Credits

The University of Minnesota Onsite Sewage Treatment Program received partial funding from the Minnesota Pollution Control Agency to update its Professional Workshop Manual to coincide with significant Administrative Rule revisions effective 02/04/2008. The following Third Edition incorporates changes to state rule effective September 2016. This considerable revision could not have been completed without the help of many contributors, namely the Manual Revision Committee. This committee was composed of members of the onsite sewage treatment industry, representing professional organizations, private industry professionals, and government regulators from the local and state level.

This publication was produced by the University of Minnesota Water Resources Center's Onsite Sewage Treatment Program team.

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Manual For Septic System Professionals in Minnesota

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SECTION 1: Introduction

INTRODUCTION

How to Use This Manual

The purpose of this manual update is threefold. The first objective of the writing team was to improve the usability of this massive text. To this end, the sections are organized primarily to follow the flow of water, from wastewater source to soil-based treatment, with subheadings providing direction for specific tasks associated with each component (design, installation, care, and inspection). Section 13 - Forms provides some guidance for system designers, installers, maintainers, and service providers. Visit septic.umn.edu/ssts-professionals/forms-worksheets to access the most up-to-date forms for system design, installation, maintenance, and inspection. This manual is completely available in a searchable format online at septic.umn.edu.

The second purpose of this manual revision was to make the manual more specific to the requirements and conditions found in Minnesota. This manual has been updated at the time of rule changes since its original development in 1974. It was originally meant to be an educational manual for extension educators focusing on sewage treatment and had a national research focus. The development of Minnesota Rules Chapter 7080-83 and the manual were directly connected. Earlier versions of the manual did not directly reference MN Rules and correlations were cited in later revisions. This version of the manual directly quotes MN Rules Chapter 7080-83 and offers explanations, discussion points, and other related suggestions. Rule language is highlighted with **bold text** (green online), while related discussion and commentary can be read in the standard black font.

Lastly, the third purpose of this manual revision was to improve the organizational framework and accessibility of this text so desired content could be easily found in different manners. Readers may use the online resource to find specific topics using the search tool available in the latest version of Adobe Reader or Adobe Acrobat, which is available as a free download at the University of Minnesota's Onsite Sewage Treatment Program (U of MN OSTP) web page (septic.umn.edu). Others may find it more convenient to use the table of contents or newly developed detailed directory (Section 14). Information can also be retrieved using the labeled tabs that separate chapters.

Ultimately, this manual is meant to provide guidance for the onsite professional. Whether you are an installer, designer, inspector, maintainer, or service provider, it is important that this manual meets your needs. If you believe that material is missing or incorrect, please contact us so we can fix any errors before the next publication.

Understanding Septic Systems

Why Are Septic Systems Necessary?

Over 25 percent of the nation's and Minnesota's households use subsurface sewage treatment systems (SSTS), commonly referred to as septic systems, to treat their wastewater. Since 1997, the US EPA has considered the use of septic systems to be a permanent part of our nation's wastewater treatment infrastructure. In their 1997 letter to Congress, they emphasized, ". . . adequately managed decentralized wastewater systems are a cost-effective and long-term option for meeting public health and water quality goals, particularly in less densely populated areas" (US EPA, 1997). While septic systems in Minnesota are designed and installed by licensed professionals to meet the needs of individual sites, homeowners are usually responsible for their system's operation and maintenance. Often septic systems fail because owners do not maintain them after installation.

This section provides basic information for septic system professionals and homeowners about:

- What septic systems are, how they work, and where to learn more in this manual
- How septic systems fail and what to do in the event of a problem
- Operation and maintenance tips
- Minnesota's system of local program administration
- Important information to communicate between SSTS professionals and owners

What Do Septic Systems Do?

Septic systems protect human health and the environment by safely recycling wastewater back into the natural environment. Septic systems treat wastewater as well as, or better than, municipal treatment systems at a reasonable cost when properly designed, installed, operated, and maintained.

Federal, state, and local regulation of onsite systems focuses on proper treatment of sewage to protect citizens, communities, and the environment.

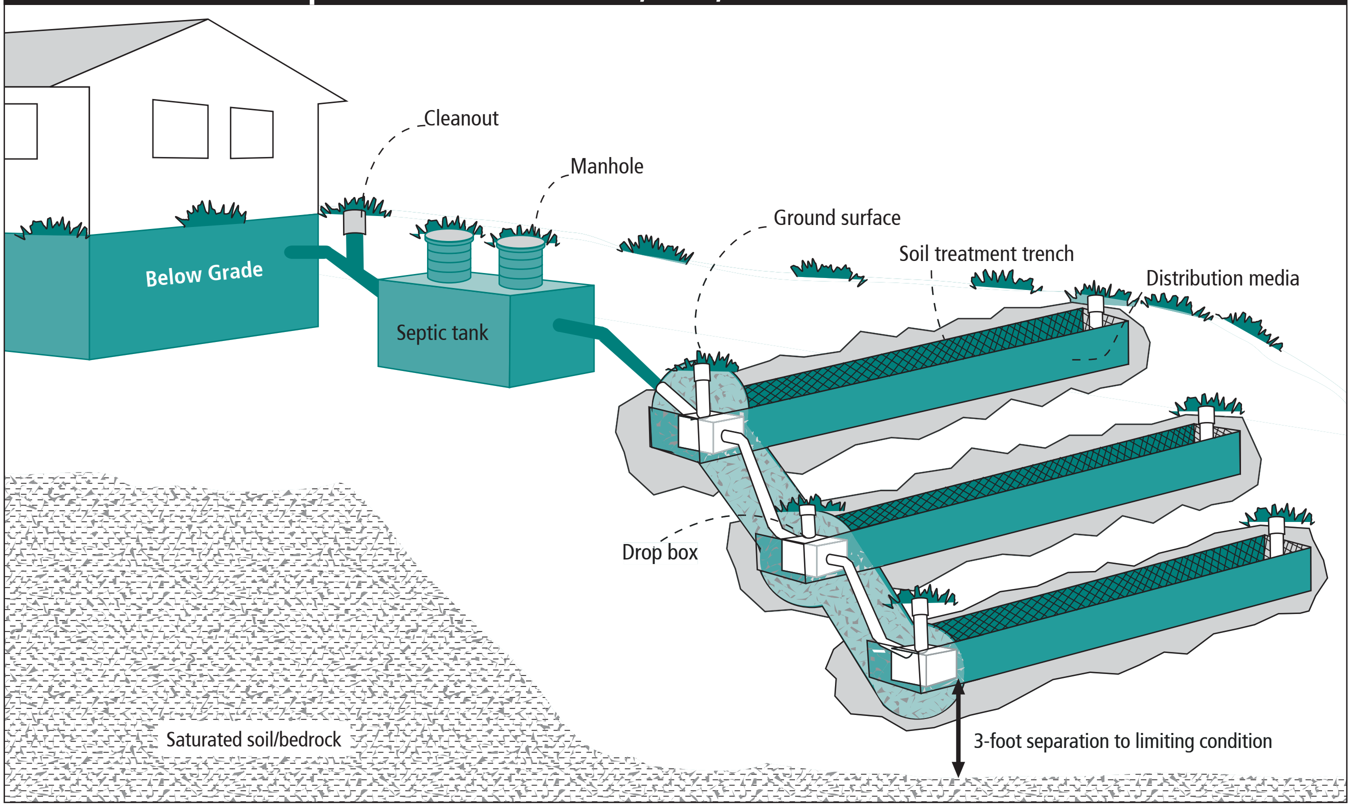
Many SSTS owners incorrectly assume that as long as their used water "goes away," their system must be working properly. Septic systems are machines that are designed to utilize physical, chemical, and biological processes to treat sewage and effluent. Disposal systems, though popular in the past, are just that—relics of a time when treatment of sewage was not considered the priority it is today. As the population grows and the demand for natural resources continues to increase, society's expectations that sewage be responsibly treated and returned to the environment will also increase. This means that many local programs will be focusing on identifying and addressing problematic disposal systems in the years to come. According to 2006 local program reporting to the Minnesota Pollution Control Agency (MPCA), approximately 1/3 of all systems in Minnesota either pose a threat to public health or are failing to protect groundwater resources (MPCA, 2007).

How Does a Septic System Work?

In typical onsite treatment systems, all wastewater is co-mingled, treated, and dispersed by one system. There are a few separation systems in which toilet wastes or grease from restaurants are treated separately from other wastewater.

Common septic systems all have three basic components: plumbing, septic tank, and a soil treatment area (see Figure 1.1). Individual systems may have variations of each of these components.

FIGURE 1.1 Three Components of a SSTS: Source, Tank, and Soil Treatment



Plumbing

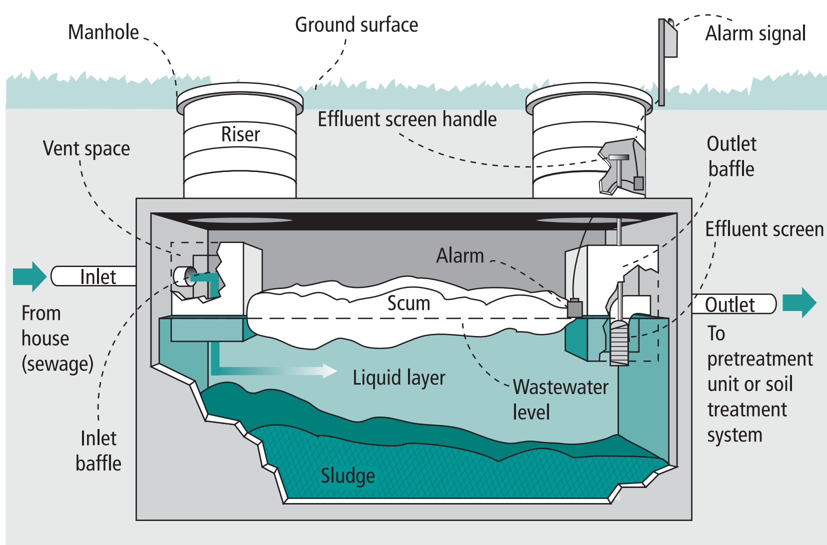
The wastewater side of household plumbing collects used water from fixtures and appliances and delivers it to the treatment system(s). Reducing the waste that enters this plumbing is an easy way to reduce the management necessary to ensure safe wastewater treatment. Determining the quantity and strength of wastewater generated on a site is the topic of Section 5. Wastewater collection specifications are highlighted in Section 6.

Septic tank - Treatment Level C

The septic tank is a solid, watertight tank, or series of tanks, that receives waste water. It separates the solids from the liquids and stores the solids until they are decomposed or removed. The liquid, called effluent, is delivered to the soil treatment system.

Inlet and outlet baffles trap the floating solids (scum) in the tank. Inspection pipes allow monitoring of the tank, and maintenance holes facilitate cleaning. Certain systems are required to add filtration to the outlet end of the tank. Effluent screens are a practical means of reducing the loading of solids to the soil treatment area and are now required in many instances. A septic tank and its components are shown in Figure 1.2. Septic tanks are the focus of Section 7 of this manual. The management of septic tanks and land application of tank septage are discussed in detail in Section 8.

FIGURE 1.2 Septic Tank and Components



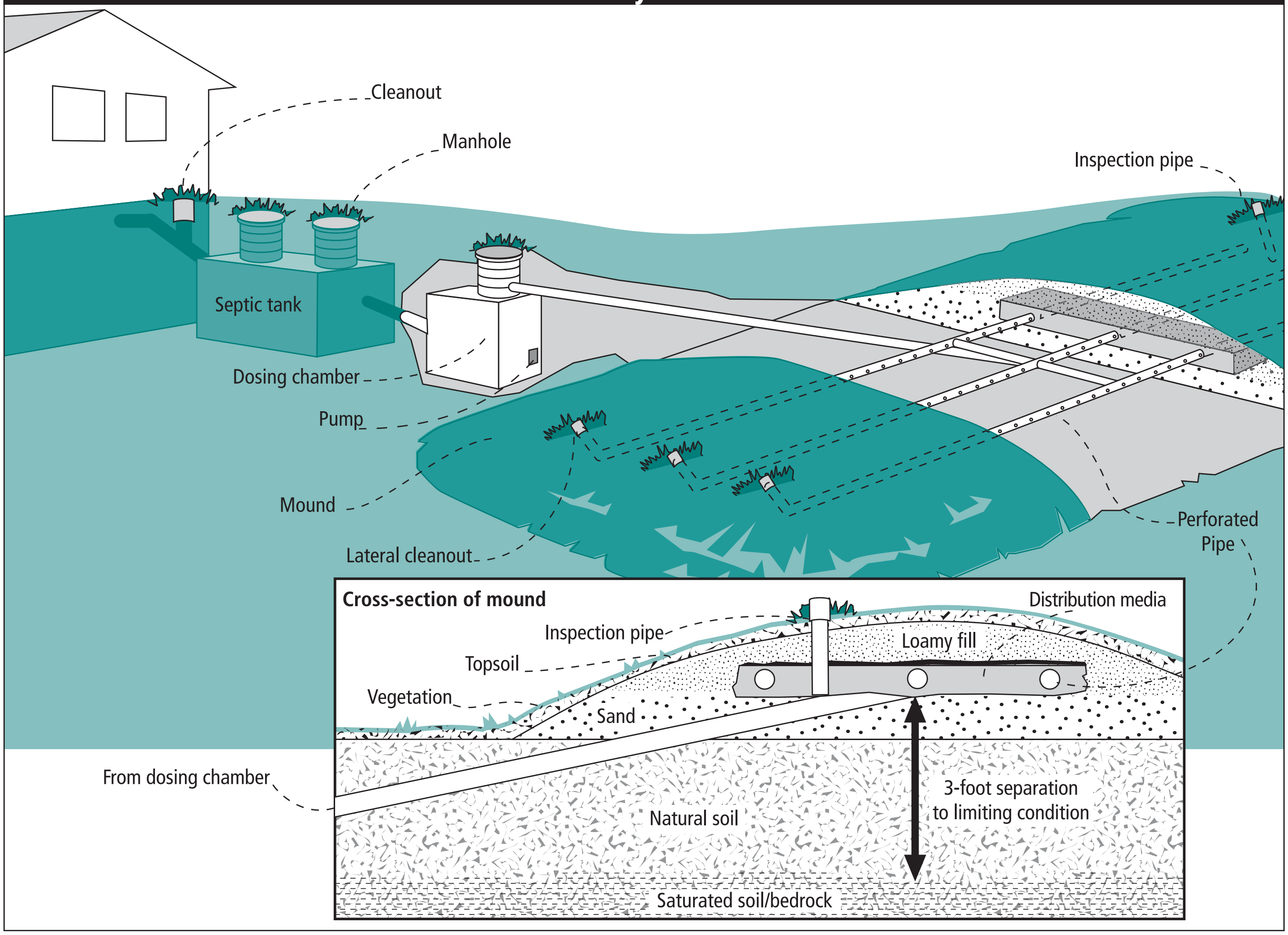
The size of the septic tank is based on the home's potential water use volume and the type of appliances used. In aerobic tank systems, pumps and other mechanisms are necessary to deliver air to the tank.

Soil treatment area

The soil treatment area for the typical septic system is a network of perforated pipes or tubes typically surrounded by small rock and soil. Some designs use large plastic tubes or chambers instead of rock to disperse effluent from the tank into the surrounding soil. Section 11 focuses on the delivery of effluent to the soil treatment area, while Section 12 provides detail about the design, installation and care of various types of soil treatment areas.

The design of the treatment area (trench, mound, etc.) is based on the depth of the limiting condition, such as saturated soil or bedrock. The soil in the treatment area must not be saturated with water for extended periods of time during the year. Three feet of unsaturated soil below the system is necessary to complete the treatment process. This is not possible in many instances in Minnesota, in which case, the system must be built at-grade or above the natural ground surface to artificially create an unsaturated treatment zone. A mound system and its components are illustrated in Figure 1.3. Details about the connection between soil science and onsite wastewater treatment are provided in Section 3 of this manual.

FIGURE 1.3 Above-Grade Soil Treatment: Mound System



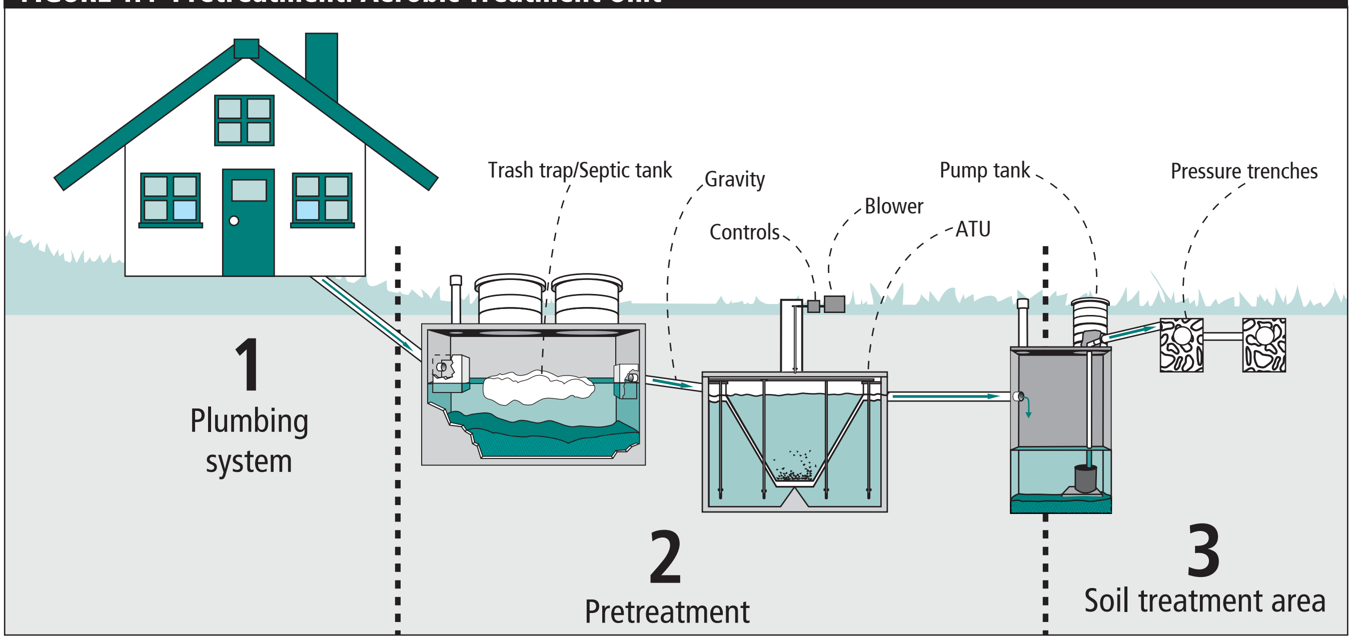
The size of the soil treatment area needed depends on the volume of water to be treated and the infiltration capacity of the soil on the site. For example, a much larger soil area is needed for a large home or a home on clay soil than for a small home or one on sandy soil.

Pumps and a lift station may be components of a system where gravity flow is not possible. For example, in systems above grade and those using advanced technologies, a pump is required to provide pressurized flow for the distribution of effluent. Section 4 provides information about conducting legal and accurate site evaluations to determine the appropriate design for a given site.

Enhancements - Treatment Levels A and B

Sometimes enhancements, known as pretreatment units, are added to septic systems. Some of the options are aerobic tanks, single pass or recirculating media filters, and constructed (lined) wetlands. These are located between the septic tank and the soil treatment area to improve the performance of the system or provide treatment in difficult soil conditions (for example, shallow bedrock or high water tables). These systems typically require additional pumps, control devices and a higher level of management. Section 10 provides information and specifications on many pretreatment devices used in Minnesota. A septic system utilizing an aerobic treatment unit is shown in Figure 1.4.

FIGURE 1.4 Pretreatment: Aerobic Treatment Unit



Separation technology systems may require containers in the home that collect and compost solid organic wastes. Other devices may collect and store wastewater for delivery to a soil treatment or dispersal unit.

How Is The Sewage Treated?

In the typical system, raw sewage is collected by the plumbing in the home and delivered to the septic tank. There the light solids float to the top, forming a scum layer, and the heavy solids sink to the bottom, forming sludge.

In the tank, organic solids such as food particles and human waste are decomposed by millions of naturally occurring bacteria. In regular septic tanks, the bacteria are anaerobic, that is, they live without air in the liquid of the septic tank. In aerobic tanks, the bacteria are aerobic and require air to live.

The septic tank delivers the partially treated liquids, or effluent, to the soil treatment area. Effluent contains pathogens (disease-causing organisms), nutrients, chemicals, and some fine solids. In order to both treat the effluent and disperse the water, the soil treatment area must be appropriately sized. The size of the soil treatment area is based on two major variables: the potential size of the home, and thus, potential water use, and the type of soils on the site, which vary significantly in conductivity, or the ability to transmit water. A thin layer of fine solids, dead bacteria, and soil bacteria, called a biomat, forms naturally where the effluent enters the soil. The biomat restricts the flow sufficiently to keep the soil beneath unsaturated. Pressurized systems dose effluent periodically to ensure unsaturated flow.

The unsaturated soil contains oxygen, which allows aerobic bacteria to live and destroy pathogenic organisms. Aerobic bacteria also consume the ever-forming biomat, creating a balance between formation (thickening) and consumption (thinning). These air spaces also force nutrients such as phosphorus to come in direct contact with soil particles to which they become attached. A portion of the nitrogen contained in the effluent passes through into the groundwater. After passing through the unsaturated soil, the effluent—now treated—returns to the soil and groundwater system. Some treated effluent does evaporate into the atmosphere, the amount of which depends on various factors such as system depth, climate, and weather.

Why Do Septic Systems Fail?

Failure of a septic system means that wastewater may come in contact with people or enter the natural environment without complete treatment of all harmful contents. Indicators of problems or a failing system include the following:

- Sewage backup into the house or surfacing in the yard
- System alarms sounding
- Frozen pipes or frozen soil treatment areas
- Algal blooms and excessive plant growth in nearby ponds or lakes
- High levels of nitrates or coliform bacteria in well water tests

System failure is most commonly the result of lack of proper maintenance, overuse of water in the home, or improper system design or installation.

Improper maintenance

The solids that accumulate in the septic tank must be removed regularly. If excessive scum or sludge builds up, it will begin to enter the soil treatment area and over time will prematurely plug it. It is required that a septic tank be cleaned (pumped) through the manhole, removing all solids, at least every three years. Cleaning frequency depends on several factors, including the number of people in the home, the size of the tank, and the use of a garbage disposal. The preferred method of completely removing solids from the tank requires flushing and back-flushing between the tank and truck several times. Another method is to agitate the contents of the tank to the extent that it becomes a "slurry" that can be completely evacuated by the vacuum truck.

Overuse of water

The typical Minnesota resident (man, woman, or child) uses about 60-70 gallons of water per day (Mayer et al., 1999). Systems are sized for typical water use, but abnormally high usage or accidental overuse (such as from leaky fixtures or tanks) can quickly overload the system. A system partially damaged from improper maintenance may not be able to accept even typical volumes of water. When ownership changes, high water use patterns by the new tenants can result in the flushing of solids to the drainfield, soil plugging, and/or system surfacing. Section 5 discusses Wastewater Sources and Flows.

Improper design or installation

This may be the result of mistakes made by the designer or installer. It is also possible that the wrong system was chosen for the site and soil conditions (for example, high water table, shallow bedrock). It is also possible that the site was compacted by construction equipment or other mistakes were made during the installation. Often times, though, the residence has been modified to house more people or to use fixtures or appliances that the system was not designed for or sized to handle.

Cleaning up a Sewage Back-up

Adapted with permission from KING COUNTY, WA Environmental Health; www.kingcounty.gov

Thorough cleaning of indoor sewage spills is necessary to protect people – especially small children – from harmful bacteria and viruses. Clean-up should begin as soon as possible to reduce the risk of exposure to sewage. The following tips are a guide to proper spill clean up.

Clean up tips:

- Keep children and pets out of the area until clean-up has been completed.
- Wear rubber gloves and boots.
- Wash your hands thoroughly and launder clothes separately after completing the clean-up.
- Remove all furniture, loose rugs, and so on from the area.
- Saturated wall-to-wall carpeting (and the pad) usually cannot be adequately cleaned. They should be removed, wrapped in plastic, and taken to a transfer station or sanitary landfill. If you decide to keep the carpeting, hire a licensed carpet cleaning company to steam clean and disinfect the carpet.
- All hard surfaces, such as linoleum, hardwood floors, concrete, wood moldings, wood, and metal furniture, and so on, should be thoroughly cleaned with hot water and a mild detergent (dish detergent), and then rinsed with a bleach solution by mixing one tablespoon of liquid household bleach to one gallon of water. Let the surface air dry.
- Upholstered furniture, loose rugs, drapery, and so on, should be professionally cleaned or discarded. Notify the cleaner of the problem.
- Remove and replace plaster, drywall, and lath that have been saturated and are soft to the touch. If the surface has been wetted, clean as you would a hard surface, but do not saturate the plaster.
- Clean sinks, dishwashers, and other plumbing fixtures that have had sewage back-up with detergent, and then rinse with bleach solution.
- Disinfect clean-up mops, brooms, and brushes with bleach solution.
- Increase air circulation to reduce odors and mold growth - open all windows and doors. The use of fans and heaters may speed this process.

Compliance Inspections

Septic systems are evaluated during a compliance inspection to assure nothing is causing back-up of sewage into the dwelling or in the yard. Systems are further evaluated to ensure the tank is watertight, and the soil treatment area is properly sited to provide treatment.

Abandonment

Septic systems must be properly abandoned when they are replaced or disconnected. The piping can remain in place or be removed and properly disposed of. Guidelines for proper tank abandonment are found in Section 7.

Operation and maintenance tips

Proper operation and maintenance will prevent costly repairs and replacement in the future.

Control water use

- Repair all leaky faucets, fixtures, and appliances immediately.
- Install low water use fixtures (especially toilets and shower heads) and appliances, such as front-loading washing machines and low-flow dishwashers.
- Do not connect roof drains and sump pump water into the septic system.
- Wash only full loads of clothing and dishes.
- Reduce length of showers and number of toilet flushings.
- Reroute water softener discharge water out of the septic system.
- Spread water use, such as laundry, evenly throughout the day and week.

Eliminate harmful products from the system

- Reduce or eliminate use of harsh cleaners, disinfectants, detergents, and bleach.
- Dispose of solvents, paints, and unwanted medications through other means.
- Keep grease, lint, food particles, cigarette butts, paper towels, disposable diapers, coffee grounds, feminine hygiene products, plastics, and other solid products out of the system.
- Use only necessary amounts of liquid non-phosphorus detergents and cleaners.

Do not use additives

It is not necessary to use additives to enhance the performance of a properly operating system. If the level of bacterial activity is low, it is because disinfectants and other products are killing the bacteria. Reduce or eliminate the use or disposal of these products in the system to allow the bacteria to re-establish. Some additives cause solids to become suspended in the liquids. These solids will move on to the soil treatment area and cause excessive plugging of the soil pores.

Regularly clean/pump and inspect the septic tank

The septic tank must be cleaned or pumped regularly to remove all solids. **Never go into the septic tank. It lacks oxygen and contains dangerous gases, creating a life-threatening environment.**

- Always clean the tank through the maintenance hole (20- to 24-inch opening).
- Always use a licensed and certified professional.
- Be sure all solids are removed (flush and back-flush).
- Inspect the baffles to be sure they are in place and functioning properly.

Maintain pumps and filters properly

- All pumps and motors should be routinely checked for proper operation.
- Replace weak or faulty pumps and motors.
- Install and clean lint filters on laundry equipment.
- Clean or replace effluent filters regularly.
- Attend to alarms on pumps and filters immediately.

Protect the soil treatment area

- Mow but do not fertilize or water turf grasses.
- Keep heavy vehicles (cars, tractors, snowmobiles, etc.) off soil treatment area.
- Do not place gardens, swing sets, or sand boxes over this area.
- Do not plant trees and shrubs on or close to this area.
- Maintain stands of appropriate plants on constructed wetland sites.

Items to Keep Out of a Septic System

It is a best practice to keep solid and liquid wastes separate. Certain materials should never be put into a septic system, and the proper disposal of solids in a garbage can will extend the life of a septic system. Coffee grounds, cat litter, cooking fats, and cigarette butts do not decompose in the septic tank and can cause rapid accumulation of solids. Paints, paint chips, solvents, some drain cleaners, and house and yard chemicals are not digested in the tank. They may actually disrupt bacterial digestion and they may pass from the tank and contaminate groundwater. Items that are nonbiodegradable may cause rapid accumulation of solids in the tank. Even paper products such as paper towels, facial tissues, sanitary wipes, etc., add to solids build up in the tank. In the absence of an effluent screen, some of these may exit the tank, posing a danger of plugging the outlet pipe, an effluent pump, dispersal system orifices or part of the soil absorption system. Items that should not be put into the tank include:

- Greases/fats/cooking oils
- Coffee grounds
- Cat litter
- Paints and chemicals
- Disinfectants
- Inorganic material (kitty litter, etc.)
- Disposable diapers
- Paper towels
- Female hygiene products
- Condoms
- Toilet wipes and similar materials
- Cigarette butts

There has been some debate about which type of toilet paper works best with septic tanks. Some arguments claim that if the paper doesn't decompose, it causes excessive solids accumulation. Others claim that if paper *does* break down in the tank, nonbiodegradable cellulose fibers can flow into the soil absorption field or next treatment component and cause clogging; still others argue that colored toilet paper causes more clogging problems than white paper. The subject certainly warrants further research. In any case, it is best to exercise moderation in the use of toilet paper and to avoid disposing of excessive amounts of "non-contaminated" paper and facial tissue (e.g., tissue used in removing makeup, etc.) in the toilet.

Hair (particularly long hair) can cause thickening and matting of the scum in the tank by entangling other solids. It may also contribute to premature clogging of effluent screens. Using drain strainers on sinks, tubs, and showers and cleaning them frequently can minimize hair in the tank.

Laundry wastewater raises another set of concerns, particularly because modern households do much more laundry than households of several decades ago. Laundry lint, which often has a high proportion of nonbiodegradable fibers, has been suggested to cause problems by matting the scum layer in septic tanks and by exiting the tank and clogging absorption systems. Several screens for intercepting laundry lint in the house plumbing are currently on the market. They are relatively inexpensive and are a simple way of avoiding a costly problem. Powdered laundry and dishwasher detergents may contain fillers and bulking agents that can add solids to the tank and can clog soil absorption fields. Washing numerous consecutive loads of laundry in a short period of time can cause turbulence that may wash solids out of the tank and cause hydraulic overloading of the soil absorption system.

As stated previously, plumbing water softener backwash water into a system is a subject of much discussion. The effects of doing so are not well understood and more study is needed in order to provide accurate guidance to practitioners and homeowners. In the interim, careful monitoring of systems receiving backwash water is warranted.

Odor Issues and Onsite Sewage Treatment Systems

Occasionally homeowners complain about odors from their onsite sewage treatment system. Although most people understand that sewage has a particular odor, steps can be taken to limit these odors in the home and yard. Gases from an onsite system that can be a problem include hydrogen sulfide, carbon dioxide and methane. Within a home these gases can be irritating, toxic and explosive. In a yard they are not typically found in high enough concentrations to be dangerous, but are still a nuisance.

There are several locations within an onsite system where odor can be an issue.

1. In the home
2. Near the septic tank
3. Near a pretreatment unit
4. Near the soil treatment area
5. In the yard

Plumbing Odors:

1. Dry trap
2. Missing P-trap
3. Damaged toilet wax ring
4. Punctured plumbing (recent picture or trim installation)

1. Odors in the home

Septic odors inside the house are both annoying and can be a health problem. Odors in a home are typically an indication of a plumbing problem. A very common problem is the drying out of a trap in a basement floor drain allowing gases from the septic tank to vent back into the home. This can be corrected by making sure all floor drain traps are periodically filled with water. Also, the cleanout access plug inside a drain may be loose and could allow for sewer gas to escape. A plumber or ISTS professional that provides line cleaning could check this out.

A second common problem is the plumbing vent located on the roof. The vent is necessary to allow the pressure in the drainpipes to equalize as wastewater flows through them. Without this vent, sinks, tubs, and toilets would gurgle, traps dry out and odors come into the home. These plumbing vents can freeze closed during prolonged cold periods or get clogged with leaves or other debris. A warm day or two will thaw out the frozen pipe but leaves will need to be removed. The pipe can be unfrozen using a jetter or warm water. Always take special precautions when working on a slippery or steep roof.

A third common plumbing problem is an improperly sealed cover on an ejector sump pump basket in the basement. The cover should be checked and a new seal applied to prevent leaks.

2. Odors near the septic tank

An occasional weak odor near the septic tank may be quite normal but if there is a particularly strong odor around the septic tank(s) the first step should be to make sure all maintenance holes and inspection pipes are securely covered. Typically a concrete lid covers the maintenance hole, although other materials such as plastic and metal lids are used. The septic tank maintenance hole can be covered with a maximum of 12" of soil for older systems. New designs require the maintenance hole to come to the surface. All tanks with a pump must come to surface to allow for repair or replacement of the pump. The newer plastic lids have a rubber seal which helps keep odors in the tank. They must also be properly secured in place with lag screws or other fasteners. If a concrete lid is leaking odors out of the maintenance hole, weather stripping or other materials can be used to create a temporary seal that will contain odors but still allow for proper maintenance of the tank. This seal will need to be replaced after maintenance.

3. Odors near a pretreatment unit

There is a growing use of pretreatment units in onsite sewage treatment systems. The most common pretreatment devices are aerobic treatment units, constructed wetlands and peat, recirculating, sand and textile filters. If an odor is persistent around one of these pretreatment units a licensed onsite professional trained to maintain the specific type of unit should be called.

4. Odors near the soil treatment area

If there are strong odors in the soil treatment area (around a below grade or above grade system), it can indicate a problem with that part of the system. All inspection pipes should be checked to make sure the pipes are not broken and they are covered. A visual inspection of the entire area should be performed to determine if there are any wet or spongy soil areas indicating that sewage is coming to the surface. If any of these conditions are found, humans and animals can come in contact with sewage. This is considered an "imminent health threat" and must be corrected immediately.

5. Odors in the yard

If the yard in general smells of septic gas, it may be that the plumbing vent pipe (described in # 1 above) on your house or a neighbor's house needs to be extended to diffuse the odors. Homes located in valleys, forested areas or low areas may not have appropriate wind patterns to carry the odors away from the living areas and the yard. As the wind blows over the house, the air currents that are supposed to carry the gases up and away can instead carry the sewer gas down into the yard. Extending the vent pipe can help diffuse the odors carrying them away from the yard. Carbon filters can also be placed on the top of the vent to help control odor. The filters do need to be changed regularly (every 1 to 5 years) to be effective. According to the Minnesota Plumbing Code a device, such as a filter, cannot obstruct the flow of air, therefore the filter must be chosen in accordance with these regulations. Check with the local unit of government if clarification is needed.

Designer Responsibilities: Providing Information to the Homeowner

As the septic designer, it is your responsibility that the homeowner clearly understands their responsibilities in maintaining their new system. This will increase the longevity of the system (and thereby be cost effective), improve customer satisfaction, and protect our water quality. MN Rules Chapter 7083.0740 identifies the system designer as the one responsible for the development of a Management Plan for all new or replacement septic systems. The checklist and information in this section provides designers with a tool to guide discussions with the homeowner about the adherence to the Management Plan. Your task as you complete the design and oversee the installation is to help the customer understand that the long-term success or failure of an onsite sewage treatment system depends on:

1. Proper design of the system
2. Proper installation of the system
3. Proper use of the system by the homeowner and occupants
4. Proper maintenance of the system by maintainer/service provider
5. Proper maintenance of the system by the homeowner

I. Pre-Design Communication

A. Pre-design meeting with system owner

- ❑ Before designing the system, complete the homeowner survey available at septic.umn.edu. Assess the property with the property owner to identify possible sites for the system while avoiding sensitive areas such as favorite trees, flower beds, play areas, etc. It is important that the designer helps the homeowner understand that the system should be sited in a manner that meets all setbacks, takes future plans (decks, garages, etc.) into consideration, and allows for access for management activities.
- ❑ Discuss the potential for plan changes and the As-Built form that will be filled out by the installer and provided to the homeowner. Discuss the importance of the homeowner reviewing the As-Built form with the installer upon completion of the system. Stress the need for saving a copy of the As-Built form and the System Management Plan in the system owner's files.

- ❑ Determine with the homeowner and installer who will complete the l andscaping and establishment of vegetative cover on the finished system. Advise the homeowner about landscaping that will not adversely affect the system.
- ❑ Discuss with the homeowner and installer how important it is that heavy equipment does not operate over the septic tank and soil absorption area. Little additional soil should be placed over the soil absorption unit other than the slight amounts necessary to fill depressions created by settling over trenches or septic or pump tank. Ensure that the top layer contains soil appropriate for establishing a good ground cover over the tank and drainfield area.

II. Post-Design Communication

A. Final design review

- ❑ After completing the system design but before construction begins, conduct a final review and walk through with the property owner to identify where each component of the system will be placed as well as the location of a second site for a replacement system (if required). Provide the system owner with a map showing the location of all of the systems, components.
- ❑ Stress the need for avoiding damage to or use of the potential second drainfield site if one is required.

B. Management Plan

- ❑ Distribute the Septic System Management Plan (Management Plan) for system based upon design. This plan is required by Minnesota Rules Chapter 7082.0100 subp. 3, J before a permit for the system can be issued. (Copies of the plans for below grade and above grade systems are available on the septic web site, septic.umn.edu.)
- ❑ Discuss the Management Plan with system owner and have the system owner sign the plan after a thorough review before a permit for the system is issued.
- ❑ Provide the system owner with a signed and dated copy of the Management Plan. (For new home construction still held by the builder, provide a copy of the Management Plan to the builder and request that the Management Plan be provided to the buyer upon completion of the sale of the home.)
- ❑ Stress the need for protecting the system through water and product use. Sources for that information include the Extension Service publication "Septic System Owner's Guide" and the OSTP website, septic.umn.edu (click on Information for Homeowners).
- ❑ For new home construction, discuss the need to remove sources of water that don't need to be treated (e.g., water softener recharge, high efficiency furnace discharge, water filters) from the septic system.
- ❑ Homeowners should refer to the Management Plan at least annually to stay on track for management tasks. It is a resource to help manage the system by tracking and recording tank cleanings and other maintenance steps, changes, and other information. This plan, along with the **"Septic System Owner's Guide,"** provides the homeowner with tracking tools for the system. When the

home is sold, the new homeowner will have a good reference point to pick up the management tasks.

- ❑ Refer homeowners to the University of Minnesota Extension Service septic web site, septic.umn.edu, for additional information. You may contact the OSTP team via the web page or call 800-322-8642 to obtain other resources you think homeowners would find valuable. We strongly encourage installers to provide homeowners with a copy of the **"Septic System Owner's Guide,"** if one was not provided with the permit in your county.

Installer Responsibilities: Providing Information to the Homeowner

As the septic professional, it is your responsibility to ensure that the homeowner clearly understands their responsibilities in maintaining their new system. This will increase the longevity of the system (and thereby be cost effective), improve customer satisfaction, and protect our water quality. The checklist and information in this section provide installers with a tool to guide discussions with the homeowner. Your task as you complete the installation is to help the customer understand that the long-term success or failure of an onsite sewage treatment system depends on:

1. Proper design of the system
2. Proper installation of the system
3. Proper use of the system by the homeowner and occupants
4. Proper maintenance of the system by maintainer/service provider
5. Proper maintenance of the system by the homeowner

I. Pre-Installation Tasks

A. Agree on establishing the vegetative cover and topsoil.

- ❑ The installer will do the final grading, add top soil suitable for vegetative cover, and plant the vegetative cover.
- ❑ The installer will do the final grading and add top soil suitable for vegetative cover. The homeowner will plant the vegetative cover.
- ❑ The homeowner will do the finishing work, adding topsoil and establishing vegetative cover. The installer will provide the final grade.
- ❑ ***Discussion with the homeowner:*** it is important that heavy equipment does not operate over the septic tank and soil absorption area. Little additional soil should be placed over the soil absorption area other than the slight amounts necessary to fill depressions created by the settling over trenches or septic or pump tank. Ensure that the top layer contains soil appropriate for establishing a good ground cover over the tank and drainfield area.

B. Septic System Management Plan (select one box)

- ❑ Yes, the homeowner received and discussed the completed Septic System Management Plan (referred to as the Management Plan from here forward) from the designer.
- ❑ The installer discussed the Management Plan with the homeowner.
    - ❑ If the designer does not have direct contact with the homeowner, the installer should review the plan with the homeowner.
    - ❑ A copy of the As-Built form has been added to the management plan.
    - ❑ Acquire signatures if still needed. Ensure the form, including all charts, is complete.
    - ❑ Be sure all who require copies, including the homeowner and permitting authority have them.

Copies of blank management plans are available on the septic web site, septic.umn.edu/ssts-professionals/forms-worksheets.

II. Post-Installation Tasks

A. Discuss ponding, run-off, and surfacing.

- ■ Discuss what ponding caused by excessive rainfall or rapid snowmelt looks like and what to watch for. If ponding occurs after the job is completed, add adequate fill and landscape to divert runoff away from the system. This may require follow-up visit to the property, especially in spring during snowmelt. Distinguish between ponding and sewage surfacing.
- ■ Offer the homeowner ideas on how to avoid runoff into the system from roofs and other impervious surfaces.

B. Explain and show the system to the homeowner.

(Check the boxes as each topic is discussed.)

- ❑ Review the As-Built form and Information on Your System, Management Plan, p. 2, with the homeowner.
    - ❑ Walk the system with the homeowner to be sure they understand all parts of the system and know the location of each component. Be sure to address all their questions and concerns. Discuss how their system was designed and built, including the type of soil treatment area installed. Remind them they are treating wastewater to protect our groundwater quality, and provide safe drinking water.
- ❑ Discuss the septic tank.
    - ❑ Discuss the role of the tank (to hold solid and scum layers).
    - ❑ Discuss how the anaerobic bacteria function.
    - ❑ Discuss pumping or cleaning the septic tank. Minnesota Chapter 7080 requires that the tank is inspected and cleaned, if needed, a minimum of every three years. Be familiar with local ordinance requirements for inspection and pumping, and share these with the homeowner.
    - ❑ Help the homeowner locate a maintainer/service provider.

    - ❑ Discuss the effluent screen. Who is responsible for cleaning and inspecting – the homeowner or the service provider? Does it have an alarm? If homeowner cleans, discuss procedure—hose over the manhole, never directly on the ground; wear protective clothing and glasses; wash hands thoroughly; secure lid tightly again.
    - ❑ Septic system additives: avoid adding any products to the tank; they can destroy helpful bacteria.
    - ❑ Discuss any pumps and their function.
    - ❑ Discuss any alarms: what to do when an alarm signals, what it means.
- ❑ Discuss the soil treatment area.
    - ❑ Discuss how it works. Include the role of the soil bacteria, removing some nutrients, and dispersing clear water back into the groundwater table.
    - ❑ Vegetative cover: discuss ideas for cover. The Landscaping Septic Systems publication available from the University of Minnesota has advice on what to plant and how to care for the vegetative cover.
    - ❑ Inspection pipes: explain that they can be cut to grade and re-capped when final grade is established.
    - ❑ Automatic sprinkler system: if they have a sprinkler system, disconnect over the soil treatment area.
    - ❑ Maintenance of the soil treatment area. Discuss these topics with the homeowner:
- ■ Mow grass regularly or care for native plantings to aid in nutrient and water uptake.
- ■ Prohibit vehicle traffic, including bicycles, four-wheelers, snowmobiles, and cars, across either an in-ground or a mound system at any time.
- ■ Protect all pipes from compaction.
- ■ Follow good practices, such as ending mowing early in the season to help prevent freezing.
    - ❑ If new construction, discuss the future soil treatment site. Help the homeowner mark it in some fashion so it remains protected. Be sure this is indicated on the design map in the Management Plan.
- ❑ Prevention of freezing: discuss vegetative cover, lack of winter protection, compaction, high efficiency furnace drip, and other issues that can cause freezing.
- ❑ Homeowner Management Tasks
    - ❑ Review p. 3 in the Management Plan with the homeowner.
    - ❑ Review the Professional Management Tasks on p. 4 of the Management Plan.
    - ❑ Encourage the homeowner to use the Maintenance Log on p. 6 of the Management Plan.

- ❑ Discuss water and product use tips, such as how to prevent system over-loading by excessive water and inappropriate product use and other household topics (see next section for help on what to discuss).
- ❑ Discuss Water-Use Appliances and Equipment in the Home, on p. 5 of the Management Plan, with the homeowner.
- ❑ Discuss the impacts to the system of future changes in the homeowner's home or lifestyle, such as the birth of a child, older teens leaving home, adding water treatment devices or a garbage disposal, starting a day care, and other changes. Remind the homeowner to include these changes in their Management Plan.
- ❑ Discuss how to prevent hydraulic overloading by repairing leaky faucets immediately and routing clear water sources such as water softener recharge away from the system.

❑ Refer homeowners to the University of Minnesota septic web site (septic.umn.edu) for additional information. The septic professional or homeowner can contact the OSTP team via the web page or call 800-322-8642 to obtain other resources you think the homeowner would find valuable. We strongly encourage installers to provide homeowners with a copy of the **"Septic System Owner's Guide,"** if one was not provided with the permit.

C. Discuss household water and product use tips with the homeowner.

Once an onsite sewage treatment system has been properly designed and installed, it becomes the responsibility of the homeowner to use and maintain the system to ensure long-term proper and safe wastewater treatment. The most common causes of system failure are:

1. Overuse of water in the home, including allowing clear water sources into the system (such as water softeners and filters, sump pumps) and leaky fixtures
2. Using products that contain ingredients harmful to septic systems
3. Improper, inadequate, or lack of maintenance

These three factors are controlled by the occupants of the home. The University of Minnesota Extension Service publication, **"Septic System Owner's Guide,"** provides many "best management practices" for homeowners. Go to the University of Minnesota Onsite Sewage Treatment Program web site (septic.umn.edu) for additional information. The Management Plan is the guideline for system care and maintenance. The installer should review the Homeowner Management Tasks in the plan with the homeowner in addition to the following list of household product and water use for homeowners. Direct them to the Homeowner section on maintenance at the OSTP web site (septic.umn.edu). A number of resources are available there, particularly "How Do I Conserve Water and Use Products Wisely to Protect my Septic System?" Installers may wish to provide copies to homeowners of resources available on the web site.

❑ Water use: Do not use more water than the average daily flow for which the sewage system was designed. A water meter may be used to monitor water use. Event counters can be used to measure how much is passing through the pumps.

- ❑ Product use and disposal: A growing concern is the increased use of strong cleansers, including bleaches, shower cleaners, toilet bowl cleaners, disposable toilet brushes, anti-bacterial soaps and cleaners, and other common products. Excessive use of these products can reduce or eliminate beneficial bacterial activity in the septic tank and soil treatment area. Eliminate use of anti-bacterial products and limit use of bleaches and other strong cleaners. Refer the homeowner to the web page, septic.umn.edu, and the “Septic System Owner’s Guide.”
- ❑ The disposal of old and unwanted medications, solvents, paints, antifreeze, and chemicals can be particularly troublesome for a system. Even the amounts of medications passing through the body of a person on heavy regiments of certain medications can cause problems for a system. UMN OSTP has a fact sheet on the proper handling of medications at: septic.umn.edu. Other hazardous wastes should be managed through local household hazardous waste programs, usually housed in departments of solid waste.
- ❑ Clear water sources, including water softener and iron filter recharge, high efficiency furnace drip, sump pumps, floor drains, and whirlpool and hot tubs should be routed away from the system. Refer to the Management Plan chart on Water-Use Appliances and Equipment in the home. Discuss with the home-owner the differences between the plumbing codes and septic codes. Help them determine where their clear water sources are being discharged.
- ❑ Best practices include using liquid laundry detergents without bleach, using gel dishwashing detergents (read the label to determine phosphorus content – aim for 0%), spreading laundry and other water uses out throughout the day and the week, avoiding the use of anti-bacterial products and automatic toilet or shower cleansers, natural-based cleansers with less chemical content when a cleanser is necessary. Do not use the toilet as a trash can – only allow toilet paper and human waste to enter the system. Do not use a garbage disposal, re-route clear water sources, repair leaks immediately.
- ❑ Homeowners should refer to the Management Plan at least annually to stay on track for management tasks. It is a resource to help manage the system, by tracking and recording tank cleanings and other maintenance steps, changes, and other information. This plan, along with the “Septic System Owner’s Guide,” provides the homeowner with tracking tools for the system. When the home is sold, the new homeowner will have a good reference point to pick up the management tasks.

Maintainer & Service Provider Responsibilities: Providing Information to the Homeowner

As the septic professional, it is your responsibility to ensure that the homeowner clearly understands their responsibilities of maintaining their new system. This will increase the longevity of the system (and thereby being cost effective), improve customer satisfaction and protect our water quality. The checklist and information in this section provide installers with a tool to guide discussions with the homeowner. Your task as you complete the installation is to help the customer understand that the long-term success or failure of an onsite sewage treatment system depends on:

1. Proper design of the system
2. Proper installation of the system
3. Proper use of the system by the homeowner and occupants
4. Proper maintenance of the system by maintainer/service provider
5. Proper maintenance of the system by the homeowner

A. Septic system Management Plan

- ❑ At each service visit, review the Septic System Management Plan (referred to as the Management Plan from here forward) with the homeowner.
    - ❑ Review page 3, Homeowner Tasks, with homeowners.
    - ❑ Use page 4, Professional Management Tasks, as your guideline for the service call.
- ■ If no Management Plan is available, one of the following situations might apply:
    - ❑ Has a plan been completed and filed with the permitting authority? If so, ask the homeowner to request a copy. The plan may be lost, or the new homeowner may not have received the plan.
    - ❑ Many existing systems do not have Management Plans. To establish one with the homeowner, obtain a blank form at septic.umn.edu. Click on Forms and Worksheets.

B. During service call, accomplish these tasks and discuss these topics with a homeowner.

- ❑ The Receipt for System Maintenance (available at septic.umn.edu, click on Forms and Worksheets) provides a comprehensive checklist of all assessments that should be accomplished on a visit. Complete the checklist and leave it with homeowner. Copy the Septic Tank Maintenance fact sheet on the back of your invoice to provide use and care reminders to the homeowner.
    - ❑ Check tank level, scum depth, sludge depth, and record these on the invoice if using the UMN invoice template. Pump if needed.
    - ❑ Verify baffle integrity, record on the invoice.
    - ❑ Verify tank integrity, record on the invoice.
    - ❑ Verify manhole/riser integrity, record on the invoice.
    - ❑ Verify functioning of any alarms; verify the homeowner understands the alarms.
    - ❑ Check inspection pipes – all in place, good covers. Replace, or recommend replacement of any damaged parts.
    - ❑ Pumps. Check that all pumps, controls, the pump vault, and any alarms are operating properly. Clean the pump vault if needed. Check the drainback. Check the event counter if there is one.
    - ❑ Walk the soil treatment area, preferably with the homeowner; check for

any concerns. Watch for surfacing, odors, ponding, and other issues. If any cleanouts are necessary, flush and clean as needed.

- ❑ Provide a system overview to the customer. If you notice any problems, discuss possible causes, and solutions. Discuss how the system works, how pathogens are destroyed, how clean water re-enters the groundwater. Check if the homeowner has any problems or concerns.

❑ If the home is in a county with a pumping requirement ordinance, determine with the homeowner who is responsible for filing the certificate.

❑ Maintenance Holes

- ❑ If no risers—encourage homeowner to add them; be sure they are insulated, sealed, and tightly secured.
- ❑ If no maintenance hole can be located—be sure to have homeowner sign the waiver found at septic.umn.edu. Click on Forms and Worksheets.
- ❑ If maintenance is not on risers and below grade—discuss with homeowner the need to expose the maintenance hole to ensure proper cleaning of the tank. Determine who will expose the maintenance hole and what, if any, additional excavating fees may apply if this is to be done by the professional.

❑ Effluent screen

- ❑ If there is none, encourage the homeowner to consult a professional about adding a screen.
- ❑ If it is pumper-maintained: clean, be sure it is functioning correctly. Check the alarm if there is one.
- ❑ If it is homeowner-maintained: verify proper cleaning is occurring. If not, help homeowner with technique.
- ❑ Discuss with the homeowner any product and water use issues evident from cleaning the screen.

❑ Discuss when the next visit should be and record on invoice.

C. Communication with the homeowner.

(Check the boxes as each topic is discussed)

❑ If not completed yet, licensed service providers should complete forms 1-1: System Description, and 1-2: System Evaluation. From the CIDWT O&M materials, available on the University of Minnesota web site: septic.umn.edu.

- ❑ At each visit – discuss these forms with the homeowner. Communicate the difference between these forms and a full compliance inspection. Update as needed.

❑ Determine any questions the homeowner has and provide information as appropriate. Review any concerns that surfaced while pumping or inspecting; do any necessary trouble-shooting.

❑ Septic system additives: remind homeowner to avoid adding any products to the tank; they can destroy helpful bacteria.

❑ Freezing prevention tips: discuss vegetative cover, winter protection, compaction, high efficiency furnace drip, and other issues that can cause freezing.

❑ Water and product use tips: discuss how to prevent system over-loading by excessive water and inappropriate product use and other household topics (see next section for help on what to discuss).

❑ Discuss Water-Use Appliances and Equipment in the Home, on page 5 of the Management Plan, with the homeowner.

❑ Prevent hydraulic overloading: talk about preventing damage to the drainfield by repairing leaky faucets immediately and routing clear water sources, such as water softener recharge, away from the system.

❑ Refer homeowners to the University of Minnesota Extension Service septic web site for additional information: septic.umn.edu. You can contact the OSTP team via the web page or call 800-322-8642 to obtain other resources you think the homeowner would find valuable. The "Septic System Owner's Guide" is a good resource for homeowners. Help them obtain a copy if they don't currently have one.

D. Discuss household water and product use tips with the homeowner.

Once an onsite sewage treatment system has been properly designed and installed, it becomes the responsibility of the homeowner to use and maintain the system to ensure long-term proper and safe wastewater treatment. The most common causes of system failure are:

1. Over-use of water in the home, including allowing clear water sources into the system (water softeners and filters, sump pumps) and leaky fixtures
2. Using products that contain ingredients harmful to septic systems
3. Improper, inadequate, or lack of maintenance

These three factors are controlled by the occupants of the home. The University of Minnesota Extension Service publication, **"Septic System Owner's Guide,"** provides many "best management practices" for homeowners. Go to the University of Minnesota OSTP web site (septic.umn.edu) for additional information. The Management Plan is the guideline for system care and maintenance. Review the Homeowner Management Tasks in the plan with the homeowner in addition to the following household product and water use guidelines for homeowners. Direct homeowners to the Homeowner section on maintenance (on the OSTP web site, septic.umn.edu). A number of resources are available there, particularly "Septic Tank Maintenance," a fact sheet for service providers to provide customers, and "How Do I Conserve Water and Use Products Wisely to Protect my Septic System?" Service providers may wish to provide copies of resources available on the web site.

Household Product and Water Use Guidelines for Homeowners

- Water use: Do not use more water than the average daily flow for which the sewage system was designed. A water meter may be used to monitor water use.
- Product use and disposal: A growing concern is the increased use of strong cleansers, including bleaches, shower cleaners, toilet bowl cleaners, disposable toilet brushes, anti-bacterial soaps and cleaners, and other common products. Excessive use of these products can reduce or eliminate beneficial bacterial

activity in the septic tank and soil treatment area. Eliminate use of anti-bacterial products and limit use of bleaches and other strong cleaners. Refer the homeowner to the web page (septic.umn.edu) and the **"Septic System Owner's Guide."**

- The disposal of old and unwanted medications, solvents, paints, antifreeze, and chemicals can be particularly troublesome for a system. Even the amounts of medications passing through the body of a person on heavy regiments of certain medications can cause problems for a system.
- Clear water sources, including water softener and iron filter recharge, high efficiency furnace drip, sump pumps, floor drains, and whirlpool and hot tubs should be routed away from the system. Refer to the Management Plan chart on Water-Use Appliances and Equipment in the home. Discuss with the homeowner the differences between the plumbing codes and septic codes. Help them determine where their clear water sources are being discharged.
- Basic best practices include using liquid laundry detergents without bleach, using gel dishwashing detergents, spreading laundry and other water uses out throughout the day and the week, avoiding the use of anti-bacterial products, and automatic toilet or shower cleansers, and using natural cleansers when a cleanser is necessary. Do not use the toilet as a trash can – only allow toilet paper and human waste to enter the system. Do not use a garbage disposal, re-route clear water sources, and repair leaks immediately.
- Homeowners should refer to the Management Plan at least annually to stay on track for management tasks. It is a resource to help manage the system by recording tank cleanings and other maintenance steps, changes in the system and other information. This plan, along with the **"Septic System Owner's Guide,"** provides the homeowner with tracking tools for the system. When the home is sold, the new homeowner will have a good reference point at which to pick up the management tasks.

More Information About Septic Systems

Local and Regional

City, Township, or County Offices of:

- Planning and Zoning
- Land Use Management
- Environmental Services
- Public Health
- Building Official
- Water Plan Coordinator
- Soil and Water Conservation District

State and National

University of Minnesota Onsite Sewage Treatment Program (OSTP)
septic.umn.edu
(800) 322-8642 - septic@umn.edu

Minnesota Pollution Control Agency (MPCA)
Search for "Subsurface Sewage Treatment" at: www.pca.state.mn.us
(651) 757-2201 or (800) 657-3659

Minnesota Department of Health (MDH)
health.state.mn.us/divs/eh/wells
(651) 201-4600 or (800) 383-9808 - health.wells@state.mn.us

National Small Flow Clearinghouse (NESC)
nesc.wvu.edu/wastewater.cfm
(304) 293-4191, ext. 3 - info@mail.nesc.wvu.edu

US Environmental Protection Agency (EPA)
https://www.epa.gov

Minnesota Onsite Wastewater Association (MOWA)
www.mowa-mn.com

Publications and DVDs

University of Minnesota Bookstore
bookstores.umn.edu

Find detailed descriptions at the University of Minnesota Bookstores. Search by product number and pay online by credit card. Bulk order pricing is available.

$5.00 Septic System Owner's Guide
SKU: 2810000084072, 33-page book

$15.00 Septic Systems Revealed: Guide to Operation, Care, and Maintenance
SKU: 2810000084089, DVD
SKU: 2810000084096, DVD & Owner's Guide Set ($19)

$50.00 Manual for Septic System Professionals in Minnesota
SKU: 2810000084263

For More Information

Please see our website at septic.umn.edu for more information about septic systems. You can also contact our staff by calling (800) 322-8642.

References

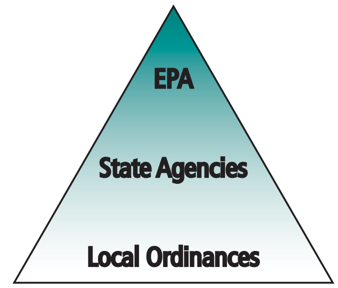
Mayer, P.W., W.B. DeOreo, E.M. Opitz, J.C Kiefer, W.Y. Davis and B. Dziegielewski. 1999. Residential End Uses of Water. AWWA Research Foundation and the American Water Works Association. Denver, CO.

MPCA. 2006 Annual LGU ISTS Program Questionnaire. Available by reaching MPCA SSTS Program at 1-800-657-3864

U.S. Environmental Protection Agency, 1997. Response to Congress on Use of Decentralized Wastewater Treatment Systems. EPA-832-R-97-001b. Washington, D.C.

SECTION 2: Administration

ADMINISTRATION



From the federal government, through state agencies and down through the local ordinance, there are many regulations to be aware of if you are involved with the design, installation, inspection, or maintenance of subsurface sewage treatment systems. This section provides an overview of those regulations.

Federal Requirements

Overview

The United States Environmental Protection Agency's (EPA) Office of Wastewater Management (OWM) oversees a range of programs contributing to the well-being of the nation's waters and watersheds. Through its programs and initiatives, OWM promotes compliance with the requirements of the Federal Water Pollution Control Act. Cleaning and protecting the nation's water is an enormous task. Under the Clean Water Act, OWM works in partnership with the Environmental Protection Agency (EPA) regions, states, and tribes to regulate discharges into surface waters such as wetlands, lakes, rivers, estuaries, bays, and oceans (also called point sources). Specifically, OWM focuses on the control of water that is collected in discrete conveyances, including pipes, ditches, and sanitary or storm sewers. OWM is also home to the Clean Water State Revolving Fund, the largest water quality funding source, which focuses on funding wastewater treatment systems, non-point source projects and estuary protection. The EPA's national role is to provide direction and support to improve the standards for decentralized systems by promoting the concept of continuous management and facilitating improved professional standards of practice.

The EPA concluded in its 1997 Report to Congress that adequately managed decentralized wastewater systems are a cost-effective and long-term option for meeting public health and water quality goals, particularly in less densely populated areas (EPA, 1997). The difference between failure and success is the implementation of an effective wastewater management program. Such a program, if properly executed, can protect public health, preserve valuable water resources, and maintain economic vitality in a community. In 2002, the EPA published an updated Onsite Wastewater Treatment Systems Manual to provide supplemental and new information to the 1980 EPA Design Manual (www.epa.gov) for wastewater treatment professionals in the public and private sectors. The updated manual has a more focused approach on Subsurface Sewage Treatment System (SSTS) treatment and management.

Management Guidelines

In 2003, the EPA published Voluntary National Guidelines for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems to help communities establish comprehensive management programs to ensure that all SSTSs function properly. Proper management of decentralized systems involves implementation of a comprehensive group of elements and activities, such as public education and participation, planning, operation and maintenance, and financial assistance and funding.

Class V Systems

Class V wells are a federal classification of dispersal systems, used to place a variety of fluids directly below the land surface (40 CFR 144.80 (e)). While most types of Class V wells are vertical boreholes used for such purposes as disposal of storm water, geothermal water reinjection, or solution mining, some SSTS's are considered class V wells if either one of the following conditions is met:

1. The SSTS, regardless of size, receives any amount of non-domestic waste (for example, industrial waste disposal wells or motor vehicle waste disposal wells). According to the EPA, industrial or commercial waste includes, but is not limited to, any waste that results from manufacturing or other industrial and commercial processes.
2. The SSTS receives solely domestic waste from more then one family residences or domestic waste from a non-residential establishment and has the capacity to serve 20 or more persons per day. In general, these systems may be found serving the following facilities: apartment buildings; trailer parks; schools and religious institutions; residential clustered or septic tank effluent pumping systems; office; shopping malls; state parks and campgrounds; recreation vehicle (RV) parks; highway rest stops; train and bus stations; hotels and restaurants; and casinos.

SSTS defined as Class V must provide inventory information (including facility name and location, legal contact name and address, ownership information, nature and type of injection wells, and operating status of the injection wells) to the state or the EPA regional UIC Program. See septic.umn.edu/ssts-professionals/forms-worksheets.

There are additional requirements for SSTSs receiving waste from a floor drain at a facility performing repair and maintenance on motor vehicles. New wells/SSTS of this nature have been banned since 2000, and existing ones in regulated areas must have been closed by January of 2007.

Visit www.epa.gov/uic/basic-information-about-class-v-injection-wells to get more information on Class V wells. Many Minnesota state agencies, including the Pollution Control Agency and Department of Health, also regulate, and in most cases, prohibit most types of Class V wells other than SSTS.

Land Application Requirements

Federal Law 40 CFR Part 503 (www.epa.gov) establishes requirements for the final use or treatment of municipal sewage sludge (biosolids) and domestic septage from SSTS tanks. Federal Law 40 CFR Part 503, www.access.gpo.gov/nara/cfr/waisidx_02/40cfr503_02.html, establishes requirements for the land application of sewage sludge (biosolids) and domestic septage. The 503 regulations, first implemented in 1993, set the minimum requirements for land application of domestic septage. All land applied septage, at a minimum, must meet these requirements.

Minnesota does not have a specific land application rule, but there are land application guidelines that are more detailed than the Federal rules; these must be followed for land application in Minnesota. Additionally, local ordinances may be stricter than the Minnesota or Federal requirements. Check with your LGU for local requirements. For more information see Section 8 or the State guidelines at www.pca.state.mn.us.

State Agencies

Overview

There are many state agencies with laws and rules relating to SSTSs. It is important that SSTS professionals in Minnesota understand all the relevant regulations to operate legally in the state.

Minnesota Pollution Control Agency

From the first voluntary state septic code - the Health Department Code in 1969 - to the development of Chapter 7080 for voluntary adoption in 1978 and statewide adoption in 1996, the rules in Minnesota have been revised over the years to reflect updated research, new technologies, and practice. US Public Health standards established in the 1950s are the basis for today's Minnesota Rule Chapters 7080 and 7081, which regulates SSTSs. In the 1970s Minnesota developed sewage treatment rules to upgrade SSTSs in shorelands. The Minnesota Pollution Control Agency (MPCA) and local government units (LGUs), counties, cities, and townships are responsible for enforcement of these rules.

The MPCA is the primary agency with responsibility for regulating wastewater treatment in Minnesota. There are four primary types of wastewater treatment systems allowed in Minnesota, each regulated differently by the MPCA:

1. ***Treatment systems that directly discharge treated effluent to surface waters such as ditches, rivers, streams, and lakes.***
2. ***Treatment systems that discharge to the land surface such as spray irrigation or rapid infiltration basins.*** Both of these system types are required to be permitted by the MPCA with a National Pollutant Discharge Elimination System (NPDES). permit and/or State Disposal (SDS) Permit. (These systems will be characterized as NPDES in this manual.) These systems are required to be designed by professional engineers and be operated by a Class A-D Wastewater Operator certification. Treatment facilities are classified as A, B, C, and D according to a rated point system based on the unit processes, loading to the plant, and the permitted final effluent limitations. In addition, a Type IV or V certified person disposes of the septage/biosolids from these MPCA permitted facilities. For information on training and licensing programs for these two programs see www.pca.state.mn.us.
3. ***Treatment systems with a designed flow greater than 10,000 gpd that disperse effluent below final grade.*** These systems are characterized as Large Subsurface Sewage Treatment Systems (LSTS). LSTS are required to obtain a SDS permit and are governed under Minnesota Rules Chapter 7001. These systems are required to be designed by professional engineers and should be an Advanced Designer, be operated by a Class A-D Wastewater Operator who is also a Service Provider and a Type IV or V licensed person dispose of the septage/biosolids. Minnesota Rules Chapter 7081.0040 states, **The owner or owners of a single SSTS or a group of SSTS under common ownership must obtain an SDS permit from the agency according to chapter 7001 when all or part of proposed or existing soil dispersal components are within one-half mile of each other and the combined flow from all proposed and existing SSTS is greater than 10,000 gallons per day.**

4. ***"Subsurface sewage treatment system" or "SSTS" is either an individual subsurface sewage treatment system as defined in subpart 41 or a midsized subsurface sewage treatment system as defined in part 7081.0020, subpart 4, as applicable. (MN Rules Chapter 7080.1100, Subp. 82).*** These systems are permitted at the local level through ordinances by counties, cities, townships or other similar entities.

   a) **"Individual subsurface sewage treatment system" or "ISTS" means a subsurface sewage treatment system or part thereof, as set forth in Minnesota Statutes, sections 115.03 and 115.55, that employs sewage tanks or other treatment devices with final discharge into the soil below the natural soil elevation or elevated final grade that are designed to receive a sewage design flow of 5,000 gallons per day or less.**

      ISTS also includes all holding tanks that are designed to receive a design flow of 10,000 gallons per day or less; sewage collection systems and associated tanks that discharge into ISTS treatment and dispersal components; and privies. ISTS does not include those components defined as plumbing under the Minnesota Plumbing Code, chaper 4714, except for a building sewer connected to a subsurface sewage treatment system. (MN Rules Chapter 7080.1100, Subp. 41).

   b) **"Midsized subsurface sewage treatment system" or "MSTS" means a subsurface sewage treatment system, or part thereof, as set forth in Minnesota Statutes, sections 115.03 and 115.55, that employs sewage tanks or other treatment devices with final discharge into the soil below the natural soil elevation or elevated final grade and that is designed to receive sewage design flow of greater than 5,000 gallons per day to 10,000 gallons per day.**

      MSTS also includes sewage collection systems and associated tanks that discharge into MSTS treatment or dispersal components. MSTS does not include those components defined as plumbing under the Minnesota Plumbing Code, chapter 4714, exceept for a building sewer conncted to a subsurface sewage treatment system. (MN Rules Chapter 7081.0020, Subp. 4).

Minnesota Statutes 115.55 and 115.56 provide the authority to the MPCA for regulations and enforcement relating to ISTS and MSTS in three main areas:

1) Revisions to the state's SSTS code (**MN Rules Chapter 7080 - 7081**)

2) Assistance with and interpretations of the code

3) Administration of the statewide certification and licensing program. This includes collecting the sewage tank fee, which installers collect at the time of installation

The MPCA also administers the groundwater rules, Chapter 7060, which can affect SSTS regulations, particularly those related to nitrogen.

Overview of Minnesota's SSTS Rules

The effective date of the most current SSTS Rules is September 6, 2016. These rules can be accessed online (at www.revisor.mn.gov) by entering 7080, 7081, 7082 or 7083 in the Chapter selection box. They are also available in PDF format at septic.umn.edu.

Minnesota Rules Chapter 7080 provides technical criteria for ISTS systems, including definitions, compliance criteria, acceptable and prohibited discharges, site evaluation and design procedures, applications and limitations, maintenance, and abandonment.

Minnesota Rules Chapter 7081 provides additional technical criteria for MSTS including definitions, variance procedures, compliance criteria, design procedures, applications and limitations, construction requirements, operation and maintenance and abandonment.

Minnesota Rules Chapter 7082 highlights the requirements of LGUs in administering a local ordinance. It sets definitions and provides regulatory administrative responsibilities, general requirements for local ordinances, permitting requirements, system management, and inspection.

Minnesota Rules Chapter 7083 sets the certification requirements for qualified employees who are employed by local or state government, and certification and licensing requirements for businesses who design, install, inspect, operate and maintain ISTS and MSTS systems. Chapter 7083 also contains the establishment, membership, terms and rules for the SSTS Advisory Committee. (Chapter 7083.6000) along with the requirements for product registration (Chapter 7083.4000).

System Classifications

All new construction or replacement ISTS must be designed to meet or exceed items A to F.

A. All treatment and dispersal methods must be designed to conform to all applicable federal, state, and local regulations.

B. Treatment and dispersal processes must prevent sewage or sewage effluent contact with humans, insects, or vermin.

C. Treatment and dispersal of sewage or sewage effluent must be in a safe manner that adequately protects from physical injury or harm.

D. An unsaturated zone in the soil must be maintained between the bottom of the soil treatment and dispersal system and the periodically saturated soil or bedrock during loading of effluent.

E. Soil treatment and dispersal systems must not be designed in floodways.

F. ISTS components must meet all set backs.

(7080.2150, Subp. 2)

Chapter 7080 has a classification system that is useful to LGUs in understanding why a system is classified as it is. The classification system also provides a basis for LGUs to make a decision about whether they will allow a system to be used, regardless of its classification. The classification system also indicates when an advanced design license and a service provider are required as shown in Table 2.1.

TABLE 2.1 System Classification Overview

Type	Pre 2008 Code Change Classification	Wastewater Characteristics	Separation to Limiting Condition	Size/Loading Rate	Maintenance Frequency	License Needed to Design**/ Maintain
I	Standard	Domestic	> or = 3 feet of original* soil (includes mound sand)	Full size	< or = 3 years	Basic Designer /Maintainer
II	Alternative	Domestic	> or = 3 feet when applicable	Full size	< 3 years	Basic Designer /Maintainer
III	Other	Domestic	> or = 3 feet of disturbed or original soil	Reduced flow or full size	< 3 years	Basic Designer /Maintainer
IV	Performance	Domestic & high strength	< 3 feet of disturbed or original soil	Reduced or full size	< 3 years Operating Permit	Advanced Designer/Service Provider
V	Performance	Domestic & high strength	< 3 feet of disturbed or original soil	Reduced or full size	< 3 years Operating Permit	Advanced Designer & PE/Service Provider

* See Section 4 - Site Evaluation for definition of original soil.
** An Advanced Designer is also required any time the design flows are greater then 2,500 gpd on any type of system or other establishment.

Type I systems

Type I systems include trench systems, seepage beds, mounds, at-grade systems, and graywater systems. The prescriptive specifications for these systems are in Chapter 7080.2210 - 7080.2240. Lots platted since 1996 must have two sites for a Type I system. Some LGUs may require a Type I system to be installed, if possible, while others may allow one of the other classifications of systems. **A lot is defined in Minnesota Rules Chapter 7080.1100, Subp. 45, as a parcel of land in a plat recorded in the office of the county recorder or registrar of titles or a parcel of land created and conveyed, using a specific legal description, for a building site to be served by an ISTS.**

A **Type I system** is a technology that has proven itself over time in a variety of locations. Type I systems are supported by adequate research behind them and offer environmental protection. Research has identified many of the problems and inefficiencies of Type I systems, but additional research on these systems is needed.

The specifications offered in Chapter 7080 for Type I systems are intended to provide adequate treatment of sewage with limited monitoring, typically visual observations and evaluations of the tank at least once every three years.

Any Type I system must:

- use 7080 flow values and loading rates
- be designed with at least the minimum septic tank capacities
- be designed with required distribution and dosing
- provide flow measurement* if a pump is included in the system
- be designed and installed with a three-foot vertical separation in natural soils
- receive septic tank effluent
- generally have a management plan** with a management and operational frequency of three years or less

*** Flow measurement means any method to accurately measure water or sewage flow, including, but not limited to, water meters, event counters, running time clocks, or electronically controlled dosing (Chapter 7080.1100, Subp. 35).**

**** A management plan means a plan that requires the periodic examination, adjustment, testing, and other operational requirements to meet system performance expectations, including a planned course of action in the event a system does not meet performance expectations (Chapter 7080.1100, Subp. 46).**

Chapter 7080.1720 requires that soil observations be done by a soil pit or hand auger to observe and interpret soil structure and consistence. If soil structure cannot be determined by observation alone, a percolation test must be performed to determine the appropriate loading rate outlined in Tables IX and IXa in **MN Rules Chapter 7080.2150, Subp. 3, (E)**.

Type II systems

Type II systems include a variety of systems with moderately well-proven design specifications for unique site conditions including, floodplain areas, privies/outhouses, and holding tanks. The prescriptive requirements for these systems can be found in **7080.2250.** Further information on the design of systems located in floodplains can be found in Chapter 4: Site Evaluation, while information on the design and installation of holding tanks and privies can be found in Chapter 7.

Any Type II system must:

- use 7080 flow values and loading rates (for floodplains)
- provide flow measurement if a pump is included in the system
- be designed and installed with a three-foot vertical separation in natural soils (for privies and floodplains)
- generally have a management plan with a management and operational frequency of three years or less

Type III systems

Generally Type III systems include those installed in a location where the soil is not natural (cut, filled, compacted, etc) or where a full-sized system is not installed. There are some prescriptive design requirements provided in 7080 for these systems.

The key components of Type III systems are:

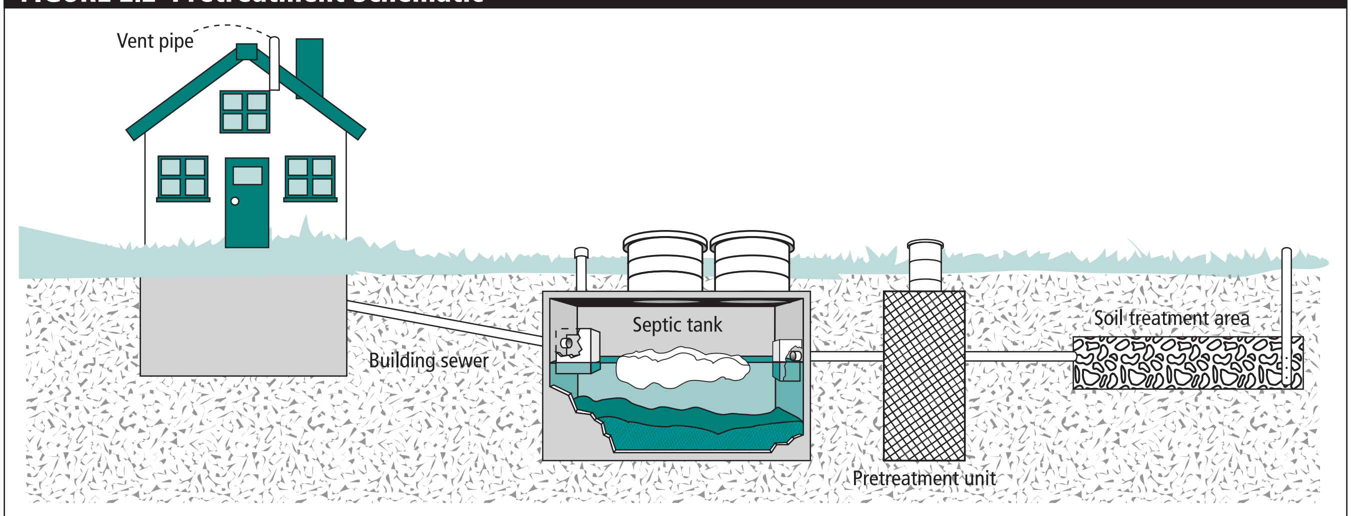
- use 7080 flow values
- provide flow measurement
  - > be designed and installed with a three-foot vertical separation and meet the other Type I soil treatment requirements
  - > receive septic tank effluent
- **If a downsized soil treatment system is designed, time dosing must be used to assure the loading rates do not exceed those in Table IX of part 7080.2150, subpart 3, (E)**
- generally have a management plan with a management and operational frequency of three years or less

An example of a Type III system is a mound built on fill soil with a management plan requiring monitoring such as visual observation and flow measurement.

Type IV systems

Type IV systems were created by the MPCA in response to the SSTS industry's request to utilize pretreatment units with reduced vertical separation distances and/or system sizing, as seen in Figure 2.2. Type IV systems are analogous to the past "Performance" and "Experimental" ISTS except the Registered Product List (RPL) will provide more guidance to designers and LGUs. To be registered, the product manufacturers are required to submit design performance testing, installation, and management requirements to the MPCA, which will manage and make the information available.

FIGURE 2.2 Pretreatment Schematic



The key characteristics of Type IV systems are:

- Use Type I tank capacity if applicable
- Use 7080 flow values and provide flow measurement
- Use Type I distribution methods
- Utilize registered secondary treatment and media products. Treatment level A & B are typically associated with the effluent from pretreatment units such as aerobic treatment units and media filters. Treatment level C is the treatment system performance level for systems designed to treat high strength waste such as from a restaurant. Table 2.2 identifies performance testing parameters for the various treatment levels identified in MN Rules Chapter 7083, **From MN Rules Chapter 7083.0020, Subp. 20 TN means the total nitrogen, which is the measure of the complete nitrogen content in wastewater including nitrate, nitrite, ammonia, ammonium, and organic nitrogen, expressed in mg/L. TP means total phosphorus, which is the sum of all forms of phosphorus in effluent, expressed as mg/L.** Secondary treatment units are listed as treatment level A, A2, B, B2, C, TN, or TP based on the performance level testing in Table 2.2 (next page).
- Have an operating permit with a frequency of fewer than three years
- Be designed and installed with less than a three-foot vertical separation according to Table 2.3 (next page)
- The product registration process allows products to meet these levels with or without separate disinfection

■ Are allowed to be designed with soil loading rate at least as large as those provided in either Table IX or IXa found in MN Rules Chapter 7080.2150 or in the Forms Section of this manual. The loading rate determination depends on soil evaluation procedures, local ordinance requirements, and the designer's professional judgement.

TABLE 2.2 Treatment System Performance Testing Levels

Level	Parameters				
	$CBOD_5$ (mg/L)[a]	TSS (mg/L)[b]	O&G (mg/L)[c]	FC (#/100 mL)[d]	Nutrient (mg/L)
A	15	15	--	1,000	--
A-2	15	15	--	--	--
B	25	30	--	10,000	--
B-2	25	30	--	--	--
C	125*	60	25	--	--
TN	--	--	--	--	<20 or actual value
TP	--	--	--	--	<5 or actual value

* BOD_5 = 170 mg/L

a Carbonaceous biochemical oxygen demand or $CBOD_5$ means the measure of the quantity of oxygen used by microorganisms in the aerobic oxidation of organic matter and other compounds containing carbon amount of oxygen required by bacteria while stabilizing, digesting, or treating the organic matter under aerobic conditions over a five-day incubation period while in the presence of a chemical inhibitor to block nitrification. $CBOD_5$ is commonly expressed in milligrams per liter (mg/L) (7080.0020, Subp. 12).

b Total suspended solids or TSS means solids that are in suspension in water and that are removable by laboratory filtering (7083.0020, Subp. 21).

c O&G means oil and grease, a component of sewage typically originating from foodstuffs such as animal fats or vegetable oils or consisting of compounds of alcohol or glycerol with fatty acids such as soaps and lotions, typically expressed in mg/L (7080.0020, Subp. 14).

d Fecal coliform or FC means bacteria common to the digestive systems of warm-blooded animals humans that are cultured in standard tests. Counts of these organisms are typically used to indicate potential contamination from sewage or to describe a level of disinfection, generally expressed in colonies per 100 mL (7080.0020, Subp. 30).

Category A: Designed to treat sewage with strength typical of a residential source when septic tank effluent is anticipated to be equal to or less than treatment Level C.
Category B: Designed to treat high-strength sewage when septic tank effluent is anticipated to be greater than treatment level C, including restaurants, grocery stores, mini-marts, group homes, medical clinics, residences, etc.
Total nitrogen and phosphorus reduction in Categories A and B

TABLE 2.3 Treatment Component Performance Levels and Method of Distribution by Texture Group[1]

Vertical Separation (inches)	Texture Group[2]		
	All sands and loamy sands	Sandy loam, loam, silt loam	Clay, clay loams
12 to 17[3]	Treatment level A Uniform distribution Timed dosing	Treatment level A Uniform distribution Timed dosing	Treatment level A Uniform distribution Timed dosing
18 to 35[3]	Treatment level B Uniform distribution Timed dosing	Treatment level B Uniform distribution Timed dosing	Treatment level B Uniform distribution
36+[3]	Treatment level A-2 or B-2 Uniform distribution Treatment level C	Treatment level A-2 or B-2 Uniform distribution Treatment level C	Treatment level A-2 or B-2 Uniform distribution Treatment level C

1 The treatment component performance levels correspond with those established for treatment components under the product testing requirements in Table III in part 7083.4030.
2 With less than 50 percent rock fragments.
3 Additional vertical separation distance is required as determined in part 7080.2150, subpart 3, item C, subitem (1), unit (b).

Examples of Type IV systems are:

1. A sand filter, listed in the registered product list (RPL), to a pressurized trench system and time dosing in sandy soils
2. An aerobic treatment unit, on the RPL, to a pressurized mound system overlying loam soil with a combination of 24 inches of soil treatment in the mound and existing soil

Type V systems

Type V systems are customized engineered systems. In general, they are similar to Type IV systems but lack the data to support the product registration process. They may be allowed to be designed based on environmental protection outcomes plus flows determined as per 7080. Prescriptive standards are not provided, and meeting the environmental protection outcomes should be demonstrated through the operating permit process. **These systems must be designed with a vertical separation that ensures adequate sewage dispersal and treatment. Design factors to consider include, but are not limited to, effluent quality, loading rates, groundwater mounding if loading rates are in excess of those used for Type IV systems, loading methods, and soil conditions. ISTS must not contaminate undergroundwaters or zones of periodic saturation with viable fecal organisms (Chapter 7080.2400).** Type V systems must be approved by the local government and be designed by a PE with an Intermediate or Advanced Design certification.

Product development permits

Chapter 7083.4110 allows product development permits to be issued by a LGU for any proprietary treatment component or sequence during the development and testing of a new product in the field. Product development permits can only be used to test products in a system that already meets standards without the device being tested. For example a new type of secondary treatment device maybe installed in an already compliant Type I system. See the Minnesota Rules chapter 7083.4110 for more information.

Compliance Criteria

A compliance inspection is an evaluation, investigation, inspection, or other such process conducted for the purpose of issuing a certificate of compliance or notice of noncompliance.

An existing system is considered compliant if:

- it is not an imminent threat to public health,
- it is not failing to protect groundwater, and
- it meets its operating permit (if applicable).

There is typically a trigger that will require an inspection, such as the addition of a bedroom (Minn. Stat. § 115.55, Subd. 5, item (b)). Local ordinances may have multiple triggers for an inspection — always check with the LGU for differences between the statute, rule and ordinance requirements.

In all cases, the goal of the inspection is to determine whether the system is in compliance. If the system is in compliance, a certificate of compliance must be issued. If the system is not in compliance, a notice of noncompliance must be issued.

For an existing system a certificate of compliance documents that the existing system is not failing to protect groundwater, is not an imminent threat to public health, and is meeting its monitoring and operating permitrequirements, if applicable. **Chapter 7080.1100 Subp. 13, defines a certificate of compliance as a document, written after a compliance inspection, certifying that a system is in compliance with applicable requirements at the time of the inspection.**

The compliance inspection for an existing system does not address the life expectancy (i.e. hydraulic acceptance of effluent) of the system or all of the technical requirements set by state or local codes. More comprehensive inspections may be done, but these go beyond the minimum state standards for an existing system compliance inspection. Certificates of compliance for new construction or replacement systems are valid for five years from the date of issuance, while a certificate for an existing system is valid for three years. LGUs should still require systems to verify that they are not imminent public health threats within the time period of validity if an inspection trigger (e.g., bedroom addition) occurs.

New construction means installing or constructing a new ISTS or altering, extending, or adding capacity to a system that has been issued an initial certificate of compliance.

Replacement means the removal or discontinued use of any major portion of an ISTS and reinstallation of that portion of the system, such as reinstallation of a new sewage tank, holding tank, pump tank, privy, or soil dispersal system.

(MN Rules Chapter 7080.1100, Subp. 66 and 71)

The statute (Minn. Stat. § 115.55, Subd. 5(c) and (d)) allowing this validity time period is written to avoid multiple tank and vertical separation inspections for homes that might trigger multiple inspections during the three-to-five-year window. Validity time periods are not a guarantee that the system will hydraulically perform for that period of time after the inspection.

There is a state inspection form that must be completed when an inspection is conducted (septic.umn.edu/ssts-professionals/forms-worksheets). In order to perform a compliance inspection you must be a licensed Basic or Advanced Inspector. For both new and existing systems classified as Type IV or V or any systems over 2,500 gpd, an Intermediate or Advanced Inspector is required to perform the compliance inspection. A Basic, Intermediate or Advanced Inspector can conduct the inspection for Type I-III systems under 2,500 gpd. Some LGUs require additional forms. If replacing a component (such as a tank), the remaining components (such as soil treatment and dispersal) must not be imminent threats to public health (ITPHS) or failing to protect groundwater.

In 2006, legislation was passed that provides an additional tool for local governments in requiring upgrades of straight pipe discharges. A straight-pipe system is a sewage disposal system that transports raw or partially settled sewage directly to a lake or stream, to a drainage system, or onto the ground. The Straight-pipe Act of 2006, Chapter 224 makes for homeowners who do not correct straight-pipe discharges within 10 months subject to MPCA issued penalties of $500 per month.

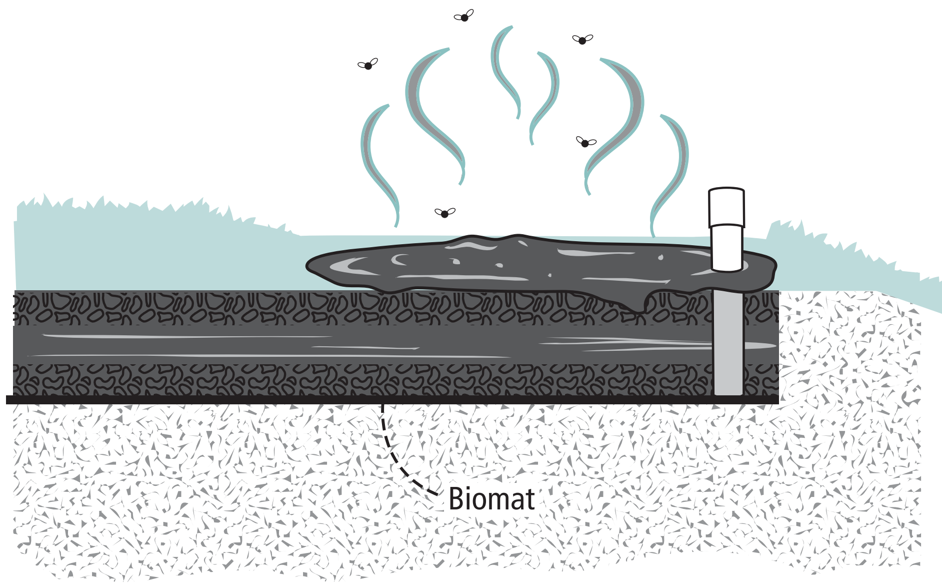
Imminent Threat to Public Health or Safety (ITPHS)

From Chapter 7080.1500, Subp. 4 (A) to be in compliance, an existing ISTS must be protective of public health and safety. A system that is not protective is considered an imminent threat to public health or safety. At a minimum, a system that is an imminent threat to public health or safety is a system with a discharge of sewage or sewage effluent to the ground surface, tile drainage systems, ditches, or storm water drains or directly to surface water; systems that cause a reoccurring sewage backup into a dwelling or other establishment; systems with electrical hazards; or sewage tanks with unsecured, damaged, or weak maintenance hole covers or weak lids. A determination of protectiveness for other conditions may be made by a qualified employee inspector or licensed inspection business.

The most serious failures are classified as ITPHS. These systems are a direct threat to public health, including the health of the systems' owners, primarily because they may be:

1. Backing-up into the home
2. Surfacing in the yard as shown in Figure 2.3

FIGURE 2.3 Surfacing ITPHS



- Surfacing sewage,
- Backup into the home,
- Surface water discharge or
- Tile discharge

Repair Time: Maximum 10 months

3. Surfacing into a water body (lake, river, stream, ditch, tile line)
4. Other unsafe situations such as sewage tanks with unsecured or weak maintenance hole covers or weak lids

These systems allow direct exposure to sewage and disease-causing organisms and must, by law, be brought into compliance within ten months based on state law or less based on local ordinance. The proper method for repair or replacement will be site-specific. Depending on the nature of the system failure it may be required or recommended to take immediate steps to prevent the surfacing of effluent such as utilizing the septic tanks as holding tanks until the system can be repaired or replaced.

Other types of water, including footing and roof drainage, and chemically treated hot-tub or pool water, should not be discharged to a SSTS. Graywater, including wastewater from bathing and washing dishes and clothes which does not contain toilet wastes (7080.1100, Subp. 37) is sewage, and all sewage must be properly treated. If graywater is discharging to the surface the system is considered an ITPHS.

Failing to protect groundwater

The upgrade time periods of systems failing to protect groundwater must be defined in the local ordinance.

The second compliance measure is a determination of the system failing to protect groundwater. **According to Minnesota Rules Chapter 7080.1500, a system that is failing to protect groundwater if it is:**

1. a seepage pit, cesspool, drywell, leaching pit, or other pit;

2. a system with less than the required vertical separation distance;

3. **a system that is no longer in use and is not abandoned in accordance with part 7080.2500.** See Section 7 - Septic Tanks for information on proper system abandonment.

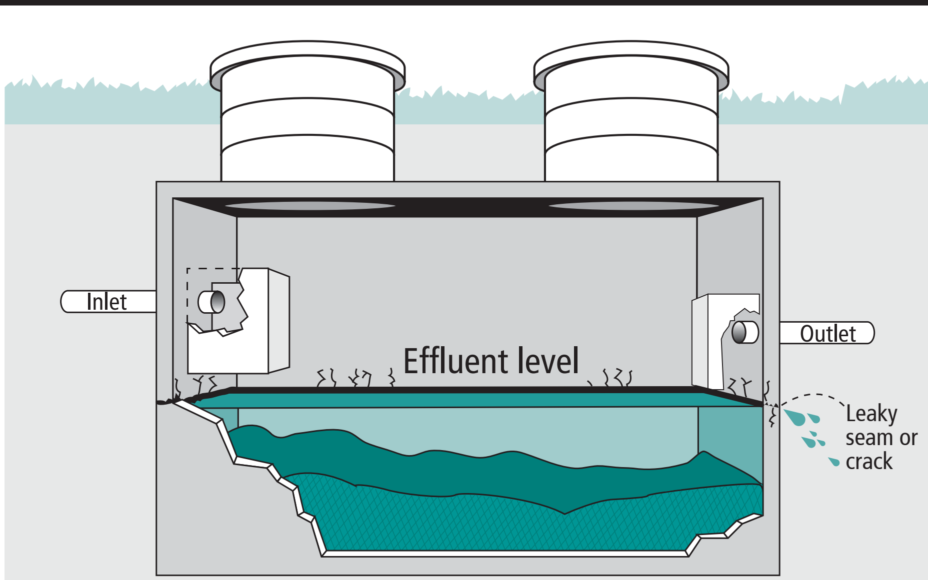
There are systems that do not adequately treat sewage even though sewage may not be surfacing. SSTSs are failing to protect groundwater (FPG) if they do not fully treat sewage before it enters the groundwater. Failure to treat sewage adequately can cause serious problems in surface waters and groundwater, including our valuable sources of drinking water. These water resources must be protected.

From Chapter 7080.1500, Subp. 4 (B) The ISTS must also be protective of groundwater. A system that is not protective is considered a system failing to protect groundwater. At a minimum, a system that is failing to protect groundwater is a system that is a seepage pit, cesspool, drywell, leaching pit, or other pit; a system with less than the required vertical separation; and a system not abandoned in accordance with part 7080.2500. A determination of the threat to groundwater quality for other conditions must be made by a qualified employee or licensed inspection business.

Cesspool, seepage pit, leaching pit, drywell

Older style SSTSs include tanks that were designed to leak. They were often installed quite deep and discharge at high rates that do not treat sewage. Cesspools and seepage pits are defined as failing to protect groundwater because they were not designed or constructed to treat waste, but only to dispose of it. **Chapter 7080.1100, Subp. 15, defines a cesspool as an underground pit, receptacle, or seepage tank that receives sewage directly from a building sewer and leaches sewage into the surrounding soil, bedrock, or other soil materials. Cesspools include sewage tanks that were designed to be watertight, but subsequently leak below the designed operating depth** as shown in Figure 2.4 - Midseam Tank Leak**.**

FIGURE 2.4 Midseam Tank Leak

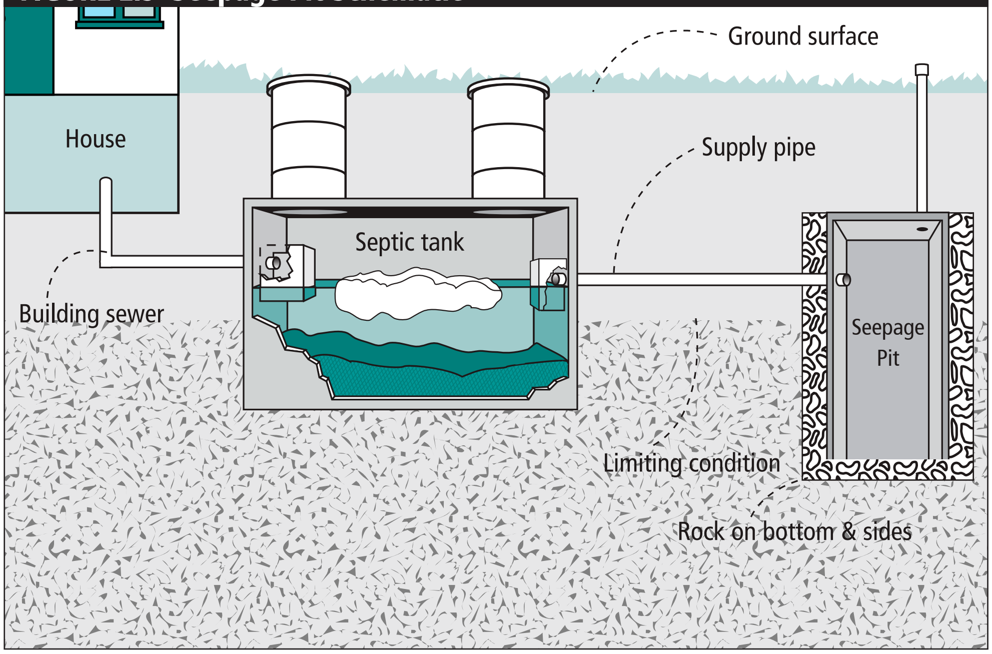


Liquid level is at level of seam. This tank is leaking at the seam.

A seepage pit is different than a cesspool in that it receives effluent from a water tight septic tank **(MN Rules Chapter 7080.1100, Subp. 68)** as shown in Figure 2.5 (next page) - Seepage Pit Schematic. **"Other pit" means any pit or other device designed to leach sewage effluent that is greater than 30 inches in height or has a bottom area loading rate of sewage greater than two gallons per square feet per day.**

There are two primary reasons why seepage pits and cesspools do not provide adequate wastewater treatment; size and depth. Sewage is discharged into a small diameter pit and causes the

FIGURE 2.5 Seepage Pit Schematic



wastewater to disperse undersaturated, anaerobic conditions, limiting soil\ treatment. The small size of these systems also increases the likelihood of sewage back-up into the dwelling and surfacing sewage. Many cesspools and seepage pits were intentionally sited with the bottom of the pit in groundwater, as the natural water movement carried the sewage away. Raw or partially treated sewage should never reach groundwater, as the impacts to an aquifer are similar to the damages in a ditch, stream, or lake. There have been numerous studies documenting contamination of ground and surface water from wastewater systems in contact with groundwater (Allen and Morrison, 1973; Anan'ev and Demin, 1971; Crane and Moore, 1983; Kligler, 1921; Vaisman, 1964).

Even though Chapter 7080 identifies existing seepage pit systems as non-compliant, their continued use may be allowed under Minnesota Statutes, section 115.55, subdivision 5a, paragraph (f), by LGUs that have adopted alternative local standards for these systems under part 7082.0050, Subp 5. For the continued use of a seepage pit to be allowed an inspection must be performed to assure the system:

A. has a sewage tank that does not obviously leak below the designed liquid capacity preceding the pit;

B. has a pit that is not located in a geologic formation that is used as a source of drinking water;

C. has at least three feet of vertical separation from the bottom of the pit to the seasonally periodically saturated soil or bedrock;

D. has an absorption area that has been determined by multiplying the average daily dividing the design flow by the soil loading rate based on the weighted average of each vertical stratum penetrated by the seepage pit, drywell, or leaching pit;

E. has a pit that has not been placed in a soil stratum with a sizing classification texture group of coarse sand or coarse and medium loamy sand

F. has a pit with a minimum inside diameter of five feet; and

G. meets all setback requirements.

(MN Rule Chapter 7080.2550, Subp. 2)

Most existing seepage pits systems will not meet these criteria and will require an upgrade. In Minnesota, noncompliant seepage pits and cesspools must be replaced with a compliant system. The time period for upgrade is based on local public health and environmental priorities and varies from location to location. Be sure to check with your local governmental unit (LGU). A list of MN LGUs can be found under "SSTS Local Units of Government" at: www.pca.state.mn.us.

The noncompliant cesspool or seepage pit must be properly abandoned to eliminate the safety hazard and impact to public health and the environment. A licensed designer must be hired to evaluate site and soil conditions to determine the proper replacement ISTS to treat and disperse the wastewater at the site. This design is reviewed by a LGU to ensure it meets Minnesota Rules, Chapter 7080 and any additional LGU requirements. A list of licensed septic professionals can be found by contacting your LGU or under "SSTS Business Licensing, Individual Certification, and Enforcement" at: www.pca.state.mn.us.

Limiting layer

Three feet of vertical separation from a limiting layer such as periodically saturated soils or bedrock allows for wastewater to be properly treated in the soil. **Vertical separation means the vertical measurement of unsaturated soil or sand between the bottom of the distribution medium and the periodically saturated soil level or bedrock (MN Rules Chapter 7080.1100, Subp. 91).** In most soils, three feet is sufficient separation for adequate treatment. Separation from bedrock is critical because only adequate separation can ensure proper treatment and prevent the contamination of wells. Where bedrock is shallow, drinking water wells frequently draw water from cracks in the bedrock. If untreated effluent enters the bedrock, it will flow in the same cracks. Wells can be contaminated very quickly.

The depth to the limiting layer must be assessed to determine if a system is in compliance. If two independent soil borings have been performed, the inspector can use those records to verify the soil conditions. Determining whether or not a system is failing requires you to know when it was constructed and what kind of establishment it serves. For any system (1) built after March 31st, 1996 or (2) located in shoreland, a wellhead protection area or serving a food, beverage, or lodging establishment, three feet of separation is required at the time of the compliance inspection. For systems (1) built previous to April 1, 1996 and (2) not located in shoreland, a wellhead protection area or serving a food, beverage or lodging establishment, two feet of vertical separation is required.

Systems in shoreland areas or wellhead protection areas or systems serving food, beverage, or lodging establishments (SWF) are defined in MN Rules Chapter 7080.1100, Subp. 84:

- **a. SSTS constructed in shoreland areas where land adjacent to public waters has been designated and delineated as shoreland by local ordinance as approved by the Department of Natural Resources;**
- **b. SSTS constructed in wellhead protection areas regulated under Minnesota Statutes, chapter 103I; and**
- **c. SSTS serving food, beverage, and lodging establishments that are required to obtain a license under Minnesota Statutes, section 157.16, subdivision 1, including manufactured home parks and recreational camping areas licensed according to Minnesota Statutes, chapter 327.**

Local ordinance may allow up to a 15% reduction in the vertical separation distance for existing systems to account for settling of sand or soil, normal variation of measurements, and interpretations of the limiting layer conditions. An inspector will need to check with their local permitting authority as adoption of this reduction needs to be specifically allowed in the local ordinance. This reduction does not apply to systems installed prior to April 1, 1996 in non-SWF areas, which only require two feet of separation or to Type IV or V systems designed with less than three feet of vertical separation distance.

Systems that were designed and installed with less then three feet of vertical separation in the past were labeled "Experimental", "Other" or Performance in past version of Chapter 7080. These systems typically have a advanced treatment unit such as an aerobic treatment unit or media filter before the soil treatment system. Therefore less vertical separation is sometimes allowed in the soil treatment system. When performing compliance inspection on these systems the design and monitoring and mitigation plan must be evaluated to determine how much vertical separation was specified in the design. Then the inspector must evaluate if the system meets these design requirements along with performance data for upstream treatment units and piezometer data when available.

FIGURE 2.6 Loading Affects Vertical Separation

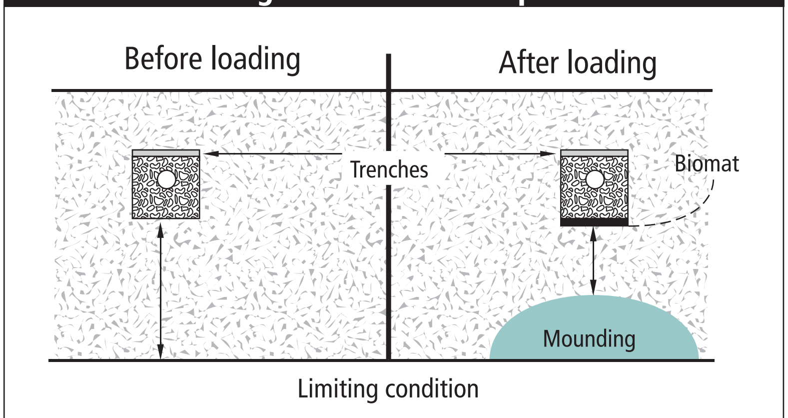
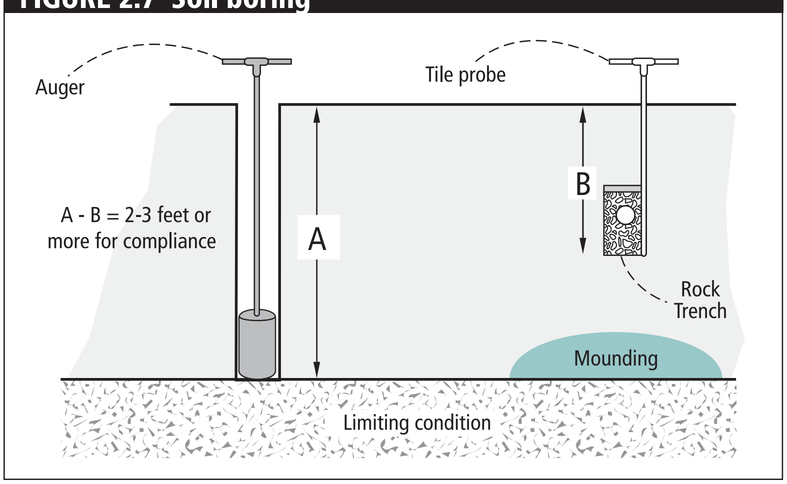


FIGURE 2.7 Soil boring



When soil treatment systems are loaded with sewage, the groundwater beneath the system mounds and reduces the designed vertical separation. The effluent moves through the soil to the limiting layer where its flow may be retarded. A groundwater mound forms here reducing the thickness of the unsaturated zone. In addition, infringement into the vertical separation zone occurs directly below the system as a biological layer (biomat) is created. These conditions are depicted in Figure 2.6. Vertical separation is measured by performing a boring outside the area of influence on the same contour and landscape position of similar soil.

The measurement is made from the bottom of the media to the limiting condition (see Figure 2.7). The inspector finds the depth of the soil's redoximorphic features or berock, measurement "A," and then finds the bottom of the soil treatment system,measurement "B." For more information about redoximorphic features, see Section 3: Sewage Treatment Utilizing Soils. The calculation for vertical separation follows: A – B = 2 or 3 feet or more for compliance. More than one boring should be conducted to get the best possible representation of the site.

Systems no longer in use that were not properly abandoned are considered FPG. These systems, particularly the tanks, can crumble, subside, cave in and collapse and potentially give way if they are allowed to sit empty and degrade over time. For more information on proper abandonment of tanks see Section 8.

Systems Not Operated or Maintained Properly

A system not operated or maintained in accordance with its operating permit is considered to be non-compliant. In order to determine if the system is in compliance the inspector must research if the requirements of the permit have been met. The steps to bring these systems into compliance are determined by the LGUs. Type IV, Type V and MSTS must all be issued an operating permit. Performance systems installed previous to the local adoption of the 2008 version of 7080 will also have operating permits.

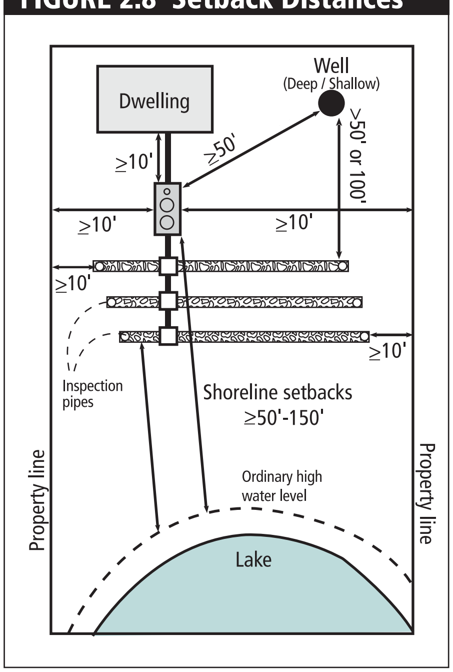
Systems with flows greater than 2,500 gpd

For systems with flows greater than 2,500 gallons per day designed under part 7080.2150, Subp. 4, item A or B, must demonstrate that the additional nutrient reduction component required under those items is in place and functioning. If existing systems are receiving replacement components they must be repaired or replaced to meet technical standards and criteria for new construction according to local ordinance. The remaining components of the existing system must result in the system being in compliance (7080.1500, Subp. 6)

Compliance criteria for systems with partial component replacement

When components of an existing system are being repaired or replaced, the new components must meet technical standards and criteria for new construction according to the local ordinance. A repair is the action of fixing or replacing substandard or damaged components; repairs can be categorized as required repairs, recommended repairs, and upgrades. The remaining components of the existing system that do not need repair or replacement must only meet the existing system compliance criteria. For example, a four-bedroom dwelling has a watertight 1000 gallon septic tank to a soil treatment dispersal system drainfield that is found to lack vertical separation to the periodically saturated soil. In this case, the soil treatment component would need to be replaced with a new soil treatment system that meets all the new system requirements, while the 1000 gallon septic tank, which for a new system would be required to be 1,500 gallons, would not need to be replaced or another subsequent tank installed. The LGU could be more restrictive than these requirements and require the entire system to meet all the new system technical requirements. Therefore, the designer of the new component must fully evaluate the system and repair or replace all components not in compliance with existing system standards and consider upgrading the others if they are essential to the long-term performance of the system.

FIGURE 2.8 Setback Distances



Non-Code System

In addition to the basic existing system compliance inspection elements, a number of other elements may be inspected, depending on local requirements and/or customer preferences. These include setback distances of system from wells and other structures or property lines, materials used in construction of the system, and the system size as shown in Figure 2.8. The existing system in this figure does not meet any of the setbacks required for a new system, but the system would be considered in compliance because the septic tank is watertight and the soil treatment dispersal system meets the required separation distance and is not hydraulically failing. These are compliance criteria for new systems but are *not* a part of an existing system inspection unless required by the LGU or your customer. An existing system may not be “up to the new construction code,” but that does not necessarily make it non-compliant. Local ordinances may be more restrictive and require these systems to be upgraded.

Inspection Process

Compliance inspections are required for all new system constructions and replacements (Minn. Stat. §115.55, Subd. 5). In shoreland, compliance inspections are required when any building permit or variance is requested (MN Rules 6120.3400, Subp. 3(D)). If an LGU administers a program for bedroom-addition permits, the system must be inspected before the bedroom – addition permit is issued. The inspection requirement before issuance of a bedroom-addition permit may be temporarily waived if the permit application is made between November 1 and April 30 (during winter). Under these circumstances, an inspection must be conducted by the following June 1 and a certificate of compliance must be submitted to the LGU and property owner by September 30.

MN Rules Chapter 7082.0700, Subp. 4 requires the following procedures be followed when completing an existing SSTS compliance inspection:

A. A compliance inspection of an existing system must first determine whether the soil dispersal system, sewage tanks, or other conditions pose an imminent threat to public health and safety as defined in part 7080.1500, subpart 4, item A. A determination must then be made as to whether the sewage tanks and soil dispersal area are failing to protect groundwater as defined in part 7080.1500, subpart 4, item B. The inspection must also verify compliance with part 7080.1500, subpart 4, item C.

B. The agency's inspection report form for existing SSTS, supplemented with any necessary or locally required supporting documentation, must be used for the existing system compliance inspections in subitems (1) to (4). Allowable supporting documentation includes tank integrity assessments made within the past three years and prior soil separation assessments.

(1) A tank integrity and safety compliance assessment must be completed by a licensed SSTS inspection, maintenance, installation, or service provider business or a qualified employee inspector with jurisdiction. An existing compliant tank integrity and safety compliance assessment is valid for three years unless a new evaluation is requested by the owner or owner's agent or is required according to local regulations.

(2) A soil separation compliance assessment must be completed by a licensed inspection business or a qualified employee inspector with jurisdiction. Compliance must be determined either by conducting new soil borings or by prior soil separation documentation made by two independent parties. The soil borings used for system design or previous inspections are allowed to be used. If the soil separation has been determined by two independent parties, a subsequent determination is not required unless requested by the owner or owner's agent or required according to local regulations.

(3) Determination of hydraulic performance and other compliance in part 7080.1500, subpart 4, item A, must be completed by either a licensed inspection business or a qualified employee inspector with jurisdiction.

(4) A determination of operational performance and other compliance in part 7080.1500, subparts 4, item C, and 5, must be completed by a licensed advanced inspection business, a qualified employee with an advanced inspector certification with jurisdiction, or a service provider. A passing report is valid until a new inspection is requested.

C. A certificate of compliance or notice of noncompliance for an existing system must be based on the results of the verifications in item B. The certificate of compliance or notice of noncompliance for an existing system must be signed by a licensed inspection business or a qualified employee inspector with jurisdiction. The certificate or notice for an existing system must be submitted to the local

unit of government with jurisdiction and the property owner or owner's agent no later than 15 days after a compliance inspection. The completed form must also be submitted to the owner or owner's agent. The certificate of compliance for an existing system is valid for three years from the date of issuance, unless a new inspection is requested by the owner or owner's agent or is required according to local regulations.

D. If a compliance inspection for an existing system indicates that the system is noncompliant, the notice must be signed by a licensed inspection business or qualified employee inspector with jurisdiction, contain a statement of noncompliance, and specify the reasons for noncompliance of each component specified in item B.

Some LGU ordinances require an inspection at other times such as at property transfer, when complaints are received, as part of an area SSTS surveys, etc. These inspections are not required by state law; however, they should require a compliance inspection that complies with the criteria for state-mandated inspections.

Disclosure vs. Inspection

Before signing an agreement to sell or transfer real estate, the seller or transferor must disclose in writing to the buyer or transferee how sewage generated at the property is managed. The disclosure must be made by delivering a statement to the buyer or transferee that either:

1. the sewage goes to a facility permitted by the agency (i.e. wastewater treatment plant); or
2. the sewage does not go to a permitted facility and is therefore subject to applicable requirement. The disclosure must further describe the system, including the legal description of the property, the county in which the property is located, and a map drawn from available information showing the location of the system on the property to the extent practicable. If the seller or transferor knows that an abandoned SSTS exists on the property, the disclosure must include a map showing its location. In the disclosure statement, the seller or transferor must indicate whether the SSTS is in use and, to the seller's or transferor's knowledge, in compliance with applicable sewage-treatment laws and rules.

The statute and state rules governing SSTSs (Minn. Stat. § 115.55 and MN Rules Chapter 7080) only require the seller to complete a written disclosure statement; however, local government ordinances, especially in shoreland areas, may require a full compliance inspection before property transfer. In addition, lending institutions, buyers, or sellers may request a compliance inspection.

If someone other than the property owner evaluates the SSTS for purposes of disclosure, that party must meet the licensing and certification requirements of Chapter 7083. In other words, the party must be qualified to perform inspections. The inspector who evaluates the SSTS must perform a compliance inspection in accordance with Chapter 7080 and 7082. A compliance inspection will determine whether the system is in compliance or failing, and whether it's an ITPHS.

7083 Certification and Licensing Requirements

Any business that designs, installs, maintains, pumps, or inspects SSTSs in Minnesota must be licensed by the MPCA. A restricted license is issued to a business whose Designated Certified Individual (DCI) is an apprentice working toward meeting the experience requirement under the supervision of a qualified employee or a designated mentor. It can also be placed on a license due to enforcement actions or to address unusual work situations. To receive a license, each business needs to:

- complete MPCA License application
- provide evidence of $100,000 of general business liability insurance and worker's compensation insurance
- provide evidence of a corporate surety bond of $25,000
- pay a $200 fee per licensed category up to a maximum of $400; and
- indicate the designated certified individual (DCI) in each licensed category.

A license is valid for one year from the date of issuance. License renewals may be requested for up to three years in advance of expiration.

Certification

A individual is certified when they meet the state training, examination, and experience requirements for working with SSTS in at least one of five specialty areas. A business must have a certified individual with a specialty in the applicable license category to qualify for a license. This employee provides direction and personal supervision to other employees who are not certified. Each LGU must have a certified inspector on staff or contracted to review, issue permits, and inspect ISTS and MSTSs.

After you have taken a specialty examination, an application to become a individual professional will automatically be sent to you with the letter explaining the results of your examination. A form documenting your experience must also be submitted as part of this application. Certification applications and Experience documentation forms are also available by calling the ISTS Certification & Licensing Coordinator at (800) 657-3659.

Licensing Exemptions

From Chapter 7080.0700, Subp. 1, a license is not required for:

a. an individual who is a qualified employee performing work as directed by a state or local government employer;

b. an individual who, after obtaining a signed site evaluation and design report from a licensed design business, constructs an ISTS to serve a dwelling that is owned by the individual and functions solely as a dwelling or seasonal dwelling for that individual. Any assistance provided to the system owner in construction of a system under this item must be performed by a licensed installation business; an individual who performs labor or services as an employee of a licensed SSTS business;

c. an individual who performs supervised labor or services as an employee of a licensed SSTS business;

d. a farmer who pumps septage from an ISTS that serves dwellings or other establishments that are owned or leased by the farmer and applies septage on land that is owned or leased by the farmer;

e. a property owner who personally gathers existing information, evaluates, and investigates an ISTS to provide a disclosure, for a dwelling that is owned by the individual and functions solely as a dwelling or seasonal dwelling for that individual;

f. an individual or business who abandons a SSTS;

g. an individual who maintains a toilet waste treatment device* for a dwelling that is owned by the individual and functions solely as a dwelling or seasonal dwelling for that individual; or

h. an individual who performs tasks identified in the system's management plan that do not require a maintainer or service provider license for a dwelling that is owned by the individual and functions solely as a dwelling or seasonal dwelling for that individual;

i. an individual or business owned by a tribal member with work conducted within the tribal reservation boundary;

j. the owner or designee of a campground or other similar facility who removes and transports sewage wastes from recreational vehicles into a holding or treatment system located on the same property as the facility.

*** According to MN Rules Chapter 7080.1100, Subp. 86, Toilet waste treatment devices are defined as other toilet waste apparatuses including incinerating, composting, biological, chemical, recirculating, or holding toilets or portable restrooms.**

Types of certification and corresponding responsibilities

There are five types of certification and licenses that a company can obtain from the MPCA:

Maintainer—(classified as Pumper prior to 2008) A DCI maintainer must have the knowledge and ability to measure scum and sludge depths for the accumulation of solids and remove these deposits; maintain toilet waste treatment devices; store and haul septage; dispose properly of septage by land application or disposal in a publicly owned treatment works; identify problems related to sewage tanks, baffles, maintenance hole covers, and extensions, and make repairs as necessary; evaluate sewage tanks, pump tanks, distribution devices, valve boxes and drop boxes for leakage; identify cesspools, seepage pits, leaching pits, and drywells; and clean supply pipes and distribution pipes. **From MN Rules Chapter 7080.0770 Maintenance licensees must:**

a. record pump-out date, gallons removed, any tank leakage below or above the operating depth, the access point used to remove the septage, the method of disposal, the reason for pumping, any safety concerns with the maintenance hole cover, and any troubleshooting or repairs conducted. This information must be submitted to the homeowner within 30 days after the maintenance work is performed. Maintenance business pumping record information must be maintained by the business for a period of five years;

b. observe and provide written reports of any noncompliance to the system owner within 30 days; and

c. obtain a signed statement if the owner refuses to allow the removal of solids and liquids through the maintenance hole.

Service Provider – In 2008, the Service Provider certification was created. A DCI service providers must have the knowledge and ability to assess the operational status and system performance by sampling, measuring, and observing in compliance with the management plan or operating permit; preserve, store, and ship samples for analysis and interpret sampling results; adjust, repair, or replace components to bring the system into proper operational compliance; assess the operational status of sewage collection systems and adjust, repair, or replace components to bring the system into proper operational status; complete and submit any necessary reporting to the system owner and the LGU; measure scum and sludge depths for the accumulation of solids; make observations if non-domestic wastes may have been discharged into the system; identify problems related to sewage tanks; and assess the condition of baffles, effluent screens, maintenance hole covers, and extensions.

Responsibilities

From MN Rules Chapter 7083.0780, Subp. 2, service provider licensees must; (A) report sampling results, operational observations, system adjustments, and other management activities in compliance with local ordinances, management plans, or operating permit requirements; and; (B) observe and provide written reports of any noncompliance to the system owner and the LGU within 30 days.

Installer – A DCI installer must have the knowledge and ability to construct, install, alter, extend, or maintain SSTSs; ensure all work is done in accordance with a written design report; notify the LGU with jurisdiction to ensure inspections are conducted for new construction or replacement; ensure site conditions allow for construction; provide evidence to verify compliance with applicable requirements; maintain quality control/quality assurance records; identify problems related to SSTSs and make repairs; provide upgrade, repair, and replacement advice; and maintain and submit to the LGU as-builts of all work sign off by a certified individual. The Certified installer must be onsite to determine, supervise and verify:

a. the system layout and placement;
b. that site conditions allow for construction;
c. the soil moisture conditions for excavation;
d. the elevations of sewage tanks and soil treatment system;
e. the quality of tanks and suitability of other materials;
f. solutions to problems encountered and
g. upgrade and repair advice.

Responsibilities

From MN Rules Chapter 7083.0760, Subp. 2, installation licensees must (A) ensure all work is done according to a design report approved by the local SSTS authority under part 7082.0500 and the plumbing program administrative authority as required under part 1300.0215, subpart 6; (B) provide adequate notice to the local unit of government and the plumbing program administrative authority when work requires inspection; (C) ensure that all work is done according to applicable storm water regulations and the Minnesota Plumbing Code; (D) provide as-built drawings to the owner and local unit of government within 30 days of system installation; (E) maintain quality control and quality assurance records for five years; (F) provide system owners with information concerning system operation and maintenance; (G) follow recommended standards and guidance documents for registered products and check the quality of materials used; (H) negotiate with the system owner and jointly determine who will be responsible for seeding, erosion and frost protection, watering, and other vegetation establishment activities; and; (I) pay the septic system tank fee and submit the form according to Minnesota Statutes, section 115.551, including notification if no tanks were installed during the reporting year. The form and payment are due to the commissioner by January 31 for the previous year's installations.

Authorization

From MN Rules Chapter 7083.0760 a licensed installation business is authorized to construct, install, alter, extend, maintain, or repair all SSTS and the building sewer connected to a subsurface sewage treatment system only according to an approved design.

Designer

1. Basic Designer—must have the knowledge and ability to design Type I-III ISTS up to 2,500 gpd, conduct site and soil evaluations, design all system components (including the building sewer connected to an SSTS) and write management plans for SSTS serving dwellings or other establishments. A Basic Designer must also have knowledge to inform the proposed system owner of the system classification, estimated costs for construction, operation, monitoring, service, component replacement, management, and anticipated system life.

2. Intermediate Designer - in addition to responsibilities of a Basic Designer, may conduct site and soil evaluations, design systems, and write management plans for a Type IV-V* ISTS as described under parts 7080.2350 to 7080.2400 serving dwellings or other establishments with a design flow of 2,500 gallons per day or less

3. Advanced Desinger - in addition to the responsibilities of a Basic Designer and Intermediate Designer, may conduct site and soil evaluations, design systems, and write management plans for all types and sizes of SSTS.

Responsibilities

From MN Rules Chapter 7083.0740, Subp. 2 all design licensees must (A) inform the proposed system owner of the type classification of the system under parts 7080.2200 to 7080.2400; (B) provide written reasonable assurance of system performance to the LGU; but not limited to 1. adherence to system type requirements; or 2. technical basis for design elements for Type II to Type V systems; (C) prepare detailed design sheets, drawings, calculations, materials, system layout, and elevations; and; (D) prior to installation, submit plans and specifications for the building sewer connected to a SSTS for approval as required by part 1300.0215, subpart 6. From the same Rule, subpart 3 states that; certified designers must conduct the soil descriptions and review other site evaluations and designs by noncertified employees. This review includes both verification of field observations and conclusions and design assumptions and calculations.

Inspector

1. Basic—must have the knowledge and ability to assess site evaluations; evaluate designs; evaluate installations, pumping and septage disposal activities; conduct compliance inspections and permitting activities; issue written certificates of compliance and notices of noncompliance; and issue and maintain inspection reports on Type I-III ISTS for up to 2,500 gpd. Each inspector from a company performing inspections must be certified.

2. Intermediate Inspector - in addition to responsibilities of a Basic Inspector, may conduct permitting and compliance management activities, compliance inspections and issue written certificates of compliance and notices of nonconpliance for an existing Type IV-V ISTS as described under parts 7080.2350 to 7080.2400 serving dwellings or other establishments with a design flow of 2,500 gallons per day or less.

3. Advanced Inspector - in addition to the responsibilitites of a Basic Inspector and Intermediate Inspector, may conduct permitting and compliance management activities, compliance inspections and issue written certificates of compliance and notices of noncompliance for all types and sizes of SSTS.

Responsibilities

From MN Rules Chapter 7083.0750, an inspection business is authorized to conduct compliance inspections and issue written certificats of noncompliance for an existing ISTS. It is allowed to install a new system for a property in which the business has conducted an existing ISTS compliance inspection, provided the business holds the appropriate licenses. A local unit of government is allowed to authorize a licensed inspection business to review and approve site evaluations and designs, inspect new construction and replacement systems, verify the submittal of management plans, and issue written certificates of compliance and notices of noncompliance for systems

According to MN Rules Chapter 7083.0750, Subp. 3, certified inspectors are responsible for personally conducting the necessary procedures to assess system compliance. Certified inspectors must complete and sign the agency's existing system inspection form. Certified inspectors may permit, inspect, or permit and inspect a building sewer connected to a subsurface sewage treatment system for compliance with the Minnesota Plumbing Code when;

A. the installation is not subject to the requirement of part 1300.0215, subpart 6, and no other approval is required by the plumbing program administrative authority; or

B. authorized by the appropriate plumbing program administrative authority.

"Public program administrative authority" means the commissioner of labor and industry or the governing body of the adopting unit of government, its agents, and its employees according to the Minnesota Plumbing Code, part 4714 (MN Rules Chapter 7080.1100, Subp. 60).

Training

To fulfill the training requirement for one or more of the specialty areas, an individual must successfully complete:

1. course work that covers basic knowledge of SSTSs and soil treatment theory; design and construction fundamentals; and state licensing requirements, standards, and criteria for systems described in Chapter 7080; and
2. course work that provides the knowledge and skills necessary to fulfill the responsibilities appropriate for each specialty area.

Training that fulfills the certification requirements must be accredited by the MPCA. The University of Minnesota's OSTP offers a complete series of accredited SSTS workshops. For more information about these courses, visit our website at septic.umn.edu/events or call (800) 322-8642.

Continuing education

Continuing education is required to maintain certification. Examinations that qualify for certification expire if continuing education requirements are not met. If your qualifying exams expire, you must complete and submit a Conditional Certification Application and agree to complete the missing number of continuing education hours re-take up to two expired exams within a one-year timeframe.

Certified individuals must complete twelve hours of continuing education training related to SSTS every three years. At least six hours must be directly related to the administration and technical parts of Chapters 7080-7083. In addition, Designers and Inspectors must take six hours of additional continuing education with a field component regarding soils. Continuing education hours earned in excess of these requirements cannot be carried over to meet the requirements for future certification periods. The continuing education requirement is not increased for multiple specialty area endorsements.

Those offering continuing education workshops must have the training accredited through the MPCA.

Exam

The examinations are based on Minnesota Rule Chapter 7080-7083 and the skill, knowledge, and education that a person must have to perform the duties and responsibilities for each specialty area. A score of 70% or better is required to pass the exam. You must also score 70% or better on the critical field portion of the Soils Exam.

An individual who fails an examination is ineligible to retake the same examination for six months unless the person has repeated the workshop in the subject matter covered by the failed examination. Official documentation of this training must be provided at the time the examination is retaken. Training hours used to fulfill this reexamination requirement may not be used to fulfill continuing education requirements. Failure to pass the examination in a specialty area or the Basic examination does not prevent the individual from taking an examination for a different specialty area.

Experience

In order to gain experience, one must have an approved experience plan (as a worker or restricted license) with a mentor. The Mentor must either be fully certified in the same discipline or be an Inspector and have had no enforcement convictions within the past five years. The Mentor must be on site and co-complete the work.

This experience can be gained by working for a company already licensed, with a restricted license of your own, through a field work training program, or other methods approved by the MPCA. The experience necessary for each level of certification is as follows:

Designer Experience –

i. 15 system designs of Type I-III systems with design flows less than 2,500 gpd. with at least one above ground, and one below-ground system
ii. observe five installations and five service or operational instances (mentorship not required)
iii. no additional experience needed for the Intermediate or Advanced designer certification

Installer Experience –

i. 15 systems installations of Basic, Advanced, or MSTS systems with at least one above-ground and one below-ground system
ii. observe five service or operational instances (no mentorship needed)

Inspector Experience –

i. 15 system inspections of Type I-III systems with flows less than 2,500 gpd. with at least one above ground, and one below-ground system
ii. observe five soil evaluations, system designs, and management plans being developed; five system installations; and five service or operational instances (mentorship not required)
iii. no additional experience is required for an Intermediate or Advanced Inspector systems

Maintainer Experience – 15 system maintenance visits of Basic, Advanced or MSTS systems

At this time, Service Provider certification does not have an experience requirement.

The full list of 15 must be submitted along with all the documents from five jobs – all 7080 documents, experience plans, and all local approvals.

Other Minnesota Regulatory Bodies

Board of Architecture, Engineering, Land Surveying, Landscape Architecture, Geoscience and Interior Design

The Minnesota Board of Architecture, Engineering, Land Surveying, Landscape Architecture, Geoscience and Interior Design (AELSLAGID) examines, licenses, and regulates the practice of architecture, professional engineering, land surveying, landscape architecture, geoscience, and use of title for certified interior design. There are professional engineers, soil scientists, and geologists involved with the design of SSTS systems who are licensed by this board. For more information, visit their website (mn.gov/aelslagid) or reach them by phone at 651.296.2388.

Board of Water and Soil Resources

The Minnesota Board of Water and Soil Resources (BWSR) is the state's administrative agency for 90 soil and water conservation districts, 46 watershed districts, 23 metropolitan watershed management organizations, and 80 county water managers. The agency's purpose, working through local government, is to protect and enhance the state's irreplaceable soil and water resources by implementing the state's soil and water conservation policy, comprehensive local water management, and the Wetland Conservation Act as it relates to the 41.7 million acres of private land in Minnesota. In reference to SSTSs, BWSR administers the wetland conservation act. (M.S. 103G and MN Rules Chapter 8420) and links water resource planning with comprehensive land use planning. SSTS professionals must understand and follow state rules and laws that outline impacts to a wetland, including the design and installation of SSTS. For more information see www.bwsr.state.mn.us or call (651) 296-3767.

Department of Health

The Minnesota Department of Health (MDH) is responsible for administering Minnesota Rules Chapter 4720 (https://revisor.mn.gov) through their Drinking Water Protection Section and Chapter 4725 through their Well Management Section. Chapter 4725 establishes the setbacks or isolation distances between wells and SSTSs, regulates the location, construction and sealing of water supply wells, dewatering wells, environmental wells, bored geothermal heat exchangers and elevator borings, and establishes specific requirements for well variances. Chapter 4720 establishes the public water supply rules, including rules for source water protection. Chapter 4717 contains the general Health Department variance rules. Food, beverage, and lodging establishments are regulated under Minnesota Statutes, Chapter 157, and Minnesota Rules, Chapter

4626, the "Food Code". The MDH may delegate portions of the well inspection, permitting, and regulatory program to local Boards of Health. At the present time, two cities (Bloomington and Minneapolis) and eight counties (Blue Earth, Dakota, Goodhue, LeSueur, Olmsted, Wabasha, Waseca, and Winona) administer the well program.

Existing Conditions – Wells and SSTS

The MDH regulates the construction, repair, and sealing of wells and borings in Minnesota through Minnesota Statutes, Chapter 103I and Minnesota Rules, Chapter 4725 (Well Code). Minnesota Rules, Chapter 4725 was amended effective August 4, 2008.

Isolation Distances

An important provision of the Well Code is the proper separation between wells and sources of contamination. The setbacks or "Isolation Distances" apply to all "water supply" wells, including drinking water wells, and wells used for irrigation or industrial supply. The setbacks also apply to abandoned but unsealed wells, and to drivepoints. The setbacks apply to the installation of a new contamination source such as a buried septic tank, absorption area or sewer, and the replacement of an existing septic tank, absorption area or buried sewer. See Table 2.5 (next page). These setbacks or "isolation" distances are measured horizontally from the closest part of the well to the closest part of the contamination source. These isolation distances must be maintained between a water supply well and a contamination source no longer in use unless all contaminants have been removed and visibly contaminated soil has been removed.

Sewers

The MDH has authority for wells, and establishes the setback requirements between wells and sewers, whereas the Department of Labor and Industry manages and enforces rules pertaining to plumbing systems. For information on requirements for construction and maintenance sewer and plumbing related components see the Department of Labor and Industry section of this manual.

Sumps, Lift Stations, Grinder Pumps

The well code requires a 50-foot setback to a non-watertight sewage sump, and a 20-foot setback to a watertight sewage sump. In order to qualify for the 20-foot distance, a sump must be less than 100 gallons, be successfully air-tested or manometer tested, and meet the material and cover requirements of the Plumbing Code.

Setbacks to Sensitive Wells

The rules require that the setback between a contamination source that directly enters the soil, like a drainfield, is doubled from a water supply well more sensitive to contamination, specifically, a well that does not have 50 feet of watertight casing, and that does not have a casing that penetrates ten feet of a confining layer or confining materials. A confining layer is sediment or rock that has a vertical hydraulic conductivity of 10^6 cm/sec or less, and includes clay, sandy clay, or silty clay. The MDH will accept multiple layers each less than 10 feet thick that added together total more than 10 feet. The setback to a "sealed" contamination source, such as a watertight septic tank, is not doubled. While many of these "sensitive" wells are shallow, it is a misnomer that this requirement only applies to shallow wells, In fact, the term "shallow well" is not used in the well code.

TABLE 2.5 Well Setbacks

Related Isolation Distances from Water Supply Well

Minnesota Department of Health Chapter 4725, 2008

This list of isolation distances is summarized from Minnesota Rules, Chapter 4725. For complete regulations, consult these rules and Minnesota Statutes, Chapter 1031. Additional information and explanation can be obtained by consulting the *Rules Handbook: A Guide to Rules Relating to Wells and Borings,* or by contacting the Well Management Section, Minnesota Department of Health: www.health.state.mn.us/divs/eh/wells

Setback (feet)	Item
300[1]	■ Absorption area with design of a SSTS flow greater than 10,000 gpd ■ Wastewater stabilization pond, municpal, 500 or more gallons/acre/day of leakage
150[1]	■ Absorption area of a SSTS serving a hospital, nursing home, mortuary, veterinary clinic, health care clinic, or similar facility with infectious or pathological wastes ■ Waste water stabilization pond, municipal or industrial, less than 500 gallons/acre/day of leakage
75[1]	■ Cesspool ■ Dry Well (sewage) ■ Leaching or Seepage Pit
50[1]	■ Absorption area of a SSTS with design flows less than or equal to 10,000 gpd not serving a facility with a larger setback (hospital, nursing home, etc.) ■ Interceptor ■ Soil treatment area ■ Septic tank, sewage pump tank ■ Sewage sump unless the sump meets the criteria for the 20-foot isolation distance, watertight sewage treatment device, watertight sewage holding tank ■ Buried sewer unless the sewer meets the criteria for the 20-foot isolation distance ■ Watertight sand filter, peat filter, or constructed wetland ■ Sewage, septage, or sludge land spreading area ■ Disposal area for water treatment backwash ■ Gray-water dispersal area ■ Unused, unsealed well or boring
20	■ Sewage sump which meets the Plumbing Code standards with a capacity of less than 100 gallons ■ Tested, approved material, buried sewer serving one building or two single family homes, except for a collector or municipal sewer or a sewer serving a hospital, nursing home, or similar facility with infectious or pathological wastes ■ Storm water drain pipe eight inches or larger in diameter ■ Gravel pocket or French drain for clear water drainage ■ Portable privy or toilet ■ Pit

Setback (feet)	Additional Isolation Distances for Community Water Supply Wells
20	■ Gravel pocket receiving clear water drainage
50[2]	■ Minimum distance from any contamination source, except as specified elsewhere in this table

[1] A water supply well with less than 50 feet of watertight casing, or which is not cased below a confining layer of at least 10 feet of thickness, must be located at least twice the indicated distance.

[2] A community public water supply well must be a minimum of 50 feet away from any contamination source. The 20-foot contamination distances (sewer, pit, storm water drain pipe, etc.) are increased to 50 feet for community water supply wells.

Water Supply Pipes

The well rules do not require any setback between a contamination source and a water supply pipe, pressure pipe or suction pipe. On the other hand, the plumbing code does not allow the installation of a new water service line within 10 feet horizontally of a contamination source (see Minnesota Rules, part 4715.1710, Subp. 3). However, the plumbing code does allow for an existing building sewer or water supply pipe to be replaced, provided that both pipes are pressure tested if they are within ten feet of each other. The plumbing code does specify the pipe material required when either pipe is replaced.

Abandoned Wells and Abandoned SSTSs

The setbacks do not need to be maintained between a new SSTS and a well sealed (abandoned) by a licensed well contractor in accordance with the sealing rules. For example, it would be allowable to place a drainfield next to a properly sealed well; however, it is recommended that a setback be maintained if possible.

MDH's rules require that a contamination source, including an abandoned contamination source, requires a setback distance from a water supply well (unless the well is properly sealed) until contaminants are gone. A leaky sewage tank, cesspool, or privy that is abandoned in accordance with 7080, or a drainfield or septage disposal area, still has a setback, unless the "contaminated" soil is removed. MDH gages "contamination" simply by visual inspection. A watertight sewage tank, watertight holding tank, or other sealed source that is pumped and abandoned in accordance with Chapter 7080 has no distance requirement. Once a sewer is disconnected from the waste system (and doesn't have sewage), there is no setback.

System Compliance

The MDH has a strong working relationship with LGUs related to the proper location of new wells and SSTSs. However, with the new SSTS requirements, the MDH has received numerous inquiries regarding the compliance status of existing wells and existing SSTSs. The determination of compliance on water well/SSTS setbacks varies according to the date of installation of the well and the SSTS. The three time periods are: before July 1, 1974; from July 1, 1974 to June 31, 1989; and from July 1, 1989 to the present.

Before July 1, 1974

There was no statewide regulation of wells prior to July 1, 1974. A few counties and other LGUs regulated well construction during this time through local ordinances. For wells or SSTS installed before July 1, 1974, the MDH has no authority to compel any corrective actions for installations that do not meet current Well Code requirements unless the installation is a public health nuisance.

July 1, 1974 to June 31, 1989

The MDH regulatory program began on July 1, 1974 with the implementation of the first well code. The well code contained detailed construction standards for newly constructed wells, including minimum isolation distances to be maintained between wells to be constructed and various sources of contamination. Although rules clearly specified the proper placement of a well in relation to various existing sources of contamination, they failed to prohibit the placement of contaminant sources closer to existing wells than the distances specified in the well code. For wells constructed after July 1, 1974, the MDH does have regulatory authority to require correction of Well Code violations. For SSTSs installed too close to existing wells, the MDH has no regulatory authority to require corrective actions for systems installed prior to July 1, 1989, unless the installation or conditions constitute a public health nuisance and is ordered corrected by the commissioner of health.

July 1, 1989 to present

The Groundwater Protection Act became effective on July 1, 1989, and included a requirement prohibiting the placement of contaminant sources any closer to an existing well than the distances prescribed in the Well Code. The MDH places a high priority on inspecting wells constructed during this period. Enforcement actions are taken if wells do not comply with Well Code requirements. The MDH will initiate enforcement actions against any person responsible for the improper placement of a SSTS or other contamination source too close to an existing well. The MDH has the authority to compel the party responsible for the violation to make the appropriate corrective action necessary to remedy the violation, which generally involves moving the contamination source or the well. Any party determined to be responsible for violations may also be subject to additional enforcement actions by the MDH.

Regardless of the date of construction of the well, the MDH does have the statutory authority to order a property owner to repair or seal a well if it is determined that the well:

- Is an intermittent threat to public health or safety (ITPHS)
- Is contaminated or may lead to the spread of contamination
- Was improperly sealed
- Is located, constructed, or maintained in a matter such that its continued use or existence endangers groundwater quality or is a safety or health hazard

Local community health boards also have broad statutory authority to control public health nuisances under Minnesota Statutes, section 145A. A publication entitled "Controlling Public Health Nuisances: A Guide for Community Health Boards" is available from the MDH.

Environmental Wells

As of July 1, 2017, new legislation combines monitoring wells, environmental bore holes, and remedial wells into a single category called an environmental well. Any boring or well 15 or more feet deep used for remediation, water sampling, water level monitoring, or testing or measuring water or earth properties, regardless of whether or not a confining layer or water is encountered, is an environmental well. This includes monitoring wells, remedial wells, geotechnical borings, test holes, piezometers, vapor recovery wells, and others. An environmental well must be constructed by either a licensed well contractor or a licensed environmental well contractor (formerly known as a monitoring well contractor).

Variances from the Well Code

For new installations where provisions of the Well Code cannot be met, the MDH may consider a variance from the Well Code. Variances are carefully considered by the MDH. Before any isolation distance requirement is reduced through a variance, the MDH must confirm that additional protections are or will be in place that safeguard the water supply well from potential contamination. These protections may consist of additional casing depth, additional grouting requirements, documentation of the presence of a low-permeability confining layer between the aquifer and the ground surface, additional testing or protections placed on the contaminant source such as containment, or additional testing of materials. Where these protections are not present, or cannot be provided, a variance from the Well Code is inappropriate. Approximately 150 variances are issued by the MDH each year to well contractors, SSTS installers, and others affected by MDH rules. A variance can only be issued by the MDH, or the MDH and a county or city with a delegated well program. Variances can not be granted after an installation has been made. The MDH recommends contacting the nearest MDH district office before submitting the variance application and fee.

For more information on wells and source water protection, contact a MDH office or visit MDH's web site at health.state.mn.us, search MDH Source Water - or call (651) 201-5000 or (888) 345-0823.

Source Water Protection

There are two primary parts of the Department of Health's Source Water Protection Program:

- Wellhead Protection
- Source Water Assessments

Wellhead Protection

Note: The following information was provided by the MDH's, Source Water Protection Unit

1. What is wellhead protection?

Wellhead protection is a method of preventing contamination of a public water supply well by managing potential contaminant sources in the area which contributes water to a public water supply well.

2. What authority does the Minnesota Department of Health have to implement wellhead protection?

The department is granted authority under Minnesota Statutes, Section 103I, subdivision 5, and Minnesota Rules, parts 4720.5100 to 4720.5590. The statutory authority was granted in 1989 and the rules governing wellhead protection were adopted in November of 1997.

3. What is the benefit of wellhead protection?

A very clear benefit of wellhead protection is the emphasis on the prevention of drinking water contamination versus the remediation of a contaminated drinking water supply. The cost of prevention is less than the cost of remediation. First and foremost to remediation, it also protects public health.

4. Does this rule affect private wells?

No. It only affects public water supply wells.

5. What is the definition of a public water supply well?

A public water supply well provides drinking water for human use to 15 or more service connections or to 25 or more persons for at least 60 days a year. A public water supply well is further defined as either a community or non-community water supply well.

a. A **community water supply well** serves 15 or more service connections used by year-round residents or at least 25 year-round residents. Examples include municipalities such as cities, and non-municipal systems such as subdivisions, nursing homes, and institutional facilities.

b. **Non-community water supply wells** are divided into two groups:

> A **non-transient** non-community supply well serves at least 25 of the same people over six months of the year. Examples include schools, factories, and hospitals.

> A **transient** non-community well serves all other public water systems. Examples include restaurants, gas stations, churches, parks, and campgrounds.

6. Is this voluntary?

No. All public water suppliers are required to implement wellhead protection measures as specified in Minnesota Rule 4720.

7. What is required of public water suppliers as a regulated group?

All public water suppliers are required to manage an inner-wellhead management zone, a 200-foot radius surrounding a public water supply, by:

- maintaining the isolation distances for newly installed potential sources of contamination defined in the state Well Code (Minnesota Rules, Chapter 4725),
- monitoring existing potential sources of contamination that do not comply with the isolation distances defined in the state Well Code, and
- implementing wellhead protection measures for potential contaminant sources in the inner-wellhead management zone.

In addition to the inner-wellhead management zone requirements, owners and operators of community and Nonmunicipal Public water supplies must prepare a wellhead protection plan which includes:

- a map showing the boundaries of the delineated wellhead protection area using the five criteria specified in the rule,
- a vulnerability assessment of the well and the wellhead protection area,
- an inventory of potential sources of contamination within the wellhead protection area based on the vulnerability assessment,
- a plan to manage and monitor existing and proposed potential sources of contamination, and
- a contingency strategy for an alternate water supply should the water supply be disrupted by contamination or mechanical failure.

8. Does a public water supplier have to own all the property within the inner-wellhead management zone (200-foot radius of a public water supply well)?

No. There is no requirement that a public water supplier own the property within the 200-foot radius which forms the inner-wellhead management zone.

9. Must contaminant source control measures be implemented before a wellhead protection plan is submitted to the department for approval?

Implementation of potential contaminant sources is done after they have been identified in the WHP plan or the Inner Well Management Zone (IWMZ) inventory. The measures are not implemented until the potential sources have been identified.

10. How much time is allowed to prepare a wellhead protection plan?

The minimum time is two years after entering the wellhead protection program.

Additional six-month blocks of time are automatically awarded on a cumulative basis when:

- a system has multiple wells,
- there is a lack of state and federal funding to support wellhead protection planning,
- public water supply systems are privately owned,
- the wellhead protection area is in two or more governmental jurisdictions, or
- pumping of a well in another system affects the boundaries of the wellhead protection area.

11. When does a public water supplier need to begin preparing a wellhead protection plan?

In most cases, a public water supplier must begin preparing a wellhead protection plan when notified by the Minnesota Department of Health. The Minnesota Department of Health has developed a phasing list that helps determine the order in which public water suppliers will be brought into the program. Community and Nonmunicipal Public water suppliers will be phased into the wellhead protection program as time and resources permit. Vulnerable wells have high priority. This phasing criterion includes water chemistry data, well construction information, and geological data. For more information related to the phasing criteria, please contact the Source Water Protection Unit at MDH.

12. What support will the Minnesota Department of Health provide public water suppliers preparing a wellhead protection plan?

The Minnesota Department of Health is committed to providing technical support in the form of staff resources, training, guidance documents, and forms. Two staff members, a planner and hydrologist, will be assigned to each public water supplier at the time they enter the program. The level of support will vary depending on criteria such as the: staff and financial resources of the public water supply, governmental authority of the public water supplier, existing pumping test information, vulnerability of the geological setting, and level of support from LGUs and other organizations like the American Water Works Association and Minnesota Rural Water Association. For public water supplies serving up to 3,300 people, the Minnesota Department of Health can provide technical services to aid completion of portions of the wellhead protection plan such as:

- delineation of the wellhead protection area,
- vulnerability assessment, and
- management plan.

Further details of this support will be presented to public water suppliers as they are phased into the wellhead protection program. Public water suppliers entering the program will be provided more detailed information on such topics as:

- delineating wellhead protection areas,
- assessing vulnerability,
- inventorying potential sources of contamination,
- communicating with LGUs,

- reviewing and approving of wellhead protection plans by the Minnesota Department of Health,
- updating wellhead protection plans, and
- implementing wellhead protection plans.

Source Water Assessments

Source Water Assessments are reports that provide a concise description of the groundwater well or surface water source —such as lakes, and rivers—used by a public water system and discuss how susceptible that source may be to contamination.

The 1996 amendments to the federal Safe Drinking Water Act require states to produce source water assessments for all their public water systems and to make the results of those assessments available to the public. Assessments are now available to the public on MDH's source water protection web page. The types of facilities for which assessments have been completed range from small businesses on their own well to large city water systems using several different water sources.

Assessments are available to the public on MDH's source water assessment web page. You can search for an assessment either by name of the facility or by county.

Department of Labor and Industry

Plumbing Code

The Minnesota Department of Labor and Industry (DLI), through the Construction Codes and Licensing Division, has primary enforcement responsibility for the protection of public health through regulation of the installation of plumbing systems in accordance with the Minnesota Plumbing Code (Minnesota Rules, Chapter 4714). The plumbing code applies to installation of all interior plumbing, building sewer and building water service connections within the property line, and storm water drainage systems.

The DLI does not review SSTS. The line between plumbing and SSTS can sometimes be confusing. As defined in the Minnesota Plumbing Code in Minnesota Rule, Chapter 4714, Section 204.0 and MN Rules Chapter 7080.1100, Subp 11a, "Building sewer" means that part of the horizontal piping of a drainage system that extends from the end of the building drain and that receives the discharge of the building drain and conveys it to the public sewer, private sewer, private sewage disposal system, or other point of disposal. MN Rules Chapter 7080.1100 defines the "building sewer connected to an SSTS" as a component of the SSTS, which means that these sewers are co-defined as both plumbing and SSTS. This means that building sewers connected to SSTS are subject to plumbing program and SSTS program requirements. By national definition, a sewer is a pipe or conduit carrying sewage, or a conduit into which sewage can back up. Sewers include gravity and pressure sewers; drain, waste, and vent piping; pipes carrying grey water; and pipes serving floor drains that are connected to the drain, waste, and vent system. The setbacks apply to all new work, including all portions of an existing sewer that are removed and replaced. The setbacks do not apply to above-ground sewers, including sewers above grade in a crawl space. The standard setback between a water-supply well and a sewer is 50 feet. See Table 2.5 for a complete list of isolation distances from water supply wells and SSTS. A buried sewer serving one building, or two or lesssingle-family residences, that is not a collector or municipal sewer or does not serve a facility handling infectious or

FIGURE 2.9 Pressure Testing Requirements

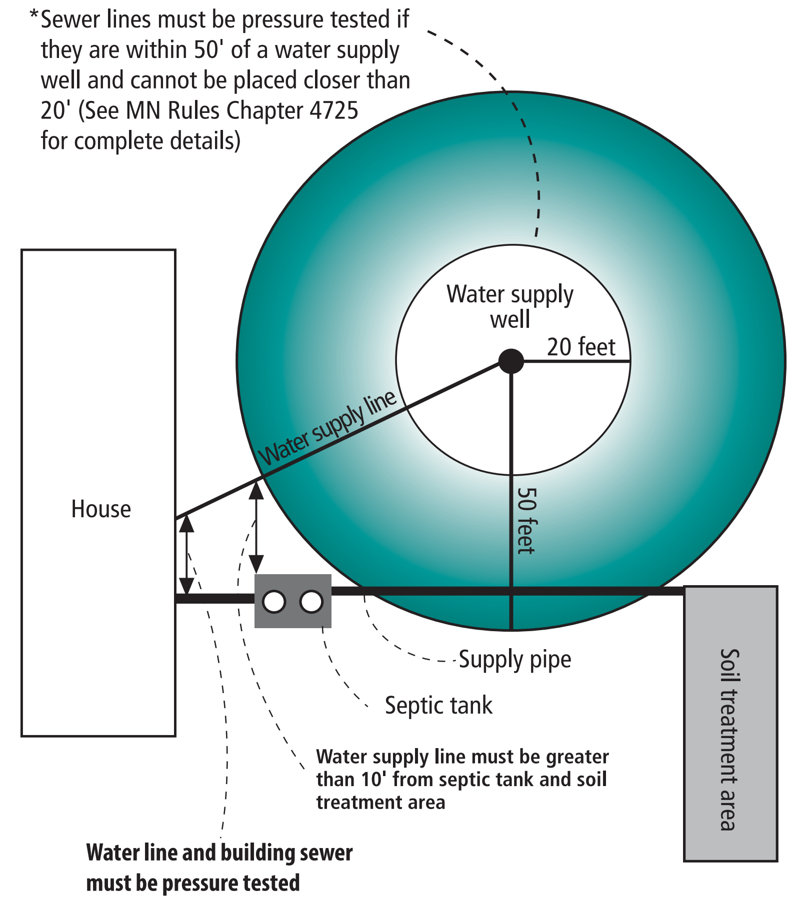
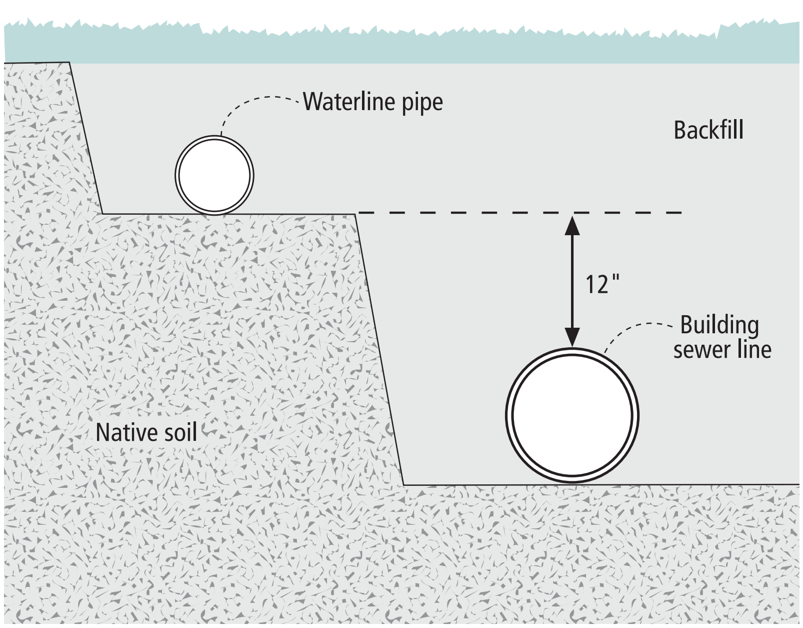


FIGURE 2.10 Water and Sewer Excavation



pathological wastes, may be installed between 20 and 50 feet from a water supply well if all of the following conditions are met:

1. The well is not a community public supply well, meaning the well does not serve more than 15 living units or 25 year-round residents such as a city, mobile home park, apartment building, or extended health care facility

2. The sewer is constructed of cast iron or plastic pipe approved for use as a building sewer by the Minnesota Plumbing Code in Minnesota Rules Chapter 4714, administered by the Minnesota Department of Labor and Industry (see DLI for more information). It should be noted that HDPE pipe, commonly used for pressure sewers, is not an approved plumbing code material and therefore does not qualify for the reduced setback.

3. The sewer has been successfully air tested at a uniform pressure of five pounds per square inch for 15 minutes without leakage, in accordance with the Minnesota Plumbing Code (see DLI for more infor mation). The air test must be done by an individual who is a licensed plumber / certified pipelayer having the appropriate code compliance bond or by the property owner and witnessed by an appropriate regulatory official. Designated certified SSTS installers are all validated as pipelayers during their SSTS certification process and may conduct this testing. A written report of the test must be submitted to the MDH or kept on file. The pressure testing form can be found at septic.umn.edu/ssts-professionals/forms-worksheets.

If the waterline and building sewer are placed in the same trench the sewer pipe must be installed at least 12 inches below the waterline as shown in Figure 2.10.

The plumbing code restricts joints in water or sewer pipes for 10 feet in any direction from a crossover of the two lines as shown in

FIGURE 2.11 Water and Sewer Cross Over Specifications

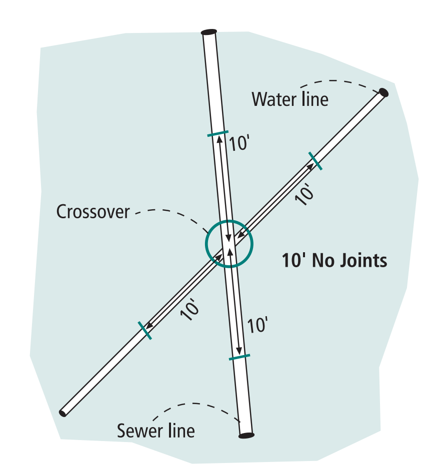


Figure 2.11. water Sewer Cross Over Specifications. The setbacks for sewers relating to wells are covered under the Minnesota Department of Health section.

A reminder to all SSTS professionals that the plumbing code has been in effect statewide since 2007. All building sewers are considered plumbing and must meet the conditions of the plumbing code.

1. SSTS designers must submit building sewer plans to the DLI when designing SSTS for all other establishments with five or more units. This application includes plan submittal instructions. Unless defined as a "state building project", all SSTS in plumbing code-enforced areas are subject to local plumbing program plan approval and inspection requirements. Use this tool to find local plumbing code jurisdictions.
2. SSTS installers must hold a current pipelayer certification or individual plumbing license and work for an appropriately licensed business when installing building sewers. Installers must provide adequate notice to the local septic system program AND appropriate plumbing program representative when work requires inspection. Designated certified SSTS Installers are all validated as pipelayers during their SSTS certification process and may conduct this testing.
3. SSTS inspectors may permit and/or inspect building sewers connected to septic systems for compliance with the Minnesota Plumbing Code when a plumbing inspection is not required or the inspector has prior permission from the local or state plumbing program with jurisdiction.

The Minnesota Plumbing Code covers plumbing systems inside buildings and also the privately owned water, sanitary sewer, and storm sewer lines inside the property lines or to the point of disposal, whichever comes first. The point of disposal can be either a SSTS or collector sewer line permitted by MPCA.

The plumbing code applies statewide to all new plumbing installations, including additions, extensions, alterations, and replacements connected to a water or sewage disposal system owned or operated by or for a municipality, institution, factory, office building, hotel, apartment building, or other place of business regardless of location or the population of the city or town in which it is located.

All plumbing installations must comply with the Minnesota Plumbing Code (Code).

For more information, please visit the Minnesota Department of Labor and Industry web site at www.dli.mn.gov/CCLD/Plumbing.asp

The DLI also licenses plumbing and water conditioning professionals, registers plumbing code compliance bonds, and reviews courses for pipelayer certification. The DLI carries out these responsibilities through a variety of compliance activities, including: engineering plan review and inspection of water distribution and building drain and sewer systems construction; plumbing and water conditioning licensing and bond administration activities; training; technical assistance; and public outreach.

More information is available at the DLI website at www.dli.mn.gov/CCLD/Plumbing.asp or by calling (651) 284-5067 or (800) 657-3944.

Occupational Safety and Health

The DLI through the Occupational Safety and Health Administration (OSHA), has responsibility to enforce the federal OSHA rules and works to assure that every worker in the state has a safe and healthful workplace by helping Minnesotans improve workplace safety and health. MNOSHA is involved with SSTS particularly in the areas of trench/excavation safety and competent person requirements. Services provided by MNOSHA include outreach, consultation, and enforcement efforts. For more information, visit OSHA'a website at http://www.dli.mn.gov/MnOsha.asp or call (651) 284-5050 or 1-800-DIAL-DLI (800-342-5354).

Boilers Operator License

The DLI also licenses those who operate boilers and install high pressure piping. Depending on the type of equipment used, those steaming out frozen SSTS may need a boiler license. For more information, visit their website at http://www.dli.mn.gov/CCLD/Boiler .asp or call (651) 284-5544 or 1-800-DIAL-DLI (800-342-5354).

Department of Natural Resources

The 1969 Shoreland Management Act required counties to adopt land use controls for their unincorporated shorelands bordering lakes and streams, and directed the Department of Natural Resources to establish statewide standards for the counties to follow. In addition to lot size, setback and other requirements, the standards required sewage treatment system setbacks from lakes and rivers. The current 1989 statewide shoreland management standards apply to both counties (unincorporated land) and municipalities (incorporated land). Septic system setbacks based on shoreland classifications are found in Minnesota Rules, Chapter 6120.3400, Subp. 3c (www.revisor.mn.gov). The shoreland rules reference the Pollution Control Agency, Chapter 7080 for septic system design standards. DNR shoreland program standards require a certificate of compliance, consistent with Minnesota Rules Chapter 7082.0700 Subp. 3, whenever a permit or variance of any type is required for any improvement on or use of the property. A sewage treatment system shall be considered compliant if the only deficiency is the system's improper setback from the ordinary high water level. There are numerous triggers instituted by local units of government to identify non-compliant systems including requiring inspections at property transfer or with a request for a building permit.

Similar standards apply for Wild and Scenic Rivers, Minnesota Rules, Chapter 6105.0120 (www.revisor.mn.gov). These standards are administered by local governments through their wild and scenic rivers ordinances. Table 2.6 has the DNR minimum setback distances for SSTS in shoreland areas. Be sure to verify with your LGU as they maybe more restrictive.

TABLE 2.6 Minimum Setback Distances from Ordinary High Water Level for SSTSs.

Feature	Septic, Holding Tank or Other Watertight Component (feet)	Soil Treatment or Absorption Area (feet)
Natural Environment Lake	150	150
Recreational Development Lake	75	75
General Development Lake	50	50
Wild River	150	150
Remote River Segments	150	150
Scenic River	100	100
Forested River Segments	100	100
Transition River Segments	100	100
Agricultural River Segments	75	75
Recreational River or Tributary	75	75

MN Rules 103G.005 Subd. 14(1) state that normal high-water mark means a mark delineating the highest water level which has been maintained for a sufficient period of time to leave evidence upon the landscape as shown in Figure 2.12. The normal high-water mark and the ordinary high-water mark are commonly points where the natural vegetation changes from predominantly aquatic to predominantly terrestrial. In areas where the ordinary high-water mark is not evident, setbacks shall be measured from the stream bank of the following water bodies that have permanent flow or open water: the main channel, adjoining side channels, backwaters, and sloughs.

FIGURE 2.12 Lake and River Setbacks

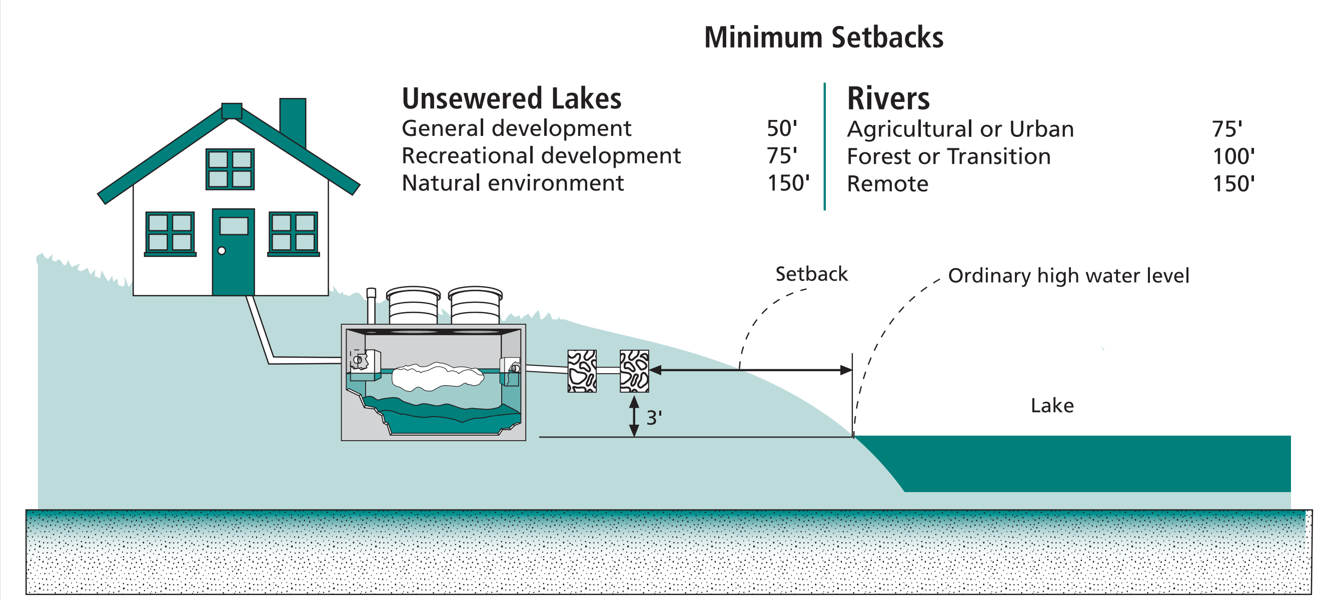
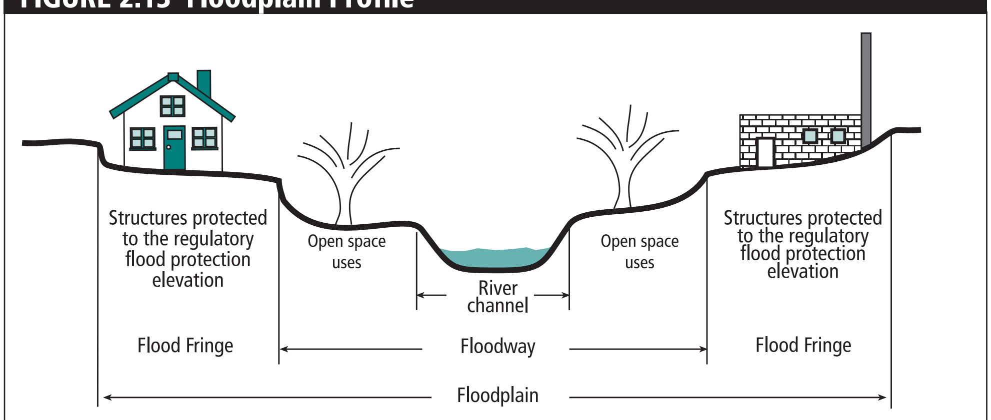


FIGURE 2.13 Floodplain Profile



From MN Rules 6105.0040, Subp. 20a, setback is defined as the minimum horizontal distance between a structure and the normal high water mark or between a structure and a road or highway.

The DNR Floodplain Management Program oversees the administration of the state Floodplain Management Program by promoting and ensuring sound land use development in flood-plain areas in order to promote the health and safety of the public, minimize loss of life, and reduce economic losses caused by flood damages. This unit also exists to oversee and administer the National Flood Insurance Program (NFIP) for the State of Minnesota. The DNR along with the Federal Emergency Management Agency (FEMA) sets the floodway and flooplain elevations shown in Figure 2.13. See Section 4 for information relating to the placement of SSTSs in floodplains.

Department of Transportation

The Minnesota Department of Transportation (MnDOT) sets the vehicle, road weight restrictions, and driver requirements for commercial vehicles. This affects Maintainer, Installer, and Designer vehicle load securement, maximum weights, seasonal usage/exemptions for road restrictions, and driver license requirements. See MnDOT's website at dot.state.mn.us or reach them by phone at (800) 657-3774.

Local Ordinances

LGUs are required to adopt and enforce Chapter 7080-7081 to regulate SSTS within their jurisdiction. Because of unique local conditions, ordinances may be more or less restrictive than state rules for both new and existing systems. More restrictive rules are adopted for many reasons, including sensitive environmental conditions, and high densities, among many other reasons. Less restrictive standards for new construction are only allowed by counties in areas with current and projected low densities and where evidence can be provided that the alternative standards will protect public health and the environment. Alternative standards are not allowed in shoreland, wellhead protection areas, or food and beverage and lodging establishments. Proposed alternative standards must be submitted to the Minnesota Pollution Control Agency (MPCA) for review.

LGUs are responsible for administering and enforcing their local SSTS ordinance. For counties, this includes assuring that there is a SSTS ordinance with a permitting and inspection program covering the entire county. If cities and towns have their own local ordinance, they must be as restrictive as the county. Each LGU is required to file an annual report with the MPCA. See 7082.0040, Subp. 5 for the list of required reporting items.

Always check with the local government (township, city or county) first to determine what the local SSTS ordinance requires. Visit the website www.pca.state.mn.us for those ordinances available online or to find contact information for a LGU.

According to Minnesota Rules Chapter 7082.0040, Subp. 4, All local governments that administer SSTS programs must have:

A. adequate personnel to properly conduct SSTS technical and administrative functions. All local governments that administer SSTS programs must have:

(1) at least one certified inspector as described in part 7083.1010, subpart 2, who is employed by the local unit of government or a contracted licensed SSTS inspection business. Multiple local units of government are allowed to contract for services with the same certified inspector; and

(2) at least one person who is employed by the local unit of government who has received accredited training on administration of local SSTS programs; and

B. an enforceable ordinance that meets the requirements of this chapter.

Each ordinance at a minimum must contain the following requirements:

1. New construction or replacement and/or repair scenarios
2. Permitting and compliance inspection requirements
3. The requirement for management plans as part of design
4. Maintenance requirements
5. Class V reporting and disclosure requirements
6. Two sites for SSTS for each newly platted lot requirements

7. Provision that a failing or imminent public health threat systems be upgraded in a specified time period
8. Abandonment requirements
9. Variance procedures
10. Allowed holding tank and floodplain applications
11. A provision that prohibits surface discharge unless a NPDES permit is obtained from the MPCA
12. Conflict resolution process
13. Operating permits requirements for Type IV, V and MSTS

Each ordinance may address:

1. Allowance/disallowance of certain Types (I-V) of systems
2. Allowance/disallowance of warrantied systems
3. Septage requirements
4. Secondary site protection requirements
5. Provision if primary or secondary site is damaged

Each ordinance must be reviewed by the MPCA within 30 days of adoption. Each LGU must prepare and make available to the MPCA and to the public a written list of all technical and administrative differences between its ordinance and Chapters 7080 and 7081.

LGUs can either adopt a conventional or performance program. Conventional programs adopt the technical requirements of 7080 and 7081 at a base level. Conventional programs can permit all types of systems in 7080 and 7081. Performance programs are more comprehensive, going beyond the minimums of 7080 and 7081, and include an education program for users, risk assessment, performance requirements based on the receiving environment, operating permits, septage tracking, enforcement, record keeping and a financial assistance program. The Performance program option is geared towards LGUs with strong local commitment to overall SSTS program management.

System Performance vs. Program Performance

The overall goal of state and local requirements regarding septic systems is to ensure that septic systems are designed, installed, and taken care of properly. The framework of the specific regulations affecting the onsite industry is based on administrative rules, which are adopted by the MPCA and administered and enforced through ordinance by local units of government. This common method of program administration allows for minimum standards to be set state-wide while allowing local flexibility to implement local programs based on the needs of each specific jurisdiction, which vary in land-use, development pressure, site conditions, political will, and natural resources. It is important to recognize, however, that high-quality work often exceeds basic requirements. This goes for private professionals, who are responsible for meeting technical standards for system design, installation, and care, and for local program administrators, who are responsible for system permitting and inspection.

Each jurisdiction is required under **7082.0100 subp 1 and 3** to draft an ordinance that outlines the administration of its program and related requirements. The rule poses a list of over 20 general requirements for all local ordinances and an optional list of recommended provisions. If a local unit of government intends to permit performance-based systems (Type IV and V), its ordinance must also define the provisions below.

The University of Minnesota recommends the addition of a management program to all local programs, regardless of whether they permit performance systems.

Local Ordinance Requirements for Performance Programs

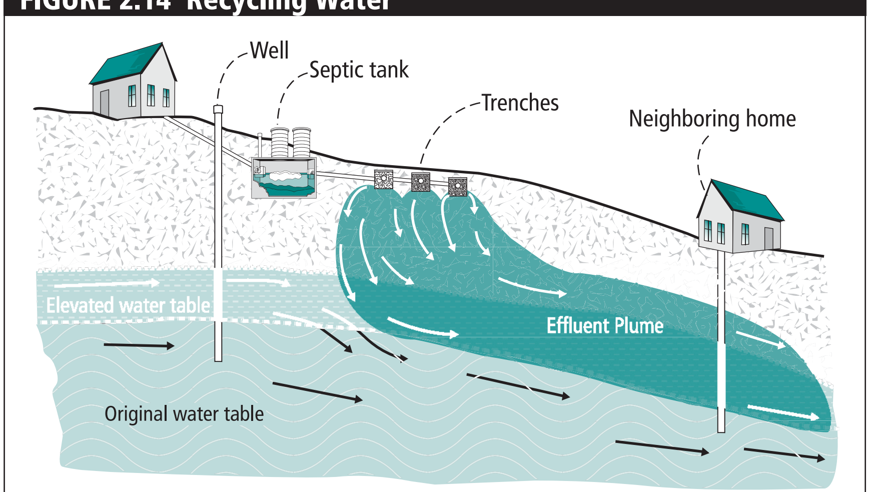
- Homeowner education program
- Risk assessment protocol for SSTS receiving environments
- Monitoring standards specification
- Site evaluation protocol
- Renewable operating permit program for certain systems
- Electronic inventory, tracking, and management program
- Septage hauling, treatment, and disposal tracking program
- Reporting program to notify homeowners of upcoming management responsibilities
- Financial support to sustain the management program
- Enforcement program including penalties for failure to comply with the ordinance

It is the private professional's responsibility to ensure that all local and state requirements are met through proper system design, installation, and management. It is the local unit of government's responsibility to make sure that septic systems permitted and inspected in its jurisdiction meet those requirements. This check and balance, if properly implemented, provides an effective method of ensuring that homeowners receive what they purchased, a functioning long-term solution for their sewage treatment needs. An additional, important part of making sure that septic systems work is ensuring that system owners are aware of their responsibilities regarding this important infrastructure.

Management

The goal of SSTSs is to protect human health and the environment by safely recycling wastewater back into the natural environment in a cost-effective manner as shown in Figure 2.14. The on-site treatment of wastewater is dependent on a properly designed, installed, operated, and maintained treatment system. A good system will not properly treat sewage throughout its intended life without appropriate and timely operation and maintenance—**management**!

FIGURE 2.14 Recycling Water



Total management of a system must involve the residents generating the sewage with varying levels of assistance from professionals. The individual owner will likely determine management responsibilities of a single household system. Traditional trench and mound systems requiring relatively simple management are typically managed by the owner using licensed Maintainers and other professionals as needed. Homeowners are capable of handling typical management tasks if they are aware of what needs to be done and make a commitment to do it. Owners of complex systems or those unwilling to make the commitment may feel the necessity or be required to hire outside professional management. More opportunities to contract out some steps will likely be available in the future.

Individual Type I-III systems are likely to be owned and managed by the individual owner. These systems typically require less management than Type IV and V systems. Owners may wish to or be required to hire professional management of their systems. Knowledge of the system and its operation and maintenance is necessary and should be provided in the system's management plan. Most systems installed prior to 2008 will not have formal management plans and may need one developed.

Type IV and V systems and those serving multiple dwellings or commercial establishments require a higher level of management. Each homeowner must be responsible for their usage of the system and rely on co-users to do the same. All of the users collectively must be responsible for the operation and maintenance of the commonly used portions of the system. Type IV and V systems may use mechanical components, living plants, or other processes that require special attention.

Management of the system must include all aspects of the system, but key components to be managed are:

- Amounts of wastewater generated by each unit and the accumulated flow
- Contents of the wastewater (solids, chemicals, nutrients, etc.)
- Maintenance of tanks, pumps, and filters
- Monitoring of overall system performance

The amount and cost of management will vary considerably with the size, type, and complexity of the treatment system. New technology usually requires more attention by the owners and regulators because of its unfamiliarity and unproven track record, so the management necessary for new technology must be established at the beginning of a project. A plan must determine who will do what and when and how they will do it. It must also be carried out to be effective! Over time, the plan will need to be re-evaluated and adjusted as necessary to ensure proper operation.

When multiple-household units and 'alternative treatment' systems are used in new developments, the local government unit and the developer likely make the ownership and management structure decisions for the future owners. When these systems are installed in existing neighborhoods, the organizational structure decision will likely involve all owners and their LGU.

In Minnesota, there are six management structure options (see Organizational Structure Matrix at septic.umn.edu):

- Environmental Subordinate Service Districts
- Sanitary Sewer Districts
- Home Owner Associations
- Municipal Utilities
- Homeowner Cooperatives
- Private Joint Ventures

The first four are currently in operation in Minnesota. Each has strengths and weaknesses to be considered in any local application.

No matter which organizational structure is used, all residents must take an active responsibility for the amounts and contents of the wastewater they generate. They must all be willing to adequately finance the care and monitoring of the entire system. Establishing rules for system users to follow in the day-to-day use of the system may be necessary to resolve problems should they arise, but early and effective education of all users is likely to be more effective in assuring appropriate day-to-day usage.

In order for a management program to be effective, it must have risk assessments, operation and maintenance, monitoring, reporting, and funding components.

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SECTION 3: Sewage Treatment Utilizing Soil

SEWAGE TREATMENT UTILIZING SOIL

Suitable soil is an effective treatment medium for sewage tank effluent because it contains a complex biological community. One tablespoon of soil can contain over one million microscopic organisms, including bacteria, protozoa, fungi, molds, and other creatures. The bacteria and other microorganisms in the soil treat the wastewater and purify it before it reaches groundwater. But the wastewater must pass through the soil slowly enough to provide adequate contact time with microorganisms. To provide adequate time for treatment of septic tank effluent, it is necessary to have at least three feet of aerated or unsaturated soil and limit the loading of effluent.

Microorganisms in soil treat wastewater physically, chemically, and biologically before it reaches the groundwater, preventing pollution and public health hazards. Under some soil conditions, subsurface absorption systems may not accept the wastewater or may fail to properly treat the wastewater unless special modifications to system design are made. The health of Minnesotans is of major concern because domestic wastewaters contain many substances that are undesirable and potentially harmful, such as pathogenic bacteria, infectious viruses, organic matter, toxic chemicals, pharmaceutical drugs (e.g. endocrine disruptors), and excess nutrients.

Soil microorganisms need the same basic conditions as humans do to live and grow: a place to live, food to eat, water, oxygen to breathe, suitable temperatures, and time to grow. Soil microorganisms attach themselves to soil particles using microbial slimes and use the oxygen and water that are present in the soil pores. To protect the public as well as the environment, wastewater must be treated in a safe and effective manner. The first component in an individual sewage treatment system is usually a septic tank, which removes some organic material and total suspended solids (TSS). TSS and organic material removal is very important because it prevents excessive clogging of the soil infiltrative surface. Table 3.1 shows the typical levels of effluent, TSS, fecal coliform bacteria, and nutrients found in septic tank effluent.

TABLE 3.1 Treatment Performance of Soil

Parameter	Raw Waste	Septic Tank Effluent	One Foot Below Distribution Media	Three Feet Below Distribution Media
BOD_5 (mg/L)	30-1147***	39-861***	0**	0**
TSS (mg/L)	18-2233***	22-276***	0**	0**
Fecal Coliform (MPN/100ml)	30,000-10,000,000,000**,***	1,000-120,000,000**,***	1-100**	0**
Viruses (PFU/ml)	unknown**	100,000-10,000,000**	0-1,000**	0**
Nitrogen (mg/L)				
Total	35-189**,***	25-124**,***	—	—
NH_4	7-40**	20-60**	*B-20**	—
NO_3	<1**	<1**	*B-40**	*B-40**
Total Phosphorus (mg/L)	10-27**	3-40***	*B-10**	*B-1**

* B = background
**Tchobanoglous and Burton, 1991
***Lowe et al., 2007

Suitably-textured soil must be deep enough to allow adequate filtration and treatment of the effluent before it is released into the natural environment. Usually this release is into groundwater. It has been determined that three feet of aerated soil will provide sufficient treatment of septic tank effluent. Therefore, a three-foot separation distance is required from the bottom of the dispersal media to a limiting soil condition such as groundwater or bedrock. This three-foot treatment zone provides sufficient detention time for final bacteria breakdown and sufficient distance for the filtration that is essential for the safe treatment of effluent BOD. In Table 3.1, the levels of effluent, TSS, bacteria, and nutrients remaining after treatment by one foot and three feet of soil are shown (Tchobanoglous and Burton, 1991).

Impacts of Effluent on Groundwater

Groundwater represents the largest volume of fresh water on earth. Only three percent of the earth's fresh water resides in streams, lakes, and other surface water bodies. The other 97 percent is beneath the surface, flowing toward points of discharge such as streams, lakes, springs, and wetlands. Groundwater becomes surface water at these discharge points.

Effective waste treatment is essential to protecting our water supplies. Approximately 25 percent of households in North America utilize groundwater for consumption and other domestic uses. These same homes employ septic systems as their means for wastewater treatment (US EPA, 2008).

As water percolates through the soil, it is purified and in most cases requires no further treatment before being consumed. However, when the soil is overloaded with a treatable contaminant, or when the contaminant cannot be treated by the soil, the quality of the underlying groundwater may change significantly.

When a septic system fails to effectively treat and disperse effluent, it can become a source of pollution. This type of failure can occur in three different ways. The first way is when effluent ponds on the soil surface, causing a wet seepy area. The second obvious way that a septic system can fail is to have effluent backing up into the dwelling. It is also important to prevent a third, and less obvious, type of failure, which is contamination of the ground or surface waters.

Pollution of groundwater (with nitrogen, pathogens, bacteria, chemicals, etc.) is very difficult to clean up, since the only access to the water table is through wells, trenches (if the water table is high enough), or natural discharge points such as springs. An incident of groundwater pollution often becomes a problem that persists for many years.

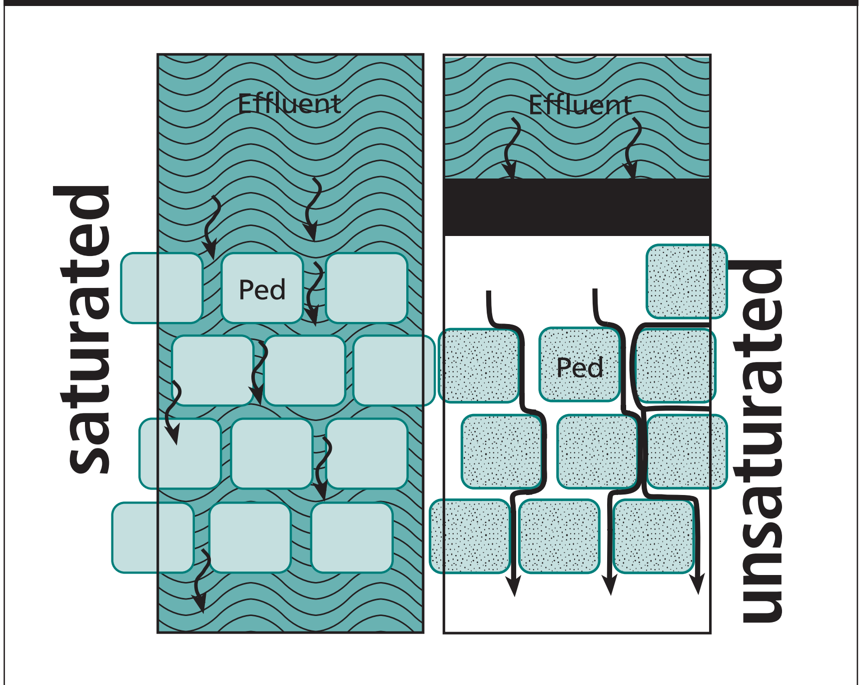
Soil Treatment Processes

The soil treatment and dispersal zone provides for the final treatment and dispersal of septic tank effluent. To varying degrees, the soil treatment and dispersal zone treats the wastewater by acting as a filter, exchanger, or absorber by providing a surface area on which many chemical and biochemical processes occur. The combination of these processes, acting on the effluent as it passes through the soil, purifies the water. In this section, the movement of effluent through the treatment zone is outlined.

Biomat

As septic tank effluent flows into a soil treatment trench, it moves vertically through the distribution media to the biomat where treatment begins. The biomat is a biological layer formed by anaerobic bacteria, which secrete a sticky substance and anchor themselves to the soil, rock particles, or other available surfaces. The biomat develops first along the trench bottom, where effluent begins to pond. The biomat develops along the soil-media contact surfaces on the trench's sidewalls. When fully developed, the gray-to-black sticky biomat layer is about one inch thick.

FIGURE 3.1 Unsaturated Flow Provides Treatment



Flow through a biomat is considerably slower than flow through natural soil, allowing unsaturated conditions to exist in the soil beneath the soil treatment trench. Unsaturated flow increases the travel time of effluent through the soil, ensuring that it has sufficient time to contact the surfaces of soil particles and microorganisms (Figure 3.1).

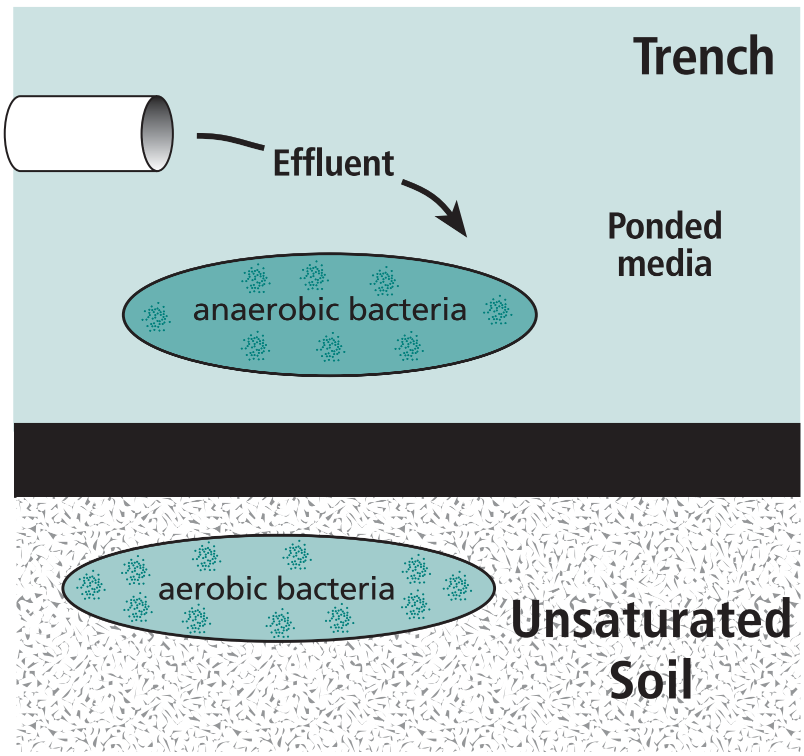
A properly functioning gravity-fed system will have wastewater ponded in the distribution media while the soil a few inches outside of and below the distribution media will be unsaturated. Unsaturated soil has pores containing both air and water so aerobic microorganisms living in the soil can effectively treat the wastewater as it travels through the soil system.

In unsaturated soil, under a biomat, water movement is restricted. In order for the wastewater to move through the soil, it must be pulled or wicked through the fine pores by capillary action.

A developed biomat reaches equilibrium over time, remaining at about the same thickness and the same permeability if effluent quality is maintained. For this equilibrium to be maintained, the biomat and the effluent ponded within the trench must be in anaerobic conditions, the organic materials in the wastewater feed the anaerobic microorganisms, which grow and multiply, increasing the thickness and decreasing the permeability of the biomat. On the soil side of the biomat beneath the drainfield, oxygen is present so that conditions are allowing aerobic soil bacteria to feed on and continuously break down the biomat. These two processes occur at about the same rate so that the thickness and permeability of the biomat remain in equilibrium (see Figure 3.2, next page).

If the quality of the effluent leaving the septic tank decreases because of failure to regularly pump out the septic tank, more food will be present for the anaerobic bacteria, which will cause an increase in the thickness of the biomat and decrease its

FIGURE 3.2 Biomat Equilibrium



permeability (Siegrist, 1987). If seasonally saturated conditions occur in the soil outside the trench, aerobic conditions will no longer exist, which will prevent aerobic bacteria from breaking down the biomat. Under these conditions the biomat will thicken, reducing its permeability and the effectiveness of effluent entering the soil.

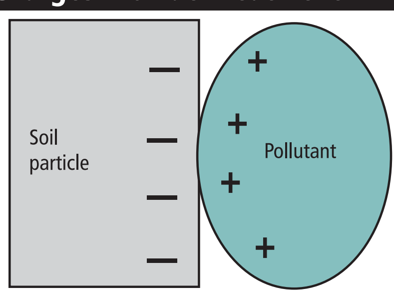
Soil Treatment

Once the effluent passes through the biomat, it enters the soil for final treatment. Soil particles, the presence of electrical charges, and the soil biological community all provide treatment of the effluent.

Soil particles provide the surface areas that septic tank effluent must contact to move. This contact provides treatment of the effluent by filtering the larger contaminants while adsorbing (e.g., attachment or binding) others. Because soil particles are negatively charged, they can attract and hold positively charged pollutants. Soils also contain minerals that bind with some pollutants and immobilize them (see Figure 3.3).

Bacteria, fungi, actinomycetes, and protozoa live in the soil, all of which feed on organic material in the septic tank effluent. Aerobic bacteria provide treatment and function optimally in aerated soil because they prefer oxygen. If the soil is saturated and no oxygen is present, anaerobic bacteria function, but they provide insufficient treatment. Bacteria and total suspended solids contained within septic tank effluent have been found to be treated and removed in the first foot of most aerated soil under the trench (Table 3.1).

FIGURE 3.3 Electrical Charges Provide Treatment



Negatively-charged soil particles can attract and hold positively-charged impurities in wastewater

Pathogen Removal

Bacteria in effluent are typically large enough, aggregated with other bacteria or associated with solids, that they are filtered out like suspended solids (Gerba and Bitton, 1984). Viruses are much smaller than bacteria, and are not filtered (Coyne, 1999). However, some contain a positive ionic charge, allowing the soil to attract and hold the viruses. Once bacteria and viruses are caught in the soil, they eventually die off because of soil conditions (e.g. temperatures, moisture levels, bacteria predation). Certain soil fungi naturally produce antibiotics that attack some contaminants. Others consume the bacteria and viruses as a food source.

In sandy soils with limited negative charges, the main means of viral attachment to soil particles is by microbial slimes laid down by soil bacteria. A soil column study conducted by Van Cuyk and Siegrist (2006) demonstrated high levels of virus removal after 6 weeks of operation (greater than 85%) by less than 2-inches of sandy soil at various hydraulic loading rates (1.2 gpd/sq ft and 6 gpd/sq ft). Studies have shown that if aerated sandy soils are loaded at no greater than

1.2 gallons per day per square foot (gpd/sqft), virus removal occurs within two feet (Magdorf et al., 1974; US EPA, 1980; Van Cuyk et al., 2001). The hydraulic loading rate for sandy soils found in Chapter 7080 reflects this loading rate.

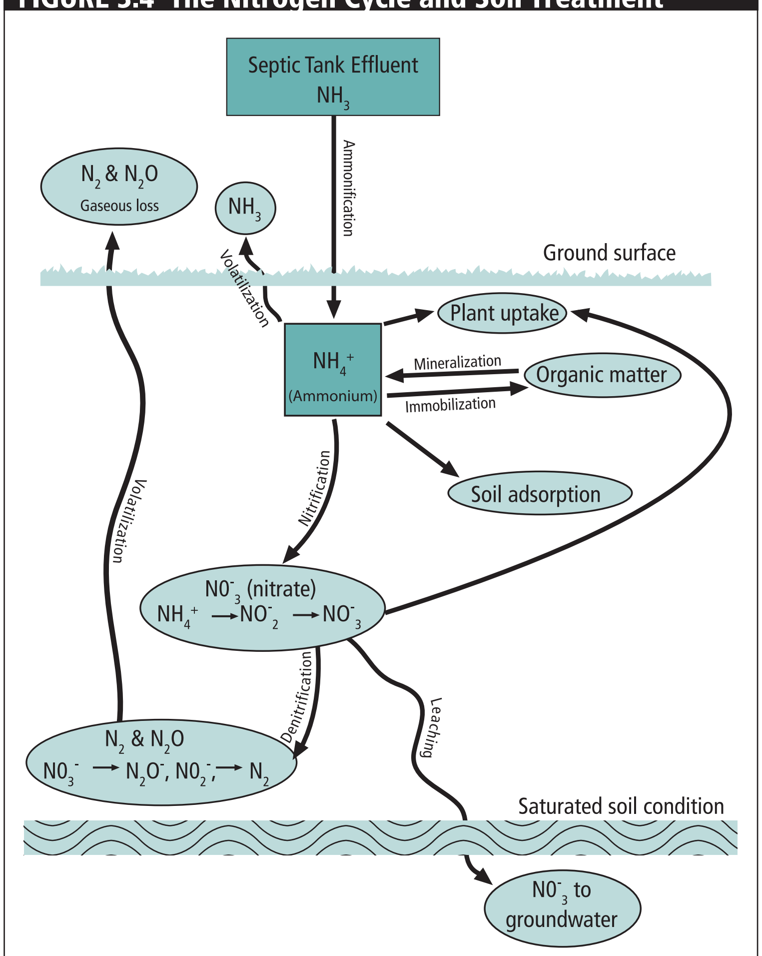
Nutrient Removal

The two principle nutrients of concern in wastewater are nitrogen and phosphorus.

Nitrogen

Nitrogen is a concern because it can contaminate drinking water. Nitrogen undergoes many changes as it travels through a septic system. Septic tank effluent contains both organic nitrogen and ammonium (NH_4^+). The predominant form entering the soil is ammonium. The transport and fate of nitrogen underneath a soil treatment system is dependent upon the forms entering and the biological conversions that take place. Figure 3.4 shows the forms and fate of nitrogen in the subsurface environment. All of these nitrogen transformations are microbially mediated and require suitable temperatures (above 41 degrees F), a usable source of carbon (organic matter) for energy, and suitable alkalinity.

FIGURE 3.4 The Nitrogen Cycle and Soil Treatment



Nitrates (NO_3^-) are formed by nitrification. Nitrification (NH_4^+ NO_2^- NO_3^-) is an aerobic reaction, so it is dependent upon the availability of oxygen in the soil.

Denitrification is another important nitrogen transformation in the soil environment below onsite systems. It is the only mechanism by which the NO_3^- concentration in the effluent can be reduced. Denitrification (NO_3-N_2O-N_2) occurs in the absence of oxygen. For denitrification to take place, the nitrogen must usually be in the form of NO_3^-, so nitrification must happen before denitrification. Mound systems facilitate this process and typically reduce nitrogen concentrations by 32 to 70 percent (Magdorf et al., 1974; Eastburn and Ritter, 1984). Additional studies have shown little total nitrogen removal below 31 at-grade systems in Wisconsin (Converse et al., 1991) and moderate rates of removal (7-15%) in laboratory studies (Van Cuyk et al., 2001).

The transport of nitrate ions may occur by movement with in solution, uptake in plants or crops, or denitrification. Since nitrate ions (NO_3^-) have a negative charge, they are not attracted to soils and are very mobile. The mobility of nitrate is further enhanced by the solubility of these ions in the soil water.

Treatment of nitrates occurs to a limited extent by the following mechanisms.

- ***Uptake by Vegetation:*** If soil treatment areas are kept near the surface, some of the nitrate will be taken up by surface vegetation during the growing season.

- ***Denitrification:*** If the ammonium (NH_4^+) is nitrified to nitrate (NO_3^-) and then encounters a saturated zone which lacks oxygen, the nitrate is converted to nitrogen gas (N_2) and is lost to the atmosphere. Mound systems provide these nitrifying and subsequently denitrifying conditions.

Once nitrates reach the groundwater, dilution with the native groundwater can mitigate this contamination. There is also a potential for some denitrification of the nitrate in the groundwater itself and when it enters a riparian area at a groundwater discharge zone. The effectiveness of dilution is dependent upon the amount of nitrate entering from other sources in the area, including agricultural practices and other improperly functioning wastewater treatment systems, along with the hydrogeologic conditions of the groundwater system.

Phosphorus

Since groundwater is ultimately discharged as surface water, the quality of Minnesota's surface water is highly dependent upon the quality of its groundwater. Phosphorus from onsite sewage treatment systems must not enter lakes through the groundwater.

Phosphorus is a concern because lakes receiving additional phosphorus will experience an increase in aquatic vegetation. The most common limiting nutrient for primary production in Minnesota lakes is phosphorus, so small additions bring about a great increase in growth. Algal blooms and heavy growth of emergent vegetation not only make surface water bodies unappealing for recreation, they also threaten the health of fish and other aquatic creatures.

Phosphorus is removed from wastewater by being chemically bound by minerals and held on exchange sites on soil particles. Iron, calcium, and aluminum are minerals that chemically bind with phosphates in a process called adsorption. When the adsorption sites are filled, newly added phosphorus must travel deeper in the soil to find fresh sites. Soils higher in clay content have more surface area and binding sites on the soil particles than soils high in sand. This means phosphorus movement is generally less in finer-textured soils. Numerous field and laboratory studies have documented these differences in phosphorus movement/leaching from soils below a soil treatment area (Sawhney, 1977; Lotse, 1976; Bouma, 1979). If the treatment system is functioning correctly, and proper setbacks are maintained from surface waters and vertical separation from periodically saturated soil, problems from phosphorus movement to surface water or groundwater should be minimal.

Residence Times

The longer contaminants remain in unsaturated soil, the greater the opportunity for treatment. One way to enhance residence times is to ensure that less water percolates through the soil to carry contaminants into groundwater before treatment is achieved. The following methods can be used to reduce the amount of water being treated by a given soil.

- Water conservation: Using less water in the home will increase contaminant residence times in the soil. Reduced flows also allow increased quiet times in septic tanks, which increases the settling of solids of contaminants in the tank so that they do not reach the soil treatment system.
- Long, narrow, and shallow systems: Soil treatment areas constructed shallow to the ground surface will allow the upward removal of water by evaporation and

transpiration through growing plants. Shallow trenches also provide good oxygen exchange with the atmosphere so that the aerobic soil bacteria provide good treatment.

- Install flow-restricting water fixtures.
- Install composting, incinerating, chemical, and low-flow toilets.
- Divert upslope water.
- Promptly repair leaks in plumbing system.

Soil Science Basics

Soil Defined

What is Soil?

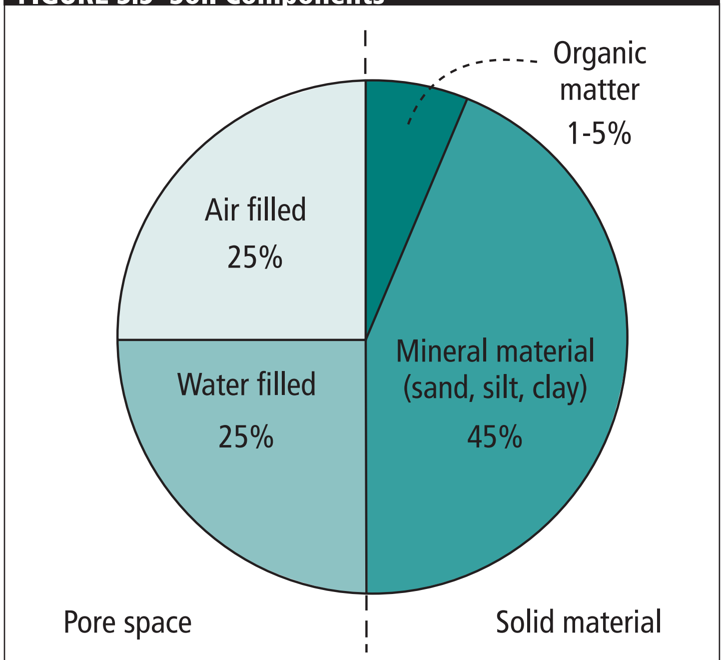
Soil is defined as the unconsolidated mineral or organic matter on the surface of the earth that has been subjected to and shows effects of the genetic and environmental factors of: climate (including water and temperature effects), and macro- and microorganisms, conditioned by relief, acting on parent material over a period of time (Soil Science Society of America, 2008).

Components of Soil

Soil contains about 50 percent solid material and 50 percent pore space. The solid portion typically contains five percent organic matter and 45 percent mineral material (see Figure 3.5).

Since both the solid material and pore space of the soil are imperative to proper septic tank effluent treatment and dispersal, we need a greater understanding of how to identify, describe, and interpret many soil properties. The ability to understand soil will provide the confidence that the subsequent SSTS design will be appropriate (in size, depth, etc.) for the soil and site conditions.

FIGURE 3.5 Soil Components



Soil Texture

Described

Soil texture is the quantity of various inorganic particle sizes present. The inorganic particles are grouped together into sand-, silt-, and clay-sized particles, which are called soil separates. You can think about texture as the "feel" of the soil. Soil texture influences how fast water moves into and through the soil. This soil-water movement is referred to as infiltration (movement at soil surface) and permeability or hydraulic conductivity (movement through the soil). Detailed soil texture analyses are required to estimate the size of the soil treatment area. While soil texture is not the only factor determining soil-water movement, it can provide helpful preliminary information.

Soil texture is the relative proportion, by mass, of the soil particles finer than two millimeters. These particles are sometimes called the fine earth fraction. Materials larger than two millimeters are called rock fragments. These fine earth fraction of soil particles largely influence moisture storage and soil-water movement, and they change the amount of surface areas of soil material that can provide treatment of the effluent.

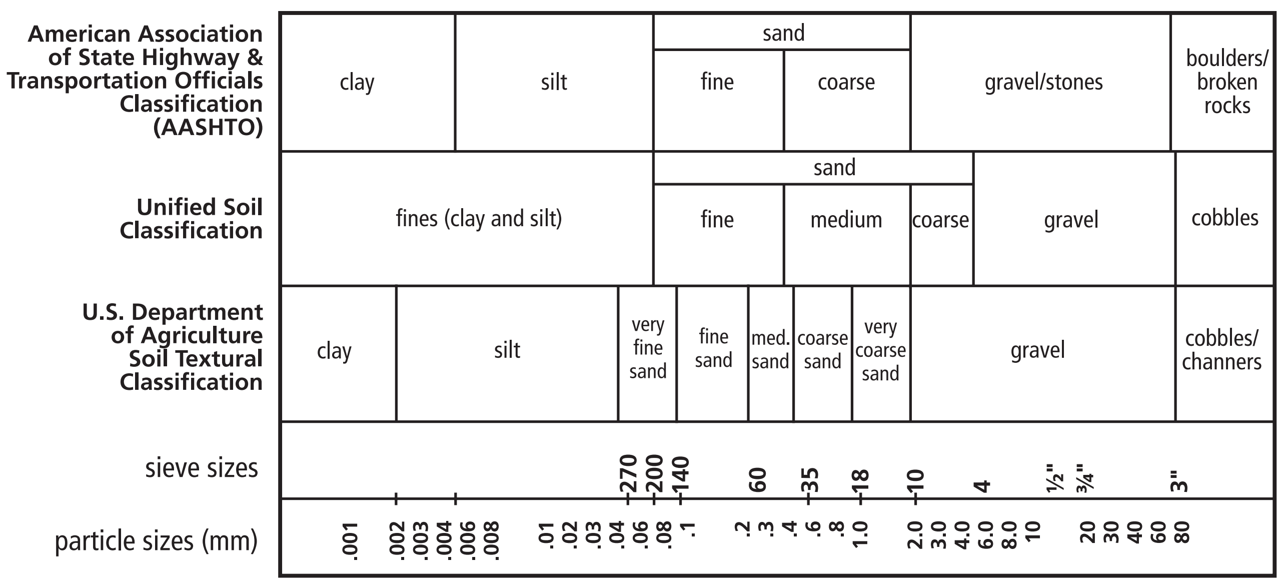
While most people believe that they have a good idea of what a sand particle looks and feels like, it is impossible to see a single clay particle with the naked eye, and it is difficult to imagine 0.002 millimeters. If a sand particle were magnified to a size ten inches in diameter, a silt particle would be about one inch in diameter, in comparison, and a clay particle would be about the size of a grain of sugar.

7080.1100 Subp. 80. Soil texture. "Soil texture" means the soil particle size classification and particle size distribution as specified in the Field Book for Describing and Sampling Soils.

Soil Textural Classification

There are several different soil textural classification systems used in the United States. Textural classification systems include the US Department of Agriculture (USDA) textural classes, the United Soil Classification, and the American Association of State

FIGURE 3.6 Soil Textural Classification Systems in the United States



Sand Separate Sizes (USDA)

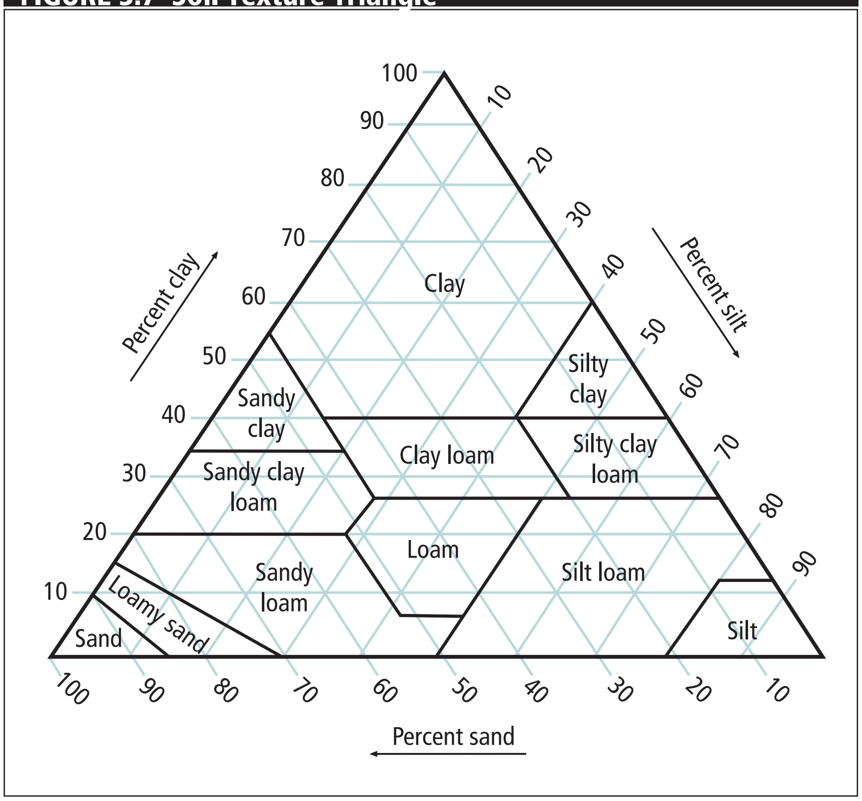
particle name	particle size range (mm)	sieve numbers
v. coarse sand	2.0 - 1.0	10 - 18
coarse sand	1.0 - 0.5	18 - 35
medium sand	0.5 - 0.25	35 - 60
fine sand	0.25 - 0.10	60 - 140
v. fine sand	0.10 - 0.05	140 - 270

Highway and Transportation Officials (AASHTO) Classification (Figure 3.6). The USDA textural classification was developed to reflect water movement in soils and is the system used in sizing SSTS systems. USDA texture classes are given as percentages of sand, silt, and clay.

Soil textural classes are defined according to the distribution of the soil separates. The basic texture classes, in order of increasing proportions of fine particles, are sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. The sand, loamy sand, and sandy loam classes may be further subdivided into coarse, fine, or very fine, according to the sand particle size.

Figure 3.7 is a diagram called the soil texture triangle, which is used to identify soil texture based upon the percentages of sand, silt, and clay in a soil sample. Be careful to enter the triangle along the proper lines for the three particle sizes. At any point on the soil triangle, the sum of the percentages of sand, silt, and clay should total 100 percent. This figure does not address non-soil particles (e.g., organic matter, rock fragments > 2mm, etc.).

FIGURE 3.7 Soil Texture Triangle



For example: Locate the soil texture for a soil possessing 20 percent clay, 40 percent silt and 40 percent sand. A soil with this combination of particles is classified as a loam. Note that a soil sample classified as a loam can have over 50 percent sand and still have the characteristics and soil-water movement of a loam.

The twelve soil textural classes

Clay is the finest textured soil. When wet, clay is quite plastic and is very sticky. When the moist soil is squeezed, it forms a long, flexible ribbon; when moist and smeared, it is shiny. A clay soil leaves a slick surface when rubbed with a long stroke and firm pressure. Due to its stickiness, clay tends to hold the thumb and forefingers together.

Silty Clay has characteristics similar to clay. It contains approximately equal amounts of silt and clay. It is both sticky and smooth feeling.

Sandy Clay also has characteristics similar to clay. It has nearly equal parts sand and clay, and very little silt. It has a sticky feel. Individual sand particles may also be felt.

Clay Loam is a fine-textured soil. The moist soil is plastic and will form a cast that will bear much handling; when formed into a long ribbon, it breaks readily. When kneaded in the hand, it does not crumble readily but tends to work into a heavy compact mass.

Silty Clay Loam is a fine-textured soil similar to clay loam. It generally contains more silt than clay, and can have up to 20 percent sand. It has a slightly sticky feel and is rather stiff. It also feels smooth or floury.

Sandy Clay Loam is composed primarily of sand with varying amounts of clay and silt and has characteristics similar to clay loam. It is slightly to fairly sticky-feeling. Individual sand grains may be felt.

Silt is too fine to be gritty to the touch, but its smooth, slick, or greasy feel lacks any stickiness.

Silt Loam is a soil having a moderate amount of the fine grades of sand and a moderate to small amount of clay, over half of the particles being of the size called "silt." When pulverized, it feels soft and floury. When moist, the soil readily runs together and puddles.

Loam feels like a relatively even mixture of sands, silt, and clay. A loam feels somewhat gritty, yet fairly smooth and highly plastic. Loam textures refer to the mineral fraction of the texture. The term "loam" is not related to the term "topsoil," as loam textures can occur at any depth in the soil.

Sandy loam is similar to loam, but contains a higher percentage of sand, with enough silt and clay to make it somewhat sticky. Individual sand grains can be seen readily and felt.

Loamy Sand is a soft, easily squeezed soil that is only slightly sticky. Individual sand particles can be felt.

Sand is commonly loose and single-grained, but it may be cemented together. Individual grains can be readily seen or felt. Squeezed in the hand when dry, it falls apart when pressure is released and does not form a ribbon. Squeezed when moist, it forms a cast that crumbles. Sand sizes can range from very gritty (coarse sand) to nearly smooth (very fine sand.)

Field Determination of Soil Texture

The determination of soil texture is made in the field mainly by feeling the soil with the fingers, and sometimes by examination under a hand lens. This requires skill and experience, but good accuracy can be obtained if the site evaluator frequently checks his or her estimation against laboratory results.

Soil samples of known textural classes can be obtained from:

Crops and Soils Club
Department of Plant and Earth Science
University of Wisconsin River Falls
River Falls, WI 54022

To determine the soil texture, moisten a sample of soil one to two inches in diameter. There should be enough moisture so that the consistency is like putty. Too much moisture results in a sticky material, which is hard to work. Too little moisture will result in the soil feeling coarser in texture. Press and squeeze the sample between thumb and forefinger. Press the thumb forward to try to form a ribbon with the soil. The amount of sand in the sample can be determined by "washing off" the silt and clay and feeling for sand particles.

Sand particles can be seen individually with the naked eye and have a gritty feel to the fingers. Many sandy soils are loose, but some are not. Silt particles cannot be seen individually without magnification; they have a smooth feel to the fingers when dry or wet. Clay soils are sticky when moist and can possess a sheen at a high clay content.

Whether and how a properly moistened soil develops a long continuous ribbon when pressed between the thumb and fingers gives a good idea of the amount of clay present. If the soil sample forms a ribbon (as do loams, clay loams, or clays) it may be desirable to determine if sand or silt predominate. If there is a gritty feel and lack of smooth talc-like feel, then sand very likely predominates. If there is not a predominance of either the smooth or gritty feel, then the sample should not be called anything other than clay, clay loam, or loam. If a sample feels quite smooth with little or no grit in it, the sample should be called silt loam.

The content of particles coarser than two millimeters cannot be evaluated by feel. The content of the coarser particles is determined by estimating the proportion of the soil volume that they occupy. Rock fragments are described as a modifier to the textural term, such as gravelly sandy loam.

FIGURE 3.8 Moisten and Mold Sample

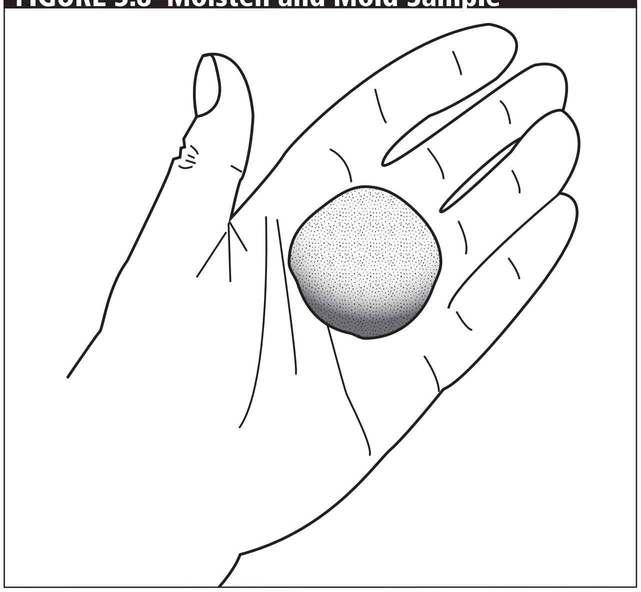
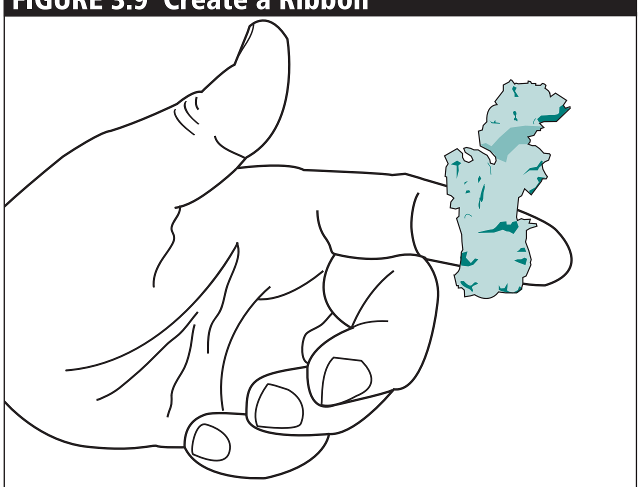


FIGURE 3.9 Create a Ribbon



An experienced site evaluator can determine the texture of soil quite accurately using both feel and sight. A good estimate of the texture class can be made using the following procedure (See Figure 3.10). Final sizing of systems without the aid of a percolation test should only be attempted by an experienced site evaluator with adequate training or by a soil scientist who can accurately determine the soil texture and structure.

Procedure

1. Moisten a sample of soil the size of a golf ball until it is workable and moldable like putty (Figure 3.8). Work it until it is uniformly moist, and then squeeze it out between your thumb and forefinger to try to form a ribbon. This is the method to estimate the clay percentage (Figure 3.9).

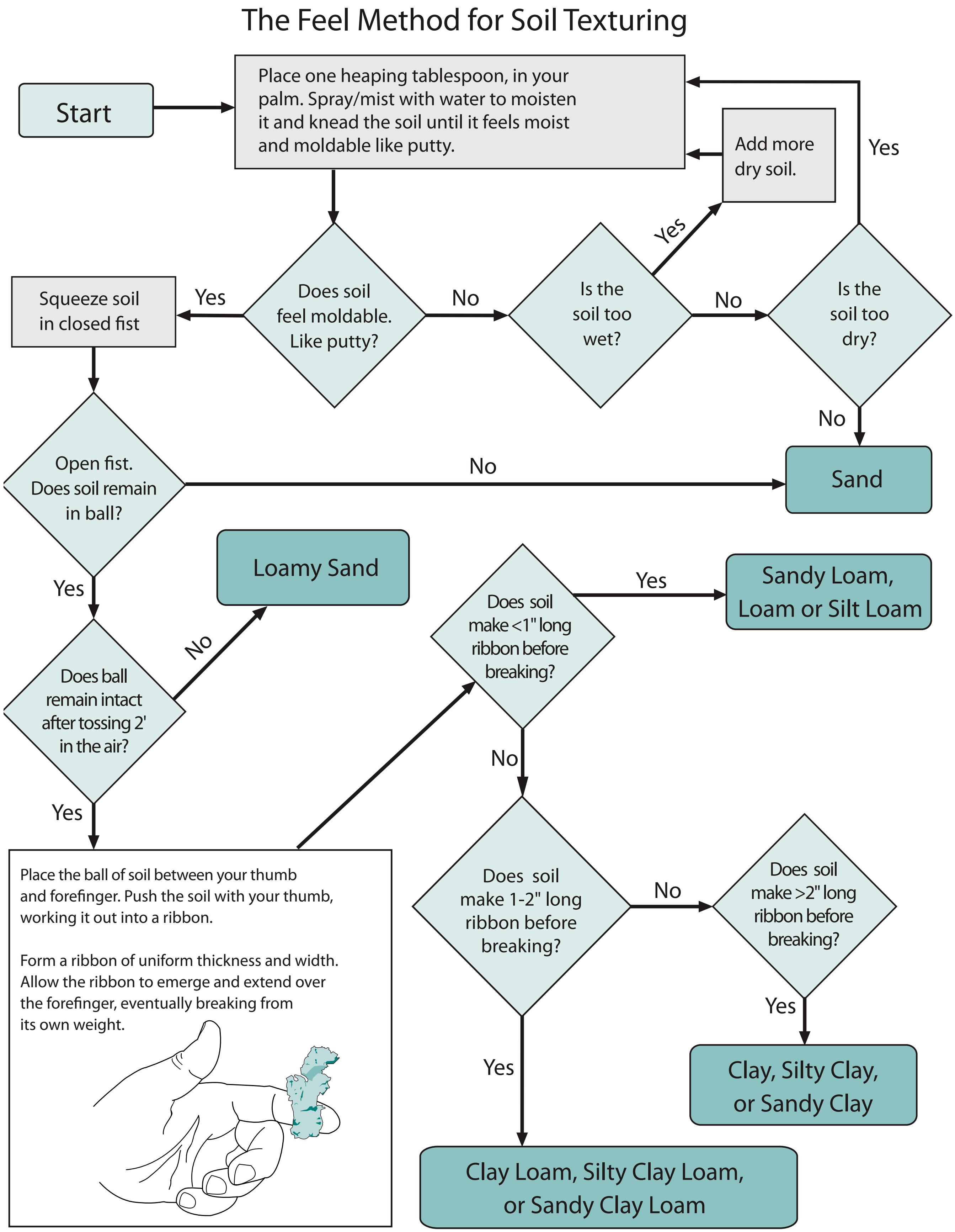
2. First decision. If the moist soil is:
   a. Extremely sticky and stiff: one of the clays
   b. Sticky and stiff to squeeze: one of the clay loams
   c. Soft, easy to squeeze, only slightly sticky: one of the loams
   d. Easy to squeeze or crumbly: one of the sands

3. Second decision. Try to add an adjective to refine the description:
   a. The soil feels very smooth: silt or silty
   b. The soil feels somewhat gritty: no adjective
   c. The soil feels very gritty: sandy

4. Third decision. Determine the amount of sand present:
   a. Very sandy (85% to 100%): sand
   b. Quite sandy (70% to 85%): loamy sand
   c. Somewhat sandy (50% to 70%): sandy loam

5. To distinguish between silt loam and silt, consider how slick or floury the soil feels.
   a. Very slick: silt
   b. Somewhat slick: silt loam

FIGURE 3.10 The Feel Method for Soil Texturing



Soil Structure

Soil structure is defined as the combination or arrangement of primary soil particles (sands, silts, and clays) into secondary units or peds (Soil Science Society of America, 2008). The secondary units are characterized on the basis of size, shape, and grade (i.e., degree of distinctness). Visually, soil structure simply describes how soil particles are glued together into larger units.

Soil structure develops over time (many hundreds to thousands of years) through physical and chemical weathering. Examples of forces forming soil structure include freeze/thaw cycles, wet/dry cycles, plant rooting, earth inhabiting invertebrate activity, etc. These forces are concentrated in the upper portion of the soil (within three to five feet of the soil surface) leaving virtually no soil structure at greater depths. If enough force is used, any body of soil material can be broken into smaller pieces. If the smaller pieces have consistent size and shape and are related to persistent planes of weakness, then this is soil structure that must be described.

Some soil layers or soils do not have orderly shapes or sizes; these are referred to as structureless. In these layers, soil clumps may be broken out of a soil sample, but they are random in size and shape, and the same pieces might not be evident during another soil observation. Depending on the nature of the underlying soil, the soil structure will commonly be described as either massive (cohesive soils) or single grain (non-cohesive soils). A massive soil does not necessarily indicate a hard and cemented layer as massive layers can be relatively easy to manipulate.

Large pores develop between soil structural units. These pores allow a soil to accept and transmit water more efficiently than soils without soil structure. Understanding soil structure is key to the proper sizing of a soil treatment system.

Because soil structure is dynamic, changing in response to moisture content, the soil solution's chemical composition, biological activity, and management practices, soil structure is easily altered or destroyed. Some soils contain clay particles that shrink and swell; montmorillonite or vertic clays, show particularly dramatic changes. When the soil peds swell upon wetting, the large pores become smaller and water movement through the soil is reduced. Therefore, when determining the hydraulic properties of a soil for wastewater treatment and dispersal, the soil's moisture content should be similar to that expected in the soil surrounding a soil treatment system.

Soil Structure in Minnesota

In Minnesota, soil structure usually is developed only in the upper three to five feet of the soil profile. Topsoil generally has a smaller structure than subsoil due to increased weathering forces. Soil structure types are distinct from one another in shape, size, and grade (i.e., distinctness).

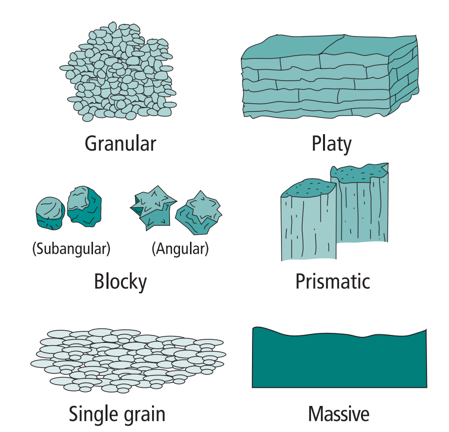
Soil Structure Description

A detailed description of the soil structure is necessary for a thorough understanding and functional design of a soil treatment area. A soil pit or large-diameter probe (e.g. >1 inch diameter) will be necessary to adequately examine the structure. The soil should be examined and described carefully, using a pick or similar device, to expose the natural cleavage and planes of weakness. Cracks in the face of the soil profile are indications of breaks between soil peds. If cracks are not visible, a sample of soil should be carefully picked out and, by hand, the structural units carefully separated until any further breakdown can only be achieved by fracturing.

In soils that have structure, the shape, size, and grade of the peds are described. Nomenclature for describing soil structure consists of separate terms for each of these properties. The three descriptive characteristics of soil structure are:

- Shape
- Size
- Grade

FIGURE 3.11 Soil Shapes



Shape

Several basic shapes of peds are recognized in soils. The following terms (Figure 3.11), describe the basic shapes and related arrangement of peds.

- ***Granular:*** The peds are approximately spherical or polyhedral and are commonly found in topsoil. These are the small, rounded peds that hang onto fine roots when soil is turned over.
- ***Platy:*** The peds are flat and plate-like. They are oriented horizontally and are usually overlapping. Platy structures are commonly found in forested areas just below the leaf litter, shallow topsoil, or compacted areas.
- ***Blocky:*** The peds are block-like or polyhedral, and are bounded by flat or slightly rounded surfaces that are casts of the faces of surrounding peds. Blocky peds have similar height, width, and length dimensions. The structure is described as angular blocky if the faces intersect at relatively sharp angles and as sub-angular blocky if the faces are a mixture of rounded and plane faces. Blocky structures are commonly found in the lower topsoil and subsoil.
- ***Prismatic:*** Surfaces of peds are flat or slightly rounded vertical faces. Peds are distinctly longer vertically and the faces are typically casts or molds of adjoining peds. Prismatic structure is commonly found in the lower subsoil.
- ***Single Grain:*** The structureless description for sandy soils. The individual particles are not held together.
- ***Massive:*** The structureless description for loamy and clayey soils. The soil particles do not break into uniform patterns. Commonly found in the lower subsoil.

Soils with granular, blocky, prismatic, or columnar structures enhance flow both horizontally and vertically. Platy structures restrict downward movement of water because the ped faces are oriented horizontally. Platy structures are often associated with lateral (sideways) movement of water.

Size

There are five size classes: very fine, fine, medium, coarse, and very coarse. The size limits of these classes refer to the smallest dimension of each ped, and vary according to their shape (Table 3.2). If units are more than twice the minimum size of "very coarse," the actual size of the units is specified.

TABLE 3.2 Soil Structure Size Classes

	Size of Structure (millimeters)			
	Shape			
Size Class	Platy	Prismatic or Columnar	Blocky	Granular
Very Fine	<1	<10	<5	<1
Fine	1-2	10-20	5-10	1-2
Medium	2-5	20-50	10-20	2-5
Coarse	5-10	50-100	20-50	5-10
Very Coarse	>10	>100	>50	>10

Grade

Grade describes the stability of peds. Describing soil structure grade in the field depends on the ease with which the soil separates into discrete peds and also on the proportion of peds that remain evident when the soil is handled. Table 3.3 identifies terms used to describe soil structure grade.

A soil description that states "strong, fine, granular structure" is describing a soil that separates almost entirely into discrete peds with a range in size from 1-2 mm and roughly spherical.

Table 3.4 (next page) shows that texture and structure affect how soil can be loaded with sewage. The table expresses the loading rates of effluent to the soil required to accept and treat effluent. In general, finer-textured soils cannot accept as much effluent as coarser-textured soils. While soils with better developed structure can accept more effluent than massive or weak grade structured soils.

TABLE 3.3 Soil Grade Descriptions

Massive (no structure) No observable aggregation, or no orderly arrangement of natural lines of weakness.
Weak Poorly formed, indistinct peds, barely observable in place
Moderate Well formed, distinct peds, moderately durable and evident, but not distinct in undisturbed soil.
Strong Durable peds that are quite evident in undisplaced soil, adhere weakly to one another, withstand displacement, and become separated when soil is disturbed.

TABLE 3.4 IX - Loading rates for determining bottom absorption area and absorption ratios using detailed soils descriptions*

USDA soil texture	Soil structure and grade	Treatment Level C		Treatment Level A, A-2, B, B-2	
		Absorption area loading rate (gpd/ft²)	Mound absorption ratio	Absorption area loading rate (gpd/ ft²)	Mound absorption ratio***
Sand, coarse sand, loamy sand, loamy coarse sand, fine sand, very fine sand, loamy fine sand, loamy very fine sand, 35 to 50% rock fragments	Single grain, granular, blocky, or prismatic structure; weak grade	**	1.0	**	1.0
Sand, coarse sand, loamy sand, loamy coarse sand, <35% rock fragments	Single grain, granular, blocky, or prismatic structure; weak grade	1.2	1.0	1.6	1.0
Fine sand, very fine sand, loamy fine sand, loamy very fine sand, <35% rock fragments	Single grain, granular, blocky, or prismatic structure; weak grade	0.6	2.0	1.0	1.6
Sandy loam, coarse sandy loam, fine sandy loam, very fine sandy loam	Granular, blocky, or prismatic structure; weak to strong grade	0.78	1.5	1.0	1.6
Sandy loam, coarse sandy loam, fine sandy loam, very fine sandy loam	Platy with weak grade or massive	0.68	1.8	0.87	1.8
Loam	Granular, blocky, or prismatic structure; weak to strong grade	0.6	2.0	0.78	2.1
Loam	Platy with weak grade or massive	0.52	2.3	0.68	2.4
Silt loam, silt	Granular, blocky, or prismatic structure; weak to strong grade	0.5	2.4	0.78	2.1
Silt loam, silt	Platy with weak grade or massive	0.42	2.9	0.65	2.5
Clay loam, sandy clay loam, silty clay loam	Granular, blocky, or prismatic structure; moderate to strong grade	0.45	2.6	0.6	2.7
Clay, sandy clay, silty clay	-	**	**	**	**

* **ONLY INCLUDES SOIL HORIZONS WITH <50% ROCK FRAGMENTS, WITH VERY FRIABLE AND FRIABLE CONSISTENCE, AND LOOSE NONCEMENTED SANDS**. All USDA sands and loamy sands with 35% or more rock fragments or any soil horizons with >50% rock fragments must not come in contact with soil dispersal system media.

** Conduct percolation test and size under Table IXa. May need to be designed under part 7080.2300.

*** Assume a hydraulic loading rate to the sand at 1.6 gpd/ft².

Consistence

Soil consistence refers to the attributes of soil material as expressed in degree of cohesion and adhesion or in resistance to deformation on rupture (Soil Science Society of America, 2017). In the field, resistance of the soil structure to rupture is used to determine consistence. Consistence is highly dependent upon on the soil-water state and should be consistent. Therefore, it is required that moist samples be used.

The amount of cohesion in the soil is important to soil-water movement. A soil with much cohesion will limit water movement compared to the same soil without a high degree of consistence.

To determine a soil's consistence, place a single soil structure or ped between thumb and forefinger. Apply force with thumb and forefinger for one second. Observe the relative force required to rupture the ped. Terms used to describe soil consistence are identified in Table 3.5.

TABLE 3.5 Rupture Resistance Classes

moist consistence class	specimen fails under
loose	(intact specimen not available.)
very friable	very slight force between fingers
friable	slight force between fingers
firm	moderate force between fingers
extremely firm	moderate force between hands or slight foot pressure
rigid	foot pressure

Soil Colors

Soil colors are any observable coloration present in a unique layer of soil. Soil color varies from place to place in the landscape and from top to bottom in a soil profile. Accurate descriptions and interpretations of soil colors and soil color patterns are critical to understanding a site and eventually designing the appropriate soil-based sewage treatment system for the site.

Significance of Color

Soil color is one of the most useful soil properties to describe because it provides valuable information about the nature and conditions of the soil. Proper color identification and description are critical during a site evaluation because many other landscape, soil and hydrologic factors are interpreted based on the soil color. For instance, soil color is an indicator of natural drainage conditions.

There are four dominant coloring effects on the soil: soil moisture, organic matter, iron, and uncoated soil grains. Soil moisture changes the color of a soil due to varying soil moisture levels. For instance, a muddy shoe has very dark soil stuck to it. When the same mud dries out, it is a lighter color due to soil moisture. For our soil coloring, we will always want to keep the soil moist.

Most people recognize darker surface colors as being humus-enriched (organic matter). In Minnesota it is quite common to have six to 12 inches or more of these "top soil" colors before getting to the subsoil. These dark soils are commonly found where decomposition of plant matter is the greatest. It is rare to find a dark soil color below a lighter color, unless the site has been disturbed. These dark colors cover or mask other features of the soil that may be important, so it is imperative to investigate these soils thoroughly.

Iron in the soil is the source for the many varying shades of red, yellow, brown, and orange in soils. Iron is mostly inherited with the soil parent material, but some can accumulate from movement of water. Where bright soil colors dominate a soil layer, there is evidence that this soil is aerated or has oxygen present the majority of the time. Reddish brown colors in Minnesota soils are generally due to the iron-rich parent material from which the soil has developed. Large areas of these soils are found in northeastern and central Minnesota.

The last coloring component to influence soil color is a lack of coatings on the soil grains. Soil colors are typically described as gray or light-colored. They can form due to vegetative conditions, soil parent materials, and/or soil saturation. A soil color description must be placed in the proper context during the site evaluation to ensure that the proper interpretation is made. Soils derived from sandy parent material(s) are generally light in color due to a lack of iron and small amounts of organic matter.

Soil horizons may contain many different colors. The colors are derived from either the parent material or the soil-forming process. These processes may result in the formation of layers, banding, clay accumulations, silts coatings, organic stains, and nodules, all of different colors.

All soil colors observed are potentially important to understanding the soil and site conditions. It is imperative that the site evaluator record all soil colors, including the dominant color (matrix color) and any additional colors (mottles) within each layer of soil. The designer will make the final interpretations as to the significance of soil colors present in a soil boring log.

7080.1100 Subp. 47. Matrix means the majority of the color in a soil horizon, as described in the Field Book for Describing and Sampling Soils.

Determining Soil Colors

Because of the importance of soil color, a standard system is needed for consistent soil color description and for the development of standard color criteria. The color system referred to for soils is the Munsell Soil Color Charts (Munsell Color Company, 2000).

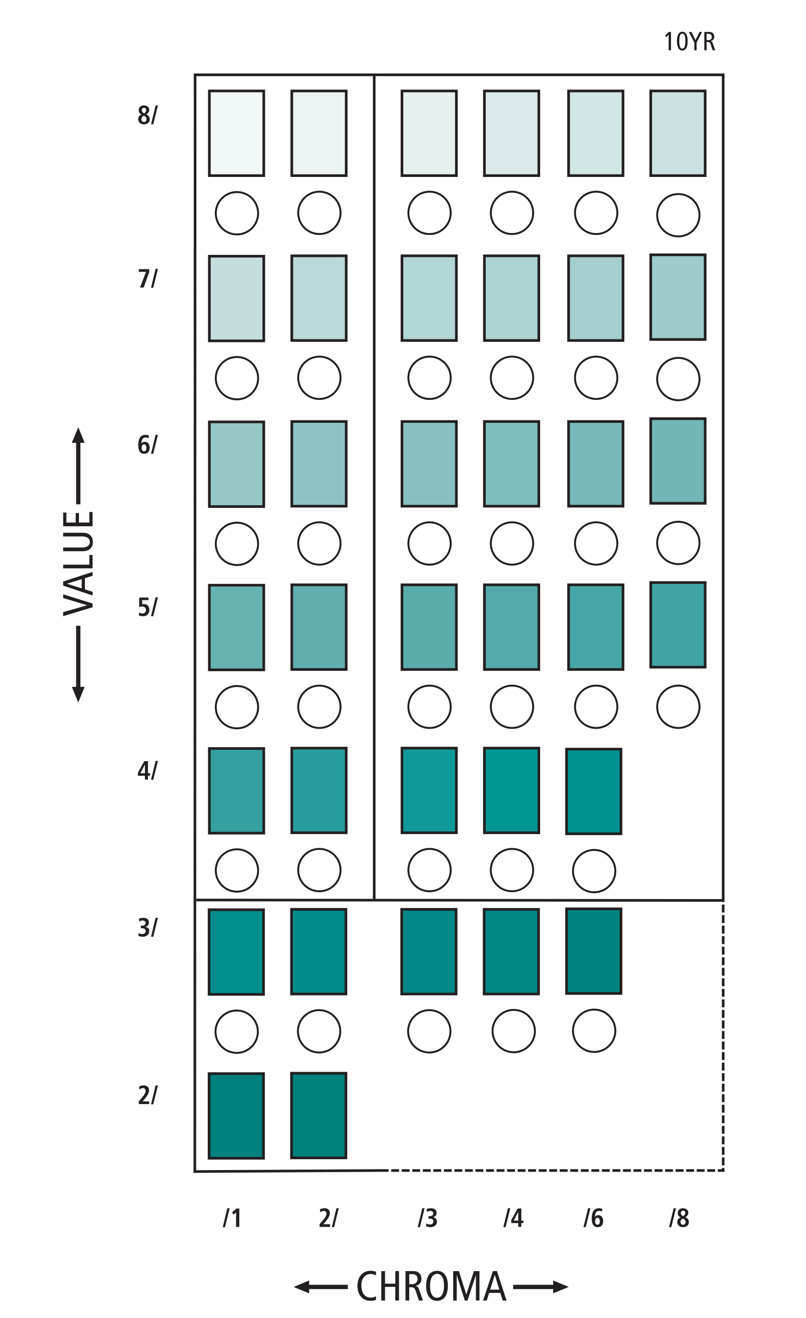
Descriptions of soil color are comprised of three variables:

- ***Hue:*** The primary colors or combinations of primary colors, such as red and yellow
- ***Value:*** The measure of darkness or lightness of color, such as light red or dark red
- ***Chroma:*** The measure of the strength of color or level of brightness, or its departure from a dull color, such as grayish red or bright red

Soil color is measured by comparison with a standard color chart. The chart used by site evaluators is the Munsell color system. The standard Munsell chart for soil color consists of about 175 differently colored chips, systematically arranged on nine cards, including two cards for gleyed soils, assembled into a loose-leaf binder. Two for the reddest hues of soils and two for the bluish and greenish hues of gleyed soils, are also available. To order Munsell color books, contact the Onsite Sewage Treatment Program.

All colors displayed on any color page are of constant hue, which is a number and letter symbol in the upper right-hand corner of the Munsell Color Chart, also referred to as the page (Figure 3.12). Chroma, the deviation from gray, increases from left to right on each page. The scale for chroma occurs at the bottom of every page. The chroma is the same for each color chip in a column (vertical). As color chips graduate to lighter colors at the top of a color page, value increases. The scale for value is located at the far left of the color chart page; each row (horizontal) of chips will have the same value. Opposite each page containing color chips is a page of color symbols and corresponding English names, so that color can be expressed both by Munsell notation and color names.

FIGURE 3.12 Page from Munsell Color Book



Conditions for Measuring Color

The quality and intensity of the light falling on a sample of soil affects the amount and quality of the light reflected from the sample to the eye. The moisture content of the sample and the roughness or smoothness of its surface also affects the amount and quality of the light reflected. The visual impression of color from the standard color chips is accurate only under standard conditions of light intensity and quality. Since the color standards are used in the field, it is important that the light be white enough that the sample reflects its true color and that the amount of light be adequate for visual distinction between chips.

When the sun is low in the sky, the light reaching the sample is lower in intensity due to filtration by the atmosphere. For this reason, color determination may be inaccurate early in the morning or late in the evening, or in late fall through early spring. Readings of the sample color during these times are commonly one or more intervals of hue redder than at midday. Colors also appear different in the subdued light of a cloudy day than in bright sunlight. If artificial light is used, the light source should be a full light spectrum bulb (not a common incandescent or fluorescent bulb) and must be utilized as near midday as possible. Intensity of the incident light is especially critical when matching soil to chips of low chroma and low value.

The color value of most soils becomes lower as the soil is moistened. Soil colors utilized in the soil survey and for SSTS determinations require coloring the soil under moist soil conditions. The soil can be moistened with water or, if too wet, dried by blowing on a small ped. Usually one small application of wter to a dry soil will provide adequate moisture for coloring a soil sample. Color determinations of overly wet soil may be in error because of the effect of light reflected from water films, while dry soil colors will appear lighter and duller.

Reading the Color

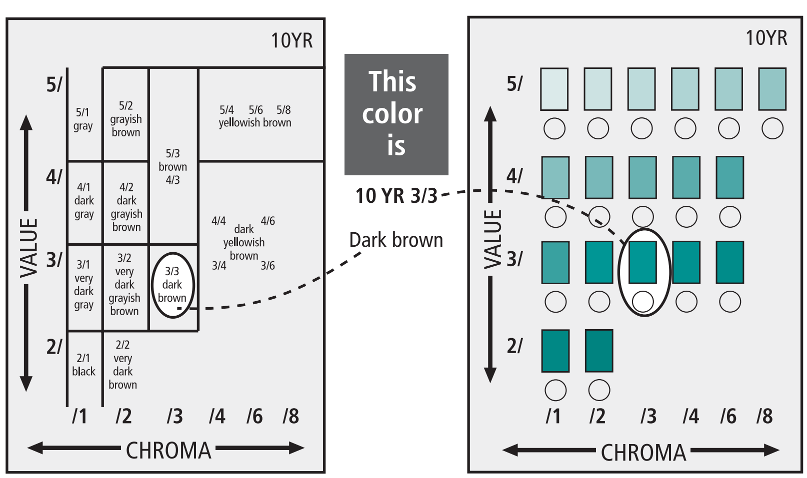
1. Take a ped from the horizon to be examined. Do not crush or break the ped.
2. Adjust the water content of the ped to "moist." This may be needed depending on field conditions.
3. Estimate the primary soil matrix color (Figure 3.13), and turn to the appropriate Munsell page.

FIGURE 3.13 Munsell's Primary Soil Matrix Color Options

5 YR	7.5 YR	10 YR	2.5 Y	5 Y	Gley
Brownish red	Reddish brown	Brown	Olive brown	Olive	Bluish/ greenish gray Pure black

4. With the sun at your back, hold the sample behind the holes of the page. Match as closely as possible with the color book page perpendicular (a right angle) to the sun angle.
5. If you are not satisfied with the match, flip the page forward for browner or redder colors, backward for more olive or gray colors.
6. Record the color or colors that provide the closest match (Figure 3.14).
7. Break, cut, or crush (but do not rub) the ped to see if the ped interior color differs from the ped surface. If so, repeat steps 3 to 6 above for the ped interior.

FIGURE 3.14 Record Soil Colors



Read moist colors of entire ped (interior and exterior) with adequate light.

Mottles

7080.1100 Subp. 49. "Mottles" means the minority of the variegated colors in a soil horizon, as described in the Field Book for Describing and Sampling Soils.

Soil mottles are the soil colors that are in the minority if more than one soil color is present (Figure 3.15). Soil mottles can be almost any color.

Figure 3.15 Mottles and Matrix

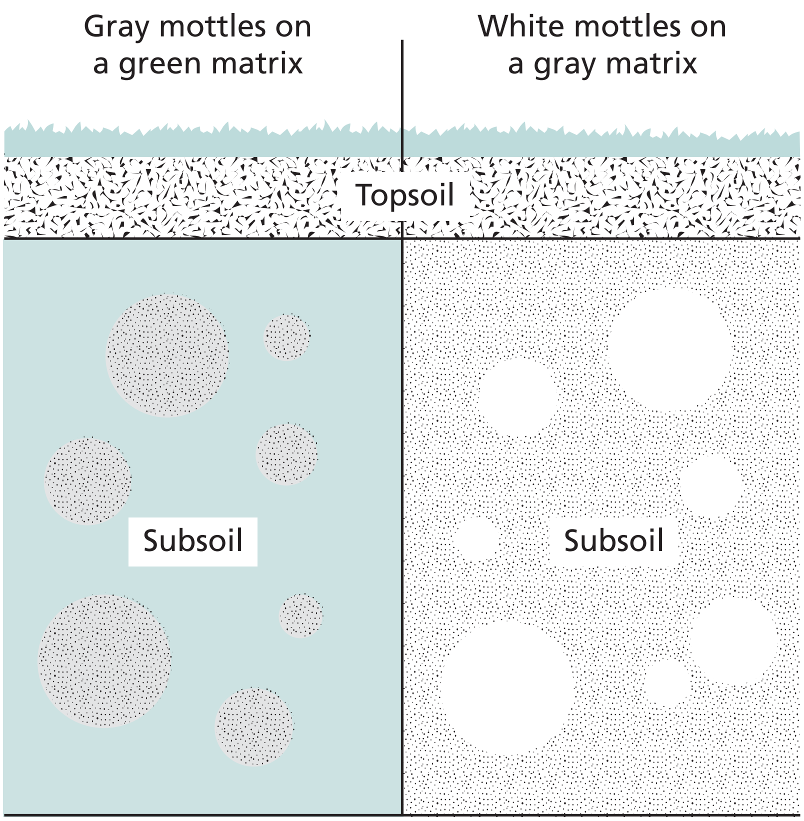
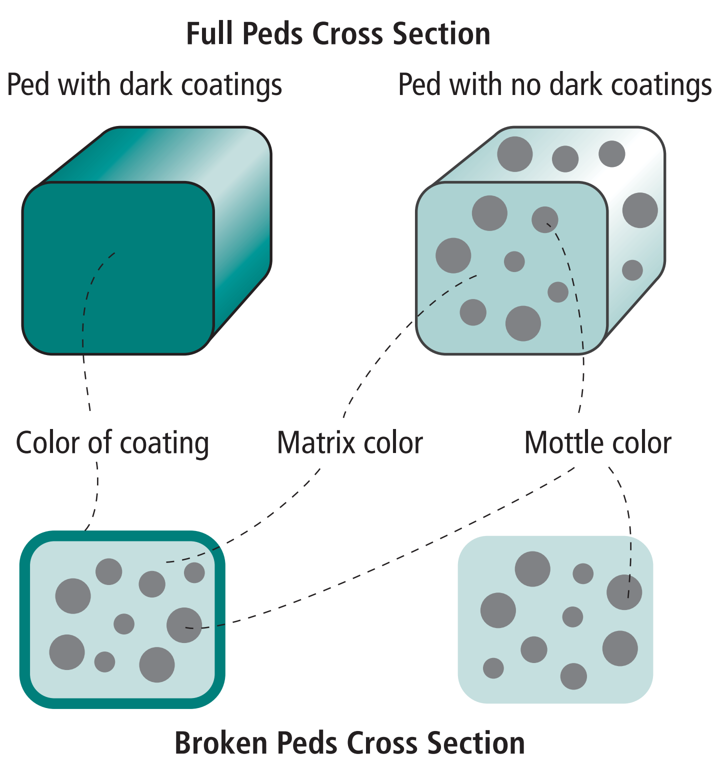


FIGURE 3.16 Interpreting Soil Peds



Color pattern within soil horizons are described for:

- Matrix color (dominant color)
- Mottle colors (minority colors including silt coats, clay accumulations, organic stains, etc.)

It is important to describe a fresh, field-moist soil face. When looking at a single unbroken ped, you may be viewing a coating on the ped. This coating can be organic material, silt, clay or an iron compound. Breaking or crushing (but not rubbing) will reveal the color of the ped interior, as shown in Figure 3.16. If the ped interior has two or more colors, the majority color is considered the matrix color, and the minority color is the mottle color. If the ped is not coated, the matrix color will be at the ped surface.

The ped exterior, ped interior, and all mottle colors should be recorded. The physical state of the sample should be recorded as broken, crushed, or cut. In mottled soils with thick ped coatings, the color and patterns of faces of peds, and those of a surface broken through the peds, can be markedly different as shown in Figure 3.16. The soil must be in a moist state when examined.

Contrast refers to the degree of visual distinction that is evident between mottle and matrix colors. Contrast may be described as faint, distinct, or prominent. See Table 3.6 (next page) for all criteria for level of contrast.

- ***Faint:*** Evident only on close examination; hue, value, and chroma of mottles and matrix are similar.

7080.1100 Subp. 29. Faint means a soil color:

a. with the same hue as another soil color but that varies from the other color by two or fewer units of value and not more than one unit of chroma;

b. that differs from another soil color by one hue and by one or fewer units of value and not more than one unit of chroma; or

c. that differs from another soil color by two units of hue with the same value and chroma.

- ***Distinct:*** Readily seen; soil color varies by one or more hue, more than two units of value, or more than one chroma.

7080.1100 Subp. 19. "Distinct" means a soil color that is not faint.

- ***Prominent:*** Observable from several feet away; soil mottle color varies significantly from matrix color. Chapter 7080 defines prominent as being distinct.

An example of prominent contrasting mottles is "pale-brown (10YR 6/3) fine sand, with many coarse, prominent, reddish-brown (5YR 5/6) mottles."

TABLE 3.6 Contrast Classes and Color Differences

Contrast Class	Code	Difference in Color Between Matrix and Mottle (Δ means "difference between")			
		Hue (h)	Value (v)		Chroma (c)
Faint[1]	F	Δh = 0:	Δv < 2	and	Δc < 1
		Δh = 1:	Δv ≤ 1	and	Δc ≤ 1
		Δh = 2:	Δv = 0	and	Δc = 0
Distinct[1]	D	Δh = 0:	Δv ≤ 2	and	Δc > 1 to < 4
		or	Δv > 2 to < 4	and	Δc < 4
		Δh = 1:	Δv ≤ 1	and	Δc > 1 to < 3
		or	Δv > 1 to < 3	and	Δc < 3
		Δh = 2:	Δv = 0	and	Δc > 0 to < 2
		or	Δv > 0 to < 2	and	Δc < 2
Prominent[1]	P	Δh = 0:	Δv ≥ 4	or	Δc ≥ 4
		Δh = 1:	Δv ≥ 3	or	Δc ≥ 3
		Δh = 2:	Δv ≥ 2	or	Δc ≥ 2
		Δh ≥ 3:			

[1] If compared colors have both a Value ≤ 3 and a Chroma of ≤ 2, the contrast is *Faint*, regardless of Hue differences.

Redoximorphic Features

A specific kind of mottle (color variation) occurs in soils that are subject to seasonal saturation, known as redoximorphic features. These color changes are the result of chemical and biological reactions that typically occur in wetter soil horizons. The presence of these features indicates there is a limiting condition present in this soil that the SSTS design must address. Minnesota state regulations require the identification of these features in order to accurately determine the suitability of each site for a SSTS.

7080.1100 Subp. 59. Periodically saturated soil means the highest elevation in the soil that is in a reduced chemical state due to soil pores filled or nearly filled with water causing anaerobic conditions. Periodically saturated soil is determined by the presence of redoximorphic features in conjunction with other established indicators as specified in part 7080.1720, subpart 5, items E and F, or determined by other scientifically established technical methods or empirical field measurements acceptable to the permitting authority in consultation with the commissioner.

These features remain evident in the soils, allowing the site evaluator to correctly identify soils subject to periodic saturation even when the soil is dry. Alternating periods of saturation and unsaturated conditions in the soil profile results in soil color changes evidenced by mottled shades of gray, reddish or orange, bluish grays, or a high content of organic matter at the soil surface (e.g. mucky).

7080.1100 Subp. 65. Redoximorphic features means:

a. a color pattern in soil, formed by oxidation or reduction of iron and manganese in saturated soil coupled with their removal, translocation, or accrual, which results in the loss (depletion) or gain (concentration) of mineral compounds compared to the matrix color; or

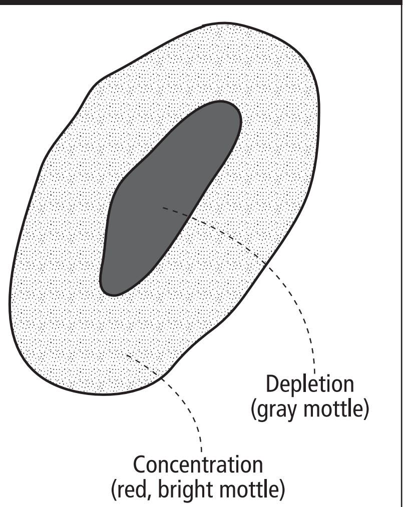
b. a soil matrix color controlled by the presence of ferrous iron. Redoximorphic features are described in part 7080.1720, subpart 5, item E.

Redoximorphic Feature Formation

A typical dry upland soil has mostly air (oxygen) filling the void spaces between the soil particles. The air can move into the soil readily and supply soil microbes with enough oxygen to survive. Brighter soil colors are a result of the oxidation (i.e., exposure to oxygen) that occurs in dry soil conditions.

When the voids or pore spaces of a soil are filled with water instead of air, soil microbes are prevented from using oxygen and must utilize other constituents in the soil to survive. Without oxygen, the microbes are able to adapt and utilize other electron acceptors in the soil, particularly iron. When iron is used in this way, the soil microbes are able to change (i.e. chemically reduce) iron from its rust (oxidized) form to its steel blue (reduced) form. Not only is this color change observable, but the higher solubility of iron in its reduced form is dissolved and transported in water, while oxidized iron is not transported in water. The movement of reduced iron with the water in the soil will result in areas where iron has been removed (i.e., depletions with dull colors), accumulated (i.e., concentrations with bright colors), and reduced but not removed (i.e., the reduced iron is still present with gleyed colors). Gley colors are typical where water levels are static or do not have strong gradients of movement. These types of formations in the soil are known collectively as redoximorphic features, soil features that form by the processes of red<u>uction</u> and ox<u>idation</u> (redox).

FIGURE 3.17 Concentrations and Depletions



Before the redox reactions can take place in the soil, the soil must meet four conditions:

a. soil is saturated, soil pores filled with water;

b. soil water is depleted of any dissolved oxygen;

c. soil temperature is above biological zero (>41 degrees F); and

d. soil contains a readily usable form of organic matter for microbial activity.

If all four of these soil conditions are simultaneously met in the soil, then the reduction reactions will occur, potentially altering soil colors.

Redoximorphic Feature Description

Redoximorphic features are described in the same way as mottling is described above. The only additional criteria to record about the redox features are the kind (depletion, concentration, or gley)(see Figure 3.17).

FIGURE 3.18 Nodules and Concretions

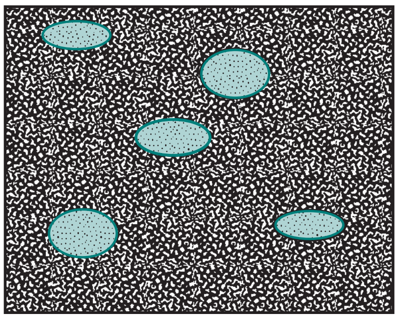


FIGURE 3.19 Soft Accumulations

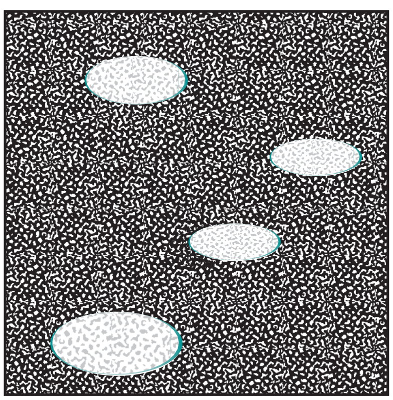
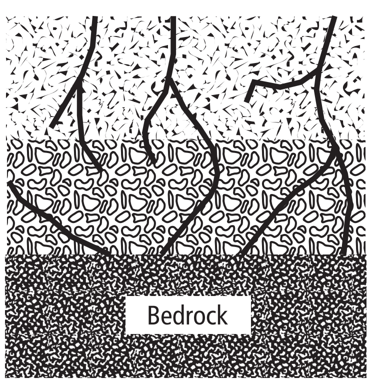


FIGURE 3.20 Roots and Root Traces



Other Soil Features

The site evaluator should be aware that there are other soil features that have not been previously described. They are important because the site evaluation may confuse some of these features with soil redoximorphic features caused by wetness. These include clay films or silt coatings on the surface of the peds. The site evaluator should include these features in their descriptions. The presence of iron-based redoximorphic features, particularly in gray (i.e., high value, low chroma) soil matrix, often indicates periodic saturation.

The features discussed here are identifiable bodies embedded in the soil. Some of these bodies are thin and sheet-like; some are spherical; others have irregular shapes. They may contrast sharply with the surrounding material in strength, composition, or internal organization.

Nodules and Concretions

Nodules and concretions are discrete bodies. They are commonly cemented. They may also be uncemented but coherent units that separate from the surrounding soil along clearly defined boundaries. They range in composition of chemical compounds (see Figure 3.18).

Soft accumulations

Soft accumulations contrast with the surrounding soil in color and composition but are not easily separated as discrete bodies, although some have clearly defined boundaries. Most soft accumulations consist of calcium carbonate, iron, and manganese (Figure 3.19).

Soft rock fragments

Soft rock fragments have rock structure, but break down or crush easily.

Surface features

The surfaces of individual peds may have coats of a variety of substances and covering part or all of the surfaces. Descriptions of surface features may include kind, location, amount, continuity, distinctness, and thickness of the features. In addition, color, texture, and other characteristics that apply may be described, especially if they contrast with the characteristics of the adjacent material.

Roots and root traces

The presence of roots in each layer is recorded in soil descriptions. The absence of roots or the orientation of roots may indicate hardpan, saturated soil, or bedrock (see Figure 3.20).

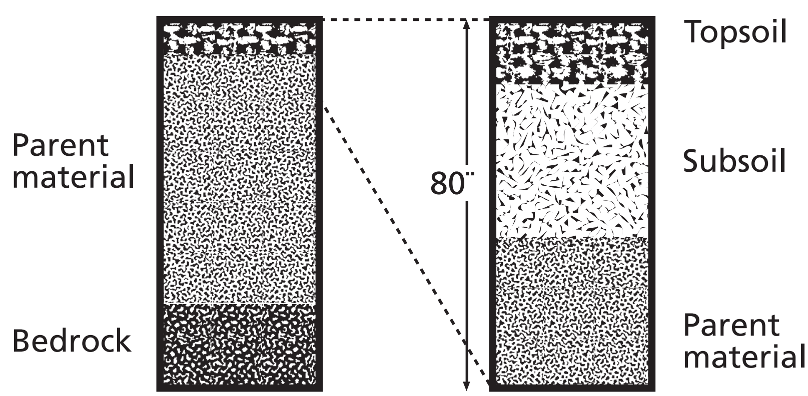
Soil Profile

A soil profile is a vertical section of a soil consisting of one or more soil horizons and the unweathered material underlying the horizons. A thorough description of a soil profile to a depth of six feet or greater provides the site evaluator with valuable information about the soil. A soil profile can inform the evaluator about the hydrology, depositional environment, limiting condition(s), problem soil situations, percentage of rock, disturbance history, and many other soil and site features. The wall of an excavation pit is a good place to study the soil profile.

Soil Horizons

Weathering of the parent material over time forms different layers in the soil called horizons. A soil horizon is a layer of soil approximately parallel to the soil surface with similar characteristics. Soil horizons are identified by observing changes in soil properties with depth. Changes in soil texture, structure and/or color are some of the characteristics used to determine soil horizons (see Figure 3.21).

FIGURE 3.21 Soil Horizons



Soils vary widely in the degree to which horizons are expressed. Relatively recent geologic formations, such as alluvial fans, may have no recognizable horizons although they may have distinct layers that reflect geologic deposition. As soil formation progresses, horizons may be detected in their early stages only by very careful examination. As weathering increases, horizons are more easily identified in the field. The term layer, rather than horizon, is used when all of the properties are inherited from the parent material (geologic strata) and not from soil-forming processes.

Typically, horizon distinctness decreases below three to five feet in depth, which corresponds to the depth of soil structure development. Horizons below this depth are characteristically thicker, and the boundaries between horizons are not easily seen. Technically, the loss of structure development is the lowest horizon of the soil; deeper horizons are actually parent material (such as unweathered glacial till or unweathered loess).

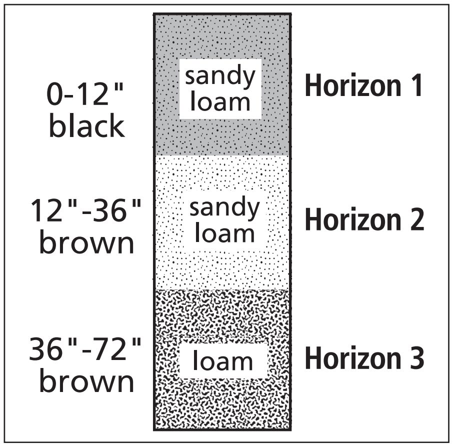
Since each horizon has its own set of soil characteristics, it will respond differently to applied sewage tank effluent. Also, the conditions at the boundary between soil horizons can significantly influence effluent movement and treatment in the soil. Effluent movement between horizons can be severely limited when extreme differences between two soil horizons exist.

Horizons are described and differentiated from one another on the basis of the following characteristics:

- Texture
- Matrix color
- Mottles
- Structure
- Consistence
- Presence or absence of roots

The depth at which one or more of these characteristics appreciably changes will be described and recorded. A soil boring log sheet is provided at septic.umn.edu/ssts-professionals/forms-worksheets to aid in recording the soil description.

FIGURE 3.22 Soil Horizon Boundaries



Determining Boundaries

Boundaries between horizons are determined by any change in color, texture, soil structure, or other soil property. For example, in Figure 3.22, Horizon 1 is 12 inches thick and is a black sandy loam. Horizon 2 is from 12 to 36 inches and is a brown sandy loam. Horizon 3 is from 36 to 72 inches and is a brown loam. At the bottom of the soil-boring log, the total depth of the boring hole should be entered as well as any evidence of mottling or saturated soil conditions.

Soil Morphology

Soil morphology is defined as the visible characteristics of the soil or any of its parts (Soil Science Society of America, 2017). It is the term used by soil scientists to refer to the complete observation, description, and interpretation of the soil profile.

Soil Pores

Soil pores are the void spaces between soil particles. These voids provide important functions in the soil, including air and liquid exchange. A soil with a high volume of pores has a high pore space. A soil described as dense or restrictive will typically have less pore space.

Pores are generally described as either macropores or micropores. Macropores are large pores. Macropores are important for preferential flow of gases and liquids through the soil. If water or liquids are applied to the soil at rates exceeding the unsaturated hydraulic conductivity, liquids move through the soil profile mainly via saturated flow through macropores, thereby bypassing micropores and rapidly transporting any solutes to the lower soil profile. This type of water movement is a concern for the proper treatment of septic tank effluent.

Micropores are the smaller voids between individual soil particles, found on the interior of soil peds. Soil water movement in these pores occurs under unsaturated soil conditions and typically is associated with increased levels of effluent treatment. Micropores are also partly responsible for the capillary fringe, which is a zone in the soil just above the plane of saturation that wicks moisture and causes saturated or almost saturated conditions.

Soil Permeability

Soil permeability is the ease with which gases, liquids, or plant roots penetrate or pass through a bulk mass of soil or a layer of soil (Soil Science Society of America, 2008). This general concept of soil permeability has no inherent measurable properties but is similar to soil saturated hydraulic conductivity. Most existing soil survey reports will list the soil permeability, but this measurement is actually a measure of the soil's saturated hydraulic conductivity.

Saturated Hydraulic Conductivity

Saturated hydraulic conductivity is a quantitative measure of a saturated soil's ability to transmit water when subjected to a hydraulic gradient. It can be thought of as the ease with which pores of a saturated soil permit water movement.

To convert from saturated hydraulic conductivity (inches per hour) to percolation units, divide the conductivity value into the number 60. For example:

60 minutes ÷ 2 in./hr = 30 minutes per inch (mpi).

To convert from percolation rate units to conductivity units, divide the percolation rate into 60. For example:

60 minutes ÷ 30 min/in. = 2 in./hr

Current soil survey publications provide soil hydraulic conductivity measurements in micrometers per second (μm/s). To convert these units to English units (in./hr) multiply micrometers per second (μm/s) by 0.14.

Soil texture is used as an indirect indicator of soil saturated hydraulic conductivity. Conductivity in the soil will typically decline as soil textures increase in clay percentage. However, texture alone cannot be used to determine the final sizing of soil-based sewage treatment systems. For instance, a natural sandy loam soil is likely to have a percolation rate in the six to 15 mpi range. If the same sandy loam soil is impacted by compaction or is non-original soil the percolation rates can decrease significantly. The conductivity relates to the soil loading rate (gallons per square foot). Table 3.7 below shows loading based on percolation rates from MN Rule Chapter 7080. Table 3.7 refers to both septic tank effluent and pretreated effluent that meets the definition of Treatment Levels A and B.

Table 3.7: Loading rates for determining bottom absorption area and absorption ratios using percolation tests

Percolation rate (MPI)	Treatment level C		Treatment levels A, A-2, B, and B-2	
	Absorption area loading rate (gpd/ft^2)	Mound absorption ratio	Absorption area loading rate (gpd/ft^2)	Mound absorption ratio
<0.1	-	1.0	-	1.0
0.1 to 5	1.2	1.0	1.6	1.0
0.1 to 5 (fine sand and loamy fine sand)	0.6	2.0	1.0	1.6
6 to 15	0.78	1.5	1.0	1.6
16 to 30	0.6	2.0	0.78	2.0
31 to 45	0.5	2.4	0.78	2.0
46 to 60	0.45	2.6	0.6	2.6
61 to 120	-	5.0	0.3	5.3
>120	-	-	-	-

Infiltration

Infiltration is the process of downward water entry into the soil. Infiltration rates are sensitive to near-surface conditions as well as to the antecedent water content. Hence, infiltration rates are subject to significant change with soil use, management, and time (Soil Survey Division Staff, 2017). Soil texture and structure can be used to approximate infiltration rates. Field measurements, such as the percolation test, also can be used to estimate the infiltration rates of soils. Such tests address changes to the soils (e.g. compaction, fill, etc.).

Plastic Limit

Plastic limit (PL) is defined as the minimum water content at which the mixture acts as a plastic solid. The behavior of dry soil changes as the soil takes on an increasing amount of water. When dry, the soil is rigid and solid, but as more water is added, it starts to lose strength. If the soil contains expansive clays, such as smectite, the soil will also begin to swell. As the soil swells, it becomes plastic and will remain in this plastic state until the liquid limit is exceeded, at which point the soil will change into a viscous liquid that will flow when disturbed. The amount of water required to shift soil from a plastic to a liquid consistency is known as the Atterburg limit and is expressed as a percent.

7080.1100 Subp. 60. Plastic limit means a soil moisture content above which manipulation will cause compaction or smearing. The plastic limit can be measured by American Society for Testing and Materials, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils, ASTM D4318 (2005).

Soils at or near the plastic limit will be significantly altered by normal construction activities (e.g., traffic, excavation, building, etc.). The alteration can render a soil that was suitable for an SSTS into one that will no longer support an SSTS. To assess the soil's ability to suitably withstand the construction activities at the current soil moisture status, the below procedure should be followed.

Procedure for Determining Plastic Limit in the Field

1. Select a handful of soil for testing. Any non-soil material, rocks, roots, etc. should be removed. Do not add moisture or let the sample dry-out. Sample should be taken at the depth of excavation (absorption area.)
2. Roll the sample between the palms (in the shape of a pencil/worm shape).
3. Continue rolling the thread until it reaches a uniform diameter of 1/8 inch if possible (See Figures 3.23 and 3.24).

FIGURE 3.23 Roll Sample Between the Palms

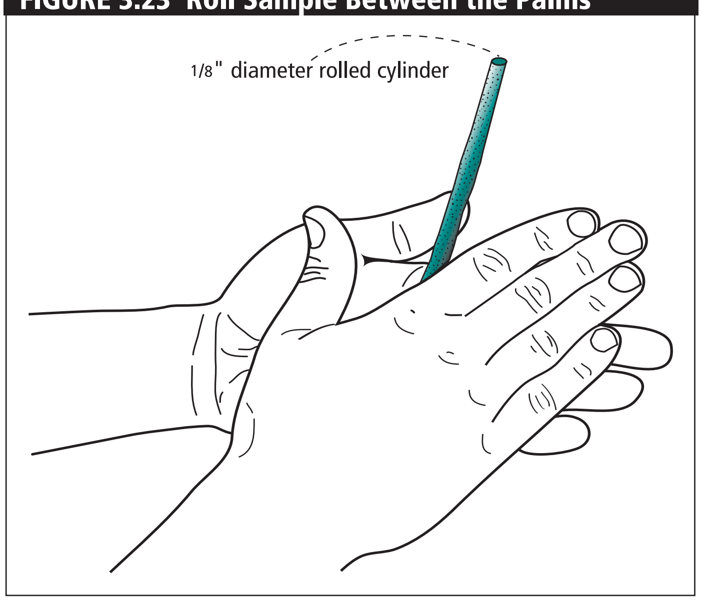
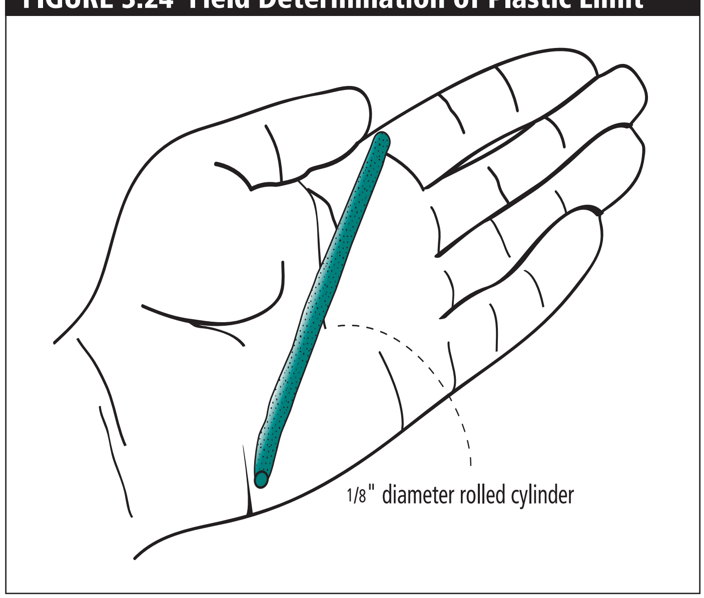


FIGURE 3.24 Field Determination of Plastic Limit



4. If the sample does not reach a diameter of 1/8 inch, the soil moisture content is lower (i.e. soil is drier) than the plastic limit and construction can proceed.
5. If the sample is rolled into a diameter equal to 1/8 inch or less before breaking, the soil is at or above the soil moisture content required to meet or exceed the plastic limit (i.e. soil is too wet) and construction should not occur.

Porosity

Porosity is a measure of the volume of pores in a soil sample (nonsolid volume) divided by the bulk volume of the sample (Soil Science Society of America, 2017). Also referred to as the amount of void space between soil particles, soil porosity can range from 35 to 50 percent of a soil volume. In disturbed or compacted soils, porosity can be much less. Texture, structure, and organic matter are all important in determining soil porosity. The higher the porosity, the more potential for efficient movement of liquids or septic tank effluent through the soil.

Bulk Density

Bulk density is an indicator of the total porosity of the soil. It is calculated as the mass (grams) per given volume of soil (cubic centimeters), which includes pore spaces. An average bulk density is 1.3 grams per cubic centimeter. As bulk density increases, liquid movement through the soil will decrease, requiring more land area to treat and hydraulically accept septic tank effluent.

Lower horizons in the natural soil profile tend to have higher bulk densities than upper layers because subsoils are generally more compacted due to the overlying weight of the upper soil. They usually contain less organic matter, and thus a less open granular structure. Often subsoils accumulate clays and iron oxides that have washed down from the upper horizons. These clay particles may become trapped in larger pores, reducing the overall pore space.

Percolation Rate

Percolation rate or perc rate, is the length of time it takes for water flow downward in or into the soil. It is measured in minutes per inch (mpi). A higher percolation rate indicates that the soil or horizon tested accepts liquids at a slower rate due to a number of soil factors. This finding suggests a larger area for treatment and acceptance of septic tank effluent will be required. Percolation testing should be completed at multiple locations in the proposed soil treatment area. Detailed instructions for completing a Percolation Test are included in Chapter 4.

Soil Formation

Soil formation describes the variables, usually interrelated natural forces, that are active in and responsible for the formation of soil. These factors are usually grouped into five major categories as follows: parent material, climate, organisms, topography, and time (Soil Science Society of America, 2017).

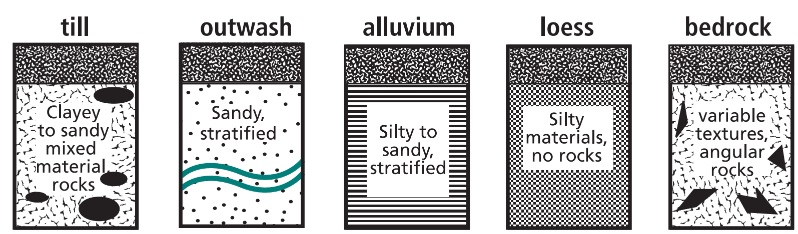
The process of soil formation is physical, chemical, and biological. During soil formation, some constituents of the parent material are lost (subtractions), others get concentrated (additions), some are altered (transformed), and others moved (translocated).

The results of soil formation are the accumulation of organic matter (topsoil development), formation of soil structure (aggregation of sand, silt, and clay into peds), horizonation, redoximorphic features formation, and the development of characteristic soil colors.

Parent Materials

Parent material is the geologic material from which a soil is formed. Knowing the type of parent material and understanding its characteristics are critical to determining whether the soil is suitable for an SSTS. In many places in Minnesota, sufficient time and resources are needed to distinguish among the kinds of parent material(s). The common types of parent materials in Minnesota are glacial till, glacial outwash, alluvium, loess, organic materials, lacustrine deposits, and weathering bedrock. They are briefly described below and are shown in Figure 3.25.

FIGURE 3.25 Minnesota's Parent Materials



Lacustrine

Lacustrine sediments are composed of material ranging from fine clay to sand derived from glaciers and are deposited in glacial lakes by water originating mainly from the melting of glacial ice. Many are bedded or laminated with varves (Soil Science Society of America, 2017). The Red River Valley of the North in northwestern Minnesota is an example of a landscape with soils derived from this process. These soils are characterized by clay soils and limitations due to saturation close to the land surface. Lacustrine landscapes are usually quite flat and absent of surface rocks. These soils are generally very limiting for SSTS due to their fine textures, flat landscapes, and wetness.

Alluvium

Alluvial sediments are deposited by the running water of streams and rivers. Deposits may occur on terraces well above present streams, on the present flood plains or deltas, or as a fan at the base of a slope. Typically these deposits are stratified, with textures including gravel, sand, silt, clay, and all variations of mixtures of these. These sediments can be extremely difficult to interpret due to the constant additions of soil materials and burial of older sediments. The suitability of alluvial soils for SSTS commonly relies on the evaluation of the slope shape, hillslope position, and elevation of the proposed site in relation to established floodplain elevations.

Colluvium

Colluvium is the unconsolidated, unsorted earth material transported or deposited on sideslopes and/or at the base of slopes by mass movement (i.e., direct gravitational action) and by local, unconcentrated runoff (Soil Science Society of America, 2017). Soil properties may at first appear to be glacial till, but a thorough investigation of the site should confine these parent materials to the bases (foot and toe slopes) of steeper hills.

Glacial Outwash

Glacial outwash is stratified sand and gravel removed or washed out of a glacier by melt-water streams and deposited in front of or beyond the end moraine or the margin of a glacier (Soil Science Society of America, 2008). These locations are typically sources of aggregate for many purposes. Because of its coarse textures, outwash presents problems for treatment of septic tank effluent. The following rule language applies to such soils when used for an ISTS.

MN Rules Chapter 7080.2150, subp. 3 C 1(b)

Any soil layers that are any of the United States Department of Agriculture (USDA) soil textures classified as sand with 35 to 50 percent rock fragments or loamy sand with 35 to 50 percent rock fragments must be credited at only one-half their thickness as part of the necessary treatment zone. Soil layers, regardless of soil texture, with greater than 50 percent rock fragments must not be credited as part of the necessary treatment zone. Layers that are given full, partial, or no credit must, in any layering arrangement in the soil profile, be cumulatively added to determine the amount of soil treatment zone in accordance with other soil treatment zone provisions;

Refer to the first three rows of Table 3.4 to identify acceptable loading rates for SSTS in these soils.

Glacial Till

Glacial till is an extensive parent material in Minnesota. Glacial till is deposited directly by glacial ice with little or no transportation by water. It is generally an unstratified, unconsolidated, heterogeneous mixture of clay, silt, sand, gravel, and boulders. Most areas composed of these materials were overridden by glaciers and today are characterized by dense and low-permeability subsoils. Till varies widely in texture and chemical composition. In Minnesota there are multiple glacial advances affecting our soils. Glaciers originated from three distinctly different directions, bringing very different glacial till materials. Reddish brown till originates out of the Lake Superior Basin. Grayish brown parent materials were transported by glacial ice traversing straight south over the Rainy River. Advances southeast from Manitoba brought yellowish brown sediments rich with calcium carbonates (crushed limestone) and numerous small fragments of sedimentary rocks.

Loess

Loess is the name given to materials transported and deposited by wind and consisting of predominantly silt-sized particles (Soil Science Society of America, 2017). Soil materials are commonly stratified and can have subtle changes in texture that may cause soil water saturation. These silt soils are very susceptible to soil erosion and should be protected from sloping and bare soil conditions. These areas are common in southeastern and southwestern corners of Minnesota.

Organic Soils

Organic soils are soils in which the original plant parts may or may not be recognizable. Organic soils form in wet landscapes where organic matter (plant materials that are no longer living) accumulates more rapidly than it decomposes. These accumulations are called by various terms depending on the level of decomposition of the organic matter, including peat, muck, Histosol, sapric, fibric, hemic, or histic. Organic matter that is sufficiently thick can become a parent material for soils. Since these soils are associated with prolonged saturated soil conditions at or very near the soil surface, SSTS cannot be built in these areas. **MN Rules Chapter 7080.1720 Subp. 5 E 3(b)** mentions organic soils or mineral soils with an organic modifier (see above terms) identification during the site evaluation/field evaluation phase. When these soils are encountered, there is zero inches of suitable original soil. These are extremely limited soils and sites and should only be considered as a last resort for existing dwellings where there is absolutely no other land area available.

Bedrock

Bedrock is a general term for the solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface (Soil Science Society of America, 2017).

7080.1100 Subp. 8. Bedrock means geologic layers, of which greater than 50 percent by volume consist of weathered in-place consolidated rock or rock fragments. Bedrock also means weathered in-place rock which cannot be hand augered or penetrated with a knife blade in a soil pit.

Types

Sedimentary rock is formed from materials deposited from suspension or precipitated from solution that are usually more or less consolidated. The principal sedimentary rocks are sandstone, shale, limestone, greywacke, and conglomerate (Soil Science Society of America, 2008). Many sedimentary rock types are located in southeastern, southcentral, and southwestern Minnesota.

Metamorphic rock is derived from preexisting rocks that have been altered physically, chemically, and/or mineralogically as a result of natural geological processes, principally heat and pressure, originating within the earth. The preexisting rocks may have been igneous, sedimentary, or another form of metamorphic rock (Soil Science Society of America, 2008). Common metamorphic rocks include slate, schist, and gneiss. These metamorphic rocks are found in northern and central Minnesota.

Igneous rock formed from the cooling and solidification of magma, and that has not been changed appreciably by weathering since its formation (Soil Science Society of America, 2008). Basalts and granites are common igneous rocks found in northeastern, northcentral, northwestern, and central Minnesota.

Issues

Bedrock presents numerous issues for the proper treatment and hydraulic acceptance of septic tank effluent due to its level of consolidation, presence near the soil surface, cracks and fissures, etc. Below are some common SSTS treatment and acceptance issues with bedrock in Minnesota.

Karst

The cause of karst land surface features is the dissolution of limestone, gypsum, or other rock as precipitation, runoff, and groundwater come into contact with limestone rock. The dissolution dissolves the carbonates in water and leaves voids in the bedrock.

These conditions are typically expressed on landscapes by sinkholes, caves, and underground drainage (Soil Science Society of America, 2017). Karstic conditions and landscapes are found in southeastern Minnesota, where limestone bedrock is common.

The common issue in karstic regions is proper treatment of septic tank effluent. The many voids in these areas that can permit water to move quickly to surface and/or groundwater, so a careful investigation of bedrock type, bedrock depth, and sinkhole proximity is imperative. It is also advantageous to use pressure distribution in karst areas to minimize the impact of the septic tank effluent on bedrock dissolution in the localized area. Mound ISTS are commonly recommended or required by local governments.

Preferential flow

The process where water and its constituents move by a preferred pathway through a porous medium is known as preferential flow (Soil Science Society of America, 2017). Preferential flow conditions can also occur in soils, but in this section preferential flow is referred to in the context of bedrock conditions.

Any site in Minnesota with bedrock near the soil surface may be susceptible to preferential movement of water through cracks, fissures, voids, etc. The nature of the local bedrock material(s) must be understood.

The proper treatment of septic tank effluent is an issue with preferential movement. Rapid vertical or horizontal movement of water through any rock type will result in minimal treatment of septic tank effluent. Proper characterization of the bedrock topography (i.e, depth across proposed soil treatment area), maintaining adequate vertical separation, and developing an understanding of the local bedrock material(s) and conditions will reduce impacts to human health and the environment.

Soft bedrock

Soft bedrock is a term used to describe various types of sedimentary rocks. The term is derived from the ability to penetrate or excavate these bedrock types with standard hand or powered equipment. Most of our sedimentary bedrock is found in southern Minnesota.

A few common issues arise with soft bedrock. First, it is difficult to distinguish between soil and bedrock in many areas. For these areas, soil pits are recommended. Second, the proper treatment of septic tank effluent is an issue where soft bedrock is found. While much of these soft bedrock areas may act similarly to soil, they have a lower ability to treat effluent due to their lack of biological activity (when compared to soil). Soft bedrock may still possess preferential flow, stratification (layering of materials), and restrictive conditions that may further limit its ability to treat effluent effectively.

Restrictive

Restrictive conditions are a general term used to describe a bedrock type or condition that prevents the vertical movement of water. They are further indicated by the need for special equipment to excavate or extract samples.

These restrictive bedrock types or conditions can occur anywhere in Minnesota when bedrock is found near the soil surface. Common occurrences of these restrictive bedrock types occur in northern and central Minnesota.

With restrictive bedrock, two issues that arise are the proper treatment of effluent and hydraulic acceptance. When restrictive bedrock occurs in an area, adequate treatment of the effluent must take place above this layer. An accurate assessment of the bedrock topography across the proposed soil treatment area should be completed. Hydraulic acceptance is another issue in restrictive bedrock situations. An area with adequate unsaturated soil conditions must be located to allow the treated effluent to permeate the soil, without causing a surface discharge.

Climate

Climate greatly affects the rate of soil formation. The two components of climate to be considered here are precipitation and temperature.

Precipitation

Water is necessary for mineral weathering and for plant growth. Surplus water participates in the downward translocation of very small mineral particles (e.g., clays and organic matter) and soluble salts (e.g., calcium carbonates). In Minnesota, precipitation increases from northwest to southeast, and in these regions subtle differences in the depths of certain minerals can be observed. Precipitation has the greatest influence on the native vegetation. Tallgrass prairies predominated the northwestern and drier portions of western Minnesota, while deciduous forests characterized the landscapes of southeastern Minnesota due in large part to precipitation differences. Variations in soils due to precipitation differences are not obvious within an area the size of a few counties, so precipitation is not usually cited as a reason for soils to vary over short distances (<100 miles).

Temperature

Temperature differences exist from north to south across Minnesota. Warmer soils have more biological activity and potential for chemical reactions. Every 10°C (approximately 18° F) increase in temperature increases the rate of biochemical reactions approximately two times. Increased weathering and clay formation occur with an increase in soil temperature. Differences in temperatures from the Canadian to the Iowan border do not significantly change our soils. Perhaps the most notable effect of temperature variation in Minnesota is the lower decomposition rates of organic matter in northern Minnesota. When this decreased decomposition is combined with wet landscapes, the result is expansive areas of peatlands.

Time of Soil Formation

The length of time over which a soil forms is another soil forming factor. Generally, a soil allowed to form for longer periods of time will have more translocated and weathered minerals. Due to our deposits of glacially-derived soil materials (12,000-18,000 years before present) in Minnesota, we have little variation in time of soil formation. There are very few older soils found in protected areas of southern Minnesota, and there are much more recent soil deposits across Minnesota due to flooding and cut and fill activities. These young soils have not had time to change to reflect their current conditions and should be interpreted with caution.

Vegetation and Organisms

Plants

Plants affect soil formation by producing organic matter, nutrient cycling, and the movement of water. The most obvious effect of organisms on soil development is that caused by the natural vegetation. Rooting of plants helps form much soil structure in our soils. Forested soils contain less organic matter than prairie soils. This difference in the amount and distribution of organic matter is related to the annual growth and fall die off of most prairie plants versus the accumulation of organic matter in the trunk and branches of trees. Accurately interpreting of the soil requires an understanding of the native vegetation that has occurred on the site.

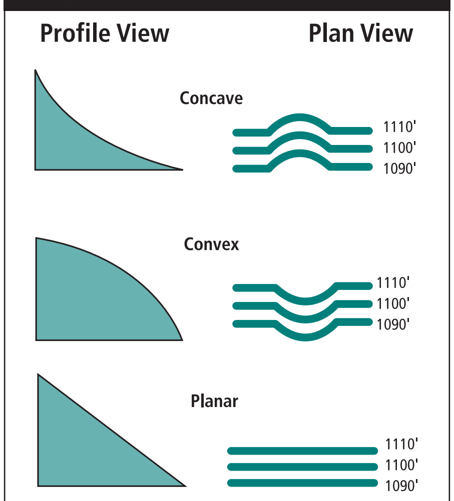
Microorganisms and Soil-Dwelling Animals

Microorganisms play an important role in organic matter mineralization and nutrient cycling. Soil animals are consumers and decomposers of organic matter; however, the most obvious role of animals appears to be that of earthmovers.

Topography

The word topography is commonly used to refer to the shape or elevations of the landscape. Differences in topography can cause wide variations in soils within the confines of a single field or single hillslope. Topography plays a role in the distribution of precipitation (runoff, run on , and infiltration) and determines the extent to which the water table influences soil development. Topography includes:

FIGURE 3.26 Slope Shapes or Curvatures



- Slope shapes or curvatures, which can be convex, concave, or planar (see Figure 3.26)
- Catchment area, also referred to as a watershed. Either term refers to all the surrounding lands that contribute water (surface or subsurface) to the site
- Relief, the difference in elevation of land surface
- Landscapes, which are a collection of related landforms; usually the land surface which the eye can comprehend in a single view
- Landforms, which are specific features in a natural landscape such as a floodplain, stream terrace, ridge-top, or valley
- Slope, the elevation difference over a unit length. Slope affects the velocity at which water moves over or through the soil

Landscape diagrams and common onsite problems encountered with certain landscapes are given in Chapter 4: Site Evaluation

Minnesota Soils

Minnesota is comprised of complex combinations of predominantly glacially-affected landscapes. A careful understanding of these landscapes and component landforms is crucial to developing a complete understanding of a soil and site for SSTS evaluation. Soil textures and soil colors vary in large part to parent material differences and water movement in the soil. Soil colors also can change due to seasonal saturation, and these color changes will remain evident even after the soil has been allowed to drain.

A complete soil boring log involves the observation, description, and interpretation of:

- Impacts of effluent on groundwater
- Soil treatment processes
- Soil texture
- Soil structure
- Consistence
- Soil colors
- Soil formation
- Water movement dynamics

Failure to consider and understand the importance of each component can result in an incomplete understanding of the soils and may cause the SSTS to function at a suboptimal level.

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SECTION 4: Site Evaluation

SITE EVALUATION

Overview of Site Evaluation Process

Purpose

A good site evaluation is the first phase of the design process and provides sufficient information to select a suitable, cost-effective treatment system. To this end, a site evaluation should be a systematic process that provides information with enough detail to be useful for the design phase.

This evaluation must collect relevant data to allow a designer to determine whether or not a lot contains a sufficiently large area with suitable soil to serve the proposed uses of the lot. The landowner/client should be aware that a soil and site evaluation does not guarantee that the lot is suitable for a subsurface sewage treatment system (SSTS). Many sites present severe limitations to the proper design of a SSTS in Minnesota. A designer should present findings objectively and honestly to the client(s).

The designer is responsible for all data reported. Portions of the site evaluation may be completed by someone other than the designer, such as helpers who dig holes and carry water to percolation holes; however, the designer must select the sites for percolation tests and soil bore holes, make measurements, evaluate and describe soil profiles, and personally certify the reported data.

Evaluators must provide reports to the proper permitting authorities and to the client(s) for each site evaluation—both for sites that are suitable and those sites that are found to be unsuitable for a SSTS.

Overview of requirements

The site evaluation considers placement of the SSTS in relation to setbacks, topography, and other factors; determines the proposed elevations of the system, with accurate and complete soil descriptions and noting periodically saturated soil, bedrock, and other limiting conditions; and determines the sizing of the SSTS by accurate soil texture, structure, and consistence description. Sizing can also be accomplished by percolation tests or testing using other approved methods.

The site evaluation consists of three parts: a preliminary evaluation, a field evaluation, and site evaluation reporting. This Section discusses each of these three parts. Forms have been created to report your findings and are found at septic.umn.edu/ssts-professionals/forms-worksheets.

Preliminary Evaluation

TABLE 4.1 Where to Find Information

Information Needed	Where to Find It
legal location house specifications (location, number of bedrooms, size water-using devices)	client, planning and zoning offices, real estate transactions
easements, utilities legal requirements of design/installation setbacks: wells, property, and roads	planning and zoning offices, MN Pollution Control Agency (PCA), MN Dept. Nat. Resources (DNR), MN Dept. Health(MDH)/MN Geol. Survey (MGS)
topography: slope, surface drainage topographic maps, soil survey information	Soil and Water Cons. Districts (SWCD), MGS, DNR, watershed districts
soils information: percolation rate, water table, bedrock, flooding, colors, textures, structures, etc.	SWCD, USDA-Natural Resources Conservation Service (NRCS)
flooding information	SWCD, DNR, local watershed districts, planning and zoning offices
well location and depth	client's well driller, MGS, MDH, planning and zoning offices, watershed districts

Gathering Information

While there is certainly no substitute for a field site evaluation, a preliminary evaluation provides useful knowledge about the site and allows the designer to work more efficiently in the field.

7080.1100 Subp. 76. Site means the area required for the proper location of the ISTS.

Conducting and reporting a complete site evaluation requires collecting and summarizing many different types of information. Designers must collect the required information from various sources, which are seldom compiled at a central location, so adequate time must be allotted to gather and summarize this information for this phase of the evaluation. Table 4.1 provides common locations where critical information can be found. The determination, location, or existence of the following characteristics is part of the requirements for the preliminary evaluation (see MN Rules Chapter 7080.1710 for all specific requirements)

Soil Survey Reports and Geologic Atlases

Soil Survey Vernacular

Although the county soil survey cannot be used to determine the suitability of a site for an ISTS, it is an excellent source of soil and site information for the preliminary evaluation of sites. The soil profile descriptions found in archived soil survey publications (www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateid=mn) are describedby trained soil scientists. Some of the information included in the soil survey may not be necessary for a preliminary site evaluation; however, the following information is provided as a minimum of items to understand from the soil survey. Section 3: Soils also provides detailed discussion of soil components, textures, classification, and structures.

The following terms are used in the field of soil science and can be found in the soil survey information as well as referenced in MN Rule Chapter 7080. A brief description of each term is included.

A horizon(s) (topsoil): These are mineral (sand, silt and clay) soil horizons that form at the ground surface. They are characterized by an accumulation of decomposing organic matter mixed with the mineral fraction. They are darker in color than horizons deeper in the soil profile.

7080.1100 Subp. 87. Topsoil means the natural, in-place organically enriched soil layer with a color value of less than 3.5.

E horizon(s): These are mineral horizons in which the main feature is loss of clay, iron, and/or aluminum, leaving a concentration of resistant sand and silt particles (Glossary of Soil Science Terms, 2017). These soil colors are commonly high value and low chroma, when colored using the Munsell Soil Color Charts. (See "Soil Colors" in Section 3: Soils for more discussion of the Munsell Soil Color Charts.) Common characteristics of E horizons are as follows:

- An E horizon is usually, but not necessarily, lighter in color than an underlying B horizon. In some soils the color is that of the uncoated sand and silt particles.
- An E horizon is most commonly differentiated from an overlying A horizon by lighter color and generally has measurably less organic matter than the A horizon.
- An E horizon is commonly near the surface below an A horizon and above a B horizon. The soil structure is commonly platy, but may be blocky or granular.

B horizons (subsoil): These horizons are formed below an A and/or E horizon and dominated by weathering of the original parent material; by concentration of organic matter, clay, iron, aluminum, carbonates or by the removal of carbonates; and has formed a platy, blocky, or prismatic structure.

7080.1100 Subp. 81. Subsoil means a soil layer that has a moist color value of 3.5 or greater and has undergone weathering and soil formation processes.

C horizons (parent material): These horizons are little affected by weathering. They have little to no structure development except for random planes of weakness. In Minnesota, the soil development ends at the start of the C horizon, which in most cases is less than five feet in depth due to freeze/thaw, wet/dry cycles and common rooting depths.

7080.1100 Subp. 57. Parent material means the unconsolidated and chemically weathered geologic mineral or organic matter from which soils are developed by soil forming processes.

Understanding the above scientific nomenclature used to designate various horizons in the soil survey will assist the designer in interpreting the soils on site for their ISTS suitability.

Soil Survey In Preliminary Site Evaluation

For the preliminary site investigation, consult the soil survey and locate the property to identify the soil map unit and determine the following soil features:

- landscape
- landform
- parent material(s)
- landscape position
- map unit inclusions
- slope
- depth to saturation
- depth to bedrock
- flooding potential
- matrix colors
- mottle colors
- texture
- structure,
- consistence
- saturated hydraulic conductivity
- redoximorphic features

Using the preliminary evaluation form to record soil survey information and other information gathered in the preliminary evaluation will assure these properties have been identified and recorded for later uses. This form can be found at septic.umn.edu/ssts-professionals/forms-worksheets.

Hard Copy Soil Surveys

Printed hard copy soil surveys are no longer supported for use by the US Department of Agriculture – Natural Resources Conservation Service (NRCS). Some counties where the map unit symbols have not changed the detailed maps at the back of these soil surveys can still be used to locate parcels and soil mapping units that may exist on the property of interest. Any soil properties or interpretations should be enerated at the Web Soil Survey websites. The tabular information and interpretations should be generated at the Web Soil Survey websites. The tabular information and interpretations from printed soil surveys are outdated and unsupported.

Online Soil Surveys

Soil surveys have entered a new era across Minnesota and the United States. The official soil survey information and documentation now resides online at https://websoilsurvey.sc.egov.usda.gov/app/homepage.htm (verified 8/29/17) or sdmdataaccess.nrcs.usda.gov (verified 8/29/17). While users may choose to print off information, the information on this site is subject to change, so the site should be checked frequently for updates.

Online soil surveys still present soil lines on a photographic background indicating the boundaries between different soil types. These maps show the occurrence and distribution of each kind of soil.

For counties that do not have published soil surveys, the county Soil and Water Conservation District or USDA NRCS office can often provide soils information. For a updated status of each county in Minnesota visit: www.nrcs.usda.gov/wps/portal/nrcs/main/mn/soils.

Locate the site on the survey (GPS coordinates, county, address, township, range, section, or use the zoom function) and, following these steps, determine what soil map units exist on the parcel:

1. Outline the desired parcel/area using the Define AOI (Area of Interest) tool, which is located in the legend along the top of the map window.
2. Once the AOI has been defined, select the tab for “Soil Map” near the top of the browser window.
3. You will now see a display of the aerial photograph with soil lines over the top. In the map’s legend, you will see a summary of map units, map unit names, acres in the AOI, and percent composition of the AOI. Map units are denoted by symbols such as 401C.
4. List the map unit symbols found at your location.
5. Select the third tab, entitled “Soil Data Explorer,” to map selected soil properties over the AOI.
6. Now select the “Suitabilities and Limitations for Use” tab.
7. Select the “Sanitary Facilities” tab.
8. Under this rating, there are numerous interpretations. The five interpretations we are interested in are:

   Septage Application - Incorporation or Injection (MN)

   Septage Application - Surface (MN)

   Septic Tank Absorption Fields - At-Grade (MN)

Septic Tank Absorption Fields - Mound (MN)

Septic Tank Absorption Fields - Trench (MN)

These interpretations were developed based on MN Rule Chapter 7080 and are accurate on a regional scale. They are not meant to be a substitute for field site evaluation work.

9. Select the "View Ratings" button to view map of ratings with tables of soil map units and their individual suitabilities.

10. Note: this does not replace recording specific soil properties, which are required by Minnesota Rule Chapter 7080.1700 (as discussed above). To determine these properties, select the "Soil Reports" tab and access the desired/required information from the selected reports. The Map Unit Description (MN) report under the AOI tab also provides some desired/required preliminary soil site information. Alternatively, you may search individual soil series' properties by accessing the Official Soil Series Descriptions (OSD) website (www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/survey/class/data/?cid=nrcs124p2_053587) and searching for soils by their specific soil series name as determined from the AOI legend on the web soil survey.

Detailed Soil Survey Maps

In order to make site evaluation interpretations accurately from soil survey information, it is necessary to have a basic understanding of how the detailed soil survey is created and what is represented on these soil maps.

Soils vary continually across a landscape. The soil survey represents how soils occur on this landscape by investigating the causes of soil variation within landscapes. This soil survey process then identifies areas with similar soils and landscape properties and delineates these areas as unique soil mapping units. While differences still exist within these map unit areas, the soil differences are understood. Soil characteristics, such as percent organic matter, depth of top soil, texture, and depth to water table or bedrock, differentiate soil map units and relate to different use and management across landscapes.

The soil scientist making a soil map uses limited and well-defined ranges in soil properties to classify soils and for development of soil map units. To accomplish this, the soil scientist studies and traverses landscapes, investigating and recording not only at soil borings, pits, and excavations, but also slope and vegetation characteristics.

These observations not only aid in predicting how soils vary across the landscape, but also in determining the suitability of a soil for a specific intended use. An experienced soil scientist maps between 300 and 600 acres of soil a day. Soil descriptions are conducted during the process to confirm and refine the predictions made about the occurrence of soils on the landscape.

During the survey process, data is collected on the physical and chemical properties of the soils as well as on the depth to saturated soil.

The finished product of a detailed soil survey is a series of soil maps prepared on a photographic base for an entire county. The size of the soil mapping unit that can be delineated on these maps is dependent on the final scale of the map. A soil map completed at a scale of 1:15,840 (one inch = 1,320 feet) will have the smallest delineation, covering about 2.5-5 acres on the land surface. This scale limitation is still present, even in the modern digital versions of the soil surveys. Soil surveys are not created to generate reliable information for a specific site.

Scale limitations impact the composition of soils within the mapping unit delineation. The inclusion of varying soils within a single delineation may at times be as much as 30% or more of the mapping unit. These soils may possess similar or different soil characteristics that influence their suitability for an ISTS. The inclusions presented are well-defined, quantified, and characterized.

Since soil treatment areas cover only 1,000 to 5,000 square feet of the parcel, a soil survey would not provide enough accuracy to determine the suitability of the soils and site. Unfortunately, a soil survey created to this detail is extremely rare and costly to produce. Only high intensity uses warrant such soil surveys. In absence of such a site-specific soil survey, the designer must investigate the site and soil characteristics and interpret their findings into a recommendation for an ISTS.

Online availability

In 2006, tabular soil survey information became available online for all counties in Minnesota, via the Soil Data Mart website. In 2008, 83 soil survey areas have digital soil maps available via the Web Soil Survey. See (www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid+nrcseprd434006&ext=pdf) for current list of digitized soil surveys. The web soil survey, official soil series descriptions, and soil data explorer should be used for all site evaluation work.

Saturated Hydraulic Conductivity

Permeability of the soil is now listed as the saturated hydraulic conductivity. For a complete discussion of saturated hydraulic conductivity, including conversions, see "Saturated Hydraulic Conductivity" in Section 3: Soils.

Linear Extensibility

Linear extensibility is the current term for what was called shrink-swell potential. The data are expressed as a percent change of an unconfined soil ped (length) as soil dries from a moist to dry state. Typically soils that possess a high linear extensibility potential have over 30% clay-sized soils and a specific type of clay that actually expands (swells) in size when moisture is present in the soil and contracts (shrinks) upon soil drying. These areas are identified and characterized by large cracks in the soil when dry. The largest area in Minnesota with this potential is in the Red River Valley of the North.

This information is available in the Soil Data Explorer > Soil Properties and Qualities > Soil Physical Properties > Linear Extensibility tab of the web soil survey (www.websoilsurvey.nrcs.usda.gov).

Water Features

The Soil Moisture, Ponding, Flooding (MN) report has improved upon data previously presented in the hard copy soil surveys. The USDA-NRCS along with various other organizations, has begun collecting and summarizing field-based water monitoring data to provide more accurate monthly high and low water status readings throughout the entire calendar year.

The Soil Moisture, Ponding, Flooding (MN) report should be utilized to address the potential for:

- Flooding hazards
- Ponding hazards
- Depths to water table and periodically saturated soil

Access this report using the web soil survey - Soil Data Explorer > Soil Properties and Qualities > Water Features > Depth to Water Table, Ponding, Flooding

Soil Treatment Areas - Trench, At-Grade, Mound

The septic tank absorption fields ratings found in the web soil survey can be a useful predictor of site limitations that may occur during a site evaluation. There are three ratings developed specific to Minnesota Rule Chapter 7080 for trench, at-grade, and mound ISTS. These ratings vary from "Not limited" to "Extremely limited." A "Not limited" rating means few limitations have been detected in the soil survey information, while a rating of "Extremely limited" indicates severe limitation(s) for that type of ISTS. The tables produced below the web soil survey map will list the soil characteristic(s) that limit suitability. Three maps for each parcel can be created for each type of ISTS.

These interpretations only exist in Minnesota and were produced through a collaboration of the USDA-NRCS, MPCA, and University of Minnesota. These ratings should be used as a guide when conducting a preliminary site evaluation.

These data can be accessed via the webs soil survey by selecting Soil Data Explorer > Sanitary Facilities > Septic Tank Absorption Fields.

TABLE 4.2 Slope Groups and Related Slope Percent

Slope Group	Typical Percent Slope
A	0-2
B	2-6
C	6-12
D	12-18
E	18-25
F	25+

Drainage Classification

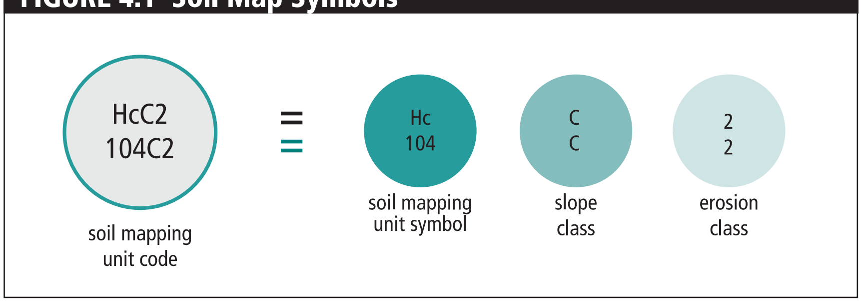
Soil drainage classification describes the natural frequency and duration of wet periods. It is an interpretation available in the soil survey that has limited application to ISTS suitability.

Within the web soil survey, select Soil Data Explorer > Suitabilities and Limitation for Use > Sanitary Facilities > Septic Tank Absorption Fields - Trench (MN), At-Grade (MN) and Mound (MN)

Slope Phases

Slope phases represent the common land slopes found within these areas on the soil survey. They are labeled after the map unit symbol.

FIGURE 4.1 Soil Map Symbols



Reading the Soil Survey

For example: The soil map unit symbol HcC2 (104C2) appears on many soils maps in Minnesota. (See Figure 4.1.) As indicated in the soil map legend, Hc or 104 refers to the soil series Hayden clay loam. The soil map unit will also include areas of other soils that were too small in area to map out. As mentioned previously, every square foot of the mapping unit area is not necessarily a Hayden clay loam.

The second part of the soil map unit symbol indicates the different slope phases used in Minnesota. They are indicated by capital letters and defined in percent of slope (Table 4.2).

TABLE 4.3 Erosion Classes

Erosion Class	Definition
1	slight or no erosion
2	moderate erosion
3	severe erosion

The third portion of the map symbol is the erosion class. This part of the soil mapping unit has been dropped in the newer soil surveys because of inaccuracies in predicting erosion. Table 4.3 explains the erosion classes 1-3.

So the map symbol ***HcC*** or ***104C*** indicates a Hayden clay loam with six to 12 percent slopes.

Map unit inclusions

The delineated areas on the aerial photographs are called soil map units, which consist primarily of the soil for which the unit is named and soils with similar characteristics. In addition, there are areas within the unit consisting of soils with different characteristics. While the soil survey alone cannot be used to determine the suitability of a specific site, it does provide useful background information and may indicate potential problems that may be encountered on the parcel.

Besides providing information on the spatial extent and kind of soil, the soil map shows other physical features. Since the map has an aerial photo background, it is possible to determine different land features and uses directly from the map, such as woodland, farmland, roads, cities, buildings, lakes, streams, and airports. Drainageways are shown with special map symbols, as are small wet spots, marshy areas, and sandy, clayey, gravely, or stony spots. The standard symbols for these features are presented in the legend of the soil survey.

To demonstrate how survey data and accompanying soil maps can be used to help determine suitability and system design, consider another typical mapping unit found in many central and southern Minnesota counties. The mapping unit could be represented on the soils map by 104B or HdB.

In either case, by looking at the soil map unit legend, the name of the mapping unit is Hayden fine sandy loam, two to six percent slopes. Series and the Map Unit Description (MN) indicate that the Hayden fine sandy loam has no zones of soil saturation to a six-foot depth and that the fine sandy loam texture at the surface changes to a sandy clay loam in the subsoil.

There is a distinct possibility that minor soil components, also called inclusions within this mapping unit may be present in the 3,000 square foot area selected. On the Web Soil Survey the Soil Reports has a check box feature to include the minor soils as part of the soil report. The survey lists three minor components. These are Nessel, Dundas, and Braham soils.

From the Map Unit Description (MN) report, it is apparent that Nessel soils have a periodically saturated zone occurring within two to five feet, with a saturated hydraulic conductivity in the subsoil about the same as that of the Hayden soils. For the Dundas soils, which occur in small, narrow drainageways, periodic zones of saturation occur within one to three feet of the surface, with a saturated conductivity in the subsoil slower than the Hayden soil. The Braham soil is a well-drained soil like Hayden, with a faster hydraulic conductivity in the surface layer and similar conductivities in the subsoils.

If Dundas or Nessel soils occur within the proposed treatment system site, there will be a problem due to the need for unsaturated soil beneath the trenches. At certain times, maintaining vertical separation to saturated soil conditions will not be possible if the trenches are installed at a depth of two to three feet in the original soil.

Any site with the Dundas or Nessel soils on the property should be avoided when the field site evaluation is conducted. On the other hand, if the Braham soil is present (even though it is different from the Hayden soil, with a coarser-texture and deeper surface layer), the installation of a shallow standard trench system can be used to take advantage of the more permeable surface layer.

Soil Series Limitations

There are numerous soil series represented on most parcels and several hundred per soil survey area. Some differences among the soil series can be quite minor, and other differences can be very significant. Soil limitations to an ISTS can vary widely.

Sand and Rock Fragment Treatment Concerns

Sands with greater than or equal to 35% rock fragments have less surface area for treatment and water holding capacity. These soils will allow septic tank effluent to permeate through these layers too rapidly and must be addressed, either by not including these layers as part of the required three feet of vertical separation if the soil contains greater than 50% rock fragments by weight, or by using a 50% thickness credit for any sand texture with 35% - 50% rock fragments (see Table IX in Section 3). Further discussion can be found in "Problem Soil Areas" later in this Section.

Sand soil textures of concern include coarse, medium, and fine sand; and loamy sand, loamy fine sand and loamy very fine sand. (7080.2150 Subp. 3 (C)).

High clay content soils: acceptance and smearing concerns

Soil textures classified as sandy clay loam or finer textures have a large amount of surface area. A high surface area will result in many potential sites for treatment of septic tank effluent and a high water holding capacity. These soils will not permit large volumes of effluent to permeate through these soils. The sizing of these systems is largely based on achieving hydraulic acceptance of effluent. There are some soils that will have too much clay to allow any significant amount of effluent to permeate through the soil and will require additional design consideration.

Plastic limit

The higher the clay content, the higher the likelihood that the soil will hold water. Soils that are saturated or nearly saturated have lower soil strength and compact, smear, and move more than the same soil under dry conditions. In order to assess the potential of a soil to smear, the plastic limit must be tested.

7080.1100 Subp. 60. Plastic limit means a soil moisture content above which manipulation will cause compaction or smearing. The plastic limit can be measured by American Society for Testing and Materials, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils, ASTM D4318 (2005).

A five-step process for determining whether a soil is suitable for construction, or above the plastic limit, is discussed in Section 3, pages 28-29.

Above ground system required

ISTS may require distribution above natural grade may be due to periodically saturated soils, bedrock, slow permeabilities, or high permeabilities.

Slopes

7080.1100 Subp. 77. Slope means the vertical rise or fall divided by the horizontal distance, expressed as a percentage.

Vegetative and topographic information is available on U.S. Geological Survey (USGS) 7.5 minute quadrangle maps, also referred to as topographic maps. These maps indicate areas of excessively steep slopes, depressions, and surface drainage characteristics. The slope information can also be assessed by investigating the soil survey report online (www.websoilsurvey.nrcs.usda.gov).

Siting an ISTS on a slope will require special construction considerations. A proper design should ensure that equipment can access and operate as expected at the proposed soil treatment area.

Water table depths

A periodically saturated soil or water table depth is a restrictive condition that limits treatment of effluent by the soil. Ordinary high water levels of surface water bodies must also be investigated to allow for proper ISTS functioning. The soil survey provides a preliminary estimate of this limiting depth, but site conditions may vary. Accurate interpretation of this soil characteristic is discussed in Section 3: Soils, Soil Colors - Redoximorphic Features.

Permeability

Soils with high permeabilities (sands) allow too much effluent to pass without proper treatment, while low permeability soils (clay loams and clays) do not hydraulically accept large volumes of effluent. See saturated hydraulic conductivity section for more information.

Property Limitations

Determining Homeowner Preferences

Before beginning the field-based evaluation or physical investigation of the lot, determine the needs and wants of the property owner. Also, it is important at this stage to evaluate the amenities of the dwelling (bedrooms, water using devices, etc.). This will help estimate flow amounts. The major items for a designer to consider in developing a lot are the following:

- Location of the house/ building improvements including the following MN code requirements:

  7080.1710 A. design flow, anticipated effluent concentrations of biochemical oxygen demand, total suspended solids, and oil and grease, and anticipated presence of nondomestic waste from the dwelling, dwellings, or other establishments;

  7080.1710 B (4). existing and proposed buildings or improvements on the lot.

- Lot line locations must be confirmed in the field using appropriate documentation including land surveying, legal descriptions, etc. including the following state and local code requirements:

  7080.1720 Subp. 2. Lot lines shall be established to the satisfaction of the property owner or the property owner's agent. Lot improvements, required setbacks, and easements must be identified.

- Proposed location of the onsite sewage treatment system and:

  7080.1710 G. all required setbacks from the system.

  To the owner of an undeveloped lot, however, major concerns usually include the location, aspect, view, and type of house proposed. In addition, such projected improvements as a driveway, garage, patio, or swimming pool may conflict with the area best suited for onsite sewage treatment. Therefore, it is important to discuss the site evaluation for the ISTS at an early stage in developing plans for the lot. It is a rare instance when all the desired improvements can be located exactly where the lot owner desires. Priorities must be established (a properly designed, sited, and installed ISTS is a high priority) and trade-offs are inevitable.

- Location of the proposed or existing water supply wells (see 7080.1710 B(1-3, 5) and 7080.1710 K. for detailed information).
- All lot setbacks and easements including the following MN code requirements:

  7080.1710 C. easements on the lot

  7080.1710 D. the ordinary high water level of public waters, if adjacent to the lot

  7080.1710 E. floodplain designation and flooding elevation from the published data or data that is acceptable to and approved by the local unit of government or the Department of Natural Resources, if applicable

This information is found in the preliminary evaluation form and will be required to properly design an ISTS, especially in the preliminary evaluation process. (A copy can be found at septic.umn.edu/ssts-professionals/forms-worksheets).

Setbacks

There are numerous reasons that a setback can exist on a site. It is the job of the designer to determine what setbacks exist, determine the extent of their impact on the parcel, and identify suitable areas for an ISTS given these limitations. It is important to note that setbacks can differ between the sewage tank and the soil treatment area.

7080.1100 Subp. 72. Setback means a separation distance measured horizontally.

Properly siting an ISTS requires an understanding of the many setback requirements. These requirements are summarized in Tables 4.4 and 4.5 below and are illustrated in Figures 4.2 and 4.3. For more information on setbacks and requirements review Section 2 of this manual, MN Rules Chapter 7080.2150 Table VII, and MN Rules Chapters 4725 (Wells), 4715 (Plumbing), 6105 (Rivers), and 6120 (Shoreland). Many of these setbacks are determined by these chapters of rule. The Preliminary Evaluation Form, available at septic.umn.edu/ssts-professionals/forms-worksheets, lists all of the setbacks that must be assessed.

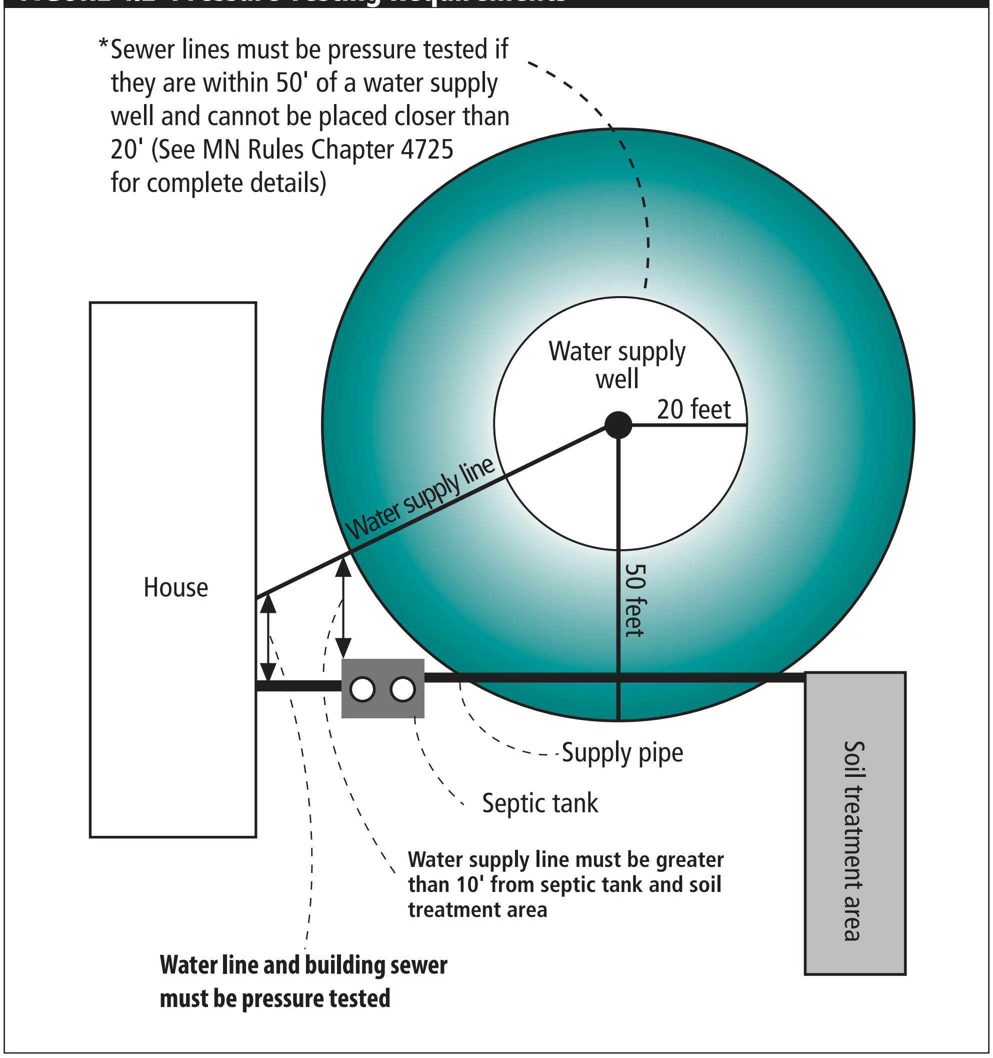
TABLE 4.4 Setbacks from a Soil Treatment System

Item	Minimum Setback
Any water supply well with less than 50 feet of casing and not encountering 10 feet of impervious material (See MN Rules Chapters 4725.4450 and 7080.1710 B. for a complete description of setbacks from all types of water supplies.)	100 feet
Any other water supply well (MN Rule Chapter 4725)	50 feet
Structure (7080.2150 Table VII)	20 feet
Streams, lakes, or other bodies of water (Shoreland Management Act (MN Rule Chapters 6105 and 6120)	50, 75, 100, 150 feet (depending on classification)
Property line or any buried pipe distributing water under pressure (7080.2150 Table VII and MN Rule Chapter 4715)	10 feet

TABLE 4.5 Setbacks from a Septic Tank

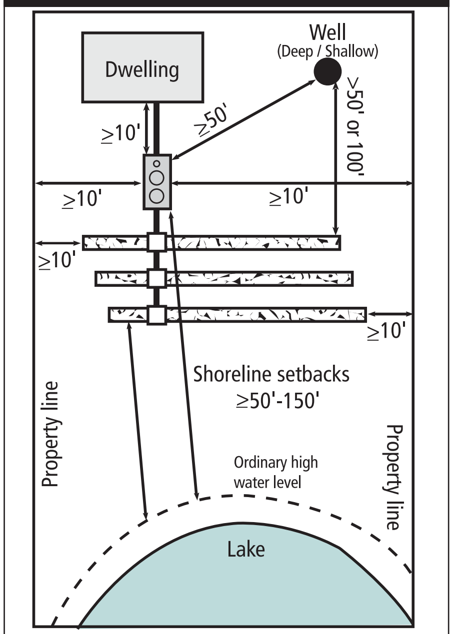
Item	Minimum Setback
Property lines (7080.2150 Table VII)	10 feet
Buried pipe distributing water under pressure (MN Rule Chapter 4715)	10 feet
Structure (7080.2150 Table VII)	10 feet
Any water supply well (MN Rule Chapter 4725)	50 feet
Streams, lakes, or other bodies of water (Shoreland Management Act (MN Rule Chapters 6105 and 6120)	50, 75, 100, 150 feet (depending on classification)

FIGURE 4.2 Pressure Testing Requirements



Unknown buried items (fuel oil tanks, old drainfields)

FIGURE 4.3 Other Critical Setbacks



These areas, where identified, may present issues for the proper functioning of various components of an ISTS, so it is best to avoid these areas when possible.

Property lines

Property lines must be established before the field-based site evaluation is completed to the satisfaction of the property owner and/or local unit of government. If the property owner or their legal representative disputes lot line locations, a licensed land surveyor should be hired to verify property lines.

Lot line verification (survey)

Lot lines can require verification in many areas. If there are not clear boundaries or identifiable survey-grade markers, then a licensed land surveyor may be required to establish the legal lot lines. Surveying lot lines assures that the home, ISTS, and etc. will all be sited in the proper locations without infringing on adjacent parcels or setbacks.

Easements

An easement is the right to use another person's land for a specific, stated purpose. Knowing where the easements are located and the type of easements that exist will prevent improper siting of a SSTS.

Road right-of-ways

A road right-of-way is a type of easement that gives road workers the right to travel across property owned by another person.

Utility easement

The utility easement will allow access by the utility company to use another person's land for the said utility.

Dwellings

Location or locations of existing and/or proposed dwellings and other buildings can severely limit the potential for an ISTS on many parcels. Careful consideration of the location of all structures is required to adequately evaluate a site.

7080.1100 Subp. 25. Dwelling means any building with provision for living, sanitary, and sleeping facilities.

Lakes, rivers, streams

According to the Shoreland Management Act (MN Rule Chapter 6120), all land within 1000 feet of lakes greater than 25 acres (10 acres in municipalities) or all land within 300 feet of rivers and designated floodplain with a drainage area of two square miles or greater must follow shoreland management standards. Included within these standards are differing distances of setbacks from lakes, depending on the lake class. Similar setbacks exist for differing river classes. The local permitting authority can make these setbacks more restrictive. It is important to verify setbacks with the local zoning office before the design phase.

Designers must also be aware of MN Rule Chapter 6105, which includes setbacks and use limitations for areas designated as Wild, Scenic and Recreational Rivers. Rules can vary for different water bodies. Currently, portions of the St. Croix River, Kettle River, Mississippi River, North Fork of the Crow River, Minnesota River, Rum River and Cannon River all fall into these classifications and may have different setback distances or restrictions. Inquire about any of these specific limitations at the local governmental unit that issues SSTS permits.

Wells

Drinking water supply and other water wells (public or private) require proper protection from contamination as a result of many human activities. To ensure that an ISTS is not negatively impacting a well, minimum setbacks have been established. The type and depth of well will have an impact on the setback distances. Also, verify with the local governmental unit that you are not in an inner wellhead management zone or the wellhead protection area of a public water supply. These requirements are part of MN Rule Chapter 7080.1710 and require knowledge of the MN Well Code, MN Rule 4725.

Ownership

Legal Land Survey Description

Legal land surveys in Minnesota are based on a township/range description, with a typical township containing 36 sections of land, each of which is one square mile, or 640 acres, in size.

Townships contain 36 sections of land numbered in a particular sequence starting at the northeast corner of the township. Thus section 7 is immediately below section 6, section 12 is immediately south of section 1, section 13 is south of section 12, section 18 is south of section 7, and so on (Figure 4.4).

FIGURE 4.4
Township Sections

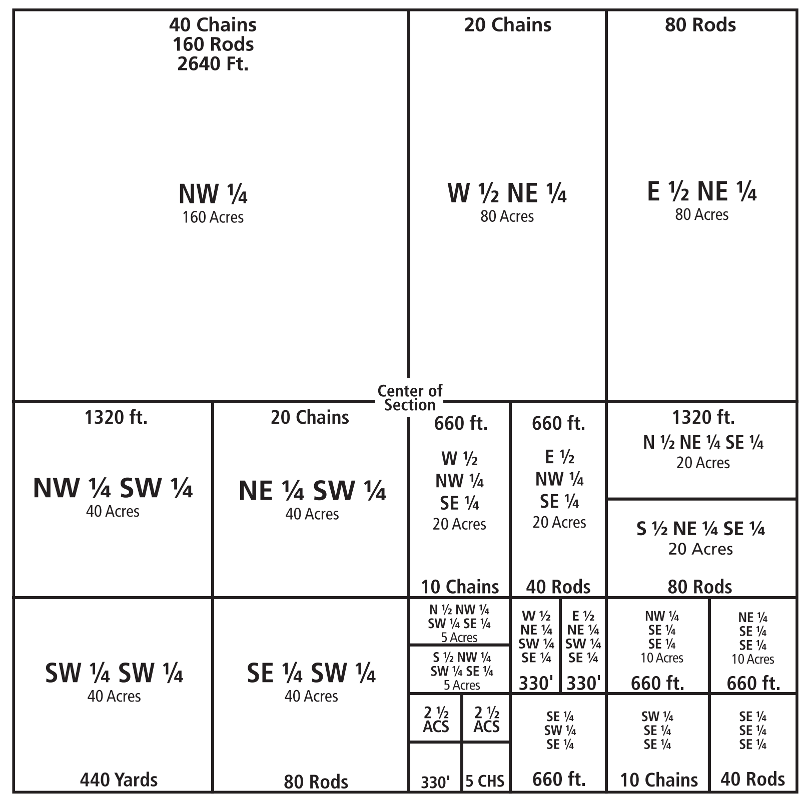
6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Within sections, divisions are made on a quarter basis with respect to the four cardinal directions. Figure 4.5 (next page) shows a typical section with its divisions. When subdivisions are platted, individual properties are assigned block lot numbers. A complete legal description includes township and range, section number, section division, block number, and lot number.

Townships also have numbers that are counted as north of baselines. The township is also given a range number measured east or west from a principal meridian. Within the section, the division is in quarters with respect to the cardinal four directions.

The southwest quarter of section 23 contains 160 acres, and the southwest quarter of the southwest quarter (SW 1/4, SW 1/4) contains 40 acres and is found in the extreme southwestern portion of section 23. This designation may be used for the legal description of larger tracts of land. When subdivisions are platted, the individual properties normally have block and lot numbers.

FIGURE 4.5 Township Section Divisions



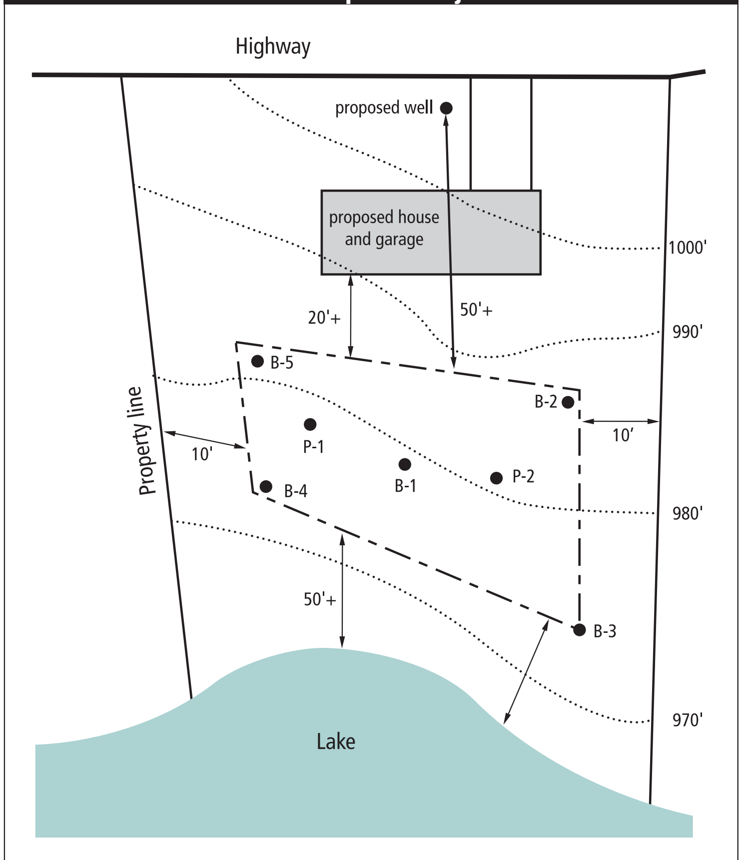
Zoning

The local zoning office can verify that the property can be used as intended/proposed. At the same time, required setbacks from buildings, property lines, road right of ways, utility easements, surface waters, wells, and any other covenants on the property should be investigated. A good way to keep track of these requirements is to locate them on a scale map. Graph or crosshatched paper can be used to make a map of the lot. In the lot illustrated in Figure 4.6, soil borings and percolation tests have been taken in the area proposed for the ISTS. The proposed house location is shown, along with the proposed well location.

The preliminary site evaluation required information is absolutely necessary on a permit application in order to determine the possibility of a location for sewage treatment. The information presented by the application should always be checked against the soil survey information together with a brief site walk through before the permit is granted

If the site is near surface waters, particularly rivers and streams, there may be a flood-plain map that gives the dimensions and elevations of areas that may be flooded. This information may be available from the local zoning office. Other potential sources are the Department of Natural Resources Regional offices and local Watershed District offices. Information on requiredsetback distances from lakes and streams are also available in these offices.

FIGURE 4.6 Site Sketch of Proposed Project



Wetlands are also a protected resource in Minnesota (Wetland Conservation Act, 1991). The local government unit or the DNR has preliminary locations of potential wetland areas. These areas must be identified and delineated by a wetland delineator before the field evaluation for an ISTS occurs. A copy of the Wetland Conservation Act Contractor Responsibility and landowner Statement Form can be found in Appendix 1. For additional information about wetlands in Minnesota, contact the Minnesota Board of Water and Soil Resources.

Field Evaluation

A field-based site evaluation is the only way to accurately determine the actual conditions present on the site. A field evaluation should be done regardless of the favorable or unfavorable results of the preliminary evaluation.

All interested parties should be present at the time of the field evaluation so that all can see the same conditions and issues can be discussed immediately.

At least 48 hours before beginning any digging for soil investigation or system construction, you must (MN State Statute 216D) contact Gopher State One Call for the location of underground utilities. In the metro area, call (651) 454-0002. Elsewhere, call (800) 252-1166. Be prepared to answer where and when you will be digging (legal address, date, etc.).

The preliminary evaluation, discussed above, is a comprehensive investigation and characterization of geological, hydrological, topographic, soil, and setback factors to determine the *potential* for site suitability. The preliminary evaluation is not meant to replace a field evaluation. It simply provides the background data for an effective and efficient field evaluation.

Nearby road cuts, railroad embankments, or other exposed slopes may provide a broad view of the landscape, soils, and geology of the area including the site, so don't limit your investigation to the lot itself. A field evaluation must include the following items per 7080.1720 (for a complete list of detailed requirements, see MN Rule Ch 7080.1720. See forms at septic.umn.edu/ssts-professionals/forms-worksheets - Field Evaluation, Soil Boring Log and Percolation Test forms.):

Subp. 2. Lot lines shall be established to the satisfaction of the property owner or the property owner's agent. Lot improvements, required setbacks, and easements must be identified.

Subp. 3. Surface features. The following surface features must be described:

a. the percent and direction of the slope at the proposed system location;

b. vegetation types;

c. any evidence of cut or filled areas or disturbed or compacted soil;

d. the flooding or run-on potential; and

e. a geomorphic description.

After lot boundaries have been established, the process of selecting locations for the various improvements can begin. The first observations on the site should rule out areas that are obviously unsuitable. A check of the vegetation and topography will help rule out some areas of wet soil, bedrock outcropping, steep slopes, and drainage ways.

Carefully evaluate topography, landforms, vegetation (including large trees the owner may want to preserve or wetland vegetation indicating a high water table), drainage ways, recent construction activities that may have disturbed or removed the topsoil, and any other physical features impacting the site. The soil treatment area should be located in original, naturally occurring mineral soil.

7080.1100 Subp. 54. "Original soil" means naturally occurring soil that has not been cut, filled, moved, smeared, compacted, altered, or manipulated to the degree that the loading rate must be reduced from that associated with natural soil conditions.

7080.1720 Subp. 4. Soil observations. A minimum of three soil observations are required for the initial and replacement soil treatment area and at least one soil observation must be performed in the portion of the soil treatment area anticipated to have the most limiting conditions. The total number of soil observations required is based on the judgment of the certified individual or the local unit of government. If the replacement soil area is not contiguous with the initial soil treatment area, then the designer would need to have a minimum of six soil observations.

The soil observations must utilize tools that preserve soil integrity so that undisturbed soil colors, textures, etc. can be described per 7080.1720 Subp. 5. The purpose of this observation is to determine depth to periodically saturated soils, bedrock, standing water and any other soil characteristics important to the proper functioning of a SSTS.

If the soil texture and structure observation is conducted in order to determine the soil loading rate, **MN Rules Chapter 7080.1720 Subp. 4 (C) states the soil observation method must allow observation of the different soil horizons that constitute the soil profile and, if determining the loading rate by part 7080.2150, subpart 3, item E, Table IX, an undisturbed sample must be observed.** This is typically done by soil pits or other method approved by the local government unit (LGU) as long as undisturbed structure can be observed. Several soil observations are commonly conducted across the proposed area to adequately assess soil variations, but a minimum of one soil observation is required for system sizing. **The minimum depth of the soil observations must be to the periodically saturated layer, to the bedrock, or three feet below the proposed depth of the system, whichever is less (7080.1720 Supb. 4 (G)).**

Subp. 5. Soil descriptions. Each soil profile observed at the proposed soil treatment area must be evaluated under adequate light conditions with the soil in a moist unfrozen state for the characteristics discussed in Section 3: Sewage Treatment Utilizing Soil, including:

- the depth of each soil horizon,
- the soil matrix and mottle colors,
- a description of the soil texture and consistence,
- depth to the bedrock,
- depth to the periodically saturated soil,
- depth of standing water in the hole, and
- any other soil characteristic, which may affect system design.

Subp. 6. Determination of loading rate and absorption area size. The effluent loading and absorption area size must be determined by either a soil description, following 7080.1720 Subp. 5. (see above discussion), or percolation tests, following 7080.1720 Subp. 6., as required by the local unit of government (see "Determination of percolation rates of most restrictive horizon" later in this Section for more detailed information.).

Subp. 7. Site protection. The proposed soil treatment and dispersal area site shall be protected from disturbance, compaction, or other damage by staking, fencing, posting, or other effective method.

Both the owner and the designer should have a written plan on uses and future plans for the property. Since it is much easier to remove lines on paper than to move structures such as water wells or other improvements, this is the time to determine the suitability of proposed locations. The crests of knolls and hills, as well as slightly sloping portions of hills, are likely areas for placement of an ISTS. Avoid depressions, drainage swales that collect runoff from the surrounding area, and excessively steep slopes. The landscape and slope forms should be observed and recorded.

Consider future landscaping plans to assure site access not only during the construction phase but also afterward, so that the septic tank can be pumped as required. Identifying two or three potential ISTS locations on the lot provides additional flexibility if the initial site is found to be unsuitable. It is required for newly platted lots (platted after March 31, 1996) that two areas suitable for a soil treatment area are located on each lot, so check with the local permitting authority before moving to phase II of the design.

Landscape Position

Landscape/Topography

Landscape is the collection of specific landforms that can be observed in a single view. Identification is facilitated by consulting with the geologic atlas and soil survey reports for the area, as well as local soils and geology professionals.

Landform

A landform is a specific feature in the landscape (e.g. hill, pothole, mountain, etc.) that has a characteristic form. We have many landforms in Minnesota that present unique soil and site issues for locating ISTS. The geologic atlas and the soil survey reports will be the best sources of this information locally, as well as local soils and geology professionals.

Hillslope Position and Slope Shape

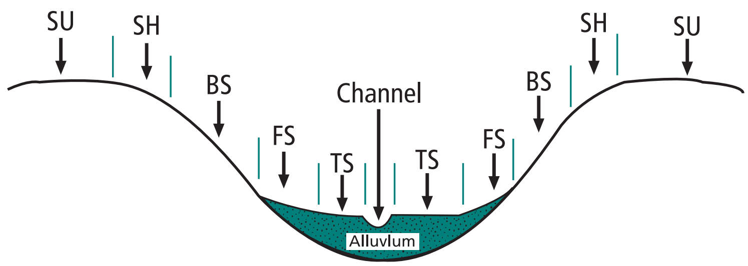
Landscape is an important factor that can determine surface and subsurface flow of water and should be a major consideration when locating an ISTS. The hillslope position and slope shape for the area should be identified as shown in Figure 4.7. This information is useful in determiningsurface and subsurface drainage patterns. For example, sloping convex areas typically have good surface and subsurface drainage away from the area, while concave sloping areas such as potholes, drainage ways, and foot slopes are more likely to possess wetter soil conditions.

More information and descriptions can be found in the Field Book for Describing and Sampling Soils (USDA-NRCS, 2012).

FIGURE 4.7 Hillslope Position

Position	Code
summit	SU
shoulder	SH
backslope	BS
footslope	FS
toeslope	TS

Hillsope - Profile Position
Two-dimensional descriptors of parts of line segments (i.e. slope position) along a transect that runs up and down the slope; e.g. backslope (BS).



Slope

The slope of the soil surface has several distinct properties: gradient, complexity, configuration, length, and aspect. Slope influences the retention and movement of water, rate and amount of runoff, potential for soil slippage, accelerated erosion, ease with which machinery can be used, and soil-water state.

Slope steepness is critical in system design and must be accurately determined and recorded. One method is to use a clinometer.

7080.1100 Subp. 77. Slope means the vertical rise or fall divided by the horizontal distance, expressed as a percentage.

Slope direction, also referred to as aspect, must also be assessed. This can be recorded as the direction of the slope or as the angle (0-360°) e.g. north-facing. This is important as many design criteria require slope direction.

Slope plays a significant role in onsite sewage treatment as it affects the following:

- Type of system to be used (no beds on slopes of six percent or greater)
- Type of gravity distribution system to be used (drop box or distribution box)
- Pressure distribution system design (if all laterals are not on the same elevation)
- Layout (trenches parallel to slope)
- Mound or at-grade design (if more than one percent slope)

Slope determination

The slope percentage of a landscape is determined by dividing the rise by the run and multiplying the answer by 100 as shown in Figure 4.8. For example: a six percent slope is a rise or fall of six feet in a run of 100 feet, or a three foot rise or fall in 50 feet, or a rise or fall of one foot in every 17 feet of horizontal run. Evaluation of the significance of the slope of a soil must be made in relation to the other properties of the soil and to the environment.

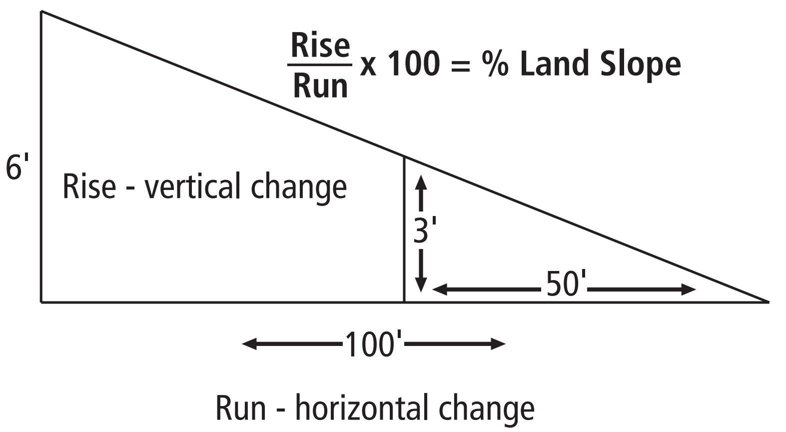
Upslope conditions–run-on/diversions

Proper location of an ISTS requires examination of upslope areas that may contribute water to the site. Additional water over the ISTS can potentially cause failures or severe erosion. Locating a system to minimize run-on is ideal. If this is not possible, divesions of surface waters and/or subsurface water should be designed to ensure proper functioning of the ISTS.

Slopes, elevations, and benchmarks

Another method of determining slope is by using surveying equipment and setting benchmarks. Using survey equipment will also allow the designer to determine contours and slopes using elevation.

FIGURE 4.8 Slope Calculation Example



System orientation to slope

For sites where slopes are 1% or greater, design of any ISTS must follow the contours of the natural landscape.

Benchmark

A vertical reference point (also called a benchmark) is required in addition to a horizontal reference point for locating the distance to test sites—unless they are both the same point. A vertical reference point is an object of permanent elevation, the height or surface of which cannot be easily changed. The vertical reference point may be a lot line corner stake, cornerstone of an existing building, top of a well casing, a centerline of a road, or a stake placed by the soil tester in a location where it will remain undisturbed for future reference.

The elevation of the vertical reference point may be arbitrarily labeled 100 feet (or any other number), as long as the elevation of the test holes are determined in relationship to the elevation of the vertical reference point.

Contours

Contours are lines of equal elevation. They should be determined on sites where slopes are greater than 1%. Flagging and mapping these lines will also help determine whether the location is suitable, due to curvatures (swales).

Flooding

The field evaluation should determine whether the site is subject to flooding. Flooding, as defined by the Minnesota Department of Natural Resources (DNR) is the temporary covering of the soil surface by flowing water from any source, such as streams overflowing their banks, runoff from adjacent or surrounding slopes, or any combination of sources. Shallow water standing or flowing during or shortly after rain and snowmelt are excluded from the definition of flooding, but both must be considered when designing an ISTS. Standing water (ponding) or water that forms a permanent covering is excluded from the definition of flooding.

7080.1710 E. floodplain designation and flooding elevation from published data or data that is acceptable to and approved by the local unit of government or the Department of Natural Resources, if applicable..

MN Rule Chapter 7080.2270 has specific requirements for designing systems within floodplain areas. Whenever possible, this practice must be avoided. If the ISTS must be placed on a floodplain, the field evaluation should accurately determine what portion of the parcel is affected by the floodplain and demonstrate that other options are not viable.

Distance from floodplain

Maps are the best way to determine the distance of the proposed ISTS to the floodplain. Distances can also be measured from field-based identification of the floodplain elevation.

Floodway, flood fringe, and floodplain identification

The floodplain is comprised of the floodway and the flood fringe. The floodway is adjacent to the channel and conducts flood waters. The flood fringe is the remainder of the floodplain where flood waters are shallow and slow moving.

Information received from the DNR or county should reveal if the site is located in an identifiable floodplain. ISTS should not be installed in the floodway areas of the floodplain. Floodway ISTS are allowed if the requirements of 7080.2270 are met.

Floodplain means the area covered by a 100-year flood event along lakes, rivers, and streams as published in technical studies by local, state, and federal agencies, or, in the absence of these studies, estimates of the 100-year flood boundaries and elevations as developed pursuant to a local unit of government's floodplain or related land-use regulations (see MN Rules 6105 and 6120).

Soil survey information should also have identified whether the soil is subject to localized flooding in such landscape positions as drainage ways or intermittent streams.

If flooding is suspected, the following can be used to determine the potential flooding hazard:

- Landscape features: Certain landscape features have developed as the result of past and present flooding, such as former river channels, oxbows, point bars, meander scrolls, sloughs, natural levees, back-swamps, sand splays, and terraces. Most of these features are easily recognizable.
- Vegetation: The vegetation that grows in flood areas may provide clues to past flooding. The survival of trees in flood-prone areas depends on the frequency, duration, and time of flooding (dormant season or growing season), and also on the age of the tree and the depth of flooding. Some species are intolerant of flooding and are not found in areas that are flooded. Other species are very tolerant of flooding and even withstand partial or total submersion during the growing season. Pure stands of these species indicate frequent or long duration flooding. A biologist or forester can help relate the vegetation to flooding frequency, duration, and flood period. See Eggers and Reed, 2011, for a list of wet plants.
- Soil Profile Characteristics: these provide clues to past flooding:
  (1) a thin strata of material of contrasting color or texture or both;
  (2) a soil layer that is darker than the layer above is an indication that the darker layer has been covered by more recent deposition; and
  (3) soil layers that have abrupt boundaries to contrasting kinds of material, indicating that the materials were laid down suddenly at different times from different sources or deposited from stream flows of different velocities.

Vegetation

Observations of the growth of both native vegetation and cultivated crops aid in recognizing soil boundaries and provide information about soil limitations.

Native Vegetation Generally, close relationships exist between native vegetation and certain soil properties, yet there are important exceptions. A reliable field evaluation cannot be made by studying vegetation alone, but with careful observations of both soils and vegetation, excellent correlations can be established. Cattails, alders, dogwood, willows, tamaracks, and sedge grasses (along with numerous other plants) all indicate wet soil areas. These areas should be noted on the site evaluation map.

Common names of the plants may be used if such names are clear and specific, but many common names are used for different species in the same region. See Appendix B-4: Wetland Plant List for a list of common wet soil indicators for use in Minnesota.

Cultivated Vegetation Over an extended period of cultivation, farmers learn which crops do well and which do poorly on different soils and adjust their cropping patterns accordingly. If the differences are large—as between crop failure and reasonable performance—the absence of a given crop may reflect the suitability of that soil for the crop. If the differences are small, many non-soil factors can determine the farmer's choice of fields for a given crop. Relationships observed must be interpreted with caution because of economic factors, management systems, and farmer preference. But within fields of a single crop, differences of vigor, stand, or color of the crop or weeds commonly mark soil differences and are valuable clues to the location of soil boundaries.

Soil Observations

Information must be reported on the thickness in inches of the different soil horizons and their suitability for treatment and hydraulic acceptance of septic tank effluent. It is required that a replacement soil treatment area be investigated and identified.

To locate the ISTS properly, thoroughly evaluate soil texture, structure and consistence, the presence of soil redoximorphic features, direct water table measurement, and presence of bedrock. Soil survey information may aid in determining parent material (see "Soil Reports and Geologic Atlases" in this Section). In some cases, an examination of road cuts, stream embankments or building excavations will also provide useful information. Wells and well driller's logs can also be used to obtain information about groundwater and subsurface conditions.

There are three methods typically used to conduct soil investigations: probing, augering, and pits. Each method has its own advantages and disadvantages. A soil probe (diameters and lengths vary in size) is a hollow tube pushed into the soil. When extracted, it displays an undisturbed column of soil for viewing. Probing is probably the quickest method of examining the soil. It also has the advantage of revealing undisturbed soil in which faint soil mottling or cemented layers may be seen. One disadvantage is that a probe can be difficult to push into rocky or dry soil. The hand probe also has a limited sampling depth, while hydraulic probes and foot driven probes have greater sampling depths.

A soil auger typically allows the designer more soil to examine. It is a hollow bucket with cutting tips that cut soil to fill the hollow bucket as the handle is turned. This method disturbs the soil a bit, but toward the middle of the sample should be an adequate sample for description. A disadvantage of auguring is that soil structure can be hard to identify. The soil series description (Official Series Description) can assist with proper identification of soil structure where significant site alteration has not occurred.

The soil pit is the optimal choice for identification and description of soil properties. A pit can be dug by hand or by an excavator. It provides the designer with a large window into the soil to describe colors, textures, structure, consistence, and any other pertinent soil conditions. There are drawbacks to the soil pit: it can be destructive to the site, hinder access to the site, be costly, and add to safety concerns. To mitigate this last drawback, proper pit excavation safety precautions must be followed at all times.

Preserving the soil sample in its most natural form is the key to a proper soil observation. For this reason, a screw type or flight auger is strictly forbidden for ISTS purposes. Whatever soil investigation method(s) is used, the designer/inspector must understand its strengths and weaknesses and develop strategies to ensure complete and accurate soil observations on each parcel. Each LGU shall list acceptable tools to conduct soil observations in their area.

Before a soil description can be written, the excavated soil from a boring or augering must be laid out on the ground surface, with the depths of the excavated soil corresponding with the depth of the hole. A tape measure should be laid alongside the excavated soil. Rain gutters cut to six-foot lengths provide for good soil preservation for the soil examination. It is not recommended to excavate an auger full of soil, briefly examine the bottom, and dump the soil into a spoil pile next to the hole.

When describing the soil, it is best to work in adequate natural light with moist soil. If naturally moist soil does not exist at the time of observation, options exist. If the soil is too dry, you can slightly wet (mist) the soil from a water bottle. Saturation of the soil sample also does not equate to moist soil conditions. If saturation exists, the soil must be left to dry or can be blown on until field moist conditions are reached.

The exposed soil is usually examined starting at the soil surface and working downward to identify significant differences in any property that would distinguish between adjacent horizons. Boundaries between horizons are then marked and described. Horizon depths are measured from the soil surface and recorded.

Soil Observations Procedure

The soil investigation can begin after a visual elimination of unsuitable areas (including all setbacks, etc.) is complete. Soil observations and descriptions can be challenging, but they are always interesting as no two soils are ever identical. The thoroughness of the soil investigation will depend upon the amount of site variability and is at the discretion of the designer.

The following is the minimum required soil observations and locations of these observations according to MN Chapter 7080.1720 Subp. 4.

A minimum of three soil observations are required for the initial and replacement soil treatment area and at least one soil observation must be performed in the portion of the soil treatment area anticipated to have the most limiting conditions. The total number of soil observations required is based on the judgment of the certified individual or the local unit of government.

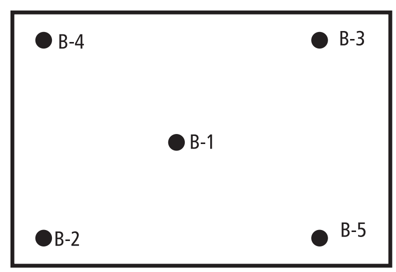
A typical soil excavation is first done to the depth of three feet below the bottom of the proposed system or until a soil limitation is encountered. The soil information gathered from the boring should include texture, soil horizon depth, changes in soil color, soil structure, consistence and presence of bedrock.

The following procedure is given for conducting soil investigations:

1. Locate the center of the proposed soil treatment area. The first soil excavation should be dug to a depth of six feet unless a limiting soil layer is encountered at shallower depths.
2. Make one soil observation (B1 in Figure 4.9).
3. Estimate maximum depth of system and the texture, structure and consistence at this depth. Find soil loading rate using Table IX in Section 13: Forms.
4. Determine the total area needed:

   (Average daily flow / soil loading rate) / trench width) * trench spacing
5. Determine the system geometry from the calculated size.
6. Make four additional observations along the contours of the soil treatment area corners (B2 to B5 in Figure 4.9). These remaining observations at the system corners must be dug to three feet below the proposed depth of the system.

FIGURE 4.9 Soil Observation Locations



For example: The first observation (in the middle) is dug to six feet with no indication of bedrock, periodically saturated soil, or other limiting conditions.The designer proposes the system depth at two feet, and the remaining excavations will then be dug to a five-foot depth.

After the initial soil observations have been observed, described, and interpreted, the proposed system locations and layout can begin.

Soil Observation Log

The OSTP website, septic.umn.edu/ssts-professionals/forms-worksheets, provides a soil observation log form for recording data during soil observations. This form should be used for any type of soil observation whether a soil pit, soil probe, soil auger or other approved soil sampling method. When conducting a soil observation, enter the soil texture whenever a change in texture occurs. For example, the top 12 inches may be a fine sandy loam; from 12 to 18 inches the texture may be loam; from 18 to 36 inches the texture may be a clay loam; and from 36 to 72 inches the texture may be clay.

At the bottom of the soil observation log form, the total depth of the observation hole should be entered, as well as any evidence of redoximorphic features or standing water along with all other information on the form.

The depth of water in the observation hole must be measured and recorded. However, this depth should not be used as the estimated high water table for designing a system. Most water tables fluctuate by many feet in a normal year. A single observation of water in a hole probably does not indicate its highest level. The observation of redoximorphic features or other indications of wetness is scientifically valid and is the MN State Rule Chapter 7080 required method to determine this depth.

Data on the depth to zones of soil saturation is presented in the Soil Moisture, Ponding, Flooding (MN) report on the web soil survey. This report can help the designer determine what limitations exist and at what depths in a general area. While useful, the soil survey information alone should never be used to make this or any other site-specific determination.

Limiting and restricting layer identification

There are numerous possibilities for limiting and restricting conditions on any site. Common conditions include:

- Redoximorphic features/saturated soils
- Bedrock (including soils with >50% rock fragments)
- Flood elevation
- Restricted percolation rates/high clay contents

Redoximorphic features

Changes in soil colors indicate a change in soil conditions. A site evaluation should carefully observe, describe, and interpret all soil color changes, whether matrix color, mottle color, or both.

A specific type of mottling that indicates saturated soil conditions is called redoximorphic features. The presence of these features in the soils is used as an indicator of soil saturation at these depths.

Formation

Refer to Section 3: Soils for a detailed description of redoximorphic feature formation in soils.

Identification

The ability to correctly identify redox features in the soils relies on an understanding of soil coloring influences and chemical reactions in saturated soils and proper site conditions. Refer to Section 3: Soils for more information on the identification of redoximorphic features and their interpretations.

Limitations

Problem soils and exceptions to the above standard redox processes exist in many areas of Minnesota. These soils and landscapes require special consideration, including careful documentation of all site evaluation parameters (soils, slopes, percolation rates, contours, etc.). Also, supporting evidence from the soil survey of the area will aid in proper identification of depth to soil saturation. Many problem soils are a direct result of human impacts (e.g., erosion, drainage, filling, raising water levels, etc.). These soil identifications are specific to one site and determinations cannot be standardized on a state or regional level. Such site evaluations should involve the ISTS professional and the Local Government Unit in the decision making process. In some problem areas, soil investigations may benefit from the expertise of a Licensed Professional Soil Scientist who is a certified SSTS designer or inspector. County inspectors, Soil and Water Conservation District staff, Natural Resources Conservation Staff, or other registered SSTS professionals are all sources of additional information. In some cases, long-term monitoring may be necessary.

Recognition of problem soils

Many times redox features do not exist in the soil, but the soil may still be limiting due to saturated soil conditions. Below are examples of areas in Minnesota where this can occur.

Red parent material

Areas of soil with Munsell color of hues 7.5YR or redder are called red parent material soils in Minnesota. They exist northwest from St. Cloud to Canada and south from Duluth to the southern Twin Cities metropolitan area, where glacial advances out of the Lake Superior Basin brought highly weathered iron minerals. These redder iron minerals do not change form as readily as iron in the rest of Minnesota soils, and result in difficult observation of redox features. If features exist, they are often very subtle. Carefully considering the landscape, landform, and vegetation will greatly assist site evaluations in these areas.

Because these soils are known to present difficulties in limiting condition identification, MN Rule Chapter 7080.1720 Subp. 5 E 1(c) addresses them specifically:

Faint redoximorphic concentrations or faint redoximorphic depletions in subsoil or parent material with a hue of 7.5YR or redder. These conditions indicate a periodically saturated soil.

Faint is defined in Section 3: Soils, "Soil Color," and Chapter 7080.1100 Subp. 33.

Thick topsoil

Thick topsoil exists over much of western and southern Minnesota as a result of prairie vegetation. Prairie grasses provide a rich annual source of organic matter (i.e., decomposing material that was once living) to the soil. Over many years, this organic matter accumulation becomes very dark and thick (greater than 12 inches). This annual accumulation of organic matter also masks (covers) any other soil colors that may be present in the soil, including redoximorphic features.

When a soil has been identified as having greater than 12 inches of topsoil (with a soil matrix color of chroma and value of three or less), MN Rule Chapter 7080.1720 Subp 5 (E) provides the following requirements for identifying redoximorphic features:

(2) in lower topsoil layers that are deeper than 12 inches from the surface and are immediately followed in depth by a periodically saturated horizon, redoximorphic features include:

- **(a) soil colors with a redoximorphic chroma of two or less; or**
- **(b) redoximorphic accumulations or depletions;**

(3) in the upper 12 inches of the topsoil layer, if it is immediately followed by a periodically saturated horizon, the depth of seasonal saturation is determined by one or more of the indicators in units (a) to (f):

- **(a) soil colors with a chroma of zero;**
- **(b) organic soil textures or mineral soil textures with an organic modifier;**
- **(c) dominance of hydrophytic vegetation;**

(d) the soil treatment area at or near the elevation of the ordinary high water level of a surface water or in a concave hill slope position;

(e) redoximorphic accumulation or depletions; or

(f) the soil expressing indicators of seasonal saturation as determined in Field Indicators of Hydric Soils in the United States: A Guide for Identifying and Delineating Hydric Soils, USDA Natural Resource Conservation Service (2006).

Elluvial horizons

Elluvial horizons (E horizons) are horizons that form immediately below the topsoil and are characterized by their loss of certain soil materials, including clay, iron, and organic matter. The conditions that most often lead to E horizon formation include forested sites. As leaves (deciduous or coniferous) are deposited on the soil surface, their decomposition releases acids that help remove soil materials below the topsoil.

The interpretation of soil saturation can be complicated by these horizons' high value and low (i.e., light and dull) chroma colors. To properly understand the reason(s) for this coloration, soil observation must continue for the next three feet to investigate soil properties that may cause saturation within this layer. Only when there is an absence in soil restrictions for the next three feet can the light and dull colors of an E horizon be considered part of the suitable soil required for an ISTS.

Lamellae

Throughout the sandy-textured soils of Minnesota, especially in the Anoka Sand Plain, it is common to observe fine-textured subsurface bands. These bands are typically identified as part of the soil forming process and are called lamellae. Properly identifying and interpreting their effect on soil water movement is of particular concern for evaluating sites for ISTSs. The University of Minnesota and the Minnesota Pollution Control Agency have prepared more information on the soils of the Anoka Sand Plain. Please contact Dan Wheeler (wheel027@umn.edu) for more information.

What do lamellae indicate?

Lamellae are finer textured layers in the soil that form due to a slowing of vertical water movement through the soil. As the water slows, anything carried in the water (silts, clays, etc.) is deposited. This creates a feedback mechanism causing more fine textures to accumulate in these areas. By themselves, lamellae indicate nothing about a saturated condition in the soil.

Is there a thickness criteria where lamellae become limiting?

The key to identifying a limiting condition where lamellae can be found is looking carefully for redoximorphic features within, above or below the bands. No matter how thick or thin the bands, the presence of redox features are the key to determination of limiting condition due to saturated soil conditions.

Calcareous

Soils commonly found throughout western and southern Minnesota have calcium carbonates inherited with their parent material. This calcium carbonate has its source as limestone bedrock that was crushed and transported by glacial activity. Soils with calcium carbonates have many white or light colored soft masses distributed throughout the soil profile. Where water moves through the soil, some calcium gets

FIGURE 4.10 Concentrations and Depletions

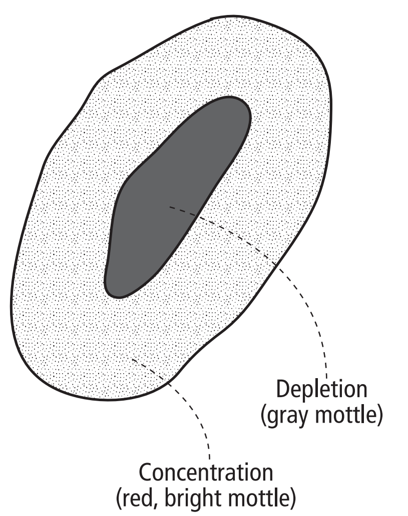


FIGURE 4.11 Near-Surface Water Table

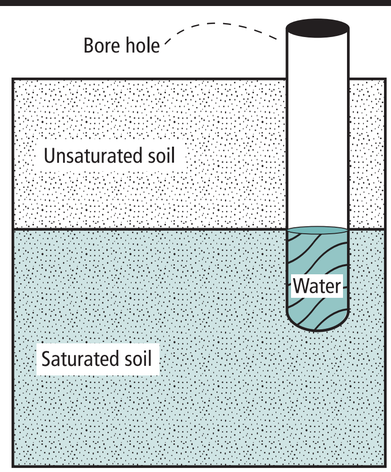
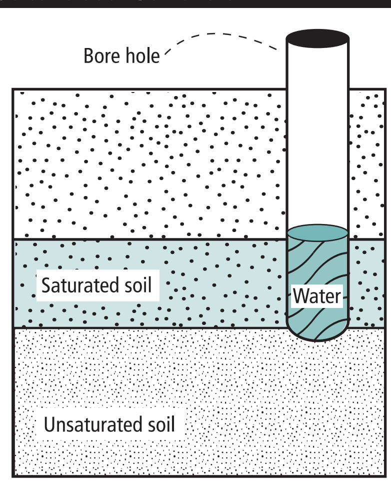


FIGURE 4.12 Perched Saturated Condition



dissolved and carried deeper into the soil (recharge hydrology), brought to the soil surface (discharge hydrology), or transported off site (later flow hydrology).

The issue with calcium carbonates and ISTS is the misinterpretation of the light colors as redox features due to the prominent contrast from the surrounding matrix color. In many of these soils, there may be redox features present in the same horizon as the calcium carbonate masses, but they are overlooked because they lack the contrast of the calcium carbonates. To properly identify redox features in these very colorful soils, look for depletions and concentrations adjacent (i.e., touching) each other (see Figure 4.10).

Highly decomposed bedrock

See Section 3: Soils, "Soil Formation" for bedrock conditions and limitations.

Saturated soils

Water Tables

Saturated soil conditions are also known as groundwater and the water table. The relationship between soil and water is critical in evaluating the use suitability for a soil. Soil wetness should be characterized by identifying the depth to the uppermost zone of saturation and the approximate duration of that saturation.

Saturated soil conditions are detrimental to soil treatment areas. Failures occur both in the movement of effluent into the soil and in its treatment. Premature system failure due to saturated soil conditions can result from:

- soil flowing at saturation and clogging the gravel beds or the distribution piping,
- accelerated clogging of the system area by bacteria that operate during saturated or wet soil conditions, or
- slow or no movement of effluent out of the system because the soil is already filled with water and is unable to accept additional liquid.

All of the preceding situations lead to effluent either surfacing on the ground or backing up into the home.

Treatment of effluent is not effectively achieved in saturated soil. Contamination of drinking water wells can occur when untreated effluent enters groundwater.

Knowledge of the times and depths at which a soil is wet is important to determine if the soil is suited for an ISTS. Free water exerts a strong influence on the physical, biological, and chemical processes that are necessary for sewage treatment and acceptance.

In some cases saturated soil conditions may be the upper level of an aquifer (see Figure 4.11). In other cases, these saturated soil conditions may be separated from a deeper aquifer by geologic materials, which may impede downward groundwater movement (Figure 4.12). In either case, there still needs to be a three-foot separation distance from the highest point of soil saturation to the bottom of the soil absorption system.

Groundwater flow rates and directions are controlled by the geologic character of an area. Recharge and discharge areas are an important concept in groundwater geology. A recharge area is usually a topographically high area from which a pressure gradient is established on the water table. From this point, the water table slopes until it intersects the surface in a stream, lake, or other groundwater discharge area.

Soil color determination

Determining the soil colors present in the soil profile will provide the designer with the proper information to determine the depth to any limiting condition, disturbance history, compaction, or other soil issues on a site. The soil colors must be identified, described, and interpreted using MN Rule Chapter 7080.1720. See also Section 3: Soils, "Soil Color."

Soil color implications

Section 3: Soils, "Soil Color" and MN Rule Chapter 7080.1720 discuss the implications of using soil colors for interpretation.

Bedrock

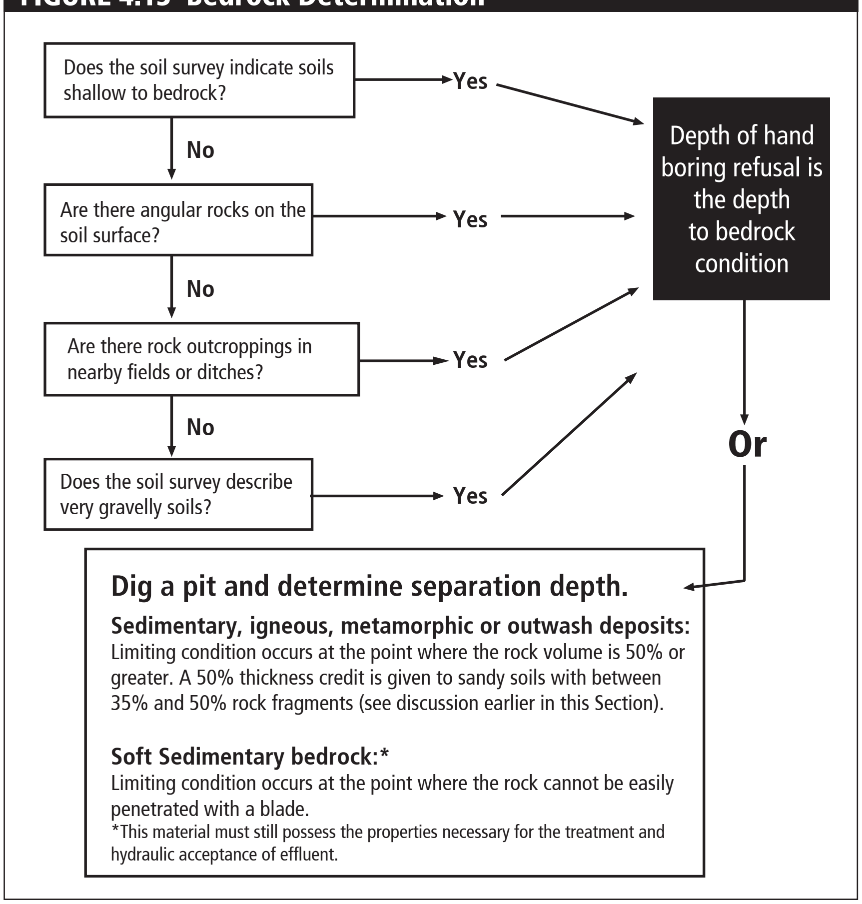
Bedrock on a site will severely limit the treatment and hydraulic acceptance of septic tank effluent. Locating these areas during a field evaluation is key to an appropriate design.

From your preliminary evaluation you should have a good idea if bedrock is present on or near your site. If bedrock is suspected, methods to determine bedrock are as follows:

- Angular rocks on the ground surface or in the auger
- Outcroppings on or near the site
- Bedrock in nearby road cuts or a backhoe pit

The depth at which soil ends and bedrock begins is dependent upon the type of bedrock as described by 7080 below.

FIGURE 4.13 Bedrock Determination



7080.1100 Subp. 8. Bedrock means geologic layers, of which greater than 50 percent by volume consist of unweathered in-place consolidated rock or rock fragments. Bedrock also means weathered in-place rock which cannot be hand augered or penetrated with a knife blade in a soil pit.

For more discussion on bedrock types and limitations, see Section 3: Soils, "Soil Formation."

An example method for determining bedrock is presented in Figure 4.13.

Restricting soil conditions

Flood Elevation

As discussed above under "Flooding", saturated soil conditions caused by flooding constitute a limiting condition due to a lack of treatment and acceptance of septic tank effluent during certain times of the year. Flood elevations must be obtained and all design/construction considerations must be followed.

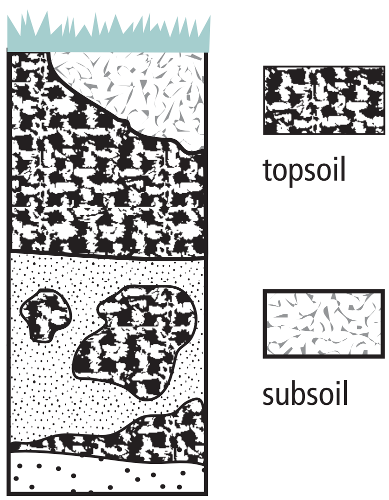
Disturbed Areas

Due to a loss of soil structure, areas that have been cut, filled, compacted, or disturbed in any way often have difficulty in accepting septic tank effluent. These areas can sometimes be identified by wheel tracks, hummocks, stunted vegetative growth, or incorporated debris. Normal agricultural and forestry uses do not constitute disturbed areas unless they are high traffic areas (e.g., skid trails, roads, fencelines, head lands, access points, etc.) or severely eroded areas.

Fill Soils

Fill soils are soils that have been moved from their geologic origin by mechanical means and deposited in a new location. This creates a man-made lithological discontinuity. When soils with textures other than clean sand are moved to a new location, the soil structure is destroyed, which liberates the silts and clays that migrate when water is added. This loss of pore space and restricted water movement between the different layers ultimately results in percolation problems in the soil, which can be severe. Percolation test results in a single area of loamy fill can range from seven mpi to over 200 mpi. This can complicate the decision of which sizing factor to use.

FIGURE 4.14 Fill Soil Profile Example



Problems in determining the depth to the periodically saturated soil are also encountered. Water tables can change when the topography is altered, and soil coloration of the fill cannot be used as an indication of the water table's height. Fill soil colors are characteristic of where it was excavated not that of its present location. Carefully considering the natural soils, landscapes, and vegetation is key to correctly identifying the limiting conditions on these sites.

Fill soils commonly have stratified layers or different colored and textured materials as indicated in Figure 4.14. These layers have abrupt boundaries. Typically, the thickness of subsoil material ranges from 1/8 inch to a few inches thick, but can vary widely. Probing or pits (not auguring) is necessary to see these layers.

Soils located in a valley or flood plain sometimes have a natural stratification of soil materials that were deposited from sediment carried by floodwaters. Each layer represents deposits from one flooding event. These layers are black to gray in color, have textures in the range of silt to fine sand, and lack rocks. These stratifications should not be confused with stratifications caused by fill activities.

Fill soils commonly have unnatural looking landscapes, such as:

- Short steep linear slopes
- Unusually flat area in a generally rolling topography
- Higher areas adjacent to wetlands or shore land
- Man-made structures (such as roads or buildings) nearby
- Sparse vegetation (if new fill area) or vegetation lacking vigor as compared to adjacent areas
- Many rocks on the soil surface

The soil survey report maps fill soils as urban land.

Cut Areas

Cut areas are areas where the land surface has been lowered by removal of earthen materials. Cut areas have usually been compacted by machinery during land leveling. This compaction may be localized and spotty or widespread, depending on wheel traffic patterns.

The topsoil and subsoil have often been removed from the cut area, exposing the native parent material, which usually has little or no soil structure to aid in water percolation. There may be a layer of topsoil added on top of the cut for lawn establishment. A restrictive condition likely occurs at this interface, slowing the movement of water. This problem is greater if the texture of the topsoil is unlike the texture of the underlying cut soil.

Altering the landscape typically alters the water table height. The depth to redoximorphic features will be shallower because the soil surface has been removed but may not reflect a change in the depth to periodically saturated soils due to altering the landscape.

Cut areas typically have an abrupt boundary between the imported topsoil and the top of the cut surface. The parent material exposed from the cut will lack soil structure and be lighter in color (i.e., soil color values of four or more).

Cut areas commonly have unnatural-looking landscapes, such as:

- Short steep linear slopes
- An unusually flat area in a generally rolling topography
- A level area cut out of a steep hillside
- A flat crest of a hill
- Man-made structures (e.g., roads or buildings) are likely to be nearby. There may be sparse vegetation as compared to adjacent areas. Soils may be dense, compacted, and difficult to probe. If cut areas are large, the soil survey report will map them as urban land or orthents.

Soils, Impacts on ISTS Design

Soil properties such as texture, structure, and consistence will determine numerous design parameters.

Soil Texture

Soil textures will predominantly be used to help determine the size of the ISTS to be designed at the parcel.

Constructability

Soil erosion is an issue for design and installation when fine sands are present. Fine sands are very susceptible to wind erosion, and proper care must be taken to preserve soils on the site.

Water erosion can cause problems on sites where silty textured soils dominate the soil textures. Until vegetation can be established on the site, mulching or protecting the soil will ensure that the required soil cover is maintained. Because silty soils lack cohesive forces, channelization of water should be avoided in these areas.

Smearing

Any sandy loam or soil of finer texture can be susceptible to smearing if enough water is present. Plastic limit determination, which is discussed in more detail in Section 3, is key to minimizing smearing during construction activities.

Compaction

Compaction can occur on any soil texture. The best way to minimize compaction is not to allow equipment on site. However, this is seldom possible, so minimizing impacts is the next best option. The following is a list of some of the techniques used to minimize the potential for soil compaction:

- distributing the weight of vehicles by tracks,
- limiting construction activities when soil is wet,
- protecting soil treatment area from trafficking,
- constructing SSTS from upslope side,
- minimizing unnecessary travel by equipment.

Soil structure - Preferential movement

In addition to soil texture, soil structure and consistence is evaluated to estimate the loading rate of an ISTS.

Soil structure is the common way that preferential flow occurs at a site. The process by which water and its constituents move by a preferred pathway through a porous medium is known as preferential flow (Glossary of Soil Science Terms, 2006). Preferential flow conditions can also occur in bedrock.

Soil water movement

The flow of water in soil depends on the soil's ability to transmit the water and the presence of a force to drive the water. An understanding of how water moves into and through soil is necessary to predict the soil's potential for septic tank effluent acceptance and treatment. In this section, hydraulic conductivity, saturated hydraulic conductivity, and the percolation test are discussed.

The movement of water through the soil is controlled by landscape, internal soil properties, and environmental factors. Soil properties influencing water movement include cracks, coarse fragments, soil structure, total porosity, size, continuity of pores, and water content of the soil. Environmental factors include form and intensity of precipitation, evapotranspiration, and temperature.

Unsaturated water movement

Water flow is unsaturated when the soil water is under tension (negative pressure). Unsaturated hydraulic conductivity is a function of the same soil properties as saturated hydraulic conductivity and also of the soil water content. Unsaturated flow is slower than saturated flow.

The ability of the soil to draw or pull water into its pores is referred to as its matric potential. The affinity of water molecules to each other and to solid surfaces produces the matric potential. Molecules within the body of water are attracted to other molecules by cohesive forces, while water molecules in contact with solid surfaces are more strongly attracted to the solid surfaces by adhesive forces. As a result of these forces acting together, water is drawn into the pores of the soil. The water tries to wet the solid surfaces of the pores; because of cohesive forces, water pulls other molecules with it.

The driving force behind unsaturated flow is not gravity, but a soil tension force (sometimes called capillary action or wicking). Under unsaturated conditions, the largest pores drain first since they are able to exert the least tension. Water is pulled through the smaller pores. Since clays have smaller pores, they can actually transmit water faster under unsaturated conditions than sands.

Water in unsaturated flow moves because of tension, not gravity; the water does not have to travel downward, but can move sideways or even up, to wherever the soil is the driest. The presence of lush green grass over the soil treatment area is evidence of this capillary movement. Figure 4.15 shows how, as a biomat develops in a trench, flow under the trench becomes entirely unsaturated.

Saturated hydraulic conductivity

Saturated hydraulic conductivity is the rate of water movement within a waterlogged soil. It is a measure of the ease with which water moves through the soil, and is measured in centimeters per hour or feet per day. Soils higher in clay contain more pore space than soils high in sand, but the individual pore spaces are smaller. As the clay content of soils increases, hydraulic conductivity decreases (Table 4.6).

TABLE 4.6 Porosity and Conductivity of Soils

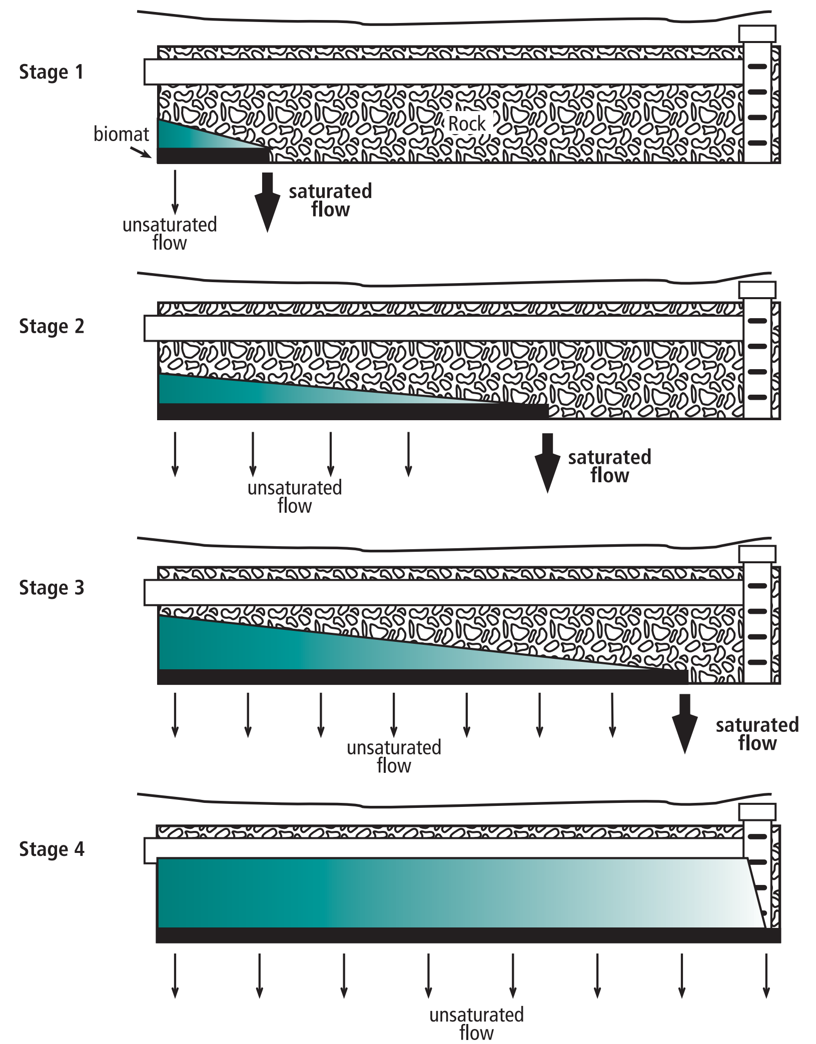
Texture Class	Mean Total Porosity %	Saturated Conductivity (Ks) ft/day
Sand	43.7	16.54
Loamy Sand	43.7	4.81
Sandy Loam	45.3	2.04
Loam	46.3	1.04
Silt Loam	50.1	0.54
Sandy Clay Loam	39.8	0.34
Clay Loam	46.4	0.18
Silty Clay Loam	47.1	0.12
Sandy Clay	43.0	0.09
Silty Clay	47.9	0.07
Clay	47.5	0.05

From Rawls et al., 1989. Estimating soil hydraulic properties from soil data

Sands and gravelly soils in good landscape positions (e.g. convex and planar slope curvatures) can transmit water downward so readily that the soil or layer remains moist for no more than a few hours after a thorough wetting. These soils have large connected voids.

After a thorough wetting, sandy loams, loams, and loamy sands commonly remain moist for no more than a few days if located in a dry landscape setting. These soils commonly have moderate to strong structure. These soils are also often considered favorable for rooting and for supplying water to plants.

FIGURE 4.15 Biomat Development in a Trench



Silt loam and clayey soils commonly transmit water downward so slowly that they remain moist for a week or more after a thorough wetting.

Other soils with low hydraulic conductivity may be structureless or have only fine and discontinuous pores (as in some clays, or cemented layers). Layers may be massive or platy. There may be few connecting pores that could conduct water when the soil is wet.

Saturated hydraulic conductivity does not necessarily describe the ability of soils, in their natural setting, to accept or transmit water internally. A soil may have very high saturated hydraulic conductivity, yet contain free water because there are restricting layers below the soil or because the soil is in a depression where water from surrounding areas accumulates faster than it passes through the soil. Therefore, the water may actually move very slowly despite the soil's high saturated conductivity.

The actual rate of water movement is a product of the saturated hydraulic conductivity and the hydraulic gradient. The hydraulic gradient at any point is determined by the elevation of that point relative to some reference level. Thus, the higher the water above this reference, the greater its gravitational potential.

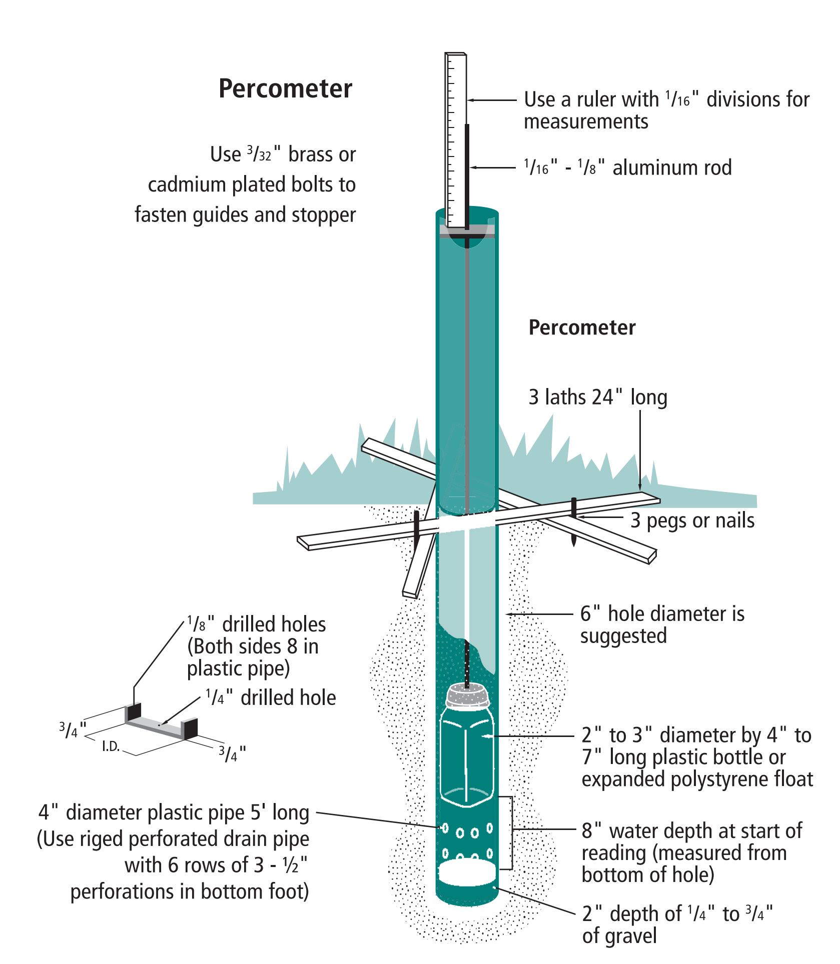
Saturated hydraulic conductivity is highly variable. Measured values for a particular soil series can vary by one hundred-fold or more. Saturated hydraulic conductivitycan be given for the soil as a whole or for a particular layer or combination of layers. The layer with the lowest value determines the saturated hydraulic conductivity classification of the soil.

The above discussion relates to water movement in soils that are saturated with water. Distinction should be maintained between saturated hydraulic conductivity and unsaturated hydraulic conductivity.

Determination of percolation rates of most restrictive horizon

The percolation test is an important part of a site evaluation as it is critical to the successful design of an onsite sewage treatment system. Suitable soil is the key to providing adequate septic tank effluent treatment. Soil observations are used to locate a suitable area before beginning the percolation test. (See "Soil Observations," this Section, for a detailed discussion of soil boring.) Percolation testing is a required step of the field evaluation to determine loading rates when soil structure and consistence

FIGURE 4.16 Percometer Specifications



are not described in the soil observation. They are also useful in providing a better understanding of site impacts (e.g. compaction, fill, etc.).

The Percometer and the Hook Gauge

Figure 4.16 shows a percometer, which is a device used to accurately measure the drop in the liquid level in soil. A rod that is fastened to the float is read by the scale or ruler at the top of the percometer. A four-inch plastic pipe can serve as the body of the percometer. Holes half an inch in diameter should be drilled near the bottom of the body to allow water to freely flow in and out of the percometer. A plastic bottle approximately one quart in size can be used as the float. A stiff wire fastened to the top of the bottle extends through the top brace of the percometer.

A different method of measuring the drop in liquid level may be used (see Figure 4.17, next page). In this case, a hook gauge is used to determine the liquid surface level, and a batter board is used as a reference point. While this is an accurate method of determining the liquid level, it is not as convenient as using the percometer. There are also electronic means of measuring water levels including pressure transducers to aid in the determination of liquid levels.

Percolation Test Data Sheet

A percolation test data sheet should be used to record the results of the test. The original percolation test data sheets should be submitted with the site evaluation report forms. A data sheet is provided at: septic.umn.edu/ssts-professionals/forms-worksheets.

Field ratings of the time and water level should show no erasures. If you make a mistake, cross out the reading and enter the correct value. Erasures can be made on computed values, but erasures made on field readings casts doubt on the validity of the data.

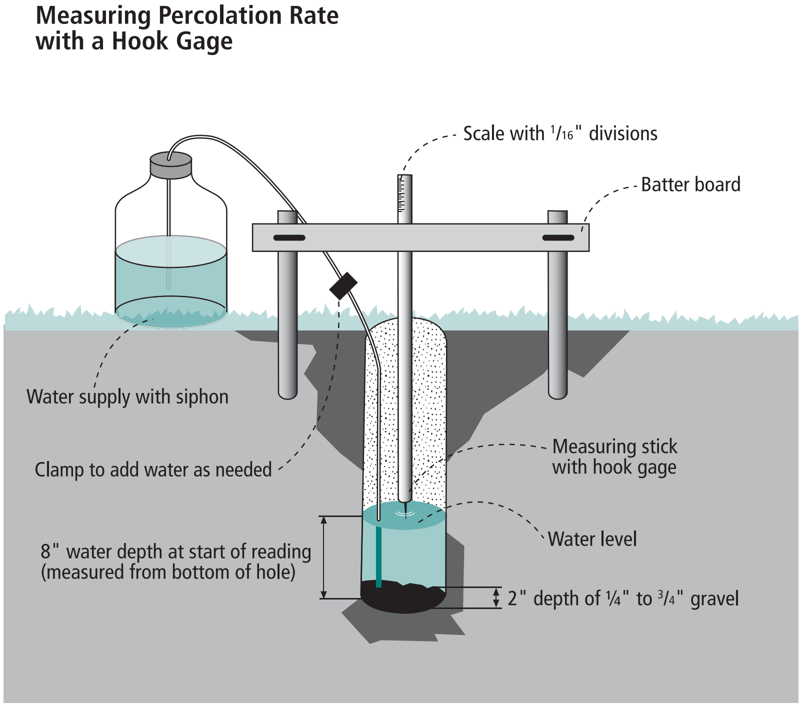
Field readings should be taken until three consecutive percolation rates vary by no more than 10%. Use the average of these three readings to determine the percolation rate for the test hole. A percolation test should not be run where frost exists below the depth of the proposed soil treatment system.

Steps in a Percolation Test

Use soil observations to locate suitable area

Soil observations should be at least three feet deeper than the proposed soil treatment system. A soil description may stop as soon as clear evidence of seasonal soil saturation

FIGURE 4.17 Percolation Rate Determined by a Hook Gage



or bedrock is encountered. Number the soil observation holes and locate them on a scale map of the site.

Locate an adequate number of test holes

If the soil texture is similar over the selected site, use at least two and preferably three percolation test holes. If the soil texture changes within the site, make at least two percolation test holes (P-1 and P-2 in Figure 4.18) in each soil texture. Space the test holes uniformly over the area proposed for the soil treatment unit.

Dig the Test Holes

The test holes should be round and at least six inches, but no larger than eight inches, in diameter. Dig each test hole as deep as you intend to excavate the soil treatment trench, bed or one foot for mounds and at-grades. The bottom of the percolation test hole must be at least three feet above the level of seasonally saturated soil or an impervious layer. A clamshell-type posthole digger can be used. If you use a six-inch auger, it is a good idea to drill a pilot hole with the three-inch auger. Observe and record the soil texture as the percolation test hole is being dug.

7080.1720 Subp. 6. B(1). Each test hole must be six to eight inches in diameter, have vertical sides, and be located in the soil. For mounds and at-grade systems, the bottom of each test hole must be in the upper 12 inches of the original soil. For trenches and seepage beds, the bottom of each test hole shall be at the depth of the absorption area.

Prepare the Test Holes

The auger or post hole digger is likely to smear the soil along the sidewalls of the test hole.

7080.1720 Subp. 6. B(3). The bottom and sides of the hole must be carefully scratched to remove any smearing and to provide a natural soil surface into which water penetrates. The scarification must not result in the hole having a diameter of greater than eight inches.

Figure 4.19 illustrates the effects of nails driven into a one-by-two-inch board, which will scarify the hole to provide an open, natural soil into which water may percolate.

7080.1720 Subp. 6. B(4). All loose material must be removed from the bottom of the test hole and two inches of one-fourth to three-fourths inch gravel or clean sand must be added to protect the bottom from scouring.

The gravel can be contained in a nylon mesh bag so it can be removed after the test is performed and used for additional percolation tests.

FIGURE 4.18 Test Hole Observations

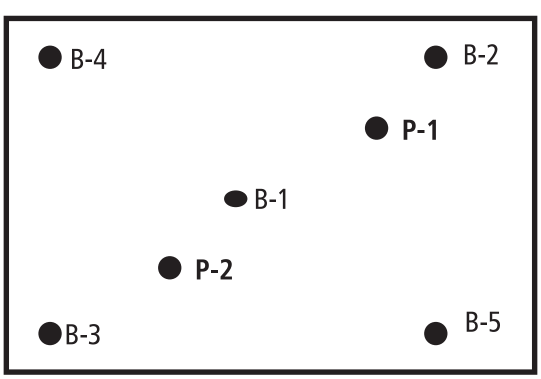
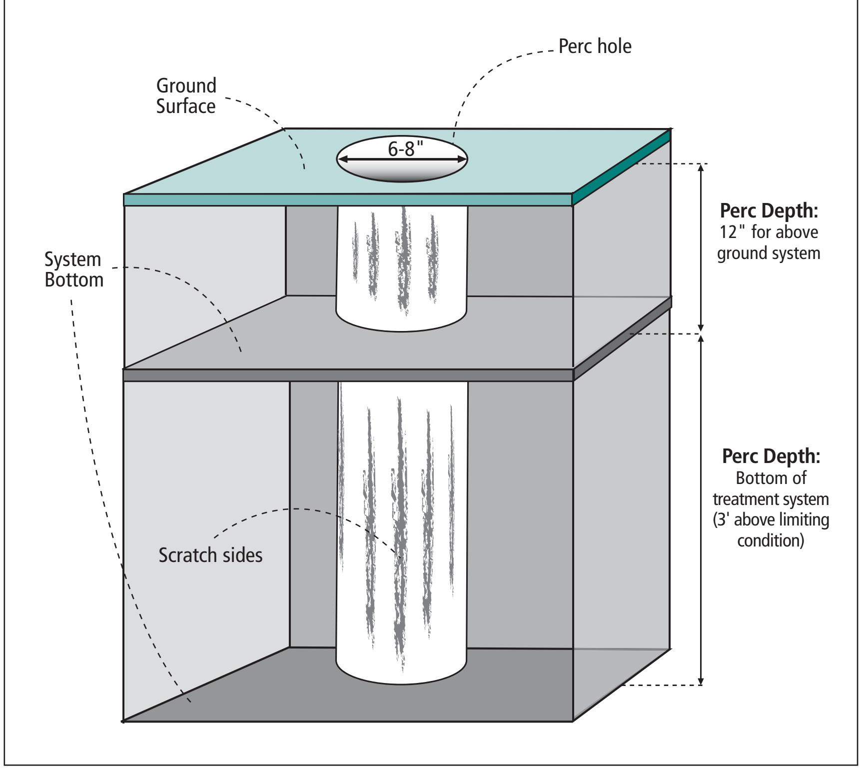


FIGURE 4.19 Prepare the Percolation Test Holes



Distinguish Between Saturation and Soil Swelling

- Saturation means that the voids between the soil particles are full of water. This can happen in a short time.
- Swelling is caused by intrusion of water into individual soil particles. This is a slow process, especially in clay soils, and is why a prolonged soaking period is necessary for some soils.

Carefully fill the percolation test hole with clear water to a depth of at least 12 inches above the soil bottom of the test hole. Use a hose to prevent the water from washing down the sides of the hole, or add the water directly in the percometer. A six-inch diameter hole requires about 1.5 gallons of water per foot of depth.

Sandy soils containing little clay do not swell. The percolation test may proceed immediately if the 12 inches of water seeps away in ten minutes or less.

For prolonged soil soaking, keep the 12-inch depth of water in the hole for at least four hours, and preferably overnight. Add water as necessary. You may use an automatic siphon or valve to maintain the 12-inch water depth (Figures 4.20 and 4.21, next page).

Measure the Percolation Rate

If more than six inches of water remain in the hole after the overnight swelling period, bail out enough water so that only six inches of water remain above the gravel (eight inches if measured from the bottom of the hole). Measure the drop in the water to the nearest 1/8 inch (preferably the nearest 1/16 inch) approximately every 30 minutes. If possible, use a percometer to determine the change in water level. A batter board can also be used as a reference point together with a hook gauge to accurately locate the water surface. The hook can be made from stiff wire or an 8d nail. After each measurement, refill the water in the hole so that the liquid depth is six inches above

FIGURE 4.20 Water Level Device for Percolation Test Hole

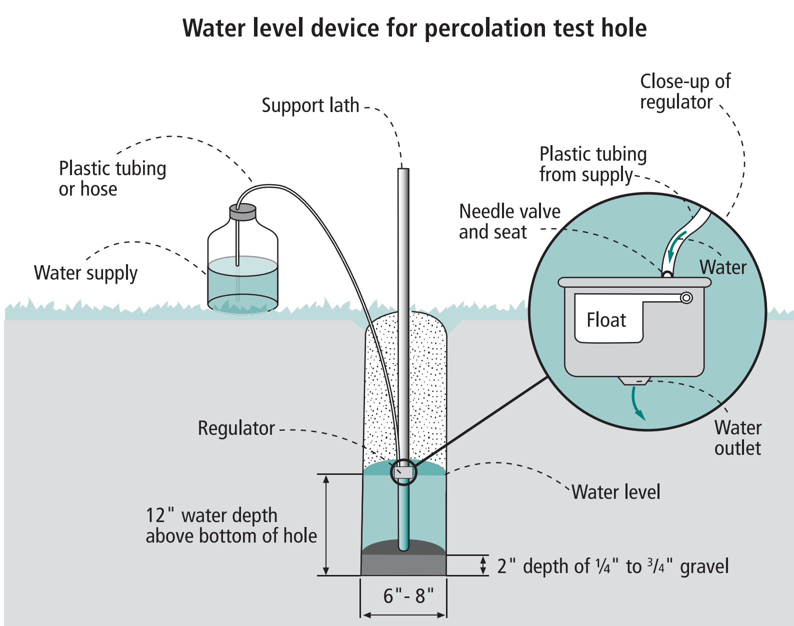
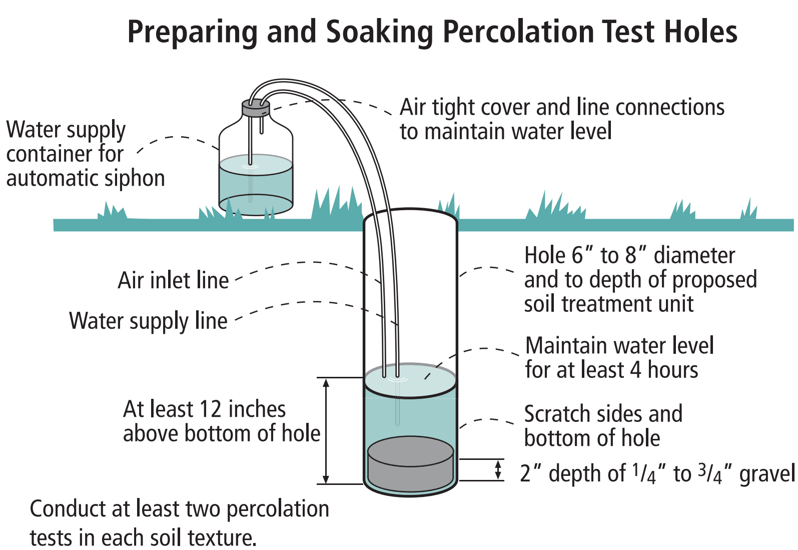


FIGURE 4.21 Preparing and Soaking Percolation Test Holes



the gravel. Continue taking measurements and filling in the percolation test data sheet until three consecutive percolation rates vary by a range of no more than ten percent.

If no water remains in the hole after the overnight swelling period, add six inches of clear water above the gravel. Measure the drop in the liquid level to the nearest 1/8 inch (preferably 1/16 inch) approximately every 30 minutes. After each measurement, refill the water to a depth of six inches above the gravel. Continue taking and recording the water level drop measurements until three consecutive percolation rates vary by no more than ten percent.

In sandy soils, or other soils in which the first six inches of water seep away in less than 30 minutes after the overnight swelling, period, allow about ten minutes between measurements. On very sandy soils, use a stop watch and measure the time in seconds for the water level to drop from six to five inches. Refill the percolation test hole after each measurement to bring water to six inches above the gravel. Continue taking readings and filling in the percolation test data sheet until three consecutive percolation rates vary by no more than ten percent.

Calculate the Percolation Rate

Divide the time interval by the drop in water level to determine the percolation rate in minutes per inch (mpi).

- If the drop in water level is one inch in 30 minutes, the percolation rate is: 30 minutes/ 1 inch = 30 mpi
- If the drop in water level is 2 1/2 inches in ten minutes, the percolation rate is: 10 minutes/ 2.5 inch = 4 mpi

Calculate the percolation rate for each reading. When three consecutive percolation rates vary by no more than 10%, use the average value of these readings to determine the percolation rate for the test hole. Percolation rates determined for each test hole should be averaged in order to determine the design percolation rate. Compare the percolation rates determined for each test hole to the soil texture to verify the soil loading rate. The percolation test data sheet showing all measurements and calculations must be submitted.

Note: A percolation test should not be run where frost exists in the soil below the depth of the proposed sewage treatment system.

Groundwater mounding

Groundwater mounding is a phenomenon that occurs in the soil when soil loading rates are greater than the soil's hydraulic acceptance rate. As this occurs, the excess water builds up or mounds in the soil. If loading rates are high enough, this groundwater mound may influence the functioning of the onsite system by reducing vertical separation or surfacing of effluent. This soil condition can be a design consideration on small lots, high water-use households, fine-textured soils, wet soil conditions, high-strength waste and cluster SSTS.

Soil Loading Rate

The final soil loading rate is a function of the soil texture, soil structure shape, soil structure grade and soil consistence.

Soil texture

Coarser-textured soils are the appropriate size for treatment of septic tank effluent while finer-textured soils are sized for hydraulic acceptance

Soil structure

Good soil structure shape and grade (e.g. strong blocky structure) will provide for more rapid acceptance of septic tank effluent and require less soil treatment area.

Soil consistence

The level of soil consistence of cementing of the soil has an influence on movement of liquids through soil. In coarse-textured soils, cementation is less desirable because liquids can move readily in these porous conditions. While, with a fine-textured soil, a moderate level of cementation results in optimal soil conditions for liquid movement.

Percolation rate

Permeability is the rate of water movement through a saturated soil in inches per hour. The percolation test measures only the rate of the drop of water in a test hole of a specific diameter and does not measure the rate of movement of water through the soil. However, the relative values obtained by the percolation test will give some index of the ability of soil to transmit water. A very slow permeability also indicates that a soil is relatively high in fine material such as silt and clay and thus, may need extreme care during the installation of the soil treatment system.

Slowly permeable layers occur in soils due to many geologic or soil-forming events. They may be layers cemented by translocation and deposition of iron, calcium, or clay. Dense layers (low porosity) are formed by the weight of glacial ice over soil parent material or by heavy construction equipment.

Basic predictive assessment methods

Proper observation, description, and interpretation of soil texture, soil structure shape, soil structure grade, and consistence will provide the designer with the information necessary to determine the correct soil loading rate. The following outlines levels of assessment in determining a soil loading rate.

Assumptions

The assumption is that the original soil conditions exist. If disturbed soils are suspected or identified, percolation tests must be run to determine the appropriate soil loading rates.

Parameters

Following the above percolation test procedures will ensure the most accurate and consistent results, when percolation tests are run multiple times at the appropriate depths. Proper soaking, hole diameter, and hole preparation will result in consistent results with published soil loading rates.

Application

The determination of the percolation rates in the soil from multiple tests for each location provides the designer with the appropriate data to determine the soil loading rate for the site and soil in question. Note: the percolation test should be used in concert with soil structure and texture identification in order to determine the most appropriate soil loading rate.

Percolation tests do not substitute for the soil description. The tests are another tool to utilize on sites where identification of soil structure is difficult or where soil disturbance(s) are suspected. Percolation tests do not indicate to the designer anything about the depth of suitable soil at the site. This must be determined by a complete evaluation of the soil profile (see Section 3: Soils).

Advanced assessment methods

There are numerous other tests available to determine saturated soil hydraulic conductivity, including the double ring infiltrometer and constant-head permeameter. They provide conductivity rates that still must be interpreted into correct soil loading rates. These methods also have limitations, as will any testing procedure.

Hydraulic Linear Loading Rate

The hydraulic linear loading rate is the potential horizontal and vertical flow patterns in the soil. Lower linear loading rates indicate fine textured soils or near surface soil limiting conditions exist.

Proper protection of tested area

Staking the Site

After initially evaluating the site, be sure to stake the location of the soil treatment area, the water supply well, the house, and other pertinent structures so that they are highly visible. The area of the proposed onsite sewage treatment system, as well as the replacement site, must be protected from any disturbance during the construction activities.

The next task is to stake off the required setbacks and home improvements. A measuring tape or wheel, stadia hairs on a level, or a range finder can measure these areas. Make sure the tank is accessible for pumping.

7080.1720 Subp. 7. The proposed soil treatment and dispersal area site shall be protected from disturbance, compaction, or other damage by staking, fencing, posting, or other effective method.

Because you called Gopher State One Call two days before beginning your soil investigation, the locations of all buried utilities have been marked.

Special equipment needed

Equipment limitations

Heavy equipment without tracks should be restricted from traveling over the soil treatment area at all times.

Traffic patterns to minimize compaction

Compaction from trafficking will damage the soil irreparably. Only allowing ISTS installation traffic with appropriate equipment on and around the soil treatment area will minimize compaction. Construct SSTS from the upslope side whenever possible.

Maximum lift/of typical pump trucks

Pump trucks must stay on compacted access points so as not to cause lawn compaction or compaction to various portions of the ISTS. Make sure that this location is accessible horizontally (hose required) and vertically (maximum lift of a pump truck is not exceeded).

Winter operation and protection from freezing

Know where winter traffic patterns will occur and require insulation of system components in these areas.

Site Evaluation Reporting Requirements

As site information is collected, it must be organized and recorded for review to determine site suitability. Providing the required information to the designer of the system eliminates the need for additional site visits.

Percolation test and soil observation data are of little value if related test sites cannot be located on a property. It is essential to relate the property location to field-identifiable reference points and to be very specific about test hole locations relative to both fixed reference points and each test site. One possible approach is to identify the distances between each test site and two reference points, such as a well and the corner of a building.

Preferably, all horizontal distances should be perpendicular to, and referenced to, a north-south line and an east-west line through the horizontal reference point, other fixed reference points, or identifiable baselines such as lot lines, roads, or fence lines.

It is the designer's responsibility to clearly identify the location of test holes by both vertical and horizontal references. The elevation of the ground surface at a test site and the reported depth of test are used to compute the elevation of the bottom of the distribution media when the system is constructed or when surface soil is removed. Quick and easy ways to measure elevations are with a builder's level, a surveying transit, or a quality hand level.

Information should be recorded on forms provided in this manual (preliminary evaluation, site map, field evaluation, percolation test and soil boring log forms). These forms should be duplicated and distributed to the permitting office and the client; a copy should be kept with the designer. The following are reporting requirements according to MN Rule Chapter 7080.1730.

a. preliminary and field evaluation results from parts 7080.1710 and 7080.1720;

b. dates of preliminary and field evaluations;

c. a map drawn to scale or dimension with a north arrow, and including (Sometimes a property is too large to illustrate conveniently all of the required information on the grid provided on the map. In these instances, use a separate sheet to draw a plot plan diagram.):

(1) horizontal and vertical reference points of the proposed soil treatment and dispersal areas, soil observations, percolation tests, and pertinent distance from the proposed ISTS to all required setbacks, lot improvements, easements, ordinary high water mark of public waters, property lines, and direction and percent slope;

(2) the location of any unsuitable, disturbed, or compacted areas; and

(3) the access route for system maintenance;

d. the estimated depth of periodically saturated soil layer, bedrock, or flood elevation, if appropriate;

All soil observations should be reported including those that were not chosen.

e. the proposed elevation of the bottom of the soil treatment and dispersal system;

f. anticipated construction-related issues;

g. the name, address, telephone number, and certified statement of the individual conducting the site evaluation;

h. an assessment of how known or reasonably foreseeable land use changes are expected to affect system performance, including, but not limited to, changes in drainage patterns, increased impervious surfaces, and proximity of new water supply wells;

i. a narrative explaining any difficulties encountered during the site evaluation, including but not limited to identifying and interpreting soil and landform features and how the difficulties were resolved; and

j. a notation of any differences between observed soil characteristics and those identified in the soil survey report.

Soil and Site Additional Reporting [Over 2,500 gpd]

As the flows of SSTSs increase, so does the inherent risks to public health and the environment. It only follows that additional soil investigations and site reporting are recommended for these systems. The following describes additional evaluation procedures.

Mounding evaluation

In previous sections, groundwater mounding was described. When larger flow SSTSs are proposed for an area, not only should groundwater mounding be considered, it should also be analyzed.

Method

There are numerous methods for analyzing groundwater mounding under various circumstances. All of the methods, even the most basic, require additional field testing and knowledge of the geometry of the proposed SSTS.

The appropriate method(s) will depend on your site/soil conditions, flow, local ordinance and potentially additional factors. Generally, hand calculations to complex computer model simulations may need to be conducted in order to analyze the potential for groundwater mounding. This analysis also provides possible solutions in loading rates, system layout, etc. Refer to the MPCA publication, "Prescriptive Designs and Design Guidance for Advanced Designers," published on the MPCA web page for more information.

Results

Most of the output from the various methods will estimate a mound height. From this output, the designer can determine if this mound height will interfere with long-term treatment and acceptance of septic tank effluent for the large SSTS. A change of location or change in geometry of the soil treatment area may lower the mounding height when the analysis is run again. This process is iterative until the geometry and the mounding height are acceptable.

Nutrient evaluation

Phosphorus and nitrogen can be issues for large SSTS and larger systems. A proper design for nutrient (i.e., phosphorus and nitrogen) reduction depends on careful consideration of the size of the system and the sensitivity of the site.

Nitrogen can exist in many forms in the SSTS. Organic N and ammonia forms of nitrogen can be stored in the soil and are not susceptible to leaching, while nitrate-nitrogen has been identified as a potential drinking water contaminant from many SSTS. As the size of the system increases, the risk of the impact of this nitrate to the groundwater is enhanced. Because nitrate-N can move through the soil with very little treatment, it is important that if nitrogen levels need to be reduced, that an appropriate pretreatment is selected and implemented.

Phosphorus is most often considered a concern near surface bodies of water. It is common to have more stringent requirements on P levels with coarser textured soils close to these surface waters. See Section 3 - Nutrient removal for nutrient dynamics in SSTSs.

Problem soils assessment

Designers can recognize many problem soils, as discussed previously (see Section 3: Soils, "Soil treatment," as well as information throughout this Section and especially in "Problem sites and soils" below). Additional soil and site concerns exist when flows are increased. Additional and deeper soil observations, preferably soil pits, will result in the proper design considerations.

Topographic and site variability evaluation

When a site is being utilized to accept and treat over 2500 gallons of septic tank effluent daily, the SSTS covers a larger portion of a site. This larger area can mean more topographic and site variability. Minimizing this variability or splitting systems into parts will allow for better site utilization while ensuring the system is appropriately placed on the contours.

Soil property variation and interpretation

Additional borings will be required to minimize or assess soil property variation. Designing for the most limiting conditions will be required for all SSTSs.

Water table monitoring basics

Some MSTS or ISTS will require water table monitoring to verify vertical separation is maintained throughout the operation of the system. A minimum of three feet of separation is required for adequate treatment of septic tank effluent. For a complete guide on installation and monitoring of water tables, consult "Installing monitoring wells/piezometers in wetlands," US Army Corps of Engineers Wetlands Regulatory Assistance Program (2000) or "Prescriptive Designs and Design Guidance for Advanced Designers" on the MPCA web page.

For vertical separation monitoring, there is no extraction of a sample, and the equipment can be installed by any qualified person. If a sample is periodically extracted to test for nutrients, contaminants, etc., and a licensed well driller must install the monitoring well.

Equipment

To build a simple monitoring well, a commercial well screen is attached at solid piping at the ground surface or above. The hole should be excavated to a minimum of three feet below the depth of the distribution media. The depth should not be great enough to enter into a less restrictive soil horizon. If this is the case, the well should be installed within the same soil horizon as the distribution media.

Monitoring with chalk tape, bubbler tubes, automated recorders, or a simple rod are all acceptable methods for determining the depth at which to install the monitoring well.

Record the data in the field on data sheets and compile on a computer spreadsheet for comparison of years, precipitation, etc.

Duration

Monitoring should occur at least four times a year (April-May, June, July-Aug., Sept-Oct.) with biweekly sampling from spring to early May. Sampling is less likely in the winter months, depending on usage patterns. The monitoring should continue for no less than three to five years to account for seasonal fluctuations in temperature and precipitation.

Proper location

In order to determine if separation is being maintained, the wells must be installed within the area of influence of the SSTS. Depending on the configuration of the system, soils and site, the location of this area can vary. Locating the monitoring well so that effluent is not preferentially moving to the new opening is critical to accurately assessing separation. It is also recommended to install a monitoring well outside of the influence of the system (along a contour) to monitor natural soil conditions in case an increase in system area is needed in the future.

Problem Sites and Soils

Type I, II, III, IV, and V Systems

Rapidly Permeable Soils

Sands and Gravels

Soil treatment systems in soils with percolation rates faster than 0.1 mpi or in sands with 35% - 50% rock fragments must not allow direct contact between the distribution media and the highly permeable soil.

7080.2150 Subp. 3 (L). The distribution media must not be in contact with soils with any of the USDA soil textures classified as sand with 35 percent or more rock fragments or loamy sand with 35 percent or more rock fragments or any soils that have a percolation rate of less than 0.1 minute per inch.

An option in these soils is a liner system consisting of trenches with at least 12 inches of clean sand placed between the drainfield rock and the coarse soil along the excavation bottom and sidewall. The soil loading rate to use in this liner situation is the sizing for the liner material, 1.20 gpd/sqft. Additional requirements must be addressed, including two additional vertical feet of suitable soils that are not sands with greater than 35% rock fragments. Another option for such a site is to keep investigating the site. Perhaps there is natural variation in soil textures that would allow for proper septic tank effluent treatment.

MN Rules Chapter 7080.2210 Subp. 4 (F) dictate the treatment techniques required for an ISTS where the distribution media is in contact with any sand textured soils:

(1) employ pressure distribution according to part 7080.2050, subpart 4;

(2) divide the total dispersal area into multiple units that employ serial distribution, with each dispersal unit having no greater than 15 percent of the required bottom absorption area; or

(3) have a vertical separation distance of at least five feet.

Loamy, Medium, and Fine Sands

Soils in this percolation range contain uniform sand sizes in the fine and very fine classes. The concern in these soils is poor distribution and little or no treatment by overloading of the trench before the biomat is formed. Using the sandy soil loading rates has led to the construction of hydraulically undersized systems, so for soils that are classified as fine sands or loamy fine sand textured (i.e., more than 50 percent fine and very fine sand by weight, between sieve sizes 270-60), the required soil loading rate is 0.60 gpd/sqft, if weak grade.

Small Lots

General Description

Generally these are existing lots in small communities, lakeshore areas, or existing developments with restricted land area. Many of these existing lots may still utilize soil-based treatment techniques, but the design and assessment will require more analyses, as specified under Type III systems in 7080.2300.

Solutions

The best solutions on these difficult lots is to provide as much treatment of the septic tank effluent as necessary before the treated effluent is discharged to the soil treatment area, as size of the soil treatment area is most often compromised. Most of these options will result in these systems being classified as Type III systems. The complete technical requirements for such systems is found in 7080.2300.

Reduce water consumption or reuse

Using low flow fixtures, practicing water conservation, and investigating reuse options will reduce the amount of flow and can result in better treatment in the soil treatment area. Accurately monitoring water flows can also raise the residents' water use awareness.

Small field with holding tank

A safety precaution: when the soil treatment area is no longer treating effluent (i.e., the effluent is surfacing or backing up) the ISTS can function as a holding tank and be pumped until the soil treatment area has recovered.

Pretreatment to reduced size drainfield

Pretreated effluent can be cleaned to similar levels as the surface and/or groundwater in the area. The soil treatment area in this case is often simply used for additional treatment and for hydraulic acceptance.

Time dosing from large pump tank

When small lots have ISTS, time dosing spreads the flow of water out evenly over the day. This allows the soil treatment area to treat water and hydraulically accept it before it is loaded with more effluent. This lowers the potential of the system surfacing.

Box mound/vertical side wall mound

The construction of a box or vertical side wall mound is another solution for small lots. It reduces the size of the absorption area.

Lack of Unsaturated Soil

A lack of unsaturated soil is common in parts of Minnesota. Careful consultation with local zoning officials is required to make sure that impacts of the ISTS do not interfere with protected wetland areas. These systems are classified as either Type IV or Type V.

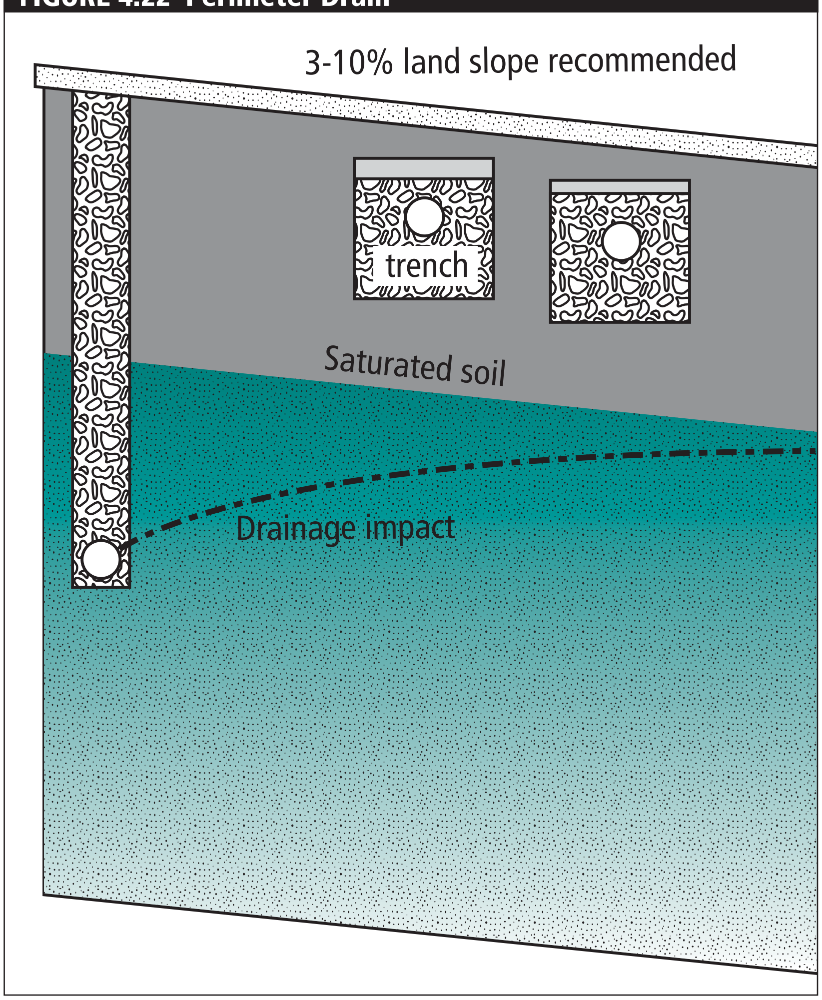
Pretreatment technologies

Pretreatment is the most reliable form of treating effluent in this situation. Following the discussion in Section 10: Pretreatment is paramount to the success of these systems. All technical requirements are discussed in rule 7080.2350 and 7080.2400.

Reduced hydraulic linear loading rate

Lowering the linear loading rates will allow for more available soil to treat each gallon of effluent. Where practical, this can provide additional treatment.

FIGURE 4.22 Perimeter Drain



Texture break

Sometimes there are textural discontinuities in the soil that cause soil to saturate, but underlying the restrictive soil layer there may be unsaturated soil conditions. SSTSs designed below these layers lack oxygen required for treatment, and often overload the underlying soil with effluent plus any additional soil-water from the perched horizon(s). In addition, as SSTS depths increase, microbial community populations decrease, which further limits treatment.

Designed perimeter drain tile/curtain drain

Note: the use of this technology is not standard. Please consult MPCA *Policy on Utilizing Artificial Drainage Methods* and the permitting authority to determine if such a system is allowed and other associated requirements before design/installation. Some site conditions warrant a subsurface drainage system that conveys upslope surface and subsurface run-on away from the soil treatment area. These systems are called perimeter or curtain drains. The are implemented on sites with perched water tables.

These drainage systems do not lower the water table, they simply remove excess water from the site as shown in figure 4.22. Frequent monitoring of these systems is required to verify that vertical separation is maintained throughout the SSTS operation.

Reduce water consumption or reuse

Using low flow fixtures, practicing water conservation, and investigating reuse options will reduce the amount of flow and can result in better treatment in the soil treatment area.

Disturbed Soil

See previous sections, discussion on types of disturbances to the soil that may warrant additional testing or design features. When soil disturbance is suspected, running percolation tests across the proposed areas will determine the extent and severity of the disturbance on soil water movement (soil loading rate). Interpreting the limiting conditions is complicated because the soils have been modified. Careful examination of surrounding areas, landscapes, aerial photographs, etc. may be required to reconstruct saturated soil elevations. Monitoring can be established to verify the vertical separation. Any design using disturbed soils will be considered a Type III, Type IV or Type V system. These systems must meet all associated requirements.

Soil modification methods

Options

There is no substitute for natural soil structure that has developed over thousands of years and is held in its characteristic shapes by organic matter, clays, and/or iron. This gluing effect is the key to consistent water movement through the soil.

There are many ways to rejuvenate the soil after disturbances have occurred; nevertheless, the one similarity of all methods is that they are temporary because they lack the gluing agents to keep the soil in aggregate forms. Rejuvenation will need to occur on a semi-regular basis throughout the life of a system. Monitoring of separation distances can help to determine when the soil has lost functionality and another rejuvenation treatment is needed. It is always recommended when you find disturbed soils that you consult with the LGU before proceeding with a design or site modification.

Excavate out the disturbed soil

One option, especially fill soil areas, is to excavate out the fill soil to the natural soil elevation. This eliminates the fill soils and lack of structure, but oftentimes there has been disturbance to the natural soils, too. They have been subjected to the additional weight of the fill soil, compacting the underlying soils. The natural soils may have also been compacted by whatever activity caused the fill to be placed in those locations. When areas such as these have been filled, they are typically low-lying or wet areas and water levels could be higher than historical levels due to the compaction.

Overexcavating the disturbed area is another option. Here caution must be used when determining the appropriate elevation of the system because simply removing the affected soil does not change the site soil-water conditions. Backfilling of the area must be completed with clean sand (mound sand). The system can then be designed and installed at the proposed elevations.

Use of the disturbed soil

Avoidance of the disturbed area(s) is the obvious and most cost-effective means of dealing with altered soils. If this cannot be accomplished, OSTP recommends a minimum of three to five percolation tests is needed across the proposed areas to attempt to evaluate the hydraulic functioning of this soil. The soil texture and soil structure (if present) should also be evaluated. The most conservative soil loading rate (largest number) should be used from the combination of both techniques. Monitoring separation distances to ensure proper operation is oftentimes a requirement.

Manipulate the disturbed soil

Another option for mound sites where the native soil has been compacted is to place six inches of clean sand over the prepared native soil. Incorporate the clean sand with the native soil by dragging the backhoe bucket teeth or deeply cultivating (subsoiling) to create channels of clean sand, permitting water movement through the compacted soil. This does not alter the depth to the saturated soil condition, but is another remediation technique for compacted mound sites.

Limitations

There are numerous limitations to any of the above modification techniques. To ensure they are appropriate for a given set of soil and site conditions, consult with the local permitting authority. If questions about effectiveness persist, contact the MPCA or the University of Minnesota for further technical assistance.

Effects

Soil compaction is permanent. Any modification is temporary and is less than ideal. This does not mean that modifications cannot work, but that they simply may be more complicated, costly, and may increase maintenance/monitoring requirements.

Design pressure distribution with varying elevation

See Section 12 - Distribution for discussion.

Valving with management

See Section 12 - Distribution for discussion.

Varying perforation sizes and spacing with valving and management

See Section 12 - Distribution for discussion

Flooding

This problem is usually associated with existing structures as construction would be prohibited in the flood plain. An existing structure in a floodplain with a failing system may need a replacement system.

The concerns about floodplain areas during flood events include surface water contamination and system damage by fine soil particles contained in the flood waters. Where ten-year flooding elevations are known, the following is a requirement for trenches,

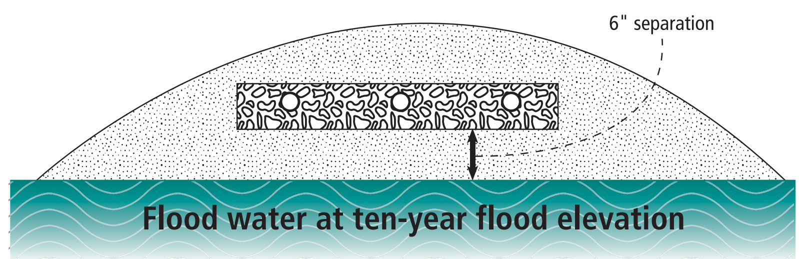
7080.2270 Subp. 5. …the bottom of the distribution media must be at least as high as the elevation of the ten-year flood.

For mounds,

7080.2270 Subp. 7. A. the elevation of the bottom of the rock bed must be at least one-half foot above the ten-year flood elevation (Figure 4.23).

The complete design criteria for Type II systems in flood fringe areas are found in MN Rule Chapter 7080.2270.

FIGURE 4.23 Vertical Separation for Ten-Year Flood Elevation



Slowly Permeable Soils

Suitable soils for Type I systems range from percolation test values of < 0.1 to 120 mpi in the soil in which the soil treatment area will be located. For soils with percolation rates higher than 60 mpi, consistent design considerations should be applied (see following section 60 to 120+ mpi). (Systems for soils with percolation rates less than five mpi are described in Systems for Rapidly Permeable Soils.)

Slowly permeable soils do provide adequate treatment, but problems are often encountered with the acceptance of effluent, construction of the ISTS, and vertical separation from saturated soils. Systems in these soils are frequently considered Type III, Type IV or Type V systems.

60 to 120+ mpi

In these soils, never dig if the soil is at all moist. Construction of seepage beds is not technically feasible because of compaction of the bottom area during construction by vehicular traffic. There is also limited oxygen exchange underneath the center of the bed. A good rule of thumb in dealing with these soils is to keep the system dry, shallow, narrow, and natural. Consult with the local permitting authority for specific requirements or preferred techniques on these difficult sites.

Solutions:

- Mound or at-grade systems with reduced loading rates and differing levels of pretreatment (depends on soil texture, structure shape, structure grade and vertical separation distance).
- A liner system, in which a liner of sand is placed in the trench to reduce the compaction and settling when distribution media is placed into the trench

Soil Descriptions

Soil descriptions are used to identify different horizons and determine if the soil has the ability to treat and dispose of the applied wastewater. Soil descriptions must be objective, complete, and clear.

Texture

See Section 3: Soils, "Soil texture" for a complete discussion on texture description and determination.

Structure

See Section 3: Soils, "Soil structure" for a complete discussion on the important aspects of soil structure.

Color

For a complete soil color discussion, see Section 3: Soils, "Soil Color."

Landscape

A complete landscape description should be included in any field evaluation and report. This includes landscape, landform, hillslope position, slope shape, slope direction, and slope gradient, as previously discussed in this Section under "Field evaluation."

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Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions [Online WWW]. Available URL: www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/home/?cid=nrcs142p2_053587 [Accessed 6 October 2017].

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United States Department of Agriculture, Natural Resources Conservation Service. 2017. Field Indicators of Hydric Soils in the United States, Version 8.1. L.M. Vasilas, G.W. Hurt and J.F. Berkowitz (eds.). USDA,NRCS, in cooperation with the National Technical Committee for Hydric Soils.

Appendix 1

Minnesota Wetland Conservation Act Contractor Responsibility and Landowner Statement Form

DEPARTMENT OF NATURAL RESOURCES

BOARD OF WATER AND SOIL RESOURCES

Landowner Statement and Contractor Responsibility

For Work in Wetlands or Public Waters

MN Statutes Sections 103G.2212 and 103G.241 stipulate that an agent or employee of another may not:

1) drain, excavate, or fill a wetland, wholly or partially; or
2) construct, reconstruct, remove, or make any change in any reservoir, dam, or the course, current, or cross-section of any public water;

unless the agent or employee has obtained a signed statement from the property owner stating that any permit or wetland replacement plan required for the work has been obtained, or that a permit or replacement plan is not required; **AND** this statement is mailed to the appropriate office with jurisdiction over the wetland or public water prior to initiating the work (see next page for information on where to send this notification).

This form is a notification only and is not an application or authorization for any activities described in it.

1. PROJECT INFORMATION

Project will affect (check all that apply):

☐ Lake, Watercourse, or Public Waters Wetland ☐ Non-Public Waters Wetland ☐ Wetland of Unknown Jurisdiction

Address or description of project location (attach map if necessary):

Legal address						
County	Gov't Lot(s)	Quarter Section(s)	Section(s)	Township(s)	Range(s)	Lot, Block, Subd.

Description of proposed work (include sketch and/or attach additional pages if needed):

2. LANDOWNER STATEMENT

I certify that, as the owner of the property listed on this form (check one):

☐ I have obtained all permits or approvals required to perform the work described above.

☐ No permits or approvals are required for this work.

Property Owner (Print Name)	Address	
Signature	Date	Phone Number and E-mail Address (Optional)

3. CONTRACTOR VERIFICATION

By signing below, I verify that I have received a signed copy of this form and will be performing the indicated work as described above.

Company and Individual Performing Proposed Work (Print)	Address	
Signature	Date	Phone Number and E-mail Address (Optional)

Note: The contractor is responsible for ensuring this form is mailed to the appropriate office when complete.

This statement is invalid if any of the above information is not supplied or is inaccurate. Work in violation of this notification requirement is a separate and independent offense from other violations of Minnesota Statutes chapter § 103G and is a misdemeanor punishable by fines up to $1,000 and/or 90 days in jail. The State Department of Natural Resources (DNR) Commissioner also has the authority to require restoration of any work done without the necessary permits or approvals or work that is beyond what was authorized.

4. INFORMATION AND RESOURCES

A Wetland Conservation Act (WCA) replacement plan is required for any wetland draining, excavation, or filling activity that is not exempt under Minnesota Rules Chapter 8420.0420. A DNR Waters permit is required for any work in public waters.

National wetland inventory maps are available for review at the County Soil and Water Conservation District (SWCD) office and online at http://www.fws.gov/wetlands/Data/Mapper.html. Many wetlands are not identified on the maps but are still restricted from draining, excavating, or filling. If you are unsure the proposed work will affect a wetland, contact your local government unit (LGU) or SWCD for assistance.

Public Waters of the State of Minnesota include the channel to the top of the channel bank for watercourses and the basin from the ordinary high water level waterward for public waters (i.e. lakes) and public waters wetlands. Public waters inventory maps are available for review at the County Auditor's office, DNR Division of Waters regional offices, and online at http://www.dnr.state.mn.us/waters/watermgmt_section/pwi/download.html.

General information about public waters, wetlands, and related regulations are available on the DNR website at http://mndnr.gov and the MN Board of Water and Soil Resources (BWSR) website at http://www.bwsr.state.mn.us.

5. WHERE TO SEND THIS NOTIFICATION

- For work in public waters (lake, watercourse, or public waters wetland), send this completed form to the DNR Regional Enforcement Office serving the project's area. See below for DNR regional office information. A map of DNR regions can be found on the DNR website at: http://files.dnr.state.mn.us/aboutdnr/dnr_regions.pdf
- For work in any wetland that is not a public waters wetland, send this completed form to the WCA LGU with jurisdiction over the project area. The LGU is usually the County or SWCD, except in urban areas the City is often the LGU. Contact any of these local governments or BWSR for assistance. BWSR also maintains a list of LGUs on its website at: http://www.bwsr.state.mn.us/directories/WCA.pdf.
- If it is not known if the wetland is a public waters wetland, send the completed form to both the DNR Regional Enforcement Office and the WCA LGU.

Department of Natural Resources Regional Offices

Northwest Region:	Northeast Region:	Central Region:	Southern Region:
2115 Birchmont Beach Rd. NE Bemidji, MN 56601 Phone: 218-308-2700	1201 E. Hwy. 2 Grand Rapids, MN 55744 Phone: 218-327-4455	1200 Warner Road St. Paul, MN 55106 Phone: 651-259-5800	21371 State Highway 15 New Ulm, MN 56073 Phone: 507-359-6000

Keep a copy of this form for your records!

SECTION 5: Wastewater Sources & Flows

WASTEWATER SOURCES AND FLOWS

Wastewater Sources

To start this section, it is first important to define these two terms:

1. Wastewater: clear water, stormwater, industrial, sewage (domestic or commercial), or any combination thereof, carried by water.
2. Source: location at which wastewater is generated.

This manual will focus on the sewage constituents of wastewater, but we need to assess the other components to discover if they will interact and affect the onsite sewage treatment system in any way.

Sewage

Definition

Sewage is waste produced by toilets, bathing, laundry, or culinary operations or the floor drains associated with these sources, and includes household cleaners, medications, and other constituents in sewage restricted to amounts normally used for domestic purposes (MN Rules Chapter 7080.1100, Subp. 73). Sewage does not include "clear" water such as swimming pool water, roof drainage, water softener recharge water, or water used to irrigate lawns or gardens.

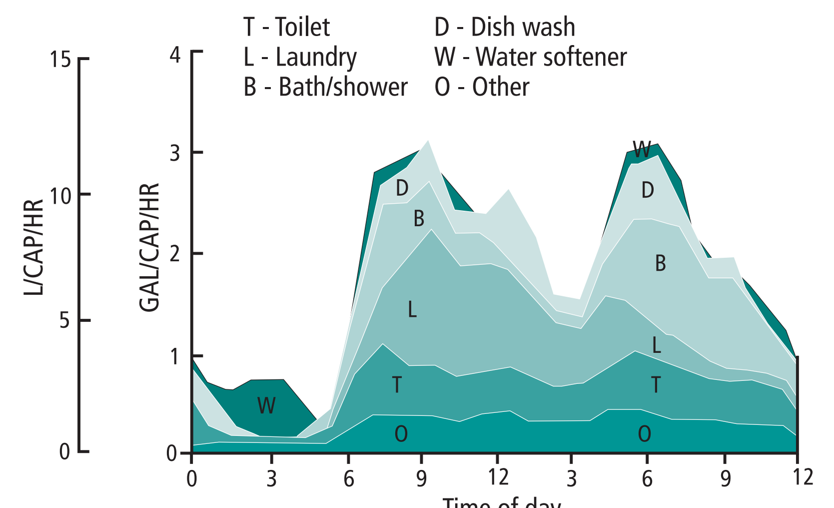
There are several types or categories of sewage that have been nationally defined by the Consortium of Institutes for Decentralized Wastewater Treatment (CIDWT, 2009):

1. Blackwater: portion of the wastewater stream that originates from toilet fixtures, dishwashers and food preparation sinks.
2. Graywater: water captured from non-food preparation sinks, showers, baths, spa baths, clothes washing machines, and laundry tubs. **Graywater is defined in MN Rules Chapter 7080.1100, Subp. 37 as sewage that does not contain toilet wastes. A Graywater system is one that receives, treats, and disperses only graywater or other similar system as designated by the commissioner (MN Rules Chapter 7080.1100, Subp. 38).** Toilet wastes from the residence or other establishment have to be treated in some other system, or the residence has to have a privy. To prevent hooking up a flush toilet onto a graywater system, the plumbing of the system must have two-inch diameter pipe, rather than four-inch. Even the floor drains have to use two-inch pipe. The exception is for a graywater system being installed for an existing building. There is no need to re-plumb the entire structure. Graywater systems cannot accept garbage disposal waste. Graywater must be fully treated and is further discussed in Section 7.
3. Yellow water: an isolated waste stream consisting of urine collected from specific fixtures and not contaminated by feces or diluted by graywater sources; see also urine separating device.

The amount and type of water discharged to an onsite sewage treatment system is one of the factors used in sizing that system. Other factors that influence sizing include soil properties such as texture, structure, and percolation rate.

Designing a wastewater treatment system based upon average daily flow would imply that the system is operating beyond its design capacity 50 percent of the time. For this reason, treatment systems are typically designed to produce the required effluent quality when treating the maximum daily flow. This accounts for the natural variability in the amount and strength of wastewater entering a SSTS as shown in Figure 5.1.

FIGURE 5.1 Peak Wastewater Flows from a Single-Family Home



Source: Univeristy of Wisconsin, 1978

The amount of wastewater entering the treatment system is the hydraulic loading rate. In sizing for the hydraulic loading rate, the volume of water flowing through the treatment process is the design parameter under consideration. For the concept of mass loading rate, the idea of the mass or weight of a particular contaminant flowing through the system over some time is considered. The "organic loading rate,"the number of pounds or kilograms of BOD per day, and the "solids loading rate," the number of pounds or kilograms of TSS per day, are common mass loading rates.

Water use varies widely among individuals, depending on such factors as background, age and economic status. For example, an individual who was raised in a household without running water will probably be very conservative in water use even when running water is available. Teenagers are typically high water users. The use of hot tubs or water-circulating devices for therapeutic services greatly increases water use.

A number of studies have been made throughout the country on water use habits and rates. In studies made during the 1970s, average water use per person, nationwide, was about 45 gallons per day. A 1999 study found a national water-use rate of about 60 gallons per person per day with a variation of plus or minus 40 gallons per day (Mayer et al. 1999).

Domestic sewage is generated by a dwelling, a toilet facility at an establishment open to the public, rental units such as motels and resort cabins, shower and toilet facilities for schools or campgrounds, or anywhere typical domestic wastewater is created.

Non sewage sources

Clear water additions

Clear water (including groundwater, rainwater, surface water, condensate, ice machine drainage, and/or discharge from pools, hot tubs, and water treatment devices) fits into this category. Sources of clear water should not be directed to the system; if connected, they can create problems in the system. A number of water-using devices (such as water softeners, iron filters and water treatment devices) do not produce sewage as defined in MN Rules Chapter 7080. These devices do produce effluent, but that effluent has not come in contact with humans or laundry to create contamination that needs to be treated or removed. Water treatment discharge is defined by CIDWT as the by-product from a water treatment device, such as regeneration water from an ion-exchange unit, reject water from a reverse-osmosis unit, or the backwash from an iron filter and does not need to be directed to a SSTS.

Water softeners reduce the number of or remove calcium and magnesium ions, which are the principal causes of hardness in water. Cation exchange resin method is most commonly used for residential and commercial water treatment. Water softener and iron filter recharge water adds a large volume of water to the system – typically 30 to 80 gallons per cycle. This is water that does not require treating.

A growing concern with water softener recharge water is that it may cause an increase in the amount of solid material that remains suspended in the liquid layer (effluent) in the septic tank and ends up in the drain field trenches or a mound. These solids may shorten the life of the soil treatment system, increasing the chance of drainfield or mound failure. Water softener discharge has conflicting results in research studies, but it does appear that scum layers are often absent in tanks where the water softener recharge water enters the septic tank.

Iron filters

Iron or manganese in water does not present a health hazard, although there are some concerns that manganese in high levels can harm the nervous system. Their presence in water may cause taste, staining and accumulation problems in the plumbing system. Iron and manganese deoposits will build up in pipelines, pressure tanks, water heaters and water softeners. This can reduce the available quantity, quality and pressure of the water supply. Iron and manganese accumulations become an expensive problem when water supply or softening equipment must be replaced. In addition, pumping water through constricted pipes or heating water with rods coated with iron or manganese minerals increases energy costs. A related problem is iron or manganese bacteria. These nonpathogenic microbes feed on iron and manganese in water. They form red-brown (iron) or black-brown (manganese) slime in toilet tanks and can clog water systems.

Standards for iron and manganese are based on levels that cause taste and staining problems and are set under EPA Secondary Drinking Water Standards. For most individuals, 0.3 parts per million (ppm) of iron and 0.05 ppm of manganese is objectionable. Usually iron and manganese do not exceed 10 ppm and 2 ppm, respectively, in natural waters. Iron and manganese can be found at higher concentrations; however, that condition is rare.

How do iron filters work?

For household water containing high levels of iron and manganese, the most common solution is a process using oxidation followed by filtration. Oxidation is accomplished by introducing an oxidant (such as oxygen) into the raw water. Sources of oxygen included the air as well as chlorine or potassium permanganate. Through a series of chemical reactions, oxidation converts soluble contaminants into insoluble solid particles. The solidified contaminants are then firltered out, and the backwash cycle removes the filtered particles from the filter.

Most iron filters remove both clear water iron and ferric iron (rust). Even water that is clear in color may contain high levels of iron. This is known as 'ferrous' or clear water iron. Using the oxidation process described above, home iron filters take this clear water iron (ferrous iron) and convert it into small particles of iron soids (ferric iron) that can be captured by a mechanical filter. These trapped particles are periodically and automatically backwashed out with the flush/backwash of the filter, usually once or twice a week. This typically results in 150-200 gallons per backwash cycle resulting in 10,000 - 20,000 additional gallons of wastewater with these iron solids being discharged annually. If being discharged to a septic system, long-term system performance may be at risk.

It is uncertain what happens to the particles that are backwards from the filter, and into a septic system, but there are several potential hazards that can impact system performance:

1. The solids may settle out in the sludge layer of the septic tank and increase the need for maintenance.

2. During times of turbulence or if sludge depths get too thick this material may travel through the septic tank to downstream components. This material can create challenges in a pretreatment system and/or the soil treatment area. In the soil treatment area, it may cause growth and plugging in the piping systems and plugging in the soil itself.

3. In the anaerobic environment of the septic tank, the insoluble iron is converte to soluble iron going into solution and traveling out of the septic tank and downstream. There is then the risk in the aerobic environment following the septic tank that the iron will be made insoluble again, form a precipitate and potentially clog piping and the soil treatment system.

Can a water softener be used to remove iron?

Water softeners remove hardness using a resin and remove dissolved clear water iron by a process known as ion exchange. However, iron, manganese and/or hydrogen sulfide gas will eventually overwhelm the resin causing fouling and failure of the ion-exchange resin. If your water contains less than 2.0 ppm of iron and manganese combined, and no sulfur odor, then a good quality water softener with a special type of resin cleaner in the brine tank will work. The resin cleaner will help clean the resin when the softener is being regenerated with the brine solution. If not, a home may need both an initial iron filter followed by a water softener. In this case, the water softener discharge water should be dealt with in the same manner as the iron filter discharge.

Challenges

There are three potential challenges related to iron filters and septic systems:

1. Iron filter recharge chemicals may contain a bleaching or sanitizing agent, which is detrimental to bacterial action in the septic system.

2. The additional water (150 to 200 gallons to recharge and backwash) several times a week adds additional wastewater into the system. Depending on other use in the home, the additional water to the septic tank and soil treatment area may cause problems with septic system operation or may overload it.

3. If the solids are suspended in the septic tank effluent or re-solubilized, they may plug downstream components.

Options

If possible, the water used for outside use and irrigation should not be filtered. This will reduce the amount of water treated and the amount of particles. Discharge of iron filter backwash to a septic system is not recommended due to the nature of these solids.

Below are some options to consider:

1. New home? If an iron filter is needed due to the source of water at the home, then the backwash discharge may be incorporated into the design of the septic system. In this case there are two options:

   a. Preferred: Install a separate soil treatment system for the regeneration water which includes a septic tank to settle out the solids. If a septic tank is not installed the separate system will likely plug over time. The trench bottom must be above the periodically saturated soil or bedrock and trench must meet water supply well setbacks.

   b. Secondary option: Discharge to the surface; not directly into a surface water, wetland or intermittent stream where water must soak into the ground where it has been discharged. Discharge must stay on the property and not cause erosion or nuisance conditions.

   c. Less preferred: Install a larger septic tank (double the capacity is the recommended minimum) with an effluent screen and alarm and clean the septic tank annually while evaluating sludge level.

2. Existing home: The best solution for an existing home will depend on the plumbing system and the related costs. This may require the installation of a sump in the basement or crawlspace to collect the backwash water.

   a. Whenever possible the backwash water should be routed to another location (see a and b above).

   b. Maintain septic tank annually to remove settled particles.

Reverse osmosis is a separation process that uses pressure to force water through a membrane that retains the solute on one side and allows the pure solvent to pass to the other side. More specifically, it is the process of forcing a liquid from a region of high solute concentration through a membrane to a region of low solute concentration by applying a pressure in excess of the osmotic pressure. This is the reverse of the normal osmosis process, which is the natural movement of solvent from an area of low solute concentration, through a membrane, to an area of high solute concentration when no external pressure is applied. The membrane here is semi-permeable, meaning it allows the passage of liquid but not of solute or particles.

The membranes used for reverse osmosis have a dense barrier layer in the polymer matrix where most separation occurs. In most cases, the membrane is designed to allow only water to pass through this dense layer while preventing the passage of solutes (such as salt ions). This process requires that a high pressure be exerted on the high concentration side of the membrane, usually 2–17 bar (30–250 psi) for fresh and brackish water, and 40–70 bar (600–1000 psi) for seawater, which has around 24 bar (350 psi) natural osmotic pressure which must be overcome.

Reverse osmosis units sold for residential purposes offer water filtration at the cost of large quantities of waste water. For every five gallons of output, a typical residential reverse osmosis filter will send around ten to 20 gallons of water down the drain (although many people capture it and use it for watering plants and lawns). In some states this water is used for irrigation.

High-efficiency furnaces operate at a high efficiency and therefore save on energy use. One of the results of the heating process is that condensation occurs in the unit. When this condensation builds up, water slowly trickles out of the unit and into the plumbing that is often connected to an onsite system. This water can cause freezing problems in the onsite system because of the slow, steady flow. In addition, this water is clean and therefore does not need to be treated. When the furnace is in operation, this water typically trickles out of the unit at a volume of five to ten gallons on a cold day.

In high-efficiency furnaces, the recharge water from water softeners and iron filters has the potential to cause problems with onsite sewage treatment systems.

Industrial wastewater

Industrial wastewater is the water or liquid-carried waste from an industrial process resulting from industry, manufacture, trade, automotive repair, vehicle wash, business or medical, activity that may contain toxic or hazardous constituents.

Garage floor drain liquid wastes from garages serving single and multi-family homes can consist of the following:

- Precipitation draining from vehicles and liquids from vehicle washing
- Spills from materials stored or used in the garage such as: Thinners, solvents, paints, pesticides, cleaners, etc.
- Liquids from vehicle repair such as: gasoline, used oil, antifreeze, other

Therefore, there is a potential for hazardous waste and other damaging waste entering the floor drain system.

Always check with local units of government for specific requirements. The following list is provided in preferential order of how to handle liquid wastes from private garages:

Preference #1: Do not install floor drains in new constructions of private garages; instead, slope the floor to the doors. For existing garages, seal the drain to prevent further discharge.

Preference #2: If a floor drain is desired, the floor drain may discharge to the homeowner's lawn surface if approved by the administrative authority (MN R. Chapter 4715.1300, subp. 6). The discharge area must be visible, and cannot drain or convey runoff directly to storm drains or ditches. The good housekeeping practices described below must be followed.

Preference #3: If a floor drain is desired and the home is connected to the municipal sanitary sewer, connect floor drain to the home's building sewer for sanitary wastes. Connection must be in compliance with the Plumbing Code (MN Rules Chapter 4715.1300). The hookup should comply with the local sewer use ordinance, and may be subject to local approval. The good housekeeping practices described below must be followed.

DO NOT:

- direct the floor drain waste to a street, ditch or water body (MN Rules Chapter 7050.0210, sub 2),
- connect to building sewer of homes served by individual sewage treatment systems (ISTS) (MN Rules Chapter 7080.0065),
- allow the floor drain to "deadhead" into the soil (MN Rules Chapter 4715.1300).

Good Housekeeping:

- Care should be taken that hazardous or other damaging waste does not come in contact with the garage floor. Any hazardous or other damaging waste reaching the garage floor must be absorbed and disposed of at a household hazardous waste facility. No hazardous or other damaging waste should be discharged to daylight via a floor drain or sloped floor, or to a floor drain connected to sanitary sewer (MN Rule Chapter 7060, subp 2). All used oil must be recycled (MN Statute 115A.916).
- Homeowners have the duty to avoid and mitigate pollution from any of the preferred disposal options (MN Statutes 115.061). Any non-hazardous/non-damaging liquid waste discharged to daylight via a floor drain or sloped floor must not create a nuisance condition or contaminate storm water runoff (MN Rule Chapter 7050.0210).
- If a floor drain remains in the garage, it is recommended that a permanent sign or plate be placed on or within view of the drain stating, "WARNING - Water Only! Floor drain leads to our water supplies".

Other Establishments

Domestic sewage is also generated by Other Establishments. **Under Chapter 7081, an "other establishment" is any public or private structure, other than a dwelling, that generates sewage and discharges it to an MSTS (7081.0020, Subp. 6).** Other establishments may have large flows and/or high-strength waste, so Chapter 7081 has special regulations for them. These systems are also regulated by the EPA Class V Rules and must complete an inventory form available at septic.umn.edu/ssts-professionals/forms-worksheets.

Non-domestic waste is generated by many sources, such as restaurants, laundromats, barber shops, car washes and other light industrial establishments. Waste other than sewage is only allowed to be discharged into a SSTS if the waste is suitable to be discharged to groundwater. If waste strength parameters exceed the values identified in MN Rules Chapter 7081.0130, Subp. 2, the system should include pretreatment.

A range of systems can be designed for Other Establishments.

a. Type I – if domestic levels of wastewater can be achieved with septic tanks alone the system is classified as at Type I system.
b. Type II or III - if site or soil conditions are limiting.
c. Type IV – if the system uses a registered product (Treatment Level C) to reduce waste strength the system is considered to be a Type IV system.
d. Type V – if the system uses a non-registered product to reduce the waste strength the system is considered to be a Type V system.

The focus of Minnesota's septic system program in the 1970's was to identify technical standards for systems that treated sewage from dwellings. At that time, not much thought was given to the treatment challenges of waste generated by structures other than dwellings, which were creatively referred to in rule as "other establishments". This led to an era of frequent premature system failures, especially for the facilities like restaurants that produced the hightest strength waste. Requirements changed as the industry learned from its experiences, and we began specifying more specific standards for systems that treat high strength waste. While we see pretreatment devices on most restaurants today, we have not adequately answered the question of how to ensure effective treatment for the other establishments with waste strength greater than dwellings but less than the obviously high strength waste from restaurants.

Local program data suggests that we continue to struggle with identifying the proper wastewater treatment solutions for other establishments. Local programs have reported over 8,500 non-residential establishments being served by septic systems in Minnesota.

The right questions about waste strength need to be asked when designing or reviewing systems for other establishments. Septic systems that serve complex waste streams need extra attention to ensure they provide long-term and cost effective treatment. We all learned that the relationship between hydraulic loading and organic strength is fundamental to effective wastewater treatment. The question is, then, how we end up with less than 10% of the systems serving other establishmentsusing Type III or Type IV solutions.

Code Requirements

Minnesota Rules Chapters 7080 - 7083 are very clear about the fact that other establishments are different than dwellings (7081.0020 Subp. 5). The rules are also very pointed about the limitations of flow-derived design calculations (7080.2150 Subp. 3, item K), and the need to provide additional treatment for systems serving in designing any septic system in Minnesota is to determine the design flow and anticipated waste strength concentrations (7080.1710 Item A).

The code does not prescribe how to anticipate the waste strength or what to do when we expect waste strength to exceed residential strength waste. The code also does not explicitly state that all other establishments produce waste strength that exceeds residential values. Research and experience does suggest that we need to pay special attention to other establishments, and it is safest to assume that all other establishment sewage exceeds residential strength values. Forms of additional treatment that are not pretreatment could include specifying extra tank capacity, grease traps, effluent screens, pressure distribution, larger soil dispersal systems, flow equalization, flow-splitting, more frequent maintenance, and other methods.

Related Licensing Requirements

Another factor comes into play when we ask which specialty area (basic, intermediate, or advanced) is required to design and inspect systems serving other establishments. The SSTS program wasn't built around the types of structures the systems serve - it was built around the sewage that needs to be treated and the system types that perform the treatment. Basic designers and inspectors are authorized under 7083.0740/0750 Subps. 1 to design, permit and inspect Types I, II, or III SSTS serving dwellings or other establishments. Intermediate or Advanced certification is currently required when the system uses pretreatment. Appropriately matching a treatment solution to a complex waste stream is complicated, and proper certification is necessary. In fact, it was one of the reasons that the advanced design and inspection certifications were introduced in the first place.

The size of the absorption area should be sized on the greater of the maximum hydraulic load or the maximum organic load. See Table 5.1 below and calculations to determine organic loading. It may be advisable to oversize the absorption area by 50% and divide the system into 3 zones for dosing and resting cycles if secondary treatment is not employed (a must for MSTS - **MN Rules Chapter 7081.0270, Subp. 5 B 3**).

TABLE 5.1 Maximum Waste Strength Loading Rates—Bottom Area Only

Soil Loading Rate (gpd/ft²)	Pounds of BOD_5/ft²/day	Pounds of TSS/ft²/day	Pounds of FOG/ft²/day
1.2	0.0017	0.0006	0.0003
0.78	0.0011	0.0004	0.0002
0.68	0.0009	0.0003	0.0001
0.6	0.0009	0.0003	0.0001
0.52	0.0008	0.0003	0.0001
0.5	0.0007	0.0003	0.0001
0.45	0.0006	0.0002	0.0001
0.42	0.0006	0.0002	0.0001

Based on organic loading to a Type I system with design flow and bottom area loading with concentrations of BOD_5 of 170 mg/L, TSS of 60 mg/L. and FOG of 25 mg/L.

To calculate:

1. BOD Loading -

_________ x (8.34 ÷ 1,000,000) x _________ = ___________

BOD conc. from treatment device (mg/L) | Hydraulic loading rate (gal/ft²/day) | Waste strength loading rate (lbs/ft²/day)

2. TSS Loading -

_________ x (8.34 ÷ 1,000,000) x __________ = ___________

TSS conc. from treatment device (mg/L) | Hydraulic loading rate (gal/ft²/day) | Waste strength loading rate (lbs/ft²/day)

3. Oil and Gease Loading -

_________ x (8.34 ÷ 1,000,000) x ___________ = _____________

O & G conc. from treatment device (mg/L) | Hydraulic loading rate (gal/ft²/day) | Waste strength loading rate (lbs/ft²/day)

Some "other establishments" include the following:

Apartment buildings

Rental situations have been known to have overuse of the system. The renter may not understand the impacts of their usage habits on the system and may have little concern about over using water. Multiple families can also impact the loading to the system. Low-flow fixtures and appliances along with education can assist in the management of the system.

Day cares

Day cares are always going to have higher flows associated with their use. The other concern here will be the cleaners that are used and the type of food that is available. In-home daycares will have higher flows than are typical for the number of bedrooms in the house due to the amount of people that are in the home and the amount of time they are there. The kitchen or waste strength will be similar to a normal home. The use of cleaners must be watched in these systems. Excessive cleaning, which is common in day cares, can lead to the killing of the bacteria and lower efficiency in the treatment tanks.

Commercial kitchen

A commercial kitchen is a food preparation center that prepares multiple meals or food products and typically generates high-strength wastewater. The food service wastewater from these facilities is non-toxic, non-hazardous wastewater and is similar in composition to domestic wastewater, but which may occasionally have one or more of its constituents exceed typical domestic ranges. It includes all the sewage wastes from commercial food preparation, food processing or food production sources.

Restaurants and bars almost always have high-strength waste that makes sewage treatment difficult. For this reason, a number of best management practices can be taken to facilitate treatment:

- Limit food particles and alcohol going down the drain.
- Limit the use of chemicals going down the drain: chemicals can kill the treatment system's good bacteria.
- Limit use of degreasers, even in cleaning supplies.
- A grease interceptor, a watertight device designed to intercept, congeal and retain or remove fats, oils, and grease (FOGs) from food-service wastewaters; may be located inside (grease separator) or outside (grease tank or grease trap) of a facility that generates commercial food service wastewater.
- Isolate kitchen waste from other sewage production.
- Design tanks for a minimum of four to seven times the daily flow.
- Be aware that high water temperatures (140°F) do not allow grease to solidify, adding to treatment concerns.
- More tanks in series can help cool effluent.
- Be aware that septic tanks alone usually will not get the job done.

When available the Designer or Service Provider should test the effluent from the last septic tank or pump tank to determine BOD/TSS/FOG levels.

Design considerations include:

1. Provide and maintain internal grease interceptor
2. Place clean out outside structure in the lines. Schedule regular line cleaning to avoid emergency services
3. Keep the first outside tank close to the establishment (i.e. a short building sewer) to keep the sewage from cooling and grease solidifying in the building sewer

4. If fat and grease are excessive, more and smaller tanks are better for cooling as there is more surface area contact with the soil. However an individual tank in series must still not be less than 25% of the total liquid capacity (MN Rules Chapter 7080.1940 B).
5. Tanks must be sized on retention time to promote adequate cooling, floatation and settling. Typical retention time for domestic wastes is 3 to 4 days. (daily flow x 3, or daily flow x 4). More retention time is likely needed for high strength wastes. The frequency of solids removal should also be considered when determining tank size.
6. If fat and grease are excessive, more capacity above the liquid level and higher baffles may be advisable. Effluent filters should (must for MSTS) be used on the final tank in series.
7. For high strength waste situations, it is recommended that the orifice size for pressure distribution system be no smaller than 1/4 and the distal head should be no less than 5 feet. Cleanouts must be provided (**MN Rules Chapter 7080.2050 sub. 4J**). More frequent doses are preferable (min of 4 doses/day is required by rule), as long as the dose volume equals or exceeds four distribution pipe volumes plus the volume of the supply pipe.
8. The size of the absorption area should be sized on the greater of the maximum hydraulic load or the maximum organic load. See Table 5.1 below and calculations to determine organic loading. It may be advisable to oversize the absorption area by 50% and divide the system into 3 zones for dosing and resting cycles if secondary treatment is not employed (a must for MSTS – **MN Rules Chapter 7081.0270, Subp. 5 B 3**).

Campgrounds

At campgrounds, it is likely that users unfamiliar with onsite treatment systems will be adding waste to the systems. Peak flows are often very high; for this reason, consider extra tank capacity, commercial-size effluent filters, and the use of timers. Pretreatment may also be needed to get the levels of the effluent down to domestic levels.

Privies

- Pit Privies must have three feet of separation below the point where sewage enters soil
- Vault Privies must meet all requirements of holding tanks
- Minimum size = 25 ft^3
- More information on Privies is detailed in Section 7

RV Dump Stations

- At RV dump stations, there is the potential for odor-control chemicals (OCC) that may be harmful to the system, including:
- Formaldehyde (OCC): the organic strength is so high that the resulting mixture in a holding tank is fifteen to twenty times stronger.
- Quats (OCC) are not biodegradable and deodorize by killing the odor-causing microorganisms.
- Enzyme-based products employ natural organic chemicals. Because they are less effective, they are not used much.

Consider operating the dump station as a holding tank if OCC are in the waste stream. Pretreating the RV waste or slowly time-dosing the RV waste to the rest of the treatment system is another option. Dump stations which should be designed with excessive tank capacity. UMN recommends a 3 or 4 day retention time for holding tank sizing based on the maximum number of trailers using the facility per day (40 gallons per day)

Laundromats

The treatment of wastewater from laundromats is often compromised by their high use of soap, chemicals, and water. Steps can be taken to mitigate these factors, including:

- Use liquid soaps only; some cheap powders have excessive fillers
- Sell only liquid soaps which do not have a bleach additive
- Consider doubling tank capacity
- Use of low water use washing machines
- Use of lint filters in facility
- Use of a commercial-size effluent filter on septic tank
- Increase outlet baffle size to 50-60% of tank depth

Office Buildings

Flow varies greatly from one office building site to the next. In general, there is the potential for high-strength waste due to low graywater content. There is also the potential that users will be unfamiliar with onsite treatment systems. System designers should be aware of any cooking facilities that may be present in the building, and should consider a commercial-size effluent filter when there is the potential for high-strength waste.

Schools and Churches

Because of the potential for high-attendance events to be held at schools and churches, peak flows can be quite high at times, and it is likely that users will be unfamiliar with onsite systems. Consider extra tanks, timers and dual fields so one can be rested. System designers should ask if a cooking facility is present. If so, the waste will be high strength and will require additional design considerations. Consider commercial-size effluent filters.

Hotels and Motels

Again, there is the potential that users at hotels and motels will be unfamiliar with onsites. System designers should ask if a cooking facility is present. Consider commercial-size effluent filters. If the facility is seasonal, consider dual fields to rest and help with freeze protection.

Medical Facilities

There is the potential for users unfamiliar with onsites. There is also the potential for harmful chemicals to enter the system, including left-over medicine and cleaning chemicals. Leftover medications should not be flushed down the toilet and janitorial staff should be educated about the appropriate use of cleaning chemicals to ensure a sanitary environment while minimizing product use. Sharps/red bag waste must not go into system. Consider commercial-size effluent filters. The well setback for medical facilities is increased to 150' for systems serving this type of waste.

Beauty Salons and Barbers

Hair and other chemicals should not be allowed to enter the system. Good catch basins/screens should be placed in sinks. Have one sink for rinsing out perms/hair color that drains to a holding tank, as the chemicals used in these processes can be hazardous. Consider a commercial-size effluent filter.

Automotive Garages

No floor drains where vehicle maintenance is being performed should drain to a SSTS. Instead, these drains should go to a holding tank. Flammable waste traps are a good idea in case of spills or misuse. Hazardous waste can not be allowed to enter the system. If a thick layer of oil/grease forms on top of the tank, laboratory analysis should be conducted to determine what the layer is composed of and should be checked for hazardous waste. If there is no hazardous waste, the wastewater may be thinly land applied or brought to a permitted waste treatment facility.

Filling Stations, Service Stations, Car Washes

The oil and grease wastes from a filling station or car wash can not be allowed to flow into a septic system. Such wastes, including floor washing wastes from the service bay, should be discharged into a holding tank which is pumped and cleaned when full. EPA prohibits floor drain waste from a service station from entering an onsite system. Only the toilet wastes from a service station should flow into a septic tank and subsurface soil absorption system. See septic.umn.edu for more information about systems for these establishments.

All of these facilities have a high potential for hazardous waste. As a Designer, be sure to communicate the care of these chemicals and the responsibility to control their discharge. As a professional developing a simple care plan is also important for the proper operation of the facility.

When a single onsite system is designed to treat an average design flow greater than 10,000 gallons per day, the owner or owners must apply for a state disposal system (SDS) permit from the Minnesota Pollution Control Agency. A professional engineer (PE) must be involved in the design of any SSTS that requires a SDS permit. According to MN Rules Chapter 7081.0040, Subp. 1:

a. **All MSTS must be designed and operated according to this chapter, except as modified through an ordinance in compliance with chapter 7082 and Minnesota Statutes, section 115.55. All MSTS must be designed, installed, inspected, pumped, and operated by a qualified employee under part 7083.1010 or a licensed business under part 7083.0710. All MSTS must conform to applicable state statutes and rules.**

b. **The owner or owners of a single SSTS or a group of SSTS under common ownership must obtain an SDS permit from the agency according to chapter 7001 when all or part of proposed or existing soil dispersal components are within one-half mile of each other and the combined flow from all proposed and existing SSTS is greater than 10,000 gallons per day. For proposed SSTS, the flow must be determined according to item D. For existing SSTS, the flow is determined by the greater of:**

   (1) the average maximum seven-day measured flow; or

   (2) the flow determined according to item D.

c. **An SDS permit is required for any subsurface sewage treatment system or group of subsurface sewage treatment systems that the commissioner determines has the potential or an increased potential to cause adverse public health or environmental impacts if not regulated under a state permit. Conditions for these permits include systems in environmentally sensitive areas, unsubstantiated or unexpected flow volumes, and systems requiring exceptional operation, monitoring, and management.**

d. **Flow amounts to calculate whether an SDS permit is required must be determined according to part 7081.0110. The highest calculated value of the various methods in Table I under part 7081.0130, subpart 1, must be used to make this determination, with no reduction allowed. An SDS permit is not required if a factor of safety is added to the design flow that results in a design flow that is in excess of the SDS permit threshold.**

Class V Inventory Form (EPA regulations)

These forms are required for all facilities that meet the following requirements:

- on-site sewage treatment systems serving 20 or more people,
- facilities that generate waste other than domestic waste, and
- inventory form must be completed and copies sent to the EPA (address listed on the form).

Hydraulics – Flow Rates

7080 Versus 7081

7080 is the rule reference for determining design flows for domestic systems from dwellings with flows less under 5,000 gpd. However, **7080.1880 states that design sewage flow and waste concentration levels for other establishments with a flow of 5,000 gallons per day or less shall be determined by part 7081.0130.**

Chapter 7081 applies to MSTS cluster systems which have flows from 5,000 to 10,000 gpd. There are many terms that apply to cluster systems that are commonly used.

- Cluster system is the sewage collection, treatment, and dispersal system designed to serve two or more sewage-generating dwellings or facilities. This implies a planning concept incorporating green space and common wastewater treatment.
- Collector system is typically an older development that needs to treat the wastewater offsite incorporating a collection system.
- Decentralized system includes the collection, treatment, and dispersal/reuse of wastewater from individual homes, clusters of homes, isolated communities, industries, or institutional facilities, at or near the point of waste generation.
- Distributed sewer system is an area-wide system of individual, community, and cluster wastewater treatment systems that is managed by one or more management entities. Systems may include all forms of treatment, dispersal, discharge, reuse or recycle alternatives.

In both Chapter 7080 and 7081 the design flows calculated are flow maximums, meaning that the systems should not actually receive this amount of wastewater daily to ensure long term performance. It is recommended that the average flow to the system be less then 70% of the design flow.

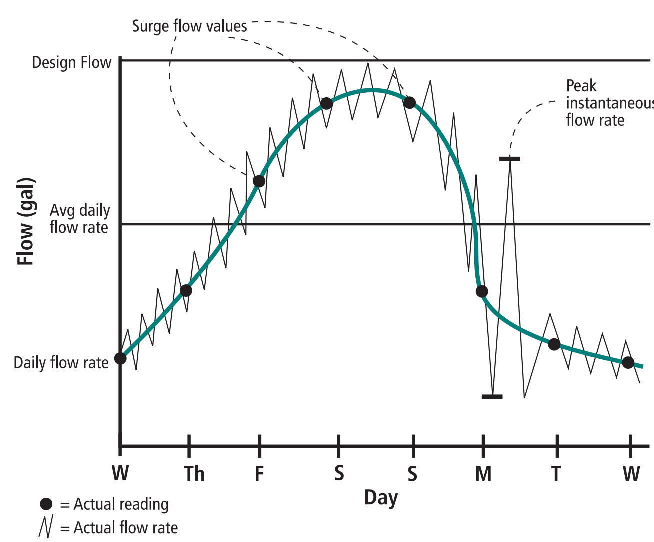
General Hydraulic Considerations

There are numerous terms used to apply to hydraulics and flow that a professional needs to understand in the design and operation of a SSTS:

- Flow rate, average daily: average volume of wastewater in a 24-hour period; calculated from values measured over a period of time
- Flow rate, daily: measured volume of wastewater generated from a facility in a 24-hour period; expressed as a volume per day
- Flow rate, daily design: estimated peak volume of wastewater for any 24-hour period; parameter used to size non-residential systems
- Flow rate, design: estimated volume of wastewater per unit of time for which a component or system is designed; commonly called 'design flow'; see flow, design
- Flow rate, peak hourly: highest flows measured for a one-hour period
- Flow rate, peak instantaneous: highest recorded flow rate occurring within a given period of time
- Flow surge: flow of effluent greater than average and occurring for short periods of time
- Flow equalization: system configuration that includes sufficient effluent storage capacity to allow for uniform flow to a subsequent component despite variable flow from the source

Figure 5.2 charts the flow entering a system over the course of a week and graphically identifies many of the above terms.

FIGURE 5.2 Flow Rates Vary Significantly



Design Process for Flow Equalization

1. The tank capacity is determined by adding:
   a. the minimum volume required to keep the pump submerged,
   b. a surge volume equal to the flow generated during the designated storage period, and
   c. the reserve volume above the alarm activation level.
2. It is recommended that the equalization tank be designed to hold at least twice the average daily flow of the facility and dose it over the course of more than a single day.
3. The flow from a surge or flow equalization tank is controlled by a timer that controls pump operation according to fixed on (dose) and off (rest) cycles. Effluent delivery can then be spread out over several days.

See the MPCA publication, “Prescriptive Designs and Design Guidance for Advanced Designers” for more information about flow equalization.

Estimates of Flow for Dwelling Design

The estimates of flow used in Minnesota to size sewage treatment systems allow for a safety factor so that systems will function properly even when serving a residence or other establishment with higher than average rates of water use. Chapter 7080 specifies estimated sewage flow rates depending upon the size of residence and the number of water-using appliances.

From 7080.1850, Subp.1 & 2, if construction of additional dwellings or bedrooms, the installation of water-using devices, or other factors likely to affect the operation of the ISTS can be reasonably anticipated, the system must be designed to accommodate these factors.

The estimated design flow for any dwelling must provide for at least two bedrooms. For multiple or multifamily dwellings, the design flow consists of the sum of the design flows for each individual unit. A bedroom is defined in 7080.1100, Subp. 9, is an area that is:

a. a room designed or used for sleeping; or

b. a room or area of a dwelling that has a minimum floor area of 70 square feet with access gained from the living area or living area hallway. Architectural features that affect the use as a bedroom under this item may be considered in making the bedroom determination.

The estimated sewage flows presented in Table 5.2 are based on the number of bedrooms in a residence. Because the individuals who occupy a residence use the water, the number of bedrooms is considered a good index of the potential water use. For a Class I residence, the estimated water use is equal to 150 gallons per day (gpd) per bedroom. This assumes occupancy of two people per bedroom, each using 75 gpd. This is a conservative estimate for many residences, although it may be low for large and high-value residences. The notes in Table 5.2 suggest a classification for the various types of residences according to home size and number of water-using appliances.

Dwelling does not include a single-family or multifamily residence that serves both as a domicile and a place of business. If the business increases the volume of sewage above what is normal for a dwelling, a designer should add the additional flow from the business to the values in Table 5.2. If the liquid waste generated from business operations no longer qualifies as domestic sewage, additional design considerations must accommodate the waste type and strength.

TABLE 5.2 Estimated Sewage Flows in Gallons per Day (from MN Rules Chapter 7080.1860 Table IV)

Number of Bedrooms	Class I	Class II	Class III	Class IV
2 or less	300	225	180	*
3	450	300	218	*
4	600	375	256	*
5	750	450	294	*
6	900	525	332	*

* Flows for Classification IV dwellings are 60 percent of the values as determined for Classification I, II, or III systems. For more than six bedrooms, the design flow is determined by the following formulas:

Classification I: Classification I dwellings are those with more than 800 square feet per bedroom, when the dwelling's total finished floor area is divided by the number of bedrooms, or where more than two of the following water-use appliances are installed or anticipated: clothes washing machine, dishwasher, water conditioning unit, bathtub greater than 40 gallons, garbage disposal, or self-cleaning humidifier in furnace. The design flow for Classification I dwellings is determined by multiplying 150 gallons by the number of bedrooms.

Classification II: Classification II dwellings are those with 500 to 800 square feet per bedroom, when the dwelling's total finished floor area is divided by the number of bedrooms, and where no more than two of the water-use appliances listed in Classification I are installed or anticipated. The design flow for Classification II dwellings is determined by adding one to the number of bedrooms and multiplying this result by 75 gallons.

Classification III: Classification III dwellings are those with less than 500 square feet per bedroom, when the dwelling's total finished floor area is divided by the number of bedrooms, and where no more than two of the water-use appliances listed in Classification I are installed or anticipated. The design flow for Classification III dwellings is determined by adding one to the number of bedrooms, multiplying this result by 38 gallons, then adding 66 gallons.

Classification IV: Classification IV dwellings are dwellings designed under part 7080.2240.

The determination of what constitutes a bedroom may seem to be an easy process; however in some cases, it has proved to be a difficult task. It should be clearly understood that the definition of a bedroom in 7080.1100, Subp. 9 is intended to be used only to estimate sewage flow from the dwelling. It must not be used to determine the adequacy or safety of a room for sleeping purposes. Please refer to the International Residential Code (www.iccsafe.org), the Minnesota State Building code (www.dli.mn.gov/ccld/codes.asp), or other pertinent building codes for those requirements.

The definition of bedroom was crafted to be as specific as possible to address a majority of the flow determination situations that will be encountered. However, there may be unique situations in which this definition may need to be interpreted. Excerpts from the MPCA's fact sheet, "Bedroom Definition for Determining SSTS Size" are offered below to provide guidance to designers and inspectors in making these unique determinations.

The main complication in crafting a definition of a bedroom is the differences between older and newer dwellings. Older dwellings were not built to a code, while newer dwellings are constructed under very detailed codes. Therefore, rooms used as bedrooms can be markedly different from older to newer dwellings. If Chapter 7080 were to be used as a bedroom definition based on a current building code, it would wrongly exclude rooms as commonly used as bedrooms in older dwellings.

A survey was taken of local SSTS administrators to aid in crafting the bedroom definition. The survey results focused on two main issues - current use and architectural issues.

Current Use

MN Rules Chapter 7080 is clear that if a room or area (even if it does not meet the size or access requirements) is currently being used as a sleeping room, it is counted as a bedroom. This includes an area used for sleeping which may be unsafe. Again, this bedroom determination is to estimate flow, not to determine the safety of the room for sleeping.

Exceptions can be made if the occupant who is using the room for sleeping is temporary. Examples would be:

- an adult child with family who has temporarily moved-in during construction of their new dwelling, and
- occasional guest(s) who sleep on a sofa-sleeper in a common living area

Other useful sources for determining if a room is a bedroom include:

- The current or most recent real estate listing of the number of bedrooms
- The number of bedrooms listed with the local Assessor's office
- Rooms labeled as bedrooms on the house plans
- Rooms with smoke detector
- All rooms on a second level that are not bathrooms

Architectural Issues

These are features common to designated bedrooms or rooms used as sleeping areas:

- Rooms or areas with legal egress
- Rooms with a closet
- Rooms which are adjacent to a three-quarter bathroom

Rooms such as dens, sewing rooms, exercise rooms and home theaters should also be given serious consideration as a bedroom as they have the potential to be easily converted.

Architectural features that are obstacles to the use of a room as a bedroom include:

- Rooms that are obviously a kitchen, bathroom, living room, dining room, laundry room, storage room (without windows) or family room
- Rooms and areas with low ceilings
- Rooms with arched doorways that lack a door
- Rooms and areas with half walls
- Rooms and areas with no privacy
- Rooms and areas without egress to the outside
- Rooms and areas with no source of light and ventilation to the outside

- Rooms and areas that are used as a passage to other rooms, stairs, or bathrooms unless this is the only sleeping area in the dwelling
- “Open” lofts

A minimum ceiling height is seven feet for basements and seven feet, six inches for upper floors; for attic areas having downward-tapering ceilings a minimum height of five feet is allowed. Areas less than five feet in height are not included in the 70 sq. ft. minimum floor area calculation.

LGU ordinance considerations

The following are examples of ordinance amendments being used by some LGUs to address whether or not a questionable room is counted as a bedroom. These may not be applicable to all LGUs.

1. Requiring documentation from builder/owner of a permanent feature that precludes the use of the room as a bedroom
2. Limiting the number of bedrooms for a typical single family dwelling
3. Requiring a minimum number of bedrooms for a typical single family dwelling
4. Requiring techniques to insulate the system if freezing is a concern for a dwelling with a large number of bedrooms but a water use well below the design volume

Financial considerations

Typically, the increase in cost of adding an additional bedroom to a system design is not exorbitant. A larger system size adds longevity and often recaptures the additional cost over the life of the system.

Sample bedroom determinations

Table 5.3 below offers some common situations, suggestions on the bedroom determination, and reasons supporting suggested determination. Always remember to check with the LGU to see whether they have stricter provisions in their ordinance.

TABLE 5.3 Bedroom Determination

Room description	Bedroom?	Supporting reasoning
Den, exercise room or sewing room on house plan that is > 70 ft^2	Yes	Meets minimum size requirements and has no precluding architectural features
Room used as bedroom in an existing dwelling that is < 70 ft^2 and has no egress	Yes	Currently being used as a bedroom
Laundry room in existing dwelling is > 70 ft^2	No	Plumbing, sinks, and washer/dryer are obstacles to use as a bedroom
Open loft in existing dwelling used as a bedroom	Yes	Currently being used as a bedroom
Open loft on house plan	No	“Open” is a an obstacle to use as a bedroom
Open loft in existing dwelling currently used as a play room	No	Not being used as a bedroom, and “Open” is an obstacle to use as a bedroom
Basement room >70 ft^2 with egress	Yes	Meets Rule requirements of size and architectural features
Basement >70 ft^2 without egress	No	Lack of egress is an obstacle to use as a bedroom

Use the Design Summary Worksheet, available at septic.umn.edu/ssts-professionals/forms-worksheets, with every design.

Estimated Flow- Class II – IV Dwellings

If flows estimates less than Type I are going to be used for design, water conservation is critical. Water conservation is defined by CIDWT as the management of water resources so as to eliminate waste or maximize efficiency utilizing such methods as using the same water again before it is wasted (becomes wastewater), installing water-efficient plumbing, or wastewater recycling and reuse. MN Rules Chapter 7080.1860 defines flow estimates for a variety of dwelling classifications.

Class II

A study on water use from the 1970's indicated that, on average, there was one more occupant in a house than the number of bedrooms. Using this information, the MPCA developed a reduced flow estimate for SSTS sizing if the dwellings contain 500 to 800 square feet per bedroom, when the dwelling's total finished floor area is divided by the number of bedrooms, and where no more than two of the water-use appliances listed in Classification I are installed or anticipated. The design flow for Classification II dwellings is determined by adding one to the number of bedrooms and multiplying this result by 75 gallons.

Class III

Classification III dwellings are those with less than 500 square feet per bedroom, when the dwelling's total finished floor area is divided by the number of bedrooms, and where no more than two of the water-use appliances listed in Classification I are installed or anticipated. The design flow for Classification III dwellings is determined by adding one to the number of bedrooms, multiplying this result by 38 gallons, then adding 66 gallons. These flow estimates are extremely conservative compared to more recent water use research (Mayer, 1999).

Class IV

A Class IV residence has no flush toilet, so the value for Class I, II, or III is reduced by 40 percent: flow x .6.

If a dwelling has a graywater system, it is a Class IV residence, and average daily flow is estimated as 60 percent of a similar house as shown in Table 5.2. Effluent from a graywater tank has to enter a soil treatment system for final treatment. It cannot be discharged to the surface. Proper sizing of the soil absorption system is based on Class IV flows and the appropriate soil hydraulic loading rate. See Section 7 for the discussion of the products available for the removal of the flush toilets from the source.

Measuring Flow for Design and Management

Flow measurement is any method used to accurately quantify the flow of liquid. **From MN Rules Chapter 7080.1100, Subp. 35, flow measurement means any method to accurately measure water or sewage flow, including, but not limited to, water meters, event counters, running time clocks, or electronically controlled dosing.** These methods are discussed below.

Water Meters

Septic systems are becoming more expensive both to install and to repair, so one goal is to design them to treat the actual amount of flow rather than an estimated amount, which may be high or low. Another goal is to get optimum use over the longest possible time from existing systems. In order to achieve these goals, it is helpful to know actual flow rates, which the water meter provides. While it is often necessary to use the values in Table 5.2 to estimate sewage flows, more accurate data should be obtained if possible. For example, if a chain restaurant is to be located beyond the reach of municipal sewer, then data should be obtained from the parent company on water use rates of comparable facilities. A water meter can help ensure successful septic system operation.

To get keep track of the amount of water entering the septic system, include a water meter in the design of the system, or add one to an existing system.

All systems with pump and MSTS (MN Rules Chapter 7081.0230 D) must have a water meter installed, or they must have some other means of measuring flow - such as a running time clock or event counter on a pump.

Water meters come in many different shapes and sizes. Most water meters are designed to deal with clean water, which means that they may not function properly if they are used to measure the flow of sewage. For example, many water meters have small paddles or wheels that move to measure flow. These moving parts can be easily plugged by solids in sewage. One way to avoid this problem is to measure the flow of clean water before it is used in the house.

These meters should measure the water used inside the house, but not the water used outside for watering lawns and gardens, filling swimming pools, or washing cars, since this water does not enter the septic system. A filter to catch small particles should be installed to protect the water meter. Placing the meter after the water softener is common. If it's difficult to install a water meter so that it does not include the water to be used outdoors, try to estimate outside use, or use only data from December to March, when there is typically no outdoor use of water.

Installation

Water meters measure flow in either gallons per minute, gallons per hour, or cubic feet per second. Before doing any calculations using data from the meter, check to be sure of the units of measurement. Designs for septic systems typically use gallons per day. If the meter measures gallons per minute, multiply by 1,440 minutes per day. If it measures gallons per hour, multiply by 24 to get the gallons per day. If it measures cubic feet per second, multiply by 646,272 to convert to gallons per day. (See Table 5.4)

TABLE 5.4 Water Meter Conversions

Meter Reading	Conversion Calculation	Converted Values
28 gallons per minute (gpm)	28 gpm x 1440	40,320 gpd
28 cubic feet (ft^3)	28 ft^3 x 7.48	209 gallons
0.5 cubic feet per second (ft^3/s)	28 ft^3/s x 646,272	323,126 gpd

The water meter should be installed by a plumber to make sure it is put in properly. Although it is installed directly into the water system, it will not affect water pressure.

Another type of clean water meter often found in houses is an on-demand water softener. These water softeners measure flow and recycle at certain set flow amounts. This system may also be used to calculate water flow. These calculations are not as straightforward as simply reading a meter and multiplying by a factor of 24 or 1,440, but this is a valid method of measuring clean water flow.

Event counter (cycle counter)

Another way to use a pump as a measurement device is to use an event counter. An event or cycle counter is a device used to record the number of times a component has been activated (e.g., activation of a pump followed by deactivation is one cycle). An event counter is a meter that records every instance of the pump turning on. By counting the number of times the pump turns on during a day you can measure the flow of wastewater going out to the system provided that you know from the septic system design how many gallons are to be pumped each time the pump turns on.

This method is not as accurate as a running time clock because the floats that turn the pump on have some variability. That is, the pump may turn on at six inches the first time and then 6-l/2 inches the second time. That can be a 15 to 20 gallon discrepancy each dose. If the event counter is turning five times a day, at a 20-gallon per time discrepancy, your calculations could be off by as much as 100 gallons of water that day. This value is critical for the drainback calculation.

Elapsed time meter

All pumps run at a certain rate, so effluent flow can be calculated and calibrated from the pump system. This calibration can be done in the following steps:

1. the level in the tank is measured,

2. the pump is run for a known amount of time (such as two timed minutes),

3. the amount of water that remains is measured,

4. the remaining amount is divided by the amount of time that the pump was running,

5. and a pumping rate in gallons per minute is the result.

Using this rate, the amount of water pumped can be calculated based on how long the pump has been running.

For example, assume you know that a tank contains 10 gallons per inch of water depth, and the depth of wastewater is three feet. (For information on determining the volume per unit depth of a tank, see Section 7). A pump is run for two minutes, and now the wastewater is measured as two feet deep. 12” x 10 gallons = 120 gallons have been pumped in two minutes, so the rate = 120 gallons / 2 minutes = 60 gallons per minute. Now find out how many minutes the pump runs in the course of a day. If the same pump ran for a total of ten minutes, then during that day it pumped 10 x 60 or 600 gallons. This is a quick way to use a pump and a clock to calculate how much water is being used.

Once you know the pump’s rate, check it regularly (annually at a minimum). The rate may slow to the point where it is not evenly distributing wastewater to the soil treatment system, or it may be failing. It is good to know before the pump stops working that there is a problem.

However it is measured, rate of flow is critical data that will allow the best design and operation of the septic system. Flow estimation is a great design tool. It allows for a safety factor and peace of mind. Measured flow is used both to design systems and to verify performance. By using both flow figures appropriately, you give the system the best chance of good long-term performance.

Other Establishments and MSTS Hydraulic Determinations

There are three components when determining flow from a non-dwelling. The three components are dwellings, other establishments and infiltration from the collection system.

1. Dwellings

The design flow for MSTS serving existing dwellings is determined by the following calculation in conjunction with part 7080.1850: the total flow from the ten highest flow dwellings + (total flow from the remaining dwellings * 0.45) (7081.0120, Subp 2).

For new housing developments to be served by a common SSTS, the developer must determine and restrict the total number of bedrooms for the development. Proposed dwellings are determined to be Classification I dwellings for flow determination purposes unless different classifications are approved by the local unit of government. The determined classification system must be used in conjunction with the flow calculation method in subpart 1. If the ultimate development of phased or segmented growth meets or exceeds the thresholds in part 7081.0040, subpart 1, item B, the initial system or systems and all subsequent systems require a state disposal system permit (7081.0120, Subp 2).

These methods are allowed due to less variability in flows and typically the number of residents averages out and the peaks flows are lower.

If construction of additional dwellings or bedrooms, installation of additional water-using devices, or other factors likely to increase the flow volumes can be reasonably anticipated, the MSTS must be designed to accommodate the additional capacity as determined by the local unit of government (7081.0120, Subp 3).

Per capita applicability

For systems that are operating, an estimate for actual use can be based on the people that are currently inhabiting the dwelling. For residential systems, an estimate between 50-75 gallons per person can be used for real flows. This is not a design flow but a check against the reading on the flow meters. For example, in a four-bedroom Type I home, the design flow would be 600 gpd; however, when four people are actually living in the home, the real flow should be closer to 4 x 50 gpd= 200 gpd to 4 x 75 gpd = 300 gpd. A measured flow of 500 gpd would point to higher risk due to high use or leaky fixture or components.

Even though size of a residence is used to estimate sewage flow, a sewage treatment system is designed for a certain number of gallons per day, not for a certain size of residence. For example, if a system is sized for 450 gallons a day (a Class I, three-bedroom home), and the home actually discharges an average of 600 or 700 gallons per day, hydraulic failure is likely to occur. The pretreatment unit will be overloaded, and each soil treatment unit has a finite capacity, which, if consistently exceeded, will lead to hydraulic overload of that system.

Table 5.5 provides information on typical residential wastewater flows.

TABLE 5.5 Residential Wastewater Flows

Study	Number of Residences	Study Duration (months)	Study Average (gal/person/day)	Study range (gal/person/day)
Brown & Caldwell (1984)	210		66.2 (250.6)[a]	57.3 – 73.0 (216.9 – 276.3)[b]
Anderson & Siegrist (1989)	90	3	70.8 (268.0)	65.9 – 75.6 (249.4 – 289.9)
Anderson, et al. (1983)	25	2	50.7 (191.9)	26.1 – 85.2 (98.9 – 322.5)
Mayer et al. (1999)	1188	1[c]	69.3 (252.3)	57.1 – 83.5 (216.1 – 316.1)
DeOreo et al., (2016)	1000	1[c]	58.6 (221.8)	

[a] Based on indoor water use monitoring and not wastewater flow monitoring
[b] Liters per person per day in parentheses
[c] Based on two weeks of continuous monitoring in each of two seasons at each home
(3) From US EPA *Onsite Wastewater Treatment Systems Manual*, EPA/625/R-00/008, US EPA Office of Water, 2002

In addition to the daily flow variation, seasonal variations may also occur. Typically, wastewater treatment processes are sized to treat the maximum daily flow rather than simply having the capacity to treat the average daily flow. The maximum daily flow is the maximum flow that occurs over the course of a single day, perhaps 450 gallons per day for a typical 3-bedroom home. The average daily flow is the average of the flows that occur during single days over the course of some period of time – perhaps years. This may be 160 gallons per day.

2. Other Establishments

According to MN Rules Chapter 7081.0130 design flows for other establishments are determined by methods A (flow estimates as shown in Table 5.6) or B (using measured flow from a seven-day period in which the establishment is at maximum capacity or use).

TABLE 5.6 Estimated Design Sewage Flow from Other Establishments

Dwelling units (also see outdoor recreation)	Unit	Design flow (gal/ day/unit)
Hotel or luxury hotel	guest square foot	55 0.28
Motel	guest square foot	38 0.33
Rooming house	resident add for each nonresident meal	45 3.3
Daycare (no meals)	child	19
Daycare (with meals)	child	23
Dormitory	person	43
Labor camp	person	18
Labor camp, semipermanent	employee	50

TABLE 5.6 Estimated Design Sewage Flow from Other Establishments (cont'd)

Commercial/Industrial	Unit	Design flow (gal/ day/unit)
Retail store	square foot customer toilet	0.13 3.8 590
Shopping center	employee square foot parking space	11.5 0.15 2.5
Office	employee/8-hour shift square foot	18 0.18
Medical office*	square foot practitioner patient	1.1 275 8
Industrial building*	employee/8-hour shift employee/8-hour shift with showers	17.5 25
Laundromat	machine load square foot	635 52.5 2.6
Barber shop*	chair	68
Beauty salon*	station	285
Flea market	nonfood vendor/space limited food vendor/space with food vendor/space	15 25 50
Eating and drinking establishments	**Unit**	**Design flow (gal/ day/unit)**
Restaurant (does not include bar or lounge)	meal without alcoholic drinks meal with alcoholic drinks seat (open 16 hours or less) seat (open more than 16 hours) seat (open 16 hours or less, single service articles) seat (open more than 16 hours, single service articles)	3.5 8 30 50 20 35
Restaurant (short order)	customer	7
Restaurant (drive-in)	car space	30
Restaurant (carry out, including caterers)	square foot	0.5
Institutional meals	meal	5.0
Food outlet	square foot	0.2
Dining hall	meal	8.5
Coffee shop	customer	7
Cafeteria	customer	2.5
Bar or lounge (no meals)	customer seat	4.5 36

TABLE 5.6 Estimated Design Sewage Flow from Other Establishments (cont'd)

Entertainment establishments	Unit	Design flow (gal/ day/unit)
Drive-in theater	car stall	5
Theater/auditorium	seat	4.5
Bowling alley	alley	185
Country club	member (no meals) member (with meals and showers) member (resident)	22 118 86
Fairground and other similar gatherings	visitor	1.5
Stadium	seat	5
Dance hall	person	6
Health club/gym	member	35
Outdoor recreation and related lodging facilities	**Unit**	**Design flow (gal/ day/unit)**
Campground	person with hook-up site with hook-up site without hook-up, with central bath site to be served by dump station	32 100 50 63
Permanent mobile home	mobile home	225
Camp, day without meals	person	20
Camp, day with meals	person	25
Camp, day and night with meals	person	45
Resort/lodge hotel	person	62
Cabin, resort	person	50
Retail resort store	customer	4
Park or swimming pool	guest	10
Visitor center	visitor	13
Transportation	**Unit**	**Design flow (gal/ day/unit)**
Gas station/convenience store	customer	3.5
Service station*	customer service bay toilet square foot	11 50 250 0.25
Car wash* (does not include car wash water)	square foot	5
Airport, bus station, rail depot	passenger square foot restroom	5 5 565
Miscellaneous	**Unit**	**Design flow (gal/ day/unit)**
Public lavatory	user	5
Public shower	shower taken	11

TABLE 5.6 Estimated Design Sewage Flow from Other Establishments (cont'd)

Institutional	Unit	Design flow (gal/ day/unit)
Hospital*	bed	220
Mental health hospital*	bed	147
Prison or jail	inmate	140
Nursing home, other adult congregate living	resident	125
Other public institution	person	105
School (no gym, no cafeteria, and no showers)	student	14
School (with cafeteria, no gym and no showers)	student	18
School (with cafeteria, gym, and showers)	student	27.5
School (boarding)	student	95
Church	seat add for each meal prepared	4 5
Assembly hall	seat	4

* Waste other than sewage is only allowed to be discharged into the system if the waste is suitable to be discharged to groundwater.

Unless otherwise noted in Table 5.6, **the flow values do not include flows generated by employees. A flow value of 15 gallons per employee per eight-hour shift must be added to the flow amount. Design flow determination for establishments not listed in Table** 5.6 **shall be determined by the best available information and approved by the local unit of government (7081.0130 Subp 1 A).**

For these establishments the waste concentration of the effluent needs to be considered if concentrations of biochemical oxygen demands, total suspended solids, and oil and grease from the sewage are expected to be higher than 170 mg/L (or 125 mg/L $CBOD_5$), 60 mg/L, or 25 mg/L respectively. **An estimated or measured average concentration must be determined and be acceptable to the local unit of government. System design must account for concentrations of these constituents so as not to cause internal system malfunction, such as, but not limited to, clogging of pipes, orifices, treatment devices, or media (7081.0130, Subp. 2).**

Measured Flow

From 7081.0130, Subp. 1(B) the measured design flow of sewage for MSTS serving other establishments is determined by averaging the measured daily flows for a consecutive seven-day period in which the establishment is at maximum capacity or use.

To calculate the measured design flow, you will need two sets of data:

1. daily flow data, and
2. capacity of the establishment for each day.

A minimum of 90 days of flow during the busiest time of the year is the minimum recommended amount of data, but one full year of data is recommended (the more data you have, the greater the confidence you will have). The worksheet "Measured Flow: Other Establishments" provides a location to calculate these values. This can be found at septic.umn.edu/ssts-professionals/forms-worksheets.

Daily flow should be in gallons per day (gpd). Some water meters give cumulative readings (so that one day the meter may measure 400 gallons, the next day 850 gallons, and the next day 1,200 gallons). If this is the case, make sure to convert the gallons into a per-day unit. In this example, 400 gallons are discharged on day 1; 850 - 450 = 400 gallons for day 2; and 1200 - 850 = 350 gallons for day 3. Make sure you are using the correct units when you use the information to design a system (see Table 5.4).

Capacity of the other establishment should be in the form of percentage full or percentage use. For example, a typical campground may estimate that 60 percent of its campground sites are in use. Remember that percentage is converted to a decimal format by dividing by 100. (60% ÷ 100 = 0.60)

Organize the data by day number, date, flow, and capacity, with additional columns for measured maximum design flow and measured average design flow.

The measured maximum design flow is calculated assuming the facility is at 100 percent capacity; therefore, the daily flows need to be converted to design flows by using the percentage capacity on that day. Calculate the measured design flow by dividing the percent capacity into the daily flow rate. Let's say for day 1 the measured flow is calculated as 2,000 ÷ 0.60 = 3,333 gpd. Calculate the measured maximum design flow for each day at 100 percent capacity for each day.

Measured design flow is calculated assuming the facility is at 100 percent capacity; therefore, the converted flows are used. To calculate measured average design flow, average the seven highest consecutive flows at 100 percent capacity. Calculate the average from days 1-7, then days 2-8, then days 3-9, etc. Select the highest value.

Design Process for Determining Flow

The worksheet "Final Flow Total" should be completed with the following information:

1. Calculate flows from dwellings, enter into number 1.
2. Calculate flows from other establishments:
    a. If existing establishment: install flow measuring device if one is not present, collect daily flow data during the time of peak facility use. A minimum of 90 days is recommended. Calculate flow characteristics from measured flow data (worksheet "Measured Flow: Other Establishments").
    b. Use Table 5.6 (7081.0130) to determine estimated flow. This value must be used for permitting purposes. If measured flow data is not available this value will also be used for design flow.
    c. Compare calculated flow to measured flow data. Based on best professional judgment on consultation with facility owner regarding current and future use provide documentation and LGU enter the appropriate value into number 2.
3. Add in I & I under number 3. According to MN Rules Chapter 7081.0140, the design flow must also include 200 gallons of infiltration and inflow per inch of collection pipe diameter per mile per day with a minimum pipe diameter of two inches to be used for the calculation. Flow values are allowed to be further increased if the system employs treatment devices that are exposed to atmospheric conditions that will infiltrate precipitation. Flow estimates as calculated in this

chapter shall not be relied upon for the design of collection systems.

4. Refer to code and design guidance and consult with LGU as to required design flow rate for various components in the system include grease traps, septic tanks, surge tanks, pretreatment unit and soil treatment area.
5. It is recommended that the operating permit have a mitigation trigger at 70% of design flow.

This form can be found at septic.umn.edu/ssts-professionals/forms-worksheets.

Design best-practices checklist

- Be sure to check with the local government unit before any changes are made to the onsite system.
- Route your furnace, water softener and iron filter discharge out of the onsite system.
- This water can be day-lighted to the surface as long as it does not directly discharge into a water body. Alternatively, it can go into an existing drywell or abandoned drain field. If it is day-lighted, remember that this water contains salt and can be hard on vegetation. Freezing can be a concern for day-lighted water in winter.
- Install a small separate section of drainfield to deal with this water (no tank is needed). In most cases 20-50 feet^2 should be sufficient.
- If only the furnace water is being added, this can go into the onsite system, but a sump or other device to collect the water must be used so water is not trickling out, causing freezing problems.
- If rerouting is not an option, a good solution for everyone is to minimize the amount of salt and water used by the softener or iron filter.
- Reduce the total volume of water used in the home.
- Adjust the water softener or iron filter to recharge less frequently. Adjusting the frequency can be done by lengthening the time between recharges on a timed unit or increasing the volume of water passing through the unit before recharging on a metered unit.

3. Infiltration from the Collection System

According to MN Rules Chapter 7081.0140, the design flow must also include 200 gallons of infiltration and inflow per inch of collection pipe diameter per mile per day with a minimum pipe diameter of two inches to be used for the calculation. Flow values are allowed to be further increased if the system employs treatment devices that are exposed to atmospheric conditions that will infiltrate precipitation. Flow estimates as calculated in this chapter shall not be relied upon for the design of collection systems.

Waste Characteristics: Waste Strength Components

Components of Wastewater

Effluent quality is the physical, biological, and chemical characteristics of a liquid flowing from a component or device. The components of wastewater may be divided into four categories:

- biochemical oxygen demand, total suspended solids and fats, oils and grease (BOD_5, TSS, FOG),
- pathogens (fecal coliform, viruses),
- nutrients (nitrogen, phosphorus), and
- other chemicals.

Table 5.7 shows typical concentrations of these components in raw waste, septic tank effluent, and soil. The waste strength of sewage and effluent as it passes through a treatment system can indicate the performance of a septic system. Understanding how these components enter the waste stream and are removed through the treatment process is critical for system designers and service providers. This section will describe these wastewater components.

TABLE 5.7 Unsaturated Flow During Soil Treatment of Septic Tank Effluent

Parameter	Raw Waste	Septic Tank Effluent	One Foot Below Distribution Media	Three Feet Below Distribution Media
BOD_5 (mg/L)	30-1147***	39-861***	0**	0**
TSS (mg/L)	18-2233***	22-276***	0**	0**
Fecal Coliform (MPN/100ml)	30,000-10,000,000,000**,***	1,000-120,000,000**,***	1-100**	0**
Viruses (PFU/ml)	unknown**	100,000-10,000,000**	0-1,000**	0**
Nitrogen (mg/L)				
Total	35-189**,***	25-124**,***	—	—
NH_4	7-40**	20-60**	*B-20**	—
NO_3	<1**	<1**	*B-40**	*B-40**
Total Phosphorus (mg/L)	10-27**	3-40***	*B-10**	*B-1**

* B = background
**Tchobanoglous and Burton, 1991
***Lowe et al., 2007

Waste Strength

Residential strength effluent is defined as septic tank effluent or other treatment device with a BOD_5 less than or equal to 170 mg/L; TSS less than or equal to 60 mg/L; and fats, oils, and grease less than or equal to 25 mg/L (7081.0130, Subp 2).

High-strength wastewater is defined as:

1. influent having BOD_5 greater than 300 mg/L; and/or TSS greater than 200 mg/L; and/or fats, oils, and grease greater than 50 mg/L entering a pretreatment component (as defined by NSF Standard 40 testing protocol);

2. effluent from a septic tank or other pretreatment component that has BOD_5 greater than 170 mg/L; and/or TSS greater than 60 mg/L; and/or fats, oils, and grease greater than 25 mg/L and is applied to an infiltrative surface.

Biochemical Oxygen Demands (BOD_5), Dissolved Oxygen, and Total Suspended Solids (TSS)

Biochemical oxygen demand (BOD_5) is the most widely used parameter applied to wastewater. BOD_5 is a measure of the dissolved oxygen required by microorganisms to oxidize or decompose the organic matter in wastewater. A typical BOD_5 value for septic tank effluent is 150 milligrams per liter. For a Type I system, the BOD_5 limit is 170 milligrams per liter.

When the dissolved oxygen (DO) contained in septic tank effluent is measured, it is usually very low, typically one milligram per liter. While DO in water can be as high as 12 milligrams per liter, the microorganisms in the septic tank normally use up any available oxygen to break down organic matter.

Total suspended solids (TSS) is a measure of the solids that remain in the wastewater after settling has occurred in the tank. A typical TSS value is 60 milligrams per liter. BOD and total suspended solids together measure the strength of the wastewater. They can serve as an indicator of system performance. Table 5.8 identifies estimated BOD for other establishments. The data is taken from a CIDWT Publication entitled, Analyzing Wastewater Treatment Systems Serving Residential and Commercial Facilities for High Strength and Hydraulic Loading, 2008. You can calculate the estimated concentration of BOD_5 by using the following equation:

Concentration (mg/L) = # lbs BOD_5 ÷ Q(gpd) ÷ 8.35 X 1,000,000

TABLE 5.8 Estimate of Waste Strengths from Other Establishments

Type of Facility	BOD (lbs/unit/day)
Airports	
Per passenger	0.02
Per employee	0.05
Apartment houses– multiple family	0.175/unit
Boarding houses	0.14/person
Bowling alley (no kitchen)	0.15/lane
Camps	
Construction (Semi-permanent)	0.140/person
Day (no meals)	0.031/person
Luxury	0.208/person
Resort - night & day/limited plumbing	0.140/person
Church (no kitchen)	0.02/seat
Country club	0.208/member
Dwelling– single family	0.17/person
Employee/personnel addition	0.04/employee
Factory	
No showers	0.073/employee
With showers	0.083/employee
Hospital	0.518/bed

TABLE 5.8 Estimate of Waste Strengths from Other Establishments (cont'd)	
Hotel	0.125 per room/ two person
Mobile home park	0.140/person
Motel	
per bed space	0.083/bed
Per room w/ bath, toilet & kitchen wastes	0.14/person
Nursing home	0.26/person
Office building (no food)	0.05/employee
Park	
toilet wastes only	0.01/person
bathhouses, showers and flush toilets	0.021/person
Restaurant	
Kitchen waste	0.015/meal
Toilet and kitchen waste	0.021/customer
Additional for bars and cocktail lounges	0.01/customer
School, day	0.031/student
Add for gym/showers	0.011/student
Add for cafeteria	0.011/student
School, boarding	0.208/student
Service station	0.021/vehicle served
Shopping center (no food service or laundry)	0.050/employee
Sports stadiums	0.20/person
Stores	0.832/toilet room
Swimming pools and bathhouses	0.021/person
Theaters	
Drive-in	0.010/car space
Indoor	0.010/seat
Trailer Park	0.35/trailer

Types of BOD

Biochemical Oxygen Demand

BOD or Biochemical Oxygen Demand is the quantity of dissolved oxygen consumed by microorganisms during the microbial and chemical oxidation of the constituents contained in a wastewater sample during an incubation period at a given temperature. The biochemical oxygen demand represents the oxygen utilized during the oxidation of both carbon and nitrogenous compounds.

Biochemical Oxygen Demand (BOD_5)

BOD_5 or Biochemical Oxygen Demand – 5-day is the quantity of dissolved oxygen consumed by microorganisms during the breakdown of organic matter in a wastewater sample during a 5-day incubation period and measured in mg/L at 20°C. It is used as a means to describe the amount of organic matter present in the water.

Biodegradable organic matter is provided in terms of pounds of BOD_5 per person (capita) per day by using the BOD_5 concentration and daily flow. Biochemical oxygen demand is a measure of the oxygen required by bacteria, chemicals, and other organisms to break down organic matter over a five day period. It is an indicator of the overall strength of the wastewater. Most designs assume that all residential sources generate a concentration of 300 mg/L of BOD_5, and after pretreatment in a properly sized septic tank the BOD_5 is reduced to approximately 170 mg/L (Table 5.7). However, these concentrations can vary from site to site.

Carbonaceous Biochemical Oxygen Demand (CBOD)

CBOD or Carbonaceous Biochemical Oxygen Demand is the quantity of dissolved oxygen consumed by microorganisms during the breakdown of organic carbon in a wastewater sample during an incubation period of 5 days at 20°C. An inhibitor is placed in the sample to prevent growth of nitrogenous oxidizing microbial populations. It is used as a means to describe the amount of organic carbon present in the water that can be broken down with microbial processes.

Nitrogenous Biochemical Oxygen Demand (NBOD)

NBOD or Nitrogenous Biochemical Oxygen Demand is the quantity of dissolved oxygen consumed by microorganisms during the oxidation of nitrogenous compounds such as protein and ammonium in a wastewater sample during an incubation period of 5 days at 20°C. It is used as a means to describe the amount of organic nitrogen (such as urea, proteins, etc.) present in the water. It is not usually used in typical wastewater analysis.

Ultimate Biochemical Oxygen Demand (UBOD)

Ultimate Biochemical Oxygen Demand is the measure of the oxygen required to complete the breakdown of the organic matter. The UBOD consists of summing the oxygen demand required to oxidize the organic matter in the wastewater, synthesize the organic matter into new cell tissue, and the endogenous respiration where cell tissue is consumed by other microbes to obtain energy for cell maintenance. The UBOD is not typically a value measured in lab analysis.

Source and Impact of BOD_5 on Systems

High BOD_5 levels are caused by high organic loading to the system. In a residential system, the number of people in the house could be greater than that for which the system was designed and originally constructed. In this situation it is also possible that the concentration might not be elevated, but the overall organic mass loading could be significantly higher. An elevated BOD_5 concentration could also be influenced by the activities that are happening at the source. In homes or restaurants, the presence of a garbage disposal, the types of foods prepared and methods to prepare them can increase the BOD_5 levels. In a home, a large portion of BOD_5 is produced from toilet water. Toilet water also produces a large part of the natural microorganisms. A high BOD_5 (> 170 mg/L) can cause the growth of excessive biomass that can clog and shorten the lifespan of the soil treatment area.

High BOD_5 in the effluent moving to the downstream components of the treatment train could also be caused by a broken inlet or outlet baffle in the septic tank, infrequent tank maintenance, or reduced biological activity in the septic tank. BOD_5 levels are roughly cut in half in a properly operating septic tank (Magdorf, 1974). Baffles manage the flow of sewage to facilitate settling and anaerobic decomposition.BOD_5 reduction is limited if baffles are not operational. Appropriately removing accumulated scum and sludge from the tank also facilitates the proper operation of a septic tank. Chemicals used by the source may play a large role in inhibiting the reduction of the BOD_5, therefore causing a high effluent BOD_5 concentration. Onsite wastewater treatment systems use naturally existing microorganisms to reduce the contaminants and treat wastewater. During treatment, the microorganisms feed on constituents in the wastewater, reducing their concentration and resulting in cleaner wastewater. Harsh chemicals, such as bleach, detergents, cleaners, and disinfectants, can kill these microorganisms and reduce their ability to breakdown contaminants such as BOD_5.

Low BOD_5 from a home may be due to a low occupancy or a low number of meals prepared at home. A low BOD_5 concentration may also be created through dilution from higher than normal hydraulic flows into the wastewater treatment system. This dilution effect could be due to the extra use of appliances, such as laundry machines, Jacuzzis, or long showers. Leaking fixtures can also add extra water. If clear water sources such as water treatment systems or condensate drains are plumbed into the system, the increase in carriage water volume will dilute the constituents in the wastewater and decrease the concentration of food supply. Commercial systems may have a low BOD_5 if a low percentage of the wastewater comes from the bathroom and the rest comes from sources with low BOD_5 contributions with significant carriage water volume.

In typical wastewater treatment trains, your senses may assist in estimating relative BOD_5 concentrations. You can recognize BOD_5 levels that are not average by the clarity of the water. Clear water is an indication of a low BOD_5 level. The cloudier the wastewater is, the higher the organic loading. This assumes suspended clays are not part of the waste stream. If the wastewater odor is sour and rancid or if it smells like a detergent or a cleaner, this may be a sign that chemicals are present that can inhibit biological treatment, resulting in a high BOD_5.

Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) is a measure of the amount of organic matter oxidized by a strong chemical oxidant. COD is used to measure organic matter in commercial, industrial, and municipal wastes that contain compounds toxic to biological life where the BOD_5 test would not work. The COD levels in a wastewater sample are almost always greater than BOD_5 levels because more compounds can be chemically oxidized in the COD test than can be biologically oxidized in the BOD test. In most cases, once the COD/BOD_5 relationship is known for a particular facility, the COD concentration of a sample can be used to approximate the BOD_5 concentration. The COD test can generally be done within 2.5 hours, whereas a BOD_5 test takes five days. A COD test is performed when a quick determination of oxygen demand is needed.

Total Suspended Solids (TSS)

Total suspended solids or TSS is the most common measure of the amount of solids in wastewater effluent. TSS is the measure of all suspended solids in a liquid, typically expressed in mg/L. It is measured by filtering a well-mixed sample through a standard glass fiber filter and drying the residue retained on the filter at 217 to 221 degrees F (103 to 105 degrees C). The increase in the weight of the filter represents the amount of total suspended solids.

Other terms and measurements of solids in wastewater treatment systems are:

- Solids, settleable: suspended solids that will settle out of suspension within a specified period of time, expressed in milliliters per liter (mL/L)
- Solids, total (TS): mineral, cells, etc. left in wastewater after evaporation of the water fraction at 103 degrees C, typically expressed in mg/L

- Solids, total dissolved (TDS): material that passes a standard glass fiber filter, and remains after evaporation at 103 degrees C, typically expressed in mg/L
- Solids, volatile: weight loss on ignition of total solids, not distinguishing between inorganic and organic matter and including loss due to decomposition or volatilization of some mineral salts at 550 degrees C

TSS and BOD_5 are typically the two parameters used to measure wastewater strength and treatment performance relating to organic/inorganic matter. TSS (as stated earlier) is measured by performing a solids analysis but can also be estimated by a turbidity test. Turbidity is the physical clarity of the water and is an indicator of the presence of suspended matter in wastewater. A "quick and dirty" TSS test can be determined with an Imhoff Cone. A visual test will determine if TSS levels are high or low when a sample of wastewater is placed in a cone against a light background.

Impact of TSS on systems

High TSS can place a great demand on the downstream devices and could lead to clogged components and orifices in distribution manifolds. High TSS can result from:

- The system being under-designed for the source supply
- Use of low flow fixtures—although they conserve water, they do not reduce the constituent mass loading and result in higher concentrations
- Use of a garbage disposal
- Kitchen practices—e.g., kitchen clean-up, food preparation, or cuisine
- Above average use of toilet paper, which can be broken down biologically but only by fungus, which needs air to function. Microbes present in septic tanks typically do not break down paper products which are wood-based
- Laundry machines—due to clothing fibers, clay, or soils present on the clothes

The volume of dirt or grime present in the laundry will directly relate to the habits, hobbies, and occupation of the residents.

Although low TSS is not a problem for the system, it could indicate that something else is wrong with the system. Low TSS could be due to:

- Fewer users on the system than considered in the original design
- Higher flows from low TSS sources
- Clear water inflows

Fats, Oils and Grease (FOG)

FOG (fats, oils, and grease) is a constituent of sewage typically originating from food stuffs (animal fats or vegetable oils) or consisting of compounds of alcohol or glycerol with fatty acids (soaps and lotions), typically measured in mg/L.

Sources of FOG

Fat found in onsite wastewater treatment systems is animal fat, oil is from vegetable and cooking oils, and grease is from petroleum based soaps. FOG are generally treated in onsite wastewater treatment systems by separating them from the wastewater stream. At high temperatures FOG are in a liquid state, but as the temperature cools, the fats component will solidify (Table 5.9). FOG can be trapped in pretreatment components, such as septic tanks and grease traps, where they typically float to the top of tanks. They are less dense and lighter than water. It is important to try to contain FOG early in the system, because they can accumulate inside pipes and lead to clogging of downstream components. FOG also contribute to BOD_5 and TSS concentrations. FOG in excessive amounts interfere with aerobic biological processes and lead to decreased treatment efficiency. The expected levels of FOG concentration must be considered during wastewater treatment design.

TABLE 5.9 Characteristics of fats, oils and grease in wastewater.

Constituent	State at Room Temperature[1]	Derived From	Comments[2]
Fats	Solid	Animal fat	Non-toxic to the system
Oils	Liquid	Vegetable and cooking oils	Non-toxic to the system
Grease	Liquid	Petroleum based products: soaps, hair conditioners, tanning oils, oil/grease on hands/clothes, bath oils, etc.	Residual material on appliances; solid material attached to pans/equipment; may potentially be toxic to microbes commonly present in the wastewater treatment system.

[1] Room temperature assumes 80°F.
[2] Warning: the use of a degreaser will move all of these components through the wastewater system

FOG in domestic wastewater will generally originate in the kitchen or bathroom. Kitchen FOG usually come from disposing animal- or vegetable-based food scraps and liquids down the sink. Households using garbage disposals will have 30-40 percent more FOG than households not using garbage disposals. Bath oils, sun tan lotions, hair conditioners, and moisturizing creams are bathroom sources of FOG that enter the wastewater stream. An increased use in cooking oils, lotions, and hair conditioners will directly increase the FOG concentration in the wastewater.

Low FOG, although it is not considered a problem, could be the result of not using the kitchen or of higher than normal flows entering the system. Low FOG can also be attributed to the use of bar soap instead of liquid soaps.

Impact of FOG on systems

Fat

Animal fat is relatively easy to hold in a tank because it's quite sensitive to temperature. It becomes a solid at 80°F, and wastewater temperature is usually less than 80°F. Animal fat will break down in the soil, but it takes four times more energy to break down than the organic matter typically measured by BOD_5. Fat is added to the system from cooking, clean up, and dish washing, so commercial systems will typically have higher levels of fat than residential systems. If a system is supplied with a lot of animal fat, it will typically stay in the septic tank. If it is contained in the septic tank, it may not be observed in FOG measurements in downstream components.

Oils

Vegetable oil is not as sensitive to temperature as fat and can pass through the system. Oil can also be broken down through a biological process, but it takes 12 times more energy to break down oil than the organic matter typically measured by BOD_5. There are many different types of oils used, but vegetable is the most common. Vegetable oil is often used in the liquid form, but it can also be solid shortening. The liquid form is harder to hold in a tank. Table 5.10 lists several different types of fats and oils that are commonly used and lists their physical properties.

TABLE 5.10 Cooking fat and oil physical properties (adapted from CIA, 1996)

Substance	Melting Point (°F)	Density (g/mL) @ 59-68 (°F)
Corn Oil	12	0.923
Olive Oil	32	0.918
Vegetable Oil	n/a	0.910
Canola Oil	14	0.92
Soy-bean Oil	3.2	0.92
Sunflower Oil	2	0.919
Cottonseed Oil	55	0.926
Shortening	115	n/a
Lard (Fat)	86	0.919

The ability of the oil to separate is influenced not only by temperature, but also by how the oil was generated and used. Free oil will rise to the wastewater surface and be easily separated when the mixture is allowed to become quiescent. Emulsified oil has been broken up into very small droplets and occurs either by mechanical or chemical action. An example of mechanical emulsification is when extremely hot water from a dishwasher is mixed with the oil. Given time and a decrease in temperature, this oil can be separated. Chemical emulsification occurs when detergents or cleaners produce a mix of oil and water. Degreasing compounds can generate dissolved oils, in which discrete oil particles are no longer present. Chemically emulsified oil will take a longer time to separate, increasing the risk of carrying it to downstream components unless long quiescent periods are available to allow separation.

Grease

Grease is petroleum-based and can be toxic to a system. Because grease is petroleum-based, it cannot be broken down, but it can be separated. Grease comes from lotions, hair products, and soaps. Typically, there will be a higher percentage of grease in the FOG from residential systems when compared to most commercial systems. Grease can build up over time, coating components and inhibiting treatment of other constituents in the wastewater.

Design Process for HSW

a. Evaluate reference documents for potential of generating HSW.

b. Evaluate other establishment sources using Facility Use Survey. See attachment.

c. Sample effluent from the existing system, if possible.

i. ***When.*** The system should be sampled within 18 hours of known peak usage. It is optimum if the tank is not in need of pumping (worst case) and not pumped recently (best case) to get a representative sample.

ii. ***Where.*** It is best to sample from the outlet of the last septic tank or pump tank.

iii. ***How.*** Samples can be either pumped from the wastewater surface inside the baffle of the tank or a bottle can be lowered into the gap taking the sample as near to the wastewater surface as possible. The sides of the baffle should be avoided so that the FOG buildup on the baffle wall is not added into the sample. If a sample is taken from a pump tank be sure to move aside a scum layer if it exists.

d. Either with estimates or measurements determine if the design must account for high strength wastewater.

e. Calculate the projected loading to the downstream components in lbs of BOD_5 per day.

Biological Treatment Processes

Wastewater Oxygen States

To fully understand the biological treatment process the oxidation states in a system are critical. Oxidation is:

1. the chemical reaction in which a loss of electrons results in an increase in oxidation number (valence) of an element; occurs concurrently with reduction of the associated reactant;
2. the chemical or biological conversion of organic matter to simpler, more stable forms in the presence of oxygen with a concurrent release of energy and
3. the process of a substance combining with oxygen.

These treatment process can either occur under aerobic, anaerobic or anoxic conditions.

1. Aerobic: having molecular oxygen (O_2) as a part of the environment, or a biological process that occurs only in the presence of molecular oxygen. Typically aerobic bacteria dominate in this environment and metabolize only in the presence of molecular oxygen.
2. Anaerobic: absence of molecular oxygen (O_2) as a part of the environment, or a biological process that occurs in the absence of molecular oxygen; bound oxygen is present in other molecules, such as nitrate (NO_3^-) sulfate (SO_4^{2-}) and carbon dioxide CO_2. Anaerobic bacteria dominate in this state because they are able to metabolize in the absence of molecular oxygen.
3. Anoxic: condition in which all constituents are in their reduced form (no oxidants present); conditions in a septic tank are generally anaerobic, but not anoxic; see also aerobic and anaerobic.

Biological processes for treatment take many different forms, including die-off, predation, oxidation, and mineralization. Natural die-off occurs when pathogens are held in nutrient-poor aerobic conditions. Predation occurs when microorganisms attack and destroy pathogenic bacteria and viruses. Biological oxidation occurs when bacteria break down organic matter into water and carbon dioxide (CO_2). Oxidation reduces BOD_5, removes pathogens, and works best under aerobic conditions. Mineralization transforms organic nitrogen into inorganic forms of nitrogen that can become part of other biologically driven treatment processes, such as nitrification and denitrification.

The microbes that are used for biological treatment require food (which is the constituents in the wastewater) and an environment consisting of optimal conditions. The following parameters can influence the effectiveness of treatment by influencing the performance of the microbes:

- Dissolved oxygen (DO)
- pH
- Temperature

These parameters are used as indicators for the presence of other constituents in the wastewater. If one of these parameters is not in the expected range, then it can be assumed that the wastewater is not being properly treated, because the microbes cannot function properly. All of these parameters can be evaluated in the field. If one of them is out of the expected range, lab tests evaluating other constituents and system performance should be run.

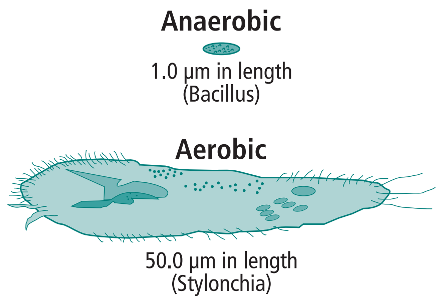
Dissolved Oxygen (DO)

Dissolved Oxygen (DO) is the amount of oxygen dissolved in water. It is influenced mainly by temperature, barometric pressure (altitude), and water salinity. As temperature decreases, the amount of dissolved oxygen that can be accepted by water increases until it becomes saturated.

The three oxygen states are aerobic, anaerobic, and anoxic conditions. The term aerobic is defined as having molecular oxygen (free oxygen, O_2) as a part of the environment or a biological process that occurs only in the presence of molecular oxygen. An anaerobic condition is the absence of molecular oxygen as a part of the environment or a biological process that occurs in the absence of molecular oxygen but can utilize oxygen bound in other molecules, such as nitrate (NO_3^-). Anoxic is the condition in which all wastewater and/or effluent constituents are in their reduced form, meaning there are no oxidants present.

The microorganisms (bugs) that are used for biological treatment can be categorized by the state of oxidation in which they operate. These categories of microorganisms include:

FIGURE 5.3 Relative Size of Anaerobic and Aerobic Bacteria



- Aerobes – thrive in aerobic conditions
- Anaerobes – thrive in anaerobic conditions
- Facultative – thrive in both aerobic and anaerobic conditions

Free oxygen (O_2) is needed for aerobic treatment to take place, and aerobic bacteria need oxygen to grow and live. Aerobic organisms respire dissolved oxygen contained in the water. Anaerobic bacteria grow and live in the absence of free oxygen. Facultative organisms have the ability to respire free oxygen when it is available and shut down the respiration process when dissolved oxygen is lacking. Table 5.11 gives the desired ranges of DO in wastewater.

Anaerobic bacteria are significantly slower at oxidation and smaller in size than aerobic bacteria (Figure 5.3), but they are much more resilient to environmental changes. Aerobic microorganisms are more sensitive to wastewater parameters (such as DO, pH and temperature), but in optimal conditions, they digest organic matter and pathogens more rapidly than do anaerobic organisms.

TABLE 5.11 Ideal Dissolved Oxygen Range in Wastewater

Microbes	Anaerobe	Facultative	Aerobe
Low DO (mg/L)	0	0	0.5
High DO (mg/L)	0.5	5	5
Typical (mg/L)	0-0.3	0-1	1-3

The septic tank is typically considered an anaerobic treatment component, although there can be aerobic zones. For the most part, septic tank microbes assimilate the waste constituents in the absence of a respiration process and are commonly referred to as anaerobic microbes. Facultative microbes utilize free oxygen or assimilate waste without respiration. During assimilation of waste, the bonds holding the oxygen are broken and allow the compounds to react with other components (i.e., SO_4^- H_2S). Therefore, septic tanks can have both anaerobic and facultative bacteria treating the wastewater.

The anaerobic bacteria do not thrive in environments with free oxygen. Water entering the septic tank has dissolved free oxygen which must be removed by the oxygen requirements of the wastewater so the anaerobic bacteria can survive. As the system matures, the anaerobic bacteria become more efficient. The oxygen demand in the system rapidly removes free oxygen entering with the influent and maintains the anaerobic environment. The greater removal rates of BOD and TSS are achieved under this fully anaerobic environment.

If the water source has low DO, then the amount of DO entering the onsite wastewater treatment system will be low. Low DO in the wastewater could also be caused by a high organic load. In aerobic treatment processes, high concentrations of BOD_5, FOG, and nutrients will exhaust the oxygen in the wastewater. This is because the microbes present in the system require more oxygen to break down the increase in food.

High DO can be attributed to the water source and/or dilution due to leaking fixtures or infiltration. Also, if there is a significant amount of dead microbes in the system due to a chemical upset, a high DO may result. The microbes are not robust and are not depleting the oxygen supply.

Although high or low DO is not a contaminant, it can be used as an indicator. Low DO is expected in the septic tank, but should be greater than 1.0 mg/L in the aeration component. Be cautious when sampling for DO not to add oxygen. In addition, the sampling method may be faulty and give inaccurate readings.

pH

pH is a term used to describe the relative amount of acidity or basicity in the wastewater. Low pH values indicate a high concentration of hydrogen ions (acids) in solution, and high pH values indicate a low concentration of hydrogen ions (basic). The pH value can range from 1 to 14 with a value of 7 being neutral. The ideal pH in wastewater will typically be around the neutral range (Table 5.12).

TABLE 5.12 Ideal range for pH in wastewater

Ideal Range in Wastewater	
Low pH	< 6.5
Ideal	7
High pH	>7.2

High pH (basic conditions) can be caused by certain laundry detergents, cleaning agents, chemicals, and high alkalinity source water. Photo developing labs and laundromats are common sources of wastewater that cause high pH. As the pH rises, the microbial population changes to organisms less efficient in the breakdown of wastewater.

Low pH (acidic conditions) can be influenced by cooking habits, low alkalinity in the water supply or acid-based cleaners. Ifthere is an above normal use of dairy products, coffee, excessive baking, or home canning, lower pH levels in the wastewater stream are likely. Just like high pH levels, low pH levels will only allow certain microbes to survive, adversely influencing wastewater treatment. The microbes at low or high pH are not as efficient as the microbes that can survive at an average pH level.

The pH level can be easily identified by the odor of the system. Low pH has a very acidic smell that absorbs readily into clothing and is hard to remove. High pH often smells like the chemical or cleaner that was used at the wastewater source that is causing the high pH. Over a relatively short period of time, our olfactory sensors become accustomed to an odor. As a result, the odor test can only be used at the very start of a testing or inspection before our senses get used to the odor.

Temperature

Septic tank effluent on average is approximately 20 degrees (°F) warmer than the ambient ground temperature. Microbial activity doubles in population every time the temperature increases by 18°F (10°C) until the optimum temperature is reached. As the microbial activity doubles, the biodegradation of constituents increases. This means that oxygen uptake is more rapid at warmer temperatures, requiring air to be supplied at a higher rate. The waste degrades more quickly at warmer temperatures, so it need not be held in the treatment system as long when it is warm. The converse is also true: in the winter, oxygen uptake is low and air need not be supplied as fast. However, the waste takes longer to degrade, and would thus need to stay in the treatment system longer during cold months. The practical implication of this is that aerators are designed using summer temperatures and detention tanks are designed using winter temperatures.

If the temperature is too high, it will damage or kill the microbes that are providing treatment. The opposite effect occurs: as temperature decreases, so does microbial activity. It has been found that microbes used in wastewater treatment become dormant at 39.2°F (4°C). The ideal range for aerobic microbes decomposing the waste is between 77° and 95°F (Table 5.13). Just as the microbial population varies under certain pH and DO ranges, there are specific microbes that can thrive at particular temperature ranges (Table 5.14).

TABLE 5.13 Ideal temperature range in wastewater

Ideal Range in Wastewater	
Low temperature	77 °F
High temperature	95 °F

TABLE 5.14 Temperature classification of bacteria (M&E, 2003)

Type	Temperature range °C (F)	Optimum range °C (F)
Psychrophilic	10-30 (50-86)	12-18 (53.6-64.4)
Mesophilic	20-50 (68-122)	25-40 (77-104)
Thermophilic	35-75 (95-167)	55-65 (131-149)

Low temperature levels can be caused by cold water entering a leaky tank or leaky plumbing, the climate, or by laundry that is washed in cold water. If the temperature is too low, the biological activity in the system will slow or stop altogether.

High temperatures in a system can be caused by long hot showers, excessive laundering using hot water, dishwashers, or leaky hot water faucets. Temperatures that are over 100 °F can dissolve greases and oils held within a tank. In ideal temperatures, FOG would float to the top of the tank and separate from the wastewater stream. With high temperatures, eventually these dissolved greases and oils will end up in dowstream components and clog them. Temperatures in excess of 122 °F can cause aerobic digestion and nitrification processes to cease. These higher temperatures in the treatment unit are unlikely for domestic wastes but may be possible in commercial units that use a lot of hot water such as commercial kitchens.

Alkalinity

Alkalinity refers to a wastewater's ability, or inability, to neutralize acids. The alkalinity in wastewater helps to buffer changes in pH caused by the addition of acids and is essential for the nitrification process (see page 47). Alkalinity typically occurs naturally in the source water.

Pathogens

The most critical component, in terms of what must be removed from wastewater, is pathogens. Pathogens are organisms that cause disease; they include viruses, protozoa, parasites, and bacteria. Examples in wastewater include Salmonella, Vibrio cholera, Entamoeba histolytica, and Cryptosporidium although almost all disease organisms could be present in wastewater. Viruses are organisms too small to be seen by light microscopy. They are an obligate parasite dependent on a host cell for its metabolic and reproductive needs. Pathogens may be found in wastewater generated anywhere in the house. Any human contact with water results in the potential to add pathogens to the environment. Because of their role in spreading disease, pathogens in wastewater make wastewater treatment a public health issue.

Fecal Coliform (FC)

Some of the microorganisms found in wastewater can cause disease while others are harmless. It is nearly impossible to identify all the pathogenic organisms in wastewater. Fecal coliform bacteria is an indicator bacteria common to the digestive systems of warm-blooded animals that is cultured in standard tests to indicate either contamination from sewage or the level of disinfection generally measured as number of colonies/100 mL or Most Probable Number (MPN). It is the most common test for pathogens because it is a relatively easy and inexpensive test. **MN Rules Chapter 7080.1100, Subp. 30, defines fecal coliform as the bacteria common to the digestive systems of humans that are cultured in standard tests. Counts of these organisms are typically used to indicate potential contamination from sewage or to describe a level of disinfection, generally expressed in colonies per 100 mL.** A colony-forming unit (cfu) is the term used to report the estimated number of bacteria in a water sample. Fecal coliform bacteria are fairly easy to test for, and their presence is an indication that pathogens, which are more difficult to isolate and identify, may also be present. An average MPN for fecal coliform bacteria in septic tank effluent is 1,000,000 cells per 100 milliliters.

Sometimes total coliform bacteria is measured instead of fecal. Total coliform is a broader group of bacteria that constitute most of the intestinal flora of warm blooded animals (including the genera Klebsiella sp., Enterobacter sp., Citrobacter sp., or Escherichia sp.)

The removal of these organisms through the soil treatment process is the key design factor for systems, although E-coli is becoming the preferred indicator organism because of their known pathogenic effects. The requirement of soil separation found in MN Rules Chapter 7080 comes from the removal of fecal coliform organisms.

Vertical separation as the vertical measurement of unsaturated soil or sand between the bottom of the distribution medium and the periodically saturated soil level or bedrock (7080.1100, Subp 91). For a SSTS to properly treat wastewater, this zone of unsaturated soil must be present in order for beneficial bacteria and microbes in the soil to remove harmful bacteria and viruses from the wastewater. The periodically saturated soil level is commonly identified by the presence of redoximorphic features. For SSTS constructed after March 31, 1996, or in a Shoreland area/Wellhead protection area/serving food, beverage, or lodging establishments (SWF area), at least three feet of vertical separation distance is required. The LGU may allow up to a 15 percent reduction in this distance; this reduction must be specified in the local ordinance.

This amount of separation is allowed to be decreased according to Table 5.15 because the effluent is treated to either level A or B before reaching the soil.

Treatment products are registered in Minnesota as products that either: 1) treat residential strength sewage or 2) treat commercial or high-strength sewage as follows:

- Category A – treatment products for residential strength sewage
- Category B – treatment products for commercial or high-strength sewage

TABLE 5.15 Treatment Component Performance Levels and Method of Distribution by Texture Group[1]

Vertical Separation (inches)	Texture Group[2]		
	All sands and loamy sands	Sandy loam, loam, silt loam	Clay, clay loams
12 to 17[3]	Treatment level A Uniform distribution Timed dosing	Treatment level A Uniform distribution Timed dosing	Treatment level A Uniform distribution Timed dosing
18 to 35[3]	Treatment level B Uniform distribution Timed dosing	Treatment level B Uniform distribution Timed dosing	Treatment level B Uniform distribution
36+[3]	Treatment level A-2 or B-2 Uniform distribution Treatment level C	Treatment level A-2 or B-2 Uniform distribution Treatment level C	Treatment level A-2 or B-2 Uniform distribution Treatment level C

[1] The treatment component performance levels correspond with those established for treatment components under the product testing requirements in Table III in part 7083.4030.
[2] With less than 50 percent rock fragments.
[3] Additional vertical separation distance is required as determined in part 7080.2150, subpart 3, item C, subitem (1), unit (b).

Category A Products and Treatment Levels

Within Category A, proprietary treatment products are listed by their ability to treat residential sewage to a specific treatment level. There are seven 'Treatment Levels' at which treatment products can be registered (Table 5.16). Products that meet the requirements of *Treatment Level A* meet the highest treatment standard in removing organic matter (15 mg/L $CBOD_5$), total suspended solids (15 mg/L TSS), and pathogenic indicator organisms (1,000 cfu/100 mL fecal coliform bacteria).

TABLE 5.16 The Seven Treatment Levels for Proprietary Treatment Products

Level	Parameters				
	$CBOD_5$ (mg/L)[a]	TSS (mg/L)[b]	O&G (mg/L)[c]	FC (#/100 mL)[d]	Nutrient (mg/L)
A	15	15	--	1,000	--
A-2	15	15	--	--	--
B	25	30	--	10,000	--
B-2	25	30	--	--	--
C	125*	60	25	--	--
TN	--	--	--	--	<20 or actual value
TP	--	--	--	--	<5 or actual value

* BOD_5 = 170 mg/L

a Carbonaceous biochemical oxygen demand or $CBOD_5$ means the measure of the quantity of oxygen used by microorganisms in the aerobic oxidation of organic matter and other compounds containing carbon amount of oxygen required by bacteria while stabilizing, digesting, or treating the organic matter under aerobic conditions over a five-day incubation period while in the presence of a chemical inhibitor to block nitrification. $CBOD_5$ is commonly expressed in milligrams per liter (mg/L) (7080.0020, Subp. 12).

b Total suspended solids or TSS means solids that are in suspension in water and that are removable by laboratory filtering (7083.0020, Subp. 21).

c O&G means oil and grease, a component of sewage typically originating from foodstuffs such as animal fats or vegetable oils or consisting of compounds of alcohol or glycerol with fatty acids such as soaps and lotions, typically expressed in mg/L (7080.0020, Subp. 14).

d Fecal coliform or FC means bacteria common to the digestive systems of warm-blooded animals humans that are cultured in standard tests. Counts of these organisms are typically used to indicate potential contamination from sewage or to describe a level of disinfection, generally expressed in colonies per 100 mL (7080.0020, Subp. 30).

Category A: Designed to treat sewage with strength typical of a residential source when septic tank effluent is anticipated to be equal to or less than treatment Level C.
Category B: Designed to treat high-strength sewage when septic tank effluent is anticipated to be greater than treatment level C, including restaurants, grocery stores, mini-marts, group homes, medical clinics, residences, etc.
Total nitrogen and phosphorus reduction in Categories A and B

Products that meet *Treatment Level B* standards have been tested to reduce organic matter to 25 mg/L $CBOD_5$, total suspended solids to 30 mg/L TSS, and fecal coliform bacteria to 10,000 cfu/100 mL. Higher quality effluents produced using products that meet Treatment Levels A and B can be dispersed into suitable soils with reduced vertical separation and increased loading rates, depending upon soil characteristics. Soil dispersal requirements using treatment products that meet Treatment Levels A and B are specified in Minnesota Rules Chapter 7080.2150, Table IX. For a residential treatment product (Category A) listed under Treatment Level A, the product would also meet treatment standards for Treatment Level B and Treatment Level C.

Category B Products and Treatment Levels

Within Category B, products can be registered for treating high strength or commercial wastewater (i.e. restaurants, grocery stores). These products have been tested to specifically reduce wastewater from high strength to typical residential strength wastewater. These products would be listed as *Treatment Level C* products, or products tested to reduce wastewater to ‘typical’ residential strength (125 mg/L $CBOD_5$, 80 mg/L TSS, and 20 mg/L oil and grease).

Nutrient Listing

Table 5.16 also identifies those products registered for use in Minnesota that have been shown to reduce nitrogen and/or phosphorus. In order to be listed for nitrogen and phosphorus removal, independent third party testing has been completed and shown to meet a total nitrogen of <20 mg/L and a total phosphorus of <5 mg/L.

Nutrients

Nutrients are elements or compounds essential as raw material for growth and development of an organism; nitrogen, phosphorus and potassium are primary nutrients. Two nutrients are of concern in wastewater treatment: phosphorus and nitrogen. These nutrients have different chemical characteristics: phosphorus tends to bind to soil particles, while nitrogen is more mobile in the soil.

MN Rule Treatment Requirements for Nutrients

In MN Rules Chapter 7080.2210, Subp. 4, for systems from 2,500 – 5,000 gpd if the system will impact the water quality of an aquifer, as defined in part 4725.0100, Subp. 21, it must employ best management practices for nitrogen reduction developed by the commissioner to mitigate water quality impacts to groundwater.

For MSTS with design flows from 5,000 – 10,000 gpd there are additional nitrogen removal requirements:

1. **if the discharge from an MSTS will impact water quality of an aquifer, as defined in part 4725.0100, subpart 21, the effluent from an MSTS, in combination with the effective recharge to the groundwater, must not exceed a concentration of total nitrogen greater than 10 mg/L at the property boundary or nearest receptor, whichever is closest; and**
2. **if the discharge from an MSTS will not impact water quality of an aquifer, as defined in part 4725.0100, subpart 21, best management practices developed by the commissioner to mitigate water quality impacts to groundwater must be employed; and not exceed a groundwater discharge**

With MSTS, Phosphorus must also be considered. **According to MN Rules 7081.0070, Subp 4 (E) discharge from the system can not exceed a groundwater discharge of phosphorus to a surface water that exceeds the phosphorus standard to the receiving water. During the Preliminary Evaluation the Designer must consider whether the ordinary high water level of public waters will be within 500 feet of the proposed soil treatment and dispersal area and if so, a preliminary assessment of phosphorus impacts to the surface water must be performed.**

SSTS may have additional nutrient compliance criteria when their design flow exceeds 2,500 gpd. **From MN Rules Chapter 7080.1550, Subp. 5 - the compliance criteria for systems with a flow of greater than 2,500 gallons per day - systems designed under part 7080.2150, subpart 4, item A or B, must demonstrate that the additional nutrient reduction component required under those items is in place and functioning.**

Portions of the following nitrogen section were taken directly from the following reference: Oakley, S. 2005. Onsite Nitrogen Removal Text. in (M.A. Gross and N.E. Deal, eds.) University Curriculum Development for Decentralized Wastewater Management. National Decentralized Water Resources Capacity Development Project. University of Arkansas, Fayetteville, AR.

Full text and Figures available Online at: www.onsiteconsortium.org/files/nitrogen.htm

Nitrogen

Nitrogen is an essential nutrient for the growth of plants and microorganisms. Nitrogen (N) is an essential chemical element and nutrient for all life forms. N constitutes 78 percent of the atmosphere by volume and is present in surface water and groundwater as ammonia (NH_3), nitrite (NO_2^-), nitrate (NO_3^-), and organic nitrogen. Total nitrogen is the measure of the complete nitrogen content in wastewater including nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_3), ammonium (NH_4^+), and organic nitrogen, expressed as mg/L of N; all these forms of nitrogen, as well as nitrogen gas (N_2), can be converted from one form to another biochemically and are components of the nitrogen cycle.

- NH_3 is the non-ionized form of reduced nitrogen.
- NH_4^+ is the ionized form of reduced nitrogen usable by plants.
- NO_3^- is the stable oxidized form of nitrogen usable by plants and usually not degraded in groundwater; nitrifying bacteria can convert nitrite (NO_2^-) to nitrate (NO_3^-) in the nitrogen cycle.
- TKN is total Kjeldahl nitrogen, which is the measure of the total concentration of organic nitrogen, ammonia, and ammonium nitrogen.
- NO_2^- is the unstable oxidized form of nitrogen.
- Organic N is the nitrogen bound in plant and animal matter, primarily amino acids and proteins; the amount of organic nitrogen can be obtained by separately measuring the ammonia nitrogen and subtracting that value from the total Kjeldahl nitrogen.

As nitrogen moves through the treatment system, it changes from ammonia to nitrate. While it is possible for nitrate to change into nitrogen gas in some systems, standard trench and bed systems do not facilitate this change, so the nitrate may move into groundwater. A range level of nitrogen in septic tank effluent is 25-124 milligrams per liter.

In drinking water, which is often from groundwater, high levels of nitrogen can be toxic to infants, causing methemaglobinemia, "blue baby syndrome." Ammonia in surface waters can be toxic to fish.

Advanced pretreatment may be required to minimize the release of nitrogen to the environment.

The principal forms of nitrogen of concern in onsite wastewater treatment and soil-groundwater interactions are Organic-N, NH_3/NH_4^+, N_2, NO_2^-, and NO_3^-(Rittman & McCarty, 2001; Sawyer et al., 1994; US EPA, 1993). Because these forms still represent four possible oxidation states that can change in the environment, it is customary to express the various forms of nitrogen in terms of nitrogen rather than the specific chemical compound: Organic-N, (35mg/L)NH_3-N, NH_4^+-N, N_2-N, NO_2^--N, and NO_3^--N. Thus, for example, 10 mg/L of NO_3^--N is equivalent to 45 mg/L of NO_3^- ion.

The Nitrogen Cycle in Soil-Groundwater Systems

Transformation of the principal nitrogen compounds (Organic-N, NH_3-N, NH_4^+-N, N_2-N, NO_2^--N, and NO_3^--N) can occur through several key mechanisms in the environment: fixation, ammonification, synthesis, nitrification, and denitrification (US EPA, 1993).

1. Nitrogen Fixation

Nitrogen fixation is the conversion of nitrogen gas into nitrogen compounds that can be assimilated by plants. Biological fixation is the most common, but fixation can also occur by lightning and through industrial processes:

Biological: N_2 Organic-N

Lightning: N_2 NO_3^-

Industrial: N_2 NO_3^-; NH_3/ NH_4^+

2. Ammonification

Ammonification is the biochemical degradation of organic-N into NH_3 or NH_4^+ by heterotrophic bacteria under aerobic or anaerobic conditions.

Organic-N + Microorganisms NH_3/ NH_4^+

Some organic-N cannot be degraded and becomes part of the humus in soils.

3. Synthesis

Synthesis is the biochemical mechanism in which NH_4^+-N or NO_3^--N is converted into plant protein (Organic-N):

NH_4^+ + CO_2 + green plants + sunlight Organic-N

NO_3^- + CO2 + green plants + sunlight Organic-N

Nitrogen fixation is also a unique form of synthesis that can only be performed by nitrogen-fixing bacteria and algae (WEF, 1998):

N-Fixing Bacteria/Algae

N_2 Organic-N

4. Nitrification

Nitrification is the biological oxidation of NH_4^+ to NO_3^- through a two-step autotrophic process by the bacteria *Nitrosomonas* and *Nitrobacter* (Rittman and McCarty, 2001; Sawyer, et al., 1994):

Nitrosomonas

Step 1: $NH_4^+ + 3/2O_2$ $NO_2^- + 2H^+ + H_2O$

Nitrobacter

Step 2: $NO_2^- + 1/2O_2$ NO_3^-

The two-step reactions are usually very rapid and hence it is rare to find nitrite levels higher than 1.0 mg/L in water (Sawyer, *et al.*, 1994). The nitrate formed by nitrification is, in the nitrogen cycle, used by plants as a nitrogen source (synthesis) or reduced to N_2 gas through the process of denitrification. Nitrate can, however, contaminate groundwater if it is not used for synthesis or reduced through denitrification as shown in Figure 1.

5. Denitrification

NO_3^- can be reduced, under anoxic conditions, to N_2 gas through heterotrophic biological denitrification as shown in the following unbalanced equation (US EPA, 1993):

Heterotrophic Bacteria

NO_3^- + Organic Matter $N_2 + CO_2 + OH^- + H_2O$

The above equation is identical to the equation for the biological oxidation of organic matter with the exception that NO_3^- is used as an electron acceptor instead of O_2:

Heterotrophic Bacteria

$$O_2 + \text{Organic Matter} \quad CO_2 + OH^- + H_2O$$

A large variety of heterotrophic bacteria can use nitrate in lieu of oxygen for the degradation of organic matter under anoxic conditions. If O_2 is present, however, the bacteria will preferentially select it instead of NO_3^- (US EPA, 1993). Thus it is very important that anoxic conditions exist in order that NO_3^- will be used as the electron acceptor. A carbon source is required as the electron donor in the above equation for denitrification to occur.

Autotrophic denitrification is also possible with either elemental sulfur or hydrogen gas used as the electron donor by autotrophic bacteria as shown in the following unbalanced equation (Rittman and McCarty, 2001):

$$NO_3^- + CO_2 + \text{Inorganic Electron Donor} \quad N_2 + \text{Oxidized Electron Donor}$$

(Elemental Sulfur or H_2 gas)

Health Effects from Groundwater Contamination with Nitrates

Contamination of groundwater with nitrates is a problem in many parts of the U.S. and has been widely documented (Bouchard, et al., 1992). Potential health concerns where contaminated groundwater is used as a drinking water source include methemoglobinemia, carcinogenesis, and birth defects.

Methemoglobinemia

High nitrate levels in drinking water supplies can cause methemoglobinemia in infants, especially those less than six months old (Bouchard, et al., 1992). After ingestion, nitrate is reduced to nitrite in the gut of the infant. The absorbed nitrite reacts with hemoglobin in the blood, forming methemoglobin. Methemoglobin, unlike hemoglobin, cannot carry oxygen. As more of the blood hemoglobin is converted to methemoglobin, the oxygen-carrying capacity of the blood is significantly reduced. Oxygen starvation of the blood can result in a bluish discoloration of the body, which is called "blue-baby" syndrome or methemoglobinemia. To prevent methemoglobinemia, the maximum contaminant level of nitrate in drinking water has been set at 10 mg/L as NO_3^--N by the US EPA (Bouchard, et al., 1992).

Carcinogenesis

High nitrate levels in drinking water could potentially have carcinogenic effects through the formation of nitrosamines. Nitrates in the human body can be converted to nitrites and then to nitrosamines, several forms of which have been classified as potential human carcinogens (Bouchard, et al., 1992). While several scientific studies have shown a positive correlation between some types of cancers and nitrate intake in animals, a cause-effect relationship for risk of cancer has not yet been demonstrated conclusively.

Birth Defects

Epidemiological studies in Canada and South Australia have shown a statistically significant increase in congenital malformations associated with nitrate-rich well water (Bouchard, et al., 1992). These studies, however, are considered to be too limited in scope to deduce a causal association between birth defects and nitrate ingestion. Experimental animal studies have not shown significant effects from elevated nitrate ingestion.

Surface Water Pollution with Nitrogen

When excess nitrogen concentrations are discharged to surface waters, several deleterious effects may occur, depending on the environmental conditions.

Eutrophication

Phosphorus is oftentimes the limiting nutrient for the growth of algae and aquatic plants in surface waters. Thus, any phosphorus can cause the stimulation of growth, resulting in algal blooms or overgrowth of aquatic plants, which can have serious consequences for the receiving water such as odors, accumulation of unsightly biomass, dissolved oxygen depletion due to biomass decay, and loss of fish and shellfish. In some cases, nitrogen is the limiting nutrient and excess nitrogen is the cause for excessive plant growth.

Oxygen Demand through Nitrification

The oxidation of Organic-N and NH_3-N/NH_4^+-N to NO_3^--N through the process of nitrification can exert a significant oxygen demand on the receiving water, which is known as the nitrogenous biochemical oxygen demand (NBOD) (Metcalf and Eddy, 1991). The NBOD of a wastewater can even be greater than the carbonaceous biochemical oxygen demand (CBOD), although it may not be exerted as rapidly. The rate of nitrification is dependent on several environmental factors, which include the population of nitrifying bacteria, temperature, alkalinity, and availability of dissolved oxygen.

Ammonia Toxicity to Aquatic Organisms

Nitrogen in the form of NH_3-N can cause acute toxicity to several species of fish. Because the concentration of NH_3-N as opposed to NH_4^+-N is pH dependent, criteria for ambient water quality have been set for unionized ammonia as a function of pH and temperature (Sawyer, et al., 1994). Many municipal wastewater treatment plants in the US are required to nitrify their effluent in order to avoid ammonia toxicity in receiving waters.

Biological Nitrification

As mentioned above, nitrification is a two-step autotrophic process (nitrifiers use CO_2 instead of organic carbon as their carbon source for cell synthesis) for the conversion of NH_4^+ to NO_3^--N. During this energy yielding reaction some of the NH_4^+ is synthesized into cell tissue giving the following overall oxidation and synthesis reaction (US EPA, 1993):

$$1.00NH_4^+ + 1.89O_2 + 0.08CO \quad 0.98NO_3^- + 0.016C_5H_7O_2N + 0.95H_2O + 1.98H^+$$

The above equation poses several key design constraints on nitrification systems. For each mole of NH_4^+ oxidized, 1.89 moles of oxygen are required and 1.98 moles of hydrogen ions will be produced. Or, in mass terms, 4.32 mg of O_2 are required for each mg of NH_4^+-N oxidized, with the subsequent loss of 7.1 mg of alkalinity as $CaCO_3$ in the wastewater, and the synthesis of 0.1 mg of new bacterial cells. Stated yet another way, the oxidation of, for example, 20 mg/L of NH_4^+-N would require the consumption of 86.4 mg/L of dissolved oxygen, the destruction of 141.4 mg/L of alkalinity as $CaCO_3$, and the production of 2.6 mg/L of nitrifying organisms (US EPA, 1993).

Nitrification can thus exert a very high nitrogenous biochemical oxygen demand (NBOD) in addition to the carbonaceous BOD (CBOD) as shown in Figure 3-3. MN Rules Chapter 7080.1100, Subp. 12 defines $CBOD_5$ as the measure of the amount of oxygen required by bacteria while stabilizing, digesting, or treating the organic matter under aerobic conditions over a five-day incubation period while in the presence of a chemical inhibitor to block nitrification. CBOD is commonly expressed in milligrams per liter (mg/L).

Using the above equation, a septic tank effluent of 40 mg/L NH_4^+-N would have a NBOD of about 184 mg/L in addition to the CBOD. This factor must be included in the design of nitrification systems to be sure there is sufficient dissolved oxygen (DO) within the system for nitrification to occur. To process 40 mg/L of NH_4^+,you must add 184 mg/L of DO. Nitrification can also cause a significant drop in pH if there is not adequate buffering capacity (alkalinity) in the wastewater.

Process Microbiology

Nitrifying organisms exhibit growth rates that are much lower than those for heterotrophic bacteria. As a result, the rate of nitrification is controlled first by concurrent heterotrophic oxidation of CBOD; as long as there is high organic (CBOD) loading to the system, the heterotrophic bacteria will dominate. Nitrification systems must thus be designed to allow sufficient detention time within the system for nitrifying bacteria to grow. Heterotrophic organisms can also play a key role in limiting oxygen transfer to nitrifying bacteria, especially in attached-growth systems (Rittman and McCarty, 2001; US EPA, 1993). After competition with heterotrophs, the rate of nitrification will be limited by the concentration of available NH_4^+-N in the system. Temperature, pH, and chemical inhibitors can also play a key role as discussed below.

At low BOD_5/TKN ratios (0.5 to 3) the population of nitrifying bacteria is high and nitrification should not be influenced by heterotrophic oxidation of CBOD (Metcalf & Eddy, 1991); this type of nitrification process is termed separate-stage nitrification. At higher BOD_5/TKN ratios, the fraction of nitrifying organisms in the system is much lower due to heterotrophic competition from oxidation of CBOD; this process is termed single-stage nitrification.

Separate-stage nitrification is highly desirable from the standpoint of process control and operation. Many onsite systems presently used or proposed for nitrogen removal, however, because of the interest in reducing size and system footprint, employ single-stage nitrification; examples include aerobic treatment units with short hydraulic detention times and sand filters or media filters that are heavily loaded organically. Single-stage systems may require more rigorous process control to ensure adequate nitrification rates.

Dissolved Oxygen Requirements and Organic Loading Rates

Suspended Growth Systems

The concentration of DO has a significant effect on nitrification in wastewater treatment. Although much research has been performed, practical experience has shown that DO levels must be maintained at approximately 2.0 mg/L in suspended-growth (aerobic) systems, especially when NH_4^+-N loadings are expected to fluctuate widely (US EPA, 1993); this may or may not be the case in domestic onsite wastewater systems.

Attached-Growth Systems

For attached-growth systems, which include both submerged and nonsubmerged processes (Crites and Tchobanoglous, 1998), DO levels must be maintained at levels that are at least 2.7 times greater than the NH_4^+-N concentrations in order to prevent oxygen transfer through the biofilm from limiting nitrification rates (US EPA, 1993). This is usually overcome in practice by using lower organic surface loadings than what would be normally applied for CBOD removal to allow for growth of nitrifying organisms; otherwise the heterotrophic organisms will dominate the bacterial film within the attached-growth media. For trickling filters, for example, the organic loading rate for nitrification is only about 1/5 to 1/8 of the CBOD loading for CBOD removal (Metcalf & Eddy, 1991; US EPA, 1993). Recirculation of effluent through the attached growth media, and use of special media, such as trickling filter plastic media with high specific surface areas, is also used to lower organic surface loadings and to promote high oxygen transfer rates.

Table 5.17 shows design organic loading rates for various attached-growth systems to achieve nitrification. Unfortunately, organic loading rates for onsite attached-growth systems are not well defined even for CBOD removal, let alone nitrification (Crites and Tchobanoglous, 1998). The more commonly used hydraulic loading rates as cited in the literature show mixed results for nitrification. This is no doubt due, at least in part, to varying organic loading rates that were not taken into consideration since the $CBOD_5$ of septic tank effluent can vary greatly, ranging from less than 100 to 480 mg/L (Ayres Associates, 1993).

TABLE 5.17 Design Loading Rates for Attached Growth Systems to Achieve >85% Nitrification

Process	Hydraulic Loading Rate, gpd/ft²	Organic Loading Rate, lbs. BOD/ft²-day	State of Knowledge for Design
Trickling Filters[1]			
Rock Media	30-900	0.04-0.12 *(0.04-0.64)*	Well Known
Plastic Media	288-1700	0.10-0.25 *(0.50-2.00)*	Well Known
Sand Filters			
Single-Pass	0.4-1.2	0.000135-0.002	Lesser Known[2]
Recirculating	3-5	0.002-0.008	Lesser Known[2]
Textile Filters			
Single-Pass	10	0.01	Lesser Known[2]
Multi-Pass[3] *(Partial Nitrification)*	30	0.03	Lesser Known[2]

[1] The values for trickling filters given for both hydraulic and organic loadings are the ranges for low rate and high rate filters. Rock filters were assumed to have a depth of 8 ft. and plastic filters a depth of 10 ft. The numbers in parentheses for organic loadings are the values for CBOD removal only without nitrification.
[2] These systems have not traditionally been designed using organic loading rates to achieve nitrification. High strength wastes thus could affect nitrification performance.
[3] At this organic loading rate only 59-76% nitrification was achieved (Leverenz, et al., 2001).

Adapted from Converse (1999); Crites and Tchobanaglous (1998); Leverenz, et al. (2001); Metcalf & Eddy (1991); and US EPA (1993).

pH and Alkalinity Effects on Nitrification

The optimum pH range for nitrification is 6.5 to 8.0 (US EPA, 1993). Because nitrification consumes about 7.1 mg of alkalinity (as $CaCO_3$) for every mg of NH_4^+-N oxidized, in low alkalinity wastewaters there is a risk that nitrification will lower the pH to inhibitory levels. If, for example, it were desired to nitrify 40 mg/L of NH_4^+-N, approximately 284 mg/L of $CaCO_3$ would be required to maintain pH levels; this may be beyond the capabilities of some wastewaters derived from water sources that do not contain relatively high alkalinity.

Temperature Effects

Temperature has a significant effect on nitrification that must be taken into consideration for design (US EPA, 1993). In general, colder temperatures require longer cell residence times in suspended-growth systems and lower hydraulic loading rates in attached-growth systems due to slower growth rates of nitrifying bacteria.

Effect of Inhibitors

Nitrifying bacteria are much more sensitive than heterotrophic bacteria and are susceptible to a wide range of organic and inorganic inhibitors as shown in Table 5.18. As has occurred in centralized wastewater treatment (US EPA, 1993), there is a need to establish a methodology for onsite wastewater systems for assessing the potential for, and occurrence of, nitrification inhibition. The introduction of chemicals shown in Table 5.18 can destroy the nitrifying bacterial populations. If these systems are not continuously monitored, the effects of these chemicals will go unnoticed.

TABLE 5.18 Examples of Nitrification Inhibitors

Inorganic Compounds		Organic Compounds
Zinc	Sodium azide	Acetone
Free Cyanide	Hydrazine	Carbon Disulfide
Perchlorate	Sodium cyanate	Chloroform
Copper	Potassium chromate	Ethanol
Mercury	Cadmium	Phenol
Chromium	Arsenic	Ethylenediamine
Nickel	Fluoride	Hexamethylene diamine
Silver	Lead	Aniline
Cobalt	Free ammonia	Monoethanolamine
Thiocyanate	Free nitrous acid	
Sodium cyanide		

Since heterotrophic bacteria are much more resilient than nitrifying bacteria, and because many of the inhibitory compounds are biodegradable organics, inhibitory effects can oftentimes be controlled by designing separate-stage nitrification systems (US EPA, 1993). In separate-stage systems the CBOD is first removed along with any biodegradable inhibitory compounds; the nitrifying organisms, which are in effect protected in the second stage, are then used to nitrify the low--CBOD, high-NH_4^+-N effluent (Figure 5).

Example: Calculation of alkalinity and oxygen requirements for nitrification

Determine the alkalinity requirements for complete nitrification for a septic tank effluent that has a CBOD of 150 mg/L and an Organic-N and NH_4^+-N concentration of 40 mg/L. What would the NBOD of this wastewater be?

Solution

1. Write a balanced equation for the nitrification reaction and include mass relationships.

Autotrophic

$$1.00NH_4^+ + 1.89O_2 + 0.08CO_2 \quad 0.98NO_3^- + 0.016C_5H_7O_2N + 0.95H_2O + 1.98H^+$$

Bacteria *bacterial cells*

18 GMW	32 GMW	113 GMW	1 GMW
14 mg as N	60.48 mg	1.81 mg	1.98 mg 1.98meq
1 mg as N	4.32 mg	0.13 mg	0.14 meq 7.1 mg as $CaCO_3$

GMW = gram molecular weight
Milliequivalent mass of $CaCO_3$ = 50 mg/meq
0.14 meq as H^+ in terms of equivalent $CaCO_3$ = 0.14 meq (50 mg $CaCO_3$/meq) = 7.1 mg as $CaCO_3$ mg as $CaCO_3$

2. Determine alkalinity requirements.

Alkalinity required = 40 mg/L Total-N (7.1 mg/L $CaCO_3$/mg N) = 284 mg/L as $CaCO_3$

3. Determine the NBOD.

NBOD = 40 mg/L total-N (4.32 mg O_2/ mg N) = 173 mg/L

Comment: The alkalinity requirements here exceed the 200 mg/L as $CaCO_3$ that has been reported to be a typical alkalinity concentration in strong, untreated domestic wastewater (Metcalf & Eddy, 1991). Alkalinity does increase as a result of water use, and the incremental range for septic tank effluent has been reported from 60-120 mg/L as $CaCO_3$ (Crites and Tchobanoglous, 1998). In areas with low-alkalinity source waters, however, nitrification could be limited. Note that the NBOD exceeds the CBOD of the septic tank effluent, which underscores the oxygen requirements for nitrification.

Summary of Nitrification Processes

Table 5.19 summarizes the various onsite technologies and their advantages and disadvantages for effective nitrification based on the factors discussed above. The available information suggests that an effective design strategy for nitrification in onsite systems would be to use attached-growth processes with relatively low organic loadings (compared to CBOD removal only) and deep, well-aerated media (such as a 2 ft. deep SPSF). This type of system would approach a separate-stage nitrification with its advantages while maintaining the cost and simplicity of a single-stage system. In this design the heterotrophic bacteria would grow in the upper levels and remove CBOD and inhibitory compounds; nitrifying bacteria would grow in the lower levels and would be protected both from shock loadings and temperature extremes. A single pass sand filter, which is well known for its nitrification reliability, is an example of this design.

TABLE 5.19 Onsite Technologies for > 85% Nitrification

Process	Effectiveness	Onsite status
Suspended growth: aerobic units	Insufficient design and performance data	Operation and maintenance unknown
Attached Growth: Single-Pass Sand Filters (SPSF)	Need more design data for organic loadings for nitrification	Fair to good performance in cold climates
Recirculating Sand Filters (RSF)	Need more design data for organic loadings for nitrification	Poorer performance in cold climates than SPSFs
Single-Pass Textile Filters	Limited data to date. Probably similar to SPSF	Need design data for organic loadings for nitrification
Multi-Pass Textile Filters	Limited data to date. Probably similar to RSF	Need design data for organic loadings for nitrification and performance in cold climates

Biological Dentrification

Denitrification is a biological process that uses NO_3^- as the electron acceptor (hence nitrification must precede denitrification) instead of O_2 to oxidize organic matter (heterotrophic denitrification) or inorganic matter such as sulfur or hydrogen (autotrophic denitrification) under anoxic conditions (Rittmann and McCarty, 2001). In the process NO_3^- is reduced to N_2 gas. Because the principal biochemical pathway is a modification of aerobic pathways (i.e., NO_3^- is used as the electron acceptor instead of O_2), the denitrification process is said to occur under anoxic conditions as opposed to anaerobic conditions (where obligate anaerobic organisms would be present). Denitrifying bacteria, whether heterotrophic or autotrophic, are facultative aerobes and can shift between oxygen respiration and nitrate respiration. For heterotrophic denitrification, the carbon source can come from the original wastewater, bacterial cell material, or an external source such as methanol or acetate. For autotrophic denitrification, which is common in water treatment but not wastewater treatment, the electron donor can come from elemental sulfur or hydrogen gas (Rittmann and McCarty, 2001).

Heterotrophic Dentrification

Wastewater as Carbon Source

The following unbalanced equation illustrates the process when wastewater or bacterial cell material is used as the carbon source (US EPA, 1993):

Heterotrophic

$$aCOHNS + bNO_3^- \quad cN_2 + dCO_2 + eC_5H_7O_2N + f\,OH^- + gH_2O + \text{end products}$$

As is shown in the following example, the reduction of 1 mg of NO_3^- is equivalent to 2.86 mg of O_2. Thus, for example, a wastewater with an ultimate BOD (BODL) of 200 mg/L could potentially reduce almost 70 mg/L of NO_3^--N if the wastewater were used as the carbon source (US EPA, 1993). This does not happen in practice, however, because a portion of the organic carbon in the wastewater must be used for cell synthesis and not nitrate reduction.

Example: Calculation of stoichiometric equations for nitrate

REDUCTION USING THE WASTEWATER AS THE CARBON SOURCE. Determine the theoretical amount of NO_3^--N that could be removed if septic tank effluent, which has a BOD_5 of 120 mg/L, is used as the carbon source. What quantity could be removed if the raw wastewater influent to the septic tank, with a BOD_5 of 220 mg/L, were used as the carbon source?

Solution

1. Write the half-reactions for oxygen and nitrate as electron acceptors (Rittmann and McCarty, 2001).

Oxygen:

$0.25O_2 + H^+ + e^- \quad 0.5\,H_2O$

32 GMW
8 g [0.25(32) = 8]
8 mg

Nitrate:

$0.2NO_3^- + 1.2H^+ + e^- \quad 0.1N_2 + 0.6H_2O$

62 GMW
14 GMW as N
2.8 g [0.2(14) = 2.8]
2.8 mg

2. Determine the stoichiometric equivalency of oxygen and nitrate.

For the acceptance of one electron, the above equations show that 8 mg of O_2 is equivalent to 2.8 mg of NO_3^--N, or that 1.0 mg of NO_3^--N is equivalent to 2.86 mg of O_2.

$$\frac{8 \text{ mg } O_2/e^- \text{ equiv.}}{2.8 \text{ mg } NO_3^- \text{-N}/e^- \text{ equiv.}} = 2.86 \text{ mg } O_2/\text{ mg } NO_3^- \text{-N}$$

3. Determine the BOD_L of the wastewater.

The stoichiometric equations must be based on the ultimate BOD (BOD_L) rather then the more commonly used BOD_5. The BOD_5 of wastewater can range between 68% to 94% of the BOD_L, depending on the value of the BOD reaction rate constant, k (Sawyer, et al., 1994). It will be assumed here that k (base e) is 0.23 d^{-1} at 20 ¡C, a typical value for domestic wastewater (Metcalf & Eddy, 1991).

Septic Tank Effluent:

$$BOD_L = \frac{BOD_5}{(1 - e^{-kt})} = \frac{120}{(1 - e^{-0.23(5)})} = \frac{120}{0.68} = 176 \text{ mg/L}$$

Septic Tank Influent:

$$BOD_L = \frac{BOD_5}{(1 - e^{-kt})} = \frac{220}{(1 - e^{-0.23(5)})} = \frac{220}{0.68} = 323 \text{ mg/L}$$

4. Determine the quantity of NO_3^- -N that could theoretically be reduced.

Septic Tank Effluent:

$$NO_3^- \text{-N Reduction} = \frac{176 \text{ mg } O_2 \text{ demand/L}}{2.86 \text{ mg } O_2 / \text{ mg } NO_3^- \text{-N}} = 61.5 \text{ mg/L}$$

Septic Tank Influent:

$$NO_3^- \text{-N Reduction} = \frac{323 \text{ mg } O_2 \text{ demand/L}}{2.86 \text{ mg } O_2 / \text{ mg } NO_3^- \text{-N}} = 113 \text{ mg/L}$$

Comment: In practice the equivalency of 2.86 mg O_2/ mg NO_3^--N is not achievable because a portion of the electron donor (i.e., the wastewater) must be used to provide carbon for cell synthesis; thus more electron donor will be needed to reduce a given amount of NO_3^--N than is predicted by the half-reactions alone. For complex organic matter such as wastewater, the stoichiometric equivalency can range from 3.46-5.07 mg BOD_L/mg NO_3^- -N, with 4.0 mg BOD_L/ mg NO_3^- -N used as a rule of thumb (Rittmann and McCarty, 2001). In terms of BOD_5, this amounts to 2.72 mg BOD_5/ mg NO_3^- -N for k (base e) = 0.23 d^{-1}.

Example: Recalculation of stoichiometric equations for nitrate reduction using the wastewater as the carbon source

Recalculate the amount of NO_3^--N that could be removed in Example 5 using the "rule of thumb" stoichiometric equivalency.

Solution

1. Express the stoichiometric equivalency in terms of the commonly used BOD_5.

$$BOD_5 = 0.68BOD_L \text{ for } k = 0.23 \text{ d}^{-1} \text{ (base e)}$$

$$\frac{4.0 \text{ mg BODL}}{\text{mg } NO_3^- \text{-N}} = 0.68(4.0) = \frac{2.72 \text{ mg } BOD_5}{\text{mg } NO_3^- \text{-N}}$$

2. Determine the quantity of NO_3^- -N that could theoretically be reduced.

Septic Tank Effluent:

$$NO_3^- \text{-N Reduction} = \frac{120 \text{ mg } BOD_5\text{/L}}{2.72 \text{ mg } BOD_5 / \text{ mg } NO_3^- \text{-N}} = 44 \text{ mg/L}$$

Septic Tank Influent:

$$NO_3^- \text{-N Reduction} = \frac{220 \text{ mg } BOD_5\text{/L}}{2.72 \text{ mg } BOD_5 / \text{ mg } NO_3^- \text{-N}} = 81 \text{ mg/L}$$

Comment: To achieve the maximum nitrate reduction potential, the wastewater should be used at the point of highest CBOD. This may not occur if septic tank effluent, for example, or a recirculation tank from a packed bed filter system, is used as the point of application of the carbon source. Imperfect mixing of the wastewater carbon source with the nitrified effluent, and the absence of anoxic conditions, can also cause a reduction in denitrification.

External Carbon Source

In cases where there is insufficient CBOD left in the wastewater to serve as an electron donor for denitrification, an external carbon source must be supplied. Although there are many possibilities, methanol and acetate have been studied the most and their stoichiometry is shown below (Rittmann and McCarty, 2001; US EPA, 1993):

Methanol:

$$NO_3^- + \underset{methanol}{1.08CH_3OH} + 0.24H_2CO_3 \xrightarrow[Bacteria]{Heterotrophic} 0.47N_2 + \underset{bacterial\ cells}{0.056C_5H_7O_2N} + HCO_3^- + 1.68H_2O$$

Acetate:

$$NO_3^- + \underset{acetate}{0.87CH_3COO^-} + H^+ \xrightarrow[Bacteria]{Heterotrophic} 0.46N_2 + \underset{bacterial\ cells}{0.08C_5H_7O_2N} + 0.87HCO_3^- + H_2O + 0.44CO_2$$

There are few examples in the literature of an external carbon source being used for onsite denitrification. Although methanol has been studied extensively in centralized wastewater treatment plants, it is probably not a good choice for onsite systems because of its toxicity and potential for contaminating groundwater supplies. Gold, et al., (1989) reported on the use of both methanol and ethanol as an external carbon source in a recirculating sand filter system with an anoxic rock filter for denitrification. They noted that although the total nitrogen removal rate was as high as 80%, the use of the chemicals required operation and maintenance of the carbon source supply system, including an on-site storage facility, a metering pump mechanism, and supplying a diluted carbon source solution. They concluded that the external carbon source could probably best be handled by a wastewater management district or a private O & M contractor (Gold, et al., 1989).

Example: Design of dentrification system using methanol as the carbon source

Determine the methanol requirements for an onsite denitrification system using a recirculating sand filter. The following conditions apply:

1. Household flowrate = 192 gpd
2. The concentration of NO_3^--N to be removed is 40 mg/L
3. Characteristics of Methanol:
   99.90% Solution = 0.7913 g CH_3OH/ml
   10.00% Solution = 0.08 g CH_3OH/ml

Solution

1. Write the balanced equation for denitrification and include mass relationships.

$$NO_3^- + 1.08CH_3OH + 0.24H_2CO_3 \xrightarrow[\text{Bacteria}]{\text{Heterotrophic}} 0.47N_2 + 0.056C_5H_7O_2N + HCO_3^- + 1.68H_2O$$

methanol; bacterial cells

62 GMW	32 GMW	113 GMW	61 GMW
14 mg as N	34.6 mg	6.3 mg	1 meq
1 mg as N	2.47 mg	0.45 mg	0.07 meq
			3.57 mg as $CaCO_3$

2. Determine the required concentration of methanol.

$$\text{Required concentration of } CH_3OH = \frac{2.47 \text{ mg}}{\text{mg } NO_3^- \text{-N}}(40 \text{ mg/L } NO_3^- \text{-N}) = 98.8 \text{ mg/L} \approx 100 \text{ mg/L}$$

3. Determine the methanol requirement.

CH_3OH requirement = (100 mg/L)(150 gpd)(3.78 L/gal)(1 g/1000 mg) = 56.7 g/day

10% Solution:

$$\frac{56.7 \text{ g/day}}{0.08 \text{ g/mL}} = 709 \text{ mL/day} = 21.3 \text{ L/month} = 5.6 \text{ gallons/month} \approx \text{one 55 gallon drum/10 mos.}$$

4. Determine the BOD_L of methanol.

$$CH_3OH + 1.5O_2 \rightarrow CO_2 + 2H_2O$$

32 GMW	32 GMW
32 mg	48 mg
1 mg	1.5 mg

5. Determine the ratio of BOD_L/NO_3^- -N reduced.

$$\frac{150 \text{ mg/L } BOD_L}{40 \text{ mg/L } NO_3^- \text{-N}} = 3.75 \text{ mg } BOD_L/\text{mg } NO_3^- \text{-N reduced.}$$

Comment. This example shows that the required BODL of methanol is higher than that predicted by half-reactions alone (2.86 mg BODL/mg NO_3^--N) because a portion of the methanol was used for cell synthesis as can be seen in the balanced equation. Note that 3.57 mg of alkalinity as CaCO3 was produced per mg of NO_3^--N reduced. Thus approximately half of the alkalinity lost during nitrification can be recovered through denitrification with methanol or wastewater as the carbon source.

Example: Design of dentrification system using acetic acid as the carbon source

Determine the acetic acid requirements for an onsite denitrification system using a recirculating sand filter. Assume the acetic acid could be used in the form of vinegar (5% solution). The following conditions from Example 6 apply:

1. Household flow rate = 192 gpd
2. The concentration of NO_3^- -N to be removed is 40 mg/L
3. Characteristics of acetic acid:
   99.5% Solution = 1.05 g CH_3COOH/mL
   5.0% Solution = 0.05 g CH_3COOH/mL

Solution

1. Write the balanced equation for denitrification and include mass relationships (Rittmann and McCarty, 2001).

Heterotrophic

$$NO_3^- + 0.87CH_3COOH + H^+ \quad 0.46N_2 + 0.08C_5H_7O_2N + 0.87HCO_3^- + H_2O + 0.44CO_2$$

acetic acid *Bacteria* *bacterial cells*

62 GMW	60 GMW	113 GMW	61 GMW
14 mg as N	52.2 mg	9.0 mg	0.87 meq
1 mg as N	3.73 mg	0.65 mg	0.06 meq
			3.0 mg as $CaCO_3$

2. Determine the required concentration of acetic acid.

$$\text{Required concentration of } CH_3COOH = \frac{3.73\text{ mg}}{\text{mg } NO_3^- \text{-N}} (40\text{ mg/L } NO_3^- \text{-N}) = 149\text{ mg/L}$$

Portions of the preceding nitrogen section were taken directly from the following reference: Oakley, S. 2005. Onsite Nitrogen Removal Text. in (M.A. Gross and N.E. Deal, eds.) University Curriculum Development for Decentralized Wastewater Management. National Decentralized Water Resources Capacity Development Project. University of Arkansas, Fayetteville, AR.

Full text and Figures available Online at: www.onsiteconsortium.org/files/nitrogen.htm

3. Determine the acetic acid requirement.

CH_3COOH requirement = (149 mg/L)(150 gpd)(3.78 L/gal)(1 g/1000 mg) = 84.5 g/day

5% Solution:

$$\frac{84.5\text{ g/day}}{0.05\text{ g/mL}} = 1690\text{ mL/day} = 50.7\text{ L/month} = 13.4\text{ gallons/month} \approx \text{one 55 gallon drum/4 mos.}$$

4. Determine the BOD_L of acetic acid.

$$CH_3COOH + 2O_2 \quad 2CO_2 + 2H_2O$$

60 GMW	32 GMW
60 mg	64 mg
1 mg	1.07 mg

1 mg of CH_3COOH 1.07 mg BOD_L
149 mg/L CH_3COOH 159 mg/L BOD_L

5. Determine the ratio of BOD_L/NO_3^- -N reduced.

$$\frac{159\text{ mg/L } BOD_L}{40\text{ mg/L } NO_3^- \text{-N}} = 3.97\text{ mg } BOD_L/\text{mg } NO_3^- \text{-N reduced.}$$

Comment: In this example, unlike methanol or wastewater, acetic acid adds acid to the system, which is neutralized by the production of alkalinity through denitrification (0.87 meq of H^+ from acetic acid would be neutralized by the 0.87 meq of HCO_3^- produced by denitrification). Thus there would not be a 50% recovery of the alkalinity lost through nitrification if acetic acid were used as the carbon source (Rittmann and McCarty, 2001).

Phosphorus

In temperate regions, such as Minnesota, phosphorus (P) is the nutrient primarily responsible for accelerating eutrophication of freshwaters, because phosphorus is usually in limited supply relative to plant demand. Wastewater contains phosphorus from feces and detergents. Phosphorus in wastewater can be categorized as orthophosphate, condensed phosphates, or organic phosphorus (Crites and Tchobanoglous 1998):

1. Orthophosphate (o-phosphate) includes H_3PO_4, H_2PO_{4-}, HPO_4^{2-}, and PO_4^{3-}. In waters with a pH close to 7, $H_2PO_4^-$ and HPO_4^{2-} are the predominant orthophosphate forms.
2. Condensed phosphates include various polyphosphate forms such as pyrophosphate ($P_2O_7^{4-}$) and $P_3O_{10}^{5-}$. Derived primarily from laundry detergents and other cleansers, condensed phosphates convert slowly to orthophosphate.
3. Organic phosphorus includes phosphorus incorporated with organic compounds, such as sugars, phospholipids, and nucleotides.

Approximately 50% of phosphorus in raw wastewater is orthophosphate, 40% polyphosphates, and 10% organic phosphorus. Estimated phosphorus loads from household sources average 1.0 to 1.3 kg/capita/year (Jenkins and Hermanowicz, 1991), broken down as follows:

- Human waste: 0.6 kg/capita/year
- Laundry detergents (with no phosphorus limitation): 0.3 kg/capita/year
- Other household detergents and cleaners: 0.1 kg/capita/year

Total phosphorus (TP) is the sum of all forms of phosphorus in effluent. Each of these forms is expressed in terms of milligrams per liter (mg/L). A typical value for phosphorus in septic tank effluent is seven - ten mg/L.

A small amount (~10%) of phosphorus removal will occur in a septic tank due to settling. Phosphorus can be naturally treated and removed in soils with the right conditions for removal. Different types of soils remove more phosphorus then others. Removal of phosphorus in soil absorption areas is dependent upon adsorption and precipitation reactions. Precipitation occurs as the phosphorus reacts with calcium, aluminum, magnesium, or iron in the soil. Adsorption is the association of phosphate with the surfaces of a particle. Studies show that phosphate adsorption takes place via formation of a bond between phosphate and a specific site on the adsorbing solid phase (Sposito, 1989). Precipitation involves "the formation of a three-dimensional solid phase arrangement of molecules from the solution phase" (Doner and Grossl, 2002). This is different than adsorption, which involves the formation of a two-dimensional structure (i.e., PO_4^{3-} on the surface of a mineral rather than within the mineral itself). The distinction between these two processes is important because surface adsorption is usually limited by a fixed availability of sorption sites in a particular soil that eventually will be used up if sewage loading occurs over long periods. Precipitation reactions are potentially sustainable provided that there is sustainable supply of aluminum, iron and/or calcium to complete the reaction.

Other Components of Wastewater

Pharmaceuticals

Pharmaceutical and personal care product (PPCP) are of growing concern in wastewater treatment systems. They are chemical substances such as a prescription or over-the-counter therapeutic drugs, fragrances, cosmetics, sunscreen agents, diagnostic agents, among others; widespread use is increasing their prevalence in the environment; their effects, even in trace amounts are being studied.

Other chemicals that are of concern in systems include trace organic contaminants that originate from residential and non-residential sources, such as ingredients in drugs, pesticides, consumer products, and industrial process agents, usually present in concentrations much lower than one mg/L, which may have adverse ecological and/or human health effects.

Chemicals and hazardous waste

Hazardous waste should not be added to a treatment system. Nonhazardous wastes, including detergents, shampoos, antibacterial soap, and salt from water softeners, have not been shown to cause detrimental effects at normal household loading. Excessive loading of any of these chemicals, however, can cause problems with the treatment process.

Of particular concern are continuous toilet cleaners and formaldehyde. Because the toilet flow represents nearly 40 percent of total wastewater, continuous use of a sanitizer can cause problems and should be avoided. Formaldehyde, typically used in chemical toilets, also causes major system problems and should be avoided.

If a residence or any other facility plans to dispose of hazardous waste into an onsite system, the Minnesota Pollution Control Agency (MPCA) must be contacted. These systems would be considered Class V injection wells and are subject to regulations other than those of Chapter 7080. Hair salons, photography businesses and taxidermists, for example, may generate hazardous waste. A Class V inventory form for any such system, as well as for any system serving 20 or more people, must be submitted to the Environmental Protection Agency and the MPCA. A form can be found at septic.umn.edu/ssts-professionals/forms-worksheets.

In the case of filling station wastes, oil, grease and floor washing wastes from the service bay should be discharged to a holding tank separate from the sewage system treating the toilet wastes. Any liquid waste containing petroleum products should not be discharged into a subsurface treatment system. A car wash area should be evaluated for hazardous waste problems, and may also need a holding tank for wastes. There is a potential for volatile compounds in these systems which are capable of being evaporated at relatively low temperatures. These are typically measured as volatile organic compound (VOC) which is the class of organic compounds that readily evaporate; includes liquids and solids at natural environmental temperature.

Monitoring Wastewater Characteristics

Many techniques can be used to monitor an onsite wastewater treatment system's performance. Monitoring is the action of verifying performance for a regulatory authority or a manufacturer (e.g., qualitative monitoring as part of service visit). It varies from something as simple as checking for sewage on the soil surface, to complicated laboratory analysis. Costs vary from lab to lab. Be sure to contact the lab prior to dropping off samples.

There are several types of samples that can be obtained from a system:

Composite Combination of individual samples collected from the same point at different times; samples may be of equal volume or may be proportional to the flow at time of sampling.

Grab Discrete sample collected at a particular time and location.

Integrated Combination of grab samples collected at a similar time but at different locations.

Certified Labs

When choosing a lab to perform analysis of wastewater characteristics, a certified lab is always the best choice, because these labs use standard procedures. The Minnesota Department of Health maintains a list of labs across Minnesota that are certified. This can be found on their website at https://apps.health.state.mn.us/eldo/public/accreditedlabs/labsearch.seam. If you do not have access to the internet call (800) 383-9808 and a hard copy of the list can be sent to you.

Sampling

There are many locations where samples can be taken. It is best if the sample locations are determined when the system is being designed, and then built in. Effluent chambers, pump tanks and sampling ports are suggested locations at which to obtain samples. A sampling port is a part or device at a particular location in a component that allows a sample to be collected for analysis.

Chapter 7081.0240 (E) requires that MSTS must be designed with sufficient access and ports to monitor the system as applicable.

Some obvious locations where the wastewater characteristics are of interest are:

- As it leaves the home
- As it leaves the tank
- At the system's "end-of-pipe"
- In groundwater (lysimeter, sampling wells)
- In soil (dry gram soil/microgram fecal)

Piezometers can be used to determine the amount of separation but are not to be used to sample groundwater. Lysimeters or soil access ports can be used to determine the amount of fecal coliform bacteria under system.

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Appendix 1

Biological Hazards in Wastewater: FAQs for Septic System Professionals

Bufford A. Ang; Sara Heger Christopherson; John M. Shutske

Q: What microorganisms are present in wastewater that can be hazardous to health?

A: Microorganisms that cause disease are known as pathogens. A variety of pathogens are present in wastewater, including (The Center to Protect Worker's Rights, 2004):

- Bacteria, such as *E. coli, Shigella, Salmonella, Vibrio cholerae, and Leptospira*. Bacteria are small, single-celled life-forms that can reproduce quickly. These bacteria can cause diarrhea, fever, cramps, vomiting, headache, weakness, or loss of appetite.
- Parasites. These use other organisms such as humans for food or a place to live and reproduce. One type of parasite is the protozoa. These are single-celled, microscopic organisms that live primarily in water. Some protozoans that cause disease include *Giardia lambia, Cryptosporidum parvum* and Amoeba. Another type of parasite includes helminths, which are worms. Roundworms, for example, can cause ascariasis. A lot of roundworms in your stomach will make you cough, and cause breathing difficulties, abdominal pain, and intestinal blockage.
- Viruses are small particles that infect cells in other organisms. A virus cannot reproduce on its own, but requires other living cells to replicate. Viruses such as Norwalk-like viruses and hepatitis A are passed through feces of infected people. Hepatitis A is the most common virus present in wastewater.

Q: What are signs of hepatitis A?

A: One obvious sign of the hepatitis A virus (HAV) is jaundice - yellowing of the skin or whites of the eyes. Other signs include tiredness, abdominal pain, nausea, and diarrhea. About 15% of people infected with HAV will have prolonged or relapsing symptoms over a 6-9 month period (Centers for Disease Control, 2005).

Q: What health risks are present in wastewater?

A: All wastewater will contain fecal coliforms. These bacteria are present in the intestines of all warm-blooded animals, including humans. Although they are important in digestion (and also help with some treatment of wastewater in septic tanks), they may cause varying degrees of illness if introduced to someone through any of the pathways listed later in this paper. Pathogens like *Giardia, Cryptosporidia, Salmonella, Shigella, Vibrio cholerae, etc.*, will be present only if those using the wastewater treatment system are infected. However, since it is unlikely you will ever know the health conditions of those using a particular system, always assume that health risks exist. Exposure to wastewater may result in a number of illnesses, some of which include (Health & Safety Executive, 2004):

- Gastroenteritis (cramping stomach pains, diarrhea, and vomiting), caused by E. coli and other bacteria; protozoans such as Giardia and Cryptosporidia; and some viruses
- Cholera (extreme diarrhea and dehydration), caused by the bacteria Vibrio cholerae
- Leptospirosis (flu-like symptoms, accompanied by a persistent and severe headache), caused by the bacteria Leptospira. Leptospirosis may result in damage to liver, kidneys and blood, and may be fatal
- Infectious hepatitis (jaundice and fever) due to the virus Hepatitis A. It causes liver inflammation
- Legionellosis (lung inflammation with fever, dry cough, and aching muscles and joints) caused by a bacteria
- Skin and eye infections

Q: How can workers come in contact with pathogens?

A: There are four main routes that explain how pathogens can enter the body. These include (Health & Safety Executive, 2004):

- ***Oral*** Ingestion via hand-to-mouth contact during eating, drinking, and smoking; and by wiping your face with contaminated hands or gloves. Ingestion is the major route of infection.
- ***Dermal*** Skin contact from wastewater splashes. Having cuts, scratches, and wounds raises the risk of infection.
- ***Eyes*** Pathogens can enter the body through the eye.
- ***Lungs*** Inhaling airborne microbes carried by dust, mist, or fumes.

Q. What are likely points of microbial contamination?

A. The following are common sites contaminated with pathogens:

- Air in the vicinity of wastewater can lead to respiratory exposure.

- Tools, vehicle door handles, radio knobs, and gear shifters result in dermal exposure.
- Lunch, cigarettes, gum, etc. can lead to ingestion of pathogens.

Q: Where are pathogens found in wastewater treatment systems?

A: Pathogens are present in wastewater, and can be found anywhere and on anything that is in contact with wastewater. This means they will be found in the septic tank, distribution pipes, and effluent treatment components such as a drainfield, mound, recirculating sand filter, etc. Highest populations are present in the septic tank, and are reduced as wastewater receives treatment while traveling through the system (see image below). In properly designed, installed, and maintained systems, research has shown there are no pathogens found in wastewater once it has traveled through soil three feet below the bottom of the drainfield (Zimmerman and Maurer, 2007). Please see table on the following page.

TABLE A-1 Numbers of pathogens found in wastewater at various stages of treatment in an onsite system (Zimmerman and Maurer, 2007)

Microorganism	Raw wastewater	Septic tank effluent	1 ft below trench	3 ft below trench
Fecal coliforms (MPN/100 ml)	1,000,000 – 100,000,000	1,000 – 1,000,000,000	0 - 100	0
Viruses (CFU/ml)	unknown	1,000 – 1,000,000,000	0 - 1000	0

In wastewater treatment plants, pathogens have been found in the following components and processes:

- Pre-treatment
- Thickening, dewatering, primary and secondary sludge treatment
- Primary clarifiers and settlers
- Aeration (biological oxidation) tank
- Sludge processing unit
- Belt press machines (belt press area)
- Sludge collection hoppers
- Sludge dewatering area
- Incoming water tunnels
- Inflow chambers
- Aerated basins with sprinkler systems
- Trickling filters
- Grit collection
- Biofilter tower interior
- Servicing and cleaning equipment
- Washing stations

Q: What can septic system workers and wastewater treatment plant employees do to protect themselves from pathogens?

A: Since pathogens are naturally found in wastewater, they CANNOT be removed. The risk of contracting a disease decreases if you practice good personal hygiene and use personal protective equipment on the job. Some pointers to keep in mind and to practice are:

- Make sure you understand the risks these microbes pose to your health, and ways that you can pick up infections.
- Always have a first aid kit handy. Clean and disinfect all exposed wounds, and cover with a sterile waterproof dressing.
- Report any injuries suffered at the work site to your supervisor right away.
- Use waterless hand cleaners, anti-bacterial soaps, and anti-bacterial handwipes on the job.
- DO NOT eat or drink in a wastewater handling area.
- Do not touch your nose, mouth, eyes, or ears with your hands unless you have just washed your hands.
- Wash your hands well with soap and clean hot water before you eat or smoke, periodically throughout the day, and at the end of your workday. Assume anything coming in contact with wastewater is contaminated!
- Clean any part of you that comes in contact with wastewater or sludge immediately.
- Keep your fingernails short and clean them frequently.
- Wear waterproof gloves when cleaning pumps or screens, or when handling wastewater, sludge, or grit. Whenever possible, wear heavy-duty gloves (double glove) and boots that are waterproof and puncture resistant (The Center to Protect Worker's Rights, 2004).
- Wear a surgical-type mask, goggle, face shield, or visor if there is a chance that you will be splashed with wastewater.
- Wear rubber boots or those that can be disinfected if you should step in wastewater.
- Report any damaged equipment right away for replacement or repair.
- Handle sharp items with extra care to prevent accidental injuries.
- Clean contaminated equipment/tools on site with a bleach solution (Miller, 2001) (1 tablespoon of bleach to 1 gallon of water). Bleach loses its effectiveness after exposure to sunlight or dirt, so keep a fresh supply handy.
- Shower and change your work clothes before leaving work for the day. Do not take contaminated clothing home for washing. Use two different lockers to separate your work and street clothes. If you must launder your clothing at home, launder your work clothing separately from family clothing.
- Wash work clothing in hot water with chlorine bleach.
- Discuss your occupation with your health care providers so they know what potential exposures you have due to your work.
- Be sure your vaccine shots are up-to-date, especially for tetanus and diphtheria. Vaccination against hepatitis A is highly recommended.

- Consult your healthcare provider for any flu-like symptoms, such as fever or severe headache, or any skin infections. Seek medical help if chest symptoms consistent with asthma appear.

Q: So, do professionals really need to worry about airborne droplets and dust that carry pathogens (bioaerosols)?

A: Yes! In 2003, Prazmo and her colleagues studied Polish sewer workers who were exposed to droplet aerosols containing infectious biological agents. These aerosols impaired the immune system and had the potential to produce allergies in susceptible individuals. Prazmo and her colleagues listed the infectious agents present, which included viruses (polioviruses, coxsackieviruses, echoviruses, rotaviruses, adenoviruses, Norwalk virus), and bacteria (*Leptospira, Salmonella spp., Shigella spp., Campylobacter jejuni, Yersinia enterocolitica, Legionella pneumophila, Helicobacter pylori, Listeria monocytogenes, Mycobacterium xenopi*). Another risk that they cited was microbial allergens and endotoxins. They stated that endotoxins, produced by bacteria, can cause respiratory and intestinal inflammation, diarrhea, fatigue, and nose irritation among sewer workers.

Q: When, what type, and how should a professional wear a respirator?

A: A respirator should be worn whenever you might come in contact with airborne pathogens, such as spray from a treatment device, or a humid atmosphere. The N-95 Respirator is recommended by the National Institute for Occupational Safety and Health (NIOSH). Fit of respirator is always important to make sure that there is a tight seal between the face and mask. A leak would result in the inhalation of contaminated air. Facial hair is discouraged, since this can interfere with proper respirator fit. To make sure respirators are fitted, worn, and used properly, a respiratory protection program for the facility is highly recommended.

Q: Just what is the level of risk for an ordinary individual to get exposed to pathogens in wastewater?

A. The answer is “It depends.” The risk for an ordinary individual getting exposed to pathogens depends upon how well the septic system was designed, installed, and maintained. If there is wastewater draining to or surfacing in the yard, there is greater risk than if the system is working properly. If the septic system was installed in an area with high groundwater levels, and/or close to a drinking water well, the risk is higher. If a homeowner maintains his/her own system and cleans the effluent screen, the risk is higher for that person than if a professional is hired. However, if that homeowner follows safety precautions, the risk will be reduced.

All in all, if a system is designed considering the strength and volume of wastewater, the soil and site specifics; installed using best management practices; and maintained properly, risk to an ordinary individual is minimal.

SECTION 6: Plumbing and Collection

PLUMBING AND COLLECTION

Introduction

The plumbing and collection portion of the system transports wastewater from the structure to the treatment system. For single-family homes this is the building sewer while for cluster systems this is a designed collection system. The size and components of the collector systems depend on the number of residences, land topography and the type of treatment system. For individual residences or other establishments, a four-inch building sewer is a simple technology, but it is critical for the long-term operation of the system. When installed properly, the building sewer will function for many years. When not installed properly, this component can be a continuing problem for the owner.

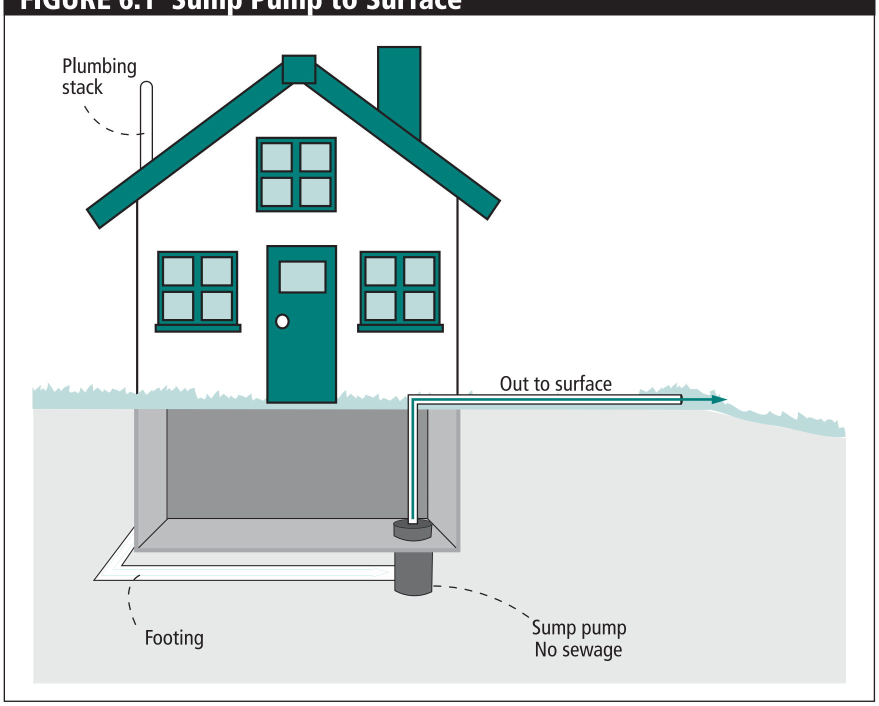
Definitions

Plumbing

Basement sump, grinder and effluent pumps

In the basement structure typical to freeze-thaw climates such as Minnesota's, there are two types of pump applications: sump pump and sewage ejector. Sump pumps deal with the footing drains and other approved clean water sources. These should never discharge into the soil treatment system. MN Rules Chapter 7080.1550 prohibits sump pump and footing drain discharge into an SSTS. In fact, the discharge should even be directed away from the system to avoid additional water to the system as shown in Figure 6.1.

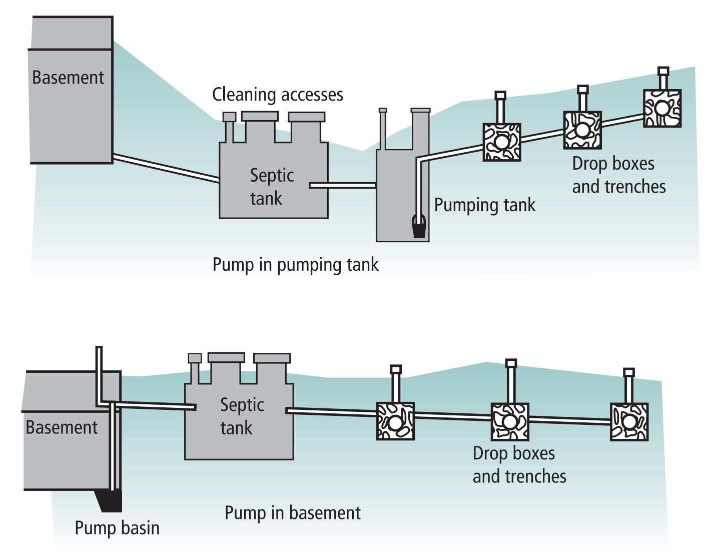
FIGURE 6.1 Sump Pump to Surface



The second type of application is a sewage ejector, which is used to lift the wastewater in lower levels of the home into the system as shown in the lower half of Figure 6.2 (next page).

These pumps are also used to lift sewage into a septic tank placed at a shallower bury depth. In these applications, minimizing the dose is important to allow for separation in the tank. When the pumping system is used, care should be taken not to overload the system. It is recommended that each dose into the tank be between 1 and 5 percent of the total septic tank volume. Also, the pumped effluent should be delivered into the 4-inch piping as far away from the septic tank as possible. This will allow for maximum energy reduction before entering the septic tank. When effluent is being delivered via a pump into the septic tank, the septic tank capacity is required to be increased by 50 percent and have multiple compartments or tanks (MN Rules Chapter 7080.1930, Subp. 3). This will allow for the tank to better separate the solids that are being applied and reduce the energy in the flow stream. It is also recommended that an effluent screen be utilized to reduce the flow of solids to the soil treatment area.

FIGURE 6.2 Pumping Applications



Effluent pumps are only used with effluent that has undergone primary settling such as in a septic tank.

Non-flush toilets

There are several types of non-flush toilets, all based on the goal of water conservation. Waterless and forced-air composting toilets produce compost. Electric toilets burn the waste. Some models use a very small amount of water or a chemical foam to assist the passage of waste to the composting chamber. A composting toilet is a self-contained unit (not connected to a septic or sewer system) which breaks-down, reduces the volume, and dehydrates human waste to a compost which can be added to soils. The toilet will consist of a place to sit (which is likely to look a lot like any other toilet), a composting chamber which breaks down and sanitizes the sewage, and a drying chamber or tray which permits moisture to escape, reducing the sewage volume. The Minnesota Plumbing Code does not recognize composting toilets as an approved fixture.

Composting toilets come in models which use a little water or no water at all, and in electric (heated and power-vented) models and non-electric models. Some models include electro-mechanical mixers which mix waste in with a mulch product to speed and improve the composting process. Properly designed and installed the toilet is vented so that there are no abnormal toilet odors. Periodically the compost must be emptied and on occasion toilet components are cleaned.

People use the toilet in a normal manner, and modern composting toilets in fact look pretty familiar, resembling water-based toilets in general shape and comfort. Waste is mixed with a “starter mulch” to begin the composting process. Composted waste is emptied from the toilet at intervals ranging from one or two months to 12 months depending on level of usage and toilet design. Composting toilets which do not mix new human waste with material already being composted produce a compost which is easier and safer to handle. This is a reason that some models use multiple containers or compartments, though there are other solutions to this problem. If the visible portions of the toilet need cleaning, normal household cleaner and toilet brush are used.

Maintenance requirements vary by manufacturers, and although minor for many systems, they may prevent wider interest. People are typically interested in composting toilets when they do not have other satisfactory toilet options (e.g. lack of space for a septic field, impossibility of using heavy equipment on a site) or when they live on nitrogen sensitive environments. The waste from a composting toilet is considered septage and must be treated properly. More information about non-flush toilets can be found in Section 7.

Flammable waste and sediment traps

The plumbing code regulates flammable waste traps. The MPCA has a fact sheet that best describes the management of floor drains and flammable traps and it is placed on the next page. (Waste/Hazardous Waste #4.18, October, 2007). From MN Rules, Chapter 4714, Sections 1009.1 and 1017.1, requires vehicle storage, repair garages, gasoline stations with grease racks, work or wash racks, auto washes, and all buildings where oily and/or flammable liquid wastes are produced have an interceptor. The interceptor is designed to catch oil, grease, and sand bearing and/or flammable wastes before building drainage system or other point of disposal when floor drains or trench drains are provided. The exception is private garages serving one and two-family dwellings.

The Minnesota Pollution Control Agency regulates the disposal of the waste produced from the cleaning of sediment traps and flammable waste traps. Hazardous waste is defined in MN Rule Chapter 7045.0135 as a waste that has one or more of the characteristics of ignitability, corrosivity, reactivity, lethality or toxicity. These wastes must be transported by a certified hazardous waste hauler. These traps must be cleaned periodically to maintain the integrity of the wastewater leaving facilities. Traps of this nature shall not be discharged to a SSTS.

Sediment traps and flammable waste traps are designed to hold solid and oily wastes that are produced from normal washing and maintenance of vehicles, equipment, and floors. The flammable waste trap generally has three layers of waste; the top oil layer, the middle water layer, and the bottom sand layer.

Best management practices should be employed to prevent flammable materials from getting into the system including:

1. Good general housekeeping
2. Clean spills immediately
3. Keep containers sealed when not in use
4. Only wash engines if absolutely necessary
5. Sweep up solids and properly dispose
6. Use screens in the drain to prevent solids from reaching the trap
7. Use drip pans to collect fluids
8. Have necessary equipment in place to quickly clean up a spill before it can escape
9. A clean sediment trap will keep the sediment out of the flammable waste trap
10. Prevent liquid wastes (solvents, oils, etc.) from entering into floor drains

Maintenance

Sediment Traps

The wash stall sediment traps need to be checked periodically. When the sediment trap is in need of cleaning, follow these procedures:

1. Drain water down outlet pipe using buckets, pumps, etc.
2. Remove sand/sediment from trap.
3. Properly dispose of sediment/sand.

Best Management Practices for Managing Floor Drains and Flammable Traps

(Post in Shop)

Using these best management practices in your shop will enable you to manage flammable trap waste as an industrial solid waste rather than a hazardous waste.

If you:	You need to know that:	Best Management Practice:
Use aerosol solvents or other degreasers	These chemicals can compound waste management problems by contaminating wash water and sludge with hazardous materials.	Clean parts over a drip pan — not on the floor; collect waste. Use a parts washer to clean engine parts and manage the solvent in the washer as a hazardous waste. To prevent contamination of the parts washer by listed* solvents, do not spray listed aerosols over the unit.
Change vehicle fluids (oil, brake fluid, antifreeze, etc.)	These chemicals can compound waste management problems by contaminating wash water and sludge with hazardous materials.	Use drip pans under vehicles to collect fluids. Recycle transmission and brake fluids with used oil. Drain radiators before flushing and recycle waste antifreeze.
Clean shop floors	Hosing down the floors with water or solvent can flush contaminants into floor drains, contaminating liquids and sludges in the drain system.	Use drip pans to collect fluids. Use dry sweeping compounds. Reuse them as long as they remain absorbent. Combustible sweeping compounds may be burned to heat your shop if burned in an approved burning device.
Accidentally spill material	Many materials used in vehicle maintenance may be hazardous and can contaminate other wastes in the plumbing system.	Clean up spills immediately. Notify the Minnesota Duty Officer at 612-649-5451 or 800-422-0798 — if it is a petroleum spill of more than 5 gallons or if it is a spill of any material of any size that impacts soil or water. Have appropriate spill cleanup materials on hand and train employees how to properly use them.
Store solvents	Spilled or leaked solvents and their vapors are dangerous and can contaminate other wastes in the plumbing system	Keep containers sealed when not in use. Store solvents in a “flammables” cabinet. Do not use solvents near drains.
Store waste vehicle fluids in a room with a floor drain	Spilled or leaked solvents and their vapors are dangerous and can contaminate other wastes in the plumbing system	Keep containers sealed when not in use. Keep waste containers in a separate storage area with no floor drain. Install a curb or berm to contain any wastes that may leak from storage containers. Inspect containers for leaks on a weekly basis. See MPCA Hazardous Waste fact sheet # 2.41, *Documenting Container Inspections.*
Wash engines	The resulting wastewater is likely to be hazardous from greases, oils and solvents.	Only wash engines if absolutely necessary. If you do, separate the resulting wastewater and evaluate it.

*Solvents on F-list like methylene chloride, methyl ethyl ketone, tetrachloroethylene, toluene and xylene.

Flammable waste interceptor

According to MN Rules Chapter 4714, Section 1017.0, each interceptor shall be of watertight construction sized in accordance with sections 1017.1 and 1017.2, be provided with a water seal of not less than two inches on the inlet and not less than 18 inches on the outlet. The minimum size of the discharge drain shall be three inches and must be vented. The interceptor may be constructed of monolithic poured reinforced concrete with a minimum floor and wall thickness of six inches, or of iron or steel of a minimum thickness of 3/16 inch, or other approved materials protected with an approved corrosion resistant coating on both the inside and outside. The administrative authority must approve all interceptors.

The interceptor must be provided with a nonperforated iron or steel cover and ring of not less than 24 inches in diameter, and the air space in the top of the tank must have a three-inch vent pipe. It shall be constructed of approved metallic material, extending separately to a point at least 12 inches above the roof of the building or in accordance with MN Rules, Chapter 4714, Section 1017.1. Drains and piping from motor vehicle areas must be a minimum of three inches in size. Drains discharging to an interceptor must not be trapped and must be constructed so as not to retain liquids. A sand interceptor that meets the requirements of MN Rules, Chapter 4714, Section 1016.0 may be installed to receive wastes before discharging into a flammable waste interceptor.

No cleanout, mechanical joint, or backwater valve shall be installed inside the interceptor that could provide a bypass of the trap seal. Only wastes that require separation shall discharge into the interceptor. A backwater valve shall be installed in the outlet branch drain whenver in the judgement of the administrative authority backflow from the building drain could occur. An interceptor must be installed to be readily accessible for service and maintenance, and must be maintained by periodic removal of accumulated liquids and solids from the interceptor.

Maintenance

The flammable waste interceptor top oil layer needs to be cleaned regularly, a minimum of once per year, to keep oils and other potential chemicals from going to the sanitary sewer. Sediment may build in the flammable waste interceptor due to improper or insufficient cleaning of the sediment interceptor and may also need to be removed. When the flammable waste interceptor is in need of cleaning, follow these procedures:

1. Separate the top oil by using absorbent/hydrophobic pads and recycle with the used oil rags and sorbents. Another option is skimming or vacuuming it off the surface. This oil can be mixed with other used oil.
2. The middle water layer can be removed and temporarily stored in clean drums. After the sediment is removed, the water can return to the flammable waste interceptor.
3. Remove sand from tank.
4. Properly dispose of sediment/sand. See following section on Bottom Sand/Sediment Layer Management.

Bottom Sand/Sediment Layer Management

1. Can be disposed in an Industrial Landfill. All liquids must be removed/separated from sand prior to disposal. The landfill must be contacted and arrangements made prior to use.
2. Can be managed in an Asphalt Plant. All liquids must be removed/separated from sand prior to disposal. The Asphalt Plant must be contacted and arrangements made prior to use. The facility must have an air quality permit, water quality permit, and pass a Mn/DOT Environmental End Site Audit.
3. Facilities can contract out cleaning, transport, and disposal through a licensed Maintainer.

Collection

The Minnesota Plumbing Code sets several definitions related to SSTS.

Building sewer as the part of the horizontal piping of a drainage system that extends from the end of the building drain and that receives the discharge of the building drain and conveys it to the public sewer, private sewer, private sewage disposal system, or other point of disposal (co-defined in 7080.1100, Subp 10b).

Plumbing system means and includes all potable water supplies and distribution pipes, all plumbing fixtures and interceptors, all drainage and vent pipes and all building drains (including their respective joints and connections, devices and appurtenances) within the property lines of the premises. It also includes potable water treatment or using equipment (MN Rules, Chapter 4714, Section 218.0).

Soil pipe means a pipe which conveys the discharge of water closets or similar fixtures containing fecal matter with or without the discharge of other fixtures to the building drain or building sewer (MN Rules, Chapter 4714, Section 221.0).

The piping is an important part of all onsite sewage treatment systems. Over the last 50 years, there have been changes in this component, particularly in the materials used for installation. Older components, such as cast iron and clay pipe, have been replaced by plastic materials. The application of the system determines the necessary pipe characteristics and how that pipe is installed. Applications can be divided into several categories. First is the building (or business) sewer that connects the treatment system to the user. Second is the supply pipe from the septic tank to another pre-treatment device, pump tank or the distribution system for final dispersal. Third is the supply pipe from a pump tank to some type of pressure distribution network. Finally, there is the gravity distribution pipe in soil treatment beds or trenches. Each application needs a specific kind, size and strength of pipe.

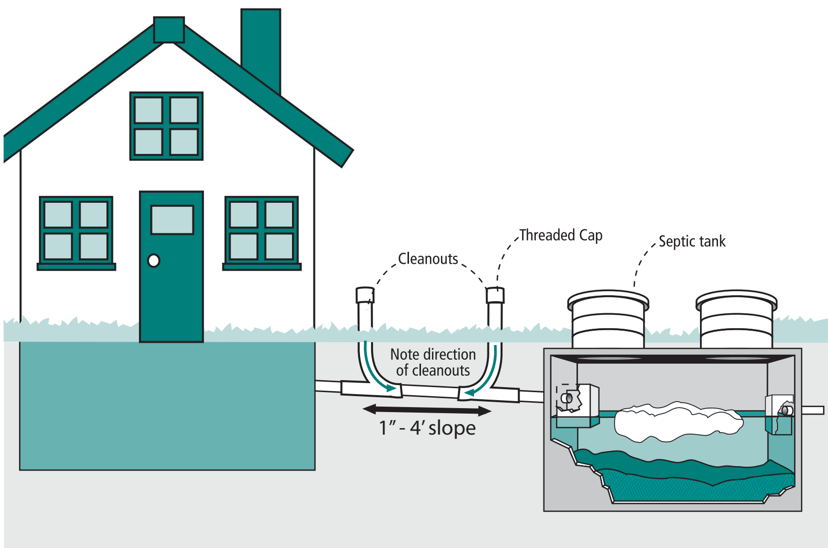
Building sewer

Definition, description, rule requirement

The building sewer is defined in the plumbing code MN Rules, Chapter 4714, Section 204.0, as the piping that runs from the structure beginning 2 feet outside the building wall to the septic tanks, as shown in Figure 6.3, or the sewer main in the road. Approved materials are identified under Table 701.1 of the Minnesota Plumbing Code. Plastic materials are recommended and used in all new construction.

Typically, building sewer plastic PVC schedule 40 (ASTM D2665) is used from the home to the septic tank. This material may be installed in the same trench as water service.

FIGURE 6.3 Building Sewer With Cleanouts



Building sewers

Pipe material

According to MN Rules Chapter 4714, Section 301.1, Quality of Materials, all materials used in any part of a drainage or plumbing system should be free from defects. No damaged or defective materials should knowingly be installed. Further, all materials must be marked, unless otherwise easily identifiable, so as to provide a visual means of identification as to types, grades, weights, and strengths. The installer should, as far as possible, position the identification marks so as to provide ease of inspection by the administrative authority (MN Rules Chapter 4714, Section 301.1.1, Identification of Materials). This means that the pipe should be installed so the lettering is viewable from the edge of the excavation. MN Rule Chapter 4714, Table 701.1 provides a list of materials approved for building sewers.

Determining load and the proper pipe size is an important step in installation. According to MN Rules Chapter 4714, Section 703.0 and Table 702.1, the load on drainage system piping should be computed in terms of drainage fixture units in accordance with subparts 2, 2a, and 3; the administrative authority may allow variations where it is shown by a hydraulic analysis of the piping system, submitted to the administrative authority, that such variation would result in a more desirable flow rate in the piping system (Subp. 1, Load on Drainage Piping). Pipe size is determined from subparts 2 and 3 on the basis of drainage load computed from MN Rules Chapter 4715.2300.

Chapter 4714, Section 703.2 and Tables 702.2(b) and 703.2. Maximum loads for horizontal drains in fixture units. Fixture units are defined as one fixture unit equals 7.5 gallons/minute pipe capacity. This information is portrayed in Table 6.1.

Design

Pumps in the basement

See Section 9 for information on pumps.

Separation technology

See section 5, 7 and 12 for more information on the design of graywater systems.

TABLE 6.1 Maximum Unit Loading and Maximum Length of Drainage and Vent Piping

Size of Pipe (inches)	1 1/4	1 1/2	2	2 1/2	3	4	5	6	8	10	12
Maximum Units Drainage Piping[1]											
Vertical	1	2[2]	16[3]	32[3]	48[4]	256	600	1380	3600	5600	8400
Horizontal	1	1	8[3]	14[3]	35[4]	216[5]	428[5]	720[5]	2640[5]	4680[5]	8200[5]
Maximum Length Drainage Piping										—	—
Vertical, (feet)	45	65	85	148	212	300	390	510	750		
Horizontal (unlimited)											
Vent Piping Horizontal and Vertical[6]										—	—
Maximum Units	1	8[3]	24	48	84	256	600	1380	3600		
Maximum Lengths, (feet)	45	60	120	180	212	300	390	750	750		

For SI units: 1 inch = 25 mm, 1 foot = 304.8 mm

Notes:

[1] Excluding trap arm.

[2] Except sinks, urinals, and dishwashers - exceeding 1 fixture unit.

[3] Except six-units traps or water closets

[4] Only four water closets or six-unit traps allowed on a vertical pipe or stack; and not to exceed three water closets or six-unit traps on a horizontal branch or drain.

[5] Based on 1/4 inch per foot (20.8 mm/m) slope. For 1/8 of an inch per foot (10.4 mm/m) slope, multiply horizontal fixture units by a factor of 0.8.

[6] The diameter of an individual vent shall be not less than 1 1/4 inches (32 mm) nor less than one-half the diameter of the drain to which it is connected. Fixture unit load values for drainage and vent piping shall be computed from Table 702.1 and Table 702.2(b). Not to exceed one-third of the total permitted length of a vent shall be permitted to be installed in a horizontal position. Where vents are increased one pipe size for their entire length, the maximum length limitations specified in this table do not apply. This table is in accordance with the requirements of Section 901.2.

Using 4" piping for building sewers should be required for all applications.

Clay and Orangeburg Pipe

The following material through page 12 was created in cooperation with the Consortium of Institutes for Decentralized Wastewater Treatment. Vitrified clay pipe (with a salt glazing applied to both the pipe's interior and exterior surfaces) was the material of choice for a lot of building sewers in the past.

Orangeburg pipe is made from wood pulp and pitch. It was used from the 1860s through the 1970s, when it was replaced by PVC pipe. The name comes from the fact that most Orangeburg pipe was manufactured in Orangeburg, New York. Be careful handling Orangeburg pipe as it has often been treated with creosote to repel rodent and root invasion.

Ductile Iron

Ductile iron, also called ductile cast iron or nodular cast iron, is a type of cast iron which is much less brittle than cast iron. Ductile iron pipe is stronger and easier to tap and requires less support compared to other pipe materials. In some instances it may be appropriate or required to sleeve plastic pipe in ductile iron for road and stream crossings.

High Density Polyethylene

The use of high density polyethylene (HDPE) pipe is limited in onsite wastewater treatment system installations because of cost. It may be the appropriate material for installations requiring a flexible piping in inaccessible, unstable, or shifting soil environments or where large temperature variations are expected. Other applications include trenchless installations like pipe bursting or horizontal direction drilling. It is commonly used at sites that require piping to be pulled through tunnels, under roads, or structures. This material can be pulled in long assembled lengths using special installation equipment.

Acrylonitrile Butadiene Styrene

Acrylonitrile butadiene styrene (ABS) is a widely approved drain-waste-vent pipe material. This material is available in Schedule 40 dimensions as specified in ASTM D2661. This specification covers fittings and single and coextruded ABS plastic drain, waste, and vent pipe (DWV) made to Schedule 40 iron pipe sizes (IPS). ABS is a good application for gravity-flow conditions, but it is not pressure rated.

Polyvinyl Chloride

Polyvinyl Chloride (PVC) is the most common pipe material used in wastewater treatment systems. It is a plastic pipe used in both gravity and pressure applications. PVC has many advantages over other piping materials:

- Light weight - half the weight of aluminum, one-fifth the weight of cast iron, and one-sixth the weight of steel
- Low friction loss due to its smooth and seamless interior walls
- Requires no special tools to cut and can be installed by cementing, threading, gasketing, or flanging
- Ease of installation, resulting in lower installation costs
- Corrosion free, both internally and externally, and inert to attack by strong acids, alkalies, salt solutions, alcohols, and many other chemicals
- Self extinguishing and does not support combustion
- High tensile and impact strength that can withstand high pressure for a long period of time
- Low thermal conductivity factor compared to metal pipe thus, piped fluids maintain a more constant temperature

PVC Standard Dimensions and Materials

As previously mentioned, PVC is the most common pipe material used in onsite wastewater treatment systems. PVC pipe manufacturers must follow accepted standards for dimensions and material strength. The installer must have some understanding of these standards in order to ensure that the correct PVC product is selected for the job.

Nominal Diameters

All pipes have a nominal diameter. This value is typically the nearest one-quarter or one-half inch value of the actual internal diameter. These nominal diameters are “name” only. By the standards listed below, each pipe size and material type must be manufactured with an internal and external diameter that meets the accepted tolerances.

Iron Pipe Standard - IPS

Many PVC pipe products conform to IPS external diameter standards. This allows PVC (with IPS dimensions) to be fitted to standard steel pipe. PVC pipe that conforms to ASTM D1785 and D2241 have IPS external diameters.

Material Codes

PVC compounds range in strength and chemical resistance. In order to specify PVC pipe for a given task, material codes were developed to provide standardization. These codes provide information about the impact strength, chemical resistance, and hydrostatic design stress of various PVC compounds. For wastewater systems, most PVC pipe has a material code of PVC 1120 or PVC 1220. The material code must be known in order to compare the pressure rating of various combinations of external diameters and wall thicknesses.

ASTM International

ASTM International provides widely recognized standards for material performance and uniform dimensions. These standards are critical to the success of piping systems; manufacturers must follow these standards in order to ensure that the designers and installers can depend on pipe materials to withstand internal and external forces and depend on the standardization of pipe dimensions.

ASTM D1785 - Schedule 40, 80, and 120

This standard established the dimensions of Schedule 40, 80, and 120 PVC pipe. Pipe that has the "Schedule" designation has the same external diameter and wall thickness independent of pipe material. In other words, 2-inch diameter Schedule 40 PVC has the same external diameter and wall thickness as 2-inch diameter Schedule 40 steel pipe.

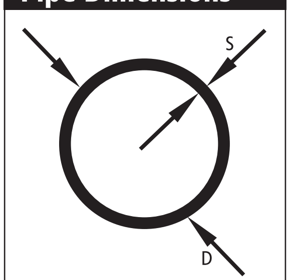
The higher the schedule number, the thicker the wall and the more pressure it can withstand. While Schedule 80 has a thicker wall than Schedule 40, for the same nominal diameter, the external diameter is the same for Schedule 40 and Schedule 80. Because the wall thickness increases, the internal diameter of Schedule 80 decreases. Thus, Schedule 80 can withstand more pressure but will transmit less fluid because of the reduced cross-sectional area.

For example: A 1-inch (25.4 millimeter) Schedule 40 pipe has an outside diameter of 1.315 inches and an inside diameter of 1.029 inches. Whereas a 1-inch Schedule 80 pipe has an outside diameter of 1.315 inches and an inside diameter of 0.936 inches.

ASTM D2241 - Pressure Rated, Standard Dimension Ratio PVC Pipe

This standard provides specification for the wall thicknesses and external diameter of various PVC materials that are needed to meet established pressure ratings. Standard Dimension Ratio (SDR) is a method of rating pressure piping. The SDR is the ratio of pipe diameter to wall thickness, as shown in Figure 6.4, and can be expressed as:

FIGURE 6.4 SDR Pipe Dimensions



$$SDR = D / s$$

Where: D = pipe outside diameter

s = pipe wall thickness

For example: An SDR 21 means that the outside diameter (D) of the pipe is 21 times the thickness of the wall.

TABLE 6.2 SDR and Pressure Class of PVC 1120 and PVC 1220

SDR	Class/ Pressure Rating [PVC 1120, 1220] (psi)
41	100
32.5	125
26	160
21	200
1.5	315

Relatively speaking, high SDR pipe has a thinner wall, and a low SDR pipe has a thicker wall. Thus, high SDR pipe has a lower pressure rating, and low SDR pipe has a higher pressure rating. Some SDR pipe is pressure rated by "class." All pipes with the same class number have the same pressure ratings. A class/pressure rating is associated with SDR's with a specific material designation. Example SDR ratios and pressure classes for PVC 1120 and PVC 1220 are shown in Table 6.2.

SDR and Schedule Comparison

Both SDR (D2241) and scheduled (D1785) pipe have outer diameters that are based on IPS, but their inner diameters differ. SDR pipes of the same outer diameter have larger inner diameters/smaller wall thicknesses than similar sized Schedule 40 pipe, as expressed in Table 6.3.

TABLE 6.3 Pipe Inner Diameter of Various Pipe Specifications, Uni-Bell, 2001

Nominal Diameter (inch)	Sch. 40	Sch. 80	SDR 26	SDR 21	SDR 13.5
	Inner diameter in inches (PVC 1120, 1220)				
1/2	0.622	0.546			
3/4	0.824	0.742		0.930	0.894
1	1.049	0.957	1.195	1.189	1.121
1-1/4	1.380	1.278	1.532	1.502	1.414
1-1/2	1.610	1.500	1.754	1.720	1.618
2	2.067	1.939	2.193	2.149	2.023
2-1/2	2.469	2.323	2.655	2.601	2.449

Additional Plastic Pipe Standards

For gravity applications, ASTM D 3034 and D 2729 pipe are typical plastic sewer main (PSM) specifications for both solid and perforated pipe. However, both materials must be approved by the plumbing authority prior to installation as alternates. Both materials are not approved for installation within 10 feet of water or at water crossings. These ASTM standards identify the required material, impact resistance, dimensions, stiffness, diameters (along with allowable minimal variations/tolerances), and thickness. These pipe standards are not for pressure-rated pipe; therefore, typical applications in onsite wastewater treatment systems are building sewers, piping between tanks and other components, and distribution system pipe for septic tank effluent.

In addition to ASTM, the American Water Works Association (AWWA) provides standards for plastic sewer pipe. Frequently, sewer mains need to connect to existing cast iron pipes. The standard dimensions for cast iron pipe are different from IPS. Thus plastic sewer pipe that conforms to AWWA C900 and C905 have the same outer diameter as cast iron pipe.

PW and DWV

Most PVC pipe is either approved for potable water (pw) or for use as a drain, waste, and/or vent pipe (dwv). This determination is made by NSF International. Most PVC pipe is marked NSF-pw (potable water) or NSF-dwv (drain, waste, or vent). This demarcation is especially important for PVC fittings. It is assumed that NSF-pw fittings are under pressure and, therefore, have more cement surface-area. Likewise, the NSF-dwv pipe is generally used in gravity-flow or low pressure flow situations, and these fittings have less surface area for bonding.

Storage and Handling

Although PVC is relatively resilient to damage, care should still be taken to prevent denting or scraping the pipe when loading, unloading, and storing the pipes. Damage can occur if tie-down straps are over tightened. Although the pipe is light, resist the tendency to throw or drag the pipe. Contact with sharp objects should be avoided. If any section becomes damaged, that piece should be cut out and discarded.

When storing pipe, protect it from direct sunlight, excessive heat, and potentially harmful chemicals. Pipe should be stored under cover or indoors if possible. When stacking the pipe, it is best to have the pipe with the strongest/thickest wall on the bottom of the pile. If long sections of pipes are stored on racks, make sure the pipe is supported along its entire length and not allowed to bow in the middle. Also, be sure to rotate stocks of stored pipe: the first pipe in storage should be the first out of storage.

Pipe Marking and Identification

All PVC has external markings along its length. The standardization for the markings has the manufacturer's name or trademark, the standard to which it conforms (for example ASTM), the nominal pipe size, and the material designation code. That information is followed by the pressure rating if it is meant for pressure or DWV if for drainage. Next, the markings indicate standard dimension ratio (SDR) or schedule number. Lastly, a marking indicates whether the material is approved for potable water use (Harvel, 2006). An example of these marking is shown in Figure 6.5.

FIGURE 6.5 PVC Markings

Pipe Colors

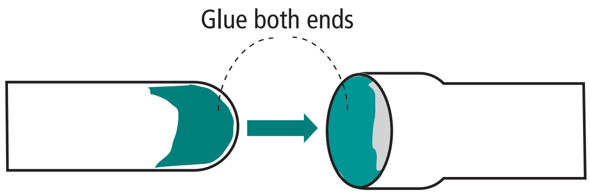
PVC materials can be made in many colors. Plumbing codes usually dictate pipe colors for various applications. Some of the typical applications and pipe colors are:

- White: sewer and water
- Blue: water
- Green: sewer and water
- Purple: water reuse (treated sewage being reused)
- Yellow: gas
- Gray: electrical
- Red: fire

Fittings and Joints

Overlapping joints are used to connect pipe lengths and fittings. Whether using threaded or solvent-welded connections, there is an expanded-diameter section that allows entry of the previous pipe. The expanded-diameter portion is the female end and it is often called a socket, bell, and/or hub. The male end is frequently called a slip or spigot.

FIGURE 6.6 Pipe Cementing

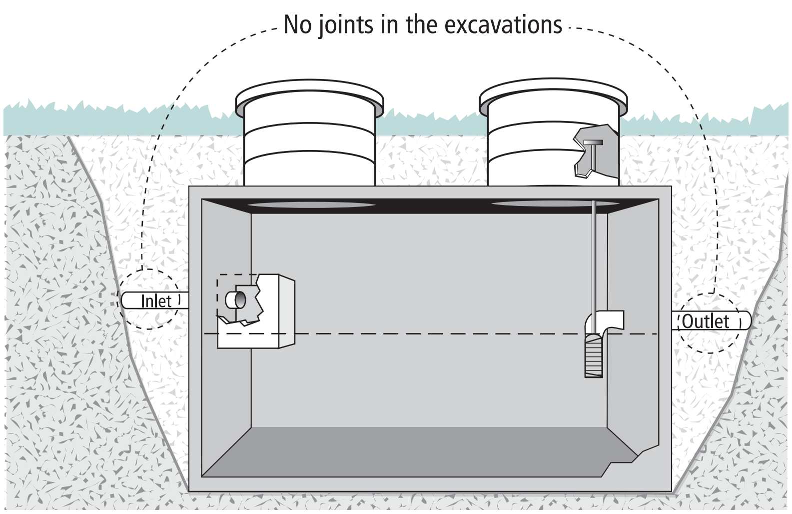


1. Measure
2. Cut and test fit
3. Deburr
4. Bevel
5. Apply primer (purple) and cement
6. Insert and twist ¼ turn

An advantage of PVC pipe is the ease of connections. In onsite wastewater applications, the most common means of connecting pipe is with solvent-welded fittings. A strong solvent is used to chemically weld pipe sections, as shown in Figure 6.6. Sometimes called "gluing" or "cementing," solvent welding provides a mechanically strong and watertight seal. As shown in Figure 6.7, joints should not be placed in areas of excavation.

PVC pipe can also be jointed with gasket fittings. This connection style uses a bell end that contains one or more molded gaskets or o-rings. The spigot end is pushed into the bell, and the o-rings provide a watertight connection. This is not a rigid connection; if the pipes and fittings are not supported by overburden or by mechanical fasteners, then water pressure within the pipe will force the fittings apart.

FIGURE 6.7 No Joints in Excavated Areas



Fittings

Among other uses, fittings are used to transition between pipe diameters, provide directional changes, and convert between solvent-welded and threaded connections. The most common fitting is a coupling, which is used to connect two sections of pipe. When many lengths of pipe are assembled, pipe should be specified that has an integral bell on one end. This eliminates the need for a coupling between the pipe lengths. A coupling adds two connections in a line that provide additional potential locations for leaks and clogs.

Couplings can be specified that transition into different pipe diameters. A "bushing" fits into a pipe hub to reduce the diameter for a smaller pipe spigot. A "reducer" connects the spigot ends of pipes with different diameters. Elbow or "El" are angled joints and allow the pipeline to change directions. Fittings are available that provide 22.5-, 45-, and 90-degree directional changes.

Most fittings have a hub (or socket) on each end. A street fitting contains both a hub on one end and a spigot on the other end. This fitting style takes up less space than two regular fittings connected with a short length of pipe. Place the spigot end of a street fitting on the downstream side whenever possible to limit catching debris.

Unions are fittings that provide a means of pipe-system disassembly. These fittings are easy to break apart. By placing a union on each side of a valve or pump, that device can be removed without damaging the pipeline.

All fittings increase the friction in a hydraulic system due to the added roughness in the transitions. The number and types of fittings can impact the required pump size. Multiple fittings can increase the required pump size.

Slope/Grade

New systems use plastic pipe for building sewer applications. The choice of plastic over other materials, such as cast iron or clay tile, is related primarily to ease of handling and cost. Ease of handling includes the ability to make watertight connections between pipe sections to reduce root intrusion or leaking. For a building sewer that carries raw sewage from the house to the septic tank, the pipe must be at least 4 inches in diameter to accommodate toilet paper and large solids in the sewage. Because of the solids, there is a maximum and a minimum slope necessary for this pipe to deliver the sewage to its destination. The two purposes for the slope in the sewer piping are to ensure movement of water and solids. In order to move water, the pipe has to point downhill. The typical minimum code requirement to maintain water flow in 4-inch pipe without allowing solids to settle is a slope of 1 inch in 4 feet, or 1/4 inch per foot (2.0 percent). For house sewers longer than 50 feet, the pipe should have a slope of not more than 1 inch in 4 feet, or 1/4 inch per foot (2.0 percent), unless otherwise approved by the plumbing administrative authority where it is impractical due to the depth of the SSTS system or septic tanks. In the building sewer, sharp bends should be avoided. When 45- or 90-degree bends are necessary, use long sweep elbows that will allow a plumber's snake to go through the sewer line. "Grade" describes the fall (slope) of a line of pipe in reference to a horizontal plane. In drainage it is usually expressed as the fall in a fraction of an inch per foot length of pipe (MN Rules Chapter 4714, Section 708.1).

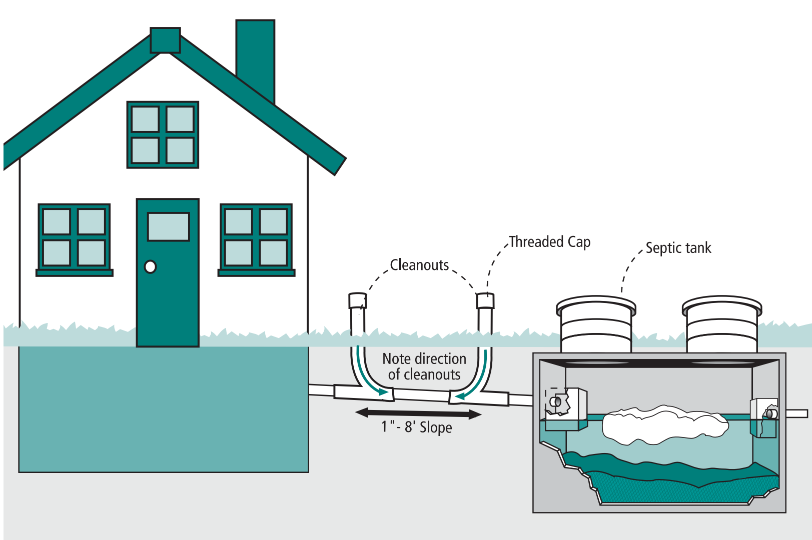
MN Rules Chapter 4714, Section 708.1, Pitch or Horizontal Drainage Piping states that horizontal drainage piping should be installed in uniform alignment at uniform slopes in accordance with the requirements detailed below.

Cleanouts

A cleanout is important for all systems. Installing a cleanout at the wall outside the home or business is a good idea if the system ever needs to be jetted or cleaned as shown in Figure 6.8. This cleanout allows all this work to be done outside, so any mess stays outside. Inside the home, there is potential for the cleanout to be hidden and the possibility of a major spill. They can either be one direction to clean the pipe either forward or backward or two directional to clean in both directions. Cleanouts should be accessible at the surface and located in a protective enclosure such as a valve box.

There should be at least two cleanouts in the building drain, one at or near the base of the stack and one near the connection between the building drain and the building sewer. The cleanout at the outside wall may be inside or outside the building, should be made with a full "Y" branch fitting, and should extend at least two inches above grade or finished floor, except when the administrative authority grants permission to use a flush cover in traffic areas.

FIGURE 6.8 Cleanouts



The cleanout should be of the same nominal size as the pipes they serve: up to four inches in diameter and not less than four inches for larger piping. The distance between cleanouts in horizontal piping should not exceed 100 feet in straight runs and for each aggregate horizontal change in direction exceeding 135 degrees (MN Rules, Chapter 4714, Section 719.1).

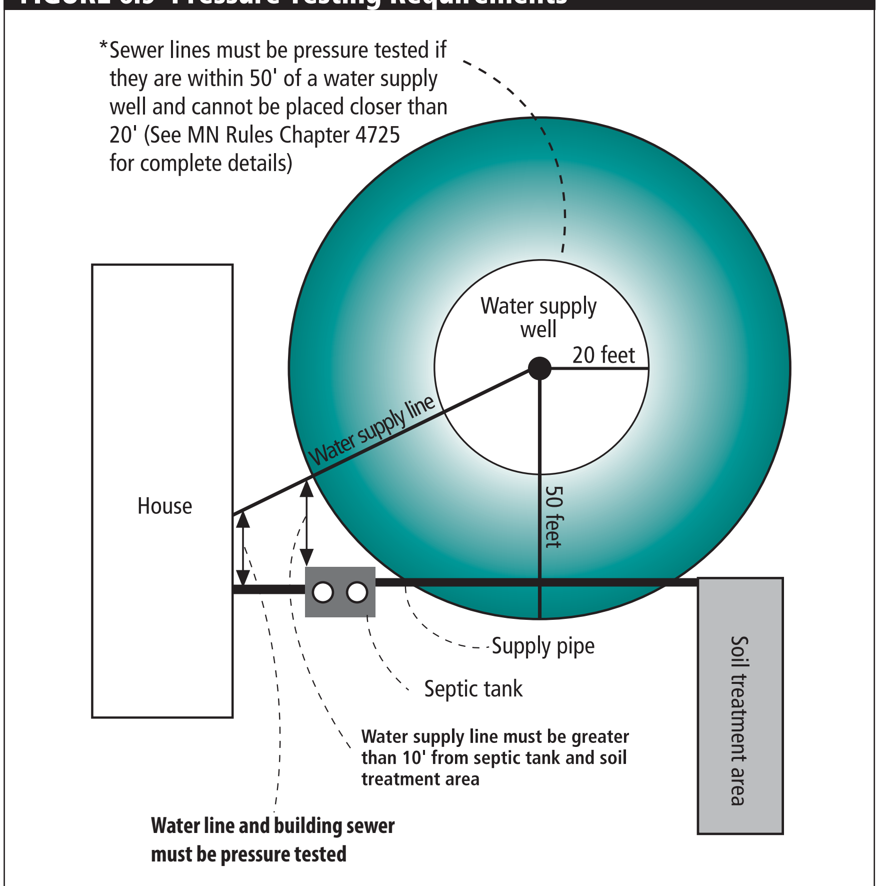
The riser pipe on the cleanout should be made to standard pipe sizes, conform in thickness to that required for pipes and fittings of the same material and extend not less than one-fourth inch above the hub. The cleanout cover or plug should be of brass, cast iron, or approved plastic. Neoprene or nordel rubber with a plastic disc and a single stainless steel (300 series) band may be used for a cleanout cover provided that it is exposed and readily accessible. Section 707.1 states that plugs should have raised square heads or approved countersunk rectangular slots.

Each cleanout, unless installed under an approved cover plate or left flush with the finished floor, should be at least two inches above grade, readily accessible, and should not be covered with cement, plaster, or other permanent finish material.

Setbacks

Setbacks refer to the required separation distances based on safety or environmental concerns. The main safety issue is to separate pipes carrying wastewater from water supply pipes. This reduces potential for drinking water contamination. To help promote separation of the two, different-colored pipes are typically used, although not required: blue for drinking water, green for sewage. Purple pipe is used for treated wastewater that is to be reused for another application. In many states this treated effluent is used for irrigation water on landscapes.

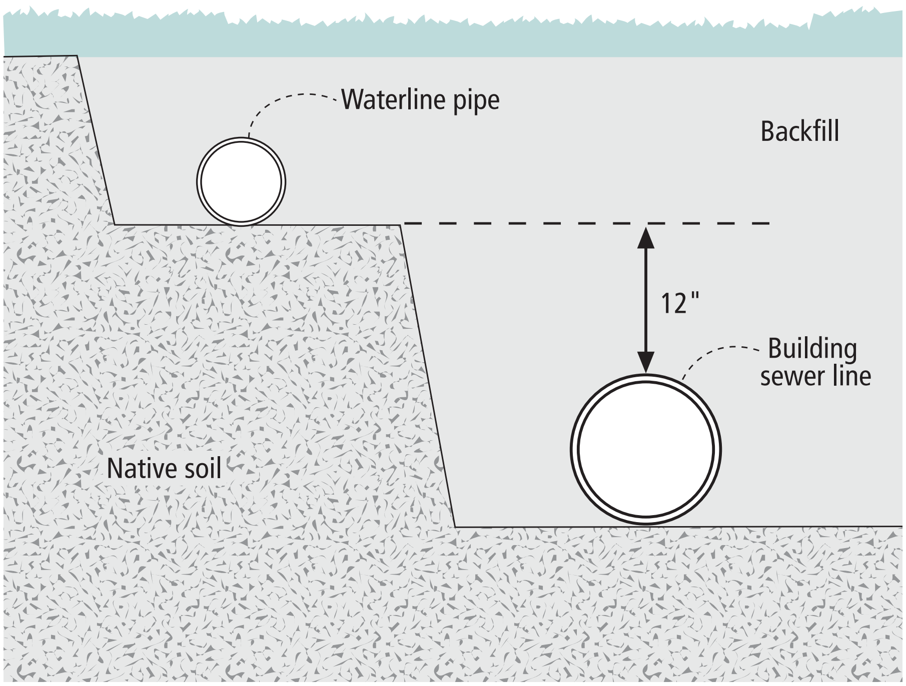
FIGURE 6.9 Pressure Testing Requirements



A safety issue aside from separation of wastewater and water supply pipes is to assure the sewage pipe does not leak. This requires proper gluing techniques, and upon completion, a pressure test should be conducted before the piping has been backfilled. This makes it simpler for any required repairs, but also means an installer needs to be careful backfilling the trench to avoid any breaks. Refer to Figure 6.9 for a detailed illustration for the setback between the building sewer and the water supply line.

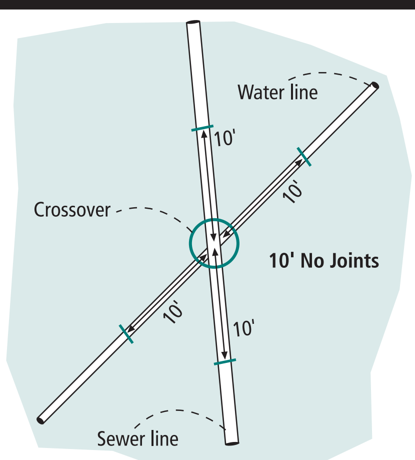
For your building sewer and other piping, the setback distance is the same as for a clean water line: 10 feet for water lines from the sewer is required. For the well itself, the setback to the building sewer is 50 feet without pressure testing. With pressure testing, it is 20 feet if the sewer is made with approved materials. Pressure tests are conducted by plugging the pipe at both ends and adding compressed air. It is important to have a method to add air and measure the pressure in the pipe. Air pressure is raised to a set level, typically 5 to 15 pounds. The pipe then should hold this pressure for 15 minutes (MN Rules Chapter 4714, Sections 609.4 and 712.0). If the pipe and joints can hold this pressure, it is considered watertight. Along with a pressure test, the proper paper work must also be completed and signed for the Minnesota DOLI and submitted to the regional offices. The air tests should be applied to the plumbing drainage system in its entirety or in sections. Sections which are found satisfactory need not be retested after completion of the entire system unless considered necessary by the proper administrative authority (MN Rules Chapter 4714, section 712).

FIGURE 6.10 Water Supply and Sewer in Same Trench



A building sewer pipe may be in a common trench with water service pipe if the sewer pipe material such as ASTM D2665 or ASTM D1785 is approved for use within a building (see MN Rules, Chapter 4714, Sections 609.2 and 720.1). If the building sewer and water line are going to be run in the same trench the water line must be placed 12 inches higher than the sewer and water pipe must be on a solid shelf at least 12 inches horizontally from the sewer in the excavation as shown in Figure 6.10.

FIGURE 6.11 Water and Sewer Line Cross-over



The bottom of the water service crossing a sewer of clay or materials not approved within a building must be at least 12 inches above the top of the sewer (see MN Rules, Chapter 4714, Sections 609.2 and 720.1). The water service should not contain any joints or connections within 10 feet of the crossing as shown in Figure 6.11. The materials used for both applications are detailed more specifically in the plumbing code.

Collection Design

The collection system delivers effluent to the first pretreatment component. This can be accomplished by either gravity or pressure. In gravity systems, 4-inch pipe is used. With larger flows, larger pipe sizes are used. A minimum flow rate of 2 feet per second is necessary to properly move the solids through the system because effluent traveling slowly can potentially cause build-up of solids over time. The 1-inch in 8-foot slope is necessary for 4-inch pipe to achieve this flow rate.

For larger diameter pipe, a lower slope will maintain these velocities. Make sure that there are clean outs every hundred feet to allow access for maintenance. As the system becomes larger, ensuring this condition becomes more complicated. **Collection of greater than 2,500 gallons per day of sewage from multiple buildings or multiple other establishments discharging into an ISTS must be:**

A. according to the Prescriptive Designs and Design Guidance for Advanced Designers, incorporated by reference under part 7080.1550, Subp. 2; or

B. designed by a Minnesota licensed professional engineer (MN Rules Chapter 7080.2440).

For pressure collection systems, there are two options for the application. The first option is grinder pump stations and grinder pumps. These systems move the effluent directly from a structure and have relatively small tanks. This will lower the capital cost and lessen some of the costs for installation. However, as a result of using a grinder, all of the solids will be smaller, potentially adding to treatment problems and capacity issues in the septic tank.

The second option is septic tank effluent pumps [STEP]. These systems insert a pump following or with a pump vault in the septic tank. The advantage of this is that solids are not being moved, so all the piping systems can be smaller. Further, it's easier to treat the effluent since some of the treatment facilities are incorporated in the structures of the homes. The downside of this is that multiple maintenance locations have to be added to the septic tanks being employed at the homes. All piping systems should be designed to drain effectively; for gravity systems, the drain is always towards the next treatment component.

Installation

The installation of plastic material sewers must comply with ASTM D2321, which requires open-trench installation on a continuous granular bed (see MN Rules, Chapter 4714, Section 718.1). All plastic pipe materials need to be placed on a solid base. The base can either be granular fill, or when appropriate, natural unexcavated soil. If the soil is excavated and then backfilled it must be compacted in 6 to 12-inch lifts. In order to properly backfill around the pipe, the trench bottom should be at least three times the diameter of pipe. This means that for 4-inch piping, a minimum of a 12-inch trench is necessary.

The identification of the benchmark is step number one for the installation of the piping. Relating back to this benchmark for both actual surface elevations and the pipe flow lines is critical for the proper installation of the system. Be sure that all of the crew understands the proper readings of the laser and target for the elevations of the pipe flow lines. Do not run the supply line through the absorption area. In mound systems this typically creates the location of the pressure manifold. Running the pump in the same trench as the gravity supply line for drop boxes can minimize excavation work.

Remember that the proper slope is required on the pipe:

For gravity systems: 1 inch per 8 feet going towards the next treatment component.

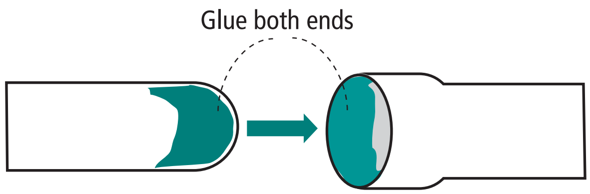
For pressure systems: 1 inch per 8 feet returning back to the dosing chamber.

Beginning excavation

The excavation should follow the designated pathway for the pipe. Good pipe installation procedures as discussed above should be followed. Be careful not to over-excavate, which will require additional work. It is best if the pipe can be bedded on natural soil, which will minimize settling, which can cause deflections or bellies to form in the pipe. If the excavation is in any organic material, such as peat, it should be removed from the excavation. Bring an inorganic (sand or pea rock) base back to the required elevation to support the piping. Use a gradation that minimizes the migration of materials when using rock for bedding and haunching.

The key for any sub base is to make sure that there will not be any settling or bellies in the pipe.

FIGURE 6.12 Watertight Pipe Connections



1. Measure
2. Cut and test fit
3. Deburr
4. Bevel
5. Apply primer (purple) and cement
6. Insert and twist ¼ turn

Pipe Cutting

Proper pipe cutting is critical to ensure that a watertight seal is created between pipes and fittings. Figure 6.12 illustrates the proper process. Below is a narrative outlining the recommended procedure for cutting pipe:

- ***Prepare:*** Examine the pipe to ensure that it is not damaged with cracks, gouges, dirt, and abrasion. If the pipe end is imperfect, cut it back to expose good material. Discard a damaged fitting. The pipe and fittings should be at the same temperature to ensure a proper joint between the two components.
- ***Cut:*** The pipe must be cut square at the end using a PVC pipe cutter, hand, or chop saw. Make sure that the end of the pipe diameter is not compromised and remains circular.
- ***Deburr:*** Cutting PVC pipe nearly always creates burrs on both the inside and outside edges of the pipe. Make sure all burrs from cutting are removed with a file, knife, or other deburring tool on both the outer and inner surface of the pipe end. If burrs are left on the end, they will scrape cement from the inside of the fitting as it is being pushed in, resulting in a non-watertight seal. Burrs on the inside pipe surface can snag hair or other debris, plugging up the pipe. With gloves on, run your fingers around both edges to feel for any burrs that might have been missed.
- ***Bevel:*** Before connecting the cut-end, bevel the end 10 to 15 degrees with a file or reamer. This prevents cement from being pushed aside by the square ends of the cut pipe. You can now apply primer and cement to both ends of the fitting. Insert the male end and twist the pipe 1/4 turn.

When using pipe lengths that have spigot and bell ends, the pipes should be arranged such that the flow travels from the bell end to the spigot end. This avoids a lip which can catch material.

Excavation and Backfilling

These two steps are related, since problems with the excavation will create problems in backfilling. The right material, proper location and the following three simple rules can help your system always move effluent the right way.

Rule 1: Avoid over-excavating the trenches when possible. If wastewater is to flow properly, the pipe must be supported. Unsupported pipe can lead to clogging and freezing problems. By minimizing unexcavated soil under the pipe, you reduce potential for development of low spots where water can collect. In general, natural soil provides a solid base (unless you work in organic or peat soils). If the trench is over-excavated, you will need to compact the soil before you place the pipe. When placing pipe in organic soils, remove the organic material and replace it with a solid material or rock with appropriate gradation. Organic soils - peat and muck - do not provide a solid base, and settling and heaving are likely to take place. This movement puts pressure and stress on the pipe and will cause leaks at the joints. More important, the pipe will not maintain the proper pipe slope.

Rule 2: Support the pipe over deep excavations. If you removed material, like organic soil, or if you installed a sewage tank and the piping going in and out of the structure, the pipe will be at least partially on fill, and this can settle. To minimize problems, use a granular fill material and compact it as the material is installed. Sand or rock is most typically used as fill. If too large of a rock is used, silting into the rock is a form of settling that can cause an aesthetic problem like a depression in the yard. Rock also can create a drain system that channels groundwater into sewage tanks. The pipe material itself can also provide support. Using a heavier pipe (such as Schedule 40) helps minimize bowing. In pressure supply pipes where 2- inch pipe is used, the smaller pipe can be placed inside a 4-inch pipe, adding strength and decreasing the potential for bowing. Be sure that the 4-inch pipe is sealed to avoid having a pipe full of soil or groundwater.

Rule 3: Backfill with good material. The backfill material has two jobs: protecting the pipe system and maintaining the slope. Protection means the pipe is surrounded by and covered with the material, providing some protection from freezing. For this to occur, the backfill must be all around the pipe. It is crucial to be careful of large stones that can damage the piping during the backfilling process. The strength of the pipe is related to its round shape. If the shape is deformed, the strength is reduced, and that can lead to failure. To minimize the weight of the cover and the potential for collapse, apply granular backfill at least to the midway point of the pipe.

Plastic pipe needs to be covered to protect it from UV rays and other surface activities that can cause failure. Lawn mowing and traffic over excavations can break and crack the pipe. You can minimize these problems by creating a backfill system that properly supports the pipe. Avoid using large stones, as these also can damage the pipe during backfilling. Big rocks should not be returned to the trench in contact with the piping. In heavier clay soils, dry soil clods can act like rocks, so don't use them to backfill the excavation. Using a granular material in contact with the pipe will minimize the impact of soil clods.

Embedment

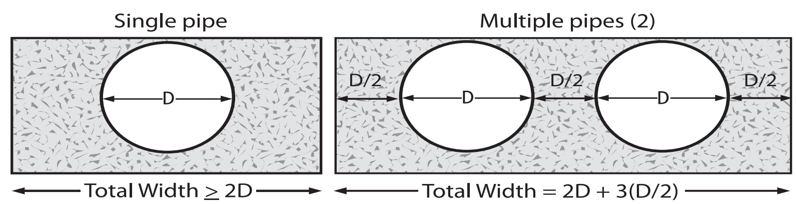
When multiple pipes are running in the same trench or in to a component, the installer should label the pipes with either a permanent marker or with a stamp to aid in future troubleshooting. It is recommended to place a marking every 20 feet and at any location where a portion of the pipe or cleanout is visible.

When piping needs to be installed in areas near a septic tank or advanced treatment unit excavation, it is best if the pipe is supported by undisturbed soil instead of running it across the top of the tank or unit. This can be done be creating a bench.

Embedment Methods

Trenches need to be dug and prepared in a way that the pipe is protected from damage. Trench bottoms should be free of rocks and debris and provide uniform support. If there is bedrock, hardpan, or large rocks on the trench bottom, the trench should be bedded. Particularly on long runs with small-diameter pipe, the trench width (TW) should be wide enough to allow the pipe to be snaked from side to side and at least twice the pipe diameter (D). From Figure 6.13, TW must be equal to or greater than two times D. The trench backfill should also be free of rocks and debris.

FIGURE 6.13 Trench Width for Pipe Installation



Where multiple lines of pipe are installed in the same trench, they should be spaced far enough apart to permit thorough tamping of earth between adjacent lines with a minimum of 0.5 times the nominal pipe diameter apart.

Bedding material and its placement is of critical importance to installation and performance. It is essential that native and imported materials are properly classified for use in bedding. Many jurisdictions have their own bedding specifications which call for special material to completely cover the pipe; care must be taken to meet these requirements. Soil to be used as bedding in the pipe zone must be appropriately compacted.

When selecting embedment materials, make sure that native soil migration from the trench walls cannot occur. A well graded, compacted granular material prevents this. In trenches subject to groundwater inundation, the granular material should be compacted.

The trench bottom should be dry. Surface water draining towards the trench must be redirected. Installation of piping is much more difficult if water is in the trench due to the tendency for pipe flotation; therefore, dewatering is required to minimize these issues and the likelihood of instability of trench walls and slopes. Groundwater should not be permitted to rise above the trench bottom until after the installed pipe is fully bedded and enough fill is in place to prevent flotation.

The foundation is the underlying natural soil material. The bedding material is usually less than 6 inches thick in trenching but can be deeper around the tank, and provides continuous support of the pipe and underside of the pipe. If a coarse, granular material is used for bedding the pipe, it should also be used up to the midpoint of the pipe. Otherwise, side support may be lost due to the migration of finer material into the bedding.

As the pipe is installed, make sure the pipe does not bow; this is a sign that the pipe is too long. The pipe should lay perfectly flat. PVC will expand or contract 3.36

inches for every 100 feet of pipe per every 100 degree F change in temperature (Vinyl Institute, 2006). To compensate for the natural expansion and contraction, the pipe can be snaked from side to side in the trench. Ideally, the pipe should be installed and the trench backfilled during the cool part of the day.

The next layer is the haunching that comes from the top of the bedding to about half way up the pipe diameter (springline) and is a strong factor controlling pipe performance and deflection. Proper selection of haunching material is essential to PVC pipes' ability to support vertical loads. It is frequently a special material with sizes not exceeding 3/4 inch. The haunching procedure is to tamp the embedment materials under the haunches and around the pipe to the midline of the pipe to providing effective support. Following haunching, initial backfill is applied followed by final backfill.

Some piping excavations do not have vertical support walls above the piping. These excavations are backfilled with a similar approach. The bedding and haunching materials extend at least one pipe diameter to the side of the piping. The initial backfill material should extend to at least half the pipe diameter over the top and sides of the pipe. The final backfill fills the remainder of the excavation. This embedment approach is used when running piping through tank excavations or benches along tank excavations.

Finishing

Finishing should be done with a soil that will establish a vegetative cover. Make sure that there is a low crown on the finishing material to allow for settling. This material should meet the definition of topsoil borrow from **MN Rules Chapter 7080.1100 Subp. 88, Topsoil borrow means a loamy soil material having:**

a. less than 5% material larger than 2 mm, #10 sieve

b. no material larger than 2.5 cm.

c. a moist color value of less than 3.5

d. adequate nutrients and pH to sustain healthy plant growth

Connecting Pipe and Fittings

Solvent welds, threaded connections, mechanical joints, and gaskets are the most common methods of connecting PVC pipe. In this manual, solvent welds with slip joints are the most common. These solvent welds will be referred to as "glued" and the solvent as "glue." The solvents (PVC primer and cement) emit strong organic vapors, so always work in a well ventilated area.

Solvent-Welding

There are many key points to keep in mind when making glued joints:

- It is critical that the exterior and the interior of the pipe be clean and dry.
- Before priming and gluing, the fit of the connection should be tested.
- Primer is a mixture of solvents, similar to those found in the glue and is used to soften or "prime" the pipe and fitting prior to adding glue. A suitable primer penetrates and softens the surfaces more quickly than the cement alone. There is no substitute for primer. It is important to note that cleaners and primers are not the same thing. Do not use water, rags, gasoline, or any other substitutes for priming PVC surfaces.

There are many different types of primers on the market. They differ mostly by viscosity. It is important to make sure that the primer is appropriate for the pipe type, size, and air temperature. The primer and glue should not be adjusted or thinned by any means. If they begin to look jelly-like or their viscosity has changed, they should be discarded. MN Rules Chapter 4714, Section 705.7, states PVC solvent weld joints must include ASTM F656 purple primer and ASTM D2564 solvent cement. The most common color for primer is purple. Read the warning labels and take necessary safety precautions such as protective equipment for eyes and skin.

Primer should be applied to the fitting socket and the pipe end, making sure that the primer does not puddle inside the socket. Time must be allowed for the surface to soften. The amount of primer and time may need to be increased when the temperature is cold.

There are a variety of applicators for primer and glue. Daubers are typically provided by the supplier and can be used on smaller diameter pipe. Brushes, with natural bristles, can be used on any diameter pipe. Rollers are commonly used for 4-inch diameter and greater. As a rule of thumb, select an applicator that is at least half the diameter of the pipe.

In order to have an effective solvent-weld, apply sufficient glue to fill the gap between the pipe and fitting. The primer and glue work to dissolve the two surfaces. When the pipe is inserted into the fitting, the two surfaces blend and become one as the primer and glue evaporate. The joint strengthens as the PVC hardens, so it must be allowed to fully cure to reach its full strength.

It is important to use the right type of glue. Read the label as the wrong glue can melt the pipe. Brush on a coat of ASTM-rated glue, such as ABS, PVC, or Styrene, that is matched to the type of pipe and fitting you are using. As the wall thickness of the pipe increases, more viscous glue is needed. Glue must be applied to the inside of the fitting as well as the outside of the pipe. Do not allow the cement to puddle or run down the inside of the fitting. The pieces must be assembled quickly while the cement is still wet. If it dries before you have connected the pieces, then you must reapply the glue.

Push the pipe fully into the fitting while turning a quarter turn to distribute the cement evenly. The twist breaks up insertion lines and helps to spread the glue. The connection must be held firmly for 15 to 30 seconds to prevent the joint from pushing apart, providing the glue a chance to begin to harden. Wipe the excess bead of glue that forms on the outside of the connection to prevent the glue from continuing to dissolve the pipe.

The joint should not be disturbed until it has initially set. The amount of time the joint needs to initially set is dependent on the air temperature and humidity. Be sure to use a primer and cement that is appropriate for the weather conditions. Table 6.4 provides the recommended initial set times.

TABLE 6.4 Initial set time for a cemented PVC joint (Charlotte, 2007)

Temperature Range	Pipe Size	Pipe Size
	1/2 to 11/4 in.	11/2 to 3 in.
60° - 100° F	15 min	30 min
40° - 60° F	1 hr	2 hr
0° - 40° F	3 hr	6 hr

The joint should not be pressure tested until it has fully cured. The exact curing time varies with temperature, humidity, and pipe size. Table 6.5 indicates suggested curing times.

The cement and primer should be stored with the lid sealed and away from heat or open flames. The glue should only be used in a well ventilated area. The glue should be used within one year of the date stamped on the container. Most importantly, all manufacturer recommendations must be followed.

TABLE 6.5 Minimum curing times for cemented PVC joints (Charlotte, 2007) with relative humidity 60* of less

Pipe Size	1/2 to 11/4 in.		11/2 to 3 in.	
Temperature Range	PSI		PSI	
	≤180	180-370	≤ 180	180-315
60° - 100° F	1 hr	6 hr	2 hr	12 hr
40° - 60° F	2 hr	12 hr	4 hr	24 hr
0° - 40° F	8 hr	48 hr	16 hr	96 hr

* For humidity above 60%, allow 50% more cure time.

Threaded Connections

Threaded connections are often needed when installing components in the pipeline. Male and female adapters are used to transition to threaded fittings. Schedule 40 and SDR pipe should not be threaded. Threading this material reduces the wall thickness, and the pressure rating of the pipe is reduced by 50 psi. If pipe nipples are needed, Schedule 80 has a thicker wall and can be threaded without significant loss of strength.

All pipe threads need to be sealed. Teflon tape is commonly used for wastewater piping systems. Pipe joint compounds, pastes, or other thread lubricants must be approved for use with PVC.

Threaded connections should be hand-tightened. At most, a strap wrench can be used for tightening. Over-tightening should be avoided as this can cause thread or fitting damage. When combining plastic and metallic threaded systems, it is recommended that plastic male threads be screwed into metallic female threads to prevent the plastic from being cracked by the expanding metal threads.

Mechanical Joints

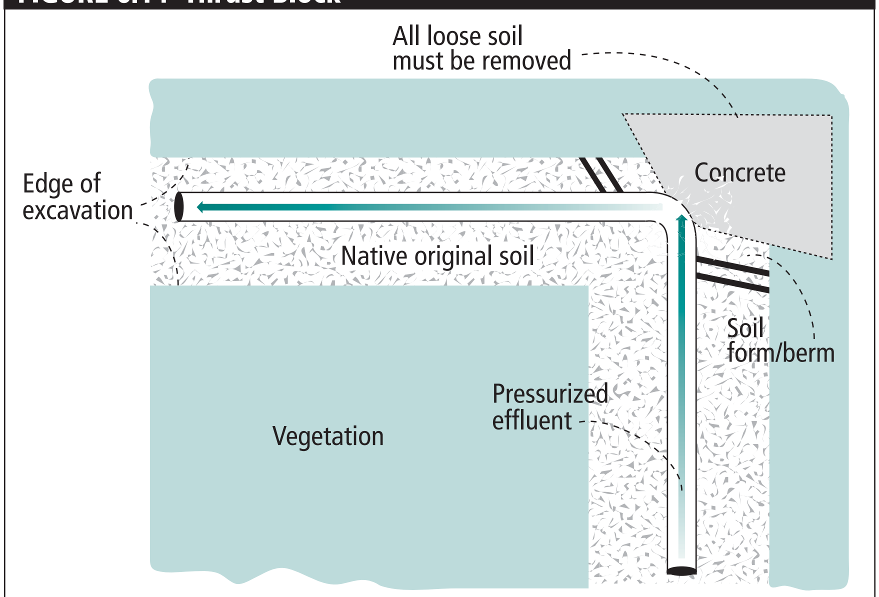
Mechanical joints have four parts: a flange cast with a bell; a rubber gasket that fits in the bell socket; a gland, or follower ring, to compress the gasket; and tee head bolts and nuts for tightening the joint. Joint assembly is labor-intensive but very simple and requires only one tool- an ordinary ratchet wrench. The mechanical joint is flexible, with the amount of deflection dependent on pipe diameter. The mechanical joint is used mainly with fittings rather than pipe. This is due to the predominant use of push-on joints, which are more economical, faster to install, more trouble-free, and offer better service than mechanical joints.

Lubrication of the plain end, socket, and gasket during assembly of mechanical joint is typically recommended. Use soapy water or approved pipe lubricant during mechanical joint assembly to improve gasket sealing and long-term performance. Do not use PVC glue or petroleum-based lubricants.

Gaskets

Some types of PVC pipe are connected with gasket joints. Sometimes the gaskets are part of the pipe (bell-end) while other times they are separate fittings. The gaskets must be clean and dry before installing. Both the gasket grove and the spigot should be clean and dry prior to making the connection. A lubricant is needed to make the connection based on the manufacturer recommendations. The lubricant is applied to the spigot end of the pipe. A good joint is made when the insertion line of the spigot end of the pipe is lined up with the edge of the bell that the spigot is inserted.

FIGURE 6.14 Thrust Block



Thrust Blocks

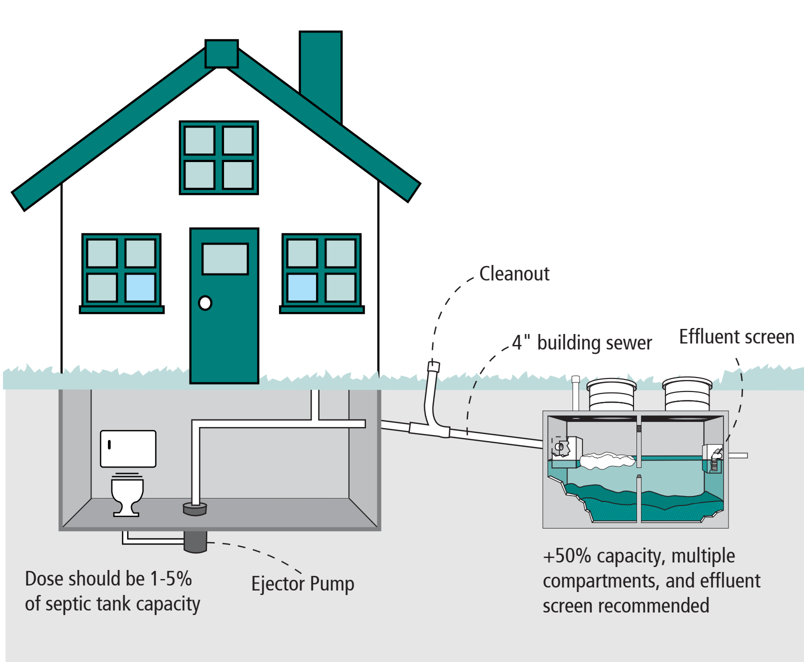
In pressurized applications, the initial force caused by starting a pump can stress pipe connections. When effluent initially flows through an empty pipe, air is the only restriction to water flow. The air moves quickly and the effluent is typically flowing at a greater than normal velocity. When the effluent reaches an elbow, it must change direction. The effluent hits the back wall of the elbow which absorbs the force and directs the effluent around the corner and further along the pipe. This initial impact of the flow can cause tremendous forces on elbows and junctions in the system, and as a result they need to be reinforced with thrust blocks. Basically a thrust block is a rough block of poured concrete which braces the pipe and helps prevent ruptures in the line, as shown in Figure 6.14. The concrete is poured on the outside of an angle fitting and extends back to native soil. The purpose is to prevent surges in flow througha pipe from flexing the fitting and wiggling it in the ground. This would over time form a larger and larger underground space, possibly allowing the pipe fitting to pull apart.

Gasketed pipe and fittings must have thrust blocks or mechanical connections. The size and location of thrust blocks should be provided in the design. Consult with the system designer if you are unsure.

O&M and Troubleshooting

Long-term management of this pipe requires access to the pipe. If there's a problem, this access is used to clean the piping. These cleanouts can be located either near the house or near the tank. Many maintainers would appreciate having a cleanout in both locations, but if there is easy access into the piping in the septic tank, the location at the house may not be necessary. A cleanout near the house is beneficial for cleaning and other work. The clean

Figure 6.15 Building Sewer Maintenance



out should be made of the same materials as the pipe. It should be the same size and a sanitary "Y" for easy access to the pipe. It should be a threaded plug or cap that is easy to take off. In Figure 6.15, the injector (sewage) pump must meet the requirements of MN Rules Chapter 4714 Section 710.3 and be connected to the plumbing venting system (MN Rules Chapter 4714, Section 710.10). The key for operating the building sewer is to assure that effluent drains through the pipe by preventing buildup plugging and freezing. Good management can maintain and extend the life of the system.

Plugging

The first issue, plugging, is related to use. Large solids that do not belong should be kept out of the piping, and toilet paper use should be minimized. Powder detergent can add to clogging problems in cast iron piping by actually precipitating caking inside the piping. A common location of plugging in new systems is at the inlet baffle in the septic tank. This is created when the piping is installed against the baffle. Be sure to have at least a six-inch separation between the pipe inlet and the baffle.

An issue related to plugging is the impact of roots on the piping. This is typically related to pipe materials and installation. If the proper plastic piping is selected, properly bedded, and installed with watertight joints, the roots will have a difficult time entering the system. If the system has older (clay, cast iron, Orangeburg) materials, replacement of the piping is the right answer for long-term performance.

Other major management concerns include the following installation issues. As the pipe is installed close to structures or decks, it becomes more difficult to maintain the pipe at proper slopes and to make good connections. The need to clean and replace pipe is the reason for specifying setback requirements from structures. Typically, 10 to 12 feet will allow the excavator to work on the piping around the structure. Decks become bigger problems because they are often built after the pipe is installed. The pipe can be crushed or broken during installation of the footings. Installers must work with homeowners to understand the importance of avoiding the pipes and planning for access in case future repairs are needed.

Freezing

In addition to plugging, freezing is a common problem that can be avoided with good management. In cold-weather areas, pipe needs to be protected from freezing. Methods to minimize freezing include making sure that the pipe is properly installed and insulated if the system is placed under a pathway or drive. This installation can take the form of purchasing insulated pipe or installing the insulation over the top of the excavation with the proper insulating products. Insulated pipe has two benefits: the insulation surrounds the pipe, and the insulation gives the pipe some additional resistance to settling. Some engineers will design the pipe at a deeper depth. This may help with the insulation; however, it may also create system issues and is not the recommended solution for cold weather. It drives the rest of the system deeper and creates a higher potential for the system to be in saturated soil conditions where leakage becomes more critical.

In city sewer systems, freeze protection is often accomplished by making sure the pipe is installed deep underground (6 to 8 feet), but in onsite systems this depth is not always available. If the bury depth is shallow, or if the pipe is under a driveway or sidewalk, it should be insulated. Traffic over the system will drive the frost deeper, increasing the potential for freezing.

There are two methods to insulate pipe. You can buy pipe with insulation attached, which is more expensive than standard piping. The other option is to install foam sheets over the pipe. Make sure you choose insulation designed for use underground. Fiberglass batting is not designed for such applications. In addition to providing insulation, it also gives the pipe more rigidity, preventing settling that results in bellies or low spots in the pipe where freezing can occur.

SECTION 7: Septic Tanks

SEPTIC TANKS

Definition and Description

The purpose of the septic tank is to provide an environment for the first stage of treatment in onsite and decentralized wastewater systems by promoting physical settling, flotation, and the anaerobic digestion of sewage. Additionally, the tank allows storage of both digested and undigested solids until they are removed. From 7080.1100:

1. **A septic tank means any watertight, covered receptacle that is designed and constructed to receive the discharge of sewage from a building sewer or preceding tank, stores liquids for a detention period that provides separation of solids from liquid and digestion of organic matter, and allows the effluent to discharge to a succeeding tank, treatment device, or soil dispersal system (Subp. 70).**
2. **A sewage tank is defined as a receptacle used in the containment or treatment of sewage and includes, but is not limited to, septic tanks, aerobic tanks, pump tanks, and holding tanks (Subp. 74).**

FIGURE 7.1 Three Layers Form In a Properly Operating Septic Tank

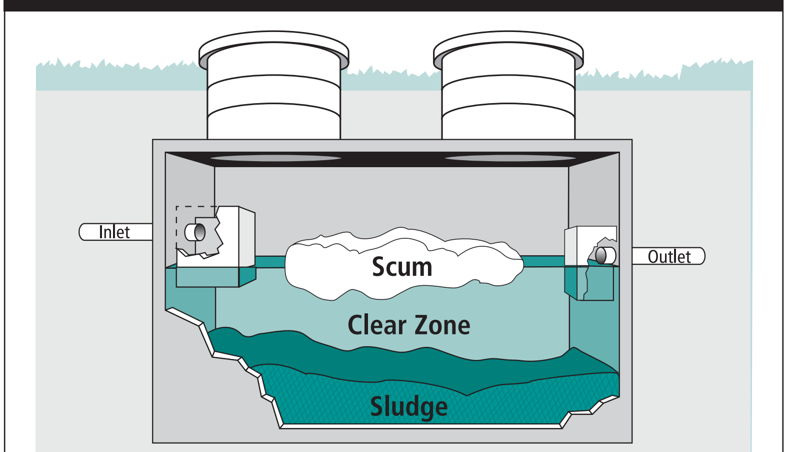
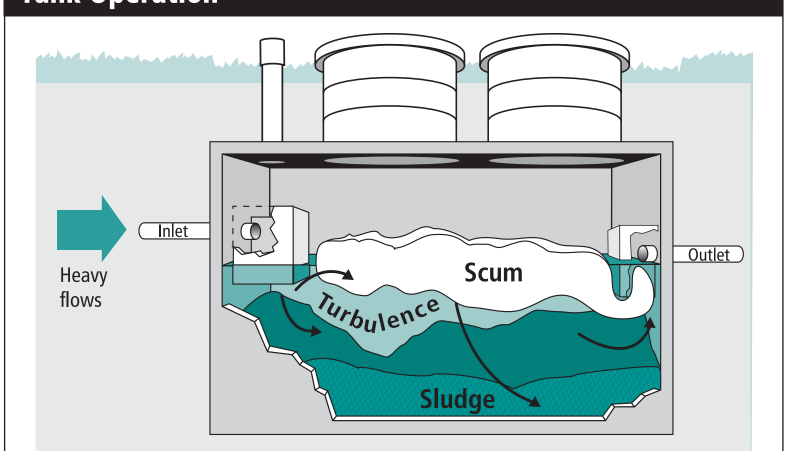


FIGURE 7.2 Large Doses and Excessive Flow Disrupts Tank Operation



Physical processes

Septic tanks allow the separation of solids from wastewater as heavier solids settle and fats, greases, and lighter solids float. The solids content of the wastewater is reduced by 60-80% within the tank. The settled solids are called *sludge*, the floated solids are called *scum*, and the liquid layer in between is called the *clear zone* as shown in Figure 7.1. Although the liquid in the clear zone is not highly treated, it is greatly clarified compared to the wastewater entering the tank, the larger particles having migrated to either the sludge or scum layers. Another important function of the tank is storage of these accumulated solids. The tank is sized large enough to hold solids until maintenance (i.e., tank pumping) is performed.

The effluent, or wastewater, that leaves the septic tank comes from the clear zone to minimize the solids loading on the downstream components of the system. The baffle, tee, or effluent screen at the outlet is designed to draw from the clear zone retaining floatable or settleable solids in the tank. The settling process requires time to occur, so the tank must be large enough to retain the wastewater in a turbulence-free environment for two to four days. Excessive flow and turbulence can disrupt the settling process as shown in Figure 7.2, so tank volume, size, shape, and inlet baffle configuration are designed to minimize turbulence.

Biological and chemical processes

Septic tank solids include both biodegradable and nonbiodegradable materials; although many of the solids will decompose, some solids will accumulate in the tank. Anaerobic and facultative biological processes in the oxygen-deficient environment of the tank provide partial digestion of some of the wastewater components. These processes are slow, incomplete, and odor producing. Gases (hydrogen sulfide, methane, carbon dioxide, and others) result from the anaerobic digestion in the tank and may create safety hazards for improperly equipped service personnel. The gases accumulate in bubbles in the sludge that, as they rise, may re-suspend settled solids. This will elevate the total suspended solids (TSS) concentration in the clear zone and ultimately send more suspended solids to downstream system components. This scenario often results when active digestion occurs during warm temperatures.

Attempts to reduce discharge of re-suspended solids led to the development of tank features such as gas deflectors. Effluent screens now help to perform this function.

Treatment achieved with domestic sewage

The septic tank provides primary anaerobic treatment (dissolved oxygen < .5 mg/L) in an onsite sewage treatment system of the raw wastewater. The effluent from the septic tank is typically treated so that it contains 140 to 220 milligrams per liter BOD, 45 to 70 milligrams per liter TSS, and 10-30 milligrams per litter FOG. **According to MN Rules Chapter 7081.0130, Subp. 2. If concentrations of biochemical oxygen demands, total suspended solids, and oil and grease from the sewage are expected to be higher than 170 mg/L, 60 mg/L, or 25 mg/L respectively, an estimated or measured average concentration must be determined and be acceptable to the local unit of government. System design must account for concentrations of these constituents so as not to cause internal system malfunction, such as, but not limited to, clogging of pipes, orifices, treatment devices, or media.**

Factors affecting septic tank performance

The anaerobic digestion processes in tanks are affected by temperature in the tank and by substances that have an adverse impact on biological organisms. Higher temperatures will enhance the rate of biological processes and inhibiting substances will reduce it. Too high of temperatures may liquefy fats, oils and greases (FOGs). Ideal temperatures in the tank allow for FOGs to solidify and bacterial activity to take place. Some factors that affect the way a tank functions include:

- strength (concentration) of the incoming wastewater;
- pH;
- introduction of harsh chemicals, drain cleaners, paint, photo processing chemicals or other inappropriate substances into the waste stream which may affect pH and biological activity;
- introduction of fats, oils and grease (FOG);

- highly variable flow patterns that affect detention time;
- introduction of pharmaceuticals (especially those for chemotherapy and dialysis; long term use of antibiotics, etc.);
- introduction of process discharge, including backwash from a water softener, and;
- lack of maintenance resulting in excess accumulation of solids, reducing effective volume and reducing detention time.

User education and care are important factors in maximizing the effectiveness of septic tank processes.

TABLE 7.1 Location of Septic Tank

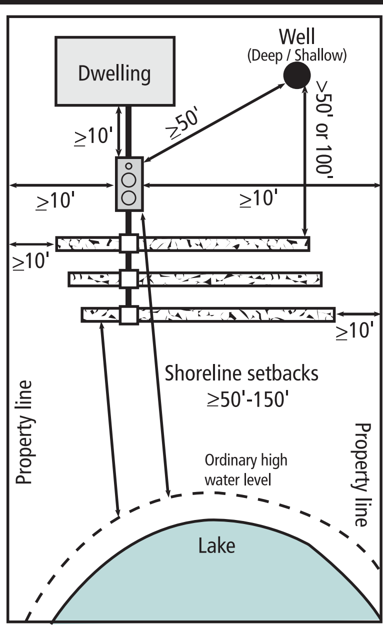
Item	Minimum Setback
Property Lines	10 feet
Buried pipe distributing water under pressure	10 feet
Building	10 feet
Water supply wells	50 feet

Setbacks

To minimize potential problems of pipe blockage, freezing and to keep cost low it is advantageous to keep the septic tank(s) located near the main source of sewage. It is also critical that the selected tank location meet all the setback distances, as listed in Table 7.1.

Figure 7.3 highlights the setbacks from the septic tank and soil treatment area to critical site features. A detailed discussion of setbacks is in Section 2 of this manual.

FIGURE 7.3 Septic System Setbacks



Design Impacts and Options

According to MN Rules 7080.1920, septic tanks must:

A. Have a liquid depth of at least 30 inches. Any liquid depth that is greater than 84 inches must not be used when calculating the septic tank liquid capacity;

B. Have a minimum of six feet between the inlet and outlet of the tank, rather than between compartments, or have a minimum of six feet from the inlet of the first tank to the outlet of the last tank in series;

C. If site conditions warrant, the inlet and outlet may be located on walls that are not opposite each other along the axis of maximum dimension; however, the requirements of item B must be met;

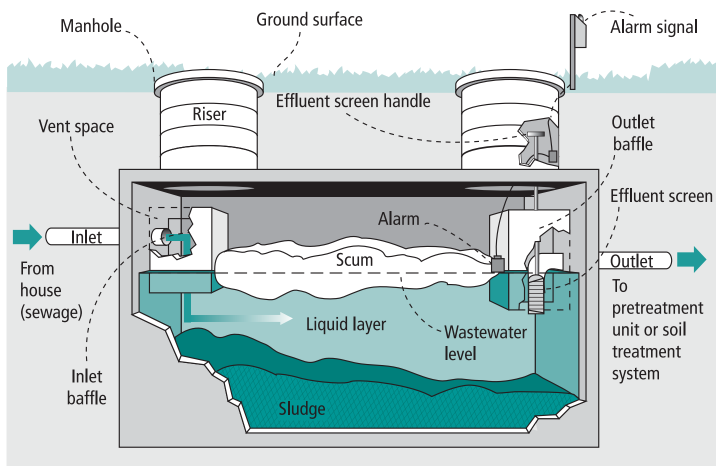
D. Have an inlet invert at least two inches above the outlet invert; and

E. Have a space between the liquid surface and the top of the inlet and outlet baffles of not less than six inches or 100 gallons, whichever is greater, for all liquid depths with an effluent screen and alarm or for liquid depths of less than 39 inches without an effluent screen and alarm. The space between the liquid surface and the top of the inlet and outlet baffles must not be less than eight inches for liquid depths of 39 inches or more without an effluent screen and alarm.

In addition, there must be at least one inch between the underside of the top of the tank and the highest point of the inlet and outlet baffles.

Figure 7.4 illustrates a septic tank with components labeled.

FIGURE 7.4 Septic Tank Components



Tank Sizing for Dwellings

Required septic tank capacities are outlined in **MN Rules Chapter 7080.1930, Subp. 1.** It states that for dwellings, the liquid capacity of septic tanks must be at least as large as the liquid capacities given in Table 7.2.

TABLE 7.2 Septic Tank Minimum Capacity for Dwellings

Number of bedrooms	Minimum Capacity of Septic Tank (gallons)	* Minimum septic tank capacity with garbage disposal and/or pump in basement (gallons)
3 or less	1,000	1,500
4 or 5	1,500	2,250
6 or 7	2,000	3,000
8 or 9	2,500	3,750

* Must include either multiple compartments or multiple tanks. An effluent screen with an alarm is recommended.

From MN Rules Chapter 7080.1100 the liquid capacity is defined as the liquid volume of a sewage tank below the invert of the outlet pipe.

According to MN Rules Chapter 7080.1930, Subp. 6, septic tank liquid capacity prior to other treatment devices must accord with manufacturer's requirements, accepted engineering principles, or as identified in the product registration recommended standards and criteria. For example a trash tank is generally installed prior to aerobic treatment units (ATUs). These tanks can be as small as one-half of the daily design flow volume (300-500 gallons for a 600 gpd design flow). The size is generally specified by the manufacturer of the unit but may be code-driven. Trash tanks can serve as an anaerobic/facultative treatment device but are mainly intended to remove non-degradable items such as plastic from the wastewater stream. They may be an integral part of some proprietary ATUs.

Garbage Disposal and Pumps in Basements

If a garbage disposal unit is anticipated or installed in a dwelling, the septic tank capacity must be at least 50 percent greater than that required in subpart 1 and must include either multiple compartments or multiple tanks. In addition, an effluent screening device is recommended (7080.1930 Subp. 2).

The use of garbage disposals adds unnecessary solids to the waste stream and encourages homeowners to introduce food scraps that result in increased BOD and FOGs. If garbage disposals are used, more frequent solids removal may be needed.

FIGURE 7.5 Ejector Pump in Basement

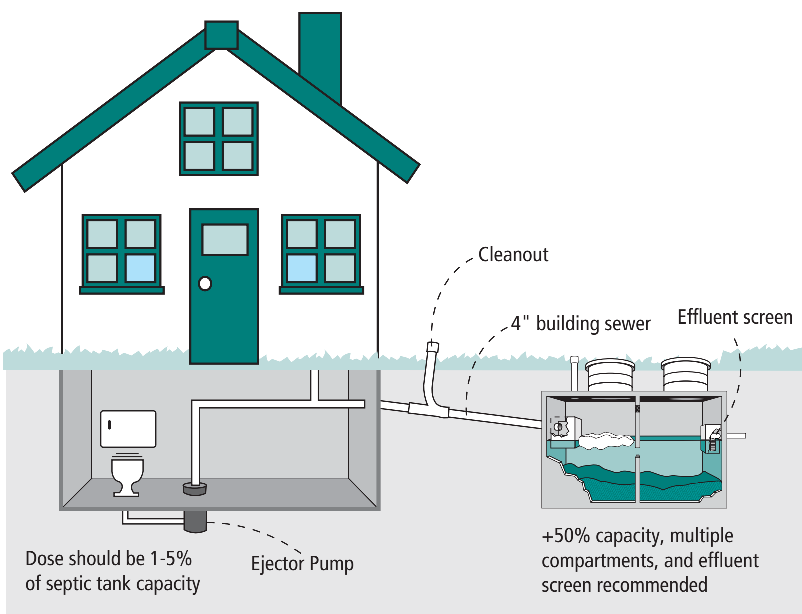
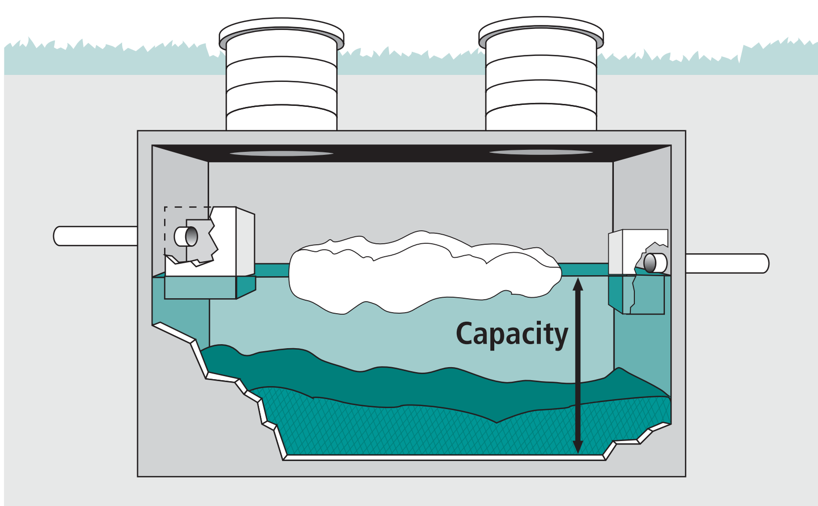


FIGURE 7.6 Effective Volume of a New Tank



The same tank capacity requirements apply if sewage is pumped from a sewage ejector or grinder pump from a dwelling to a septic tank (**7080.1930 Subp. 3**). This is required because the discharge line cannot be restricted by a valve and because the pumping rate is so rapid, a great deal of agitation will take place in the first tank. The second compartment/tank is necessary for a quiet zone to exist for proper solids separation. The pump dose volume from the ejector pump is recommended to be limited to less then five percent of the volume of the first tank or compartment tank as shown in Figure 7.5.

Subpart 4 states that, **if conditions in both subparts 2 and 3 apply to a dwelling, the mitigative requirements of either subpart 2 or 3 apply; the requirements of both subparts 2 and 3 need not be additive (7080.1930).**

For systems serving multiple dwellings with a common septic tank, the liquid capacity must be determined by adding the capacities for each dwelling as determined in Table 7.2.

Determining Tank Capacities

New tanks have a rated volume based upon the depth from the bottom of the tank to the invert of the outlet (Figure 7.6). Over time, the rated volume stays the same, but the effective volume is decreased as solids and scum accumulate. Septic tanks should be large enough to retain the wastewater in a calm, turbulence-free enviroment for sufficient settling. The average length of time that the wastewater spends in the tank is called detention time. Detention time is a function of the effective volume and the rate of flow into the tank.

Liquid volume is calculated by using the surface area and the liquid depth as established by the bottom of the outlet pipe. The minimum recommended detention time to allow adequate settling of solids is two days. The tank should also have sufficient volume to accommodate storage of sludge and scum. Finally, if wastewater is recirculated from an advanced treatment device back to a treatment tank, the increased hydraulic load and reduced hydraulic detention time must be addressed in tank sizing. An additional 50% can help in these conditions.

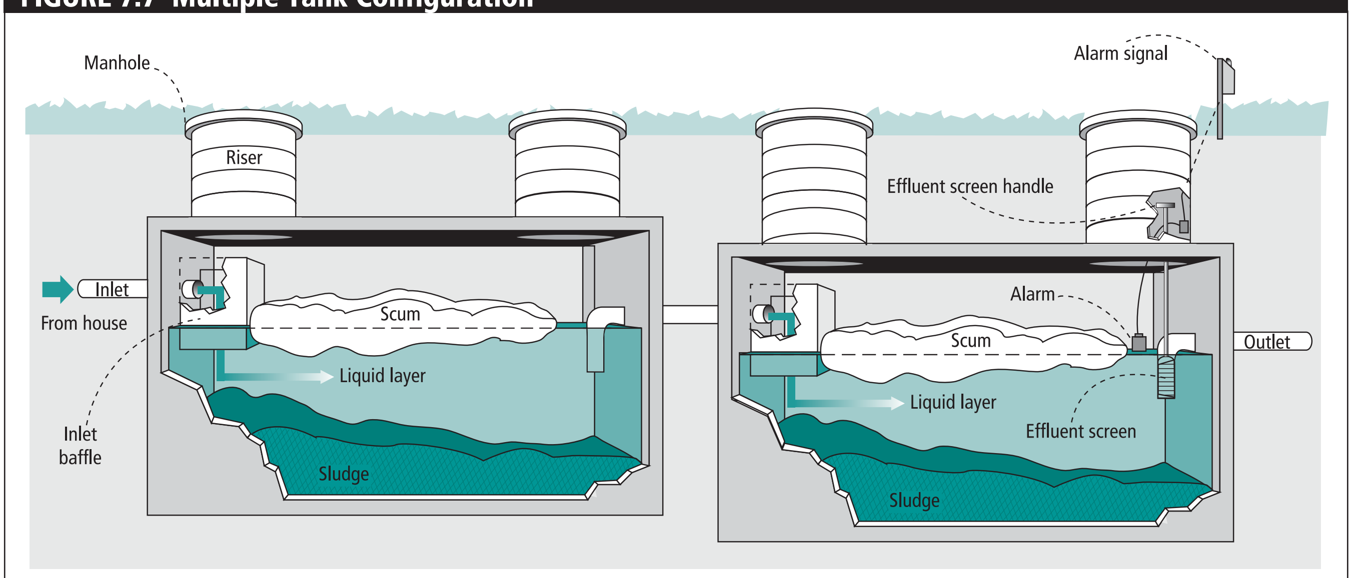
For example, if a tank has inside dimensions of 4 feet 6 inches by 9 feet 6 inches, the surface area is equal to 4.5 x 9.5 = 42.75 ft^2 and the volume is 42.75ft^3 per foot of depth. If a septic tank is to contain 1,500 gallons, this is equivalent to 200 cubic feet of liquid (1,500 gal.÷ 7.5 gal/ft^3). If each foot of depth contains 42.75ft^3 of liquid, then 200.0 ÷ 42.75 = 4.68 feet of depth. This is equivalent to 56 inches of tank depth between the bottom of the tank and the bottom of the outlet pipe.

There will need to be additional volume in the tank to allow for floating scum storage. Sewage tanks should be placed so as to be accessible through the manhole for the removal of liquids and accumulated solids. They should be placed on firm and compacted soil capable of bearing the weight of the tank and its contents. Sewage tanks should not be placed in areas subject to flooding.

Multiple Tanks

One advantage of using multiple tanks is when very warm effluent is being discharged such as from a high temperature dishwasher. In these cases, multiple tanks will have more surface area in contact with the native soil to help cool the effluent. Another reason to consider using multiple tanks versus a large tank with compartments is based on local availability. Often large tanks may not be readily available. **From MN Rules 7080.1940, if more than one septic tank is used to obtain the required liquid septic tanks must be connected in series or employ multiple collection systems. If tanks are connected in series, each tank or compartment must contain at least 25 percent of the required total liquid capacity.** The use of multiple tanks allow delivery and placement of smaller, lighter tanks and reduces the overall excavation width. The disadvantage of using multiple tanks is the installation and maintenance of the 2” drop in subsequent tanks. A multiple tank configuration is shown in Figure 7.7.

FIGURE 7.7 Multiple Tank Configuration



Compartmentalization of Single Tanks

Any time a garbage disposal is installed or a pump is delivering effluent into the septic tank compartments or multiple tanks are required. The additional barrier helps slow down the effluent and retain solids. **From MN Rules Chapter 7080.1950, if septic tanks are compartmentalized, items A to E apply:**

A. **When septic tanks are divided into compartments, the volume of the first compartment must be equal to or larger than any succeeding compartments. Each compartment must contain at least 25 percent of the total required liquid capacity and have an inside horizontal dimension of at least 24 inches.**

B. **Flow between compartments can be achieved by an unbaffled transfer hole with a minimum size of 50 square inches located in the clarified liquid zone or a minimum 12-square-inch transfer hole located above the clarified liquid zone that is baffled according to part 7080.1960. The final compartment of a tank that employs a transfer hole in the clarified zone shall not be used as a pump tank.**

C. **Septic tanks must have at least a two-inch drop between the invert of the inlet to the invert of the outlet. No liquid level drop is required between the compartments.**

D. **Adequate venting must be provided between compartments by baffles or by an opening of at least 12 square inches near the top of the compartment wall.**

E. **All compartmental walls must be designed to withstand the weight of the effluent against an empty compartment.**

Figure 7.8 below outlines the specifics for compartmented tanks.

A less common tank design is a meandering tank with one or more baffle walls arranged longitudinally in the tank as shown in Figure 7.9. The flow enters one corner

FIGURE 7.8 Compartmented Tank Specifications

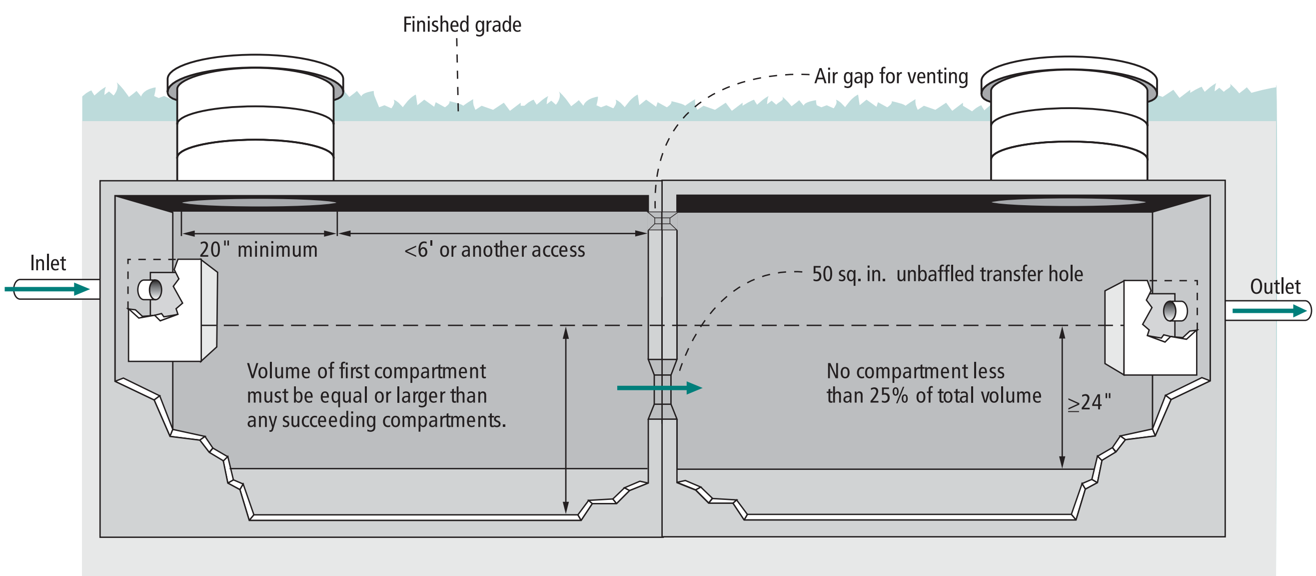
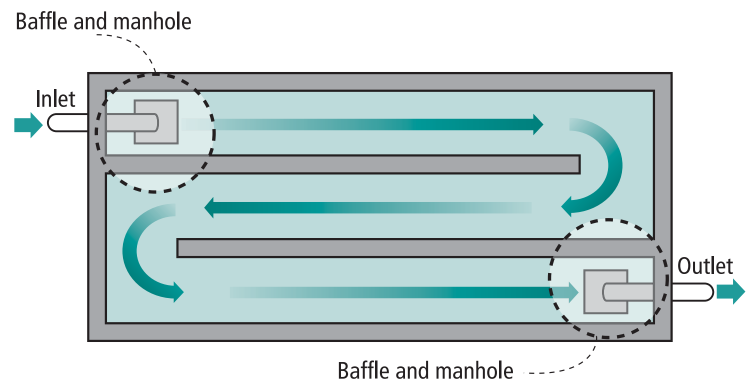


FIGURE 7.9 Meandering Septic Tank



of the tank and travels the length of the tank where it moves across the tank to the next long chamber, changes direction, and travels toward the outlet. Here it may exit or be directed again into another longitudinal chamber and flow in the other direction once again. The objective of this circuitous flow path is to increase the length-to-width ratio, reduce short circuiting, reduce inlet and outlet turbulent zones, and improve overall tank effectiveness. One of the challenges of this design is to provide appropriate access ports for effective solids removal.

If a compartmented tank is used as a pump tank, the baffle wall should have an opening near the bottom to allow equalization of liquid level across the entire tank. The opening should be a product of the original manufacturing process. If an opening is retrofitted into the tank wall, care must be taken to preserve the wall's structural integrity. If no opening is included, the wall dividing the two compartments must have the structural strength to support the pressure of the water from one side. Otherwise when pump operation lowers the liquid level, the wall may collapse due to the force of the effluent in the other compartment. The compartment wall should be designed and manufactured to function as a load bearing wall.

Septic tank sizing for MSTS and other establishments

All sewage tanks for MSTS and other establishments must conform to MN Rules Chapter 7080.1900 and 7081.0240 unless they are designed by a professional engineer and approved by a local unit of government. The U of M recommends that all tanks follow MN Rules Chapters 7081. Table 7.3 provides total tank capacity based on design flow.

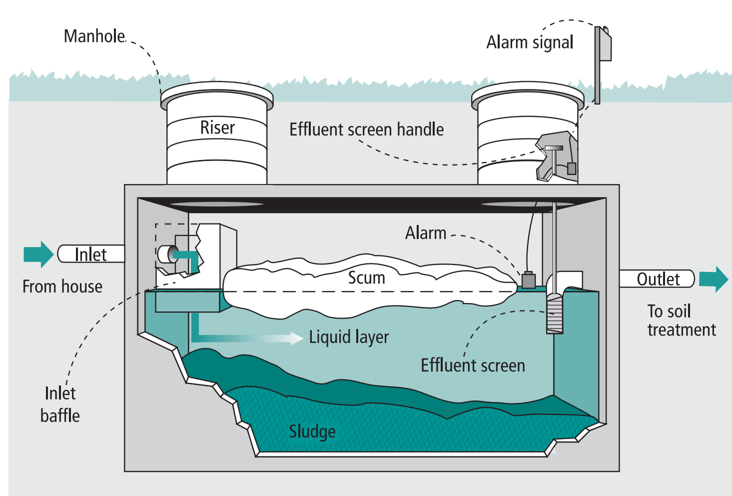
TABLE 7.3 Example Minimum Septic Tank Capacity for Other Establishments

Design Flow (gpd)	Minimum Capacity with Gravity Flow (gallons)	Minimum Capacity with Pressure Flow (gallons)
500	1,500	2,000
1,000	3,000	4,000
2,000	6,000	8,000
3,000	9,000	12,000
4,000	12,000	16,000
5,000	15,000	20,000

Lint filters, effluent screens, and pressure filters

Effluent screens must be used as the outlet baffle on the sole or final septic tank or pressure filters must be used in the pump tank. Alarms must be employed on tanks equipped with effluent screens (**7081.0240, Subp. 3**). Figure 7.10 illustrates a tank with an effluent screen and a high water alarm that will notify the owner if the screen is plugged.

FIGURE 7.10 Septic Tank with Effluent Screen



Tank geometry

The maximum liquid depth of septic tanks to determine liquid capacity must be no greater than 84 inches. The length-to-width ratio and the length-to-depth ratio must facilitate settling of solids. (7081.0240, Subp. 4).

Septic tank design allows for a quiescent zone in order to slow the velocity of the wastewater stream and optimize the settling of solids. In order to achieve this, the distance between the inlet and outlet should be maximized. A length to width ratio of at least 3:1 is preferable, with a recommended liquid depth of 3 feet. The practice of industry in some areas is to utilize tanks with length to width ratios in the range of 1.5:1 to 2.5:1, but 3:1 is preferable. For a given volume, shallower tanks result in increased surface area. This configuration will attenuate flow and promote settling of solids. The outlet pipe must be a minimum of 2 inches lower than the inlet pipe elevation, and a freeboard or air space must exist above the liquid level to allow venting of gases between compartments and out through the vent stack on the plumbing system of the house.

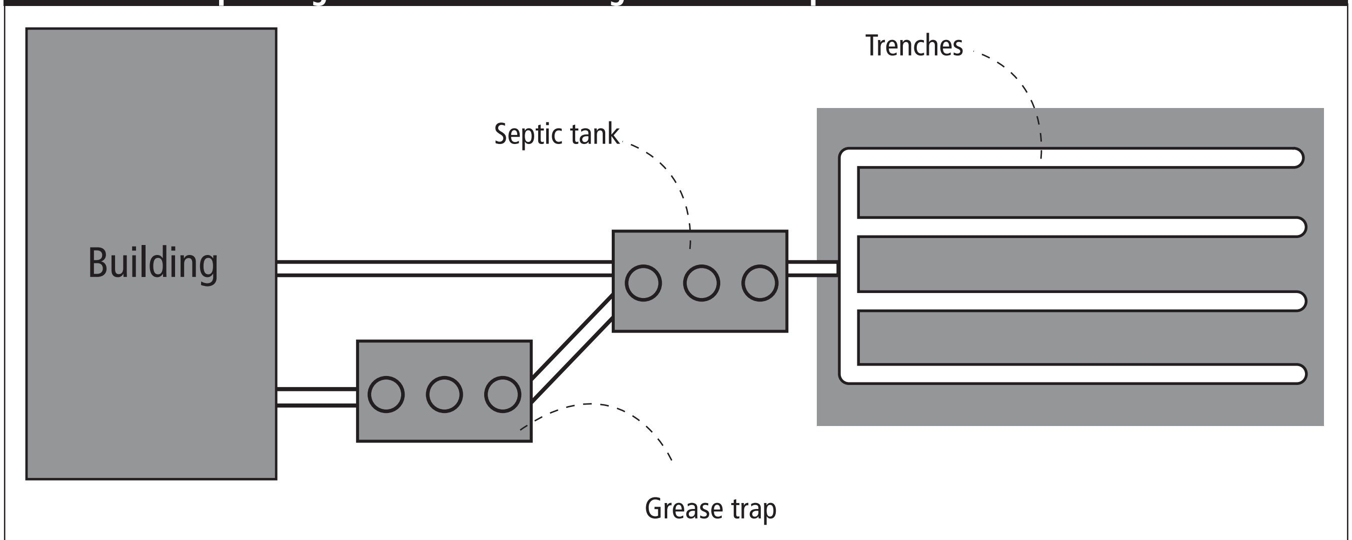
Special considerations in septic tank design

Special considerations should be made when designing a septic tank for any establishment that does not receive domestic strength sewage. Examples of those considerations can be found below.

External grease traps

Grease traps should be included in residential or commercial treatment trains that produce high levels of organics and fats, oils, and grease (FOG). Typically, the kitchen waste stream is plumbed to a grease trap while other waste streams are plumbed directly to a septic tank or other treatment tank as shown in Figure 7.11. The kitchen waste stream is typically high in organic material, including FOGs. Grease traps are specifically designed to retain these constituents, provide minimal anaerobic treatment, and store undigested solids until they are removed from the tank. A grease interceptor is a smaller unit installed within the facility (instead of in an outside excavation like a grease trap) that serves the same purpose. Use of grease traps is particularly important on systems serving commercial food establishments because the kitchen waste stream is often the largest portion of the total wastewater generated. Removal of solids through use of a grease trap and periodic pumping protects downstream components that will malfunction if bypass occurs. Access for operation and maintenance (O&M) is critical for optimum performance because of the need for regularly-scheduled pumping of the component.

FIGURE 7.11 Separating Kitchen Wastes through a Grease Trap



Restaurants

Restaurant wastes typically contain large amounts of cooking fats, oils and greases (FOG). For the FOG to again coagulate and separate from the liquid as part of the scum layer, both dilution and cooling must take place. High temperature dishwashers, which have internal heaters, may discharge wastewater with temperatures as high as 1400°F. Tanks that are in series, and thus with tank walls in contact with more soil, provide better cooling. Alcohol and dairy products have a high level of BOD that will not settle effectively.

Septic tank capacities along with additional pretreatment for restaurants should be large enough that the effluent from the tank(s) is of strength similar to that of domestic strength effluent. The BOD of the effluent should be less than 170 mg/L, the TSS should be less than 60 mg/L, and the FOGs should be less than 25 mg/L. It has been suggested that up to 7 days of detention time should be designed for establishments with high levels of organics and FOG.

Laundromats

Laundromats have the problem of excessive detergent use, along with the lint that is typically discharged with the wash water. Lint traps should be located in the facility to limit the discharge into the septic tanks. **Lint filters are required if the sewage contains laundry waste (7081.0240, Subp. 3).** Effluent screens are also required. The outlet baffles should be submerged to 50 or 60 percent of the liquid depth to retain more floating solids. Generally, very little sludge accumulates in the septic tanks of laundromat systems.

Slaughterhouses

Blood has an extremely high soluble BOD, and is therefore very difficult to break down in a septic system. When slaughterhouses have their own onsite system, no blood should be allowed to enter the septic tank. There may be small amounts of blood entering with the cleanup water, but the great majority of the blood should be collected and disposed of separately from the sewage system. Pretreatment is the preferred design option for handling waste of this strength.

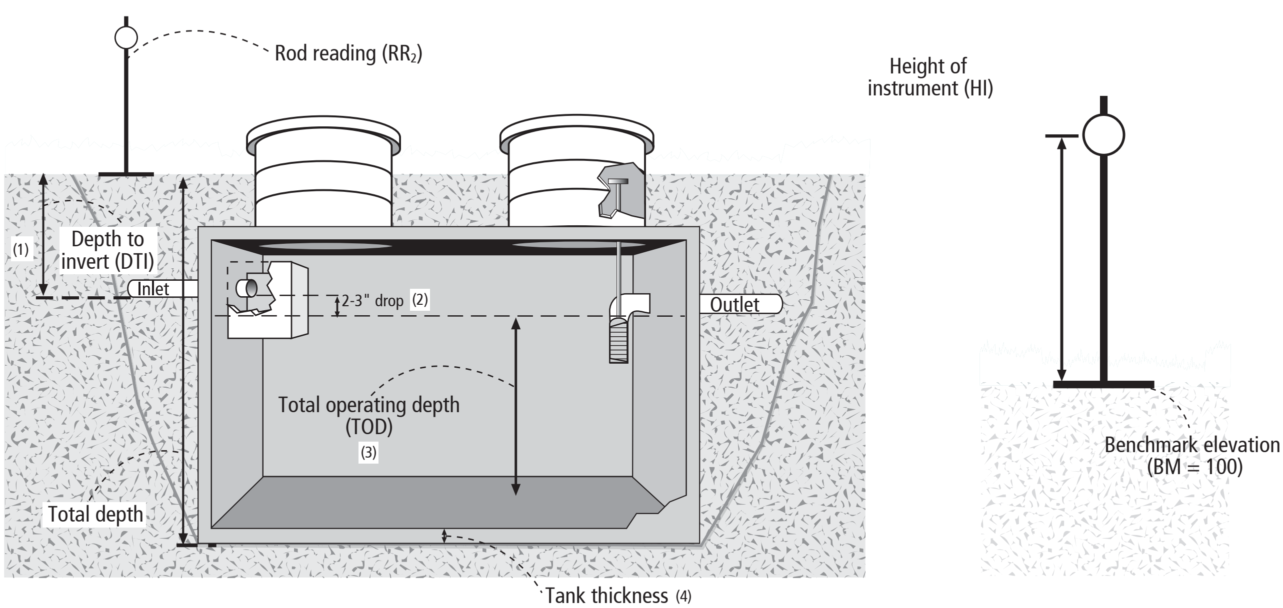
Dairies, milkhouses

Milkhouse waste has a high level of soluble BOD and high levels of sanitizing chemicals. Consequently, a typical onsite drainfield should not be used with milk wastes. There are a number of ways to dispose of milk wastes if they are kept separate from other wastes. See www.extension.umn.edu/agriculture/manure-management-and-air-quality/wastewater-systems for more information.

Tank Location and Bury Depth

The tank location should be determined considering both constructability and long term care. Chapter 7080 identifies setback distances for ease of construction and avoidance of management concerns. The code goes on to make sure the tank can be serviced long-term. These requirements include the avoidance of obstructions and the maximum bury depth of 48 inches. The access requirements also fit into these long-term management requirements. The schematic below (Figure 7.12) illustrates how to identify the proper bury depth given certain benchmark elevations.

FIGURE 7.12 Determining Tank Bury Depth



Total depth = DTI + Drop + TOD + Tank thickness
(1) (2) (3) (4)

Elevation = (BM + HI) - RR_2 - Total Depth
(Tank bottom)

According to MN Rule Chapter 7080.2000, Location and Installation of Tanks:

A. Sewage tanks must not be placed in areas that prohibit the removal of solids and liquids from the tank according to part 7080.2450.

B. Sewage tanks must be set back as specified in Table VII in part 7080.2150, subpart 2, item F.

C. The top of sewage tanks must not be buried deeper than four feet from final grade for new dwellings, unless a local ordinance allows for burial at a greater depth, not to exceed the tank manufacturer's maximum designed depth for the tank. The minimum depth of soil cover over the insulation on the top of the tank is six inches.

D. Sewage tanks must not be placed in floodways, drainageways, or swales. Upslope drainage must be diverted away from the location of all tanks. A tank's final cover must be crowned or sloped to shed surface water.

E. Sewage tanks must not be placed in areas subject to vehicular traffic unless engineered for the anticipated load.

F. Sewage tanks must be placed on firm and evenly compacted soil and with the soil level in all directions. The bottom shall be excavated in a manner so the vertical load is borne by the tank walls and not the tank bottom. If the bottom of the tank excavation contains rocks, bedding material must be used according to manufacturer's instructions. The soil beneath the tank must be capable of bearing the weight of the tank and its contents.

G. Sewage tanks and risers must be installed according to manufacturer's requirements and in a structurally sound and watertight fashion.

H. If the top of a sewage tank is to be less than two feet from final grade, the lid of the tank must be insulated to an R-value of ten. Maintenance hole covers must be insulated to an R-value of ten. All insulating materials must be resistant to water absorption.

I. Sewage tanks placed below the level of the periodically saturated soil must employ a method to protect against flotation under periodic saturated soil conditions when the tank is empty.

J. Connections between the concrete tank and the building sewer or supply pipe must meet the requirements of American Society for Testing and Materials, Standard Specification for Resilient Connectors Between Reinforced Concrete Manhole Structures, Pipes, and Laterals, ASTM C923 (2002), or equivalent. The standard is incorporated by reference, is available through the Minitex interlibrary loan system, and is not subject to frequent change.

K. Joints of concrete tanks, concrete tank lids, and concrete risers must be sealed using a bonding compound that meets American Society for Testing and Materials, Standard Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants, ASTM C990 (2003). The standard is incorporated by reference, is available through the Minitex interlibrary loan system, and is not subject to frequent change.

Insulating Tanks

Insulation is necessary to maintain the internal tank temperatures necessary for active digestion when sufficient soil cover is not available. MN Rules Chapter 7080.2000, Subp. H identifies that maintenance holes must be insulated if the top of the tank is less than two feet from final grade.

Vehicular Traffic

Standard concrete septic tanks are not intended to be installed under vehicular traffic loads. However, concrete tanks designed for traffic loading or special situations are available. Among the applicable industry standards that address designing load requirements for concrete tanks is ASTM C-857: Standard Practice for Minimum Structural Design Loading for Precast Concrete Utility Structures. Table 7.4 lists design criteria from Section 4 of the ASTM standard.

TABLE 7.4 Design Loads for Concrete Utility Structures (ASTM C-857)

Designations	Maximum Loads	Typical Uses
A-16	16,000 lbf/wheel	Heavy Traffic
A-12	12,000 lbf/wheel	Medium Traffic
A-8	8,000 lbf/wheel	Light Traffic
A-0.3	300 lbf/ft^2	Pedestrian Walkways

When designing an onsite system which may be subject to some form of live load factors due to potential vehicular traffic, a designer must follow established engineering analysis, including such items as: soil type, depth to groundwater, bedding materials, backfill materials, potential lateral earth pressures, and vertical loads. When designing onsite systems over which there may be vehicular traffic, designers would benefit from referring to AASHTO C98-HB-16 Standard Specification for Highway Bridges 16th Edition. The International Association of Plumbing and Mechanical Officials (IAPMO) Standard for Prefabricated Septic Tanks (IAPMO PS 1-2004) states that "septic tanks and covers shall be designed for an earth load of not less than five hundred (500) pounds per square foot when the maximum coverage does not exceed three feet".

When considering use of tanks other than concrete in vehicular traffic areas, consult with the manufacturer or a structural engineer.

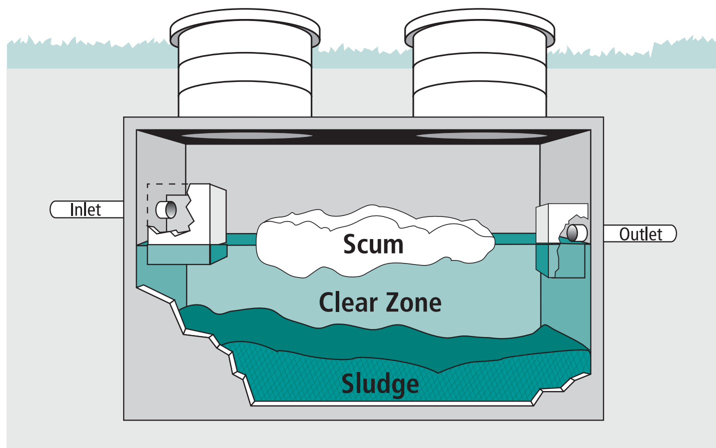
Septic tank alarms

Septic tanks with effluent screens are recommended to have a high water alarm. This alarm will indicate if the filter is slowing down the flow of effluent to a concerning level. The alarm can be as complex as an audible and visual alarm or can be as simple as a mechanical non-powered alarm (a float with a section of pipe that raises a visual indicator when the wastewater level is too high in the tank). Telemetry may be included as well. In this case, a high-water alarm triggers a phone or radio signal to alert someone (typically, the system O&M Maintainer/Service Provider) that an alarm has been triggered. The height at which the alarm should be activated is dependent on how much storage is necessary after the alarm sounds. The elevation should be specified in the plans.

Tees and baffles

From MN Rules Chapter 7080.1100, Subp. 7, a baffle is defined as a device installed in a septic tank to retain solids and includes, but is not limited to, vented sanitary tees with submerged pipes and effluent screens. Baffles are structures made of various materials placed around the inlet or outlet pipe. These devices serve to direct incoming flow to or draw flow from the clear zone. Baffles extend only part of the way to the top or to the bottom of the tank.

FIGURE 7.13 Septic Tank Baffles



According to MN Rules Chapter 7080.1960, **All septic tanks must be baffled according to items A to G. Effluent screens may be substituted for outlet baffles.**

A. **Baffles must be installed at each inlet and outlet of septic tanks. Outlet baffles are required on compartment walls if the transfer hole is at the liquid level.**

B. **Baffles must be resistant to corrosion or decay. Inlet baffles must not restrict the movement of solids.**

C. **Baffles must be integrally cast with the tank or affixed at the top and bottom with connectors that are not subject to corrosion or decay. Baffles for fiberglass-reinforced polyester tanks are allowed to be either resin bonded or secured with suitable structural adhesive. Sanitary tees used as baffles must be affixed to the inlet or outlet pipes with a permanent waterproof adhesive.**

D. **The inlet baffle must extend at least six inches, but not more than 20 percent of the total liquid depth, below the liquid surface. The inlet baffle must extend above the liquid surface in compliance with part 7080.1920, item E, and at least one inch above the crown of the inlet sewer.**

E. **The outlet baffle and any baffles between compartments must extend below the liquid surface a distance equal to 40 percent of the liquid depth, except that the penetration of the indicated baffles or sanitary tees for horizontal cylindrical tanks must be 35 percent of the total liquid depth. They must also extend above the liquid surface as determined in part 7080.1920, item E.**

F. **There must be at least one inch between the underside of the top of the tank and the highest point of the inlet and outlet baffles.**

G. **The nearest point on the inlet baffles other than sanitary tees must be no less than six inches and no more than 12 inches from the end of the inlet pipe. The nearest point on the outlet baffle, other than sanitary tees, must not be closer than six inches and no more than 12 inches from the beginning of the outlet pipe to the baffle. Sanitary tees used as inlet or outlet baffles must be at least four inches in diameter.**

Curtain baffles are partial walls (usually constructed of the same material as the tank itself) that extend across the short dimension and down into the clear zone of the tank near the inlet or outlet port. In the past, curtain baffles and pipe tees used as baffles were made of concrete or vitrified clay, which had a tendency to deteriorate over time in the septic tank environment. With the availability of composite materials, curtain baffles are not often used in modern tank construction and have been replaced by tees made of PVC. As the name implies, these are T-shaped pipes attached to inlet and/or outlet pipes.

TABLE 7.5 Baffle or Sanitary Tee Dimensions for Septic Tanks (inches)

	Inlet Baffle					Outlet Baffle***		
	Below Liquid		Above Liquid*	Total Length		Below Liquid	Above Liquid*	Total Length
Liquid Depth	min	max		min	max			
30	6	6.0	6" or 100 gallons, whichever is greater	12	12.0	12.0	6" or 100 gallons, whichever is greater	18.0
33	6	6.5		12	12.5	13.0		19.0
36	6	7.0		12	13.0	14.5		20.5
39	6	8.0	8**	14	16.0	15.5	8**	23.5
42	6	8.5	8**	14	16.5	17.0	8**	25.0
45	6	9.0	8**	14	17.0	18.0	8**	26.0
48	6	9.5	8**	14	17.5	19.0	8**	27.0
51	6	10.0	8**	14	18.0	20.5	8**	28.5
54	6	11.0	8**	14	19.0	21.5	8**	29.5
57	6	11.5	8**	14	19.5	23.0	8**	31.0
60	6	12.0	8**	14	20.0	24.0	8**	32.0
63	6	12.5	8**	14	20.5	25.0	8**	33.0
66	6	13.0	8**	14	21.0	26.5	8**	34.5
69	6	14.0	8**	14	22.0	27.5	8**	35.5
72	6	14.5	8**	14	22.5	29.0	8**	37.0
75	6	15.0	8**	14	23.0	30.0	8**	38.0
78	6	15.5	8**	14	23.5	31.0	8**	39.0

* And at least one inch above the crown of the inlet sewer, and at least one inch between the top of the baffle and the underside of the tank lid.

** For septic tanks with effluent screens and an operating depth > 39" the 'Above Liquid' length would be 6".

*** The 'Below Liquid' outlet baffle length for horizontal cylindrical tanks must be 35% of total liquid depth.

The use of a baffle or tee at the inlet is critical for proper tank operation. Baffles direct incoming wastewater flow downward to the level of the clear zone, dissipating the energy of the incoming flow to prevent turbulence and disruption of the segregated solids in the tank. They may also prevent short-circuiting of flow across the top of an accumulated scum layer to the outlet.

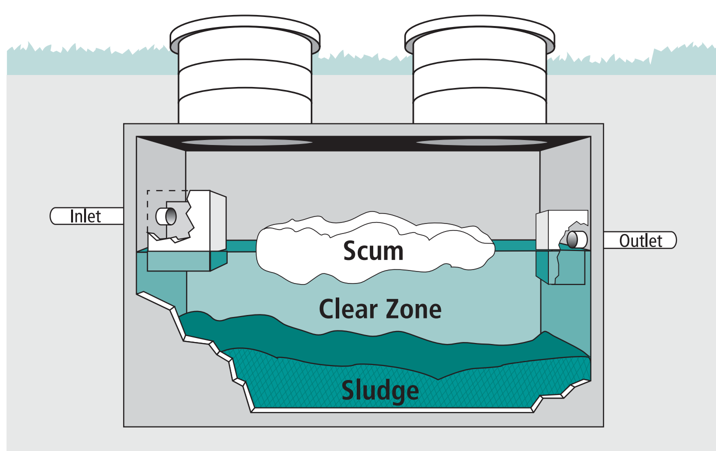
Outlet ports of septic tanks may be fitted with sanitary tees with drop pipes or with effluent screens. These are designed to retain floating solids in the tank. Outlet tees should extend far enough above the wastewater surface and deep enough into the clear zone to keep the scum layer from entering the outlet port. The scum layer can float several inches above the water level, so extending the outlet baffle above the top of the outlet pipe 4 to 6 inches is recommended. It should penetrate to about 40 percent of the liquid depth. Access openings or risers should be located so that the inlet and outlet devices can be inspected and serviced. In all cases, there must be a storage space between the top of the sewage and the top of the baffles of eight inches or 100 gallons, whichever is greater (MN Rules Chapter 7080.1920, Item E). Table 7.5 above identifies allowable baffle dimensions based on tank size.

Access risers and inspection ports

Structurally sound and watertight risers are required over each tank access port in order to provide access for inspection and maintenance of tank appurtenances such as effluent screens and/or pumps. Risers and their lids may be made of concrete or composite materials such as polyethylene, PVC, ABS, or polypropylene. They are shown in Figure 7.14.

Access risers leading into septic tanks have traditionally been buried six to twelve inches beneath the ground in order to prevent unauthorized access to a tank. The practice of burying risers was viewed as a safety precaution to keep children from entering the potentially deadly environment. Chapter 7080 now requires that all access risers be brought to grade.

FIGURE 7.14 Septic Tank Risers



According to MN Rules 7080.1970:

A. Septic tanks must have a minimum of two maintenance holes with a minimum diameter of 20 inches (least dimension). Maintenance holes must be placed over the inlet baffle or the center of the tank and the outlet device (baffle or screen). The maintenance holes must be large enough to allow pumping without interference. Enough maintenance holes must be provided so access can be gained

within six feet of all walls for solids removal of each compartment. Inspection pipes of no less than six inches must be provided over any baffles that are not otherwise accessible through a maintenance hole.

B. Pump tanks must have a minimum of one maintenance hole with a minimum diameter of 20 inches (least dimension). Enough maintenance holes must be provided so access can be gained within six feet of all walls for solids removal.

C. All maintenance hole risers must extend through the tank cover above final grade.

D. Covers for maintenance holes must:

(1) be secured by being locked, being bolted or screwed, having a weight of at least 95 pounds, or other methods approved by the local unit of government. Covers shall also be leak resistant; and be designed so the cover cannot be slid or flipped, which could allow unauthorized access to the tank;

(2) have a written and graphic label warning of the hazardous conditions inside the tank;

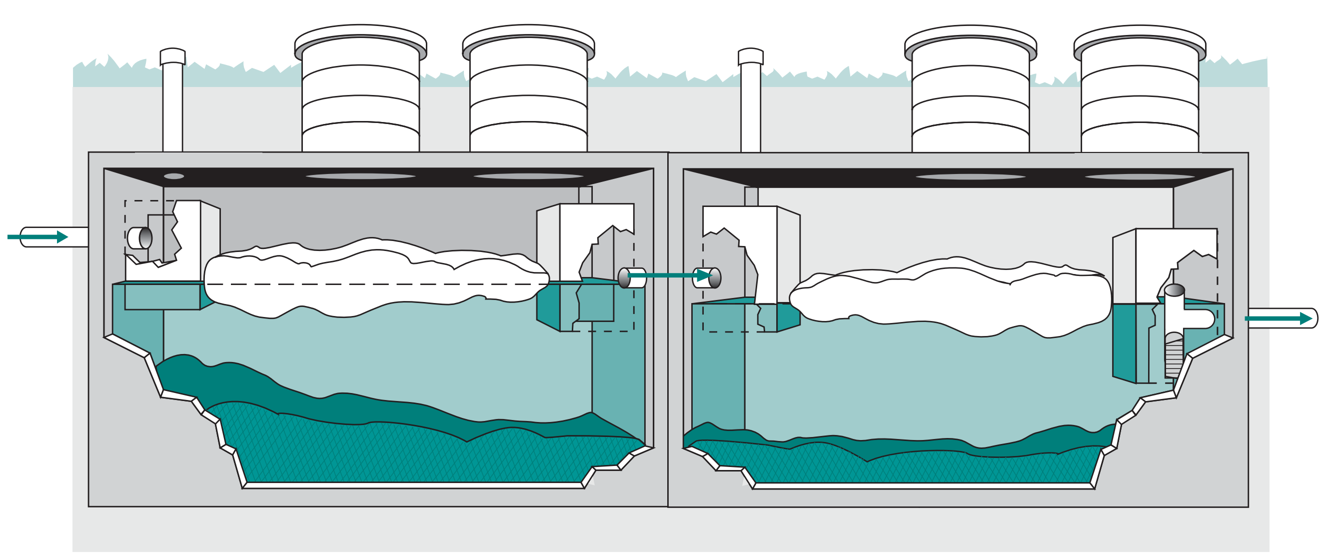
(3) be capable of withstanding a load that the cover is anticipated to receive; and

(4) be made of a material suitable for outdoor use and resistant to ultraviolet degradation.

The lid should be strong enough to support the weight of a man (about 200 pounds). If the lid is at the soil surface, strength is critical. Some concrete tank lids have two different thicknesses to hold them in place, which is a good idea, but if the top lid is too thin there can be problems.

The tank must also have an inspection pipe with a minimum diameter of six inches over the inlet baffle if the maintenance hole is located near the center of the tank. The purpose of the inspection pipes is for cleaning the inlet baffle and for periodically evaluating the amount of sludge in the tank. Refer to Figure 7.15. A maintenance hole over the inlet meets this requirement.

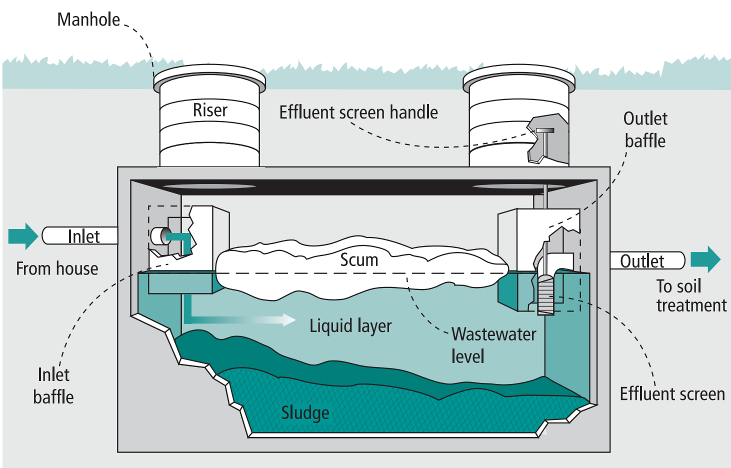
FIGURE 7.15 Inspection Pipes over the Inlet Baffle



Septic Tank Effluent Screens

Septic tanks are designed to retain solids that accumulate over time. Some of these solids are byproducts of the waste treatment process, while others are materials that may not be capable of being processed, such as human hair. It is important that the solids are retained in the septic tank and not released to the drain field. Excessive discharge of solids to the drain field can cause it to plug and lose efficiency in treatment and dispersal of the normal liquid flow. If the problem persists, the drain field may need to be replaced.

FIGURE 7.16 Septic Tank Effluent Screen



From MN Rules Chapter 7080.1100, Subp. 26 an effluent screen is a device installed on the outlet piping of a septic tank for the purpose of retaining solids of a specific size. Effluent screens are designed to help keep solids in the tank. These devices trap suspended solids, reduce the TSS concentration in septic tank effluent, and help protect the soil absorption field or other downstream treatment unit. They typically replace the outlet baffle in the final compartment of the tank. All wastewater that exits the tank must first pass through the screen. Refer to Figure 7.16.

Several types of effluent screens are available, including multiple plates assembled with slots between, slotted cylinders, and multiple perforated tubes assembled together. Others may be fitted with an alarm or used in conjunction with a pump for pressurized applications. Although it is easier to install effluent screens in a new septic tank, several types can be retrofitted to existing tanks. In addition to models that can be placed directly into concrete baffles, installation options include (1) replacement of PVC outlet tee or baffle with the effluent screen and housing; (2) placement in a sump outside the tank; and (3) placement within the pump vault of a pumped system. Solid accumulation in the screen will cause poor performance of the septic tank, but creates a problem that is far easier and less expensive to clean and maintain than solids accumulation in the drain field. If the septic tank is maintained properly, including frequent inspection for solids accumulation and removal, then a screen may not be necessary.

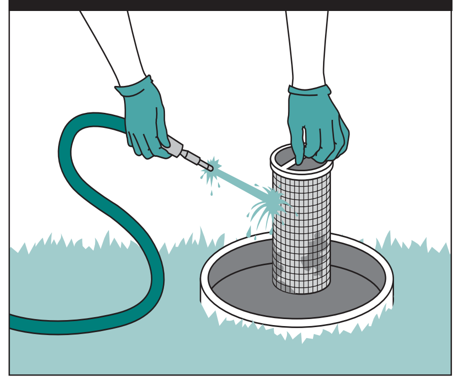
Most screens are made of plastic with 1/16th inch to 1/8th-inch screen slots.

Choose and install effluent screens with ease of serviceability in mind since all will require service. Cleaning frequency depends on the overall size of the unit, screen opening size, and use. A screen in the second compartment of a two-compartment tank should require less service than a unit in a single compartment tank. Some effluent screens have shut-off mechanisms or secondary screens to keep solids from moving out of the tank when the screen is being cleaned. If such a device is not included, some solids may be discharged downstream when the screen is removed, thereby reducing its overall effectiveness. One method of preventing such solids discharge is to pump down the tank level before removing the screen for cleaning.

Effluent screens come in a variety of shapes and sizes, are produced by several different manufacturers, and have a range of applications from individual homes to commercial sites. The basic principle of the effluent screen is to provide additional surface area for suspended solids to collect and attach, before they can pass to the drainfield. Each screen is unique in its individual design, but all are similar in purpose; that is, to decrease the amount of solids carryover to the drainfield and by doing so reduces BOD and TSS.

Independent research performed at Tennessee Technological University (Treanor, 1995) suggests that effluent screens do indeed reduce suspended solids as well as BOD in onsite systems. The study was performed as research for a master's thesis, and was conducted at eight unrelated locations, under different loading rates and uses. Three different effluent screens were used. Statistical analysis showed that the screens significantly reduced the BOD and suspended solids in septic tank effluents. Although other research is being performed, there is still some debate on the overall effectiveness of septic tank effluent screens.

FIGURE 7.17 Cleaning an Effluent Screen



The effluent screen requires regular maintenance and must be periodically checked. As a concern for the homeowner's safety in dealing with the components of a septic system, most manufacturers and regulatory agencies recommend that a certified inspector or septic tank Maintainer or Service Provider provide this maintenance. The screen must periodically be removed from the tank, and the solids, which have been trapped and attached to the screen, must be washed back into the septic tank as shown in Figure 7.17. For this reason, it is more appropriate to have this maintenance done when the septic tank is being pumped. This perhaps is the one disadvantage of having an effluent screen. If the screen is not maintained, it will potentially clog and create problems for the onsite wastewater treatment system. Such an example could be plugging the septic tank, causing the sewage to back up into the home.

In choosing and installing an effluent screen, the following factors must be considered:

- Effluent screens are designed to reduce solids discharge, not necessarily BOD discharge.
- The screen case should act as an outlet baffle.
- Screens should allow solids of no greater than 1/16 to 1/8 inch to pass through the cartridge, depending on system design and regulatory specifications.
- The screen cartridge should be secured in place and should not allow bypass of unscreened solids if the screen openings become clogged.
- The effluent screen housing should be sized and placed so that it does not interfere with normal pumping of the tank.
- The estimated wastewater flow from the house should be matched with the surface area of the screen (i.e., as the design flow increases, more surface area must be provided).

- An access opening at grade over the screen should be provided for screen removal and cleaning as needed.
- The design should include a mechanism to prevent solids bypass during cleaning.

Tank Construction

Overview

From MN Rules 7080.1980:

A. All precast reinforced concrete sewage tanks must be constructed to meet the requirements of this chapter. Information on best practices for tank construction is found in the National Precast Concrete Association's best practices manual, Precast Concrete On-site Wastewater Tanks (2005)

B. All fiberglass-reinforced polyester and polyethylene tanks must be constructed to meet the requirements of this chapter. Information on best practices for these tanks is found in the International Association of Plumbing and Mechanical Officials (IAPMO), Material and Property Standard for Prefabricated Septic Tanks, Standard PS 1-2006 (2006).

Sewage Tank Registration

Since 2012, sewage tanks used in Minnesota are required to be registered with the MPCA. Sewage tanks include the following types of tanks: septic tanks, trash tanks, holding tanks, pump tanks, surge storage tanks, recirculation tanks, privy vaults, and other processing tanks.

The MPCA maintains a list of manufactured tanks deemed to adequately meet requirements of MN Rules 7080.2010. The goal of having this list is to save counties and other local units of government time by not having to complete the tank verification process on their own. The current list is located at the MPCA website best found by typing "SSTS registered tank" in the search box. Basic information about the tanks, such as model number, manufacturer, and liquid capacity is also available on the site.

If not on the list, it can still potentially be used. The rules recognized that in some cases, modifications to registered tanks or one of a kind tanks would be needed for site-specific situations. The rule allows for this needed flexibility in MN Rules 7080.2010, and the local unit of government accepts the proposed changes to the registered tank or a one of a kind tank. This flexibility was developed in rule to allow for easier approval of one of a kind tanks or registered tanks with slight modifications made to accommodate a specific installation.

Materials

Historically, many different materials have been used to construct septic tanks. Materials used in the past include redwood planks, bricks and mortar, and coated metal. Currently tanks are constructed using one of three materials: precast concrete, fiberglass-reinforced plastic (FRP), or rotationally-molded polyethylene/polypropylene resin (poly).

Reinforced concrete tanks have traditionally been used for onsite systems. This is reflected in the amount of information available regarding concrete tanks relative to tanks made of other materials. Concrete tanks are readily available, generally lower in cost than alternative materials and have, for the most part, proven to be reliable. Use of tanks fabricated from FRP and rotationally-molded polyethylene is becoming more common. Installing these tanks requires following manufacturer specifications and requirements.

Structural soundness

All septic tanks must be structurally sound in order to prevent collapse. They must be able to withstand handling and transport after manufacturing and not be susceptible to damage during installation. Additionally, tanks must be capable of supporting anticipated soil loads as well as a 2500-pound wheel load, and be able to withstand both internal and external hydraulic pressure. Regardless of the materials used in the production of septic tanks, structural integrity depends on good design, use of quality materials, proper manufacturing methods, and careful construction techniques. MN Rules Chapter 7080.1910 spells out the requirements for all sewage tanks:

Subpart 1. Requirements. Tanks, fittings, risers, and apertures must:

A. be capable of supporting long-term vertical loads for the conditions in which the tank will be placed. These loads include, but are not limited to, saturated soil load, based on 130 pounds per cubic foot;

B. be capable of withstanding a lateral load for the conditions the tank will be placed;

C. with proper maintenance and venting, not be subject to failure due to corrosion and degradation from sewage or sewage gases, including risers and maintenance hole covers; and

D. be structurally capable of withstanding exposure and stresses from freezing conditions.

Subp. 2. Poured-in-place concrete tanks must be designed to meet each requirement of subpart 1 and be designed by a Minnesota licensed professional engineer.

Tank storage, transport, and use

According to MN Rule Chapter 7080.1990, Subp. 1 and 2, the following rules apply to tank storage, transport, and use:

Precast reinforced concrete tanks must:

A. have a method to lift the tank for an ultimate load that is four times the working load;

B. undergo proper curing to achieve a compressive strength of 4,000 pounds per square inch before transport, placement, or use; and

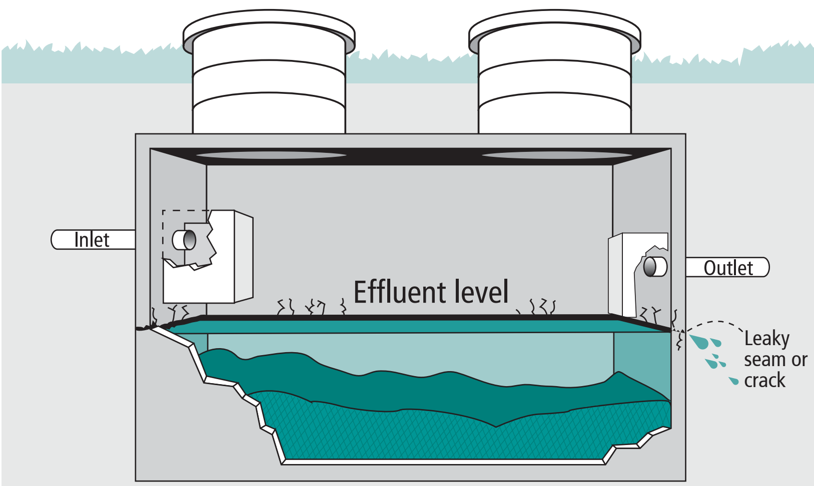
C. have no pipe penetration points or openings in the exterior walls or tank bottom below the tank liquid level, unless designed for a specific operational purpose and approved by the local unit of government.

Subp. 2. Fiberglass-reinforced polyester or polyethylene tanks must be protected against deterioration during storage.

Precast concrete septic tanks and sealing materials

Precast tanks are widely accepted, readily available, and have proven long-term reliability. It is critical that they be manufactured properly to avoid leakage of water into the tanks or untreated sewage into the environment, as shown in Figure 7.18.

FIGURE 7.18 Improperly Joined Midseam Septic Tank



Liquid level is at level of seam. This tank is leaking at the seam.

Materials used to seal multiple-piece precast tanks typically consist of blended sealant compounds listed as butyl rubber-based or asphalt-based (bituminous). Fuel/oil resistant sealants are also available for use on grease traps or in situations where petroleum products may be part of the waste stream. Both types of sealant compounds should conform to ASTM Standard C-990 and AASHTO M198-75B standards that specify relative amounts of butyl rubber and fillers used in production. The federal standard SS-S-210(210A) provides information on the ratio of hydro-carbon to filler (typically cellulous or limestone) and temperature ranges for effective use.

Compressibility in cold temperatures (i.e., ambient temperature below 40^{o}F) is a critical characteristic of a sealant compound. Bituminous (tar-based) mastic is widely used in warmer climates but is not appropriate in colder areas since it tends to crack under those conditions. In any climate, installation at low temperatures can render any seal ineffective. If tank sections are to be joined at temperatures below 40^{o}F, measures should be taken to keep the sealant warm such as storing it in the cab of the delivery truck prior to use.

Quality mastic should not excessively compress when squeezed between the thumb and forefinger; when stretched, it should not shred or snap. Currently, there are no standards for mastic size, and the actual measurement of nominal one-inch mastic can vary in size to some extent. Because of this, a critical factor when evaluating the sealing potential of a sealant is its cross-sectional volume. Cross-sectional volume is defined as the geometrical shape of the sealant (i.e., 3/4 inches (H) x 1 inch (W)). Industry experience has shown that a sealant's cross-sectional height must be compressed a minimum of 30 percent to create a good seal, with 50 percent compression being desirable.

The seams to be joined should be clean and dry. If this is not the case, mastic manufacturers can provide information on primers to be used with their products. These are typically of three general types:

1. Liquid rubber

2. A water based product that dries to a 'sticky' state

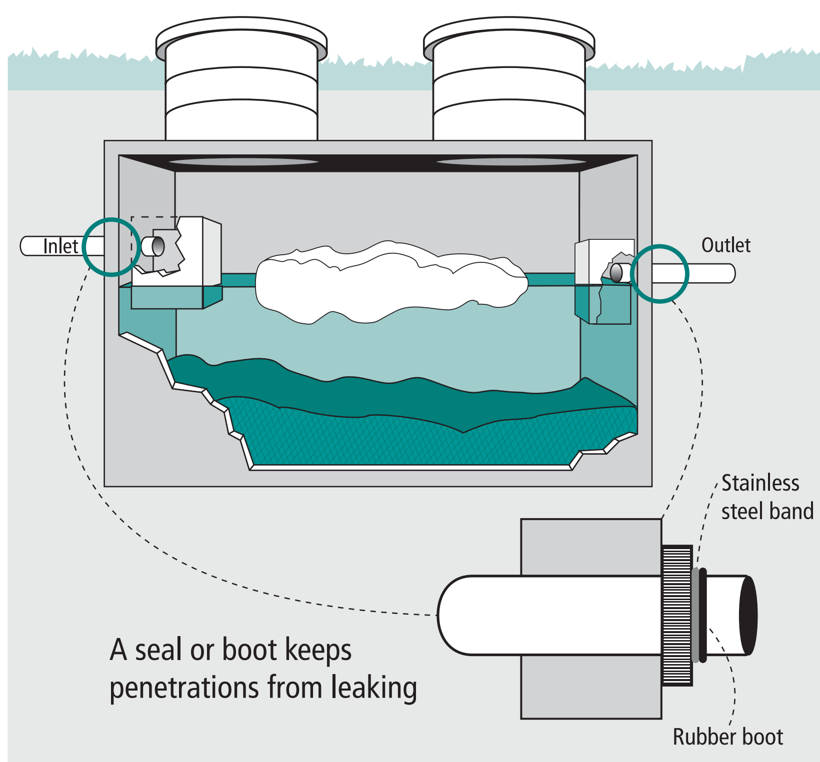
3. An all-season type that can be applied to wet or dry surfaces

Mastics should be applied in a continuous bead. Opinions vary on how to join two pieces of mastic: the ends can be overlapped and kneaded together or the two ropes can be carefully butted up to one another. Ultimately it is critical to ensure a good joint seal. When placing mastic in a seam, a higher rope is better than a wider one. For extra assurance for watertightness after assembling the tank halves, a butyl rubber wrap (approximately 1/8-inch thick and 4 to 12 inches wide) can be applied to the seam.

Pipe penetrations for precast concrete tanks

Inlet and outlet pipe penetrations are a common potential point of leakage, particularly if the tank or piping settles or shifts after installation. These connections should be mechanically sealed to the tank so that they are watertight and flexible. Although bituminous seal, mastic, or concrete grout have been used for many years, newer flexible gasket and boot fittings are available that can be cast in place at the time of tank manufacture and provide a much more reliable seal. Rubber boot seals are particularly desirable because they are flexible and retain a seal during backfilling and settling as shown in Figure 7.19. Be sure the pipe is supported by the tank wall since the rubber boots will not structurally support the pipe.

FIGURE 7.19 Rubber Boots Seal Penetrations



Rotationally molded polyethylene/polypropylene septic tanks

Polyethylene/polypropylene ("poly") tanks are a relatively new innovation. Some early poly tanks were prone to deflection and splitting. Newer model tanks have a ribbed design to enhance structural stability. These tanks are lighter than concrete tanks. However, they are more prone than concrete tanks to float out of the ground in areas of high water tables, and precise installation practices must be followed when using them. (These practices are discussed in Section V: Installation.) Manufacturers of non-concrete tanks state that they are not subject to rust or corrosion and are resistant to the chemicals and gases present in sewage and soil. Although there are no uniform standards for manufacture of plastic septic tanks per se, their use in the onsite industry dictates that they meet the same requirements for structural stability and watertightness as all other septic tanks. As time passes, industry standards for manufacturing will undoubtedly evolve.

Poly tanks are rotationally molded in one piece. Sufficient, high-quality raw material and careful attention to manufacturing practices are essential for structural soundness and watertightness. Walls of these tanks are typically ¼ inch thick, and defects in wall thickness will compromise the integrity of the tank. As with tanks made of other materials, access riser joints and pipe penetrations must be properly sealed to make sure they do not leak. Rubber and plastic pipe seals are routinely used in the production of poly tanks, and access risers are typically made of the same poly materials as the tank itself.

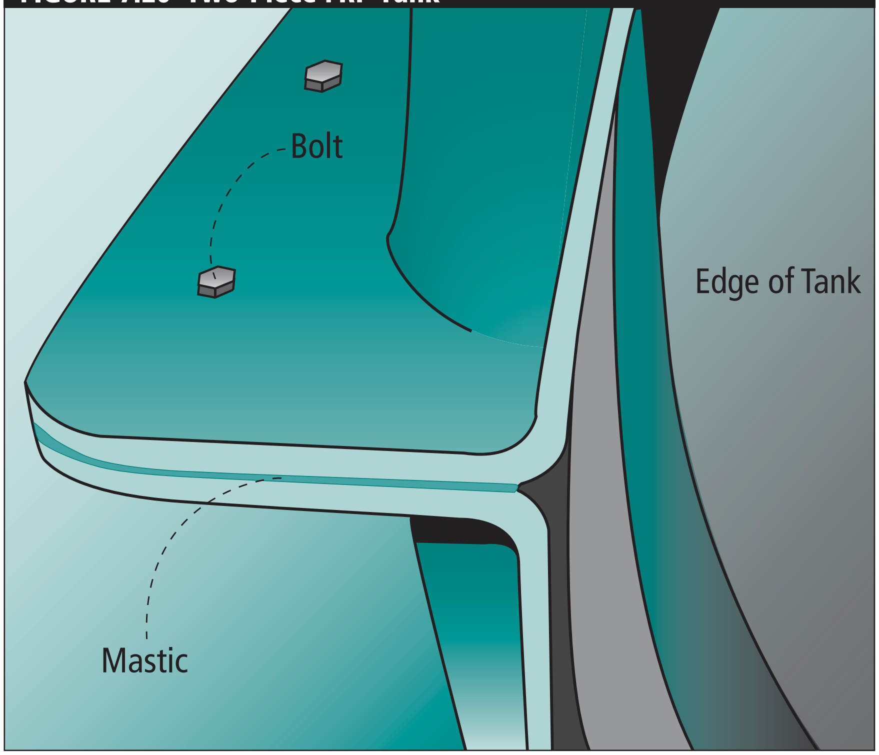
While their one-piece design implies that poly tanks should be watertight, it is imperative that they (and tanks of all other materials) be tested via appropriate methods. Most local codes specify where and how these tanks may be used; the reader is thus advised to review the strength requirements included in local and state codes when assessing the use of any tank in onsite systems.

Fiberglass reinforced plastic septic tanks

Fiberglass reinforced plastic (FRP) tanks are also relatively new compared to precast concrete tanks. Like the poly tanks discussed in the previous section, FRP tanks are lightweight; so the same concerns regarding flotation and installation must be addressed. Manufacturers of FRP tanks advocate their use on the basis that they are not subject to rust or corrosion and are resistant to the chemicals and gases present in sewage and soil. There are established industry standards that address materials such as plastic laminates, rigid plastic, and cured reinforced resins. These may have a bearing on the production of FRP tanks. Specific standards for using FRP in the manufacturing of septic tanks are being considered by industry groups. Clearly, their use in the onsite industry dictates that they meet the same requirements for structural stability and watertightness as all other septic tanks. The reader is again advised to review the strength requirements included in local and state codes when assessing use of these tanks in onsite systems.

Some FRP tanks are produced in one piece. Others are produced in two pieces using an injection molding process. As stated previously, sufficient, high-quality raw material and careful attention to manufacturing standards are essential for structural soundness and watertightness. It is possible (though not common) for FRP tanks to

FIGURE 7.20 Two-Piece FRP Tank



leak as a result of shipping damage, a substandard batch of adhesive, uneven application of adhesive, or stress placed on the midseam during installation.

Two-piece FRP tanks are often shipped unassembled and must be permanently fastened together before placement. The assembly process must be carefully done so that the joint will not leak or separate. Generally, this is achieved using appropriate adhesives and stainless steel bolts, as shown in Figure 7.20. The bolts are primarily used to hold the halves in place while the adhesive cures. As with tanks made of other materials, pipe penetrations and access riser joints must be properly sealed to make sure they do not leak. Rubber and plastic pipe seals are routinely used in the production of these tanks.

Constructing pour-in-place tanks

If the design specifies a pour-in-place tank, check with the system designer for specific design and installation requirements. An engineer must design these tanks.

Overall Quality of Precast Concrete, FRP, and Poly Septic Tanks

Notwithstanding the wastewater source, the septic tank is the first component of any septic system. As such, it is important that high-quality, watertight tanks be used. If you are unsure about the quality of a tank, consult with a qualified structural engineer regarding potential problems with structural integrity. Ultimately, a hydrostatic or vacuum test of the tank after installation will indicate the status of watertightness.

A quality concrete tank should have the following characteristics:

- Reasonably smooth surface
- No honeycombing or cracks
- No efflorescence (the changing of crystalline compounds to a whitish powder through loss of water) that may indicate a very old tank or a bad pour
- No exposed rebar or wire (inside or outside)
- Smooth, well-made tongue-and-groove or lap joint with properly applied mastic

A quality poly tank should have the following characteristics:

- Uniform wall thickness
- No pin holes
- No deformation of tank or riser openings

A quality FRP tank should have the following characteristics:

- Properly sealed mid-seam (if two-piece)
- No imperfections in lay-up
- Uniform wall thickness
- No de-lamination
- No cracks or dings from handling

Additionally, tanks made from any of these materials should have:

- Flexible, watertight pipe seals at all pipe penetrations
- Cast-in-place or mechanically-attached riser with tight fitting lid

Keep in mind that a tank may have cosmetic deficiencies that do not affect performance in any way. Likewise, a tank may have an attractive appearance and still have structural deficiencies. Ultimately, hydrostatic or vacuum testing should be employed to measure tank quality. These tests are discussed in the next section, Watertightness Testing.

Watertightness testing

All tanks used for MSTS must be tested for watertightness. The test shall be conducted to include the watertightness of all connections and risers (7081.0240, Subp. 5). Also all holding tanks must be tested (7080.2290 (B)).

There are many reasons to ensure that all septic tanks are watertight. Leakage from the tank releases minimally treated sewage into subsurface soils and/or groundwater. Sewage injected deeply in the soil profile is much less likely to be adequately treated as it moves down through the soil. In areas of relatively shallow water tables or where tanks are located in low areas, groundwater or surface water can leak into the tank. Inflow of groundwater can disrupt settling, treatment, and storage of solids (i.e., the important functions of the tank) as well as the function of downstream components of the wastewater treatment system. Possible locations on a septic tank where leakage can occur include:

1. Weep holes at the base of the tank (Weep holes were used in some precast concrete tanks to release forms from tanks and to prevent collection of rainwater during storage prior to installation. If used, these should be sealed appropriately prior to installation. They are not allowed under **MN Rules Chapter 7080.1990, Subp. 1, C.**)
2. Mid-seam joint
3. Inlet/outlet pipe penetrations
4. Top-seam joint

5. Tank top/access riser joint

6. Access riser/lid joint

7. Any damaged, improperly-formed location or area where material is too thin

MN Rules 7080.2010, Subp. 1-3 provide instructions for tank testing:

A. All sewage tanks must be watertight, including all tank and riser joints, riser connections, and pipe connections.

B. An assessment of all models of sewage tanks to be used must be conducted to determine:

1. the structural integrity of the tank design; and

2. the adequacy of the manufacturing process of watertightness.

C. Sewage tanks, including riser joints, riser connections, and pipe connections must be designed, manufactured, and installed to be watertight under normal use.

Subp. 2. The structural integrity of each model of tank manufactured and all poured-in-place tanks must be verified by calculation, proof testing, or a licensed professional engineer to determine the horizontal and vertical loads that the tank can withstand when empty. Tanks must be reverified for structural integrity if the design, materials, or construction methods are modified. A licensed professional engineer shall certify in writing if different manufactured models are similar enough so that the structural integrity information for one model is valid for other models. Verifications must be submitted to the commissioner. The commissioner shall maintain and make available the verifications upon request.

Subp. 3. Watertightness test.

A. At least one tank per year, per model must be tested for watertightness. All poured-in-place tanks shall be tested for watertightness. Records of testing must be maintained by the manufacturer for three years and must be available to the commissioner and local unit of government if requested. Tanks must be tested and meet or exceed the applicable requirements of subitem (1), (2), or (3):

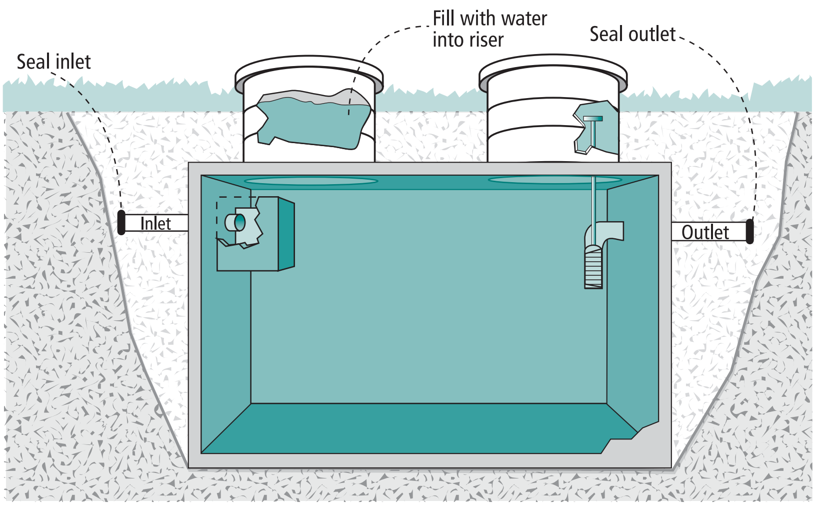
1. when empty, a tank must maintain a vacuum of at least two inches of mercury for five minutes, without loss of pressure;

2. concrete tanks must hold water for one hour, without loss, after the tank has been filled with water to the top of the tank, let stand for 24 hours, and then refilled to the same level; or

3. fiberglass-reinforced polyester or polyethylene sewage tanks must hold water without loss for one hour after being filled.

B. Sewage tanks that do not pass the tests listed in item A must not be used until repaired and retested. The repair and retest procedure must be repeated until the tank passes the test or the tank must not be used.

FIGURE 7.21 Hydrostatic Testing



1. Seal tank and fill with water into riser
2. Allow to stand for 24 hours
3. Check and refill if necessary (1-2" drop is acceptable)
4. Check 4 hours later and measure (There should no measurable drop)

Hydrostatic testing

New tanks can be tested for watertightness by filling with water (hydrostatic testing) or by vacuum testing. In both cases, the tank should be tested in the ready-to-use state. Inlets and outlets should be plumbed with the appropriate pipes, which can then be plugged for the test as shown in Figure 7.21.

Be careful when performing hydrostatic tests on plastic and fiberglass tanks as they gather much of their strength from soil support. For all mid-seam tanks, keep the backfill near the mid-seam, but leave the seam itself exposed to monitor the test.

The following is a suggested water testing procedure for tanks. Note that this test does not evaluate the tank's ability to withstand external pressures; that issue must be assured through adequate engineering design.

Hydrostatic testing procedure for tanks:

1. Plug the inlet and outlet pipes with a watertight plug, pipe and cap or other seal. Seal the pipes away from the tank to test any pipe connections that may be of concern.
2. If testing a mid-seam tank, ensure that the seam is exposed for the water test.
3. Fill the tank to the top.
4. If the tank has a riser, add water into the riser to a maximum of 2-inches above the tank/riser seam. Care must be taken not to overfill as the top section of a two-piece tank may become buoyant.
5. Measure and record the level of the water.
6. Let the tank sit for 24 hours. Any obvious leakage during this time should be evaluated and remedied by the application of a suitable sealing compound.
7. If the test reveals leaks that cannot be repaired, the tank is considered unacceptable.
8. Refill concrete tanks to original level after 24 hours as they will absorb some water.
9. If the tank holds water for one hour, without loss, the tank is considered acceptable.

Tables 7.6 and 7.7 provide information for calculating volumes in square and round risers.

TABLE 7.6 Depth Change Equivalent to One Gallon in Round Risers of Various Interior Diameters

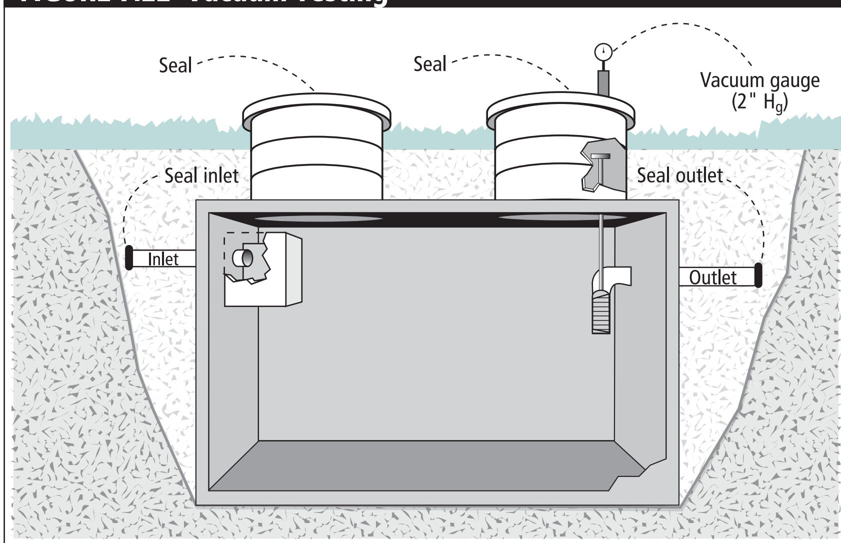
Riser diameter (Inches)	Depth Equal to One Gallon (Inches)
18	0.91
24	0.51
30	0.33
36	0.23

TABLE 7.7 Depth Change Equivalent to One Gallon in Square Risers of Given Interior Dimensions

Riser Dimensions (Inches)	Depth Equal to One Gallon (Inches)
18 x 18	0.71
24 x 24	0.40
36 x 36	0.18

When performing hydrostatic testing in cold climates, there are a few important points to consider. First, water is its densest at about 4 degrees C (just above freezing), so water put into a tank at 10-20 degrees C (typical of groundwater) and left in the tank overnight at freezing temperatures will drop the level in the tank a substantial amount (about 2%, or 3 gallons in a 1500 gal tank). A "loss" of 3 gallons in the risers will look like a leak. Additionally, water used in the test will freeze and expand by approximately 9%. If the site is not occupied quickly, the tank may crack as a result of the test itself.

FIGURE 7.22 Vacuum Testing



1. Seal tank - Cap inlet and outlet pipe
2. Apply vacuum to 2" of H_g
3. No loss of pressure in five minutes

Vacuum testing

Vacuum testing of tanks requires less time than hydrostatic testing and can be performed without having water available on the site. Testing should be done on the tank in its ready-to-use state (i.e., pipes in the inlet and outlet, risers with lids, etc.). In this test, all pipe penetrations, manholes and risers are sealed airtight, and a special insert is sealed on one of the tank manholes. Using a pump, air is evacuated through this insert to a standard vacuum level, and the reading on a vacuum gage is recorded. Local codes, ASTM standard C-1227, or the National Precast Concrete Association (NPCA) standard can be used to determine the target vacuum for the size, shape, and tank material being used. Be careful not to exceed the recommended vacuum level. It is possible to damage or implode a tank.

As of August 2003, the NPCA standard states: "The recommended (vacuum test) procedure is to introduce a vacuum of 2 inches of mercury. Hold this pressure for 5 minutes. During this initial 5 minutes, there is an allowable pressure equalization loss of up to a half-inch of mercury. If the pressure drops, it must be brought back to 2 inches and held for a further five minutes with no pressure drop." **MN Rules Chapter 7080.2210 Subp. 3, (A,1) states, "when empty, a tank must maintain a vacuum of at least two inches of mercury for five minutes, without loss of pressure".**

If a tank will not hold the vacuum, leaks must be located and repaired. The test can then be repeated. If the tank cannot be repaired and rendered watertight, it should be replaced. Note that vacuum testing of concrete tanks draws seams together for a positive mastic seal, assuming there are no other problems. With any tank, collapse, deflection, deformation, or cracking indicate a poor quality tank. It is important to test the entire system: tank, pipe sleeves, risers, inspection ports and lids.

Visually examining existing tanks

It is more difficult to check watertightness in an existing septic tank. Adequate testing requires a period of several hours to a day or more without inflow to the tank and that inlet and outlet pipes be sealed off. Seal the line at the distribution box (or other appropriate place in the case of secondary treatment units) and at the clean-out between the building and the tank. Apply vacuum or water as desired. If there are no leaks, the entire system passes in one step. If there are leaks, successive tests will locate the source or sources.

Although actual testing of existing tanks may be impractical, much can be discerned by a thorough inspection of a tank both before and after it has been pumped out. Most tanks built using older methods of construction (such as built-in-place block or brick tanks) would typically not be watertight or structurally sound and probably cannot reasonably be repaired. In some cases, it may be possible to do more to check existing tanks. If the soil around the tank is saturated, the tank contents can be pumped down and observations made over the next few hours to detect leakage into the tank around pipe penetrations, seams, or through breaks in the tank. Caution should be exercised, however, as high groundwater may cause empty tanks to become buoyant and float out of the ground. Alternately, excessive soil pressure may collapse a tank. If there is any doubt about the integrity of the existing tank, it should be replaced. MN Rules Chapter 7080.2450, Subp. 2 (A) requires the tank to be visually inspected for leakage no less than every three years.

If a tank will be reused, with a new system, all local requirements must be followed and the tank must at a minimum meet existing system compliance criteria from 7080.1500 Subp. 6.

Tank labeling

According to MN Rules 7080.2020 sewage tanks must be properly labeled at the outlet with the following information:

1. the manufacturer's name;

2. model number;

3. liquid capacity;

4. date of manufacture; and

5. maximum depth of burial.

In addition the tank inlet or outlet must be clearly marked and the installer shall submit items 1-5 above with the as-built drawing.

Tank installation

Safety

Maintaining a safe working environment during installation is essential. All excavations should comply with OSHA standards and must be done so that they are protected from sidewall collapse. Once a tank is in the hole, workers should never be in the hole between the tank and the excavation walls. If for some reason this is necessary, excavate back the sidewalls to prevent collapse, or use trench boxes for support. As a boom truck or other machine handles the tank, workers must stay clear of the unit and never be directly under the tank. Lifting slings must always be placed in grooves of concrete tanks or attached to lifting rings of FRP . Lifting slings must be placed at the appropriate location on poly tanks.

Planning and excavation

The first step in tank installation is to be sure the building stub-out elevation is consistent with that required to install the tank and soil treatment system at the correct elevations. Tanks should be kept as shallow as possible to minimize soil pressure and potential groundwater infiltration, and (where site conditions or regulations dictate) to keep the soil treatment system as shallow as possible. The tank inlet must be set to provide a slope of between 1 percent and 2 percent (i.e., 1/8 inch to ¼ inch drop per foot of run) on the building collection pipe from the stub-out to the tank. The tank dimensions must be known so that the excavation can be made to the proper depth, assuring that the tank inlet will be set at the proper elevation. Proper compaction of the underlying soils and bedding materials is critical to minimize later settling. Excessive tank settling is measurable, predictable and preventable. Proper evaluation of the original soil, bedding materials, depth to groundwater, backfill materials, and potential stress loads reduces the extent of later settling.

Setting and securing a tank

Workers must be safely positioned while tanks are being set. Compliance with OSHA standards is critical. The tank must be set level to provide the proper drop from inlet to outlet. Level of the tank should be carefully checked as it is set in the excavation.

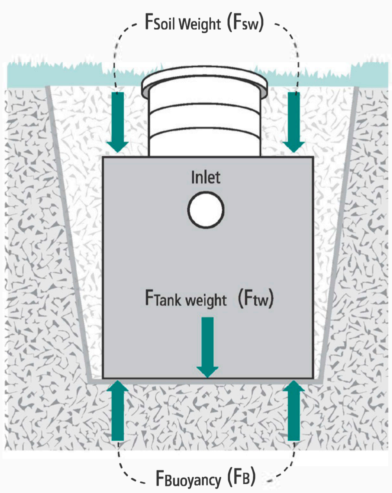
Installing two-piece concrete or FRP tanks requires that sealing materials be properly applied to a clean, smooth surface so that the joints will be watertight. Seams may be sealed at the point of manufacture or in the field.

Sewage tanks and risers must be installed according to manufacturer’s requirements and in a structurally sound and watertight fashion. Sewage tanks placed below the level of the seasonally saturated soil must be anchored or have sufficient weight to protect against flotation under high-water table conditions when the tank is empty.

Installation in high water table conditions

All tanks have the potential of being lifted out of the ground due to forces acting on the tank in saturated soil. If the tank weighs less than the force of water displacement, it will float- particularly when empty. Under some soils and site conditions, granular backfill may create a void area where subsurface water can collect, creating hydrostatic pressure on the exterior of a tank where high groundwater conditions are not otherwise present. In many instances, the tank hole is excavated into a relatively solid material. Once the tank is placed in the excavation, the hole is backfilled with a less dense material that allows water to collect in the excavation. Even though the surrounding soil is not saturated, the excavated volume may still become saturated. The upward force (buoyant force) is equal to the weight of the water displaced by the tank. If the weight of the tank and the soil cover does not exceed the buoyant force, there is a risk of floatation. Trenching leading to and from the tank excavation should include earthen dikes or diversions to prevent the free flow of groundwater into the tank excavation. Failure to include such water diversions may result in the creation of a "French Drain", which channels water directly to the tank excavation. When installing in areas with high water tables it may be necessary to incorporate a separate drain tile system to divert water away from the septic system.

FIGURE 7.23 Calculating Tank Buoyancy



$F_{SW} + F_{TW} > 1.2 \times F_B$

$F_{SW} = V_{Soil} \times 80$ lbs/ft^3

F_{TW} = Weight of tank

F_B = Total tank volume x 62.4 lbs/ft^3

To ensure a tank will not float when in saturated soil, a buoyancy analysis must be conducted as shown in Figure 7.23. In order to carry out the analysis you must know the:

1. Force/weight of the empty tank (F_{TW})
2. Force/weight of the soil directly above the tank (F_{SW})
3. Buoyant force (F_B)

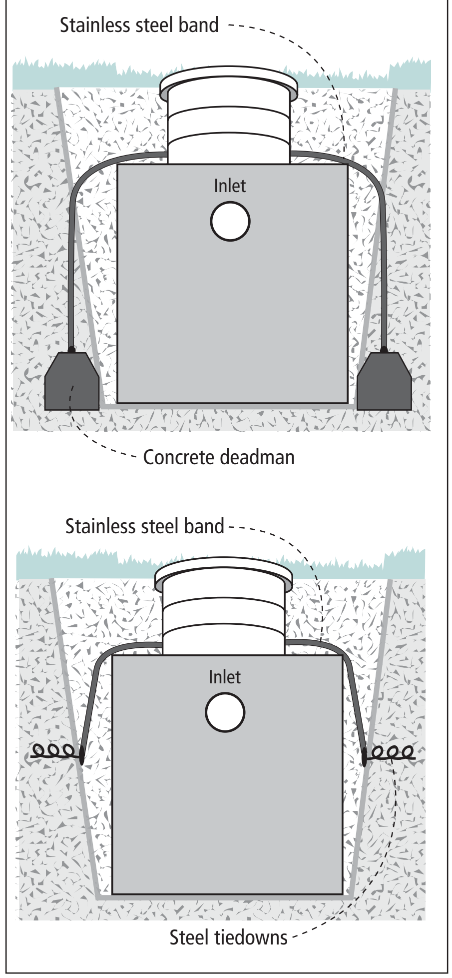
The weight of the tank and the weight of the cover soil create a downward force. In order to prevent the tank from rising, the total downward force must be greater than the buoyant force. In simple terms, the water in the soil around the tank pushes the tank up and the weight of the tank and soil hold it down. If ($F_{TW} + F_{SW}$) > F_B*1.2 then the tank should not float (The 1.2 multiplier is a safety factor that is incorporated into the equation). This safety factor can be adjusted based on your best professional judgment.

The F_{TW} can be obtained from the manufacturer or be calculated. The weight can be calculated by multiplying the volume (in cubic feet) by the specific weight of concrete making up the tank (150 lbs/ ft^3). The volume of concrete is found using the inside and outside dimensions of the tank to subtract the void space inside the tank from the overall volume of the tank. Be sure to compensate for the walls as well as the top and bottom of the tank. Some concrete tanks have internal concrete baffles. The baffle volume must also be considered in the tank weight.

The F_{SW} will contribute to the downward forces on the tank. In the worst case scenario when the soil above the tank is saturated, some of the downward force generated by the weight of the soil will be counteracted by the upward buoyant force of the water in the soil pores. The net downward force can be found by multiplying the volume of soil above the tank lid by the difference between the specific weight of the soil and the specific weight of water. The volume of the soil is found by multiplying the area of the top of the tank by the depth of soil cover. The density of the soil is dependent on the soil type. For example, a sandy soil has a specific weight around 120 lbs/ft^3 and clay would be about 90 lbs/ft^3. A safety factor will be added to the calculation to account for risers which will generate a void space.

To calculate the F_B the conservative approach is to assume that the tank could potentially be fully submerged in saturated soil and will be sitting empty, as tanks should be designed to stay buried even when empty. The buoyancy force is the outside volume (in cubic feet) of the tank multiplied by the specific weight of water 62.4 lbs/ft^3. A safety factor of 1.2 will be added to the calculation to account for risers which will generate a void space.

FIGURE 7.24 Buoyancy Countermeasures



Example:

A tank has the outside dimensions: width = 4 feet, length = 7 feet and depth = 6 feet. This tank is buried 3 feet deep in clay soil and weighs 11,000 lbs (provided by manufacturer).

1. F_{TW} = 11,000 pounds
2. F_{SW} = Area of top of tank multiplied by bury depth multiplied by the difference between the weight of soil and the weight of water:

   F_{SW} = 4 feet x 7 feet x 3 feet = 84 ft^3

   F_{SW} = 84 ft^3 x (90 pounds/ ft^3 - 62.4 pounds/ ft^3)

   F_{SW} = 2,318 pounds
3. F_B = Volume of tank multiplied by specific weight of water multiplied by safety factor (1.2).

   F_B = 4 feet x 7 feet x 6 feet= 168 ft^3

   F_B = 168 ft^3 X 62.4 pounds/ ft^3 = 10,483 pounds

   F_B*1.2 = 10,483 pounds x 1.2 = 12,580 pounds
4. Total downward force = F_{TW} + F_{SW} = 11,000 pounds + 2,318 pounds = 13,318 pounds

$F_{TW} + F_{SW} > F_B$; so this tank will not float.

If the analysis results in a buoyant force that is greater than the weight of the tank and soil, the design should specify a measure to counteract the force such as:

1. A concrete collar poured around tank (note that the use of a concrete collar with poly tanks may have an adverse affect on tank integrity because of chemical interaction between the materials,) if concrete is submerged for antifloatation, then 90 lbs/ft^3 is used to calculate how much is needed

2. Installation of "deadmen" steel cables attached to heavy concrete blocks or soil tie-downs as shown in Figure 7.24
3. Increased soil depth on top of tank

No matter what anti-floatation methods are used, be sure that the tank can handle any increased load and be sure that the buoyant force acting on the bottom of the tank will not cause the tank bottom to implode.

Dimension/capacity check and the use of existing tanks

It is the responsibility of the Installer to verify that new tanks delivered to the site meet the minimum requirements of the design. If the design indicates that an existing tank be used as part of a replacement system, either the Designer or Installer must verify that the existing tank is watertight.

A design will either indicate the required tank capacity or specify a particular tank from a designated manufacturer. It may also state that an equivalent tank may be used. Adequate tank capacity is critical to effective performance and must always be the starting point for determining tank equivalency. Configuration should be considered next. The length of a septic tank determines the length of the flow path and thus the time available for settling and floatation of solids. A shorter septic tank has less operating depth which means less storage for solids. When evaluating equivalency of tanks, the installer must consider this relationship between tank dimensions, operating depth, and operating volume.

The overall tank dimensions (both inside and outside) should be documented. The outside tank dimensions (length, width, and total depth) must be known so that the excavation can be made to the proper length, width, and depth. The depth below the pipe inverts is typically the measurement used to determine the depth of the excavation. **There must be a drop of 2 inches between the inlet pipe and the outlet pipe (MN Rules Chapter 7080.1920).**

Placing and bedding tanks

Sewage tanks must be placed on firm and evenly compacted soil and with the soil level in all directions. The bottom of the tank excavation should be excavated so that the vertical load is borne by the tank walls and not the tank bottom. If the bottom of the tank excavation contains rocks, bedding material must be used according to manufacturer's instructions. The soil beneath the tank must be capable of bearing the weight of the tank and its contents.

The depth of the excavation should take into consideration a layer of granular material (washed stone or coarse sand) with which tanks should be bedded. This bedding is helpful to fully support the bottom of the tank and distribute the weight evenly. Avoid over-excavating the hole to maintain relatively undisturbed soil under the granular material. In the event of over-excavation, clean, granular material should be used to re-establish the correct elevation. Ensure that there are no native rocks under the tank that could rupture the structure. This is important for all types of tanks. Note that in some cases, naturally occurring soil may serve as suitable bedding material.

Insulating tanks

According to MN Rules Chapter 7080.2000, Item H, if the top of a sewage tank is to be less than two feet from final grade, the lid of the tank must be insulated to an R-value of ten. Maintenance hole covers must be insulated to an R-value of ten. Maintenance hole risers should be insulated to an R-value of ten. All insulating materials must be resistant to water absorption. Tank walls, lids, and risers may all be insulated, and a number of options are available for this purpose:

- Insulation board can be placed along the side and on top of the tank prior to backfilling.
- A flexible insulation board can be wrapped around the riser.
- If a riser is installed over a smaller tank opening a piece of insulation can be placed inside the riser above the smaller tank opening.
- Two feet of soil (although some contractors use 48 inches as the measure below the frost line) should provide enough insulation for operation in cold climates Tanks buried at shallow depths (less than 2 feet of soil cover) may require additional insulation.
- In most situations, just the tank lid will be insulated with foam board.
- Spray-on insulation is now available and provides an additional sealant for seams coated in the insulation. In order for this option to be effective, there must be no loose-fitting manholes, broken inspection pipes, or unsealed conduit that may allow cold air to be drawn into the tank.

Be sure that the insulation used for the tank is designed for burial. Keep in mind that insulation is not necessary for all tanks buried deeper than two feet. For example, if the system is not used during colder times of the year, the tank contents may freeze because warmer water is not being added. In this case, insulation can actually delay the thawing process in the spring.

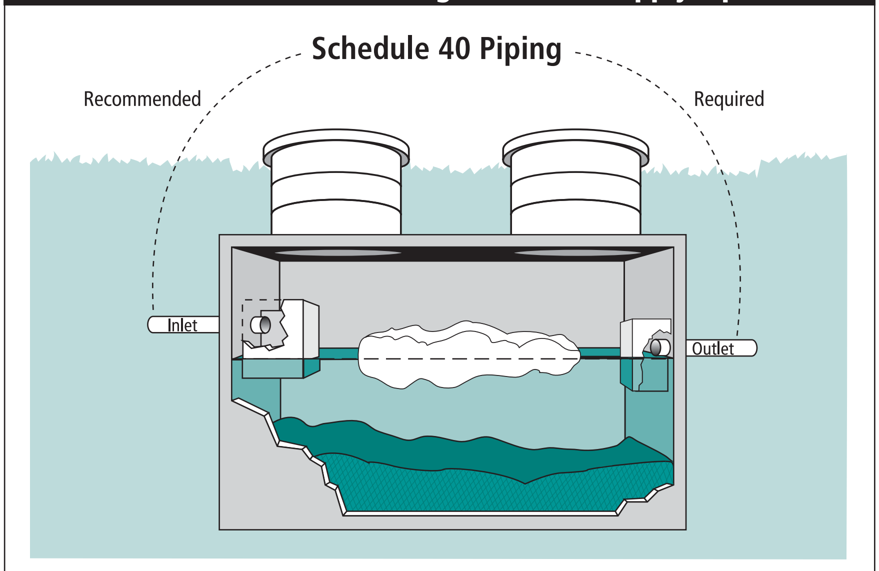
Pipe penetrations

Connections between the concrete tank and the building sewer or supply pipe must meet the requirements of American Society for Testing and Materials, Standard Specification for Resilient Connectors Between Reinforced Concrete Manhole Structures, Pipes, and Laterals, ASTM C923 (2002), or equivalent.

Check for settling of soil around the tank. Depressions in the soil at the edges of the tank can lead to ponding of rainwater, followed by infiltration. The pipe going out of the tank should also be constructed and installed to minimize soil settling. For existing systems, note the presence of cast iron pipe, clay pipe, or orangeburg, which can react with soap products, causing corrosion and eventual flow problems. Cast iron pipe should be avoided or replaced if at all possible.

For all types of tanks, pipe penetrations must remain watertight after backfill; therefore, it is critical to assure that there is no movement of the inlet and outlet pipe during the backfill process. Movement of this pipe during or after backfilling can alter the working liquid elevation in the tank and can damage or displace the effluent screen and case. Tamp the backfilled soil under the pipe to give it a firm foundation. The section of pipe across the excavation from tank to undisturbed soil should be rigid (Schedule 40 PVC or stronger) to reduce deflection. Pipe seals formed with mortar, mastic, and some rigid plastic seals are likely to be sufficiently stressed during the backfill operation that they may leak and allow root penetration. Attempting to bond wet mortar to dry concrete or PVC is not an effective pipe seal. As illustrated in Figure 7.19, flexible boot seals can overcome this problem and are highly recommended.

FIGURE 7.25 Schedule 40 Building Sewer and Supply Pipe



Even though the MN Rules 7080-83 code only specifically addresses the supply or outlet piping, the principles apply to both sides. The pipe should be supported and stiff enough to avoid settling across the excavation. This includes compacting and using at a minimum schedule 40 pipe as shown in Figure 7.25.

Baffling

Some tanks have baffles that must be installed by the installer. A tank may have an inlet, outlet, and/or a compartment baffle.

An inlet baffle is intended to direct the incoming flow downward into the clear zone and protect the inlet piping from being clogged by the scum layer. There are typically two different kinds of inlet baffles used in tanks. One type is a plate or partial wall baffle which is separate from the piping. These devices must be attached to the walls using appropriate fasteners (i.e., stainless steel connectors). Plate baffles may be installed by the manufacturer prior to delivery of the tank or by the installer after the delivery. Be sure that as the building sewer pipe comes into the tank that a sufficient space exists (6”-12”) to allow solid chunks to drop and not block the pipe.

Another type of inlet baffle is a sanitary tee. A sanitary tee is different from a standard tee in that it has a flow line that will not catch solids. Like plate baffles, these can be installed at the site by direct attachment to the inlet piping (building sewer) on the inside of the tank. This standard PVC connection must be made using the proper materials and procedures as described in the piping section. Some tanks are delivered with a sanitary tee already installed. If the inlet baffle is installed by the manufacturer, be sure that the stub of piping is long enough to extend past the excavation so that the joint to the next pipe section is located over unexcavated soil. Care must be taken to support this connection because any settling increases the potential for leaks or shifting of the tee out of plumb.

Like the inlet baffle, an outlet baffle may be either a partial wall baffle or a pipe configuration. The outlet baffle typically extends to the middle of the operating depth of the tank so that effluent is drawn from the clear zone of the outlet.

An effluent screen is typically placed in the tank outlet to remove additional suspended solids that could potentially clog downstream components. Proprietary screens often include a housing that essentially serves as a tee. Alternately, the screen is designed to be inserted into a standard tee. The screen must be installed under the tank access so that it can be inspected and maintained.

Sealing between joints, inlet and outlet pipes

Joints of concrete tanks and concrete tank lids must be sealed using a bonding compound that meets American Society for Testing and Materials, Standard Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants, ASTM C990 (2003).

Access risers and inspection pipes

Risers must extend to the final finished grade (preferably, 1 to 3 inches above) and the ground should be sloped away to prevent surface water collection or inflow around the riser. Access risers for use with concrete tanks are available in a variety of materials. Typically, risers for precast concrete tanks are manufactured from precast concrete, polyethylene, polypropylene or ribbed PVC. No matter what material is used, the riser must be structurally sound and watertight.

Concrete risers may be cast into concrete tanks with a “cold joint”. The riser itself is produced separately and allowed to cure. It is then placed into the tank or tank lid form, and the structure is poured. This cold joint will require further sealing (mastic or other appropriate sealants) to ensure watertightness. Concrete riser section joints should also be wrapped to better seal them. Polyethylene, polypropylene and PVC risers can also be cast directly into concrete tanks. Because of concerns regarding an effective bond between concrete and some of these materials, supplemental seals should be used to ensure watertightness. If additional riser sections are added, joints should again be wrapped. Note that cast-in-place risers are the best choice in high groundwater conditions and in cold climates where frost heaves might otherwise cause separation of a riser that was added after the tank is produced.

When concrete risers are attached to a tank after it is made, an integrated (tongue and groove) connection in combination with mastic or other appropriate sealant is more likely to remain undisturbed and watertight compared to a mortared seam. If additional concrete riser sections are added, these should also be made with tongue and groove joints and sealed with mastic. Wrapping seams provides additional protection especially in high water table- and freezing/thawing soil conditions.

Polyethylene and polypropylene risers are typically connected to a precast tank using an adapter ring cast into the tank. Another option is to attach mechanically a flange to the tank top using butyl rubber and stainless bolts. The riser is then sealed in place using appropriate adhesives.

It is essential to note that no matter what materials are used, access riser joints on tanks installed in areas where freezing and thawing soil conditions occur will require supplemental sealing to remain watertight.

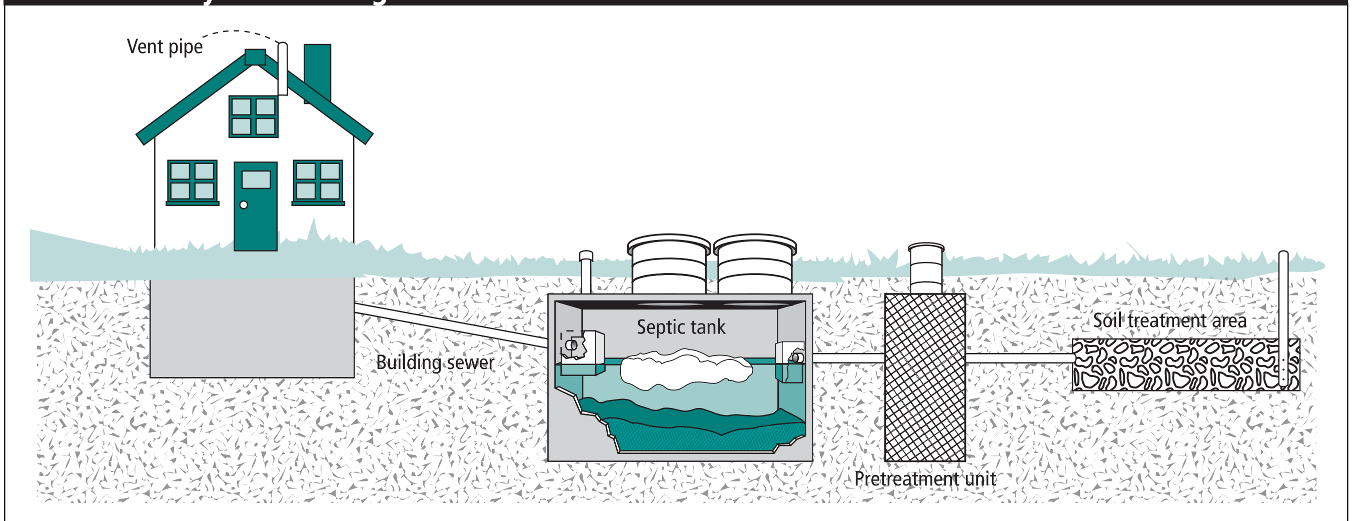
Cleaning accesses

A manhole at least 20 inches in diameter must be located within six feet of any wall of the septic tank to allow adequate cleaning. The cleaning access cover should be secured or have proper soil cover to prevent the untrained from attempting to get into the tank. Since the cleaning access is not covered with soil in newly constructed systems, the cover must be secured to prevent unauthorized access. This is for purposes of safety, since the gases in a septic tank may be toxic or cause asphyxiation. There have been people who have drowned in septic tanks with improperly protected cleaning accesses.

Tank Venting

Tanks must be vented to prevent accumulation of odorous gases. Venting also minimizes accumulation of hydrogen sulfide gas which may be converted to sulfuric acid in the head space of tanks. Concrete tanks are prone to corrosion under such conditions. All residential systems are designed to vent through the tanks and out the plumbing stack as shown in Figure 7.26, but additional vents may be included at the tank and these may include a filter.

FIGURE 7.26 System Venting



Air must flow from one compartment to another for proper ventilation of sewer gases through the plumbing stack in the facility. Verify that air can pass from one compartment to another via a gap in the top of the baffle wall. A smoke test may be used for verification. For concrete tanks with a slot or center hole positioned over the wall, a thin film of concrete left over from the pouring process must be removed for venting to occur. The thin film of concrete can be removed with a light tap of a hammer.

Backfilling tanks

All tanks should be backfilled with successive tamped "lifts" or depth increments of uniform gradation with no deleterious material or stones larger than 2 ½ inches in diameter. Crushed rock or pea gravel of ½-inch diameter is preferred if native materials are not appropriate. Each layer should be uniform, no greater than 24 inches thick and nearly equal height around the perimeter of the tank. Compaction under the haunch (bottom curvature of some tanks) is best done in 6 to 12-inch layers. When installing non-concrete tanks, it is critical to simultaneously fill the tank with water to just above the backfill level to avoid uneven or excessive pressures on the tank walls during the installation process and to minimize the risk of the tank shifting position. A tamping tool may be necessary to provide good contact against and between tank sides. Be careful not to damage the tank when carefully backfilling a tank installation.

Backfill with granular material to at least the midseam of the tank. Flowable fill or native soil free of deleterious material may be used above midseam. Note: never try to backfill an empty fiberglass or poly tank as it may collapse.

Supply pipe

The supply pipe extending from the septic tank to the undisturbed soil beyond the tank excavation must meet the strength requirements of American Society for Testing and Materials (ASTM), Schedule 40 Pipe, contained in Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120, ASTM D1785 (2006) (MN Rules 7080.2050, Subp. 2).

This pipe must not be subject to corrosion and decay. Experience has shown that outlet sewers from septic tanks that are cast iron will corrode shut or structurally fail in five to 15 years. Schedule 40 plastic must be used over the excavation, and it must be properly supported between the edge of the septic tank and the edge of the natural soil base in the excavation so that it will not sag or be broken during backfilling. The soil around the pipe extending from the septic tank must be compacted to original density for a length of three feet beyond the edge of the tank excavation. The location of the outlet pipes in the tank must be watertight.

Final grading

A final cover must be applied, mounded to allow for settling, and graded away from the tank and components as appropriate. The ground should be sloped away to prevent surface water collection or inflow around the riser. The Installer should indicate the type of soil material used for the final cover and document the proper mounding and grading so that surface water sheds away from the tank and components.

Operation and Maintenance

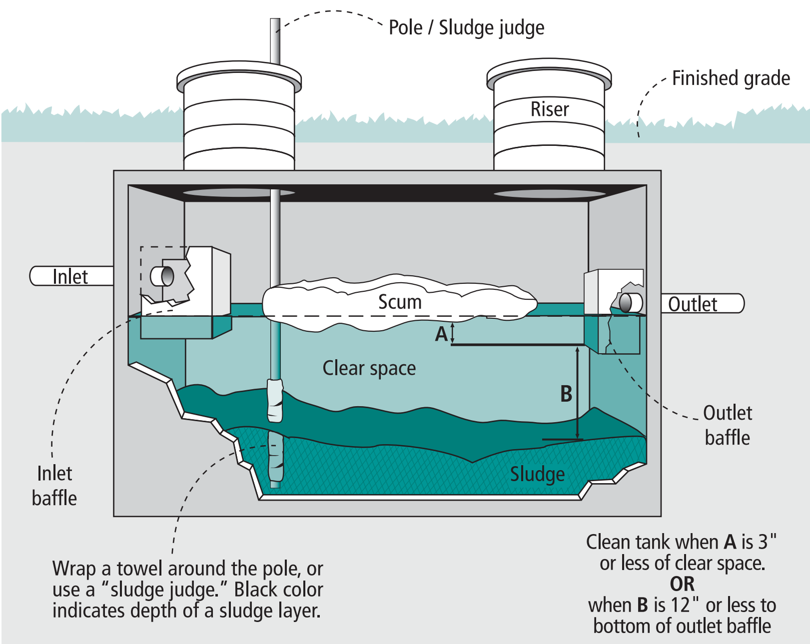
In most cases, system owners are the operators of septic tanks and the entire onsite system. They should be provided with basic information by a certified professional about how to assure that their systems are properly operated and maintained. **From MN Rules Chapter 7080.2450, Subp. 2, the owner of an ISTS or the owner's agent shall regularly, but in no case less frequently than every three years**

1. **assess whether sewage tanks leak below the designed operating depth and whether sewage tank tops, riser joints, and riser connections leak through visual evidence of major defects; and**
2. **measure or remove the accumulations of scum, grease, and other floating materials at the top of each septic tank and compartment, along with the sludge, which consists of the solids denser than water**

Tank cleaning

If a tank is operating properly, solids are retained and take up increasingly more volume. At some time they must be removed. (If there is little accumulation of solids, either the household is extremely conservative with water use and waste generation or there is a problem causing solids to pass through the tank.) When there is little clear zone left, proper solids separation will no longer occur, detention time for settling is

FIGURE 7.27 Determining Scum and Sludge Depth



further reduced, and solids will wash out of the tank, eventually clog the soil treatment area, and cause system failure.

Research on solids accumulation shows the interval between pumpings depends on tank size, number of people in the house, and the nature of the sewage (which in turn depends on household habits and lifestyles). Many publications and maintenance programs recommend a three to five year pumpout interval. This interval is probably reasonable but checking sludge levels at the time of service can provide a better estimate of the necessary pumpout interval.

The most reliable method for determining the need to pump is regular inspection of the tank, including measurement of sludge and scum thickness. If we use regular inspection as a method for determining pumpout needs, MN Rules Chapter 7080.2450 Subp. 3 (A) considers a tank "full" when the top of the sludge layer reaches to 12 inches below the bottom of the outlet baffle (B), or when the bottom of the scum layer reaches a level 3 inches above the bottom of the outlet baffle (A), as shown in Figure 7.27. MN Rules Chapter 7080.2450 also states a tank should be pumped based on total scum and sludge thickness, as a proportion of tank volume occupied by solids. A typical guideline is pumping when scum and sludge levels reach 25 percent of tank liquid capacity. MN Rules Chapter 7080.2450, Subp. 3 (A) states that a tank must be cleaned when the total volume of scum and sludge exceeds 25%, as shown in Table 7.8. The tank must be pumped if either condition is met.

TABLE 7.8 When to Pump a Tank

Add depths of scum and sludge. If the combined depth is 25% of the tank depth, it is time to pump the tank.

Tank Depth (inches)	Depth of Scum plus Depth of Sludge
30	7.5
33	8.25
36	9
39	9.75
42	10.5
45	11.25
48	12
51	12.75
54	13.5
57	14.25
60	15.0
63	15.75
66	16.5
69	17.25
72	18
75	18.75
78	19.5

When inspecting two-compartment tanks or systems with two tanks in series, it is important to open and evaluate both of the compartments and tanks. Although solids may accumulate at a much slower rate in the second compartment, it will still need to be pumped at some time and is usually pumped at the same time as the first compartment. Solids are removed from septic tanks using vacuum tanker trucks operated by a licensed Maintainer.

There are many devices that can be used to either determine sludge and scum accumulations periodically or to monitor levels on a continuous basis. The Sludge Judge™ and the Bigger Dipper™ are proprietary devices made using clear PVC pipe, and are tools for measuring the sludge and thin scum. Devices can be constructed of a small paddle on a stick or an L-shaped rod for measuring thicker scum levels.

Pumping too frequently may prohibit development of a normal population of beneficial microbes. From the perspective of system longevity, it may be best to err on the side of pumping too often rather than not enough; however, excessive pumping increases the burden on septage disposal facilities adds unnecessary cost for the owner. In addition, there is some evidence that when tanks are pumped every year or even more frequently, they sometimes do not develop normal scum and sludge layers. Decision-making based on actual tank conditions observed during inspection is recommended.

Tanks that are not designed, installed, and used correctly may float out of the ground when they are pumped during seasons of high groundwater. If a tank must be pumped under high groundwater conditions, consider placing a uniformly distributed static load over the tank until it can be refilled with water immediately after pumping. The static load should be sufficient to ballast the tank without causing structural damage. In addition, tanks may collapse from external soil pressure. This can be costly since the tank must be re-excavated and replaced. To prevent flotation or collapse, it is best to pump at a time during the year when the seasonal water table is below the tank.

When servicing septic systems, damaged tees and baffles are sometimes observed in older tanks. Concrete baffles and clay and concrete tees used as baffles may deteriorate in the moist, corrosive atmosphere of a tank. Deteriorated or missing baffles must be replaced as soon as the condition is discovered. This is usually done by replacing the original unit with a PVC or other plastic baffle tee. It is recommended that an effluent screen be added as part of any outlet baffle replacement operation. A failed outlet baffle can usually be replaced by inserting a section of 4-inch PVC into the outlet pipe and adding necessary fittings inside the tank to either use a 3-inch baffle tee or fit to a selected outlet screen.

At the time of tank pumping or service, access risers and lids must be checked for leakage or any structural damage. Any leaks should be repaired or patched, but structural damage indicates the need for replacement.

Effluent screens

Effluent screens should be removed and cleaned upon service. Proper instructions for the cleaning and troubleshooting of an effluent screen are provided in Section 8.

Myths and additives

There are many myths about substances that can help start biological activity or "improve performance" of septic tanks. Dead chickens and dead cats used to be favorite recommendations. They do nothing to enhance the function of the tank. Another myth is that a few inches of solids should be left in the tank when it is pumped to "start the tank up again". There will be sufficient bacteria left in the tank even after a thorough pump-out, as well as bacteria carried in the incoming wastewater, to begin digestion again. However, the tank should not be washed or excessively cleaned during pump-out.

One of the most frequently asked questions about septic tanks is "what about septic tank additives?" Some chemical additives are corrosive and can actually harm the tank or its normal biological processes. Repeated use of drain cleaners, antiseptic products, medicines and laundry bleach by homeowners can upset the bacteriologic balance in the septic tank. Biological additives (bacteria and enzymes) are not likely to harm the tank, but evidence as to their usefulness in residential septic tanks has not yet been conclusively shown in carefully controlled studies. Studies show no significant positive effect associated with additives. In these studies, there was some minor reduction of the scum layer. This may mean that the floatable solids moved into the soil treatment area.

Thus, the additives may actually defeat the purpose of the tank i.e., to retain solids and protect the soil treatment system. Some people promote the addition of yeast to a new or recently pumped tank. While this is harmless, it is not needed.

Some additives advertise, "Never pump your septic tank again". With these products the homeowner may be fooled into ignoring proper inspection and maintenance of their septic tank. Pumping is not just for solids removal; it provides an opportunity to observe potential problems and identify needed repairs. There is no substitute for proper operation, inspection, and maintenance of a tank to keep the system working as intended.

MN Rules Chapter 7080.2450, Subp. 5, specifies that ISTS additives, which are products added to the sewage or to the system with the intent to lower the accumulated solids in sewage, must not be used as a means to reduce the frequency of proper maintenance and removal of sewage solids from the sewage tanks as specified in this part. The use of additives does not fulfill the solids removal requirement of this part or a management plan. ISTS additives that contain hazardous materials must not be used in an ISTS.

Tank inspections and troubleshooting

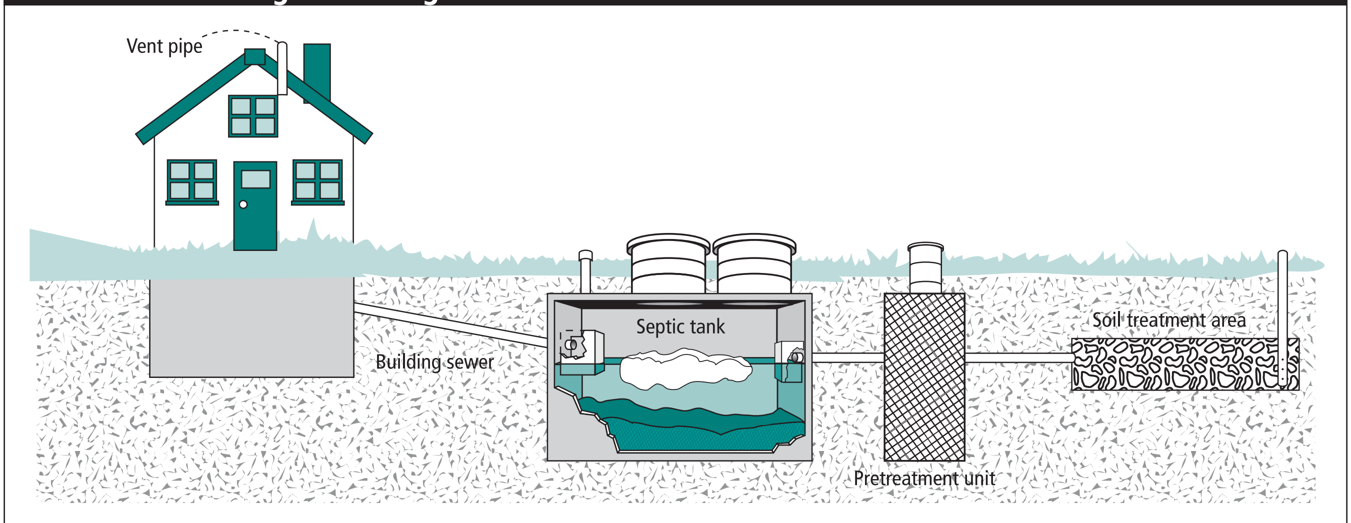
A trained and experienced Maintainer or Service Provider (SP) can perform troubleshooting relatively easily through an inspection of the septic tank. The process requires removal of the lids over the inlet and outlet portions of the tank. The SP will first note the liquid level in the tank by either looking directly at the water level in or behind the outlet baffle or tee. The water should be at the level of the invert (bottom inside lip) of the outlet pipe if no water has recently flowed into the tank. If the water level is not elevated above the invert, the sludge and scum levels can be measured. For more information about this, refer to Operation and Maintenance (Section VI). If the water level is below the invert, there is a leak in the tank that should be located and repaired.

If the level is above the outlet invert, there is a blockage in the outlet pipe or effluent screen or a back up from the soil treatment system. Pipe blockages can be a result of many different things: root intrusion, crushed pipes, deteriorated clay or concrete pipes, or a pipe with a "dip" that prohibits gravity flow. If the soil treatment system seems normal, investigate for a line blockage. It may be possible to run a plumber's snake through the line from the tank (after pumping the tank), or it may be necessary to expose and cut into the pipe outside the tank to get a snake into the line. This can be an unpleasant job if there is effluent backed up in the line. It is a good practice to have a vacuum truck at the site to remove effluent as needed. Additionally, gloves and eye protection should always be worn.

Odor

Is there any odor in the vicinity of the tank? Odors typically indicate a venting problem, but may indicate system failure. Odors should be vented out through the system, not back through the house. Make sure that the system is not venting through the electrical system or through the lids.

FIGURE 7.28 Investigate Venting If Odors Persist



Odor from and around septic tanks may be noticed in some systems. Odor around older systems may be caused by deterioration of tank components, broken tank tops, or submergence of the inlet that prevents proper venting of the tank through the plumbing roof stack. Odor may also be detectable from a new tank that has not developed normal biological processes yet or a tank that has been recently pumped. Normal odor may come from the roof stack. This may be especially prevalent during times of still air and particularly during temperature inversions that may occur early morning or late evening. Possible remedies for stack odor include extending roof vents higher to an elevation above the roof ridge or installing activated carbon filters on the top of vent pipes to filter odor.

Evaluating sewage tank performance

The tank holds a wealth of information about the operation and performance of the whole onsite system. Some regulatory programs use the tank as the single point of information about an entire system. Although your inspection will include examinations of other system components, start by opening the tank and looking into it. This means opening the 20-inch manhole. For other tanks, it means taking off a section of the lid. You have to be able to see the inside of the tank, so opening the four-inch inspection pipe will not be sufficient.

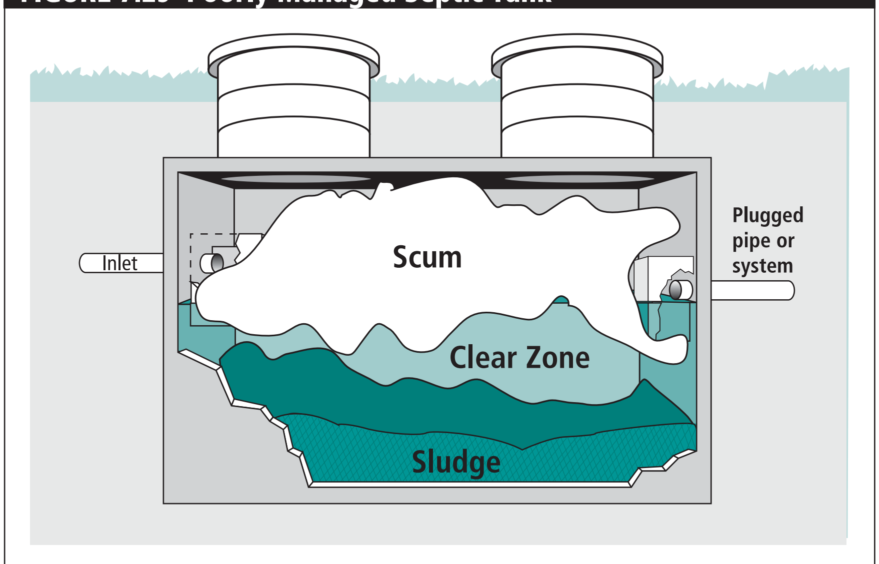
Finding the tank can be difficult. Water flows downhill, so usually the tank is downhill from the house. The sewer service coming out of the house will give you a general direction, and then look for clues: an inspection pipe, a low spot, dead grass, early snow melt, or other landscaping.

Flow, settling and bacterial action

First, get a general overview of the tank and its contents. If there's a lot of floating material that doesn't belong in the tank, such as plastic products or undigested food, you know that the users of the system may be causing some problems.

The tank should be developing three layers, a scum layer on top, clear water in the middle, and a sludge layer on the bottom. If these three separate layers are not present, then the system is not operating the way it should, and you need to find out why. When wastewater does not form these three layers, it is often because some chemical has been added that has killed the bacteria, or because one of the baffles in the tank is missing. Sometimes the layers will form but then become mixed due to turbulence in the water, particularly if there is a pump in the basement introducing too much water into the system.

FIGURE 7.29 Poorly Managed Septic Tank



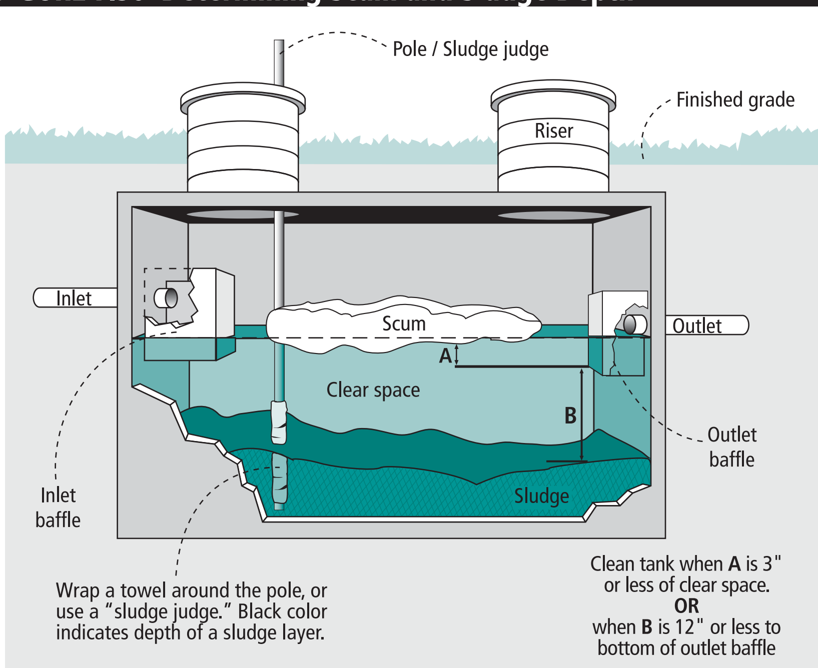
Evaluate the scum layer. It should not be excessively thick, and should always be less than three inches from the bottom of the outlet baffle to ensure that excessive scum is not leaving the tank. The scum layer should also not be higher than the outlet baffle or overflowing the baffle and flowing into the outlet as shown in Figure 7.29.

Excessive scum in the tank may mean that the tank needs to be cleaned out, or it may mean that the wastewater has high levels of soap or grease. Users of the system may be able to reduce the amount of soap or grease in the water, or they may have to have the tank cleaned on a more frequent basis. For systems serving commercial establishments, such as restaurants, it may be a good idea to extend the outlet baffles, so that the first of two or three tanks becomes a grease trap.

If a particularly thick scum layer contains a large proportion of undigested food, there is usually a problem in the house, either with excessive garbage disposal use or a medical problem such as bulimia. Only the users of the system can deal with these issues.

Other problem materials to check for include feminine hygiene products, such as tampons and pads, and barrier-method birth control products, such as condoms. These products should not be in the tank! They will neither sink nor float; instead, they will tend to flow through the tank and into the soil system, where they can plug both the outlet line and the soil system. Users of the system should understand that these products must not become part of the sewage flow. For systems serving restaurants or other commercial establishments, an effluent screen to prevent these materials from leaving the tank may be necessary.

FIGURE 7.30 Determining Scum and Sludge Depth



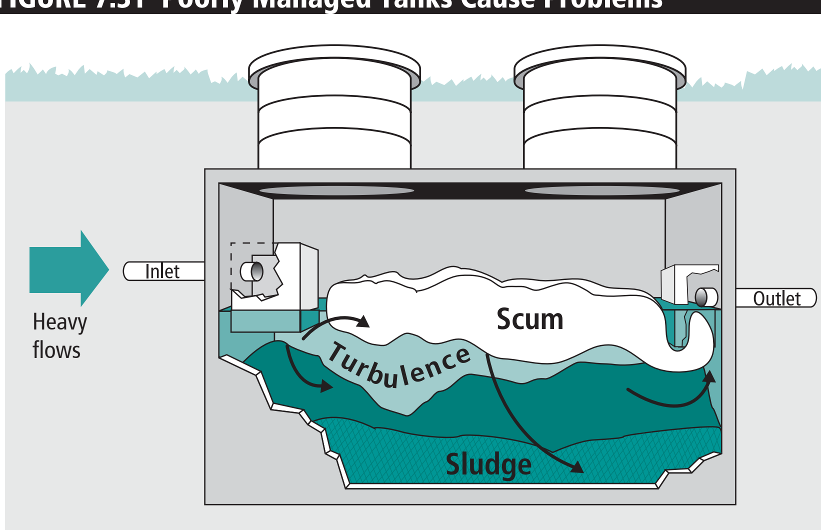
Evaluate the sludge layer. It should not be within 12 inches of the bottom of the outlet as shown in Figure 7.30. Allow time for the sludge to settle before measuring this distance. Verify that the sludge is settling well and that there is not excessive movement of sludge out of the tank. Sludge will not settle properly if the water in the tank is turbulent. Turbulent conditions could be from a pump in the basement adding high volumes of water, “stirring up” the wastewater, or there may simply be too much water entering the tank.

If sewage flow from the house to the tank has increased since the tank was designed and constructed, the tank may not be large enough to handle the amount of wastewater entering it. Users of the system may be able to reduce their water use to improve the performance of the system.

If there is an excess of material that cannot be broken down by the bacteria in the tank, such as coffee grounds, soil, or soap, both the scum and the sludge layers can quickly become too thick. The only way to get these materials out of the tank is by pumping.

If the tank is over-full (if the water level is higher than the outlet invert), the system is not operating as it should. An over-full tank is not conducive to settling, so sludge and other solids may reach the soil treatment area. There may be plugging in the lines, effluent screen, or the soil treatment system (Figure 7.31).

FIGURE 7.31 Poorly Managed Tanks Cause Problems



If a pump tank is part of the system, he pumps may have had problems, causing the tank to overfill. If, after pumping out the tank, there is excessive runback (water entering the tank from the outlet side) into the tank, there is certainly plugging of the soil treatment area.

Effluent quality

The performance of a septic system can be determined by laboratory testing of the effluent. Septic tanks should produce effluent with a BOD of less than 170 mg per liter, TSS less than 60 mg per liter and FOGs less than 25 milligrams per liter. When effluent has higher values than these, soil treatment systems typically develop clogging problems.

Watertightness

An inspector must determine if an existing tank is watertight during a compliance inspection. Without inspecting the tank for soundness, the inspector cannot issue a certificate of compliance. Any tank that is not watertight is, in essence, a cesspool. If the tank is watertight, then it meets the minimum requirement. Maintainers must also determine the watertightness of tanks they service, record this information, and share it with the system owner.

Watertight means that water is not allowed to flow in or out of the tank other than through the design penetrations (inlet and outlet pipes). Watertightness is critical to tank performance. Excess water entering the tank from surface runoff can result in inadequately-treated effluent entering the soil treatment system, causing premature failure of the soil system. Untreated wastewater entering the soil from a leaky tank presents health risks to humans and can have serious environmental consequences. A licensed Maintainer can help determine if the tank is watertight, and may be a useful resource about the system. General experience has been that most tanks without a maintenance access are not watertight.

To assess a tank's watertightness, verify that the concrete walls are watertight. Pay particular attention to seams in the walls. Tanks with mid-wall seams have a higher probability of breaking through and not being watertight. These walls should include some type of tongue and groove; check this joint.

Inspection of the walls includes checking the corners where the cover and the walls meet. These joints also should have a tongue-and-groove connection and some type of a mastic sealer in and on them. The other watertight surface is the tank bottom. This may seem straightforward, but tank floors were not properly constructed or installed in years past and may no longer be watertight.

Next, check all the penetrations, including inlet, outlet, manhole riser, lid of the manhole, and inspection pipes. All of these should be watertight. A very good hint that they are not is the intrusion of roots. The presence of roots indicates a problem that has been in existence for a long time.

Another indication of a problem is a trickle of water entering the tank. Surface water must not be allowed to enter the system. One place water might enter is through the manhole, which can be buried to minimize access. If it is not buried, it should be elevated at least one inch above the finished grade to guarantee that there is not extra flow into the tank. Sealing this lid with a mastic may seem like a good option, but sometimes a sealed manhole lid becomes permanently sealed and cannot be opened for maintenance. A number of local units of government required that the maintenance access be brought to the surface and MN Rules 7080.1970, Item B currently requires this of all new systems. This is a good idea, but if access is not brought to the surface, the system can still be in compliance.

Inspection pipes must be watertight at the surface of the tank. More importantly, they must have a cover on them. A coffee can is not a cover. The cover should be a tight-fitting plastic pipe. The best cover would be a threaded cap, to allow repeated opening without affecting the fit of the cover.

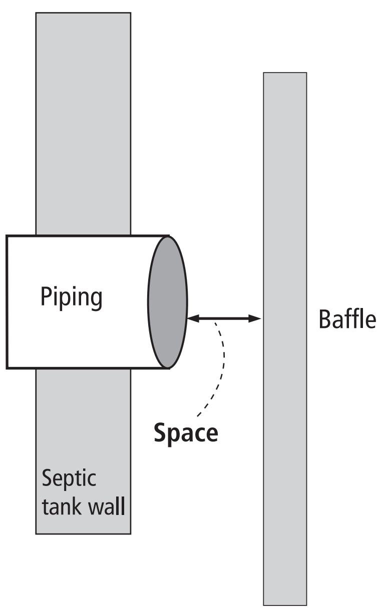
There should be self-sealing gaskets wherever penetrations meet the tank walls or lid. A number of the newer septic tanks have gaskets that require some type of a masonry support to work.

The riser itself needs to be watertight at all joints; plastic and concrete materials are available to achieve this. The typical length of the riser is ten to 12 inches, so using concrete means more pieces are necessary to bring it to the surface, and every connection must be watertight.

With large-diameter smooth-wall plastic pipe, it is critical that a seal be made where the pipe is connected to the tank. Simply setting the pipe on top of the tank does not make a watertight connection. Staining in the risers will identify leaks going into the system.

Another consideration is the location of the tank in the landscape. It should be located where a minimum amount of water will run off over it. Be particularly aware of hard surfaces from which the most water will run off; ideally, the tank would be upslope from these.

FIGURE 7.32 Spacing Between Inlet and Baffle



The space between baffle and inlet must be maintained (6-12")

Baffles

Check the baffles in the tank. The baffles begin the settling process by forcing the flow down, keep the scum inside the tank, and ensure that effluent leaving the tank comes from the clear liquid layer. If there are problems with the baffles, the system cannot work properly. One way to correct the problem of too many solids leaving the tank is to install effluent screens.

There are two general types of baffles: plastic pipe (sanitary tees) and wall baffles. The advantage of wall baffles is that they are built in. They have a larger space to allow larger solids to enter the tank. The downside of the wall baffles is that if the tank is not properly constructed the baffles will be significantly impaired. It's also difficult to add effluent screens to a tank with wall baffles. But either type of baffle will work adequately as long as it is in place.

Baffles must be properly connected. A wall baffle or a large pipe baffle should be connected in such a way that it will not corrode. All baffles must be securely attached so they remain in place over the life of the tank, and they must be inspectable. Baffles made of PVC sanitary tees must be properly glued and affixed onto the system.

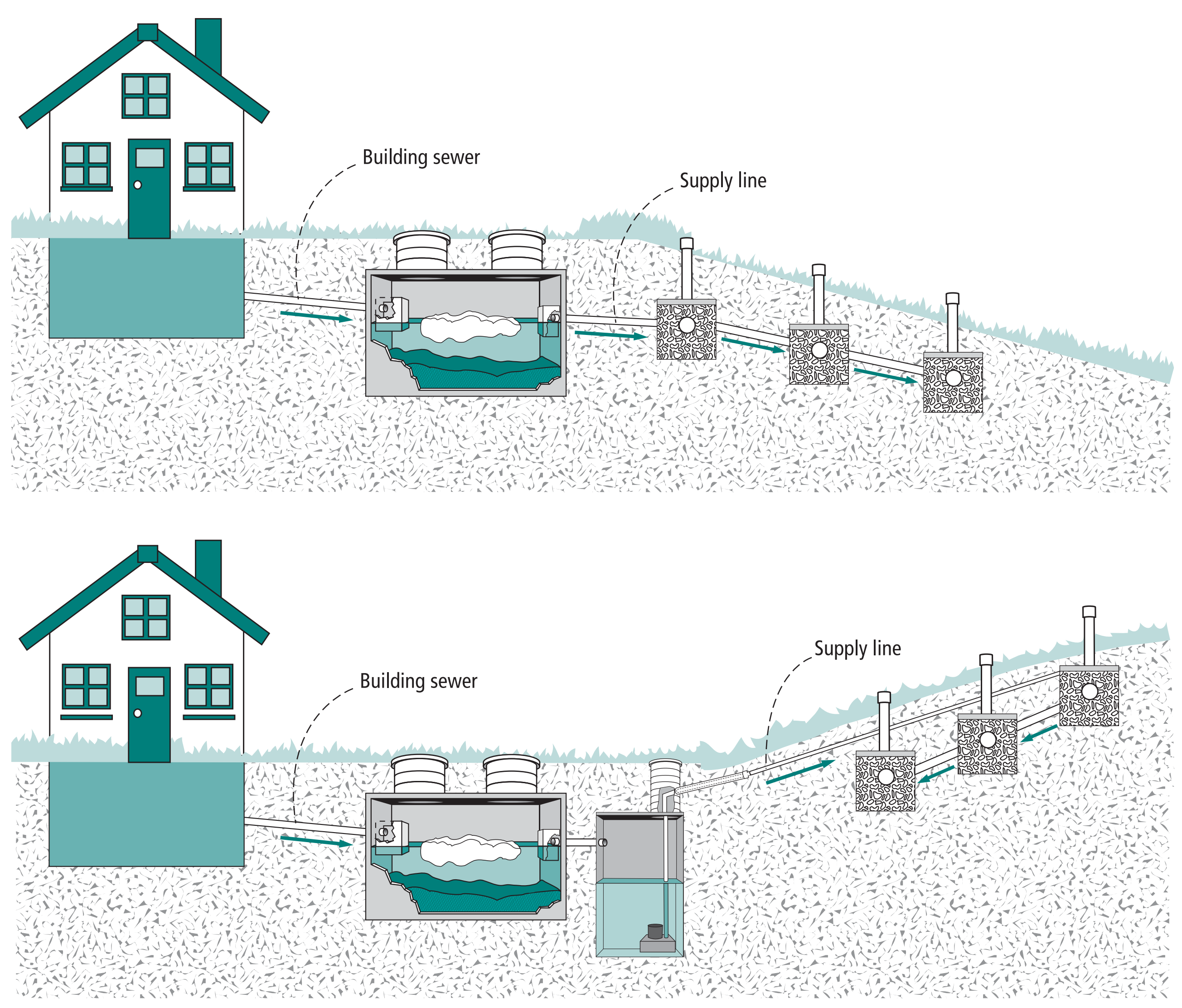
During the inspection it should be verified that nothing is plugging the baffles. It's also a good idea to verify that there is enough free space between the inlet pipe and the baffle to allow the free flow of both water and the solids in the water. There should be six to twelve inches between pipe and baffle, as shown in Figure 7.32. Note the depths of the baffles: the inlet baffle should be at least six inches deep. The outlet baffle should be drawing from the clear portion of the tank, typically about 40 percent of the depth. If the tank's function is to handle excessive suds or grease, the depth of the outlet baffle may be lowered so that the tank functions as a grease trap.

Supply lines

Outlet sewer

The outlet sewer or supply pipe carries the septic tank effluent to another septic tank, a pumping station or to the soil treatment area. This pipe should have a minimum slope of 1 inch per rise of 8 feet to ensure that water will flow properly. You do not have to be concerned about a maximum slope because the solids have been removed in the septic tank. For gravity systems, the outlet sewer delivers the effluent to a drop box or distribution box. From there it is delivered into the distribution network of trenches or beds. Here, a lighter plastic pipe with 1/2- inch holes every 6 inches can be used in rock-filled trenches or beds. In most cases, if pressure distribution is being used,

FIGURE 7.33 Gravity (Top) and Pumping (Bottom) Situations



Schedule 40 pipe should be chosen for the supply pipe from the pump station to the pressure distribution system in the soil treatment area. This is important in cold climates as it allows the water to drain out of the supply pipe to avoid freezing. Due to its higher lateral strength, Schedule 40 is less likely to develop small dips in the pipe as it is laid. This prevents water from standing in the pipe and freezing. Placing smaller-diameter pipe 1 to 2 inches in a larger (4-inch) pipe can also minimize settling across excavated areas. Typically, pressure distribution manifolds and laterals are also Schedule 40 pipe, as this helps contractors avoid dealing with multiple grades of pipe on the job.

The line that delivers the effluent from the septic tank and solid pipe throughout the system is identified as the supply line. A supply line can use either gravity or pressure for its operation, both shown in Figure 7.33. As in any piping, the supply pipe should drain properly. If gravity is being used the pipes must have proper slope to allow drainage to the next treatment unit. If the supply pipe relies on a pump, the drainback when the pump shuts off should drain back to the pump tank. The minimum pipe slope of 1 inch per 8 feet applies to both of these locations.

For gravity systems, 4-inch pipe should be used. For pressure systems, the size of the pipe is going to impact the pressure loss in the system. Typically 2 to 3-inch pipe is used for the supply lines. The size of the pipe also impacts the pipe's strength. Smaller-diameter pipe will have a thinner wall and therefore will be more flexible. This is an advantage during installation in that the pipe can be bent to allow for placement with fittings in the layout of the supply line. The problem with smaller-diameter pipe is that if there is settling, smaller pipes have a tendency to create sagging. To avoid this, a number of solutions can be employed. One is to go to larger-diameter pipe, which will be less likely to settle. Settling creates problems in terms of additional drain back, resulting in pump inefficiency. The other option is to support the pipe. Placing the smaller supply-line in a larger diameter pipe is an excellent way to accomplish this support. For example, run a 2-inch supply line inside a 4-inch schedule 40 pipe for support. This will adequately support the pipe and settling issues will be avoided. This also will insulate the 2-inch pipe and protect it from other damage. When applying larger pipe around smaller pipe, be sure that the larger-diameter pipe is sealed at the ends. This can be done with a fitting or with expandable foam.

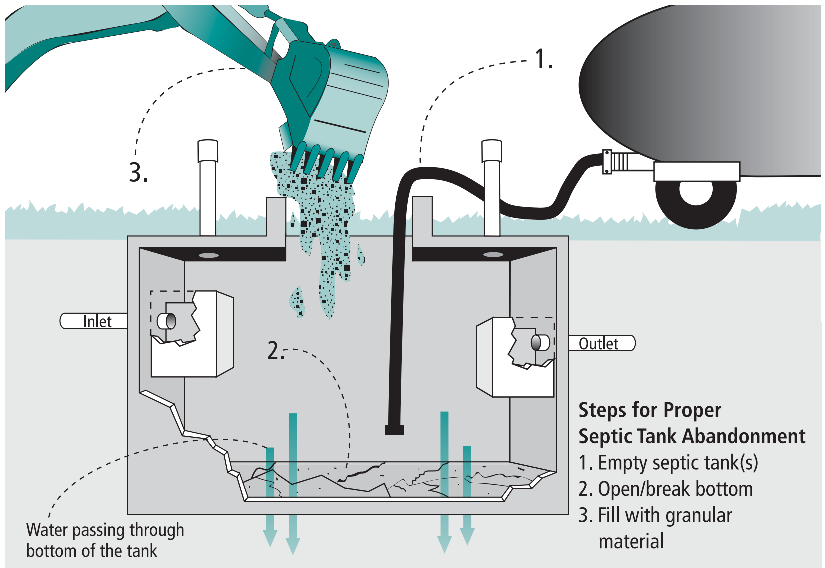
Management of supply lines

Management of supply lines is necessary to make sure that the wastewater will move through the system. It is important to use proper construction techniques that will allow the pipeline flow to be maintained. The potential for plugging in these lines is minimal, but downstream or at pressure orifices plugging is greater. The use of an in-line filter is a method to minimize potential for plugging. These filters are installed at the outlet of the pump using a metal screen to capture solids leaving the pump tank. Maintenance of these components is as directed by the manufacturer.

Tank abandonment

Tank abandonment should be performed by a licensed professional as shown in Figure 7.34. When a tank is no longer going to be used, specific procedures from MN Rules 7080.2500, must be followed:

FIGURE 7.34 Tank Abandonment Procedures



Subpart 1. Tank abandonment.

All systems with no future intent for use must be abandoned according to this part. Tank abandonment procedures for sewage tanks, cesspools, leaching pits, drywells, seepage pits, vault privies, and pit privies must meet the requirements in items A to C.

- **A. All solids and liquids must be removed and disposed of according to part 7080.2450, subpart 6, by a licensed maintenance business.**
- **B. All electrical devices and devices containing mercury must be removed and disposed of according to applicable regulations.**
- **C. Abandoned tanks or any other underground cavities must be removed or remain in place and crushed with the remaining cavity filled with soil or rock material.**

Subp. 2. Future discharge.

Access for future discharge to the system must be permanently denied.

Subp. 3. Removal of system.

If soil treatment and dispersal systems are removed, contaminated materials shall be properly handled to prevent human contact. Contaminated materials include distribution media, soil or sand within three feet of the system bottom, distribution pipes, tanks, and contaminated soil around leaky tanks. Contaminated material also includes any soil that received sewage from a surface failure. Contaminated materials must be disposed of according to items A to D.

- **A. Contaminated materials disposed of off-site must be disposed of according to part 7080.2450, subpart 6.**

B. If contaminated material is to be spread or used on-site within one year of contact with sewage, the material must be placed in an area meeting the soil and setback requirements described in part 7080.2150, subparts 2, item F, Table VII, and 3, item C, and the material must be covered with a minimum of six inches of uncontaminated soil and protected from erosion. After one year following contact with sewage, the material is allowed to be spread in any location meeting the setback requirement of part 4725.4450, covered with a minimum of six inches of uncontaminated soil, and protected from erosion. After one year following contact with sewage, the material is allowed to be used to fill in the abandoned in-place sewage tanks.

C. Contaminated pipe, geotextile fabric, or other material must be dried and disposed of in a mixed municipal solid waste landfill.

D. The person or business abandoning the system must complete and sign a record of abandonment that states the system was abandoned according to this part. The record must be sent to the local unit of government within 90 days of abandonment.

In the event that a septic tank is no longer used (because of an alternate connection to city sewer, tank replacement during system upgrade or repair, etc.), the tank must be properly abandoned. Local codes may list specific requirements for this activity and must be followed. In the absence of specific code requirements, the following procedures are recommended. The goal is to render the area of the old tank safe and free of environmental or public health impacts.

The tank must first be completely emptied of its contents using vacuum tanker trucks operated by a licensed Maintainer. Three common processes for dealing with the empty tank are listed below:

- Remove and dispose of the tank at an approved site (normally a landfill).
- Crush the tank completely and backfill.
- Fill the tank with granular material or some other inert, flowable material such as concrete.

The abandoned tank must present no collapse or confined-space hazard.

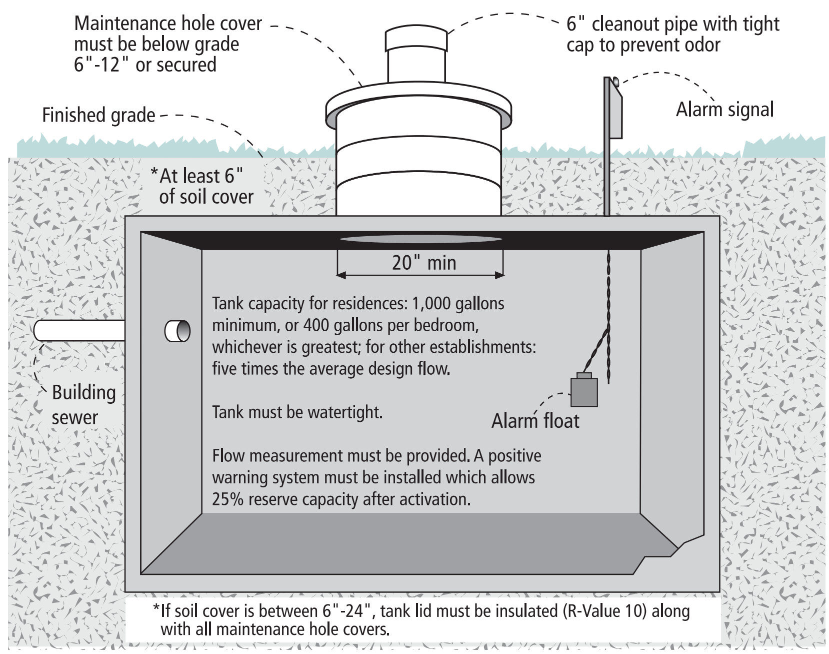
Holding Tanks, Privies and Graywater Systems

Holding Tanks

A holding tank system is a watertight tank into which sewage from a facility flows to be properly removed and disposed of. While holding tanks are not recommended for installation on newly developed lots, there are some developed lots which do not have adequate area for a sewage treatment system. In some cases, a holding tank may be the only alternative.

A holding tank is a watertight device capable of storing several days of wastewater generated by a facility and is not intended for treatment. Holding tanks are typically prohibited except under extenuating circumstances and used either as a last resort or on a temporary basis while alternatives for permanent use are explored. Use of a holding tank in an onsite wastewater treatment system incorporates the services of a sewage maintainer and off-site treatment for the sewage generated.

FIGURE 7.35 Holding Tank Specifications



Definition

From MN Rules Chapter 7080.1100, Subp. 40, a holding tank is a tank for storage of sewage until it can be transported to a point of treatment and dispersal. Holding tanks are considered a septic system tank under Minnesota Statutes, section 115.55.

Holding tanks are considered Type II systems under MN Rules Chapter 7080.2290. Holding tanks may be allowed by the local unit of government as replacement for existing failing systems which pose an imminent threat to public health and safety, or on existing lots. Holding tanks should only be installed where it can be conclusively shown that no other options are available. Figure 7.35 identifies specifications for holding tanks.

Under MN Rules Chapter 7082.0100, Subp. 3 (G) LGUs must address the allowance of holding tanks in their ordinance. **The ordinance must specify holding tank operation and maintenance requirements. At a minimum, a monitoring and disposal contract signed by the owner and a licensed maintenance business is required unless the owner is a farmer exempt from licensing under Minnesota Statutes 115.56, Subd. 2, (b), (3). The homeowner is responsible for ensuring that the contract guarantees the removal of the tank contents before overflow or any discharge.**

A sample monitoring and disposal contract can be found at septic.umn.edu/ssts-professionals/forms-worksheets. Local units of government should require an operating permit for these systems and track the compliance of these systems (**7082.0100, Item K**).

Rule Requirements

According to Minnesota Rules Chapter 7080.2290, to qualify as a holding tank, the tank must meet or exceed applicable requirements of parts septic tank strength, design, construction, storage, transport and use, location, installation, assessment and identification covered in 7080.1900 to 7080.2030. Holding tanks must also meet or exceed the applicable requirements of part 7080.2150, Subp. 2 which are the general technical requirements for all systems including setbacks.

These systems must all employ structural components and joint sealants that meet or exceed the system's expected design life (MN Rules Chapter 7080.2150, Subp. 3 (B)).

Setbacks and location

Where holding tanks are used, they must be installed:

- **In an area readily accessible to the pump truck under all weather conditions**
- **Where accidental spillage during pumping will not create a nuisance**
- At least ten feet from property lines, buried pipe distributing water under pressure, structures, and at least 50 feet from any source of domestic water supply or buried water suction line; and meet all lake, river and stream setbacks set in MN Rules 6105 and 6120

In addition, all tanks used as holding tanks must be tested for watertightness as specified in part 7080.2010, Subp. 3. The MPCA has stated that this testing can occur either at the site or at the manufacturing facility and that only the tank needs to be tested, not the supply line. The University of Minnesota recommends that the tank be tested after being installed to minimize concerns relating to cracks developing during transport and installation and potential leaks in the inlet and risers.

A cleanout pipe of at least six inches in diameter must extend to the ground surface and be provided with seals to prevent odor emissions and exclude insects and vermin. A maintenance hole of at least 20 inches in dimension must extend through the cover to a point within 12 inches, but no closer than six inches, below finished grade. If the maintenance hole is covered with less than six inches of soil, the cover must be secured according to part 7080.1970, D:

1. **be secured by being locked, being bolted or screwed, having a weight of at least 95 pounds, or other methods approved by the local unit of government. Covers shall also be leak resistant; and be designed so the cover cannot be slid or flipped, which could allow unauthorized access to the tank;**
2. **have a written and graphic label warning of the hazardous conditions inside the tank;**
3. **be capable of withstanding a load that the cover is anticipated to receive; and**
4. **be made of a material suitable for outdoor use and resistant to ultraviolet degradation.**

Holding tanks must have an alarm device to minimize the chance of accidental sewage overflows unless regularly scheduled pumping is used. An alarm device shall identify when the holding tank is at 75 percent capacity (7080.2290, Item F).

Application and Design

There are several issues to consider when choosing whether to use a holding tank. First, the cost of hauling the sewage can be excessive. Based on an informal survey of SSTS Maintainers, costs of pumping septic tanks are about $200 for approximately 1,000 gallons. Costs may differ somewhat for holding tanks since they are usually readily accessible and the material is not as difficult to remove due to the reduced amount of sludge. A family of four is likely to generate approximately 200 gallons of sewage per day. At a cost of $200 per 1,000 gallons, the annual cost to remove the sewage would be $14,600. Cost will vary with amount of sewage and hauling fees. Water conservation will reduce sewage flow, hauling costs and disposal fees. It should also be taken into consideration that weather conditions or road restrictions may prevent pumping and hauling when necessary and require that the plumbing systems not be used until the holding tank has been pumped.

Also, the liquid level in the holding tank will need to be continuously monitored in order to prevent an overflow. A water meter is recommended and can be used to determine the amount of sewage pumped and hauled and make sure that the tank is not allowing surface or groundwater into the tank or leaking untreated sewage out.

A continuous contract must be maintained to be sure that pumping service is available and that the sewage can be treated and disposed of.

Capacity

For a single family dwelling, not located in a flood plain, holding tank capacity should be 1,000 gallons or 400 gallons times the number of bedrooms, whichever yields the greatest volume.

For other establishments, the capacity should be based on measured flow rates or estimated flow rates. **Holding tanks serving other establishments must provide storage of at least five times the design flow (7081.0240, Subp. 2 (E)).**

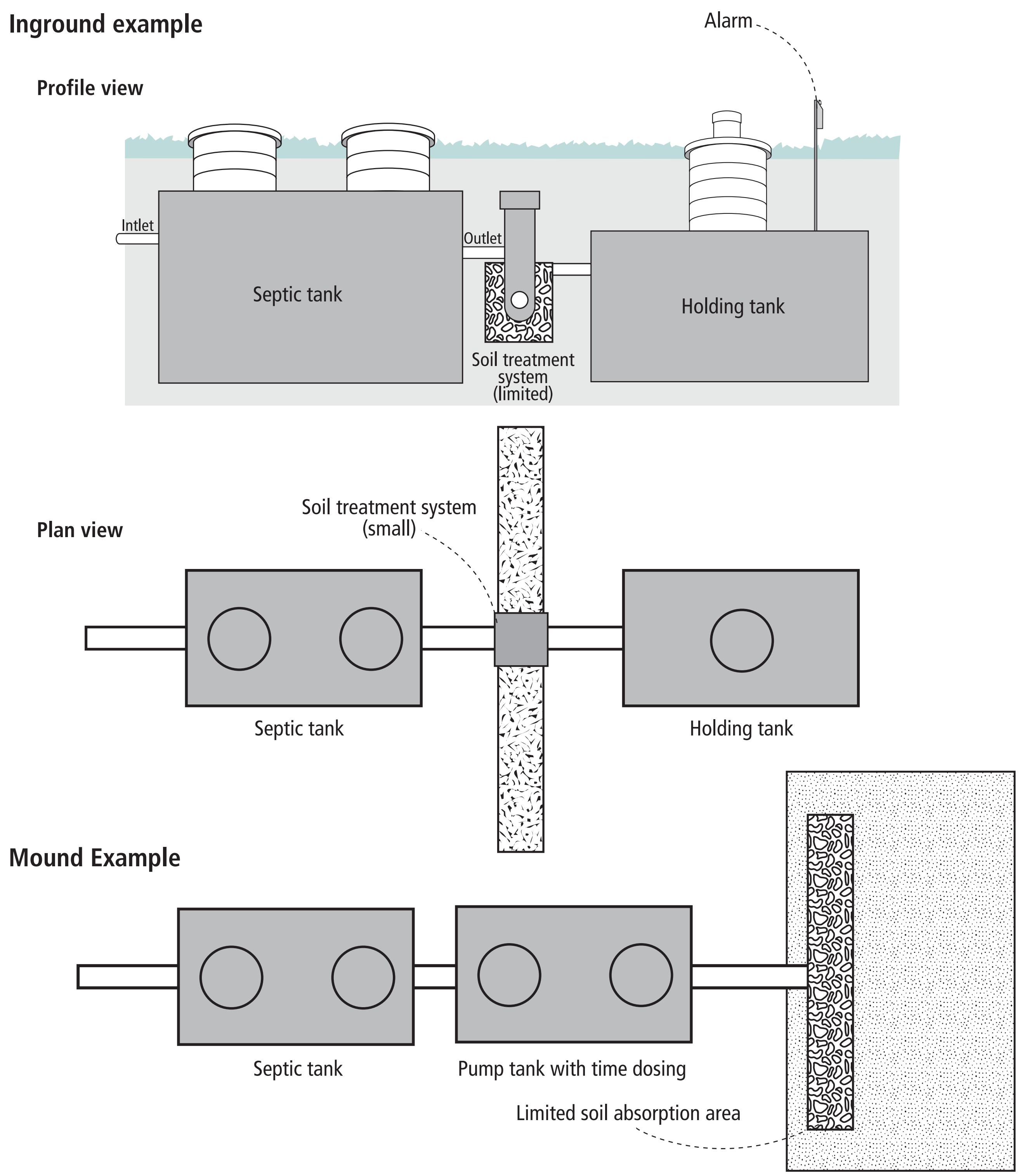
Floodplain areas

In floodplain areas, the capacity is 100 gallons times the number of bedrooms, times the number of days the site is flooded during a ten-year flood, or 1,000 gallons, whichever is greater. Information regarding the number of days of flooding is available from the 100-year hydrograph or by contacting the local planning and zoning agency. **The system must be designed to permit rapid diversion of sewage into the holding tank when the system is inundated. The holding tank must be accessible for removal of tank contents under flooded conditions (7080.2270 Subp. 9 &10).**

Reduced-size systems

Many of the design criteria used for designing sewage systems are quite conservative, particularly with respect to estimated water use. Some local government units will not allow anything other than a full-size sewage system to be installed, and base their sizing criteria upon 150 gallons per day per bedroom, although actual use may be much less. The systems proposed in Figure 7.36 should be seriously considered for lots that do not have area for Type I system.

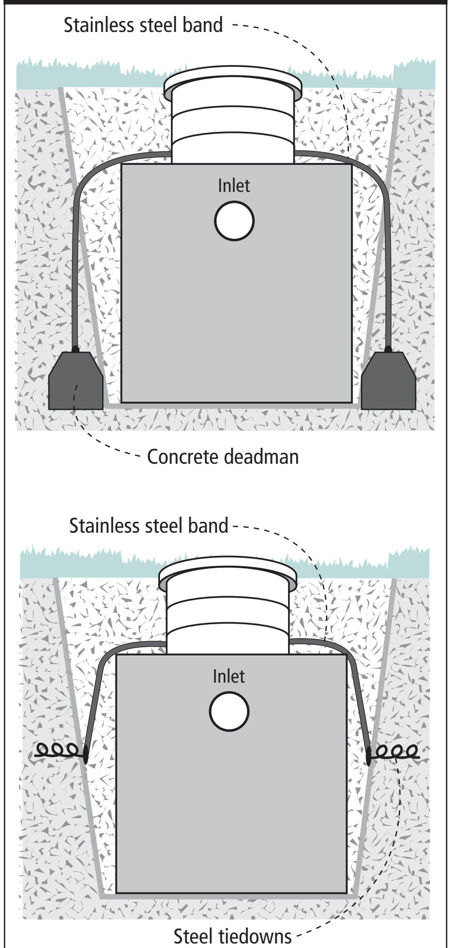
FIGURE 7.36 Small Lot Solutions



Holding Tank with Drainfield: An Alternative

This installation has successfully been used in a number of areas in Minnesota where allowed by local ordinance and teaches homeowners to conserve water. If the volume of liquid wastes generated is less than the treatment capacity of the soil absorption system, then no wastes will flow into the holding tank. The use of a timer in these systems assures that the system is not overloaded and can be a long term solution for the property.

FIGURE 7.37 Protecting Against Flotation



Installation

Holding tanks are constructed of the same materials and by the same procedures as septic tanks. Because these systems can be empty during wet times of the year, they must be designed to stay buried. This can be accomplished by the weight of the soil over the holding tank or by anchoring the tank in the soil as shown in Figure 7.37. Weight can also be added to the bottom of the tank to effectively keep the tank buried.

The tanks should be protected against flotation under high water table conditions by the weight of tank, earth anchors or shallow bury depth (page 7-32).

Operation, Maintenance and Troubleshooting

According to MN Rules Chapter 7080.2450, Subp. 3 (B) when holding tanks are maintained the liquid and solids removal can occur through clean out pipes even though removal of accumulated sludge, scum, and liquids from septic tanks and pump tanks must be through the maintenance hole. The University of Minnesota recommends that the maintenance hole be used to empty the tank so the overall tank characteristics can be evaluated and any heavier material that may have settled out be properly removed.

The largest challenge with holding tanks is tank leakage. Having a flow meter in the dwelling is critical for troubleshooting as this value can be compared to the volume and time between emptying the holding tank.

Inspection and Abandonment

Holding tanks are inspected and abandoned following the same procedure as septic tanks covered previously in this section of the manual

Privies

Definition

From MN Rules Chapter 7080.1100, Subp. 62, a privy is an above ground structure with an underground cavity meeting the requirements of part 7080.2280 that is used for the storage or treatment and dispersal of toilet wastes, excluding water for flushing and graywater. A privy also means a non-dwelling structure containing a toilet waste treatment device.

Outhouses are sometimes also referred to as a pit toilet defined by the Consortium of Institutes for Decentralized Wastewater Treatment (CIDWT) as a self-contained water-less toilet used for disposal of non-water carried human waste consisting of a shelter built above a pit in the ground into which human waste falls.

Rule Requirements

The use of privies is allowed by the provisions of Chapter 7080.2280, Subp. 2). If the pit has an earth bottom, this point should be at least three feet above saturated soil conditions. If this separation distance cannot be achieved in the location of the privy, then the pit should be liquid-tight, with the wastes periodically removed by someone who services septic tanks. The privy should be securely attached to the ground or to the tank used for the pit.

FIGURE 7.38 Privy Specs: Flat View

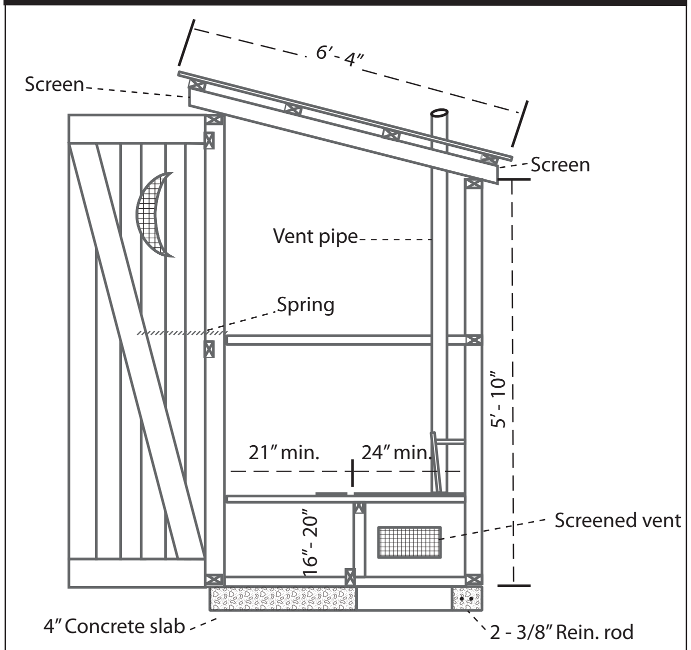
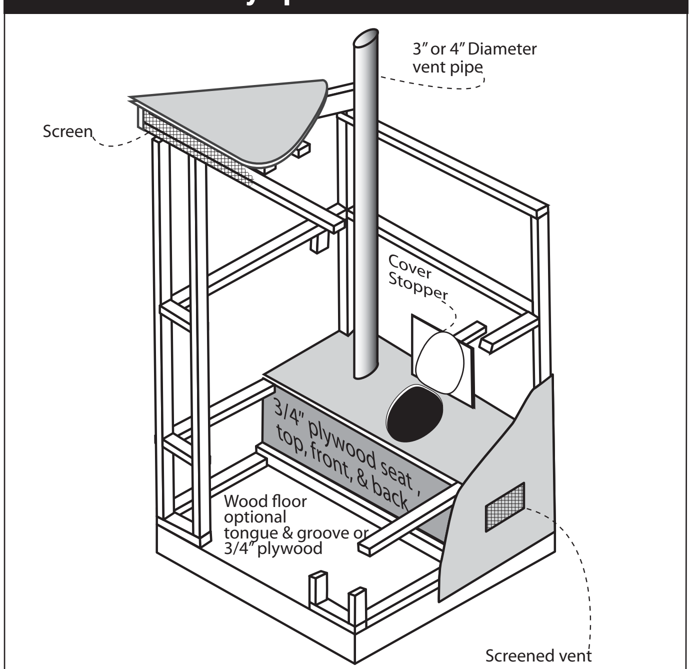


FIGURE 7.39 Privy Specs: Isometric View



According to MN Rules Chapter 7080.2280, to qualify as a privy, a system must meet the general technical requirements for all systems covered in 7080.2150, Subp. 2

Design and Setbacks

Suggested specifications for the outer portion of an outhouse are provided in Figures 38 and 39. MN Rules Chapter 7080.2280 outline requirements for the proper application of a privy. There are two options for the design of a privy:

1. **A pit can be dug that meets the 3 foot separation requirement. This means that the soil beneath the bottom of the pit that meets or exceeds the requirements of part 7080.2150, Subp. 3 (C). Pits or vaults must have sufficient capacity for the dwelling they serve, but must have at least 25 cubic feet of capacity. The sides of the pit must be curbed to prevent cave in (MN Rules Chapter 7080.2280, Items B and C). The pit must meet all the same setbacks as any soil treatment system.**
2. **A watertight holding tank meeting applicable requirements of parts 7080.1900 to 7080.2030 can be used instead of a pit. This tank must meet the same setbacks as septic tanks.**

Ventilation

From MN Rules Chapter 7080.2280 (E), privies must be adequately vented. To minimize odors in the upper part of the privy a vent should extend from the underside of the seat board through the roof or up to a horizontal vent open to the sides of the toilet. The vent must be flush with the underside of the seat board and must not extend down into the pit. Gases which cause odors are lighter than air, and if the vent extends down below the seat board, these gasses will collect under the seat board to be released upward into the privy when the seat cover is opened. At the top of the privy there should be a screened opening on each side or, preferably, all the way around the top to allow air to pass through and carry away any odors which may seep into the upper part of the structure.

From MN Rules Chapter 7080.2280, (D), the privy must be easily maintained and insect proof. The door and seat must be self-closing. All exterior openings, including vent openings, shall be screened. All vent openings to the outside should be properly screened to keep out insects. Insect-proof openings should be placed in the walls below the seat.

The opening in the seat board must have a tight-fitting cover. The type of seat and cover used on a flush toilet is not satisfactory unless weather stripping is added. The cover should be kept in place when the privy is not in use, and can be hinged to close automatically.

A tight-fitting door, preferably with a self-closing feature, such as a spring, should be used to minimize the number of insects that get into the privy. (A crescent-shaped window, also screened, may be cut into the door so that the utility of the structure will be recognized.)

Operation and Maintenance

According to MN Rules Chapter 7080.2450, Subp. 4 (B), when the privy is filled to one half of its capacity, the solids must be removed. Abandoned pits must have the sewage solids and contaminated soil removed and must be filled with clean earth and slightly mounded to allow for settling. Removed solids shall be disposed of properly.

Odor Control

A number of products on the market claim to minimize odors in a sanitary privy. One that is reasonably effective is hydrated lime. Associated compounds containing the same chemical are slaked lime, quicklime, hot lime, chloride of lime, and pebbled lime.

Approximately one cup of hydrated lime sprinkled over the solids in the pit will minimize odors and aid in decomposition. As the odors again become objectionable, another cup of lime should be added. Excess amounts of hydrated lime will retard decomposition, however, rather than promote it, although the generation of odors will be inhibited. Caution should be used to keep the hydrated lime dust out of eyes and nostrils.

Commercial compounds are available and may be tried by the individual owner in order to determine their effectiveness. Some of them are odor suppressants while others change the bacterial environment within the pit.

Keeping wood odor-free

Any odors which in the past have risen into the structure of an old privy have probably become entrapped in the pores of the wood. To remove these odors, make a solution of disinfectant and tri-sodium phosphate, and scrub the inside walls and all other inside surfaces of the privy. This solution will remove odors from the pores of the wood. After the wood has dried, paint the inside of the privy with a polyurethane compound to prevent any additional odors from penetrating the wood.

These techniques should minimize the odor that collects in the structure of a sanitary privy. Proper air circulation can be very helpful in carrying away any odors, so proper venting of the structure is absolutely essential.

Even though bacteria are decomposing the organic waste, there will be some residue remaining. This residue will gradually build up until it must either be removed or the structure moved to a new location. Usually the solids can be removed by a septic tank Maintainer or someone with equipment to perform the task in a sanitary manner. The frequency of solids removal will depend upon the size of the pit and the amount of use.

Troubleshooting

Odors

An outdoor toilet can be kept relatively odor-free and can be constructed for year-round use. But while an outdoor toilet is the least costly alternative to a flush toilet, it may be the least desirable alternative for a residence in a northern climate.

An improperly constructed and maintained privy can be an abomination to both eyes and nose. Several methods can be used to minimize the sanitary privy odor problem caused by decomposition of the organic matter in the pit:

- Use chemical compounds to change the bacterial action to reduce odor generation.
- Vent both the pit and the upper part of the structure.
- Place tight-fitting covers on the seat openings.
- Finally, the inside of the structure should be painted with a polyurethane-type paint to minimize the penetration of odors into the wood.

Inspection

When an existing privy is being inspected it is either evaluated as a soil treatment system needed to meet the two to three foot separation or as a holding tank which needs to be watertight. See the tank inspection portion of this section or the inspection criteria identified in Section 12 for ensuring appropriate vertical separation.

Abandonment

The abandonment of a privy is a relatively simple procedure. If a soil pit was used all liquid should be removed and the pit filled with granular material. If a holding tank is being abandoned it should follow the septic tank abandonment procedures discussed previously in this section of the manual.

Graywater Systems

Definition and Applications

Graywater is defined as sewage that does not contain toilet wastes (MN Rules Chapter 7080.1100, Subp. 37). This includes water captured from non-food preparation sinks, showers, baths, spa baths, clothes washing machines, and laundry tubs. Graywater systems are systems that remove the toilet waste from the system.

The primary reason why a homeowner may want to separate this waste is to conserve space on their lot, as graywater systems allow a 40% reduction in the required size of the soil treatment area. Other reasons include using graywater systems to reduce nitrogen loading in sensitive areas and reusing non-toilet water for other applications. Other separation of flows may also benefit other establishments with high fat, oil, or grease content.

Rule Requirements

MN Rules Chapter 7080.1100, Subp. 37 & 38 defines graywater as sewage that does not contain toilet wastes and a graywater system that receives, treats, and disperses only graywater or other similar system as designated by the commissioner.

Graywater systems designed according to parts 7080.2260 to 7080.2290 are considered Type I systems (7080.2250). According to MN Rules Chapter 7080, Chapter 2240, Subp. 1, to qualify as a graywater system, the system must meet or exceed the following requirements:

- **employ 60 percent of the flow values in part 7080.1850**

TABLE 7.9 Estimated Sewage Flows in Gallons per Day

Number of Bedrooms	Class I	Class II	Class III	Class IV
2 or less	300	225	180	*
3	450	300	218	*
4	600	375	256	*
5	750	450	294	*
6	900	525	332	*

* Flows for Classification IV dwellings are 60 percent of the values as determined for Classification I, II, or III systems. For more than six bedrooms, the design flow is determined by the following formulas:

Classification I: Classification I dwellings are those with more than 800 square feet per bedroom, when the dwelling's total finished floor area is divided by the number of bedrooms, or where more than two of the following water-use appliances are installed or anticipated: clothes washing machine, dishwasher, water conditioning unit, bathtub greater than 40 gallons, garbage disposal, or self-cleaning humidifier in furnace. The design flow for Classification I dwellings is determined by multiplying 150 gallons by the number of bedrooms.

Classification II: Classification II dwellings are those with 500 to 800 square feet per bedroom, when the dwelling's total finished floor area is divided by the number of bedrooms, and where no more than two of the water-use appliances listed in Classification I are installed or anticipated. The design flow for Classification II dwellings is determined by adding one to the number of bedrooms and multiplying this result by 75 gallons.

Classification III: Classification III dwellings are those with less than 500 square feet per bedroom, when the dwelling's total finished floor area is divided by the number of bedrooms, and where no more than two of the water-use appliances listed in Classification I are installed or anticipated. The design flow for Classification III dwellings is determined by adding one to the number of bedrooms, multiplying this result by 38 gallons, then adding 66 gallons.

Classification IV: Classification IV dwellings are dwellings designed under part 7080.2240.

In addition, no toilet waste may enter a graywater system (7080.2240, Subp. 2). Graywater septic tanks must meet the requirements of part 7080.1900, except that the liquid capacity of a graywater septic tank serving a dwelling must be based on the number of bedrooms existing and anticipated in the dwelling served and should be at least as large as the capacities given in Table 7.10 (7080.2240, Subp. 3).

TABLE 7.10 Septic Tank Capacity is Based on Bedroom Count

Number of bedrooms	Minimum Septic Tank Liquid Capacity (gallons)
3 or less	750
4 or 5	1,000
6 or 7	1,250
8 or 9	1,500

For ten or more bedrooms, the graywater septic tank shall be sized as: (1,500 + ((# of bedrooms - 9) x 150)).

The following text is courtesy of the Model Decentralized Wastewater Practitioner Curriculum Technology Overview

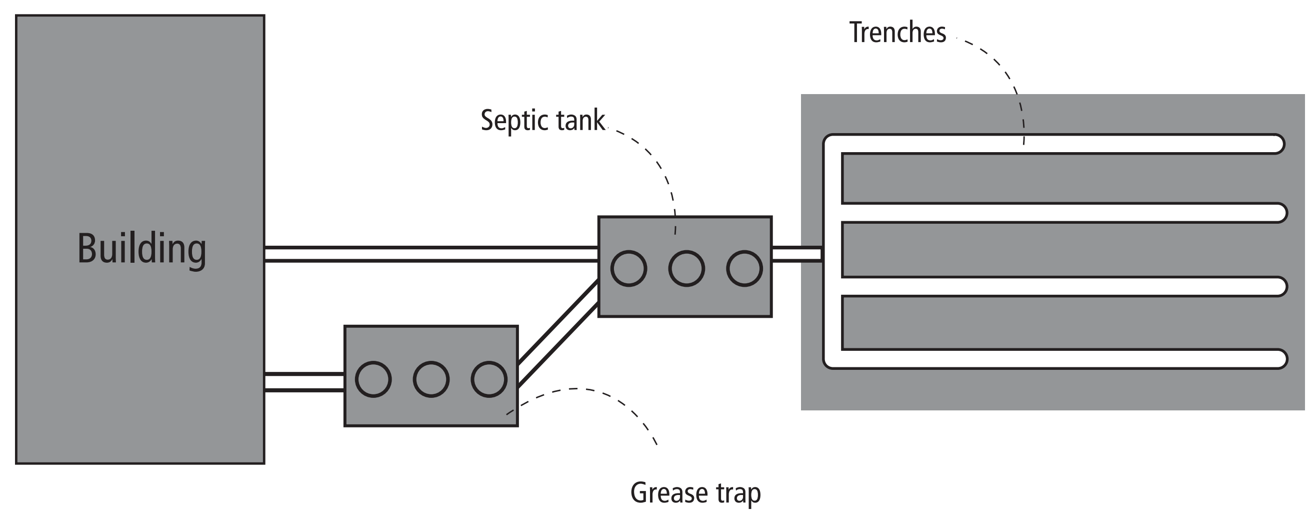
Segregation of wastewater flows

Wastewater that is treated by SSTS is generated by a number of activities in a residence or other facility. Wastewater uses have been identified as consisting of blackwater (in most locations this is just wastewater from toilets) and graywater (wastewater from all other plumbing fixtures). Most of the time, systems treat the combined wastewater from all sources in a structure. Occasionally, the decision is made to split the system so one or more components treat one source of wastewater while another one or more components treat other sources. This will require separate plumbing networks in the residence or other structure.

The primary reasons for splitting flows include:

1. Have separate systems treat blackwater and graywater:
    a. Nitrogen being discharged to ground or surface water in nitrogen sensitive areas by using non-discharging blackwater toilets, such as composting or incinerating toilets. These toilets retain most of the nitrogen in residential wastewater flows, since most of the nitrogen is in the blackwater.
    b. Reuse wastewater where wastewater reuse is a priority, by treating and reusing graywater for landscape irrigation, toilet flush water or other uses.
2. Keep wastes containing high concentrations of fats, oils and greases (commercial kitchens) from fouling components handling wastewater from other sources until the fat, oil and grease concentrations have been significantly reduced.

FIGURE 7.40 Typical Split Flow System Combined for Dispersal



Sometimes, even though the flows are initially split, they are combined somewhere downstream. For example, when a grease trap or interceptor is used to handle wastewater from the kitchen only, the resulting effluent may be combined with the rest of the waste-water in a downstream septic tank. See Figure 7.40.

Other times this separation continues throughout the entire system, so there are two complete wastewater systems. See Figure 7.40. Examples of this are when non-discharging toilets (composting toilets & holding tanks) are used to handle the blackwater and another pretreatment and dispersal system is designed and constructed to handle the graywater.

Graywater may go through one or more treatment processes so that the graywater can be used for one or more non-potable uses: irrigation, toilet flushing, and greenhouses. This allows the graywater to be reused as a resource. Graywater may be collected in a holding tank, where permitted, and periodically pumped and hauled away to a site that can treat and dispose of it properly.

Data indicate that graywater contains significant concentrations of organic and inorganic material (whatever is poured down a sink or drain). Graywater also can contain fecal coliform concentrations as high as those found in blackwater. Thus, graywater must be treated like all sewage. If a typical SSTS is used, it may be reduced in size since just the graywater is being treated. Alternatively, some jurisdictions may require a typical full size system. When reductions in size have been permitted for an SSTS to handle graywater, there have been historical concerns that a non-discharging blackwater toilet will be replaced with a flush toilet.

When graywater is being treated for a later non-potable use (toilet flush water, landscape irrigation), there must be assurances that the treatment is being reliably provided. Ongoing monitoring and maintenance is critical. Effects of not meeting treatment standards include: 1) clogging of pipes, valves, and orifices by nutrients, algae, and solids, and 2) exposure of humans to pathogens in inadequately treated reuse water.

Non-flush toilets

From MN Rules Chapter 7080.1100, Subp. 86, a toilet waste treatment devices is a toilet waste apparatuses including incinerating, composting, biological, chemical, recirculating, or holding toilets or portable restrooms.

For primitive dwellings using toilet waste treatment devices in low dwelling density areas, septage disposal from these devices by the owner must be in accordance with local ordinances. If no ordinance exists, the septage must not be discharged to surface waters, drainageways, steeply sloping areas, or wet areas in a manner or volume that is harmful to the environment or public health or that creates a nuisance. The material must be buried or covered with soil. For site conditions not met in this subpart, the solids disposal from toilet waste treatment devices shall be done by a licensed maintenance business (7080.2450, Subp. 4).

Following is information on three different classes of non-discharging toilets to handle blackwater. In some jurisdictions, plumbing codes may prohibit non-discharging toilets for some uses. The MN Plumbing code requires that all plumbing fixtures be connected to the building sewer (MN Rules Chapter 4715.1200). Non-discharging toilets, though, may not be considered a plumbing fixture and therefore may be used where local ordinance allows.

Incinerating toilet

An incinerating toilet reduces human excreta and urine to ash and vapor by incineration. This toilet only handles blackwater and is not designed for any water-carried sewage. This process is fueled by natural gas or electricity.

Careful consideration must be given to select the appropriate model and size for a specific application. As this process only handles blackwater, a system providing treatment and dispersal for the graywater is necessary. This blackwater handling process is located inside a residence, requiring extra considerations for the SSTS professional, especially those responsible for monitoring and maintenance. This option requires the use of a bowl liner and/or other methods specified by the manufacturer to keep the toilet bowl clean. There are gases that must be properly ventilated. Residual ash must be taken from the toilet and disposed of properly. Operation of the toilet (i.e. use of a liner and activating the burning cycle) is unfamiliar to the general public and, therefore, may not be appropriate for public access restrooms.

Composting toilet

A composting toilet receives human excreta and urine, and some carbonaceous kitchen wastes and transmits it to a composting chamber. Depending on the size of the composting chamber, the material undergoes drying and varying degrees of decomposition.

Toilets may be large or small capacity units. Careful consideration must be given to select the appropriate model and size for a specific application. If larger units are to be used, they are usually installed as part of a building's construction. Retrofitting an existing structure with a larger unit can be difficult. As this process only handles blackwater, a system providing treatment and dispersal for the graywater is necessary. This blackwater handling process is located inside a residence, requiring extra considerations for the SSTS professional, especially those responsible for monitoring and maintenance. Some of the units are relatively small and are self-contained. Others have big chambers under the toilet, requiring space in a basement or crawl space. These units have been used extensively in many public and commercial recreational facilities. They have also been used in communities to minimize wasteful use of valuable potable water. The toilets contain mechanical agitators, thermostats, humidistats, heaters and fans to assure the proper moisture content and temperature are maintained. The toilets must be properly vented. Direct homeowner involvement in the operation, monitoring and maintenance of the toilet is required, even if a management structure exists to provide on-going system monitoring and maintenance. This involvement includes monitoring moisture content, control of flies, periodic mixing of the composting material, and periodic removal and proper disposal of the composted material. The fact that most of the composting toilet's sub-components may be inside a residence or structure complicates the ability for a third-party management entity to care for the toilet.

Chemical toilet

In most chemical toilets, a charge of chemical is added to a small amount of water. After use, the liquid is recirculated by an electric or hand-operated pump to flush the wastes into a holding chamber. The initial charge of chemical is adequate for 40-160 uses, depending on the model used. When the holding chamber is full, a valve can be opened to discharge wastes into a holding tank. On some chemical toilets, the holding chamber can be removed for waste disposal. Wastes are reduced to about two percent of those from a conventional flush toilet.

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SECTION 8: Tank Management and Land Application

TANK MANAGEMENT AND LAND APPLICATION

All systems need to be managed to operate properly. It is critical that all system owners understand that all properly operating systems will have a management aspect in order to serve as a long term solution. These activities are straight forward but necessary and time sensitive for systems to operate properly. See Section 1 for more information about communicating with the homeowner about monitoring and maintenance tanks. The UMN Septic System Management Plans also clearly identify homeowner vs. professional responsibilities in the management of a septic system.

Tank Maintenance

Cleaning

How frequently a septic tank should be cleaned depends upon the tank capacity, the number of people using the system, and appliances that send waste to the tank, such as a garbage disposal. The solids from one person will, on the average, occupy about 50 gallons of tank capacity per year.

MN Rules Chapter 7080.2450, Subp. 2 requires an assessment of every tank every three years, at minimum. This assessment includes the measurement or removal of scum and sludge accumulations as well as a determination of whether the sewage tank leaks below the designed operating depth or at penetrations such as tank tops, riser joints or riser connections. The tank should be cleaned when:

- 1/4 of the initial liquid capacity is occupied by floating and settled solids (for example, 250 gallons in a 1,000-gallon tank),
- when the top of the sludge layer reaches twelve inches below the outlet baffle, or
- when the bottom of the scum layer reaches three inches above the outlet baffle.

Some tanks may need cleaning within two years or even sooner, while others may go longer before they need cleaning.

Tanks with a shorter distance between the inlet and outlet baffles will need more frequent cleaning in order to protect the soil treatment unit. Once sludge scours through the tank outlet, it can quickly plug a soil treatment unit to the point where a new one is required.

Scum and Sludge Accumulations

Scum and sludge accumulations should be periodically evaluated. At least once every three years, the owner of the tank or a septic system professional must inspect the tank and measure the accumulation of sludge and scum. In addition, the tank must be checked to assure that it is not leaking below the operating depth or at any joints or connections. Equipment is commercially available to measure scum and sludge accumulations.

According to **MN Rules Chapter 7080.2450, Subp. 3 (A and B)**, the septic tank must be cleaned through the maintenance hole:

- whenever the sludge and scum depths are greater than **25%** of the tank depth, or
- the top of the sludge layer is closer than 12 inches to the bottom of the outlet baffle, or
- whenever the bottom of the scum layer is closer than three inches to the bottom of the outlet baffle.

Tank capacity and, consequently, detention time, is reduced as solids build up. A tank detention time of much less than 24 hours may result in some solids being discharged with the effluent and carried to the soil treatment unit. To protect the soil treatment unit, periodic removal of accumulated solids in the septic tank is necessary.

It is a good idea to check the accumulated solids in a new septic tank one to two months after the tank is put into operation. The measurement of the accumulated solids will help to predict the frequency of solids removal.

Septic Tank Cleaning Procedure

How to Clean a Tank

1. Locate Maintenance Hole

The first step in pumping a septic tank is to locate the maintenance hole for servicing. **MN Rules Chapter 7080.2450, Subp. 3 (B)** requires that the tank be pumped through the maintenance hole. The use of any other opening like the 4" inspection pipes, is not considered maintenance, and the owner must approve these improper activities (see #11). The use of any other opening besides the maintenance hole is only permissible in emergency situations such as winter freeze-ups or early spring plugging, or in the case of a deep install with an older tank with out risers or no maintenance hole available. In both of these situations, deep tanks or emergency service, the pumping frequency should be shortened due to the inability to clean the tank thoroughly.

Experience is helpful in finding the maintenance hole. If you are new to onsite system maintenance, ask the county what the older tanks in the area look like and the typical location for the maintenance hole. Typically, a maintenance hole is located in the center or at the baffles (inlet and outlet). You will learn the actual design in your area once you have experienced digging up a number of the lids.

Deep digging should be a one-time happening. The addition of a riser to the maintenance hole for any tank deeper than 12 inches should be a local requirement or at least well marketed by the maintainer. The connection of the riser is critical to maintaining a water-tight tank. The deeper the system, the more critical is the connection to the tank, and time should be invested in the connection on the tank. More information about this critical connection is found in Section 7.

2. Open Maintenance Hole

Opening the 20 inch maintenance cover is critical for proper maintenance. **MN Rules Chapter 7080.2450, Subp. 3 (C)** also requires the professional to assess the cover and its level of secureness. A plastic cover must be properly secured with bolts or screws. A concrete lid is considered secure by **MN Rules Chapter 7080.1970 C** if it weighs at least 95 lbs. Older covers that are in sound physical condition can be considered secure by the local unit of government. Both of these conditions require proper tools for the professional to access the septic tank. Do not arrive at a site to find that you can't properly open the tank!

3. Inspect Contents

Checking the three layers in the tank is an important step for the tank's long-term operation. The scum, sludge and clear zones should be measured and verified at the time of maintenance. The depth of the sludge and scum determines the need for their removal, and the appearance of the clear zone can tell much about the performance of the system.

The scum layer should be present. A missing scum layer can be the result of a loss of the outlet baffle or the chemicals that are being added to the tank. The chemical addition can be assessed using your nose and testing the pH level. The pH level should be between 6- 7.7. If the pH level is out of this range, the tank will be struggling to support active bacterial activity. Low pH values are caused by acids (cleaners or dairy) being added to the system. High pH values are caused by basic cleaners or other chemicals.

Another possible cause of a missing scum layer is the addition of water softener recharge water. This product can reduce the tank's ability to release and hold the soap scum in the tank, causing them to flow through the system.

The clear zone should be at least 75 percent of the tank depth. The appearance of flocculent,(small floating bacteria) will also speak to tank operation. A clear zone with little flocculent means the tank is working well. A cloudy clear zone usually identifies high BOD content, the BOD typically related to a soluble source, soda, dairy or alcohol. An absent clear zone is the result of an anti-bacterial addition that has significantly impacted bacterial action.

The sludge zone and the scum at 25 percent of the tank depth should be removed. A dark sludge may be related to the use of an iron filter. These water conditioners may discharge a solid {iron precipitate} into the tank as part of typical operation. This water using component will increase the maintenance frequency.

4. Remove All Tank Contents

All solids and scum in the tank should be removed. Chapter 7080 requires that the solids should be removed to within 1 inch of the bottom of the tank. This means that seeing the bottom is critical for a successful cleaning. A number of choices for cleaning are available. Mechanical mixing, air mixing or back flushing are all methods to deal with the solids.

Cleaning Procedure

Removing all of the septic tank solids involves more than just pumping the tank. When the septic tank is cleaned, the cleaning access cover or the tank cover must be removed to facilitate cleaning and to ensure that all solids have been pumped out. A septic tank cannot be cleaned adequately by pumping out liquids through a four or six inch inspection pipe. This process often results in the scum layer plugging the outlet baffle when liquid again fills the tank. Removal of all sludge, scum, and liquid must be done through the maintenance hole. If no maintenance hole exists, one must be installed.

The tank cleaning job must be performed by a professional having adequate equipment. Some of the liquid is first withdrawn from the tank and then pumped back into the tank under pressure to agitate all the solids into suspension. If the scum layer is hard, it may be necessary to agitate the tank with air, a mixer, or a long-handled shovel through the cleaning access in order to break up the scum layer.

When all of the solids have been broken up and are suspended in the liquid, the mixture is pumped out of the septic tank into the truck. Unless the cleaning access is open, it will be virtually impossible to tell if all of the solids have been removed from the tank.

Mechanical Mixing

Mechanical mixing of the tank contents can make the removal of solids an easier job. A crust buster is a device designed to agitate and mix the scum and solids, even stirring the corners of the tank. It can shorten the time necessary to clean the tank. Be sure the effluent level in the tank is below the outlet piping so no solids are pushed out of the tank.

This device can make the cleaning job easier quicker and reduce the time at the site as well as the time your pump needs to operate.

Back Flush

Another method for removing and mixing the solids is back flushing. In this method, the tank is partially emptied and the septage is pushed back into the tank for further mixing and cleaning of the tank. This is a good way to allow for the removal of the solids. Be careful that the back flush volume being put back into the tank is not more than the tank capacity; overfilling the tank puts solids in bad locations like the basement or the soil treatment area. If someone has attempted to service a septic tank through the inspection pipes over the inlet and outlet baffles, those baffles may be broken or dislodged. When the septic tank cleaning access is open, check the condition, length, and submergence of the inlet and outlet baffles. Septic tank service personnel should replace the baffles if they are the wrong length or in poor condition. It is not necessary to leave solids in the septic tank to "start" it again. Sufficient bacteria remain in the tank on the walls and bottom.

5. Inspect Tank

Once the tank is empty, it should be inspected to ensure it meets minimum requirements of tank performance. By checking for baffles, water tightness and inflow, you can offer the owner the ability to deal with small problems before they become large.

Baffles

Identifying the inlet and outlet baffles is critical for the tank's good performance. The loss of a baffle can reduce system life and performance. The requirement of effluent screens in the tanks will increase the need to check the outlet end of the tank. Be sure that at least a four-inch gap between the piping and each baffle exists in the tank. Excessive corrosion or breakdown of the baffles may be a result of hydrogen sulfide buildup in the tank. This is a naturally created gas that needs to be vented from the septic tank. The breakdown is caused by a lack of venting, so verify that the tank is properly venting through the plumbing stack on the structure.

Water tightness

Verifying that the tank is water tight starts when the tank is opened. The effluent level in the tank should be at the outlet piping. If the effluent is lower, the tank is not water tight. After pumping, the submerged portion of the tank is checked for visible cracks or roots. In many cases these will be identified by water leaking into the tank. A tank is noncompliant if it is not water tight below the operating depth and is not working correctly if it is not water tight above the operating depth.

Inflow from System

Effluent running back into the tank shows that the system is not accepting the effluent as designed, so the soil treatment area should be further explored. Sewage running in from the structure shows that there is a leaky fixture, and this also should be addressed with the owner.

6. Replace Maintenance Hole Cover

Be sure the cover is in good shape and properly secured. This can mean that all the screws are replaced for a plastic lid or that the cement lid meets the weight requirements in Chapter 7080. **Maintainers are required under MN Rules Chapter 7080.2450, Subp. 3 (C) to bring the tank access into compliance with MN Rules 7080.1970 (D):**

Covers for maintenance holes must:

1. **be secured by being locked, being bolted or screwed, having a weight of at least 95 pounds, or other methods approved by the local unit of government. Covers shall also be leak resistant; and be designed so the cover cannot be slid or flipped, which could allow unauthorized access to the tank;**
2. **have a written and graphic label warning of the hazardous conditions inside the tank;**
3. **be capable of withstanding a load that the cover is anticipated to receive; and**
4. **be made of a material suitable for outdoor use and resistant to ultraviolet degradation.**

Be sure the cover is in good shape; if there are odors, a little weather stripping can seal the cover. Do not use caulk or expandable foam since these products are not designed for removal. Be careful to not strip the plastic threading when returning screws - stripped screws pose an ITPHS (7080.1500 Subp. 4 (A))!

7. Restore Yard

Leaving the property as you found it is a small but important step to minimize problems at the site. Making sure the power is on and the lids are all secure is a must. This is also a great time to check and pick up all the tools used at the job.

8. Get Paid

This step can be the hardest and one that each business deals with differently. Be certain that it is being addressed.

9. Proper Land Application of the Septage

Septage must be land applied or taken to a treatment facility following all applicable rules and regulations. This is discussed in detail later in this section.

10. Receipt

According to MN Rules Chapter 7083.0770, Subp. 2 (A), a record of the pump out must be provided to the homeowner. It is good practice to make this a part of the receipt for services provided to the homeowner upon payment. This record must include:

- **The pump-out date**
- **Gallons removed**
- **Any tank leakage below or above the operating depth**
- **Access point used to remove septage**
- **Method of disposal**
- **The reason for pumping**
- **Any safety concerns with the maintenance hole cover**
- **Any troubleshooting or repairs conducted**

A receipt should identify the method of recycling that is applied to the waste as well as the treatment method. A tank maintenance reporting form can be found online at septic.umn.edu/ssts-professionals/forms-worksheets, and includes additional information recommended for the owner. A clear picture of the system is valuable to the owner. In some counties, septic tank compliance may be required to be submitted by the Maintainer.

11. Improper Maintenance Notice

Chapter 7080 only allows the removal of solids through a maintenance hole. If the owner will not allow solids to be removed in this way, it should be noted in your records. The note should include a statement from the owner identifying that it was their choice and the reason for the decision. MN Rules Chapter 7083.0770, Subp 2 (C) states that a signed statement by the owner is required if they refuse to allow removal of solids and liquids through the maintenance hole.

Effluent screens

Effluent screens should be removed and cleaned upon service. Screens can either be replaced with new ones or they can be rinsed off with a hose stream over the inlet opening of the tank so all material removed in cleaning goes back into the tank. Safety dictates always wearing gloves when performing this task. Never allow the screen cleanings to be left on the ground surface. Observations should be made regarding past or present elevated liquid level in the tank caused by a screen clogging or other downstream conditions. If the liquid level is elevated, the tank must be pumped down before removing the screen to avoid passing the solids out into the soil treatment system as the screen is removed. Some screens have a secondary device to prevent solids bypass.

In most cases, the effluent screen is cleaned when the tank is pumped, but it should be inspected at a frequency of at least every one to two years. Observations show that frequency of cleaning the screen is less when the screen is placed in the second compartment of a two-compartment tank than if placed in a single compartment tank. Other factors that can increase the frequency of maintenance include:

- High content of fats, greases, and oils
- Presence of hair or laundry lint
- Presence of excessive solids through use of garbage disposal or excessive toilet tissue
- High water usage and peak flows

There is some evidence that when backwash from water softening units is plumbed into the septic system, increased effluent screen maintenance may be required. More research is needed in this area. Clogging of screens should not be considered an indication of a problem with the screen unit since the purpose of a screen is to catch suspended solids. Rather, *premature* clogging may be an indicator of problems such as:

- Reduced detention time due to excessive flows
- Neglecting to pump out the septic tank as needed
- Excessive flushing of grease or oil down the kitchen drain
- Use of a garbage grinder
- Excessive toilet paper use

If a screen requires servicing more frequently than anticipated by design, either the effluent screen or the wastewater characteristics should be evaluated to find the cause for premature clogging. This may indicate leaks in the fixtures, excess water use, poor wastewater quality, or that the screen is not adequately sized for that application.

Cleaning an effluent screen

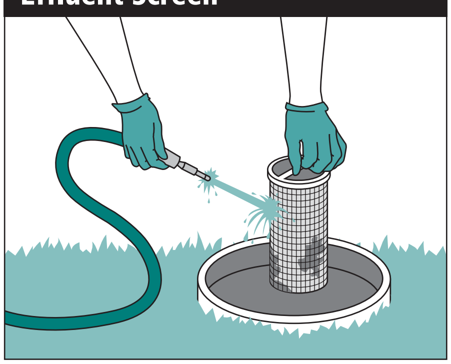
1. DO NOT ENTER the septic tank for any reason!

   Noxious gasses exist in septic tanks and can result in serious injury or death. You do not need to enter the tank in order to clean the screen.

2. Put on waterproof, disposable gloves and safety glasses. Remove the maintenance hole cover of the septic tank and note the liquid level in the tank. The liquid level should be at the bottom of the outlet pipe. If it is below the outlet pipe this is a sign that the tank is not water tight and you should call a septic professional to help troubleshoot the problem. If the liquid level is above the outlet pipe or the effluent screen do not remove the screen. This is a sign of problems somewhere in the system; a plugged screen, pump failure, plugged soil treatment area, etc. Pump the tank before removing the screen. This will prevent a surge of excess effluent, containing unwanted solids, from moving into the next component of the treatment system.

3. If the liquid level is at the bottom of the outlet pipe, remove the screen from its casing. Note the condition of the screen and the extent of build-up. Using a garden hose, spray off the screen over the first septic tank maintenance hole (as shown in Figure 8.1) or place the screen in a 5-gallon bucket and spray off all material into the bucket. Be careful to prevent splashing onto your body or clothes or into the yard. Do not clean the effluent screen in the grass next to the septic tank; raw sewage in the yard is a public health hazard.

FIGURE 8.1 Cleaning An Effluent Screen



4. Return the screen to its casing once it has been cleaned. Dump the contents of the bucket into the septic tank and add a small amount of bleach and rinse the bucket several times (emptying the rinse water into the septic tank each time.) Secure the maintenance hole cover once you are finished. The solids from the screen cleaning will settle and get removed the next time the tank is pumped during routine maintenance.

   Make sure the screen is reinstalled properly to ensure proper operation.

5. Once the job is complete, dispose of the gloves and wash your hands thoroughly with soap and hot water. If your clothes were contaminated, remove them immediately and launder in hot water.

Troubleshooting an Effluent Screen

If an effluent screen seems to need excessive cleaning, it may be that the homeowner has too many solids, chemicals or too much water going down the drains.

- Large volumes of wastewater generated in a short period of time can result in turbulence in the septic tank and reduced retention time, which can lead to solids plugging the effluent screen. To avoid this situation:
  - Do not do all the laundry in one day. Spread wash loads throughout the week and wash at times when there is not a lot of water being used in the home.
  - Do not run multiple water-using devices at the same time, such as showering or running the dishwasher while doing the laundry.
  - Disconnect water treatment devices such as iron removers and water conditioners from the septic system. The discharge water from these devices is considered clean and does not need further treatment.
- Garbage disposals and dishwashers with food grinders are notorious for adding solids to a septic tank. Minimize the use of the garbage disposal, or eliminate its use altogether by placing food scraps into a compost bin or trash can. Most new dishwashers are equipped with food grinders which act as garbage disposals. To keep solids out of your system, scrape all dishes well before placing them in the dishwasher.
- Washing machines can add a significant amount of lint to your septic tank. Avoid this by placing a simple lint filter on the end of the outlet hose.
- Do not use the toilet as a trash can. Nothing other than human waste and toilet paper should be flushed. Do not flush tissues, hygiene products, cigarette butts, etc.
- Reduce the amount of strong cleaning chemicals and antibacterial soaps used in the home. Bleach and other antibacterials can kill the beneficial bacteria in the septic tank, reducing the rate of solids decomposition.
- Do not flush unused or expired medications. These products can kill the beneficial bacteria in your septic tank.
- Do not use products advertised as septic additives or septic cleaners. These products are not necessary and may kill the beneficial bacteria in your septic tank.

Problems: Professional Cleaning, Not Additives

A 1,000 gallon septic tank serving a three-bedroom home with four or five occupants should be cleaned every one to three years. To estimate the proper cleaning frequency, it is recommended that the septic tank be assessed six months after it is first placed into service by a new owner. This will allow the Maintainer to determine the rate at which solids accumulate according to current use. This also allows for removal of any chemicals from the new construction or significant cleaning/painting associated with new tenants and will identify typical use. It's particularly important that all three layers (sludge, clear zone, and floating scum) are developing.

Septic tank solids should be removed from the tank and hauled away periodically by licensed maintainers. Additives are not recommended because their use may flush the solids into the soil treatment area, plugging the soil pores.

A septic tank has three layers: a floating scum layer, a sludge layer at the bottom and a clear layer in between. When the septic tank accumulates too much scum and sludge, flow through the clear layer is too fast and solids are flushed out into the soil treatment area. A good cleaning service will agitate the scum and sludge layers into suspension, remove the entire contents of the tank, and haul them away.

Additives may chemically agitate the tank, flushing the contents into the soil treatment area. This harms the soil by plugging its pores.

Three types of additives are marketed. One type adds bacteria and enzymes. Plenty of these are already present in the septic tank. Another type of additive increases the volume of the bottom sludge layer so that it is washed out into the soil treatment area. A third type breaks down the scum layer, again washing this into the soil treatment area. The last two can cause permanent damage to the soil treatment area.

When considering whether or not to use an additive, ask three questions:

1. Are the additive claims substantiated by laboratory tests rather than testimonials?
2. Will the additive cause damage to any other parts of the sewage treatment system?
3. Will the additive cause damage to the environment, such as by adding dangerous chemicals to the groundwater?

Proper cleaning of the septic tank by a licensed Maintainer will prevent most tank problems. **MN Rules Chapter 7080.2450, Subp. 5** strictly prohibits the use of additives as a means to reduce the frequency of proper maintenance.

Effect of Using Hydrogen Peroxide

The use of hydrogen peroxide as an additive to reduce the biomat in the soil treatment area was researched in the early 1980's and was found to aggressively impact the organic material, but only with sand columns. Additional research on various soil textures found that the use of hydrogen peroxide as an additive would be detrimental to most soil treatment systems.

The following are excerpts from a report entitled "Chemical Rehabilitation of Soil Wastewater Absorption Systems Using Hydrogen Peroxide: Effects on Soil Permeability," by David L. Hargett, E. Jerry Tyler, and James C. Converse, 1983.

Experiments on wastewater-clogged columns of four soil types demonstrated that H_2O_2 application may further reduce infiltration rate, beyond the clogged state, in medium and fine textured soils. High H_2O_2 loading rates produced some degree of reclamation of infiltrative capacity in clogged sandy loam columns, but none of the H_2O_2 treatments resulted in infiltration rated greater than 35 percent of initial values.

These research results definitively show that H_2O_2 can do serious, and possibly irreversible, damage to the physical integrity and infiltrative capacity of most soils. This data, in combination with a rigorous review of the previous research, do not substantiate the use of H_2O_2 for wastewater soil absorption systems, even those in sands.

Safety Keys for Maintainers

Safety gear for Maintainers

1. Safety goggles
2. Emergency eyewash station
3. First aid kit
4. Half-mask respirator with appropriate cartridge
5. Gloves
6. Shoulder-length fully coated neoprene gloves
7. Carbon dioxide fire extinguisher

Onsite wastewater systems for domestic wastes pose a number of potentially life-threatening situations. The greatest hazards are:

- Enclosed spaces
- Electrical shock
- Explosion
- The presence of pathogens
- Collapse of structures due to corrosion

Safety for Confined Spaces

A septic tank is considered a confined space. All OSHA requirements must be met before entering a septic tank for any period of time for any reason. This manual discusses how to conduct most management activities without ever needing to enter a tank.

Of the enclosed spaces associated with onsite systems, septic tanks are the most likely to be hazardous, but any enclosed space should be considered dangerous. The gas space must be adequately ventilated using blowers and a large diameter, flexible hose. Be sure to test the gas space frequently for:

- Sufficient oxygen. Use an oxygen deficiency meter. Sufficient oxygen generally ensures that carbon dioxide will also be in a safe range.
- Hydrogen sulfide. Use lead acetate paper or a hydrogen sulfide detector.
- Explosive conditions. Use a combustible gas indicator.

A person entering the confined space must be secured with a lifeline, preferably attached to a safety harness. Appropriate lifelines are 3/4-inch manila, 1/2-inch nylon, or 1/2-inch polypropylene. The free end of the line should be tied to an appropriate object so that it does not fall into the tank.

Two physically able people must remain on the surface when someone enters a tank. Rescue of a person who has collapsed in a confined space without a lifeline should be undertaken only by someone wearing a self-contained breathing apparatus and a lifeline, or after adequate ventilation and testing as previously described. The entry of a second person without adequate protection will only result in two casualties.

Remember, no flames, sparks, or electrical tools are allowable until the atmosphere of a confined space is proven non-explosive. Do not smoke.

Suffocation due to oxygen deficiency is one hazard of enclosed spaces. Chemical and biological activities present in onsite sewage systems consume oxygen. Also, the proportion of atmospheric oxygen to other gases can be substantially decreased because of the production of such gases as carbon dioxide and methane. These can seep through joints, cracks, and even soil into confined spaces.

Be aware of the danger levels of oxygen depletion. Normal air **contains 21 percent oxygen**. At 14 to 16 percent, the minimum safe exposure is eight hours. For a short time, humans can tolerate levels as low as 12 percent, but levels below ten percent are potentially fatal. At seven percent or below, conditions are considered fatal.

Toxic gases, which are common at onsite waste water systems, are another hazard. The following are some of the attributes of toxic gases that may be present in an onsite system:

Hydrogen Sulfide (H_2S)

- Forms during anaerobic decomposition
- Has a rotten egg odor in small concentrations: sense of smell is rapidly impaired as concentrations increase; loss of smell occurs in two to 15 minutes at 0.01%, faster at higher levels
- Causes death in a few minutes at 0.2%; acute poisoning is rapid at 0.07 to 0.1%
- Maximum safe 60-minute exposure level is 0.02%
- Maximum safe eight-hour exposure level is 0.001%

Carbon Dioxide (CO_2)

- Forms during aerobic or anaerobic decomposition
- Appears colorless, odorless, and may have acid taste at high concentrations
- Is heavier than air, so found near bottom
- Cannot be endured at 10% or higher for more than a few minutes, even if sufficient oxygen is present
- Maximum safe 60-minute exposure level is 4%
- Maximum safe eight-hour exposure level is 0.5%

Gasoline Fumes

- Result from spills or improper disposal
- Rapidly fatal at 2.4%
- Maximum safe six-minute exposure level is 0.4%

Electricity Hazards

Electricity and water are a lethal combination. Safety precautions include:

- All equipment must be properly grounded with a third wire.
- All hand tools must be double insulated or properly grounded.
- Ground fault interrupters should be used on circuits with potential exposure to water.
- Be aware of the location of lines, cards, etc. to prevent cutting through the insulation.

- Unless a wire is absolutely known to be dead and it is impossible for it to accidentally become live again, handle it as though it were a live wire.
- One person should never work alone on energized equipment that operates at 440 volts.
- All equipment that is installed in a confined/enclosed space (such as sump or dry well) should be of explosion-proof design.
- All lights and switches should be of explosion-proof design.

Explosion Hazards

Explosions are another hazard. The most common explosive agent found in onsite systems is methane. Methane is colorless and odorless. It is not in itself toxic, but it may cause oxygen depletion. The explosive limits are atmospheric concentrations of five to 15 percent.

The septic tank head space may contain as much as **60 percent** methane. Even though there may be little or no oxygen to support combustion, an explosion may nonetheless occur. As a tank is pumped, the inrushing air can create an explosive condition when none had previously existed. Be aware that methane, which is less dense than air, may seep into areas containing electrical equipment.

Another explosive agent you may encounter is gasoline. The explosive limits for gasoline fumes are atmospheric concentrations of 1.3 to six percent. These fumes are denser than air, so they are more likely to be near the bottom of the gas space.

Infectious Disease Hazards

Wastewater should be assumed to be infectious. All workers should keep their hands and fingers from their noses, mouths, and eyes while working with wastewater. A good rule is to keep your hands below your collar while you work. Before eating, drinking, or smoking, be sure to wash up thoroughly, and, preferably, change your clothes. You should provide yourself with a way to change out of your work clothes and wash up before entering a food store, restaurant, or even your car or home.

Maintain current vaccinations against typhoid, paratyphoid, tetanus, hepatitis A and B, and polio.

Structural Collapse Hazards

Metal parts may fail due to corrosion. Most metals, when exposed to high humidity and particularly to condensed moisture, will corrode rapidly, thus losing their structural integrity. Anaerobic decomposition produces gases which can dramatically increase corrosion rates.

For the above reasons, always test structural components such as ladders, brackets, or railings before relying on them for support. To avoid the hazards of collapsing materials, structural components that are installed in confined or enclosed spaces should be of corrosion-resistant materials.

Introduction to Land Application

These guidelines provide maintainers with information on how to manage septage and restaurant grease trap wastes. Because land application is a common and sometimes complex management option, these guidelines focus on requirements for land application. These guidelines combine the federal rule requirements and the

Minnesota Pollution Control Agency (MPCA) management guidelines for land application of septage into one document. If these guidelines are followed, maintainers will be in compliance with 40 CFR, part 503, and the MPCA septage management guidelines. These guidelines also include requirements for land application of restaurant grease trap waste. If these guidelines are followed, maintainers will also be in compliance with MPCA requirements for land application of restaurant grease trap waste. Requirements for land application of commercial wastes, other than restaurant grease trap waste, are not included in these guidelines.

Definitions

"Agronomic rate for nitrogen" is the amount of septage that will provide the nitrogen required for crops or other vegetation grown on the land.

"Cover crop" is a small grain or other close-growing vegetation not grown for harvest (e.g. vegetation growing on the land set aside for conservation purposes).

"Cropping year" means a year beginning on September 1 of the year prior to the growing season and ending August 31 the year the crop is harvested. For example, the 1994 cropping year began September 1, 1993 and ended August 31, 1994.

"Domestic septage" *(federal definition) means either liquid or solid material removed from a septic tank, cesspool, portable toilet, Type III marine sanitation device, or similar treatment works that receives only domestic sewage. Domestic septage does not include liquid or solid material removed from a septic tank, cesspool, or similar treatment works that receives either commercial wastewater or industrial wastewater and does not include grease removed from a grease trap at a restaurant.*

"Fallow land" is land that is not cropped and kept cultivated throughout a growing season and has a vegetative cover of less than 25 percent. Any land that is not cropped and cultivated during the months of September through May where a crop will be grown the following growing season is not considered fallow land.

"Feed Crops" are crops produced primarily for consumption by animals.

"Fiber Crops" are crops such as flax and cotton.

"Food Crops" are crops consumed by humans. These include but are not limited to fruits, vegetables, and tobacco.

"Highly permeable soil" means soil whose soil leaching potentials are rated as severe, poor filter for soil pestacide loss, by the Natural Resource Conservation Service using the procedure found in part 620, Soil Interpretation Rating Guides of the United States Department of Agriculture-Natural Resources Conservation Service National Soil Survey Handbook.

"Pathogens" are organisms that can cause an infection or disease in a susceptible host.

"pH" is the degree of acidity or alkalinity of a solution and is a measure of the strength of an acid or a base. It is expressed as the logarithm of the reciprocal of the hydrogen ion concentration measured at 25 degrees Celsius (77 degrees Fahrenheit) or measured at another temperature and then converted to an equivalent value at 25 degrees Celsius.

"Maintainer" is an individual or business holding a Maintainer license issued by the Minnesota Pollution Control Agency in accordance with MN rule chap. 7080.

"Residential development" means ten or more places of habitation concentrated within ten acres of land. The term also includes schools, churches, hospitals, nursing homes, businesses, offices, and apartment buildings or complexes having ten or more living units.

"Septage" (State Definition) means solids and liquids removed from an SSTS and includes solids and liquids from cesspools, seepage pits, other pits, or similar systems or devices that receive sewage. Septage also includes solids and liquids that are removed from portable, incinerating, composting, holding, or other toilets. Waste from Type III marine sanitation devices, as defined in Code of Federal Regulations, title 33, section 159.3, and material that has come into contact with untreated sewage within the past 12 months is also considered septage.

"Winter" is the time that soils are frozen or snow covered, so that incorporation or injection are not possible. This time period varies from year to year.

At the federal level, land application of domestic septage is regulated by 40 CFR, part 503. At the state level, MN Rule Chapter 7080 requires anyone that pumps individual sewage treatment systems to be licensed by the MPCA. A table of differences between Minnesota's Guidelines and EPA's 40 CFR, part 503 can be found in Table 8.1

TABLE 8.1 Comparison of Federal EPA Requirements and the Minnesota (MPCA) Guidelines for the Land Application of Domestic Septage to Non-Public Contact Sites

	Federal 503 Rules	Minnesota [1] Guidelines
PERMITS REQUIRED	No	No
APPLICATION RATE		
Based on:	Crop Nitrogen Requirement	Crop Nitrogen Requirement and Other Nitrogen Impacts
Maximum Annual Rate (gal/ac/year)	No	Yes
Hydraulic Loading Limits	No	Yes
Maximum **Daily** Rate	No	15,000 gal/ac (total for winter) [2] 10,000 gal/ac (surface applied) [3]
RECORD KEEPING	Yes	Yes
Reporting Required	None	None
Years to be retained	Five years	Five years
Required Information		
Site location	Yes	Yes
Date of application	Yes	Yes
Time of application	Yes	No
Number of acres	Yes	No
Amount of septage applied	Yes	Yes
Crop grown	Yes	Yes
Weather conditions	No	No
Certification	Yes	Yes
Depth to water table	No	Yes
Percent vegetative cover	No	No
PATHOGEN REDUCTION	pH of 12 for 30 minutes (temp adjusted) and harvesting restrictions **OR** Site and harvesting restrictions	pH of 12 for 30 minutes (temp adjusted) and harvesting restrictions **OR** Site and harvesting restrictions

TABLE 8.1 Comparison of Federal EPA Requirements and the Minnesota (MPCA) Guidelines for the Land Application of Domestic Septage to Non-Public Contact Sites

	Federal 503 Rules	Minnesota [1] Guidelines
VECTOR ATTRACTION REDUCTION	Three Options: pH of 12 for 30 minutes (temp adjusted) **OR** Injection **OR** Incorporation	Three Options: pH of 12 for 30 minutes (temp adjusted) **OR** Injection **OR** Incorporation
CROP HARVESTING RESTRICTIONS		
Human Food Crops With Harvestable Portions That Touch the Soil Surface But Are Totally Above Ground	14 Months	14 Months [4]
Root Crops	20 Months [6] 38 Months [7]	20 Months [6] 38 Months [7]
Other Food, Fibers or Feed	30 Days	30 Days
Grazing	30 Days [4]	30 Days [4]
Turf	1 Year [4]	1 Year [4]
ACCESS RESTRICTION		
(Fencing, posting, remoteness, etc.)	Required for Non-Stabilized	Required
SET BACK REQUIREMENTS		
Surface Waters	None	Varies with site slope [8]
Public Water Supply Well	None	1000 ft [8]
Private Drinking Water Well	None	200 ft [8]
Residence	None	200 ft [8]
Property Boundary	None	10 ft [8]
Recreational Area	None	600 ft (200 ft trails) [8]
Intermittent Streams	None	100 ft [8]
Road Right-of-Ways	None	10 ft [8]
Holes and Channels	None	Varies with site slope [8]
SOIL REQUIREMENTS		
Slope	None	0-6% (if surface spread) 0-12% (injected)
Minimum Depth to Seasonally Saturated Soil or Bedrock	None	3 ft
Permeability	None	If 0.2 inches/hour or less, this soil is suitable only for surface application with incorporation within 48 hours or injection.
Flooding	None	Free from flooding hazard

Notes: 1 = Minnesota's entered information is guidelines, not regulation.
2 = Medium-textured soils.
3 = Fine-texture soils.
4 = Non-treated septage.
5 = Use of septage not allowed on leafy vegetables or tobacco.
6 = If septage remains on the sol surface for four months or longer.
7 = If septage remains on the soil surface for less than four months.
8 = Non-stabilized, surface spread septage.

Commercial wastes are any liquid or solid materials removed from septic tanks, holding tanks, or similar treatment works that receive either commercial or industrial wastewater. A waste is not considered commercial if the wastewater is only from the sanitary facilities from the business. Examples of commercial wastes include waste pumped from small animal slaughtering operations, pre-treatment wastes from a food processing facility, or waste from a flammable trap at a car wash. Land application of non-hazardous commercial waste is regulated at the federal level by 40 CFR, part 257, and at the state level by MN Rules Chapters 7001 and 7035.

It is important for maintainers to be aware that not all commercial wastes can be legally land applied safely. Before land applying commercial wastes other than restaurant grease trap waste, the MPCA district office should be contacted to determine if the waste can be land applied. In most cases, testing of the waste is needed before land application can take place, and in some cases an MPCA permit is required.

Land applying septage is becoming more and more visible to the public. Because of this, maintainers may find themselves having to communicate more with the public and local government officials than in the past. Public relations has become part of the job and are not something that everyone finds enjoyable. However, ignoring concerns of the public and other groups can cause time consuming controversies and leave you without a land application site to use. Following the recommendations from the MPCA will not always mean that the public or other organized groups will support what you are doing. You have to find the best way that you can to work with the people in your community to show them land application is an acceptable option for managing septage.

Septage Treatment

Septage and Its Characteristics

Septage is managed in a variety of ways throughout the country and in Minnesota. Common methods of management include transferring septage to a Publicly Operated Treatment Works (POTWs), land application, and land filling.

In Minnesota, the options for management are determined by where you are located in the state. In the larger metropolitan areas, it is common for septage to be discharged into a POTW where it is treated and managed as biosolids. The septage becomes the POTW's responsibility and is subject to the requirements of MN Rule Chap. 7041 (Sewage Sludge Management Rules) and 40 CFR, part 503. In smaller communities or areas that are not close to a POTW, transfers are not practical and septage is typically land applied. **Land filling of septage is not allowed** in Minnesota because it is in liquid form, and landfills cannot accept materials containing free liquids.

Some wastewater treatment plant managers will not accept septage because they are concerned that it will overload their system. Septage is a waste that has a very high Biochemical Oxygen Demand (about 6480 mg/L) and can shock a wastewater treatment plant and reduce treatment. At most plants, changing the way septage is added to the system can lessen the impact to the plant. You may receive instructions on where and when septage should be discharged into the system to prevent problems from occurring. You need approval from the operator of the wastewater treatment plant to discharge septage into their facility.

The quantity of septage removed from septic tanks each year is not tracked by the state or the federal government at this time; however, estimates have been made by using the following assumptions: approximately 500,000 homes in Minnesota have individual sewage treatment systems; these systems should be pumped every three years if maintained properly; and the average septic tank capacity is 1500 gallons. Using these assumptions, about 250,000,000 gallons of septage are pumped each year. Of this total, about 173,000,000 gallons of septage are land applied, and the remaining 77,000,000 gallons are transferred to POTWs. This makes land application the most common method for managing septage in Minnesota.

Federal requirements for land application provide limited information on how to prevent runoff or contamination of groundwater. The federal 503 rule simply states that these must not occur. The state guidelines provide maintainers with detailed information on site suitability, separation distances to features such as surface waters and wells, and detailed site management requirements. These are practices commonly used for land application of other by-products and wastes in Minnesota. They have proven to be effective for preventing the problems from runoff of wastes and contaminants from application sites and preventing contamination of groundwater.

Maintainers are not required to analyze septage before it is land applied, though they should observe the waste in the tank to determine if it may be industrial or hazardous waste as shown in Figure 8.2. Both state and federal requirements use average septage analysis results to calculate allowable application rates. Table 8.2 contains concentrations for specific parameters in septage that have been determined by testing. Septage supplies about five pounds of nitrogen, and two pounds of phosphorus per 1000 gallons.

FIGURE 8.2 Observe Waste in Tank

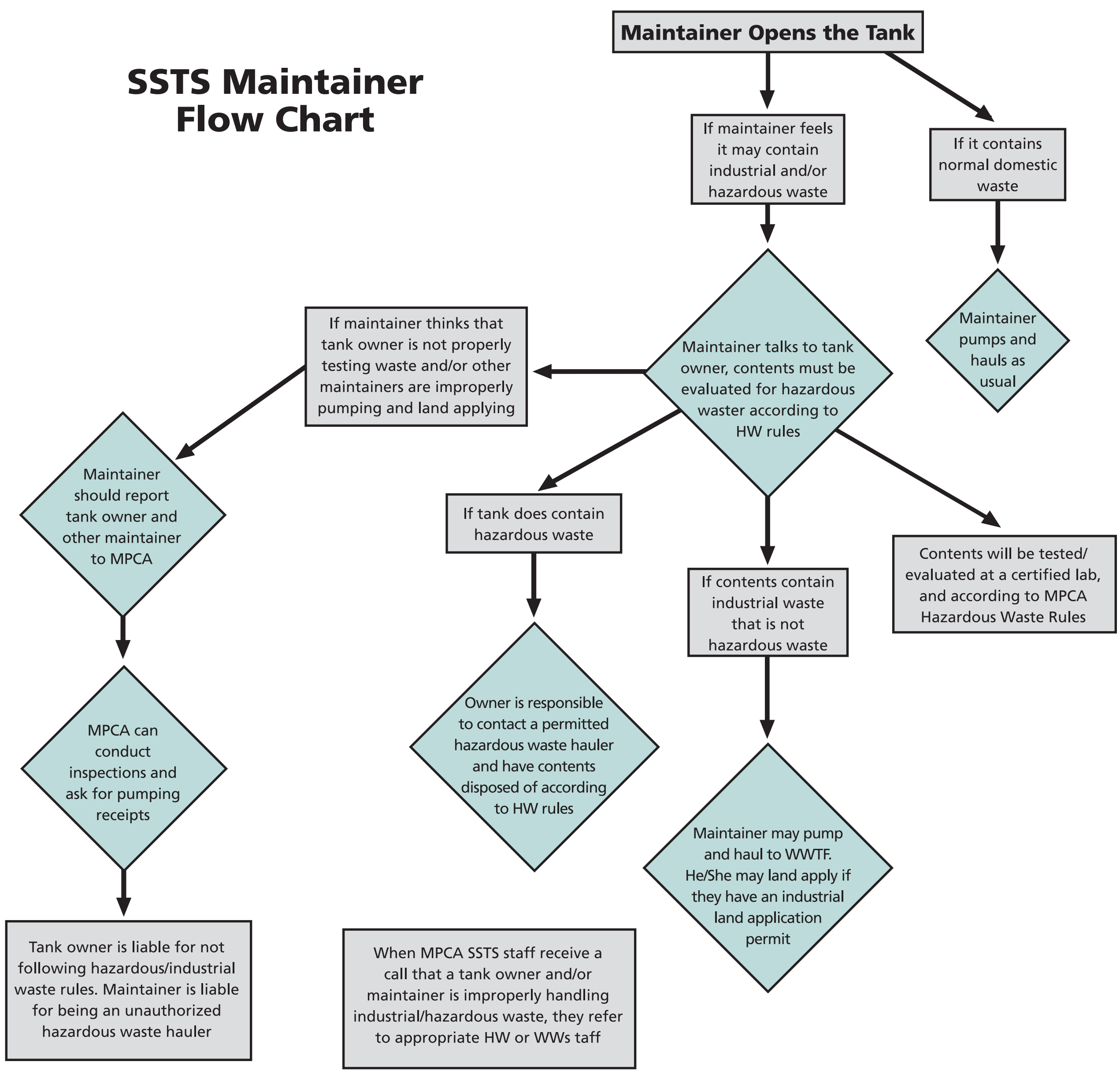


TABLE 8.2 Characteristics of Septage[1]

Parameter	Concentration (mg/L)		
	Average	Minimum	Maximum
Conventional Parameters			
Total Solids	34,106	1,132	130,475
Total Volatile Solids	23,100	353	71,402
Total Suspended Solids	12,862	310	93,378
Volatile Suspended Solids	9,027	95	51,500
Biochemical Oxygen Demand	6,480	440	78,600
Chemical Oxygen Demand	31,900	1,500	703,000
Total Kjeldahl Nitrogen	588	66	1,060
Ammonia Nitrogen	97	3	116
Total Phosphorus	210	20	760
Alkalinity	970	522	4,190
Grease	5,600	208	23,368
pH	—	1.5	12.6
Metals			
Arsenic	0.141	0	3.5
Barium	5.76	0.002	202
Cadmium	0.097	0.005	8.1
Chromium (total)	0.49	0.01	34
Cobalt	0.406	<0.003	3.45
Copper	4.84	0.01	261
Cyanide	0.469	0.001	1.53
Iron	39.3	0.2	2,740
Lead	1.21	<0.025	118
Manganese	6.09	0.55	17.1
Mercury	0.005	0.0001	0.742
Nickel	0.526	0.01	37
Silver	0.099	<0.003	5
Tin	0.076	<0.015	1
Zinc	9.97	<0.001	444
Organics			
Methyl Alcohol	15.8	1	396
Isopropyl Alcohol	14.1	1	391
Acetone	10.6	0	21
Methyl Ethyl Ketone	3.65	1	240
Toluene	0.17	0.005	1.95
Methylene Chloride	0.101	0.005	2.2
Ethylbenzene	0.067	0.005	1.7
Benzene	0.062	0.005	3.1
Xylene	0.051	0.005	0.72

[1] Taken from "EPA Guide to Septage Treatment and Disposal", EPA/625/R-94/002, September 1994.

Variability of Septage

The rate at which solids accumulate in a septic tank depends upon the nature of the raw sewage and the use of the septic system.

For example, the use of a garbage disposal will approximately double the rate of solids accumulation. Although a septic tank should be maintained on a regular basis, many homeowners wait until problems arise with the treatment system. Other homeowners will have the solids removed from their septic tank each year regardless of the amount of accumulation.

Consequently, the nature of septage is highly variable from one load to the next and also varies by geographic areas in the state. Some average values for the characteristics of septage were measured by the Department of Agricultural Engineering at the University of Minnesota and are presented in Table 8.3. Values for nitrogen are presented in milligrams per liter and in pounds per 1,000-gallon truckload.

The three-year study on the characteristics of septage and the pollution potential of land-spread septage on groundwater quality was made possible through the financial support of the Minnesota Water Resources Research Center. Landspreading sites were selected in Crow Wing County, and instrumentation was installed to evaluate the movement of nitrates and coliform bacteria.

TABLE 8.3 Characteristics of Septage in Minnesota

Characteristic	Mean Values	
	Brainerd Area	White Bear Lake Area
chemical oxygen demand*	16,100 mg/L	13,600 mg/L
total solids	1.9%	4.3%
volitile solids	1.0%	2.4%
total Kjeldahl nitrogen	486 mg/L (4.05lbs/1,000gal)	983 mg/L (8.2lbs/1,000gal)
nitrogen as nitrate	115 mg/L (0.96lbs/1,000gal)	133 mg/L (1.11lbs/1,000gal)

* Chemical Oxygen Demand (COD) is a measure of the amount of oxygen necessary to decompose all organic matter. COD is usually
higher than BOD because more compounds can be oxidized chemically than biologically.

Restaurant Grease Trap Wastes

Grease traps are used by restaurants to prevent fats, oils, and greases from entering the soil treatment area of an individual sewage treatment system or the collection system of a centralized sewage treatment system. Wastes that are pumped from these traps are very high in fats and oils and may or may not contain sanitary wastes.

Grease traps are set up in two main configurations. One configuration is a separate tank that receives only wastewater from the kitchen that is high in fats, oils, and greases. The effluent from the tank is then discharged to a centralized sewage treatment system or an individual sewage treatment system septic tank. Restaurants that have individual sewage treatment systems generally install several septic tanks in series to provide a cleaner effluent before discharging it to the soil treatment area. In this system design, the first septic tank in the series acts as a grease trap. In these guidelines, the first septic tank in the series will be considered the same as a grease trap, and the remaining tanks in series regular septic tanks.

Grease trap wastes may be transferred to a POTW; however, the same issues exist as those for septage transfers. It is not likely that smaller POTWs will accept this waste because of the high biochemical oxygen demand of fats and oils. Landfills cannot accept this waste because of the liquid content; therefore, land application is a common form of management, though issues exist with this method, as shown in Table 8.4.

TABLE 8.4 The Problems with FOG (Fats, Oils, and Grease)

Soil Systems	Septage Application
Clogging of soil pores	Clogging of soil pores
Slow breakdown	Clinging to and killing vegetation
Plugging of distribution	Low nitrogen

Table 8.5 provides an analysis from a composite of four restaurant grease traps. This data shows that, unlike septage, grease trap wastes are low in nitrogen.

TABLE 8.5 Grease Trap Waste Characterization[1]

Parameter	Results on Wet Weight Basis
Total Solids (%)	6.0
Total Volatile Solids (%)	88.0
Fats, Oils & Grease (%)	1.1
pH (SU)	4.4
Total Nitrogen (%)	0.0056
Total Phosphorus (%)	0.0029
Potassium (%)	0.0036

1Taken from: Rohm, S.P., "Land Treatment of Grease Trap Wastes - A Beneficial Use. Approach", Pumper. March 2000.

Limited research has been conducted on the effects of land applied grease trap wastes on the soil or plants. Some studies suggest that the soil can break down this waste and that the waste may even be beneficial to the soil. The National Association of Waste Haulers conducted a demonstration project and documented observations made on areas receiving grease trap wastes. It was concluded that restaurant grease trap wastes can be land applied safely if rates are limited to four dry tons/acre/year (Rohm, 2000). This is approximately 16,000 gallons/acre using a total solids content of 6 percent.

Wastes similar to those from grease traps are permitted for land application in Minnesota. Sludges produced by treating wastewaters from meat and poultry processing industries can also contain high percentages of fats, oils, and greases. These wastes have been land applied for many years without causing any known problems. Some farmers believe that application of these sludges has actually improved their soil by making it more permeable and better aerated (though these are not measured observations).

Potential Complications

One of the problems that occurs when grease traps wastes are applied to forage or cover crops is that the above-ground portions of the plant are coated with the fats, oils, and greases. This kills the above-ground portion of the plant temporarily. Plants do recover since the roots are not damaged; however, yields are likely affected.

Excessive application rates of FOG can cause clogging of soil pores. This could lead to problems with soil aeration or runoff, since the soil's infiltration capacity and rate may be reduced. To avoid this problem, application rates must be limited, especially when surface applied. The application rate that causes problems like this to occur has not been established, so these guidelines use conservative application rate limits (see section on requirements for land application of restaurant grease trap wastes).

Another concern with land application of grease trap wastes is that they can be very odorous. Odor is not only a nuisance condition but can attract vectors such as flies and rodents to application sites. To reduce the odor problem, it is recommended that incorporation or injection be used as an application method whenever possible and that care be taken when locating sites that will be used for land application of grease trap wastes. If these wastes are applied to the surface, they must be mixed with septage and lime stabilized.

Some maintainers have noted that restaurant grease traps can contain a lot of floating oils. These oils should be collected in the restaurant and recycled. If there are a lot of oils in the grease trap, the management of the restaurant should be informed and their workers trained on how to collect and manage this oil. Restaurant managers should be encouraged to train their workers to catch as much of the fats, greases, and oils as possible before they go down the drain. This will not only reduce problems with their effluent, it will also limit the amount of this waste that is land applied.

Septage Storage

MPCA SSTS Maintenance businesses are allowed to store up to 50,000 gallons of septage in registered underground sewage tanks without a state disposal system permit (SDS permit) as long as a local SSTS permit is issued for the practice. The following conditions must be met before septage storage up to 50,000 gallons is conducted under a local SSTS permit in lieu of an MPCA permit.

- Limit of 50,000 gallons of septage storage
- Local construction permits issued, may include operating permits at local discretion
- Land application by MPCA-licensed SSTS Maintenance businesses
- Underground storage in sewage tanks that are verified and listed by the MPCA
- Tanks and facility must meet requirements for holding tanks contained in Chapter 7080.2290
- If a Maintenance business seeks storage on more than one site, the MPCA permit threshold will be evaluated based on the provision of Chapter 7081.0040, Subp. 1(B)
- All other local requirements must be met (setbacks, zoning considerations, etc.)

Transferring Septage and Restaurant Grease Trap Waste to a Publicly Owned Treatment Works (POTW)

Septage and restaurant grease trap waste can be transferred to a POTW with their permission. Because these two waste types have high biochemical oxygen demands, not all POTWs are willing or able to accept them. POTWs may be more willing to accept domestic holding tank waste because the biochemical oxygen demand averages about 500 mg/L .

Each POTW has the authority to refuse or accept these wastes. This decision is based on how the transfers could affect their system's operation. Information is available to assist POTWs in determining whether they can accept septage or holding tank wastes at their facility. The following documents contain useful information for POTWs trying to decide whether they should accept septage at their facility:

> "Accepting Septage at a Wastewater Treatment Plant" (available from MPCA, Resource Management and Assistance, Certification and Training).
>
> "Septage Handling", (1997). Water Environment Federation Manual of Practice, No. 24. Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314-1994, (703) 684-2400.

"Handbook Septage Disposal Guide", (1984). EPA-625/6-84-009, U.S. Environmental Protection Agency Publication.

If septage or restaurant grease trap waste is transferred to a POTW, this information must be indicated on the hauler's daily record log. This also will apply to the other septage wastes like marine toilets and/or portable toilets. This type of record is needed to show the final destination of the waste to prove it has been properly managed.

Septage Storage Requirements

A structure used to store or treat septage pumped from multiple sources when the structure is not located at a permitted wastewater treatment facility requires a MPCA permit. Requirements for permitting are covered by MN Rules Chapter 7041. Mobile storage units used for the transport of septage do not require an MPCA permit.

To determine if your septage storage structure requires an MPCA permit, contact (800) 657-3864. If a permit is required you will be requested to submit a permit application.

Land Application Requirements for Septage

These requirements are only for land application of septage on areas referred to as non-public contact sites. These are agricultural, forest, and mine lands. Areas that are frequented by the public such as ball fields, golf courses, cemeteries, etc. must meet the more detailed requirements of 40 CFR, part 503, for sewage sludge.

It is important for maintainers to check with local units of government to find out if they have land application requirements or ordinances that must be followed. It is the maintainer's responsibility to be up to date on all rules and ordinances related to land application.

Requirements for Pathogen Control and Vector Attraction Reduction

All septage that is land applied must meet the requirements for pathogen control and vector attraction reduction. These requirements are intended to provide protection against transfer of diseases from the application area. This is done by reducing the number of pathogens present, preventing vectors such as flies and rodents from being attracted to the application site, and by following restrictions on site use. Maintainers must select from the options described in this section to ensure that pathogen control and vector attraction reduction requirements are met.

Pathogen Control Requirements

One of the following options for pathogen control must be met when septage is land applied:

Option 1 - Site Restrictions: The site restrictions A through F in Table 8.6 must be maintained. Table 8.7 provides examples of crops' relationship to the ground surface.

Option 2 – Lime Stabilization with Site Restrictions: The pH of the septage must be raised to 12.0 or greater by alkali addition and without the addition of more alkali, must remain at 12.0 or higher for 30 minutes, and the site restrictions A through C in Table 8.6 must be maintained.

Maintainers are responsible for ensuring that farmers or other end users are informed of site use restrictions and that appropriate precautions are taken to prevent access to sites. This may require that some sites be posted with signs informing the public to stay off the site.

TABLE 8.6 Land Application Site Restrictions

Restriction Reference	Restricted Activity	Waiting Period
A	Food crops whose harvested part may touch the soil/septage mixture	14 months
B	Food crops with harvested parts below the surface	38 months[1]
C	Feed, food, or fiber crops that do not touch the soil surface	30 days
D[2]	Turf harvest	12 months
E[2]	Grazing of animals	30 days
F[2,3]	Public access to land High potential for exposure Low potential for exposure	12 months 30 days

[1]This can be reduced to a 20 month duration between application and harvest when the septage is surface applied and stays on the soil surface four months or longer prior to incorporation into the soil.
[2]Not required if lime stabilization used for pathogen control.
[3]Lands with high potential for exposure are public contact sites, reclamation sites located in populated areas, turf farms, or plant nurseries.
Lands with low potential for exposure are lands with infrequent public use and include areas such as agricultural land, forests, or reclamation sites located in an unpopulated area.

TABLE 8.7 Examples of Crops Impacted by Domestic Septage Site Use Restrictions

These crops have harvested parts that…		
Usually do not touch the ground	**Usually touch the ground**	**Are below the ground**
Peaches	Melons	Potatoes
Apples	Eggplants	Yams
Corn	Squash	Sweet Potatoes
Wheat	Tomatoes	Rutabagas
Oats	Cucumbers	Peanuts
Barley	Celery	Onions
Oranges	Strawberries	Leeks
Grapefruits	Cabbage	Radishes
Cotton	Hay	Turnips
Soybeans	Lettuce	Beets

Vector Attraction Reduction Requirements

One of the following options for vector attraction reduction must be met when septage is land applied:

Option 1 - Injection: Septage must be injected into the soil. No significant amount of septage can be present on the soil surface within one hour after injection has taken place.

Option 2 - Immediate Incorporation: Septage must be incorporated by tillage within 6 hours after surface application.

Option 3 - Lime stabilization: The pH of the septage must be raised to 12.0 or greater by alkali addition and without the addition of more alkali must remain at 12.0 or higher for 30 minutes.

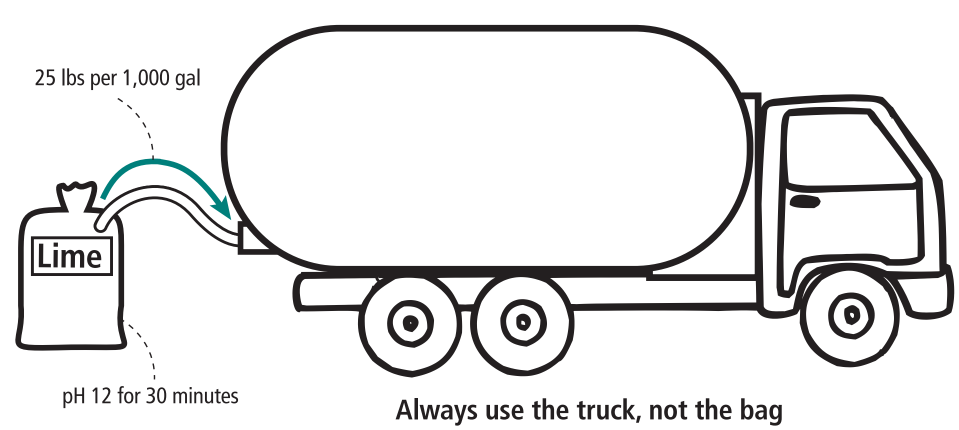
NOTE: When lime stabilization is used for either pathogen control or vector attraction reduction, the temperature of the septage must be taken into account when measuring pH. The reading must be taken at the standard temperature of 25° C (77° F), or corrected to 25° C (see the Maintainers Manual for a detailed explanation on how to make this correction).

Lime Stabilization Treatment

The purpose of adding lime to septage is to treat and reduce the number of pathogens present in the septage and to reduce odors. The high pH kills bacteria, viruses, and parasites. Odor reduction occurs because the high pH slows the biological activity and break down of the septage taking place. The reduction in odor is a benefit because it improves public acceptance of septage and also reduces its attractiveness to vectors. It is important to remember that lime treatment does not kill all of the pathogens present; therefore, site use restrictions are still required.

A side benefit of adding lime to septage is that, in some soils, it can change the soil pH. This is a benefit for farmers that have low pH soils. Farmers prefer soils that are near neutral in pH because it makes nutrients more available to their crops. The pH adjustment is dependent on many factors including soil texture, initial soil pH, etc. Monitoring the soil pH is a standard farming practice, so you can work with the farmer to see if and how much the soil pH is changing after septage is applied.

FIGURE 8.3 Draw Lime as Slurry into Truck Tank



Lime must be added to septage properly. The goal is to achieve a pH of 12.0 and hold it at 12.0 for 30 minutes. **To get to this pH, approximately 25 pounds of lime per 1,000 gallons of septage is needed.** This can change with the solids content of the septage; therefore, you must measure the pH to ensure that it is 12.0 for 30 minutes. **The pH of the septage must remain at 12 or higher for at least 30 minutes after the lime is added.**

There are a number of ways to add the lime. One is to draw powdered lime as a solid into your truck tank. Care must be taken to avoid bringing it into the pumps since lime dust can cause damage to your equipment. Another way is to add the lime as a slurry, as shown in Figure 8.3 (previous page). This is done by mixing lime with water before adding it to the truck tank. There are many methods for adding and mixing lime with septage. Experiment, talk with others, and find a method that works for you. The important thing is to get good mixing of the lime and septage, so that the pH change happens.

Hydrated lime is the most common type of lime used for lime treatment. Quicklime can also be used, but takes special precautions to be followed because of its reactive nature. Agricultural lime **cannot** be used because it will not increase the pH of the septage sufficiently to work. Follow safety precautions when working with lime. Protection of the eyes and lungs is very important, so wear goggles and a dust mask.

CAUTION: Quicklime is more reactive than hydrated lime and it releases a lot of heat. **If quicklime is used, you must take safety precautions!** Quicklime can cause bad burns if it gets onto moist skin or into your eyes. Appropriate safety precautions include the use of rubberized gloves, a respirator to exclude dust, protective eyewear and clothing to keep moist skin from contacting the quicklime. In addition, a fire could start if a bag of quicklime gets wet and sits around. Any fire involving quicklime must be put out using a chemical fire extinguisher.

Measuring pH: The pH of the septage can be measured using a pH meter or litmus paper. If a meter is used, follow the manufacturer's directions for calibration and use. Sources for pH meters are included in this manual. Using litmus paper is an easy way to measure pH, but the litmus paper must be sensitive enough to work. You should use litmus paper with a pH range between 10 and 14 that has a sensitivity that can measure changes in pH at 0.1 increments. For example, the litmus paper must be sensitive enough to be able to show the difference between a pH of 11.9 and 12.0 or it should not be used. You must request this sensitivity when ordering the paper.

Another important measurement when taking the pH is the temperature of the septage. Because the solubility of lime changes with temperature, the pH that you measure will not be accurate unless you make a temperature correction. There is approximately a 0.03 change in pH for each degree change in temperature above or below 25° Celsius (77° Fahrenheit).

Actual pH = Measured pH + [0.0167 x (Temp °F - 77)]

For example, using Table 8.8: You measure the temperature of the septage on a cold winter day. The septage temperature is 45° F. This means you must add enough lime to increase the pH of the septage to 12.5. When you do this, the actual pH of the septage mixture is 12.0 and meets the requirements of the rule.

The pH of the septage must be measured and recorded **after** lime has been added and measured and recorded again at least 30 minutes later. The purpose of these measurements is to show that the pH of the septage was kept at 12.0 or greater for a minimum of 30 minutes. Your records must show that this requirement has been met.

TABLE 8.8 Temperature/pH Correction Table

Temperature °F	Temperature °C	Required Minimum pH Reading	Actual pH	Temperature °F	Temperature °C	Required Minimum pH Reading	Actual pH
35	1.7	12.7	12.0	58	14.4	12.3	12.0
36	2.2	12.7	12.0	59	15.0	12.3	12.0
37	2.8	12.7	12.0	60	15.6	12.3	12.0
38	3.3	12.7	12.0	61	16.1	12.3	12.0
39	3.9	12.6	12.0	62	16.7	12.3	12.0
40	4.4	12.6	12.0	63	17.2	12.2	12.0
41	5.0	12.6	12.0	64	17.8	12.2	12.0
42	5.6	12.6	12.0	65	18.3	12.2	12.0
43	6.1	12.6	12.0	66	18.9	12.2	12.0
44	6.7	12.6	12.0	67	19.4	12.2	12.0
45	7.2	12.5	12.0	68	20.0	12.2	12.0
46	7.8	12.5	12.0	69	20.6	12.1	12.0
47	8.3	12.5	12.0	70	21.1	12.1	12.0
48	8.9	12.5	12.0	71	21.7	12.1	12.0
49	9.4	12.5	12.0	72	22.2	12.1	12.0
50	10.0	12.5	12.0	73	22.8	12.1	12.0
51	10.6	12.4	12.0	74	23.3	12.1	12.0
52	11.1	12.4	12.0	75	23.9	12.0	12.0
53	11.7	12.4	12.0	76	24.4	12.0	12.0
54	12.2	12.4	12.0	77	25.0	12.0	12.0
55	12.8	12.4	12.0	78	25.6	12.0	12.0
56	13.3	12.4	12.0	79	26.1	12.0	12.0
57	13.9	12.3	12.0	80	26.7	12.0	12.0

Actual pH = Measured pH + [0.0167 x (Temp °F - 77)]

Pathogen Reduction Alternative #1 for Domestic Septage with pH Treatment Applied to Non-Public Contact Sites

The domestic septage pumped from the septic tank or holding tank has had its pH raised to 12 or higher by the addition of material such as hydrated lime or quicklime and, without adding more alkaline material, the domestic septage remains at a pH of 12 or higher for at least 30 minutes prior to being land applied, AND

Crop Restrictions

1. Food crops with harvested parts that touch the septage/soil mixture and are totally above ground shall not be harvested for 14 months after application of domestic septage. Food crops with harvested parts below the surface of the land shall not be harvested for 20 months after application of domestic septage when the domestic septage remains on the land surface for four months or longer prior to incorporation into the soil.
2. Food crops with harvested parts below the surface of the land shall not be harvested for 38 months after application of domestic septage when the domestic septage remains on the land surface for less than four months prior to incorporation into the soil.
3. Animal feed, fiber, and those food crops whose harvested parts do not touch the soil surface shall not be harvested for 30 days after application of domestic septage. Domestic septage may only be applied to hay land within 7 days after cutting and removal of the hay
4. Turf grown on land where domestic septage is applied shall not be harvested for one year after application of the domestic septage when the harvested turf is placed on either a lawn or land with a high potential for public exposure, unless otherwise permitted by the permitting authority.

Grazing Restrictions

NONE

Site Restrictions

NONE

You must meet either of the two pathogen-reduction alternatives.

Note: if you meet this pathogen reduction alternative, you also meet Vector Attraction Reduction alternative # 3.

Pathogen Reduction Alternative #2 for Domestic Septage without Additional Treatment Applied to Non-Public Contact Sites

Domestic septage is pumped from the septic tank or holding tank and land applied without treatment, incorporated within six hours, AND

Crop Restrictions

1. Food crops with harvested parts that touch the septage/soil mixture and are totally above ground shall not be harvested for 14 months after application of domestic septage.
2. Food crops with harvested parts below the surface of the land shall not be harvested for 38 months after the application of the domestic septage.
3. Animal feed, fiber, and those food crops that do not touch the soil surface shall not be harvested for 30 days after application of the domestic septage. Domestic septage may only be applied to hay land within 7 days after cutting and removal of the hay
4. Turf grown on land where domestic septage is applied shall not be harvested for one year after application of the domestic septage when the harvested turf is placed on either a lawn or land with a high potential for public exposure, unless otherwise specified by the permitting authority.

Grazing Restrictions

Animals shall not be allowed to graze on the land for 30 days after the application of domestic septage.

Site Restrictions

Public access to land with a low potential for public exposure shall be restricted for 30 days after application of domestic septage. Examples of restricted access include the remoteness of site, posting with no trespassing signs, and/or simple fencing.

You must meet either of the two pathogen reduction alternatives (not both).

Benefits

The first "benefit" of lime is a public perception benefit. People like the idea that the septage is treated.

The second benefit is odor reduction.

The third benefit is the removal of pathogens. Even though removal is not complete, the addition of lime makes a difference and allows for the use of septage on more sites.

The fourth is soil modification. Many farmers add lime to their soil to allow better transfer of nutrients, so by using lime you actually open places up that were not usable for land application of septage in the past.

Vector Attraction Reduction Alternatives for Domestic Septage Applied to Non-Public Contact Land

Alternative 1: Injection

Domestic septage shall be injected below the surface of the land, AND no significant amount of the domestic septage shall be present on the land surface within one hour after the domestic septage is injected.

Alternative 2: Incorporation

Domestic septage applied to the land surface shall be incorporated into the soil surface plow layer within six hours after application.

Alternative 3: pH Adjustment

The pH of domestic septage shall be raised to 12 or higher by addition of alkaline material and, without the addition of more alkaline material, shall remain at 12 or higher for 30 minutes.

You must meet vector attraction reduction alternative 1, 2, or 3 (not all three).

pH Indicator Paper and Meter Sources

Hach Company
P.O. Box 389
Loveland, Colorado 80539-0389
Phone: 800-227-4224
www.hach.com

Fischer Scientific
2000 Park Lane Drive
Pittsburgh, PA 15275
Phone: 800-766-7000
www.fishersci.com

Lab Safety Supply
PO Box 1368
Janesville, WI 53547-1368
Phone: 800-356-0783
www.labsafety.com

Thomas Scientific
PO Box 99
Swedesboro, NJ 08085
Phone: 800-345-2100
www.thomassci.com

Brands of pH meters include Oakton, Fischer and Corning. Suitable meters cost between $50 - $150 depending on features. Indicator paper is a much cheaper method of monitoring pH- a 50-foot roll of pH paper costs under $15.

Site Suitability Requirements for Septage Application

Soil Terminology: Definitions for Septage Application

Slope is the change in elevation with distance. This is calculated as the "rise" divided by the horizontal distance, and expressed as a percent.

Bedrock is hard or weathered rock material that underlies the soil and may also be exposed at the surface.

"Highly permeable soil" means soils whose soil leaching potentials are rated as severe, poor filter for soil pesticide loss, by the Natural Resources Conservation Service using the procedure found in part 620, Soil Interpretation Rating Guides of the United States Department of Agriculture-Natural Resources Conservation Service National Soil Survey Handbook.

Saturated Soil is the upper surface of the zone of soil (or underlying material) that is saturated by water.

Soil texture refers to the relative mixture of sand, silt, and clay in a soil.

Permeability is the maximum rate of water movement through the soil, usually expressed in inches per hour.

Note: A soil is made up of layers called horizons. A vertical section of a soil made up of all its horizons is called a soil profile.

The maintainer must determine whether land application sites are suitable. Sites are considered suitable if the suitable soil conditions in Table 8.9, slope restrictions in Table 8.10, and separation distances in Table 8.11 are met.

TABLE 8.9 Suitable Soil Conditions[1]

Site Characteristic	Minimum Requirement
Soil Texture	At the zone of application the soil texture must be listed below*
Surface horizon permeability	If 0.2 inches or less, this soil is suitable for surface application with incorporation within 6 hours or injection
Depth to bedrock[2]	3 feet
Depth to saturated soil[2,3]	3 feet
Frequency of Flooding	Must not be frequent

* Fine sand, loamy fine sand, loamy sand, sandy loam, loam, silt, silt loam, sandy clay loam, clay loam, silty clay loam, silty clay, clay

TABLE 8.10 Slope Restrictions for Application Sites Where Septage Is Land Applied

Slope (percent)[1]	Surface Application	Injection or Immediate Incorporation[2]
Summer: 0–6 >6–12 >12	Allowed Not Allowed Not Allowed	Allowed Allowed Not Allowed
Winter: 0–2	Only areas with slopes from 0 to 2% can be used for winter applications of septage	

[1] This information can be obtained from the soil surveys published by the Natural Resources Conservation Service or by characterization of the site by a state of Minnesota licensed soil scientist or other qualified person.
[2] Immediate incorporation is mixing of septage into the soil with some form of tillage within 46 hours of application.

Site Selection

To select a site for soil treatment of septage, the following factors should be considered:

- soil texture;
- topography (slope and surface drainage patterns);
- separation distances from:
  - > groundwater,
  - > surface waters, lakes or streams,
  - > roads,
  - > occupied structures,
  - > residential or commercial developments,
  - > water supply wells, and
  - > public road rights-of-way;
- vegetative cover; and
- access by the tank truck hauling septage.

Some odors may be associated with the land spreading of septage. While sunlight acts as an affective bactericide and the odor soon dissipates from the area, common sense should be used when spreading septage on the soil surface. Usually several sites are available in a general area. The prevailing wind direction during the day should be noted when selecting the site upon which to spread the septage.

If land spreading is not an option, the septage must be delivered to a municipal sewage treatment facility.

TABLE 8.11 Minimum Separation Distances From the Land Application Site

Feature		Separation Distances in Feet		
		Surface Applied	Incorp. w/in 6 hours	Injected
Private drinking water supply wells		200	200	200
Public drinking water supply wells[1]		1000	1000	1000
Irrigation wells		50	25	25
Residences[2]		200	200	100
Residential developments		600	600	300
Public contact sites		600	600	300
Property boundaries and Public roads		10	10	10
Down gradient lakes, rivers, streams,wetlands, intermittent streams, or tile inlets connected to these surface water features[2], and sinkholes	Slope 0% to 6%	200	50	50
	Slope 6% to 12%	Not Allowed	100	100
	Winter (0% to 2%)	600	N/A	N/A
Grassed Water Ways[3]				
Slope 0 % to 6%		100	33	33
Slope 6 % to 12%		Not Allowed	33	33

[1] There may be special requirements if the land application site is within the boundaries of a wellhead protection area. Check with the Minnesota Department of Health or local unit of government.
[2] Intermittent streams means a drainage channel with definable banks that provides for runoff flow to any of the surface waters listed in the above table during snow melt or rainfall events.
[3] Separation distances are measured from the centerline of grassed waterways. For grassed waterways that are wider than these separation distances, application is allowed to the edge of the grass strip. Grassed waterways are natural or constructed, typically broad and shallow, and seeded to grass as protection against erosion.

Using the Soil Survey

Soil surveys have entered a new era across Minnesota and the United States. The official soil survey information and documentation now resides online at:

websoilsurvey.nrcs.usda.gov (verified 8/8/17).

Those that seek to land apply septage should use this tool to help determine if a site is suitable for land application. While users may choose to print off information, this information is subject to change and should be checked online frequently for updates.

Online soil surveys still present soil lines on a photographic background indicating the boundaries between different soil types. These maps show the occurrence and distribution of each kind of soil.

For counties that do not have published soil surveys, the county Soil and Water Conservation District office can often provide soils information.

In order to use the Web Soil Survey to assist in identifying site suitability, locate the site on the survey (GPS coordinates, county, address, township, range, section, or simply zoom) and determine what soil map units exist on the parcel:

1. Outline the desired parcel/area using the Define AOI (Area of Interest) tool.
2. Once the AOI has been defined, select the tab for “Soil Map” near the top of the browser window.

3. You will now see a display of the aerial photograph with soil lines over the top. On the left of the map (legend), you will see a summary of map units, map unit names, acres in the AOI and percent composition of the AOI. Map units are denoted by symbols such as 401C.
4. List the map unit symbols found at your location.
5. Selecting the third tab entitled "Soil Data Explorer" allows the mapping of selected soil properties over the AOI.
6. Now select the "Suitabilities and Limitations for Use" tab.
7. Under this tab, there is a suitabilities rating for "Sanitary Facilities." Select this rating.
8. Under this rating, there are numerous interpretations. The five interpretations we are interested in include:

   Septage Application - Incorporation or Injection (MN)

   Septage Application - Surface (MN)

These interpretations were developed based on Septage and Restaurant Grease Trap Waste Management Guidelines (MPCA, 2002) and are accurate on a regional scale.

9. Select the "View Ratings" button to view map of ratings with tables of soil map units and their individual suitabilities.

If you do not have access to the Web Soil Survey, use of the hard copy Soil Surveys can also provide valuable information:

Soil Survey Tables: Useful Information for Determining Suitability of Soils for Septage Application

The Web Soil Survey's "Soil Data Explorer" has a section for "Suitabilities and Limitations for Use" that includes a tool for rating Septage Application.

I. Engineering Properties and Classifications

> These give the **soil texture** for each horizon. Make sure the surface texture is **not** sand, loamy sand, peaty, or mucky.

II. Soil and Water Features:

Use this table to make sure:

1. There is **no flooding hazard,** and
2. depths to bedrock and the high water table are **3 feet or more.**

   Take note of these two depths!! You will need them later.

III. Physical and Chemical Properties of Soils

This table gives the permeability and available water holding capacity of each soil horizon. Use it to make sure:

1. One (or more) horizons have a permeability of fewer than six inches/hour
2. If septage will be surface applied, the permeability of the surface layer is greater than 0.2 inches/hour
3. "High permeable soil" increases up to five feet

General Site Management

The following general site management practices must be followed:

1. Application of septage is not allowed on areas of a site ponded with water or septage.
2. Septage cannot be applied by spraying from public roads or across road right of ways.
3. The application area must be clearly identified with flags, stakes, or other easily seen markers at the time of application to identify the site boundaries, separation distances, and unsuitable application areas within the site. Where site boundaries can be identified by field roads, fences, etc., identification is not necessary.
4. All septage that is land applied must be uniformly distributed over the area of the site used during application.
5. A distribution device (splash plate or spreader) is required on the application vehicle so that even application of septage is possible and application rate limits can be met.
6. Measures must be taken to ensure that septage remains where it was applied and does not run off and concentrate in low areas of the field or run off the site.
7. The application vehicle must be moving at all times during application.
8. Winter applications cannot occur unless measures are taken that allow septage to be applied evenly over the application area. This generally means that fields must be plowed or cleared of snow in some way.

Allowable Application Rates

Typically, nitrogen is the nutrient used to determine how much septage can be applied to an application site. Septage must be applied at a rate that supplies no more nitrogen than a crop needs. This is referred to as the agronomic application rate. In this guide, the Maximum Allowable Nitrogen Application (MANA) rate is used to calculate the gallons of septage that can be applied to a site over an entire cropping year. Maintainers can choose one of the following options for determining their maximum annual septage application rate:

Land Spreading

Spreading septage on the surface of the soil is an effective method of treatment, particularly for the removal of pathogenic bacteria. After the organic material begins to decompose, there will be some downward movement of nitrates through the soil profile. Thus, it appears that the application rate of the septage should be based on nutrient removal by a crop in the succeeding year.

In general, septage cannot be applied during the growing season of a crop. A practical method of application is to apply septage based on crop nitrogen requirements and plan to harvest a crop the following year. Since the nitrogen in septage is mostly in the organic form, it will be stored in the soil and utilized by the crop the following year if other plant nutrients are balanced. It is advisable to utilize the nutrients in septage for crops that are consumed as livestock feed, such as small grains or forage.

When septage is applied to a soil, a portion of the nitrogen as nitrate will volatilize or be lost to the atmosphere rather than be incorporated into the soil and become available to plants. The amount of volatilization depends upon a number of factors such as temperature, wind, and pH. Thus, the actual nitrogen loading rate will be somewhat less than that indicated by the total Kjeldahl nitrogen (TKN) concentration.

Septage Application Rate Limits

There are several rate limits for land applied septage. They are:

- **daily hydraulic loading limit of 10,000 gallons/acre/day when surface applied;**
- **winter hydraulic limit of 15,000 gallons/acre/winter; and**
- **nitrogen application rate limits equal to the agronomic rate for the crop or vegetation grown on the site (limit varies depending on the crop grown).**

The **daily** hydraulic limit of 10,000 gallons/acre/day is set for surface applications of septage. This limit is set to prevent ponding of septage and runoff.

A **winter** hydraulic limit of 15,000 gallons/acre/winter cannot be exceeded for the time period that begins when the ground is frozen or snow covered and ends when the ground is no longer frozen or snow covered in the spring. Winter is defined as "the time period that the ground is frozen and snow covered, so that injection or incorporation are not possible". The time period when this occurs varies from year to year; therefore, no dates are set for winter. In general, this time period begins sometime in November and ends sometime in early April.

The **nitrogen** application rate limit is based on how much nitrogen the plants growing on the site can use over a cropping year. Septage must be applied at a rate that supplies no more nitrogen than a crop needs. This is referred to as the agronomic rate for nitrogen. The agronomic rate varies depending on the type of crop grown, the yield that can realistically be expected, soil type it is grown on, and other factors.

Annual application rate limits use what is termed a **cropping year.** The cropping year goes from September 1st through August 31st each year. For example, the 1999 cropping year went from September 1, 1998 to August 31, 1999. The cropping year corresponds to the growing season that the plant will actually use the nitrogen applied. The cropping year starts September 1 because nitrogen and other nutrients applied in the late fall will be used by the crop the next spring and summer.

Maximum Allowable Nitrogen Application (MANA) rate is used to calculate the gallons of septage that can be applied to a site over an entire cropping year. Maintainers can choose one of the following options for determining their maximum annual septage application rate:

Option 1: Apply septage at rates that do not exceed the MANA rates identified under option 1 of Table 7 in the MPCA's Septage and Restaurant Grease Trap Waste Management Guidelines.

Option 2: Apply septage at rates that supply the MANA rates identified under option 2 of Table 7 in the MPCA's Septage and Restaurant Grease Trap Waste Management Guidelines, and calculate loadings using the following equation:

$$\text{Maximum Allowable Septage Application Rate (gal/ac/yr)} = \frac{\text{MANA rate lbs/acre/yr}}{\text{0.0026 lbs N/gal}}$$

For both options, the MANA rate must be adjusted by subtracting out other nitrogen applied to the site from fertilizers, manure, or other by-products. These are called nitrogen credits and are subtracted from the MANA rate to determine the amount of nitrogen that can be supplied by the septage.

Realistic yield goals are needed to determine MANA rates when using option 2 and can be determined by one of the following methods:

- Use the most recent five-year average crop yield, excluding the worst year.
- Use the most recent three to five-year average crop yield increased by 10 percent.
- Use information from the Natural Resource Conservation Service, county extension office, or a crop consultant on typical yields for the soil type and management being used in the area.

Additional Nitrogen Management Requirements

- After the last cutting of a hay crop for each year the septage application rate must be reduced so that no more than half of the MANA rate for the cropping year is applied. For example, if the MANA rate for the hay crop is 100 lb/acre, no more than 50 lb/acre can be applied after the second cutting.
- Septage cannot be applied on land that remains fallow for the entire cropping year. Fallow land is kept bare for the entire summer. A crop must be grown at some time during the year if septage is to be applied on the site.
- If septage is applied on a site that has no crop growing during the months of July 1 through August 31, the following requirements must be met (this may happen after harvest of small grains or other early season crops):
  - > Application rates are limited to 20,000 gallons/acre (50 lb N/acre).
  - > All nitrogen applied must be used as a nitrogen credit the following cropping year.
  - > A crop must be grown the following cropping year.

EXAMPLE 1: MANA rate determined using option 1

Crop grown: oats
MANA Rate: 50 lb N/acre
Nitrogen Credits: Farmer did not apply any other nitrogen to the site.

Maximum Allowable Septage Application Rate: 20,000 gal/acre

EXAMPLE 2: MANA rate determined using option 1

Crop grown: oats
MANA Rate: 50 lb N/acre
Nitrogen Credits: Farmer applied 20 lb/acre of fertilizer nitrogen.
MANA Rate Adjusted for N Credits: 30 lb N/acre

$$\textbf{Maximum Allowable Septage Application Rate (gal/ac/yr)} = \frac{30 \text{ lb N/acre}}{0.0026} = \underline{\textbf{11,539 gal/acre}}$$

EXAMPLE 3: MANA rate determined using option 2

Crop Grown: Oats
Realistic Yield Goal: 70 bu/acre
Previously Grown Crop: corn
Soil Organic Matter Content: low
MANA Rate: 80 lb/acre
Nitrogen Credits: Farmer did not apply any other nitrogen to the site.

Maximum Allowable Septage		80 lb N/acre
Application Rate (gal/ac/yr)		0.0026
	=	**30,769 gal/acre**

EXAMPLE 4: MANA rate determined using option 2

Crop Grown: Oats
Realistic Yield Goal: 70 bu/acre
Previously Grown Crop: corn
Soil Organic Matter Content: low
MANA Rate: 80 lb/acre
Nitrogen Credits: Farmer applied 20 lb/acre of nitrogen fertilizer.
MANA Rate Adjusted for N Credits: 60 lb N/acre

Maximum Allowable Septage		60 lb N/acre
Application Rate (gal/ac/yr)		0.0026
	=	**23,076 gal/acre**

Truck Calibration

Application rates need to be accurate. This means that the area of the site where septage is applied needs to be known, and the amount of septage applied on any given area needs to be known. Without this information, application rates will only be a guess.

To find out the rate of septage application, the equipment must be calibrated. There are several ways to calibrate your equipment. One of the simplest methods is to fill the tank with a known amount of septage or water. Go to the field and spread the liquid at the speed that you normally drive at. When done, measure the area the liquid covered in square feet. Then convert this to a rate per acre. If you drive at different speeds, you need to adjust the rate accordingly (twice the speed would be half the application rate, etc.).

Another way is to figure out the pumping rate from your truck in gallons/minute. If your tank is emptied by gravity and not a pump, you will need to figure out what your pumping rate is. Then you can use a chart with different speeds and spread widths to determine your rate of application.

To figure out how much liquid you have in the tank, you can weigh the truck empty and full. Assume that the septage weighs the same as water (8.34 pounds per gallon). If you always fill the tank to the same level, you will know the quantity of septage you are spreading in each load. If not, you can weigh the truck at several levels so that you can estimate fairly accurately how much septage is in your truck at different levels. Another way you can know how much septage is in your truck is to put a flow meter on the truck so you know how much you are spreading.

To get a more even application and a lower application rate, some type of spreader or splash plate is needed. This also helps to reduce soil erosion as the septage falls on the ground from the application truck and reduces damage to the crop if spreading on hay or other forage type crops.

Some people find it difficult to apply septage at low rates because of their equipment. There are a few things you can do to lower the gallon/acre rate applied such as:

- Drive at a higher speed if this is possible.
- Use a splash plate that spreads the septage out over more surface area.
- Reduce the size of the valve opening that septage is being spread out of by using o-rings or other devices to make the opening smaller.

EXAMPLE CALIBRATION:

Weight of liquid in the truck tank: 20,850 pounds
Weight of liquid per gallon: 8.34 lb/gal
Quantity of septage in the truck tank: 20,850 lb = 2,500 gallons, 8.34 lb/gal
Speed traveling: 4 mph
Area Covered: 15 feet
Distance Traveled: 750 feet

1 acre = 43,560 ft^2

$$\text{Rate} = \frac{20{,}850 \text{ lb}}{15 \text{ ft X } 750 \text{ ft}} = \frac{2{,}500 \text{ gal}}{11{,}250 \text{ ft}^2} = 0.22 \text{ gal/ft}^2$$

0.22 gal/ft^2 X 43,560 ft^2/acre = 9,680 gal/acre

With this information, you can determine your rate at different speeds. For example, if you are traveling at two mph, then your application rate would be doubled, so it would be 19,360 gal/acre (this would exceed the 10,000 gal/acre/day limit).

Specific Nitrogen Management Requirements:

The nitrogen management requirements in this section were developed to prevent nitrogen from being lost by leaching into groundwater. All of the requirements in this section must be followed.

a. After the second cutting of a hay crop, the septage application rate must be reduced to supply no more than half of the MANA rate for the cropping year.
b. Septage cannot be applied on land that remains fallow for the entire cropping year.
c. When no crop is grown on the application site during the time period July 1 through August 31 (this generally occurs on sites where early maturing crops such as oats, sweet corn, or peas have been harvested), the following requirements apply:
   > applications of septage are limited to rates that supply no more than 50 pounds of nitrogen per acre (20,000 gallons/acre);
   > all nitrogen applied must be credited to the following cropping year; and
   > a crop must be grown the following cropping year.

Hydraulic Loading Rate Limits

Hydraulic loading rate limits are set to prevent ponding of septage on the soil surface and runoff of septage from where it was applied. The following requirements must be met:

a. Daily application rates for surface applied septage are limited to 10,000 gallons/acre/day.
b. Field conditions must be taken into account to ensure that the following requirements are met:
   > No runoff of septage from the application site is allowed.
   > No surface ponding of septage is allowed after six hours from the time of application.
   > Minimal movement of septage from where it was applied occurs.
c. Application rates are limited to a total of 15,000 gallons/acre over the entire winter period.

Maintainer Qualifications

All septage must be land applied by a state of Minnesota licensed maintainer.

Record Keeping

You must keep records that show you are meeting land application requirements. Records must be kept for a minimum of five years. These records are the first thing requested during any complaint investigation. Records for sites should be kept on a cropping year basis. Example record keeping forms are included in this manual. You can set up your own record keeping forms and system as long as your records include the information described below.

For each land application site, the following information must be kept:

- Location of each land application site used. This can be recorded as the street address, latitude and longitude of the site, or legal description indicating the quarter section, township coordinate, range coordinate, township name, and county name
- A map of the land application site with the site boundaries identified. The map must be from a soil survey when available. If not available, another map with comparable information can be used. Any areas of the site which are not used because they are unsuitable should be indicated on the map by coloring or crosshatching
- Total usable acreage of the site (unsuitable areas should not be included in the site acreage, because application rates are based on the actual area septage is applied)
- Crop grown on the site
- Maximum allowable nitrogen application rate for the cropping year in pounds/acre

- Maximum allowable septage application rate for the cropping year in gal/acre
- Running total of gallons of septage applied on the site
- A written description of how the pathogen reduction requirements have been met

Example Statement:

"Each load of septage that was applied on this site was lime stabilized for 30 minutes. This was done by adding hydrated lime at a rate of about 25 pounds per 1000 gallons. The pH was measured using litmus paper after lime addition and again after 30 minutes to make sure a pH of 12.0 or greater was met for 30 minutes. In addition, site restrictions were used."

- A written description of how the vector attraction reduction requirements have been met

Example Statement:

"Each load of septage that was applied on this site was lime stabilized for 30 minutes. This was done by adding hydrated lime at a rate of about 25 pounds per 1000 gallons. The pH was measured using litmus paper after lime addition and again after 30 minutes to make sure a pH of 12.0 or greater was met for 30 minutes."

- The following signed certification statement:

"I certify under penalty of law, that the information that will be used to determine compliance with the pathogen requirements [insert either 503.32(c)(1) or 503.32(c)(2)] and the vector attraction reduction requirement [insert either 503.33(b)(9), 503.33(b)(10) or 503.33(b)(12)] was prepared under my direction and supervision in accordance with the system designed to ensure that qualified personnel properly gather and evaluate this information. I am aware that there are significant penalties for false certification including the possibility of fine and imprisonment."

For each load of septage applied to a site, the following detailed information must be kept:

- Source(s) of septage in the load. This means the home or facility the material was removed from and can be indicated by property owner name, or invoice number. The type of material pumped should be identified (septage, grease trap waste, etc.)
- The date each load of septage is applied on the site
- Total gallons land applied
- Total acres covered
- Rate applied in gallons/acre
- If surface applied, specific pH, temperature and time information

Requirements for Land Application of Restaurant Grease Trap Waste

Restaurant grease traps are designed to remove greases, fats, and oils before they enter a centralized sewage treatment system or the soil treatment area of an individual sewage treatment system. The waste that is removed from the tank described in Example 1 and the first septic tank described in Example 2 are restaurant grease trap wastes and must be managed by following the special management requirements of this section.

Example 1 – Tanks designed for the purpose of removing fats, oils, and greases from effluent before discharge to a centralized sewage treatment system or to an individual sewage treatment system septic tank.

Example 2 – When there is no tank specifically dedicated to the collection of greases, fats, and oils, the first septic tank that receives effluent from a restaurant is considered the grease trap.

Restaurant grease trap waste can be land applied if **all** of the previously discussed requirements for the land application of septage are followed. **In addition,** one of the following four options for management must be met:

Option 1: Restaurant grease trap waste must be *incorporated* into the soil within *six hours of surface* application and is limited to an application rate of *15,000 gallons/acre/year.*

Option 2: Restaurant grease trap waste must be *injected* into the soil and is limited to an application rate of *15,000 gallons/acre/year.*

Option 3: Restaurant grease trap waste from a tank, as described by Example 1, must be mixed with domestic septage prior to *land application.* The quantity of restaurant grease trap waste mixed with septage cannot exceed *25% of the mixture by volume.* Maximum application rates of this mixture are limited to *60,000 gallons/acre/year.*

Option 4: Restaurant grease trap waste from the first septic tank, as described by Example 2, must be combined with domestic septage and mixed prior to *land application.* The quantity of restaurant grease trap waste mixed with septage cannot exceed *50% of the mixture by volume.* The source of the septage used for diluting the grease trap waste can be from the other tanks in series with the first or from another ISTS system. Maximum application rates of this mixture are limited to *30,000 gallons/acre/year.*

In addition to the application rate limits specified for each option, the application rate limits used for septage also apply. This means that the maximum application rate for restaurant grease trap waste cannot cause the annual application rate limit specified for septage to be exceeded.

Additional septage may also be applied to sites receiving restaurant grease trap waste or mixtures of restaurant grease trap waste and septage as long as the sum of all these wastes are counted as part of the year's maximum allowable application rate for septage.

References

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EPA (1994). Guide to Septage Treatment and Disposal, U.S. Environmental Protection Agency Publication No. EPA/625/R-94/002, Cincinnati, OH.

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EPA (1993). 40 Code of Federal Regulations Part 503. Standards for the use of disposal of sewage sludge. Federal Register 58(32), 9387-9414.

Minnesota Pollution Control Agency (2002). Septage and Restaurant Grease Trap Waste Management Guidelines. Water/Wastewater-ISTS #4.20.

Minnesota Pollution Control Agency (2003). Minnesota Rules Chapter 7041, Sewage Sludge Management Rules", Office of the Revisor, St. Paul, MN.

Rohm, S.P. (2000) "Land Treatment of Grease Trap Wastes - A Beneficial Use Approach" Pumper. March 2000.

Minnesota Pollution Control Agency Offices

All offices can be reached by calling 800-657-3864

SECTION 9: Pumping Systems

PUMPING SYSTEMS

Overview

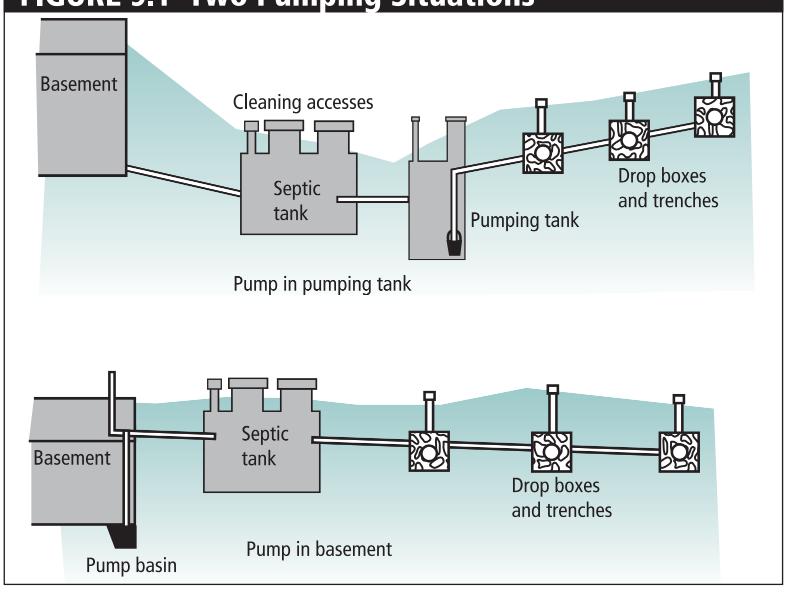
Pumps are used to move either raw sewage or septic tank effluent to different parts of the onsite sewage treatment system. Whether the pump handles raw sewage or septic tank effluent, a pumping system consists of four parts: 1) a pump tank or sump; 2) the discharge assembly; 3) the controls; and 4) the pump. How the sewage is expected to move through the system will determine where the pump is located, and the location of the pump often impacts the sizing and appearance of the four components. In one scenario, the pump is expected to deliver raw sewage to the pretreatment device, usually a septic tank. In another scenario, septic tank effluent is moved to an additional pretreatment device, such as a sand filter or to the final soil dispersal and treatment site. In certain situations, more than one pump may be required.

Pumping Applications

Pumping in Gravity Systems

Figure 9.1 shows two different gravity pumping situations. The upper figure shows the raw sewage flowing by gravity to a deep (≥4' cover depth) septic tank and from there by gravity to a pump tank. The pump is then used to lift the septic tank effluent to the final soil treatment area where it is distributed by gravity or pressure. In the event of pump failure, water use would need to be restricted until the pump could be repaired or replaced. The amount of storage (reserve capacity) available is determined by the volume in the pump tank above the high alarm level.

FIGURE 9.1 Two Pumping Situations



The lower part of Figure 9.1 shows a pump located in the basement that delivers wastewater generated in the basement to the house sewer, from which point the wastes flow by gravity into the septic tank. Many times this is referred to as a sump basket that holds the pump. However, the pump cannot be a sump pump because it will be handling sewage. If there is a basement toilet, a sewage ejector or solids handling pump would be used to lift the sewage to the house sewer. If there is a pump in the basement, a compartmented tank or two tanks in series should be installed to provide septic tank capacity for adequate solids separation. Even though only a portion of the sewage wastes are pumped, there will still be considerable turbulence in the first septic tank when the pump operates. In the event of pump failure, only the basement plumbing could not be used.

FIGURE 9.2 Pumping Uphill to Acceptable Soils

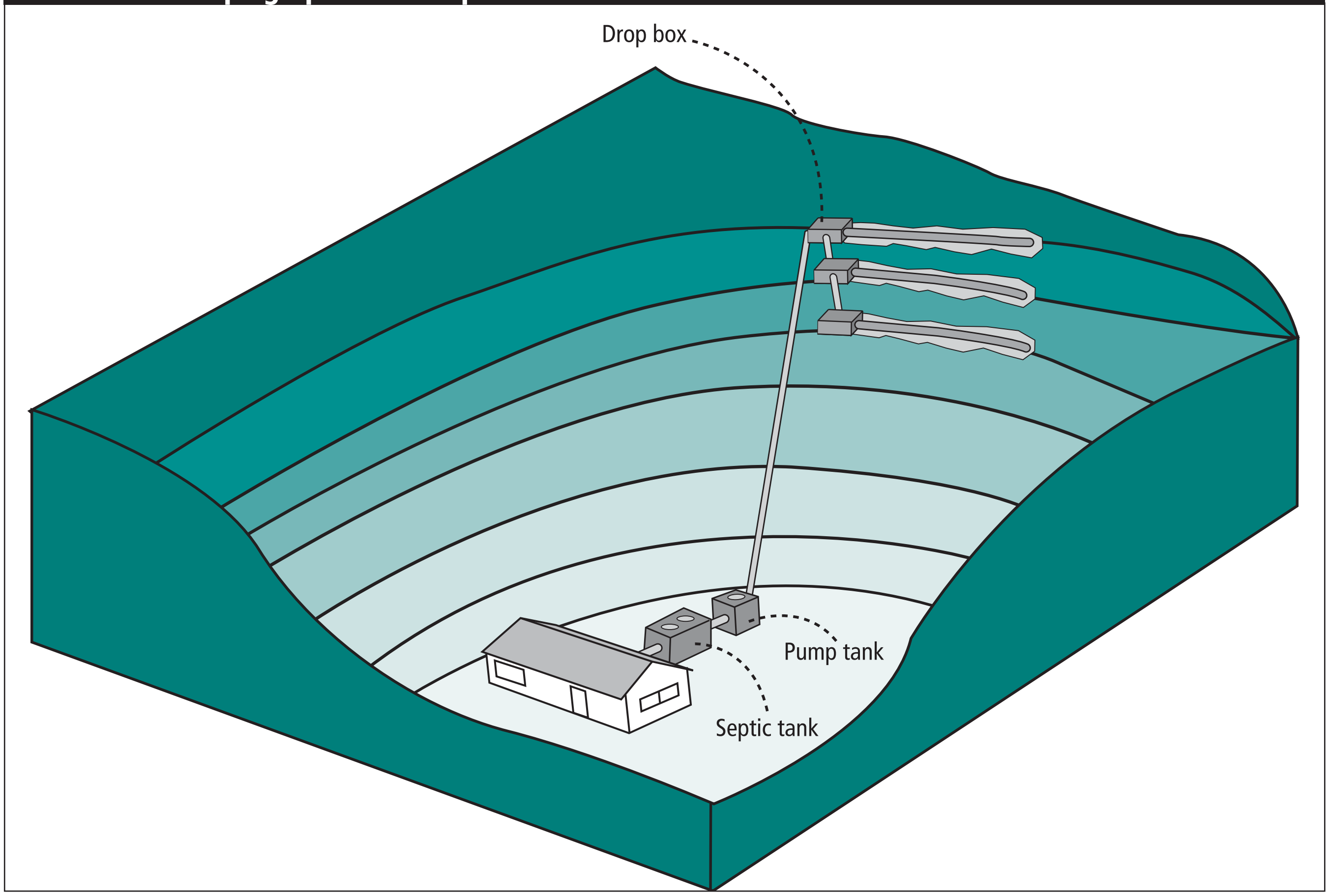


Figure 9.2 shows a typical pumping situation where the sewage source is at an elevation lower than where the soil is suitable for below grade, gravity sewage treatment and dispersal. Why not locate the house at an elevation high enough so that sewage could flow by gravity into the soil treatment unit? In some instances, the property owner may want the house at a certain elevation. In other instances, proper planning was not done with respect to the relative location of the house and the sewage treatment system. In the past, many people have incorrectly thought that low areas were suitable for sewage treatment, even though they were too wet for any other purpose.

Note that the pump delivers effluent to a series of trenches using drop box distribution. Figure 9.3 shows the first drop box in this system, which accepts the effluent from the pump tank. Notice the device attached to the inlet of this box. A similar device should be installed to dissipate the force from the incoming pumped effluent. The bottom of the discharge piping from the pump must be at least two inches higher than the supply line to the next drop box, to avoid any liquid drainback to the pumping station, other than that contained in the pipe from the pump.

The discharge line from the pump must be directed to flow against a wall of the drop box where there is no outlet, or into a device installed to dissipate the force from the pump. This placement is necessary to assure that the effluent does not all flow out a single pipe but is instead first distributed to the initial trench, with the remainder then flowing through the supply line to the next drop box. Subsequent drop boxes in the system in Figure 9.2 will be similar to the one shown in Figure 9.4. The pump capacity for these applications should be between 15-45 gpm. Using the pump curve and rise in elevation can allow for proper selection.

FIGURE 9.3 Drop Box with Inlet Pressure Displacement

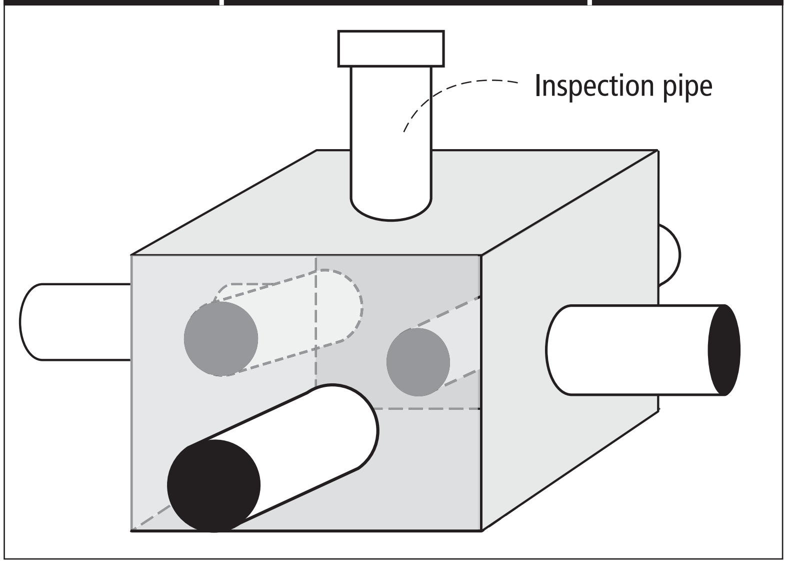
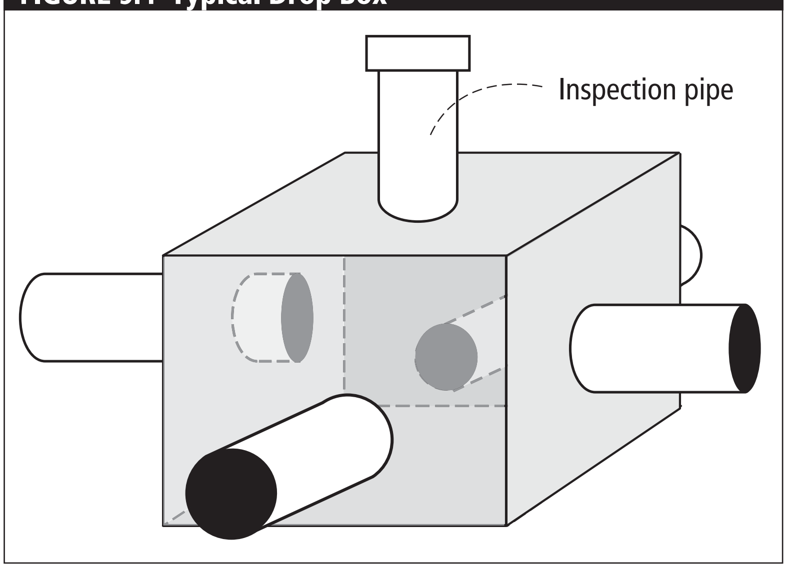


FIGURE 9.4 Typical Drop Box



Pumping in Pressure Systems

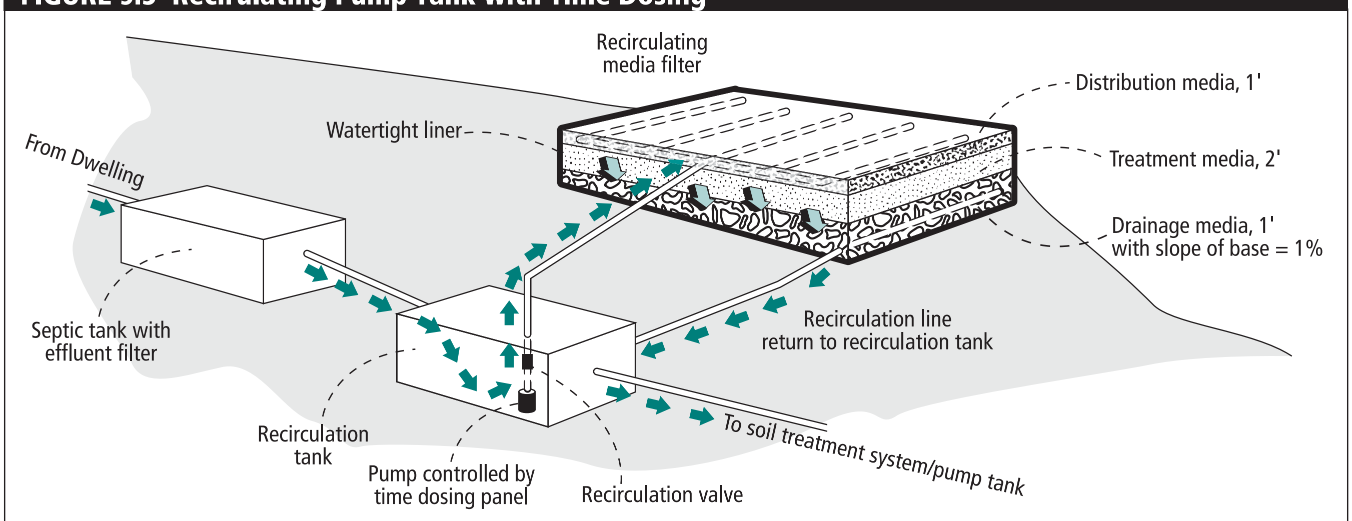
There exists a third situation in which the pump is used to pump septic tank effluent to the next component (which could be another pretreatment device) or through a pressure distribution network in the soil treatment area. Both of these conditions have similar pump requirements, but they have different sizing specifications depending on the pressure distribution network. **Under Chapter 7080.2050, Subp 4 (A), pressure distribution is required in several situations:**

1. Mound systems
2. At-grade systems
3. All seepage beds with a width greater than 12 feet
4. Systems receiving pretreated effluent (levels A, A2, B, or B2)
5. All systems where the distribution network is installed above the original grade
6. All MSTS systems (7081.0250)

MN Rules Chapter 7080.2210 Subp. 4 (F) (1) identifies pressure distribution as one of three treatment options for trenches or seepage beds in which the distribution media is in contact with any sand textured soils with a percolation rate of 0.1 to 5 minutes per inch.

Figure 9.5 below shows an example of a pump tank being used as a recirculation tank for a media filter. Section 12 provides detailed information and examples about the design and installation of pressurized effluent distribution.

FIGURE 9.5 Recirulating Pump Tank with Time Dosing



Sump and Pump Tank Specifications

Sump Basket

Sump baskets are installed in the basement when the objective is to lift a portion of the flow to the house sewer. These baskets are usually constructed of plastic and hold 30 to 50 gallons. The size can be smaller than other dosing tanks since the delivery to the pre-treatment device should be continuous as sewage is generated in the basement. Any problems with the pump will be apparent very quickly because of the lack of storage in the sump. When a problem becomes apparent, water use in the basement will have to stop until the situation is corrected. When grinder pump designs are employed, the size of the sump basket does not change; however, size becomes more important if there are problems and the pump must be easily and quickly exchanged.

Specifications

The sump's specifications are important to its function as part of a pumping system. Sump design must follow MN Rules Chapter 4715.2440, "Design of Sumps," which is outlined below. People working on these types of applications must be certified plumbing contractors under Minnesota Statutes Chapter 326B.46.

Construction

As specified in Subpart 1, sumps and receiving tank shall be constructed of poured concrete, metal, or other approved materials. If constructed of poured concrete, the walls and bottom shall be adequately reinforced and designed to acceptable standards. Metal sumps or tanks shall be thick enough to serve their intended purpose and shall be treated both internally and externally to resist corrosion.

Discharge line

Subpart 2 states that the discharge line from the pumping equipment shall be provided with an accessible backwater valve and gate valve, and if the gravity drainage line to which the discharge line connects is horizontal, the two shall be connected from the top through a wye branch fitting. The minimum size of any pump or discharge pipe from a sump connected to a water closet shall be at least two inches.

Sumps for buildings

Building drains or building sewers receiving discharge from any pumping equipment shall be adequately sized to prevent overloading. In all buildings (except single and two-family dwellings), if three or more water closets discharge into the sump, duplicate pumping equipment shall be installed (Subp. 3).

Covers

Subpart 4 states that sumps and receiving tanks must be provided with gastight covers, except that float control or switch rods must operate without binding. The cover must be of a bolt and gasket type or equivalent manhole opening to permit access for inspection, repairs, and cleaning. Covers must be metal or other structurally sound material that is water-resistant and impervious to moisture, and must be adequate to support anticipated loads in the area of use.

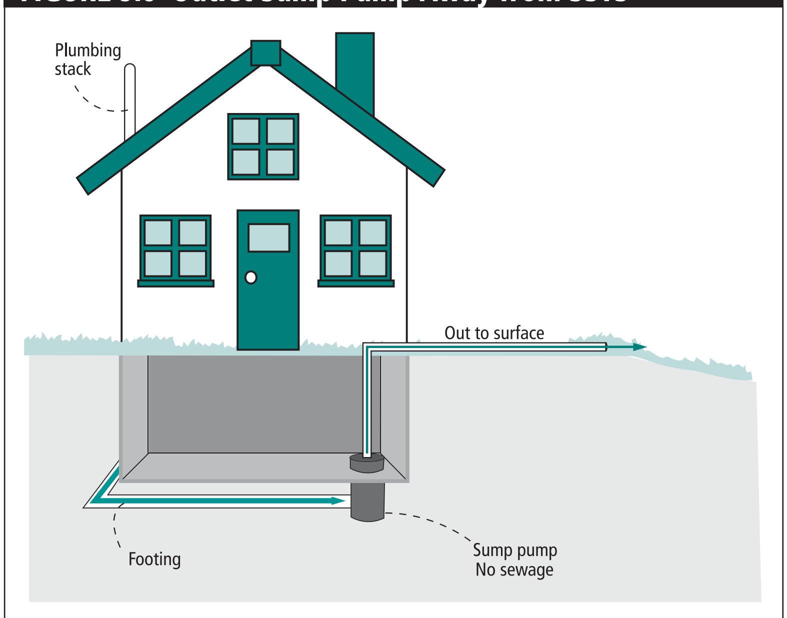
Single family dwellings

In single-family dwellings the minimum capacity of a sump shall be 18 gallons (Subp. 5).

Sump vent

According to Subpart 6, the top of the sump tank shall be provided with a vent pipe that shall extend separately through the roof, or may be combined with other vent pipes. Such vent shall be large enough to maintain atmospheric pressure within the sump under all normal operating conditions and in no case less than in accordance with the number of fixture units discharging into the sump. When the foregoing requirements are met and the vent, after leaving the sump, is combined with vents from fixtures discharging into the sump, the size of the combined vent need not exceed that required for the total number of fixtures discharging into the sump. No vent from an air-operated sewage ejector shall combine with other vents.

FIGURE 9.6 Outlet Sump Pump Away from SSTS



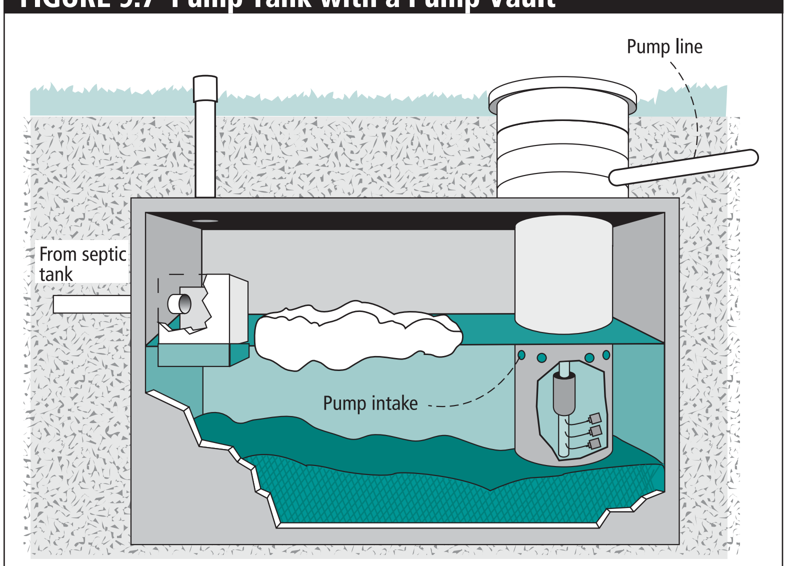
Clear water sumps

These types of sumps must not be hooked to an SSTS, as shown in Figure 9.6. When they are installed and discharged to alternate locations, Subpart 7 states that sumps and receiving tanks which receive only clear water drainage, and from which sewage is excluded, need not be airtight or vented. Sumps and receiving tanks must be provided with covers fastened or secured so as to prevent entry by children. The covers must be adequate to support anticipated loads in area of use. In nonresidential buildings, guard rails constructed in accordance with Chapter 1305, Minnesota Building Code, may be used in lieu of covers.

Pump Tank

A pump should never be installed directly in a septic tank to pump to the final soil treatment unit. There is a large risk that sewage solids will plug either the pump or be carried to the soil treatment unit, which will cause premature failure. Install a two-compartment septic tank or use a separate watertight tank beyond the septic tank. Under these conditions, solids will be separated in the septic tank, and the pump will handle only sewage effluent, which is a relatively clear liquid. Some proprietary products utilize a pump vault to protect the pump as shown in Figure 9.7. This application still typically follows a separate septic tank.

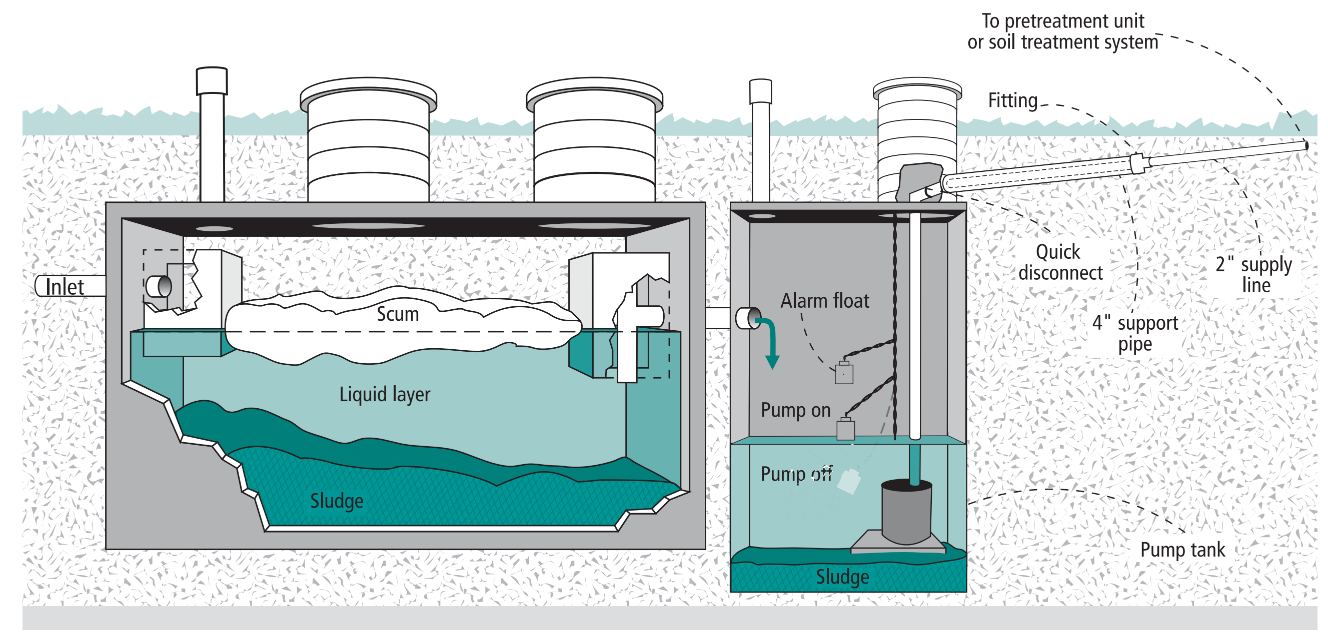
FIGURE 9.7 Pump Tank with a Pump Vault



Definition

A pump tank is a sewage tank or separate compartment within a sewage tank, which receives sewage tank effluent, that serves as a reservoir for a pump. A separate tank used as a pump tank is considered a septic system tank under Minnesota Statutes, section 115.55, subdivision 1, paragraph (p). (MN Rules Chapter 7080.1100, Subp. 64).

FIGURE 9.8 Pump Tank with Float Tree



Pump tanks may also be referred to as “dosing chambers” and these terms are interchangeable. A pump tank or dosing chamber is the tank where the effluent from a septic tank or other pretreatment device is stored to be pumped to the next component in the system. The chamber can be a separate tank (as shown in Figure 9.8), a second compartment in a septic tank, or in some media filter designs, it is incorporated into the sump at the bottom of the filter. It is very important that a compartmented tank with a transfer hole in the clarified zone as described in 7080.1950(B) not be used as a pump tank.

The size of the tank is determined by the total daily flow, should be large enough to supply the dose volume, and should provide some reserve capacity to provide time for maintenance if the pump fails to operate. The pump tank should have a capacity of at least 500 gallons, or be large enough to hold the average daily sewage flow from the establishment, whichever is greatest. The pump tank must either include an alternating two pump system or have a minimum total capacity of 500 gallons for average daily flow values of 600 gallons per day or less, or 100 percent of the average daily flow for average daily flow values of greater than 600 gallons per day. A 500 gallon tank is allowed for a home with a maximum of four bedrooms. If the home is too large, alternating pumps can substitute the additional required volume in the pump tank.

Pump tanks can be round or rectangular. A riser to the ground surface is needed for access to the pump. The pump in a pump tank should be set 4 inches off the tank bottom to provide storage space for any solids that may have carried over from the septic tank. At least two four-inch to eight-inch concrete blocks make a good pedestal for the pump.

In some systems the solids may accumulate in the pump tank. In these systems the pump intake level is critical to minimize solids entering the system. To increase the pump intake a pump basket may be added to the system. This is a basket surrounding the pump and drawing effluent from a higher elevation. Be careful that the floats do not accumulate around the lip of the pump basket.

Requirements

The pump tank construction requirements are the same as for sewage tanks since they are defined as such in **7080.1100, Subp. 74**. The tank must be durable and watertight and must withstand the soil loads, which tend to push in on the walls. The environment in the tanks is very corrosive, so no metal parts or fittings should be used. The major difference between a septic tank and a pump tank is that the pump tank is emptied on a daily basis. Since the tank will be filled and drawn down every day, anchoring it against flotation is critical in areas with a high seasonal or permanent water table, where mound systems, which require pressure distribution, are often used.

MN Rules Chapter 7080.2100, Subp. 2 identify that:

A. Pump tanks shall meet or exceed the requirements of parts 7080.1910, 7080.1970, and 7080.1980 to 7080.2020. All pump tanks must be vented.

B. The pump, pump controls, and pump discharge line must be installed to allow access for servicing or replacement without entering the pump tank.

C. The pump tank must either include an alternating two-pump system or have a minimum total capacity of 500 gallons for design flow values of 600 gallons per day or less or 100 percent of the design flow for design flow values of greater than 600 gallons per day.

D. An ISTS with a pump must employ an alarm device to warn of failure.

E. The inlet of pumps must be elevated at least four inches from the bottom of the pump tank or protected in some other manner to prevent the pump from drawing excessive settled solids.

F. Electrical installations must comply with applicable laws and ordinances including the most current codes, rules, and regulations of public authorities having jurisdiction and with part 1315.0200, which incorporates the National Electrical Code.

The pump tank is placed between the sewage tank and the lateral system to accumulate effluent. A pump is turned on when enough effluent collects in the pump tank, and turns off when the dose has been delivered. In demand-dose systems, the pump is controlled by a set of float switches suspended in the tank. Setting the floats is usually accomplished with a float tree. There is an on switch and an off switch. A third switch is used to trigger an alarm to warn the user when the effluent collected in the pump tank reaches a water level above normal operation. This indicates there has been a pump malfunction. Proper pump tank construction, placement and sizing must be considered to ensure reliable system operation.

Dosing Regimens: Demand vs. Timed

A pump system can be dosed either on demand or according to a timer as discussed in the next section. The configurations used for each of these regimes are specific and should not be altered without consulting the designer. **All ISTS with pumps must be alarmed and provide flow measurement (MN Rules Chapter 7080.2100 Subp. 2 (D)).**

Demand Dosing

Demand dosing is a common method used for delivering effluent to the final treatment and dispersal component. The pump activates when a volume of effluent fills the pump tank to a prescribed level and is solely dependent on the amount of water used in the dwelling or facility. Each time the pump is activated, a designated volume of wastewater is delivered based upon the float elevations and the tank size. This is the simplest form of dosing but results in variable delivery of effluent to the following component of the system.

The most basic form of demand dosing is a float-operated, motor-rated switch into which the pump is plugged. The float is a single wide-angle or differential float control and the configuration is usually called a "piggyback control". Although still specified and used in some areas, this configuration provides no information on system performance if meters or counters are not included. These can be temporarily wired into the panel (by qualified personnel) for troubleshooting purposes. If the system has only piggyback controls, an upgrade to a control panel should be strongly recommended to facilitate data collection during operation and maintenance over the course of system use. Certainly, a high water alarm float switch should be wired into the panel to signal excessive hydraulic loading.

In a demand dosing system, the on/off function can be performed by a single wide-angle (differential) float control. Because a single float has a limited lower and upper operating range two separate floats should be used for pump on and pump off function if a very small or very large dose is required. In this configuration, the pump activates when the effluent rises to the on float elevation, pumps effluent down to the off float elevation, and then deactivates. An additional float should be included to trigger an audible and visible alarm if flow exceeds capacity. A counter that records alarm events is desirable.

In duplex systems, two pumps are alternately activated. When effluent rises to the pump on elevation, pump 1 is activated and delivers the dose volume. The next time a dose is called for, pump 2 is activated, etc. If one pump fails or if flows into the pump tank are excessive, the effluent level rises to the level of the lag switch which activates the resting pump. To provide early indication of excessive flows, the alarm switch may be positioned below the lag switch or the two may be combined. A cycle counter should be included in the control panel to track alarm events.

Timed Dosing

Timed dosing configurations include an adjustable timer that controls pump rest interval and run time for specific dosing regimes. Utilizing timed dosing instead of demand dosing mitigates variations or peaks in wastewater flow. Peak flows from the dwelling are stored and then dosed to subsequent components evenly throughout the day. Timed dosing configurations are more commonly found in systems that include advanced pretreatment devices or flow equalization regimes.

Timed dosing also uses floats to control operation. However, the float switch is a signal float instead of a motor-rated switch. When activated by the rising effluent level, the float sends the electrical signal to the control panel. The electrical signal enables the timer. After the prescribed rest interval, pump operation is initiated by a motor contactor in the control panel and the pump operates for a specified (timer programmed) amount of time. The specified dose volume of effluent is delivered based upon the actual pump delivery rate (PDR). As with demand dosing, other devices such as pressure transducers and ultrasonic water level sensors may be used in lieu of floats.

Many different configurations are possible in timed-dosing. One method includes a separate redundant off float in the drawing on the left. When this float is in the off position (indicating a low level of effluent in the tank), it protects the pump by not allowing it to operate, regardless of the pumping schedule set on the timer. Timer enable and redundant off function may be controlled by the same float. Another option is a configuration that includes a peak enable float installed between the timer enable float and the alarm float. When activated during high flow events, a peak enable float shortens the rest period between normal doses. As a result, more dosing events occur each day and reduce the effluent level in the tank more quickly. Peak enable and alarm function may be controlled by a single float. Note that systems which include peak enable floats are set so that forward flow does not exceed the capacity of the next component or the design flow of the system. Again, a cycle counter should be included to track the number of times the peak enable float is activated.

A timer override float is a differential switch that delivers a different volume to the next component. It essentially (and temporarily) changes the function of the timed dosed system to a demand-dosed regime until the effluent in the tank is reduced to a normal operating level. These are not recommended because they can defeat the purpose of the timer system. It is critical that a counter is included to track how often a timer override float is activated because this indicates how often the system has been hydraulically overloaded.

Whether or not the float or sensor that operates the alarm is combined with other floats, the alarm should consist of an audible device and an easily visible light. It should be wired on an electrical circuit separate from the pump. Without a separate circuit, the pump can overload the circuit and the alarm will not operate.

Flow Equalization

When effluent is pumped from one system component to another, there is an increased need for management. Flow equalization is a management concept that can help reduce stress on system performance due to high peak flows. In flow equalization, the peak flows are stored for a period of time to be delivered to the soil treatment unit over a longer period of time. Usually the flow for one day is equalized over a 24 hour period, but it can be done for longer periods of time, especially if peak flows last for longer than one full day. For this to be accomplished, the tank must be large enough to handle these flows, and the pump operation should be controlled by a timer as opposed to a float. The pump tank capacity for a single family residence using flow equalization is a minimum of 1,000 gallons or two times the daily design flow, whichever is largest. For non-domestic systems, there are two values that need to be calculated to determine storage requirements, design flow and required storage (plus a 20% safety factor).

The sum of these values is used to determine the required capacity.

To use these values, real flow data (daily flow values) is necessary for the design of the system. The average flow is the calculated average for the daily flow reading for a certain time period. Typically, 45-90 days of data will give a clear idea of the use at the site. Regular events should be factored into the flow equalization design. Annual events can be dealt with using other methods of flow control such as portable toilets or pumping. The storage is calculated as the sum of the flows above the average that needs to be held in the system.

Pumps

There are several factors to consider when selecting the proper pump for use in onsite wastewater treatment systems. The main factors are the solids handling capability of the pump and flow/pressure relationships within the system. Solids handling and effluent are the two main types of pumps used for sewage purposes. Clean water sump pumps should not be used in sewage applications because they are not designed to withstand the corrosive environment of onsite wastewater treatment systems.

Rule Requirements

Pumps for Gravity Distribution

From MN Rules 7080.2100, Subp. 3, (A-C) The pump must discharge at least ten gallons per minute but no more than 45 gallons per minute. The pump must be constructed and fitted with sound, durable, and corrosion-resistant materials. The pump must have sufficient dynamic head for both the elevation difference and friction loss.

Pumps for Pressure Distribution

Pumps for pressure distribution must meet the requirements in MN Rules 7080.2100, Subp 4 (A to D):

A. Pumps must be constructed and fitted with sound, durable, and corrosion-resistant materials.

B. The pump discharge capacity must be based on the perforation discharges for a minimum average head of 1.0 foot for 3/16-inch to 1/4-inch perforations and 2.0 feet for 1/8-inch perforations for dwellings. The minimum average head must be 2.0 feet for other establishments with 3/16- to 1/4-inch perforations and 5.0 feet of head for 1/8-inch perforations. Perforation discharge is determined by the following formula:

$$Q = 19.65\, cd^2h^{1/2}$$

where: Q = discharge in gallons per minute

c = 0.60 = coefficient of discharge

d = perforation diameter in inches

h = head in feet.

C. The pump discharge head must be at least five feet greater than the head required to overcome pipe friction losses and the elevation difference between the pump and the distribution device.

D. The quantity of effluent delivered for each pump cycle must be no greater than 25 percent of the design flow and at least four times the volume of the distribution pipes plus the volume of the supply pipe.

Water Meters and Event Counters

MN Rules Chapter 7080 states that a flow measurement device is required for all systems that use a pump as part of the system. All MSTS must employ flow management per MN Rules Chapter 7081.0230 Subp. D. **Flow measurement means any method to accurately measure water or sewage flow, including, but not limited to, water meters, event counters, running time clocks, or electronically controlled dosing (MN Rules Chapter 7080.1100 Subp. 35.).**

For systems that have effluent pumped to a soil treatment system, an electrical event counter or running time clock is an easy way to meet this rule requirement. Section 1 discusses the importance of using the flow measurement device in your conversation with the system owner about the acceptable use of their septic system.

For MSTS systems in MN Rules 7081.0260 (C).The pump discharge capacity must be based on the perforation's discharge, with a minimum average head of two feet for 1/4 inch and 3/16 inch perforations and five feet for 1/8 inch perforations.

Type of Pumps

It is important to select the right kind of pump for the desired application. Following is a brief description of pump choices and applications.

Raw Sewage Pumps

Solids handling pumps are positioned before septic tanks and move raw, unsettled wastewater. Grinder pumps are a type of solids handling pump that incorporate a grinder or shredder in the impeller design. Grinder pumps that discharge directly into septic tanks disrupt critical settling processes because they disperse small particles at considerable force. Treatment trains that include grinder pumps must be designed to mitigate this effect or solids bypass will occur to the detriment of the rest of the system. If a grinder pump is specified, the design should include appropriate measures to avoid excessive solids suspension. Options include:

- Pumping to the inlet pipe instead of directly to the septic tank
- Pumping to a tank installed prior to the septic tank

Whenever sewage solids are pumped, a sewage ejector or solids-handling pump must be used. The diameter of the discharge piping must be of the same diameter as the discharge size of the pump. The sewage must flow through the pipe at a velocity of at least two feet per second to transport the solids.

1. ***Grinder pumps*** can also handle raw sewage. A rotating blade shears or grinds sewage into smaller particles before pumping it. Grinder pumps have a high starting torque and must use a particular type of starting mechanism on the electric motor. In addition, grinder pumps require relatively high maintenance, such as sharpening blades and replacing bearings. Since all sewage must pass through the grinding mechanism, a grinder pump may experience blockage as the grinding mechanism becomes dull or is clogged by foreign debris.
2. ***Effluent pumps*** require that the wastewater be relatively free of solids. They are positioned after septic tanks or within a screened pump vault located at the outlet end of the septic tank. Most effluent pumps use centrifugal force to push the liquid through the pump. Single- and multi-stage pumps provide a broad range of

pressure and flow options for use with various systems. Low head pumps (single-stage) provide a relatively large rate of flow at a lower pressure. High head (multi-stage) pumps provide a relatively lower rate of flow at a greater pressure. Multi-stage pumps are more sensitive to the amount and size of solids in effluent.

Both types of pumps are cooled by the effluent around them. The intake for single-stage pumps is typically located at the bottom of the housing and below the motor. Single-stage pumps are filled with oil that dissipates heat to the pump housing which is then cooled by the surrounding wastewater. The intake for a multi-stage pump may be located above the motor at the mid-point of the pump housing. Such pumps often use a "flow inducer." This may be a manufacturer- or designer-specified PVC pipe that surrounds the pump. The pipe is slotted at the bottom which forces effluent to flow around the motor before entering the intake. Alternately, if the pump is designed so that the motor is in the path of the flow a flow inducer is not needed. Setting the pump off elevation above the top of all pump housings is imperative to allow them to cool by remaining submerged in effluent. This also prevents corrosion of the housing by minimizing exposure to corrosive gases.

High head and low head pumps have different uses in onsite wastewater treatment systems. Typically, high head pumps are required when moving effluent to high elevations and/or through long supply lines where loss of pressure due to friction in pipe and fittings is an issue. Low head pumps (single-stage) move more flow at less pressure than high head pumps and are used when those needs arise.

Other Pumps

1. ***Sump pumps*** are typically used in basements to pump groundwater from around foundations. These pumps should not be used to pump sewage effluent.
2. ***Ejector pumps*** are commonly installed in basements to pump sewage solids up to a gravity sewer line. The volume of the pump tank must be large enough to accommodate any drainback from the piping and to effectively dose the system. Whenever such a pump is used to deliver toilet waste to a septic tank, dose volume must be limited to minimize the impact on the tank.

Friction Loss in a Pipe

Friction loss is the reduction in pressure of liquid flowing through pipe and associated devices as a result of contact between the liquid and the pipe walls, valves, and fittings. Friction loss varies with flow rate and pipe diameter. The values are given in friction loss per 100 feet so the length of the pipe must first be divided by 100 before being multiplied by the factor given in the table or graph. This is discussed in more detail in Section 11. The values from the table are estimated using the Hazen-Williams equation:

$$\textit{Friction} \quad \textit{Loss} = 10.46L\frac{\left(\frac{Q}{C}\right)^{1.852}}{D^{4.871}}$$

Where

L = length of pipe (feet; include addition of equivalent lengths for fittings in Table 9.2)

Q = flow rate (gpm)

D = actual pipe inner diameter (inches)

C = friction coefficient (The friction factor - C) is a unitless value that is dependent of the pipe's inner surface's roughness. The lower the value of C, the greater the friction loss. Values for the friction factor for PVC pipe range from 130 to 150. For new pipe, 150 is often used as the factor. This manual assumes that with time the pipes will become less smooth resulting in a lower friction factor so a value of 130 was used in estimating the friction loss in tables).

Note: The smaller the pipe diameter and the greater the flow rate, the more friction loss in a given length of pipe.

Friction Loss Example:

What is the friction loss generated by liquid flowing at 32 gpm through 100 feet of 1 1/2-inch Schedule 40 PVC, assuming C=130?

Friction loss (ft) = $10.46 \times 100 \times [(32/130)^{1.852}] / (1.5^{4.871})$

= $1046 \times (.246^{1.855}) / 7.21$

= $1046 \times .075/7.21$

= 10.9 ft of friction loss

Sensors for Pumps

Sensor is the general term used for all the different devices used to sense water levels in the tank and activate the pump, including ultrasonic sensors, or using sound to measure depth. Another option is pressure sensors, which use the pressure created by the depth of water to determine the depth. These pressure sensors are valuable since they can read out the actual depths. However, the most commonly used and simple device is a float.

Control switches (floats) sense the water level in the pump tank and signal the pump or alarm system. A failure of the control switches can cause sewage to back up into the home or come out the top of the pump tank. Some switches provide power to the pump directly, while others require a relay.

Mechanical switches or floats encased in plastic or neoprene are recommended. They are simple and reliable. In some designs, the system uses a single float to operate the pump. In other designs, two floats are used to operate the pump. In two float situations, one switch turns the pump on and a second switch is placed below it to turn the pump off. A third switch is used to activate an alarm if the effluent level exceeds the storage capacity. The distance needed between the on and off switches for a given dose volume depends on the size and shape of the pump tank.

Pump Controls

The cables that connect to the pump control switch, alarm switch, and pump all originate from the pump and alarm control. The control should either be placed inside a nearby building or inside a weatherproof box on a post near the entrance port to the pump tank. Never place the control system inside the pump tank or riser. The moisture in the pump tank will cause the system to corrode and fail.

The preferred location for the control and alarm center is indoors, such as in a basement or garage. Conventional indoor wiring material may be used. Order pump and controls with extra-long cables. When a nearby building is not available, locate the control center in a weatherproof enclosure mounted to a treated wood or steel post near the pump tank. In either case, it is important to use wire, connectors, and weatherproof enclosures appropriate for outdoor use.

A pump motor relay with built-in motor overcurrent protection can be used. The pump motor start and stop switches control the relay coil current. Conduit is used for physical protection of the conductors and cables entering and leaving the box.

A pump motor controlled by the mercury switches and relay built into a plug-in type unit is another option. Overcurrent protection for the motor is supplied by the ground-fault circuit interrupter (GFCI)/circuit breaker combination in a weather-proof enclosure. National Electric Code requirements state that all outdoor outlets of a residence must be GFCI-protected. The GFCI-protected receptacle for the pump power and control circuit should be enclosed in a watertight box. Another alternative is to use a receptacle with built-in GFCI protection and a standard circuit breaker. In either configuration, the alarm system is powered from a separate circuit breaker to prevent tripping the alarm circuit when the pump circuit is tripped. Schematics and additional discussion about pump controls can be found above Figure 9.16 on pg. 26.

Alarm

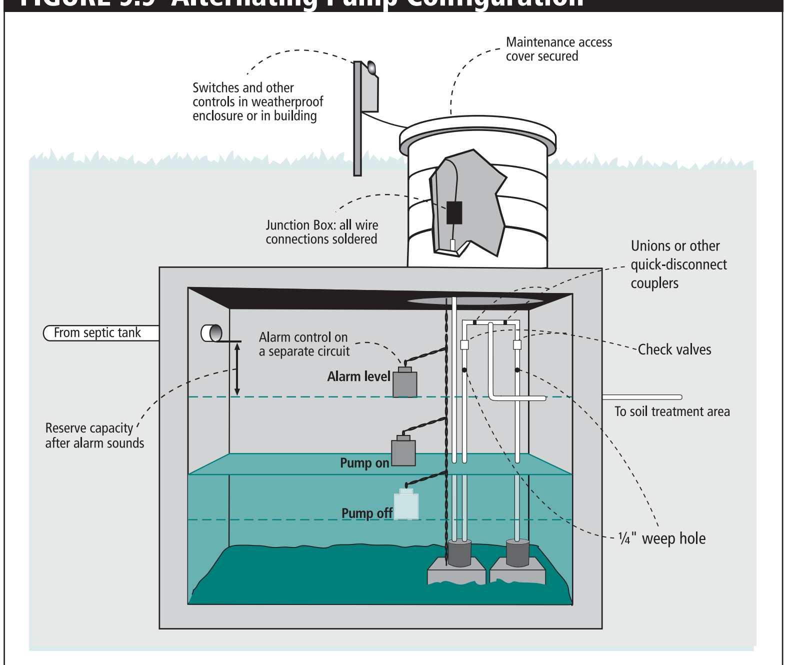
An ISTS with a pump must employ an alarm device to warn of failure. **Alarm device is defined as a device that alerts a system operator or system owner of a component's status using a visual or audible device; an alarm device can be either on site or remotely located (MN Rules Chapter 7080.1100, Subp. 4).**

An alarm float should be located on an electrical circuit separate from the pump to alert the homeowner in case of electrical failure in the pump circuit. The alarm float should be set to activate approximately three inches higher than the pump start level. It is recommended that the alarm mechanism should be both visible and audible, and located where it can be easily seen and heard.

The reserve capacity of the tank is the remaining volume after the alarm sounds. This volume can then be recorded and allows the owner a time period within which the maintainer must come to correct the issue causing the alarm to sound.

The alarm system must be powered in such a way that if the pump circuit fails, the alarm will still operate. Provide a means to turn off the alarm without losing power to the pump.

FIGURE 9.9 Alternating Pump Configuration



Dual Pumps

All MSTS Systems must have multiple pumps according to MN Rules Chapter 7081.0260 (B) where it specified that the dosing system must include an alternating two-pump system and have a minimum total capacity of 50 percent of the design flow. For two or more residences that have a common soil treatment unit, for collector system pump tanks, or for an establishment that deals with the public such as a restaurant or motel, dual alternating pumps are recommended. The pump size may be similar to that used for a single residence, but a control is required to operate the pumps on alternate cycles. The pump control mechanism also has an alarm device in case one pump fails to operate when called upon. A dual pump configuration is shown in Figure 9.9 (previous page).

If liquid flows into the pumping tank faster than one pump can handle, both pumps should operate. If one pump fails, an alarm will sound, and the other pump will continue in service until repairs can be made. Note that an alarm device must also be installed on a separate electrical circuit, so that if a power failure occurs in the pump circuit, and the alarm on the pump control mechanism does not operate, an alarm still will sound.

FIGURE 9.10 Two Compartment Septic Tank

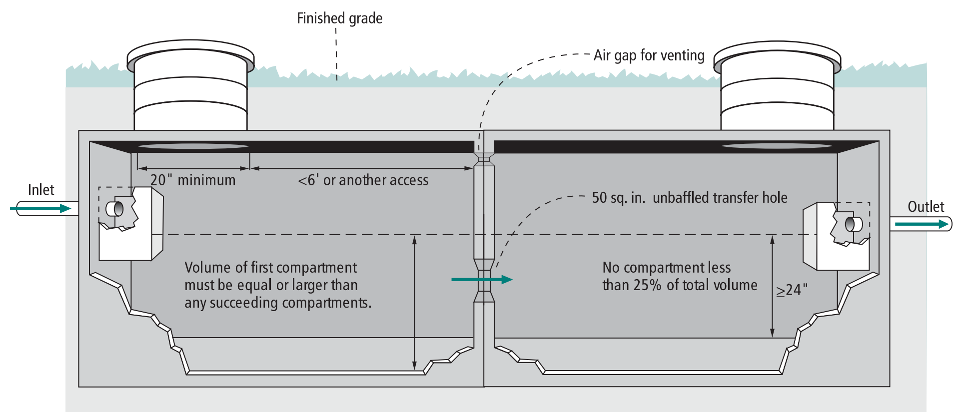
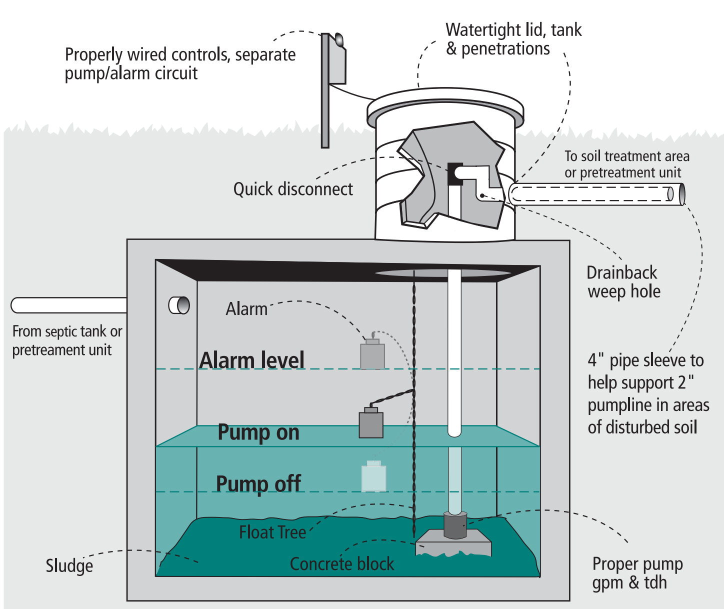


FIGURE 9.11 Pump Tank Specifications



For a combination septic tank/pump tank, all specifications must also be carefully followed for the septic tank portion, including baffle submergence, cleaning access and inspection pipes. Effluent from the septic tank compartment flows by gravity into the pump tank compartment, which has essentially the same specifications as both Figures 9.10 and 9.11. **MN Rules Chapter 7080.1950 (B) state that the final compartment of a tank that employs a transfer hole in the clarified zone shall not be used as a pump tank,** meaning that this transfer must be baffled. Combination tanks are commonly available or can be manufactured upon request. The pump tank compartment must have a volume of at least 500 gallons or 100 percent of the average design flow, whichever is greater, or an alternating two-pump system. These systems will need two check valves to make sure the effluent doesn't recycle into the tank. To avoid problems be sure the supply line still drains and an air release hole is installed between the pump and the check valve.

Designing Pumping Systems

Selecting Pumps

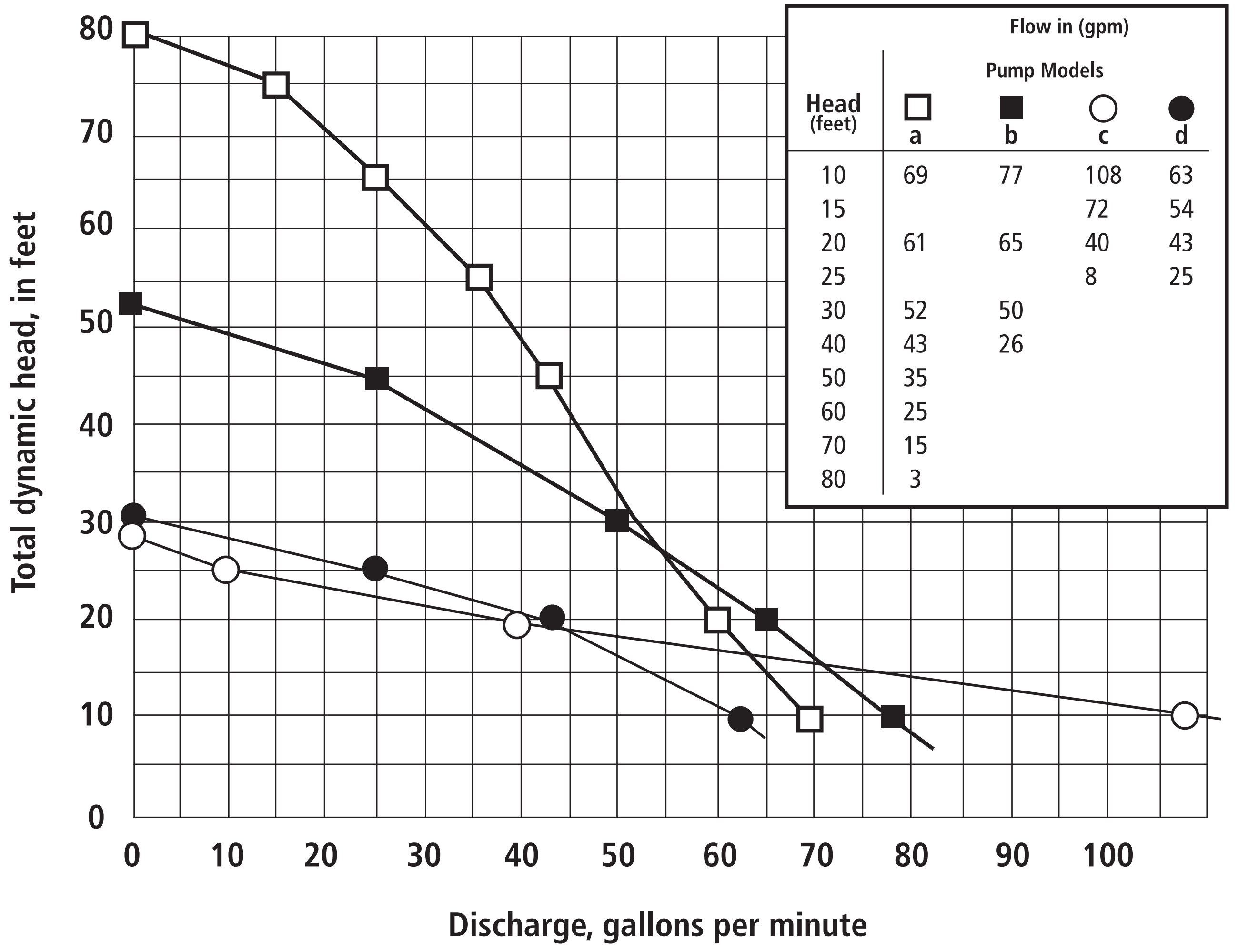
Selection of the pump is based upon the configuration of pipes the pump will be connected to, the elevation that must be overcome, and the flow requirements for the system.

Pump Curves

A pump curve describes the amount of total dynamic head (TDH) a given pump can overcome at various flows while a system curve describes the TDH in a given system over a range of flows. Pump manufacturers develop pump curves by documenting actual pump operation of each model of pump that they sell.

Figure 9.12 shows performance characteristics of four different submersible pumps. The head-discharge relationship of a pump is called the **characteristic curve**. The lowest curve represents the pump with the least power and the top curve the pump with most power for a particular pump series. Each pump will operate on its own characteristic curve, and the curve describes the pump in two ways: the desired **capacity** in gallons

FIGURE 9.12 Pump Curve Example



Head (feet)	Flow in (gpm) Pump Models a (□)	b (■)	c (○)	d (●)
10	69	77	108	63
15			72	54
20	61	65	40	43
25			8	25
30	52	50		
40	43	26		
50	35			
60	25			
70	15			
80	3			

per minute or per hour, and the **total dynamic head**, the amount of elevation the pump can deliver. As the discharge rate increases, the amount of head a centrifugal pump delivers will decrease. The point where the characteristic curve intersects the vertical axis is called the shutoff head. The point describing the necessary capacity and total dynamic head must fall *under* the curve. If it doesn't, choose a different pump.

Referring to the example pump curves in Figure 9.12, if pumping requirements are 20 gallons per minute at 20 feet of total dynamic head, none of the pumps presented in Figure 9.12 will deliver precisely this specification. If exactly 20 gallons per minute are needed, a gate valve will need to be installed to dissipate a small amount of head so that the actual head delivered by the pump will be approximately 20 feet. If the 1/2-hp-b high-head pump is used, and 20 feet of head are required, the pump will deliver 45 feet of total head and 25 feet of the head will be dissipated in the gate valve.

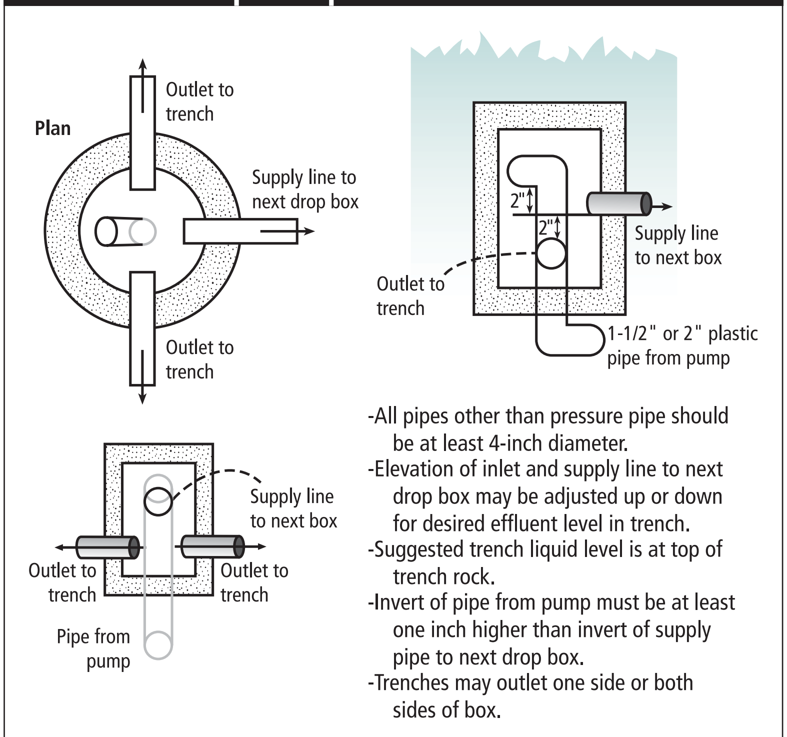
When the pump discharge is to a pressure distribution system in a mound, this system is self-balancing. As the flow increases, pressure at the perforations also increases, and the pump will operate at some point on its own particular characteristic curve. There is no need to install a gate valve with a pressure distribution system.

Refer to the form on the website, septic.umn.edu/ssts-professionals/forms-worksheets, to follow this design process.

a. Choosing a Pump for a Gravity-Distribution Soil Treatment System

Because pump capacity needs to be greater than the domestic water use rate, a minimum flow of 600 gallons per hour, which is equivalent to 10 gallons per minute, is required when a pump used for a dwelling discharges to a gravity-fed soil treatment system. When choosing a pump, look at the pump curve to deliver at least 15 feet of head at the elevation difference. For most pumps this will guarantee at least 10 gpm when the friction loss is included.

FIGURE 9.13 Drop Box Specifications



The maximum discharge rate for delivery to a drop box of a dwelling's sewage system is 45 gallons per minute, which is the approximate amount that will flow by gravity through a four-inch pipe. Choosing a pump that delivers at or less than 45 gpm at the elevation difference will minimize substantial head in the drop box. It would not be good practice to develop any substantial head in a drop box. Follow specifications provided in Figure 9.13.

The sizing procedure is to measure the elevation difference. Applying this as the head loss to the pump curve and then making sure the pump capacity is between 15-45 gpm, the system will work effectively.

b. Choosing a Pump for Pressure-Distribution Soil Treatment Systems

In a pressure distribution system, the required gallons per minute is set by the configuration and perforation sizing in the system. Refer to Section 12 on Distribution and the Pressure Distribution Worksheet for more information.

Head requirements

These parameters are expressed as total dynamic head or TDH. TDH is the sum of:

a. **Static head or elevation head:** the difference in elevation between the "pump off" elevation in the pump tank and the highest elevation of pipes in the STA expressed in feet as shown in Figure 9.14.

FIGURE 9.14 Elevation Head

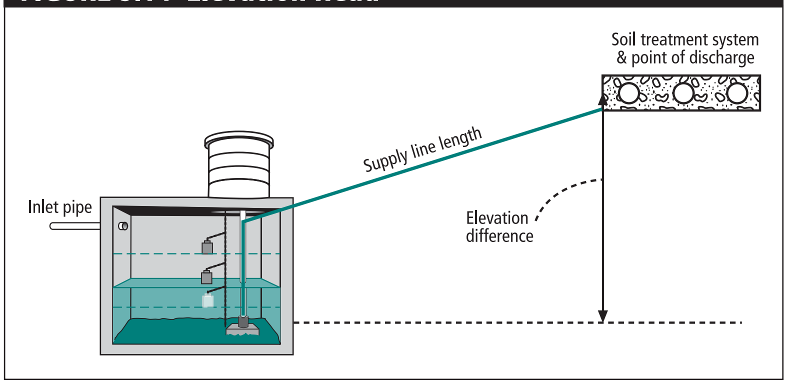


TABLE 9.1 Friction Loss in Plastic Pipe/100 feet (C=130)

Flow Rate (gpm)	Nominal Pipe Diameter				
	1"	1 1/4"	1 1/2"	2"	3"
10	9.1	3.1	1.3	0.3	—
12	12.8	4.3	1.8	0.4	—
14	17.0	5.7	2.4	0.6	—
16	21.8	7.3	3.0	0.7	0.1
18	—	9.1	3.8	0.9	0.1
20	—	11.1	4.6	1.1	0.2
25	—	16.8	6.9	1.7	0.2
30	—	23.5	9.7	2.4	0.3
35	—	—	12.9	3.2	0.4
40	—	—	16.5	4.1	0.6
45	—	—	20.5	5.0	0.7
50	—	—	—	6.1	0.9
55	—	—	—	7.3	1.0
60	—	—	—	8.6	1.2
65	—	—	—	10.0	1.4
70	—	—	—	11.4	1.6

b. **Distribution Head Loss:** (or residual pressure): the pressure required for a component or device to operate properly. If a pressure distribution system is used, five – ten feet should be entered here. For pumping to a drop box of a trench system, zero would be entered.

c. **Friction loss is** the reduction in pressure of liquid flowing through pipe and associated devices as a result of contact between the liquid and the pipe walls, valves, and fittings. Friction loss depends upon type of pipe, pipe diameter (Step 6), length of pipe (Step 6), and flow rate (Step 1). Friction loss values for plastic pipe are shown in Table 9.1. For the chosen flow rate and pipe size, find the feet lost per 100 feet and enter into Step 7. Note from Table 9.1 that friction loss increases very rapidly as pipe diameter decreases. For example, friction loss for 35 gpm in 1-1/2 inch pipe would be 12.9 gallons.

Fittings as Equivalent Straight Pipe

Friction loss calculations can be calculated in two ways: either by estimating a percentage loss or calculating actual losses in the pipe network. The first method can be used for single family homes with simple piping networks with tanks and soil treatment systems in close proximity. The second method should be used for complex piping networks.

Method 1: Estimating a percentage

In addition to straight pipe, a piping system has elbows, tees and other fittings. Each of these fittings can be expressed in equivalent lengths of straight pipe. A simplified way to account for these fittings is to multiply the length of the straight pipe by a factor of 1.25 under Step 8 of the Pump Selection Design Worksheet.

Method 2: Calculating actual losses

This method considers pipe length and all bends and fittings as individual components contributing to friction loss. Assume the distance from the pump to the mound manifold is 140 feet. Also assume there are four 45-degree and two standard 90-degree elbows.

TABLE 9.2 Equivalent Length Factors (ft.) for PVC Pipe Fittings

Fitting Type	Pipe Diameter (in.)		
	1 1/2″	2″	3″
Gate Valve	1.07	1.38	2.04
90° Elbow	4.03	5.17	7.67
45° Elbow	2.15	2.76	4.09
Tee- Flow Thru	2.68	3.45	5.11
Tee- Branch Flow	8.05	10.30	15.30
Swing Check Valve	13.40	17.20	25.50
Angle Valve	20.10	25.80	38.40
Globe Valve	45.60	58.60	86.90
Butterfly Valve	-	7.75	11.50

Method 2 requires the elbows to be converted into an equivalent pipe length. Refer to Table 9.2 or your plumbing supplier to determine the equivalent pipe length for each type of bend, fitting and obstruction in the piping system.

Example:

Actual Pipe length= 140’

+ Four 45° elbows= 4 x 2.76 = 11.04’

+ Two 90° elbows= 2 x 5.17 = 10.34’

= 140’ + 11.04’ + 10.34’ = 161.38’

Using a flow rate of 35 gallons per minute (from Table 9.1), the total friction loss is:

161.38’ x (3.2’/100’) = 5.16 feet.

Sizing the Pump Tank

Refer to septic.umn.edu/ssts-professionals/forms-worksheets to follow this design process.

Dose volume

1. Determining Area and Gallons per Inch

A designer first needs to know the **gallons per inch** of the pump tank that may be used for the design. After going through the float and timer settings, it may be that the chosen tank may end up too small for the required application and a larger tank needed. The gallons per inch is typically provided by the tank manufacturer, but it can also be calculated by the designer. To determine the gallons per inch of a tank you must determine the area of the tank, either rectangular or circular. There are examples of this calculation under number 4.

If the tank to be installed is unknown the Designer may assume one or pick a gallons per inch, but it is very important to note this on the design as the Installer will need to modify the float settings if a different gallons per inch is chosen.

2. Determining Tank Capacity

Then the next step is to select and/or determine the **tank capacity**. The pump tank must have a capacity of at least 500 gallons, or be large enough to hold the average daily sewage flow from the establishment, whichever is greatest. The pump tank must either include an alternating two pump system or have a minimum total capacity of 500 gallons for average daily flow values of 600 gallons per day or less, or 100 percent of the average daily flow for average daily flow values of greater than 600 gallons per day.

A 500 gallon tank is allowed for a home with a maximum of four bedrooms. As flow increases alternating dual pumps are recommended. If an exiting tank is being used the total tank capacity can be determined by multiplying the depth from the liquid depth of the tank by the gallons per inch which will provide the gallonage.

The Designer then specifies the **Volume to Cover** the pump. This is calculated by entering a pump height including a block and adding 2 inches to cover the pump. Then this is multiplied by the gallons per inch to calculate the volume. This capacity is lost as part of the dosing as effluent must always cover the pump.

3. Setting the Dose Volume

For pumping to gravity applications the dose capacity must be no greater than 25 percent of the average design flow.

Example

Estimated average design flow from a four-bedroom, Class I home is 600 gallons per day. Thus, the start and stop levels should be set to pump no more than 0.25 x 600 = 150 gallons.

For pumping to pressure applications the same rule applies that the dose must not be greater then 25 percent of the average design flow, but is also must be as large as the volume of the supply line plus four times the volume of the distribution pipes to allow a reasonable pump operation time. Refer to the Pressure Distribution Worksheet for this calculation. The **Dose Volume** must be between the volume of the supply line plus four times the volume of the distribution piping (at a minimum), and 25% of the **Design Flow** (at a maximum).

TABLE 9.3 Water Volume by Pipe Diameter

Pipe Diameter (inches)	Gallons per 100 Feet	Gallons per Foot
1	4.49	0.045
1.25	7.77	0.077
1.5	10.58	0.110
2	17.43	0.174
2.5	24.87	0.249
3	38.4	0.380
4	66.1	0.661

Example

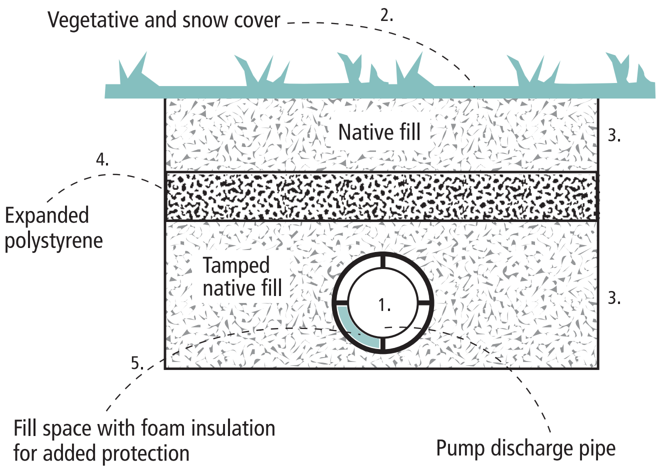
If the system has three laterals that are 1.5 inches in diameter and 37 feet long what is the minimum dose?

Using Table 9.3, the laterals need 3 laterals x 37 feet x 0.110 gallons per foot to fill them. Chapter 7080 requires four times this value (12.2 gallons) or 12.2 x 4 = 48.8 gallons plus the volume of the supply line. This value should be added to the drainback as you calculate the minimum dose.

The Designer will also want to consider the manifold impact upon drainback. Remember, this is determined by the style of manifold-to-lateral connections. In staggered tee connections, the manifold drains through the holes. In tee-to-tee connections, the manifold drains back to the pump tank.

Check valves are sometimes used on very long mains to eliminate the need to drain and refill them. In this case, the dose volume will have no drainback volume added. However, main lines with check valves must be protected from freezing as shown in Figure 9.15 (next page). Drainback is the best design practice for septic systems in Minnesota.

FIGURE 9.15 Frost Proofing Discharge Pipe



5 Options to Reduce Frozen Pipes:

1. Keep discharge pipe on a grade back to pump, and do not allow low spots in discharge line
2. Vegetative and snow cover. When snow cover is light, place six inches of hay or straw on ground above pipe
3. Proper cover and backfill
4. Sheets of expanded polystyrene
5. Pipe sleeved in larger diameter pipe with or without foam insulation

The maximum **Doses per Day** is then calculated by taking the Design Flow and dividing it by the Dose Volume. Hopefully, the system will not receive this many doses per day as the Design Flow should not be a flow that the system sees normally, but only during peak events.

In most domestic applications, the pipe from the pumping station is buried only deep enough to prevent physical damage. It is sloped to drain back to the tank after each pump operation. If exactly 150 gallons are to be pumped in a dose, the amount of drainback must be accounted for. The **Drainback** is calculated by setting the diameter and length of the supply pipe. Referring to Table 9.3 the volume of liquid in pipe based on the diameter can be chosen.

Then the total amount of drainback is calculated by multiplying the length of pipe in feet times the volume of the liquid per linear foot.

The **Total Dose Volume** is then found by adding the **Dose Volume** and the **Drainback**.

Float and Timer Setting

See Step 4 on the Pump Tank Sizing, Dosing and Float and Timer Setting Worksheet.

Demand Dosing

If demand dosing is used where the floats alone control the pump the **Float Separation Distance** is calculated by taking the **Dose Volume** divided by the **Gallons per Inch**.

Example

Cylindrical Tanks

The gallons per inch in a cylindrical tank can be determined by:

π x (radius)^2 x 7.5 gallons per cubic foot / 12 inches per foot

π has a value of 3.14, so if a circular tank of two feet in radius is used as the pumping tank, the calculation is:

3.14 x 2^2 x 7.5 / 12 = 7.85 gallons per inch

If 150 gallons are to be pumped, float separation is calculated as:

150 / 7.85 = 19 inches

The start control must be set 19 inches higher than the stop control in order to pump out 150 gallons per pump cycle.

Rectangular Tanks

The gallons per inch of depth in a rectangular tank can be determined by:

width x length x 7.5 gallons per cubic foot / 12 inches per foot

If a rectangular pumping tank has inside dimensions of four feet by five feet, the volume per depth is:

5 x 4 x 7.5 / 12 = 12.5 gallons per inch

To pump 150 gallons, calculate:

150 / 12.5 = 12 inches

The alarm depth then needs to be determined. Typically the alarm is triggered when the effluent gets 2-3 inches above the pump start level. To determine this volume chose an alarm depth and multiply by the gallons per inch. The **Alarm Volume** is then added to the **Volume to Cover the Pump** plus the **Dose volume** to determine the **Total Gallons**. If the Total Gallons is divided by the gallon per inch the **Minimum Tank Depth** is calculated.

Then set the **Pump Off-Float** by taking the Pump Height +Block Height + 2 inches. The **Pump On-Float** level should be set at twelve inches above the **Pump Off-Float** level. This is calculated by taking the **Distance for the Off-Float** calculated above and adding in the **Float Separation Distance**.

The alarm float height is then the **Distance to set the Pump–On Float** + **Alarm Depth**.

Time Dosing

When a timer is being used to control the pump the **Gallons per Minute** of the pump being used must be defined. In most instances this will come from the pressure distribution design, but also may be chosen in gravity applications. During installation or on existing systems the gallons per minute must be calculated by performing a draw down test where the change in depth in a tank in inches is recorded over a period of time and multiplied by the gallons per inch of the tank. This is the only way to have an accurate dose.

Timer On

To calculate the **Timer On** the **Dose Volume** is divided by the **Gallons per Minute** of the pump. This will provide the number of minutes the pump will run each time it turns on. The pump will not activate if sufficient sewage is not present to be dosed.

Timer Off

To determine the **Timer Off** take the number of minutes in a day (1440) divided by the likely or typical **Doses per Day** and subtract the **Timer On**. This will establish the amount of time between doses in minutes. This time may need to be adjusted over time if current usage per day is unknown.

The Pump-Off float is still set to cover by taking the Gallons to Cover the Pump and dividing by the Gallons per Inch of the tank.

Installing Pumps and Pump Tanks

Pump Tank

Ensuring that the pump tank is watertight is critical. In areas with a high seasonal or permanent water table, groundwater may leak into the pump tank and overload the system. The seals around the pipes that enter and exit the pump tank are especially vulnerable to leaks. If the pump is running more than the few minutes a day it takes to pump out the accumulated septic tank effluent, groundwater may be leaking into the septic tank or pump tank.

The installation of the riser is the same as discussed in Section 7. The piping may leave through the riser, adding to the importance of proper backfilling. Be sure the pipe is well supported and drains back to the tank. This includes the installation of a weep hole in the supply line in the tank. This ¼-inch hole should be placed on the bottom of the pipe to assure that the supply pipe will drain. It should be placed so minimal standing water is in the pipe. MN Rules Chapter 7080 requires either 100 percent of design flow or dual alternating pumps.

The pipe should be well supported outside the tank. All the components for the discharge assembly should be installed and the wiring safely brought into the pump tank. Using the proper size conduit for this is critical. A two to three-inch conduit is necessary to allow for the pump to be changed without cutting the cord. Be sure that conduit with sweep 90's are used to allow for removing and returning the cords. This conduit also needs to be properly sealed to avoid venting of odors and cold air entering the system. The conduit should be sealed with a removable material such as duct seal. Do not use expandable foam insulation since it cannot be removed.

A complete pumping system includes a pump tank, pump and controls. The pump tank must be watertight and constructed of materials that will not corrode or decay. The cleaning access must be installed to the ground surface and securely fastened or locked so that unauthorized persons cannot get into the tank. Pumps are sized according to the specifications of each system and a specific model should be indicated in the design. A "similar" pump should not be used unless confirmed in writing by the designer.

Buoyancy

If the pumping tank is installed where the water table is high, consider the potential problem of tank buoyancy. Be sure the weight of the tank will be adequate to prevent flotation when the tank is nearly empty (which it will be much of the time). Otherwise, anchors may be needed to prevent tank flotation. This issue is discussed in full in Section 7, Septic Tanks.

Flotation or buoyancy usually is not a problem with concrete tanks but should be verified for any design and installation. These tanks will be empty at times, so the buoyancy should be checked. The weight of the tank and the cover weight of the soil are the forces keeping the tank the ground. For the lighter weight materials, the manufacturer may have certain requirements. Such tanks are very likely to need anchoring according to manufacturer's specifications. The use of buried curbing and strapping is a method to assure the tank will not float.

A compartmented tank where the first compartment is the septic tank and the second compartment is the pump tank may be employed in some sites. A compartmented tank can help to reduce the buoyancy problem since the septic tank portion is typically full. When a compartmented tank is used, the strength of the inside wall between the septic tank and the pump tank is critical. Since there will be constant water pressure on one side of the wall, the tank needs to be designed to withstand that pressure. Be sure that the septic capacity is adequate for the use. Remember that any solids will impact the pump and the dosing system.

Pump Discharge Assembly

The discharge assembly is made up of all the piping and components from the pump discharge point to the point at which the supply line leaves the tank. The assembly should be accessible and reachable from the ground surface. A length of nylon rope, stainless steel cable, or other non-corrodible material should be attached to the pump to facilitate removal during maintenance activities. It must have sufficient strength to lift the weight of the pump. In larger systems, a corrosion-resistant rail system may be specified. The pump discharge assembly should have a union or other quick-disconnect coupler to facilitate removal of the pump without having to cut the discharge pipe. This may be a three-part threaded union, a cam lock fitting, or other simple inline disconnect able to withstand the pressure created by the pump system. Rubber connectors are not designed to withstand the pressure created in these systems.

If the elevation of the supply line changes significantly from the tank to the next component, air may become trapped in the line during rest periods. In this situation, an air release valve should be placed at the highest elevation of the pipe. The valve should be housed in a vault that comes to grade to allow for inspection and maintenance.

Sensors

There should be *no electromechanical devices or connections located in the pump tank* or in the pump tank cleaning access. The electrical plug-ins should be located in a weather-proof enclosure near the pumping tank or located in a nearby building. It's a good idea to attach the control wires to a separate pipe (float tree) and the pump to a plastic rope or chain with an anchor so that the control wires can be removed without removing the pump. Also, if the pump has failed, it can be removed without disturbing the control wires.

The access for the pump and other components should come to the finished grade. The pump and components should be located directly under this lid, and easy access to these components for management is a must. The cover of the pumping tank, the cover of the septic tank, and all cleaning access extensions must be made absolutely watertight to prevent any groundwater from infiltrating the system. Pipe connections to the tanks also must be sealed to be absolutely watertight. Be extremely careful to make sure the supply line from the pump tank does not settle. Additional support is necessary to ensure the system will operate without freezing. Placing the supply line in conduit throughout the area of excavation is a recommended practice.

Controls

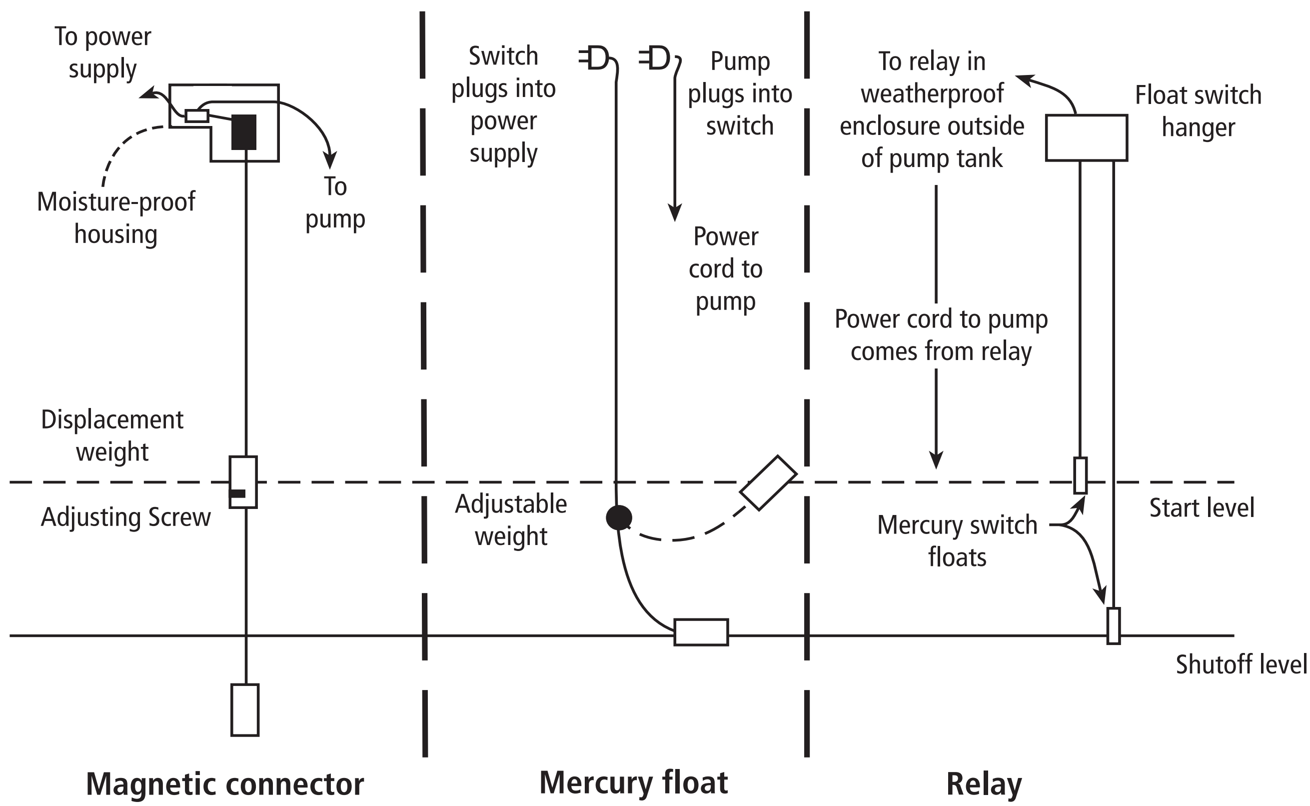
Pump systems should include a control panel. The control panel can be quite simple or more complex based on the functions it must perform.

Electrical components in the panel respond to water level sensors or floats in the tank. The components then perform a variety of basic functions:

- Automatically turning the pump on and off with a manual override
- Sounding an alarm to indicate problems
- Providing a means of monitoring the system (meters/counters)
- Initiating a telemetry device for system alerts
- Activation of equipment for remote system operation

There are several types of devices to achieve these functions as shown in Figure 9.16

FIGURE 9.16 Three Styles of Water Level Sensors



Liquid level at location of stop control must be above pump case.

In all cases, electrical components and connections must be properly protected from the elements and from the corrosive environment of the pump tank. Ideally, this is achieved through use of a National Electrical Manufacturers Association (NEMA) 4X enclosure (4X refers to watertight and corrosion protection enclosure) with properly sealed connections. Electrical connections are ideally located outside of the pump chamber to avoid that corrosive environment.

Pump and Alarm

Proper installation of a pump requires three specific items: 1) the pump is accessible, 2) replaceable, and 3) properly wired. This also applies to the discharge assembly.

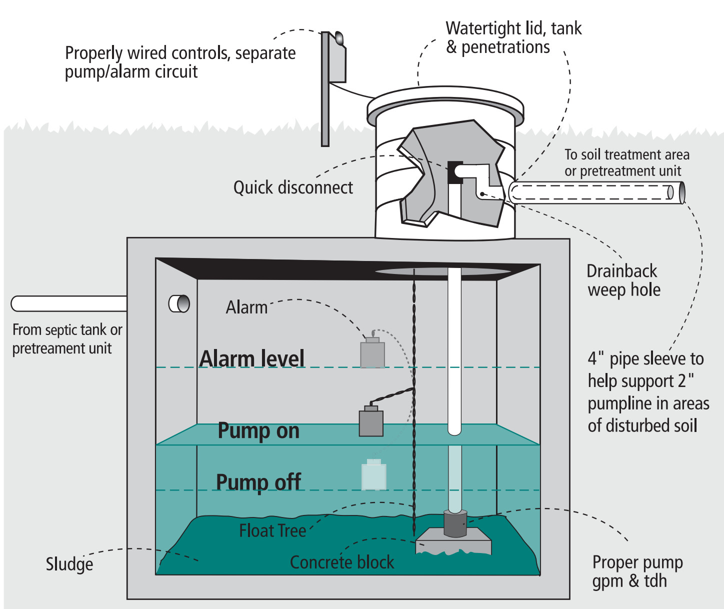
Accessible

The pump, pump controls, and pump discharge line must be installed to allow access for servicing or replacement without entering the pump tank. Accessible means that the pump is underneath the manhole. It should be noted that the access manhole should be brought to the surface; the pump will need maintenance at some point, and if the manhole is not at the surface, what could be simple is complicated each time service is necessary. The pump should be placed directly below this manhole. If it is not, maintenance becomes a SCUBA-dive.

The pump should have a quick disconnect as part of the pump assembly. This quick disconnect allows for the quick and easy removal and reinstallation of the pump, which should be able to be accomplished with little to no need for significant tools. A cordless Sawzall is not considered a quick disconnect but can be very useful for fixing other minimal installations. A Fernco (a rubber piece with two hose clamps) is useful for gravity installation but is not a quick disconnect; it is an automatic disconnect. A Fernco is not designed for pressure greater than 7 to 10 feet of head. Even a pressure Fernco doesn't allow for typical pressures in a pressure system.

A final factor in pump accessibility is that the pump assembly is reachable from the surface. Typically this means 18 to 20 inches from the access lid to the piping for removal of the pump. It is also helpful if the pump has a rope for assisting in the removal of the pump. This will make it easier for the pump to be lifted and replaced.

FIGURE 9.17 Easy Access Allows Maintenance



Replaceable

The pump and controls should be replaceable. For the pump, this means that it is accessible as described above as well as removable from the tank. Removable means that the pump wiring can be taken out without significant excavation. The wires should run through a conduit. Chipped concrete is not a good conduit for the wires entering and exiting the tank. The conduit should be large enough to allow for any plugs to be pulled through the conduit and the box. It is important to remember that if the plug is removed from the pump, the warranty is typically voided. Make sure that all wiring meets all applicable state and national electrical standards.

It is also helpful that to have the pump floats on a separate float tree. This allows for the removal of the pump without removing the floats, and vice versa. The use of a float tree will ensure quick access and removal when necessary. Figure 9.17 highlights key practices that allow for the simple replacement of a broken pump.

The pump should also be elevated three to four inches off the bottom of the tank. The elevation protects the pump and the soil treatment area from solids that can accumulate in the bottom of the pump tank. When doing this, use enough blocks so that you can replace the pump from the surface. A single block at the bottom of the tank will not be sufficient: trying to balance a half- horse pump on the end of 8 to 10 foot section of 2-inch pipe can be a very difficult job. Adding several bricks to give a wider base is helpful and will not negatively impact the system.

Properly Wired

Electrical installations must comply with applicable laws and ordinances, including the most current codes, rules, and regulations of public authorities having jurisdiction and with MN Rules Chapter 1315.0200, which incorporates the National Electrical Code.

The pump must be properly wired. This means that watertight fittings are necessary; the conduit should be properly sealed so that gases cannot advance through the control panel, and the wire from the electrical box to the pump should be the right size.

The inside of the tank is a very corrosive environment, so the splices or wiring must be protected if the connections are made inside the tank. The sealing of the conduit is also critical. In many states it is required that there is a vent or separation of the conduit from the control panel. Be sure the size of the wire is big enough to meet the power demand of the pump. If the wire is too small the pump will not operate properly and wear out quickly. The proper gauge of the wire is related to the length of wire and the size (horsepower) of the pump. The horsepower of the pump dictates the size of a motor and the electrical draw. If the total distance from the pump to the control panel is too great for the wire size, the pump will not receive the proper amps for the motor. This will cause an early failure.

All wastewater distribution systems that utilize a pump require electrical power and control systems. Proper wiring materials and installation procedures are critical to the safety of the installer, the sewage system users, and all individuals involved in future repairs and maintenance. Adequate wiring ensures reliable pump and system performance. Follow a few basic guidelines to ensure safe and reliable operation at a reasonable cost. In all cases, installation procedures must follow the specifications of the U.S. National Electric Code (NEC). Contact local electrical inspection authorities for permits and inspection requirements. Work should be done by a qualified electrical installer.

Make no electrical connections inside the pump tank. This includes plug-ins, screw-type, twisted wire, boxes, relays, or any other type of connection that requires movement to connect or operate. If connections or splices must be made, they should be located in a watertight, corrosion-resistant junction box with watertight, corrosion-resistant fittings and a cover sealed by a gasket.

Materials for Outdoor Wiring

The materials and installation procedures for outside wiring are considerably different from indoor wiring. Outdoor wiring must be able to withstand exposure to water, weather, and corrosive environments. This is certainly the case for wiring septic system pump tanks.

Boxes and Panels

Outdoor equipment used in residential wiring must be weatherproof. The two most common types of weatherproof equipment are **driptight** and **watertight**.

Driptight equipment seals against water falling vertically. Driptight boxes are usually made of painted sheet metal and have shrouds or shields that deflect rain falling from above. These boxes are not waterproof and should not be used where water can spray or splash on the unit. Driptight boxes are usually used for control or circuit breaker panels.

Watertight boxes seal against water coming from any direction. Individual junction boxes, switch boxes and receptacle boxes will usually be of the watertight type. Watertight boxes are designed to withstand temporary immersion or spray streams from any direction. They are commonly made of cast aluminum, zinc-dipped iron, bronze or heavy plastic and have threaded entries for watertight fittings and covers sealed by gaskets.

Power to the pump and alarm system control center, when located outside a building, will most frequently be supplied by an underground branch circuit from a nearby service entrance or sub-panel. Follow electrical code specifications for materials and burial depths as described earlier. Avoid routing buried wiring through existing or anticipated gardens or landscaping areas to minimize the chances of damage due to spading.

Power to the control center should be from a single branch circuit with no other loads. The circuit breaker or fuse supplying this circuit should be clearly marked at the service entrance location.

Two methods, or a combination of the two, are common in outdoor wiring. One method is to place electrical wires inside a conduit. The other is to use cable. In either case, protection from physical damage, water, and corrosion must be provided.

Running wires through sealed conduit provides physical, water, and corrosion protection. Several kinds of conduit are acceptable for outdoor use. Rigid metal conduit made from aluminum or steel provides equivalent wire protection. However, aluminum conduit is not recommended for installation where it is directly in contact with soil. Rigid PVC conduit can be used above ground. High-density polyethylene conduit is suitable for underground installation. Do not use thinwall conduit (EMT) for underground or outdoor installations.

An underground feeder cable can be buried without conduit protection, but physical protection for underground cable is highly recommended to reduce the risk of spading through the cable at a later time. This is particularly true around the septic tank. A redwood or treated wood board buried just above the cable is highly recommended to provide physical protection. Do not use nonmetallic cable for underground installations. While it is an excellent material for interior wiring, it will not withstand the moisture conditions in the soil.

Because electrical components will be used, running power to the area will be critical. Make sure the wire has the proper capacity for the electrical demands of the pump. This is done by comparing the length of wire necessary from the pump to the power box and the horsepower required for the pump. Having these two values allows for proper selection of the wire sizes. A second wire should be run for the alarm and should be on a second circuit.

Combining the conduit and cable wiring methods is also an option. Conduit can be used around cable for physical protection. Conduit is particularly useful to protect cables where they enter and exit the soil. If conduit and cable are used in combination, appropriate connectors and bushings are needed for transitions from one system to the other. Minimum burial requirements apply to wire in conduit and cables. The size of the wire is determined from the electrical need (the motor size) and the length of wire. Table 9.4 gives wire specifications for various lengths and motor ratings.

TABLE 9.4 Wire Length for Pump Motor Ratings

Motor Rating		AWG Copper Wire Size					
volts	hp	14	12	10	8	6	4
115	1/3	130	210	340	540	840	1300
115	1/2	100	160	250	390	620	960
230	1/3	550	880	1390	2190	3400	5250
230	1/2	400	650	1020	1610	2510	3880
230	3/4	300	480	760	1200	1870	2890
230	1	250	400	630	990	1540	2380
230	1 1/2	190	310	480	770	1200	1870
230	2	150	250	390	620	970	1530
230	3	120*	190	300	470	750	1190
230	5	0	0	180	280	450	710
230	7 1/2	0	0	0	200*	310	490
230	10	0	0	0	160*	250*	390
230	15	0	0	0	0	170*	270*

2- or 3-wire cable, maximum length in feet, service entrance to motor

* Lengths meet U.S. National Electric Code (NEC) ampacity only for individual conductor 60C cable in free air or water, not in conduit. If cable rated other that 60C is used, lengths remain unchanged, but minimum size acceptable for each rating must be based on the NEC table column for that temperature cable.

Lengths without asterisks meet NEC ampacity for individual conductors and jacketed 60C cable.

Flat molded cable is considered jacketed cable.

Maximum lengths shown maintain motor voltage at 95% service entrance voltage, running at maximum nameplate amperes. If service entrance voltage will be at least motor nameplate voltage under normal load conditions, 50% additional length is permissible for all sizes.

Table based on copper wire. If aluminum wire is used, it must be two sizes larger. If table calls for #12 copper, for example, #10 aluminum would be required.

Wiring from the pump and alarm controls to the pump and switches

The power cable to the pump and float switch cables running from the control center into the tank should be run in conduit (metal or PVC) where physical protection is needed. The area around the conduit entering the tank should be sealed to prevent surface water from entering the tank through the conduit. If the conduit provides a continuous connection between the control center box and the tank, the conduit entrance to the box should be plugged with electrical putty to prevent the movement of moisture and corrosive gases into the control box. Provide an outlet for the wires through the side of the cleaning access. Consider installing a section of six-inch plastic pipe with a cap alongside the cleaning access to contain the pumping station wires.

Power cables used in these installations, such as Types SE, SJ or SOW, must be suitable for moist and corrosive environments. The power cable to the pump must have a grounding conductor (usually a green insulated wire) to ground the pump motor frame. Metallic conduit should not be used for equipment grounding to or within the tank. Since the pump is considered a motor load, it must have appropriate disconnecting means. The disconnect for units of one horsepower or greater (circuit breaker or switch) must be clearly marked and either in sight of the pump location or lockable. This prevents inadvertent reactivation of the circuit during servicing of the unit. Below one hp, receptacles and plugs listed for motor loads (hp listed) may be used.

NEMA Ratings

NEMA stands for National Electrical Manufacturer Association. Their website is at www.nema.org. NEMA ratings are standards that are useful in defining the types of environments in which an electrical enclosure can be used. The NEMA rating system is defined by the National Electrical Manufacturer Association, and frequently signifies a fixed enclosure's ability to withstand certain environmental conditions. In non-hazardous locations, there are several different NEMA ratings for specific enclosure "types", their applications, and the environmental conditions they are designed to protect against, when completely and properly installed. The following provides an overview of the NEMA Types. For complete definitions, descriptions, and test criteria, see the National Electrical Manufacturers Association (NEMA) Standards Publication No. 250.

NEMA type 1

Type 1 enclosures are intended for indoor use primarily to provide a degree of protection against contact with the enclosed equipment in locations where unusual service conditions do not exist.

NEMA type 3R

Type 3 enclosures are intended for outdoor use primarily to provide a degree of protection against windblown dust, rain, sleet, and external ice formation.

NEMA type 4

Type 4 enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against windblown dust and rain, splashing water, and hose-directed water and external ice formation.

NEMA type 4X non-metallic, corrosion-resistant

Type 4X enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against corrosion, windblown dust and rain, splashing water, and hose-directed water. Enclosure is manufactured with a synthetic rubber gasket between cover and base. This is ideal for such industries as chemical plants and paper mills.

Meeting these requirements—accessible, removable and properly wired will alleviate the majority of problems that could be experienced with pump systems, and will make the pumping system easier to maintain.

Operation, Maintenance and Troubleshooting

According to MN Rules Chapter 7080.2450, Subp. 3 (E), pump tanks must be maintained according to this part. Sludge must be removed if within one inch of the pump intake.

Pumping Costs

The amount of energy required for pumping sewage is relatively small. If a pump delivers 40 gallons per minute and 174 gallons are to be pumped per dose, then pump operating time is 4.35 minutes per cycle with four cycles per day, for a total time of 17.4 minutes per day. The 1/2-hp pump in the example above is about a 1500-watt pump. (The actual nameplate amperage of a pump may be multiplied by the voltage to determine the wattage.) The pump in the example will use approximately 0.44 kilowatt hours per day of operation. Energy costs may be calculated using current prices.

Calculating Flow

Calculating the amount of flow that reaches various treatment components is critical to assessing performance. Components are designed for a particular flow and if actual flow varies considerably from design flow, results must be interpreted accordingly.

In order to calculate the flow through a system, some simple information must be collected. The cycle counters, pump dose volumes, elapsed time meters, and pump capacity for both the pretreatment and final dispersal step should be documented. If available, water meter readings for the structure are helpful to estimate incoming flows.

The pump dose volume is related to either the float settings (dose volume) or the timer settings for that system. In a timed dosed system, the pump flow (gpm) multiplied by the pump run time (minutes) equals the total volume that the pump delivers through the supply line. Care should be exercised in this calculation because the volume delivered to the supply line may not be the same volume delivered to the pretreatment unit (or final treatment and dispersal). The return volume (drainback) to the pump tank or vault must be subtracted from the total volume pumped. This is the actual volume of effluent delivered to the pretreatment unit (or the final treatment and dispersal component).

When using a demand dosed system, the dose volume is used for flow measurement. The volume is the number of events counted by the cycle counter multiplied by the volume of the dose. The current cycle counter reading is subtracted from the previous pump cycle counter reading. This is the number of times the pump has been on. Again, any pipe drainback needs to be subtracted. An important consideration is that the dose volume may be more in those cases when the pump is activated and there is influent onto the pump vault.

Demand Dosed vs. Timed Dosed

In a demand dosed configuration, the pump is activated whenever a prescribed volume of effluent flows into the pump tank and activates the floats or sensors. The dose to the next component is subject to variations in water usage from the source. This is the simplest form of dosing but results in the most variable delivery of effluent in pressure distribution systems because the dose depends on the activity of the users.

The timed dosed system is controlled by a system that automatically doses the treatment component on a timed basis. The timer allows a motor controller to activate the pump for a specified amount of time and deliver a specified dose volume based upon the actual pump delivery rate. This same dose volume is delivered every time the pump is turned on at a specific time interval. A float or other sensor detects if there is enough liquid level in the tank for the timer to operate. If the liquid level drops below a specified elevation, the timer stops operating and the pump ceases to operate until enough liquid in the tank allows for the timer to resume pump operation.

In a demand dosed system, the dose volume (DV) can be calculated by multiplying gallons/inch (GPI) by the number of inches of separation between the pump on and pump off float elevations

Inches pumped = Pump off (in.) – Pump on (in.)
DV (gal) = gpi x in. per dose

The pump delivery rate (PDR) in gpm can be calculated by running the pump for a specified period of time and measuring the elevation of the effluent at the elevations that the pump activates and deactivates.

The pump operation time should allow for full pressurization of the system. A pressure gauge can be used to verify that this has been accomplished or measurements can be taken in the pump tank at designated times. Generally, a runtime of 4 or 5 minutes is sufficient. Using the measurements, PDR in gpm is calculated thus:

Gal/min (gpm) = dose volume (DV) [gal] ÷ Verified pump run time (min)

For example, if a pump delivers 40 gallons to a soil treatment area in 5 minutes then the PDR is: 40 gallons/5min = 8 gal/min

Dose volume verification

The dose volume should be verified in the field. Design volume (DV) from the design and divided by the volume per vertical inch of the tank. This division results in the draw-down required in the tank to deliver the required volume. The relative elevations of the sensors that determine dose volume should be verified either by adding water to the tank or lifting the float switch to activate the pump. Indicate which method is used.

The drawdown should be measured. The drawdown can be measured from the moment the pump activates to the moment the pump ceases. This distance is recorded as the drawdown. Drainback (if installed) may raise the level in the tank. The difference between the lowest elevation (immediately after the pump ceases to operate) and the level after drainback has concluded is the drawdown needed to fill the system of pipes. The rest of the drawdown is the actual dose that reached the component.

Multiplying the drawdown just calculated by the gpi of the tank results in the calculation of the dose volume (DV). This measured DV must be comparable to the design DV.

Pump delivery rate

In order to determine if the pump is operating properly, the pump delivery rate should be measured. First the pump run time should be verified. Multiply the gallons pumped (measured dose volume) by the pump run time to obtain the gallons per minute of the pump. This is an important parameter for the startup of components that require recirculation or specific dosing.

Troubleshooting

The Pump Will Not Start

1. Check power.
   a. Verify the power is on in the structure. The circuit breaker could be opened in the electric panel. Check the voltage in the line. Damage to the wiring could have taken place in excavation work.
2. Check panel.
   a. Verify the power is on in the panel. The circuit breaker could be opened in the panel. Check the voltage in the line.
   b. Check floats.

Effluent Stays in the Tank

1. Pump is not working.
   a. Check pump for plugged impeller.
   b. Check pump for available tdh. This could be related to wear in the electric motor.
   c. Verify that the pump is receiving the proper voltage (220).
   d. Check for plugging in the distribution system.
2. Event counter and running time clock don't match.
   a. Owner is operating system. Typically the running time clock flows will be higher than the event counter flow rates. The owner is turning the system on when the alarm operates.

Inspection

When the pumping component is constructed, it is critical that the required pieces are in place: two circuits for the alarm and the pump, accessibility to the pump, a quick disconnect, and all other wiring should be in place. The pump should be sized properly, and checking this at the inspection is a good idea. Checking the ability to rewire the pump and the proper float setting is important for the long-term operation of the system.

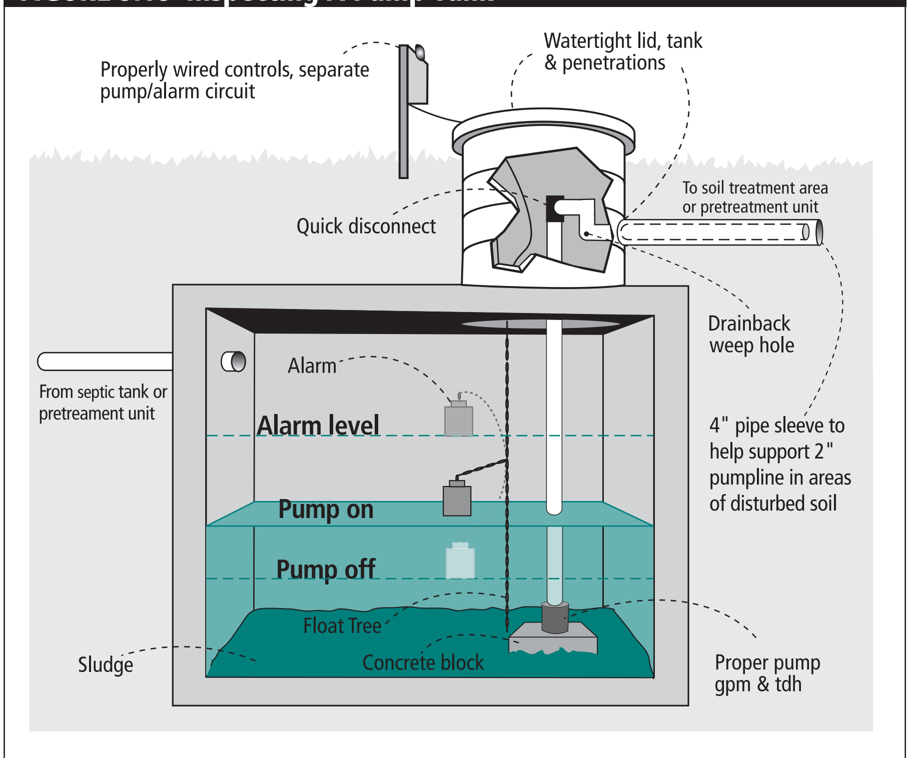
Evaluating the Pump Tank and Components

Safety precautions

Never enter a pump tank. Any work to replace pumps, switches or connections should be performed from the outside, and the pump, pump controls, and pump discharge line must be removable from the surface. The sewage gases produced in the tank can kill a person in a matter of minutes. When working on a tank, make sure the area is well-ventilated and someone is standing nearby should something go wrong. Never go into a pump tank to retrieve someone who has accidentally fallen in without a self-contained breathing apparatus. While waiting for help, the best thing to do is to put a fan at the top of the tank to blow in fresh air. (See Section 7 for a discussion of safety precautions and practices for working with sewage tanks.)

Inspect how the water is moved out to the soil treatment system, beginning with the pump tank as shown in Figure 9.18. You should be able to access the pump without having to enter the tank. The manhole should be brought to the surface, all electrical connections should be such that there is no smoking, sparks, or shocks and there should be a remote shut-off for the pump.

FIGURE 9.18 Inspecting A Pump Tank



There should be no sludge moving into the pump tank. If there's excessive sludge in the lift station or the first section of the trenches, there are probably turbulent conditions in the tank, resulting in poor settling. As discussed above, users of the system can often make changes to alleviate the turbulence.

Adding a pump basin is another method to minimize solids transfer. A pump basin is a container surrounding the pump. The container lip becomes the pump intake adding solids storage to the pump tank. The floats or controls must be set to assure that they do not get stuck on the container edges. Check the pump tank to see that it's watertight, and inspect its structural integrity just as you inspected the septic tank. Verify that the pump has adequate capacity, taking into consideration friction loss. This means that effluent leaves the tank at the rate indicated on the design. There should be a quick disconnect setup. Make sure that there is no standing water in the piping.

Abandonment

All electrical devices and devices containing mercury must be removed and disposed of according to applicable regulations (MN Rules Chapter 7080.2500, Subp. 1(B). The pump tanks are abandoned similarly to other tanks as described in Section 7: Septic Tanks. All the components must be removed before backfilling. If the old floats were mercury floats, these must be handled as a hazardous material. Be careful that the mercury vial is not broken during the process. All the wiring should be removed; the conduit can be left buried but should be capped.

SECTION 10: Pretreatment

PRETREATMENT

Application

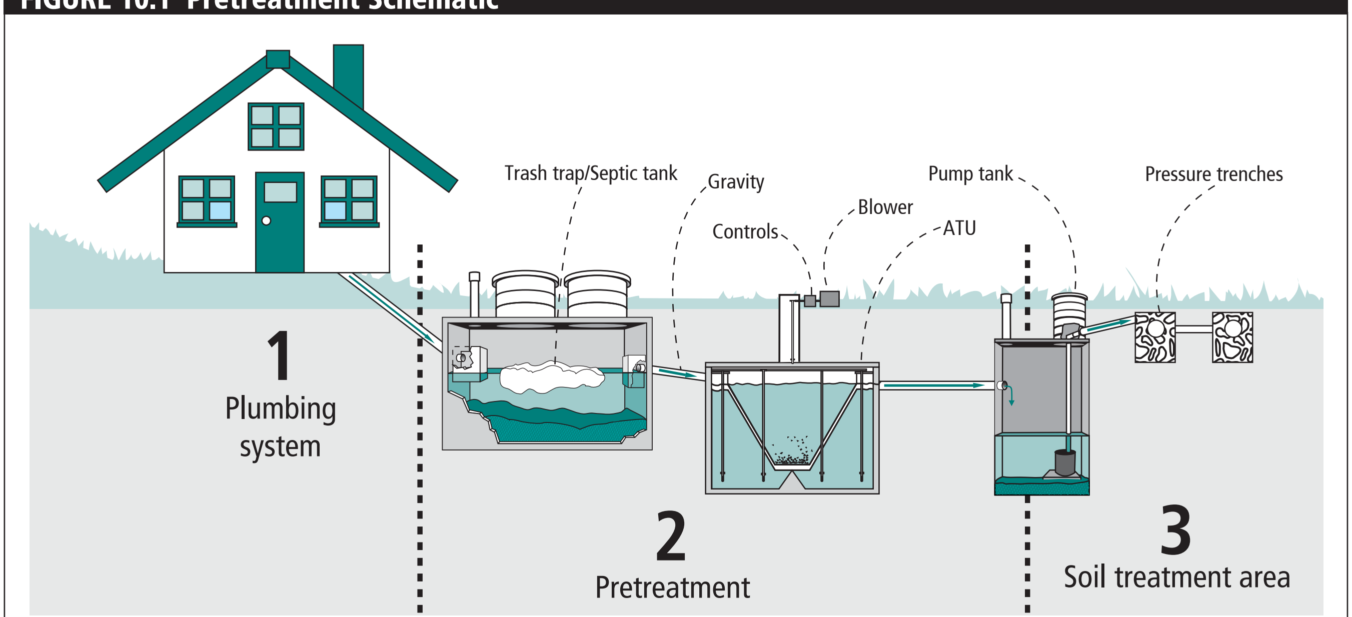
Conventional SSTS technology consists of a septic tank and gravity flow to a series of soil treatment trenches or a pressurized bed or mound. New choices for treatment have become available in recent years, including aerobic treatment units, sand filters, peat filters, and constructed wetlands, with variations on both the conventional septic tank and the conventional SSTS. Combining technologies, determining which choices are best-suited to sites, and sizing systems using these new technologies can be challenging.

Because the effluent exiting a pretreatment unit has undergone additional treatment beyond a septic tank, the soil in a trench or mound SSTS may be better able to accept it, and the system may work longer. Soil treatment systems receiving pretreated effluent may have reduced vertical separation to the limiting condition as described in **Chapter 7080.2350 Subp. 2, Table XI,** and reductions in the bottom absorption area (conversely, increased soil loading rates) as indicated in **7080.2150, Subp. 3, Tables IX and IXa**. The U of MN OSTP does not recommend downsizing soil treatment systems unless a Type I soil loading rate and vertical separation can not be achieved.

Pretreatment units could also be particularly useful in areas where only sites with disturbed soil are available for SSTSs, again because the effluent flowing into the SSTS is cleaner. Pretreatment units could be useful in environmentally sensitive areas for pretreating effluent before it is delivered to a soil treatment system, or where it is desirable to discharge effluent into soils that can benefit from effluent that has undergone further treatment than a septic tank provides. In Minnesota, these sensitive locations would include shallow bedrock areas, aquifer recharge areas, and wellhead protection areas.

A typical system has three major components, as shown in Figure 10.1. The plumbing (1) collects effluent from toilets, sinks, washing machines, and other water-using devices.

FIGURE 10.1 Pretreatment Schematic



Regulations and the practices of the individuals using the system determine the size of the system. Ultimately, the residents control the amount of water they use, and the amount of greases, oils, cleaning products, and other chemicals, decomposable and non-decomposable organic matter, soap, and cleaners that enter the system. In a Type I system, the pretreatment device (2) is a septic tank. Many additional pretreatment components further treat septic tank effluent before its discharge to the soil treatment area, the third (3) component.

Performance

The primary consideration in selecting any of these pretreatment technologies is whether they are able to adequately treat effluent before it is discharged into the environment and the water is used again. Critical treatment criteria in Minnesota include the removal of pathogens, bacteria and nutrients, nitrogen, and phosphorous. Once the goals of treatment are established, such as reducing the strength of the organic component (CBOD), pathogenic bacteria and viruses, and nutrients (commonly nitrogen and phosphorus), various technologies can be analyzed for their effectiveness. For instance, the conventional choice (a septic tank and trenches with at least three feet of soil separating the system from the limiting condition) does an excellent job of treating pathogens.

Performance standards for the treatment of septic tank effluent are based on these conventional systems: the performance goal of any new technology is to reduce the organic content to protect the drainfield from biomat plugging that causes saturation and failure to meet other treatment objectives like pathogen removal. Numerically, the standards for a treatment system are zero fecal coliform, less than one milligram per liter phosphorous, and a nitrate level lower than drinking water standards.

Once it has been established that a technology can provide the desired level of treatment, the next criterion to assess is the technology's reliability. In analyzing reliability, identify the part(s) of the system where things could go wrong. When one component of the system fails or breaks, will it alter or shut down the treatment process? In any system that is dosed with a pump, replacement when failure occurs is critical. For example, air flow is critical to the reliability of an aerobic system. An aerobic treatment unit functions very well as long as it is getting air; however, as soon as the air is turned off, the aerobic treatment unit becomes a septic tank very quickly. The design of a septic tank and an aerobic treatment unit are significantly different. Most aerobic units can not function as conventional septic tanks. In this case, the failure of one aspect of the system causes the entire system to fail to meet its treatment objectives.

Regular monitoring of its operation is necessary to ensure that the aerobic treatment unit is operating in the way intended. If a component is easily broken, it is not reliable. Less reliable components may be chosen (and there may be various reasons for such a choice), but there should always be a comprehensive management plan in place that includes frequent monitoring and regular maintenance of parts of the system in order to find and fix faulty components before they fail.

Management of the System

Management is providing for the ongoing care of the entire system through both operation and maintenance. Operation is the day-to-day upkeep of the system, and every system will have some operational requirements. Maintenance is the attention to routine critical processes of the system so as to ensure the system's proper operation and long life. Just as changing the oil in a car or tractor maintains its proper operation, so does maintaining a treatment system to ensure its operation and longevity. A Type I SSTS has a three-part maintenance requirement: using the appropriate amount of water; pumping the septic tank at regular intervals (typically once every three years); and staying off of or otherwise protecting the soil treatment area. Systems utilizing pretreatment technologies have additional management requirements.

A final important aspect of management is replacement. As an SSTS wears out, it must be fixed and, when necessary, replaced. In a conventional system, replacement is the responsibility of the homeowner and occurs approximately every 20 to 40 years. With the ongoing development of new technologies and new models of system management, as each part of a system is replaced, it can also be updated, possibly minimizing the expense of total replacement by prolonging system life.

Designing with Management in Mind

How can the designer of these systems coordinate technology and management? In the past, there was a standard technology (septic tank and three feet of soil) and standard management (pumping the tank every two to three years). Now, new technology requires new management strategies. As new technology is added to a system, the management of that system must change. If it does not, the system will not work as intended. For those systems that need additional management to ensure reliability, an adequate management plan is critical. Management strategies must be specific to each treatment system.

A system's management will limit the technology chosen. If proper management is not in place, problems with the system will show up very quickly. For example a holding tank stores effluent and has to be pumped as soon as it becomes full. Under the old management schedule, the holding tank was pumped every two years—not nearly often enough. A holding tank may fill in two weeks! The management needs of the holding tank were higher than the level of management available. The holding tank, which is a fine solution, had become limited in its application because of the cost associated with hauling the sewage away for proper treatment.

Before a technology is chosen, the costs, management requirements, reliability, performance, and future plans all must be considered. When designing a new system, all of the pieces need to fit together, so the system will work well into the future. Effects of poor planning are increasingly apparent in areas of small cabin lots surrounding lakes in Minnesota. Each cabin owner is responsible for their own wastewater treatment. If every lake had adequate space for an ISTS system, or for a central treatment plant to which each house had a sewer hookup, as they do in cities, the small lots would not pose a challenge. Many of the lots were platted before running water and electricity were available. As lakeshore Minnesotans increasingly demand modern lifestyle amenities, they will continue to face the challenges of what to do with their wastewater. These new life-style choices were not considered when these lots were platted, and now the current owners are paying the price for upgrading their properties.

Economics

The cost of solving these challenges is twofold: the cost of the technology (taking into account the reliability and longevity of the system) and the cost of the management (taking care of the system). Both kinds of costs need to be considered "up front" in the planning process. All of the information pertaining to new technologies—performance, longevity, management, and flexibility—needs to be considered in order to make the right choices for each site.

Product Review and Registration Process

Overview

Minnesota Rules Chapter 7083 does not list proprietary products and treatment devices but instead refers to a registered product list (RPL). The details of this process can be found in **7083.4000.** The MPCA will maintain this list on their web site and associated materials. Registered products, applications will be accompanied by guidance for use of these products in design as well as operation and maintenance. The registration process includes:

1. Treatment devices (aerobic treatment units, media filters, etc.) must be tested under standardized protocols. Based on test results, treatment devices will be assigned a category according to the product testing performance levels as shown in Table 10.1. Treatment levels may correspond to reduced requirements for separation to seasonally saturated soil. The amount of reduction in separation and design specifications depend on the soil type classification. Soil treatment systems are also allowed to have downsized soil treatment areas if A, A-2, B, or B-2 technologies are utilized as shown in **Tables IX and IXa in MN Rules Chapter 7080.2150 Subp. 3.**

TABLE 10.1 Treatment System Performance Testing Levels (7083.4030, Table III)

Level	Parameters				
	$CBOD_5$ (mg/L)[a]	TSS (mg/L)[b]	O&G (mg/L)[c]	FC (#/100 mL)[d]	Nutrient (mg/L)
A	15	15	--	1,000	--
A-2	15	15	--	--	--
B	25	30	--	10,000	--
B-2	25	30	--	--	--
C	125*	60	25	--	--
TN	--	--	--	--	<20 or actual value
TP	--	--	--	--	<5 or actual value

* BOD_5 = 170 mg/L

a Carbonaceous biochemical oxygen demand or $CBOD_5$ means the measure of the quantity of oxygen used by microorganisms in the aerobic oxidation of organic matter and other compounds containing carbon amount of oxygen required by bacteria while stabilizing, digesting, or treating the organic matter under aerobic conditions over a five-day incubation period while in the presence of a chemical inhibitor to block nitrification. $CBOD_5$ is commonly expressed in milligrams per liter (mg/L) (7080.0020, Subp. 12).

b Total suspended solids or TSS means solids that are in suspension in water and that are removable by laboratory filtering (7083.0020, Subp. 21).

c O&G means oil and grease, a component of sewage typically originating from foodstuffs such as animal fats or vegetable oils or consisting of compounds of alcohol or glycerol with fatty acids such as soaps and lotions, typically expressed in mg/L (7080.0020, Subp. 14).

d Fecal coliform or FC means bacteria common to the digestive systems of warm-blooded animals humans that are cultured in standard tests. Counts of these organisms are typically used to indicate potential contamination from sewage or to describe a level of disinfection, generally expressed in colonies per 100 mL (7080.0020, Subp. 30).

Category A: Designed to treat sewage with strength typical of a residential source when septic tank effluent is anticipated to be equal to or less than treatment Level C.
Category B: Designed to treat high-strength sewage when septic tank effluent is anticipated to be greater than treatment level C, including restaurants, grocery stores, mini-marts, group homes, medical clinics, residences, etc.
Total nitrogen and phosphorus reduction in Categories A and B

2. Distribution media sizing criteria will be based on actual exposed trench-bottom and sidewall absorption area and will be communicated through information associated with the registered product list. Registered products may include drip distribution, chambers, gravelless pipe, and other distribution technologies. See Section 12 for more information on these distribution medias.

A Technical Advisory Subcommittee of the SSTS Advisory Committee advises the product registration and product registration renewal processes. Contested case hearings are provided for situations where product registration or renewal has been denied.

LGUs will be allowed to issue a product development permit (PDP) in situations where registered products are not used **(MN Rules Chapter 7083.4110)** and experimental systems are permitted following the rule requirements:

a. The purpose of PDP is to gather data about the product's performance in the field during product development.
b. The PDP is not an alternative to testing and registration.
c. The PDP is not the same as a Type V system and must be used in conjunction with a more conventional, existing system.

Types of Pretreatment Units

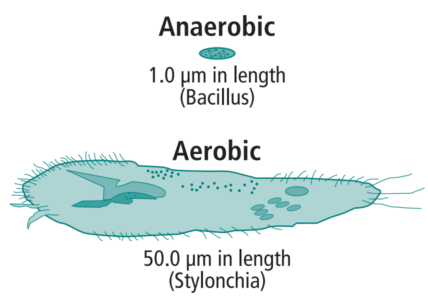
Aerobic Treatment Units

Definition and Description

An aerobic treatment unit (ATU) is a:

1. Pretreatment component that provides for aerobic degradation or decomposition of effluent constituents by bringing the effluent into direct contact with air (oxygen).
2. Term traditionally used to describe proprietary devices that use direct introduction of air into effluent by mechanical means to maintain aerobic conditions within the treatment component.

FIGURE 10.2 Comparison of Aerobic and Anaerobic Bacteria (not to scale)



ATUs pretreat effluent by adding air to break down organic matter, reduce pathogens, and transform nutrients in what is known as the activated sludge (AS) treatment process. Naturally occurring microorganisms consume the organic material in sewage. Commonly, bacteria and other microorganisms are considered to be undesirable components of effluent, yet only a small fraction of the microbes found in effluent are truly pathogenic. Aerobic effluent treatment encourages the growth of naturally-occurring aerobic microorganisms as a means of treating effluent. Such microbes are the engines of effluent treatment. Most decomposing microbes prefer aerobic conditions to anaerobic conditions. As shown in Figure 10.2, aerobic bacteria are much larger than anaerobic bacteria and digest organic matter more rapidly under the right conditions. When dissolved oxygen is available, microorganisms in decomposing organic matter consume oxygen dissolved in the water. The oxygen available in the ATU also effectively transforms the ammonia to nitrate. Under anoxic conditions (no oxygen), the nitrate is denitrified to nitrogen gas. Some ATUs are designed to also provide denitrification as part of their operation. Design modifications include intermittently supplying air and recirculating the nitrified effluent into the anoxic regions within the treatment unit.

Rule Requirements and System Classification

According to **Minnesota Rules Chapter 7080.1100 Subp. 74**, ATUs are considered to be sewage tanks by the following definition:

"Sewage tank" means a receptacle used in the containment or treatment of sewage and includes, but is not limited to, septic tanks, aerobic tanks, pump tanks, and holding tanks.

In Minnesota, ATU systems with registered products are considered Type IV systems; those without registered products are Type V. Both types of systems require operating permits and flow measurement.

The National Sanitation Foundation (NSF) International and the American National Standards Institute (ANSI) publish a standardized procedure that independent evaluators may follow to certify the performance and reliability of aeration units. NSF/ANSI Standard 40-2000, Residential Effluent Treatment Systems, establishes minimum materials, design and construction, and performance requirements for residential effluent treatment systems having single, defined

TABLE 10.2 NSF/ANSI Standard Number 40-2000 Class I performance classifications.

Parameter	30 day average shall not exceed	7 day average shall not exceed
CBOD5	25 mg/L	40 mg/L
TSS	30 mg/L	45 mg/L
Color	Individual samples shall be less than 15 NTU units.	
Threshold Odor	Non-offensive	
Oily Film	None visible other than air bubbles	
Foam	None	
pH	The individual effluent samples shall be between 6.0 and 9.0	

discharge points and treatment capacities between 400 and 1500 gallons per day. The Standard 40 certification serves as a starting point for acquiring the data necessary for the product registration process, but typically additional data is required to determine effectiveness of the unit in removing fecal coliform (see Table 10.2).

The NSF testing protocol has varied loading periods that typically represent design capacity. Designers and service providers have experienced homes with actual flows substantially less than design flow. Accordingly, those homes have detention times of 3 or more days.

Treatment Processes

The treatment processes in an ATU biologically converts non-settleable (suspended, dissolved, and colloidal) organic materials to a settleable product using aerobic and facultative microorganisms; this is typically followed by clarification and sludge return. The result of the ATU treatment process is the conversion of organic pollutants into inorganic compounds and new microbial cells. The net production of cells (creation of new cells versus the death of old cells) will simply settle out or slough and media will form an accumulation of material which will eventually need to removed from the unit.

Effluent treatment in an ATU is different from that in septic tanks, both in the speed and quality of treatment. Bacteria in an ATU use oxygen to break down organic matter efficiently, achieving relatively quick decomposition of organic solids and reducing the concentration of pathogens in the effluent. In addition to their more effective removal of organic matter in effluent, ATUs generate far less hydrogen sulfide than do conventional septic tanks, creating fewer odor problems. Solids settle out of the effluent, and the clear effluent is distributed to a SSTS. Compared to conventional septic tanks, ATUs break down organic matter more efficiently, achieve quicker decomposition of organic solids, and reduce the concentration of pathogens in the effluent by a larger margin.

ATUs work by creating a highly oxygenated (aerobic) environment for bacteria, usually by bubbling compressed air through the liquid in the tank. Aeration is provided by one of the following methods:

1. ***Mechanical aeration -*** introduction of air via mechanical means. A mechanical method of injecting air is to machine orifices into pipes and plates. Streams of air serve to transfer oxygen and to provide vigorous mixing of the basin contents. Surface mixers or subsurface mixers with draft tubes where air is drawn down a hollow shaft and sparged into the fluid are also used. The bubbler or stirrer keeps the water agitated, so solids cannot settle out, and floating materials stay mixed.
2. ***Diffused aeration -*** introduction of air bubbles under pressure into a treatment unit using a compressor or blower and a diffuser. Submerged devices inject air into the effluent. There are various classes of diffuser based on the diameter of the bubbles as shown in Table 10.3.

TABLE 10.3. Classification of Diffusers

Class	Size (mm)
Coarse	3 – 8
Fine	0.2 – 3
Micro	< 0.2

The smaller the bubble, the greater the oxygen transfer rate into the effluent. Additionally, bubbles formed deep within the chamber will have more pressure to drive the oxygen transfer and more time-of-contact with the air-water interface. One method of creating small bubbles is with porous ceramic diffusers. The small, interconnected passageways inside the ceramic matrix create a tremendous loss of air pressure and many points of outflow. This combination produces streams of small bubbles over the surface of the ceramic diffuser.

Cycling the aeration system provides some energy savings and promotes nitrogen removal (temporary anoxic conditions). Care must be taken, as this technique can produce a poor settling biomass due to gas flotation and non-flocculating microbes. In an ATU, the bubbler agitates the water so solids cannot settle out and floating materials stay mixed in the liquid. Well-designed ATUs allow time and space for settling while providing oxygen to the bacteria and mixing the bacteria and its food source (sewage).

Design Basis and Operational Theory

Most ATUs include a pretreatment step to remove or reduce gross solids (e.g., grease, garbage grindings, and trash). Pretreatment may include trash traps, septic tanks, sewage grinders, and serrated surge chambers. The use of trash traps or septic tanks can reduce or eliminate such problems as floating debris on clarifier surfaces, clogging of flow lines, and plugging of pumps. Some types of ATUs prefer reduced septic tank capacity compared to the requirements in Chapter 7080 due to a decrease in food for the bacteria and the production of hydrogen sulfide when full sized septic tanks are used. If the manufacturer requested reduced septic tank sizing as part of their product registration process, the reduced capacity is permissible.

Most ATUs operate as an intermittent-flow, complete mix tank, constant volume reactors. Effluent flow is intermittent versus continuous because influent is not constant. (The pretreatment step can also serve to dampen some of the effluent flow peaks.) Effluent enters the aeration chamber, where contents are thoroughly mixed to maximize the contact between dissolved oxygen, microbes, and effluent. Effluent moves out of the aeration chamber and into a clarifier. The rate of discharge is in direct proportion to the rate of inflow. Sequencing batch reactors are the exception to this generalization.

The sizing of aerobic systems is based on the flow, the addition of oxygen, the concentration of organic matter in the effluent, and the settling characteristics of the chosen system. There are units that can handle from 400 - 40,000+ gpd of effluent. Each type of ATU is designed to handle a specific maximum load of BOD per day.

Pounds of BOD is calculated using the following equation:

Pounds of BOD = Flow (gpd) x BOD (mg/L) x 8.35 x 10-6

Where: Flow = the measured values + safety factor or estimated flow

BOD = measured or estimated value leaving the septic/trash tank

8.25 x 10-6 = 0.00000825 = conversion factor from gpd and mg/L to pounds/day

The detention time in the unit, horsepower of the blower, air dispersal method, and desired treatment goal determine which size of unit is needed. An ATU will perform more consistently if the effluent is time-dosed into the unit. This creates a more stable source of food for the bacteria, better matches the air supply to the necessary organic breakdown, and reduces the impacts of toxins.

An ATU should be equipped with an alarm to indicate when the air supply is interrupted or a high water level exists. Power required to operate an aerobic unit ranges from 2.5 to ten kWh/d, depending on motor design and time of operation. The power usage can rise dramatically if the unit is wired incorrectly or if it shorts out due to corrosion.

For the unit to perform, its microorganisms must be provided with an environment that allows them to thrive. Temperature, pH, dissolved oxygen, and other factors affect the natural selection, survival, and growth of microorganisms and their rate of biochemical oxidation. Overall, as temperature decreases, microbial activity decreases. Generally speaking, ATUs are buried, the soil acting as a sink for the heat generated by the activity within the treatment unit. The cold temperatures of the upper Midwest can cause reduced performance during the colder months of the year. In addition to ambient temperature, the influent's pH significantly impacts effluent treatment; the optimum pH for microbial growth is between 6.5 and 7.5, which is common in most domestic sewage.

Types of ATUs

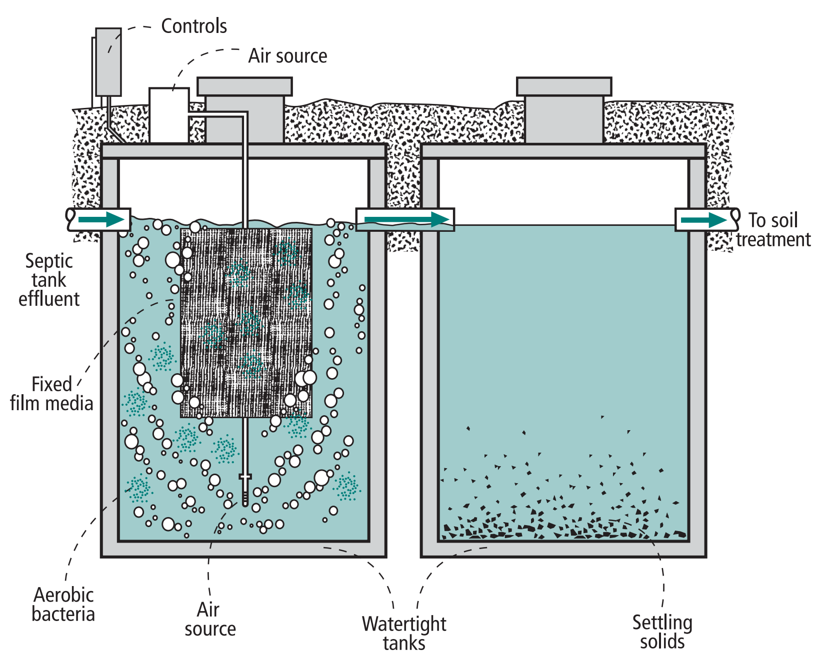
All available ATUs are proprietary products with differences in design, installation, and maintenance procedures. Generally, all brands fit into one of three basic types of aerobic treatment units: fixed-film, suspended growth, or sequencing batch.

Fixed film

An attached growth or fixed film reactor is a configuration wherein the microorganisms responsible for treatment colonize a fixed medium. In an ATU, aerobic bacteria grow on a specific surface in the tank, and air is provided to that part of the tank. The bacteria can grow on almost any surface—fabric, plastic, or gravel. Decomposition is limited to this area, and settling occurs outside of the bacteria's growing surface. This design tends to be the most expensive, but the effluent is consistently pretreated. These units typically operate with constant aeration, long detention times, low food-to-micro-organism ratio, and low biomass accumulation.

Problems due to bulking (the formation of chains or colonies of bacteria that do not settle or sink to the bottom as they should) in these tanks are uncommon, because the bacteria stay on the film, and there is no need for a system to return them from the settling chamber. See Figure 10.3 This type of ATU generally provides the most consistent treatment because the bacteria are more stable.

FIGURE 10.3 Fixed Film ATU



Suspended growth

A suspended-growth ATU has a configuration wherein the microorganisms responsible for treatment are maintained in suspension within a liquid. Typically, a suspended-growth ATU is composed of a main treatment chamber where bacteria are free-floating and air is bubbled through the liquid. In most units the air supply is constant. The second chamber, where the solids settle out, is separated from the main tank by a wall or baffle. The two chambers are connected at the bottom or by a pump, and settled bacteria from the second chamber are brought back into the main treatment chamber. This return and mixing is critical for proper operation. Treated effluent from the second chamber is piped to the SSTS. See Figure 10.4.

FIGURE 10.4 Suspended Growth ATU

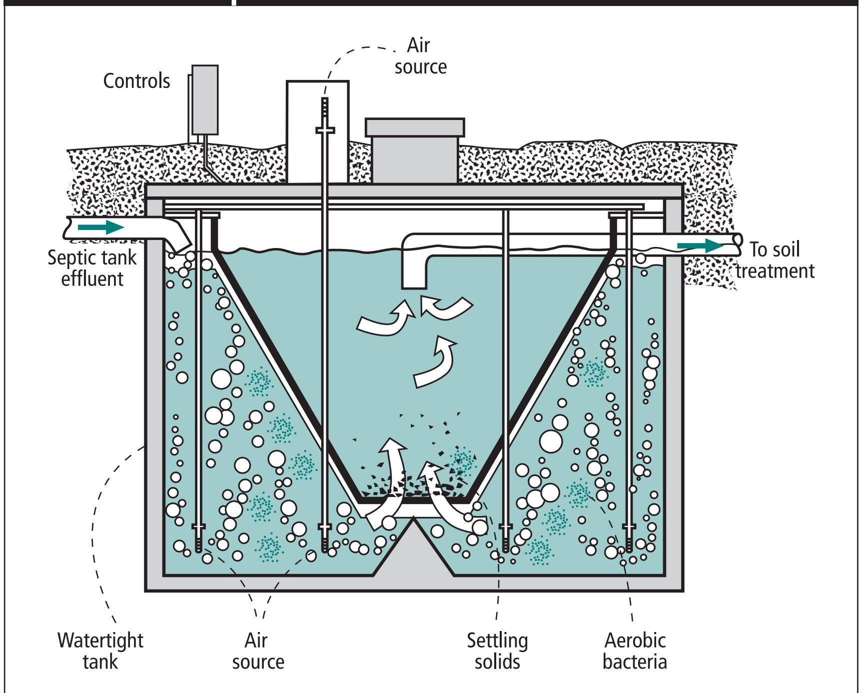
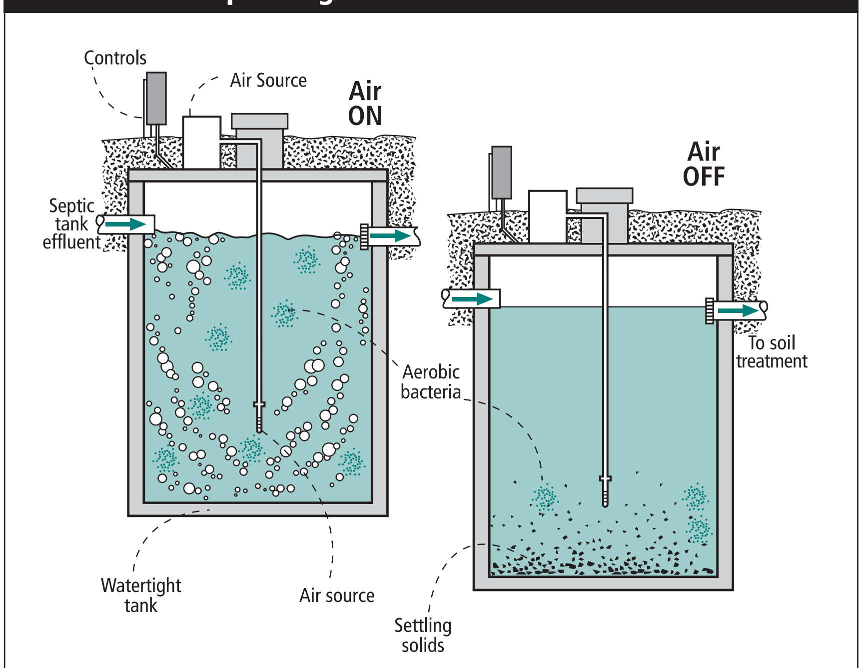


FIGURE 10.5 Sequencing Batch Reactor ATU



Though simple, the system is likely to have problems with bulking. Bulking is caused by changes in effluent strength or quantity. When too little or too much effluent is added to the system, the bacteria can run out of food or become overloaded. Bulked bacteria remain suspended in the liquid and can clog the outflow.

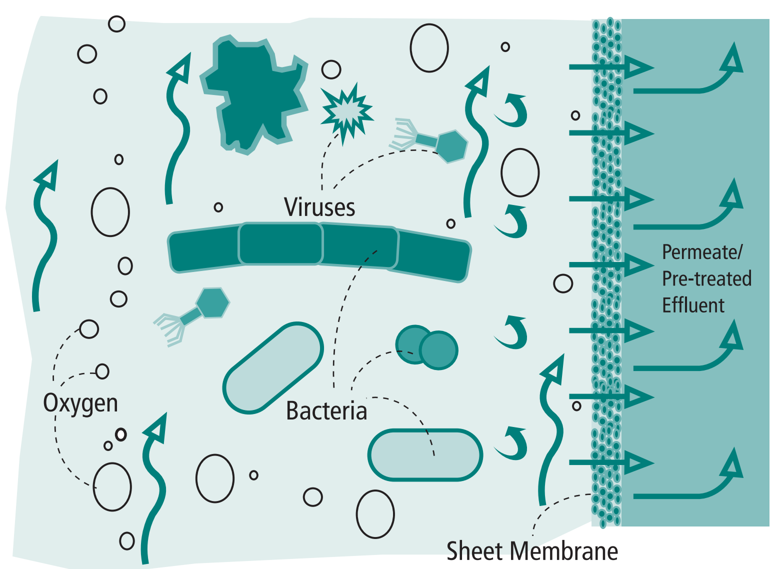
Sequencing batch reactor

In a sequencing batch reactor, aerobic decomposition, settling, and return occur in the same chamber. These units are typically operated in batch mode in which flow is controlled so that effluent neither enters nor leaves the treatment component while a specific operation is performed. During the decomposition cycle, air is bubbled through the liquid for a predetermined period. Then, the air supply shuts off and the effluent goes through a settling cycle. Once the air supply resumes, and the tank re-enters the decomposition cycle, the settled bacteria return to an aerobic environment. More solids settle out in this kind of tank than in the previous two types, which is desirable, but these tanks have more moving parts and are controller-dependent so therefore have more potential for mechanical or electrical failure. See Figure 10.5.

Membrane Bioreactors

Membrane Bioreactors (MBR) are a newer type of ATU recently made available in Minnesota for small-scale effluent treatment systems. MBRs were first developed in the 1960s; but they have seen significant modifications since the late 1990s. These modifications have resulted in a more robust and practical pretreatment unit for applications in SSTSs. MBRs combine two basic processes—biological degradation through the activated sludge (AS) treatment process and membrane separation—into a single process during which suspended solids and microorganisms responsible for degradation are separated from treated water by membrane filtration units, which pull water through a membrane with very small pores. While there are many designs of MBRs, the MBR systems commonly available share typical characteristics. For instance, most MBRs use ultra-filtration membranes with a 0.02 to 0.05 micron pore size, which traps solids on the outside as shown in Figure 10.6. The membrane is typically made of polypropylene, cellulose acetate, aromatic polyamides, or thin-film composite (Metcalf & Eddy, 2003).

FIGURE 10.6 Membrane Bioreactor



MBR systems retain the biomass, which results in a high level of mixed liquor suspended solids (MLSS - the volume of suspended solids in the mixed liquor of an aeration tank) benefiting the bacteria with low growth rates.

Currently, there are two primary types of MBRs used: flat sheet and hollow fiber membranes. Typically both types are immersed in a tank, and a slight suction is applied to pull the treated effluent through the membrane. With time, a thin biofilm forms on the membrane, which in turn reduces the pore size of the membrane and further limits the diameter of organism which can pass through the barrier (Stephensen and Simon, 2000). The rate of effluent passing through a unit area of the membrane per unit time is defined as the flux rate and is an important design variable. The membranes are kept clean by various strategies including low flux operation, air scouring by bubbling, intermittent operation, and backwashing (Fane and Change, 2002).

There are two very important design considerations when you are dealing with MBRs:

1. Accurate flow determination and appropriate application; the system has to be able to handle peak flows while the units are sized to handle a specified flow.
2. MBRs also need to have an appropriate screening process. Things that could either clog the unit or scrape/cut the unit need to be excluded. Most of the time the septic tank and an effluent screen provide enough filtering.

The activated sludge process combined with membrane separation is able to achieve very high removal efficiencies of organic material, with >95% common for biochemical oxygen demand (BOD) and total suspended solids (TSS) (Schuler and Meuler, 2006). In addition to removing biodegradable organics and suspended solids, MBRs remove a very high percentage of pathogenic organisms, providing disinfection of the effluent with 99.9% removal of fecal coliform (Schuler and Meuler, 2006; Stephenson et al., 2000), with two to five log virus removal (Fane, 1996) and more than 5 log removal of protozoa (Trussell et al., 2003).

MBRs with advanced removal process design have been found to eliminate 60-90% of total nitrogen and phosphorus in bench scale testing (Chiemshaisri and Yamamoto, 2005). In order to achieve these rates of nutrient reductions, special design modifications were required. These include varying aeration schemes and recirculating effluent to an anaerobic mixing tank.

Particularly in SSTS, MBRs are an innovative technology. Most MBR installation are fewer then 10 years old and are located on small effluent treatment plants with varying design parameters (Wallis-Lage, 2003).

Performance Levels

Although there are more than 20 brands of ATUs available, there is wide variability in treatment efficiency. A properly operating ATU should produce pretreated effluent containing less than 25 mg/Liter BOD, 25 mg/L TSS, and with a 1-2 log removal of fecal coliform bacteria. Toxic additions into the unit (such as bleaches, cleaners, antibacterial soaps) must be limited for the unit to perform to these standards.

This is one series of tests at one research site and is not intended to represent the entire ATU industry.

A suspended growth ATU was operated as per the recommendation of the local distributor and it was monitored through independent third party testing by the Natural Resources Research Institute (NRRI) at the Minnesota NERCC (Northeast Regional Correction Center) research facility for about 15 months, from October 1997 through January 1999. During this time, the ATU unit did not consistently achieve the manufacturer's treatment performance standards for solids (<30 mg/L TSS), organic matter (<30 mg/L BOD_5), or nitrogen (<10 NO_3-N). Solids averaged 44 to 75 mg/L TSS (12% and -50% removal), during summer and winter, respectively. Organic matter averaged 56 to 91 mg/L BOD_5 (81% and 66% removal), summer and winter, respectively. At a daily flow of 250 gallons/day (the high end of loading the ATU at NERCC) with 275 mg/L BOD_5, the ATU received ~0.6 lbs BOD_5/day, or 50% of its design organic loading. Effluent NO_3-N averaged 35 to 54 mg/L NO_3- N during winter and summer, respectively. The average annual removal of nutrients (nitrogen and phosphorus) by the ATU was low, with TN <20% removal and TP <14% removal. The removal of TN was slightly better in the winter (20 % TN removed) than in the summer (10% TN removed). The ATU nitrified the effluent year-round, with a higher level (~70%) of nitrification during the summer, presumably due to warm temperatures providing beneficial effects on nitrifying bacteria. Fecal coliform bacteria levels were reduced by 90-96%, with slightly better performance in the summer (19,000 cfu/100mL) than in the winter (42,000 cfu/100mL). The overall performance of the ATU was better during the warmer months, with decreased performance during colder periods of the year (McCarthy et al., 2001).

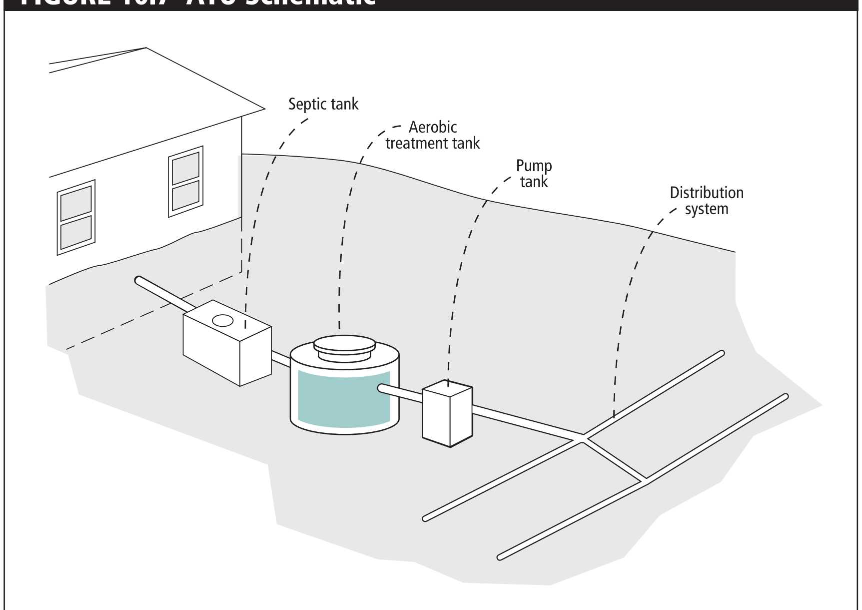
Applications

There are numerous applications for ATUs. ATUs are an option when insufficient soil is available for the proper installation of a traditional septic tank and soil absorption area. Increasingly, homes and small commercial establishments are being constructed in rural areas with no central sewer and on sites with marginal soils. One of the notable benefits of an ATU is the small space a unit requires.

ATUs could also be particularly useful in areas where only sites with disturbed soil are available for SSTSs, again because the effluent flowing into the SSTS is much cleaner. ATUs could be useful in environmentally sensitive areas for pretreating effluent before it is delivered to a soil treatment system, or where it is desirable to discharge effluent into soils that can benefit from effluent that has undergone further treatment than a septic tank provides. In Minnesota, these sensitive locations would be shallow bedrock areas, aquifer recharge areas, and wellhead protection areas. ATUs may also be an option considered in the recovery of soil treatment systems that have been organically overloaded.

A few brands of ATUs have been successfully used to reduce high strength waste from facilities like restaurants, RV dump stations, and milk houses. In Minnesota, ATUs are most commonly used to more fully treat effluent before its final treatment in a SSTS. When effluent has been pretreated, reductions in separation and size are allowed if the unit is on the registered product list. The UMN OSTP does not recommend downsizing soil treatment systems unless a Type I soil loading rate and vertical separation can not be achieved on the available soil and site. Even though additional pretreatment of the septic tank effluent can be achieved with an ATU, the soil treatment system should be located in the most suitable, natural soil conditions to promote overall system longevity.

FIGURE 10.7 ATU Schematic



ATU discharge is appropriate for discharge into a drip distribution system, though drip has not been registered as of the publication of this manual, so it would be considered a Type V system and require a PE and Advanced Designer to prepare specifications. Another application for an ATU may be to lengthen the life of a Type I system. Since the effluent from the ATU will be much cleaner then septic tank effluent the soil treatment system will typically last a longer period of time as long as the ATU is properly operated and maintained. Figure 10.7 shows an ATU using pressurized trenches for final treatment and dispersal.

Another application that is growing in use with ATUs is nitrogen reduction achieved by effluent recirculation. As effluent is treated in the ATU it becomes oxygenated and a majority of the nitrogen is in the form of nitrate. When returned to a processing or recirculation tank, it becomes anoxic (low in dissolved oxygen) and bacteria can break down nitrates in the effluent and release nitrogen gas to the atmosphere in a process called denitrification.

Management

ATUs are more maintenance-intensive than septic tanks. If the supply of air to the bacteria is compromised, the tank loses all effectiveness. If there are problems with settling, which are more common in ATUs than in conventional tanks, there will be problems in the SSTS. It is therefore critical that these tanks be monitored on a regular and frequent basis, and be repaired as needed. With proper design and a good maintenance program, the aerobic system should perform well and treat effluent for a long time.

Frequent maintenance is essential. Owners of aerobic treatment units must have a contract for maintenance. The frequency of visits by a professional for an ATU is typically every six months. A service provider will perform a general assessment of the unit by checking that the air supply is hooked up and providing air to the unit by a visual inspection of hoses, clamps, and bubbling action during the visit. A dissolved oxygen meter or kit is an effective tool to determine if the conditions in the ATU are aerobic. The dissolved oxygen should be greater than two mg/L in the ATU chamber where air is supplied. During maintenance, examination of the mixed liquor is performed to determine if the tank requires pumping. Pumping is generally needed when the solids levels are above 6,000 mg/L or the final settle chamber is more than one-third full of solids (EPA, 2002). For many brands of ATU pumping should occur on an annual basis, but frequency is highly dependent upon use. It is advised to check with the manufacturer for more specific requirements regarding pumping of the ATU. Cleaning of filters, removal of any debris, and inspection of the effluent are also performed during a maintenance visit. The effluent may require laboratory testing if this is required in the operating permit. ATUs are commonly evaluated for removal of BOD, TSS, and fecal coliform.

Management plan

The homeowner should know what to expect from a well-functioning treatment system so as to be able to detect when the system is malfunctioning. Homeowner neglect is one of the common complaints from suppliers and regulatory agencies.

Education of the homeowner should begin before the pretreatment and effluent dispersal system is selected and continue thereafter. People moving from urban to rural areas appear to have an especially challenging time adjusting to the change in sewage treatment practices. Excess water use and disposal of toxic household chemicals are two of the more serious problems they encounter.

The design package will include the management plan, which should include specific instructions to the system owner and their service provider. Several product-specific Managment Plans are located on the OSTP website: septic.umn.edu The management plan should contain:

- Diagrams of the system components and their location
- Explanation of general system function, operational expectations, and owner responsibilities
- Specifications of all electrical and mechanical components installed
- Names and telephone numbers of the system designer, LGU, component manufacturer, supplier/installer, and the management entity to be contacted in the event of a failure

- Information on the periodic maintenance requirements of the sewage system: septic tank, dosing and recirculating/mixing tanks, media filter unit, pumps, switches, alarms, and dispersal unit
- Information on troubleshooting operational challenges. This information should be detailed and complete to assist the system owner in making accurate decisions about when and how to attempt corrections of operational problems, and when to call for professional assistance
- Information on the final landscaping of the site, including limitation about future plantings, and identification of activities that can not occur on or around the system and reserve area
- Maintenance, monitoring, and sampling requirements/recommendations - this includes inspecting monitoring ports, looking for leaking plumbing fixtures and tanks, and evidence of site protection. This should include forms and methodologies to be used
- A complete maintenance and operation document should be developed by the manufacturer and made available to the system owner; this document should also be provided to the LGU, prior to the issuance of the local installation/operating permit
- Recommended maintenance, which includes verifying:
  - > Pumping frequency from pump counters and elapsed run time meters
  - > Operation of pumps, floats, valves, electrical controls, and alarms
  - > Pump delivery rate (draw down test)
  - > Dosing volume and measure or calculate average pump run time

Installation

Siting and construction considerations for ATUs are the same as for septic tanks. ATUs require very little installation space, which allows for placement flexibility. A typical ATU space requirement is 25 square feet for a three-bedroom home. ATUs are typically sold as prepackaged units with great ease of installation.

Troubleshooting

Odor is often the first indication of a problem with an ATU's operation. Systems should also be equipped with an alarm that is triggered at the onset of an operational failure. Odor issues can arise due to improper installation techniques that cause the airline (the piping that conveys air from the source to the point of diffusion) to settle and restrict or stop the supply of air to the unit. If the system has been upset due to heavy laundry water loads that are low in soluble BOD, the population may be reduced because of the lack of food. Additionally, wash-out of microbes can occur if the hydraulic loading is greater than the designed outflow rate of the clarifier. When the next heavy dose of organic material enters the tank, there may not be a sufficient microbial population to complete the digestion of BOD during the hydraulic detention period.

Sludge bulking is a phenomenon that develops in the aeration tank when a growth of filamentous bacteria (primarily sphaerotilus) attaches to the floc particles and impede settling (Crites and Tchobanoglous, 1998). Such microorganisms can tolerate large changes in dissolved oxygen and nutrients, a situation that occurs frequently in small aerobic treatment units. When these conditions occur, the result can be the carryover of solids in the effluent. This phenomenon is particularly troublesome to smaller plants where there may be considerable fluctuation in organic loading and a lack of technical support.

When an excessive growth of nocardia (a hydrophobic bacterium) occurs, foaming and frothing on the liquid surface in the aeration chamber (and the clarifier) may result. The problem is exacerbated by the fact that the baffles in the clarifier trap the foam and foster more growth (Crites and Tchobanoglous, 1998). Some ATU manufacturers provide froth spray pumps. The froth spray serves to reduce the surface tension of the water and break down the froth (Ohio EPA, 2000).

Although ATUs use the extended aeration process, endogenous degradation cannot completely prevent the accumulation of old biomass. Biomass and non-biodegradable solids will accumulate in a low area of the ATU, and periodically, a maintenance provider must remove a portion of these solids. During removal, it is important to leave some of the solids in the aerobic chamber to serve as seed to repopulate the biological floc.

There are numerous reasons why an ATU may experience operational issues. See Table 10.4 below for some of the more common challenges and likely causes.

TABLE 10.4 Common Challenges and Potential Causes

Challenge	Possible Cause
Experience slow flush in home but electronics are in good working order	■ Unacceptable level of solids in septic tank ■ Building sewer has blockage
Foaming and frothing in and around ATU	■ Excessive use of surfactants (soaps) ■ Bacteria community dominated by nocardia bacterium
Treatment below design goals	■ System hydraulically or organically overloaded ■ Sludge bulking ■ Air supply problem ■ Poor installation including leaky components ■ Chemicals have killed the system
Effluent ponding on surface of soil treatment system	■ ATU not operating properly ■ Soil treatment system not designed properly ■ System hydraulically or organically overloaded
Production of odor	■ ATU experiencing a disruption ■ Anaerobic conditions exist ■ Lids not gastight ■ Roof vent odor could be confused with filter odor ■ System not maintained correctly
Pump not operating properly- alarm condition	■ Hydraulic overload (due to homeowner, leaky tanks, etc) ■ Control and electrical problems: float switch or timer incorrectly set, incorrect or low voltage, pump mechanical problems, defective electrical components, debris on or under float switch, panel fuses and breakers tripped

Compliance Inspections

The monitoring or management plan for any ATU must be evaluated before inspection to determine what steps were required for the system. If the unit does not meet these requirements, the unit is determined to be in non-compliance and the LGU should determine what steps are required to bring the system back into compliance.

Abandonment

If an ATU requires abandonment, the manufacturer of the unit should be consulted to determine if complete removal of the unit is required.

Media Filters

Definition

A media filter is a device that uses unsaturated material designed to treat effluent to a desired quality by reducing BOD and/or removing suspended solids. Biological treatment is facilitated via biomass growth on the surface of the media. Media can be designed to operate in single-pass mode in which effluent moves through a treatment component only once, or a recirculating mode in which a portion of the effluent is returned to the treatment component either for further treatment or to facilitate a specific treatment process.

Treatment Process in Media Filters

The treatment mechanisms in a media filter are: physical filtering of solids, ion exchange (i.e., alteration of compounds by binding and releasing their components), and decomposition of organic waste by soil-dwelling bacteria. Effluent is distributed across the surface of the media. As effluent passes through the bed, a biologically active film of organisms forms on the surface of the media. Fixed film reactors reduce the BOD of effluent by exposing the organic compounds to the attached (fixed) microorganisms. Microorganisms play an essential role in treating the effluent as it flows over media surfaces, digesting the organic material during rest periods and converting it to cell mass, heat, water, and carbon dioxide.

Certain bacteria known as primary colonizers attach (via adsorption) to the media surfaces and differentiate to form a complex, multi-cellular structure known as a biofilm. For this biofilm to form, proper environmental conditions are needed. Sufficient moisture is the most important factor. Temperature and the amount of readily available oxygen also play important roles. If these factors are conducive, a biofilm will form around a host particle. Adequate moisture is not generally a problem in media filters, but maintaining adequate air movement through the system to provide the needed oxygen is problematic in some systems.

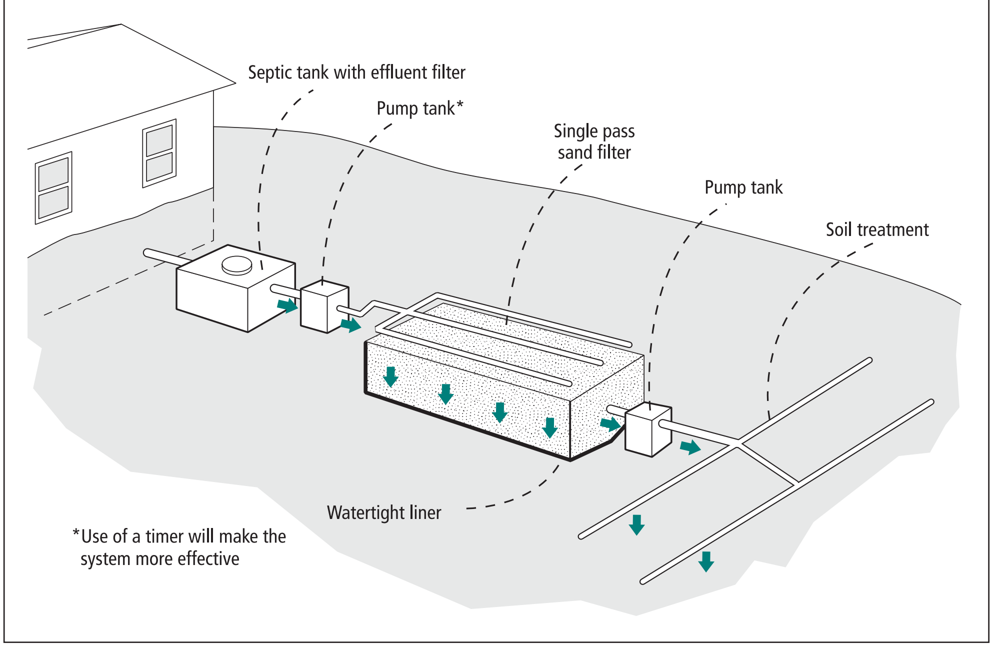
Types of Media Filters and Operation

Single pass media filters

A single-pass media filter (SPMF) typically uses sand or peat as the media for effluent treatment, in addition to a septic tank and soil treatment area. Sand filters have been widely used around the United States, and various sand filter types and designs have been extensively tested. Media used in other SPMFs include peat, pea gravel, crushed glass, and many other experimental mediums. A majority of SPMFs load at approximately one gallon per square foot.

Sand filters are generally constructed on site with a PVC watertight liner with two feet of sand with a particle size between 0.05 and 2.0 millimeters in diameter. A general cross section of a sand filter is shown in Figure 10.8. Sand filters have been widely used around the United States, and the various sand filter types and their designs have been extensively tested and documented. The sand size particles are screened to meet specific grain size distribution specifications. 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 sufficiently large voids to prevent rapid clogging by the combination of filtered solids and biological growth. Peat filters, on the other hand, are typically packaged as pre-fabricated modules designed with two feet of peat soil material in which the original plant parts are recognizable. Peat has a high surface area, which is a positive attribute for media in both single pass and recirculation mode. Peat will degrade over time and need replacement after some years.

FIGURE 10.8 Single Pass Sand Filter Schematic

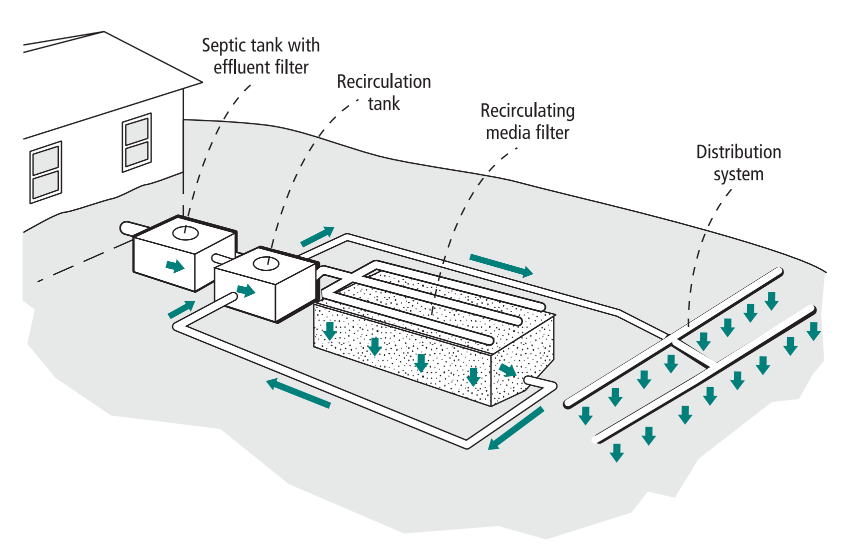


Recirculating Media Filters

A recirculating media filter (RMF) system contains the following:

- A septic tank with an effluent screen
- A recirculating tank containing a pump and related controls that distribute effluent to the filter and a means for transmitting filter effluent (via a pump or gravity) to a SSTS
- A recirculating filter, consisting of:
  - > filter media,
  - > a distribution system,
  - > an underdrain that collects filtered effluent and directs it back to the recirculating tank, and
  - > a liner or container.
- A soil treatment and dispersal system

FIGURE 10.9 Recirculating Media Filter Schematic



A RMF uses coarse sand, gravel, peat, foam, textile, or other media for effluent treatment in addition to a septic tank, recirculation tank, and SSTS. The recirculation tank contains a blend of septic tank effluent and media filter effluent. This blend, combined with media with more pore space, allows for higher loading rates than does a SPMF (typically greater then three gallons per square foot). Coarse sand has been the most widely used medium in RMFs, but use of synthetic media is increasing. RMFs are either constructed on site with water-tight liners or sold as prefabricated units, commonly with two feet of media. The flow path through a typical recirculating system is shown in Figure 10.9.

Effluent from the primary treatment of effluent in a septic tank or other treatment component is transmitted to a recirculating/mixing tank. In the tank, effluent from the treatment component mixes with effluent that has been recirculated through the media. This mixture is applied by a pressure distribution network onto an infiltration bed of a specified media. The effluent flows downward from the bed into and through the filter media. Biological treatment occurs as the effluent passes the surfaces of the filter media.

Treated effluent is collected at the bottom and is discharged by gravity or pressure back to the recirculating/mixing tank where the recirculating cycle begins again. As levels in the recirculating tank rise, treated effluent will be discharged to a dispersal component by pumping.

Sand is an attractive media for a number for reasons. They are equipped to handle higher strength waste (where biological oxygen demand, a measure of organic matter, is less than 1,000 mg/L) and higher hydraulic and organic loading rates, yet they have a small size and land use requirement. Higher loading capacities are especially beneficial in applications where it is necessary to fit a filter into a small site or where the system must handle larger flows.

In addition, the recirculation an RSF system offers is beneficial in areas where nitrogen is a problem. Recirculation may be advantageous in situations where it is desirable to design for enhanced nitrogen removal through the treatment process. As effluent moves through the filter, it becomes oxygenated. When it is captured in the recirculation tank, it becomes anoxic (low in dissolved oxygen) and bacteria can break down nitrates in the effluent and release N back to the atmosphere in a process called denitrification. Multiple- pass recirculation processes also provide operation and maintenance benefits with respect to process flexibility in treating peak hydraulic surges and greater periodic organic loads.

Applications and Performance

Because the effluent leaving a media filter is pretreated, the soil in a trench or mound SSTS may be better able to accept it, and the soil treatment area may work longer. Soil treatment systems receiving pretreated effluent may have reduced vertical separation to the limiting condition as described in **Chapter 7080.2350 Subp. 2, Table XI,** and reductions in the bottom absorption area (conversely, increased soil loading rates) as indicated in **7080.2150, Subp. 3, Tables IX and IXa**. The U of MN OSTP does not recommend downsizing soil treatment systems unless a Type I soil loading rate and vertical separation can not be achieved.

Media filters could also be particularly useful in areas where only sites with disturbed soil are available for SSTSs, again because the effluent flowing into the SSTS is much cleaner. Media filters could be useful in environmentally sensitive areas for pretreating effluent before it is delivered to a soil treatment system, or where it is desirable to discharge effluent into soils that can benefit from effluent that has undergone further treatment than a septic tank provides. In Minnesota, these sensitive locations would be shallow bedrock areas, aquifer recharge areas, and wellhead protection areas.

Two demonstration RMFs were installed at dwellings in Minnesota to remediate soil treatment systems. One of the trench systems had only two feet of separation between it and the water table, while the other was on a steep slope and had surfaced. In both examples, the addition of the RMF was successful, although one of the RMFs has had ongoing operational issues due to the homeowner management (Gustafson et al., 1999).

Media filters could also be applied successfully in areas with shallow soils over bedrock or saturated soil. Pretreatment utilizing registered products may allow a reduction in the required distance from the SSTS to this limiting soil layer **(7080.2350 Subp. 2, Table XI)**. Even though additional pretreatment of the septic tank effluent can be achieved with a media filter, the soil treatment system should be located in the most suitable, natural soil conditions to promote overall system longevity.

Media filter systems can also be appropriate in the recovery of existing drainfields. Where drainfields have failed due to lack of maintenance or due to excessive organic loading, it is possible that an existing system can continue to be used if aerobically treated effluent is delivered to the SSTS (Converse and Tyler, 1995).

Media filters are used to produce effluent that is low in BOD and TSS, and has a greatly reduced concentration of pathogenic organisms compared to septic tank effluent. The resulting effluent can be discharged to soils at higher rates than septic tank effluent without developing a biological clogging mat (biomat) at the infiltrative surface of the soil absorption system. Table 10.5 (Loudon et al., 2003) shows typical performance of single pass media filters.

TABLE 10.5 Typical Domestic Strength Septic Tank Effluent and Media Filter Effluent *

	BOD (mg/L)	TSS (mg/L)	Nitrate-N (mg/L)	Ammonium-N (mg/L)	DO (mg/L)	Fecal Coliform Org/100 mL
Septic Tank Effluent	130-250	30-130	0-2	25-60	<2	$10^5 – 10^7$
Media Filter Effluent	5-25	5-30	15-30	0-4	3-5	10^2 - 10^4

* Total Phosphorus (P) content depends on the type of media used, but over time all media will reach its capacity of P removal

Media Filters are a beneficial option for SSTS in several situations such as:

- Environmentally sensitive areas where a higher level of treatment is desired
- Sites with soils that are not considered hydraulically acceptable for septic tank effluent
- Soils that provide less vertical separation between the level of application and a limiting layer
- Systems with large flows where it is desirable to load the soil at a higher hydraulic application rate than can be done with septic effluent

The sixth year of operation data collected in Minnesota suggests that two sand filters at NERCC research sites performed well. They were loaded at approximately 195 gal/day (0.6 gal/ft^2/day). The single-pass sand filters required only routine maintenance, limited to flushing the pressure distribution network. Overall, of the alternatives evaluated, the sand filters provided the best performance in removing BOD (99%), TSS (96-99%), phosphorus (48-50%), and fecal coliform bacteria (>99.8%), followed closely by the modular peat filter containing standard Irish peat. At the site near Duluth, the single pass sand filters removed the most phosphorus, 48-50%, presumably due to the iron content of the media, which was removed from a mine pit on the north of Virginia. Overall nitrogen removal was minimal (4%) by the sand filters, but nitrification was nearly complete at >95% and ammonium levels averaged <3 mg N/L) (Axler, 2004).

RMFs are a particularly attractive alternative because of their small size and land use requirement and their ability to handle higher strength waste (BOD <1,000 mg/L). RMFs can offer significant benefits in areas where nitrogen contamination of groundwater has been a problem: as effluent moves through the filter, it becomes oxygenated; however, when it is captured in the recirculation tank, it becomes anoxic (low in dissolved oxygen). During the anoxic cycle, bacteria can break down nitrates in the effluent.

A research site was developed in southern Minnesota in 1995 to test alternative technologies, including two recirculating sand filters (RSFs). In addition, in 1998, two RSFs were added to existing residential soil treatment systems that were having problems because of inadequate separation and fill soil conditions. All RSFs in this study used 0.6 meters of coarse sand for treatment, were loaded at approximately five gallons per square foot per day) with a recirculation rate of 5:1. All the RSFs have effectively reduced BOD, TSS, fecal coliform (FC) and nutrients (nitrogen and phosphorus).These systems are able to achieve secondary effluent treatment levels for BOD and TSS. The median FC reduction was 90%, with a value of 5.7 E4 cfu/100mL, indicating additional soil treatment is necessary to protect health and the environment. The RSFs consistently removed 25% or more total phosphorous (TP) and 40% or more total nitrogen (TN). The RSFs did not show significantly decreased performance during the winter months. Two of the RSFs receiving rather high strength waste were able to reduce a greater percentage of total nitrogen, indicating that the addition of carbon from the high strength waste is a benefit resulting in greater TN removal (Christopherson, 2001).

A modular RSF was also tested at the NERCC site. The textile filter performed reasonably well in removing organic matter (97% BOD) and pathogens (99.98% removal fecal coliform bacteria) at a flow of 248 gal/day. Secondary level effluent quality was produced consistently throughout the year with means of 6 mg BOD/L, 7 mg TSS/L and a geometric mean of 101 fecal cfus/100mL. As expected phosphorus removal was low (7%) because there was no adsorbent. N-removal was also relatively low at 21%, but the filter nearly entirely removed ammonium after May by nitrifying it to nitrate. The filter remained aerobic throughout the year with DO levels always > 3mg. This filter reduced fecals to <1000 cfu/100mL for 92% of the samplings and <200 for 64%, which was generally similar to its two previous years of operation. Overall, its summer removal to <200 cfu/mL was 56% in summer and 13% in winter. Removal to <1000 cfu/mL increased to 73% in both summer and winter. The textile filter typically removed >99.5% of the influent fecal coliform bacteria for the entire period of record since 1999. A polishing sand filter further improved the system's efficiency to >99.9% for fecals in 1999-2000 but eventually failed (i.e., it ponded) due to undersizing (Axler et al., 2004).

Rule Requirements

Media filters are classified as Type IV if they utilize Registered Products or Type V systems if they do not. They are all required to be operated under a local operating permit and measure flow. **According to MN Rules Chapter 7083.4000, Subp. 1 (B):**

The commissioner shall develop recommended standards and guidance to assist local units of government in permitting different types of sewage treatment technologies and sewage distribution technologies, including the following five categories:

(1) public domain treatment technologies, such as sand filters;

(2) proprietary treatment technologies, such as manufactured aerobic treatment systems;

(3) public domain distribution technologies, such as drainfield rock or generic drainfield rock substitutes;

(4) proprietary distribution technologies, such as gravelless distribution products; and

(5) proprietary drip dispersal systems.

A public domain technology means a sewage treatment or distribution technology, method, or material not subject to a patent or trademark (7083.0020, Subp 16).

The standards and guidance documents for single-pass and recirculating sand filters are maintained on the MPCA web site. Design worksheets for these pretreatment systems can be found at septic.umn.edu/ssts-professionals/forms-worksheets.

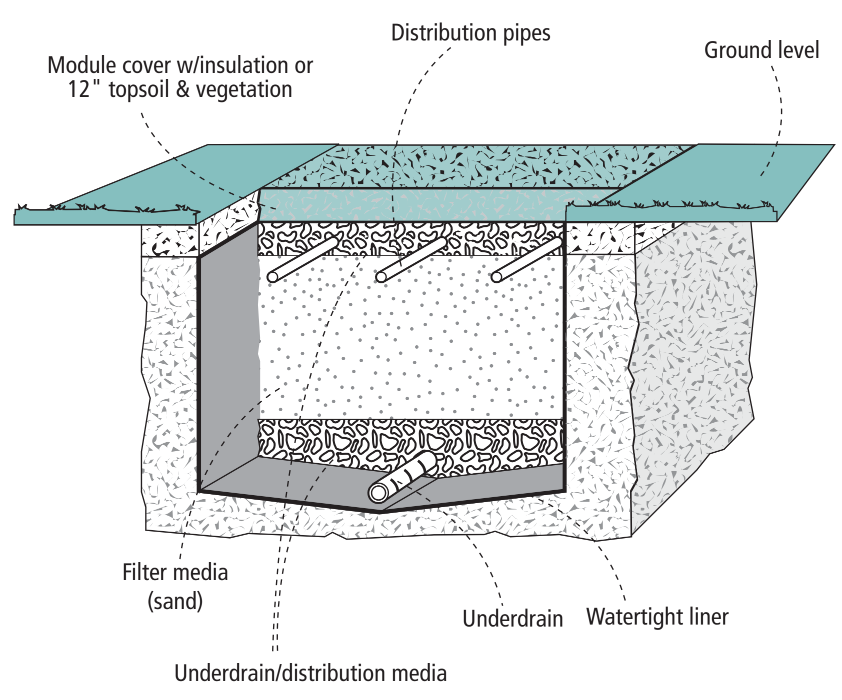
Design

Single Pass Sand Filters

A single pass sand filter (SPSF) is typically confined in a lined or watertight container having an underdrain for the removal of filtered effluent with subsequent dispersal in a soil absorption system. Occasionally an unlined, "bottomless" sand filter is used where the water table or any limiting layer is deep and the soil at a site has adequate permeability directly below the sand filter to safely disperse the effluent into the natural soil at the loading rate of the SPSF. Since the loading rate to a SPSF is fairly low, it requires a large amount of space compared to a RMF. A SPSF system contains the following components:

1. Septic tank(s) with effluent screen
2. Pressure distribution components:
   a. Pump chamber
   b. Pump controls
   c. Pressure distribution laterals for the sand filter itself and often as a way to supply the soil treatment area
3. The sand filter as shown in Figure 10.10, consisting of:
   a. Filter media
   b. An infiltration bed
   c. A distribution system
   d. A soil cap and topsoil cover
   e. An underdrain and a means for gravity flow or pumping from the filter
   f. A watertight liner
4. Soil dispersal system

FIGURE 10.10 SPSF Cross Section



Effluent from the septic tank is transmitted to a pressure distribution network within the infiltration bed of a SPSF. The effluent flows downward from the bed through at least two feet of filter media where it undergoes physical, chemical, and biological treatment. SPSFs, as well as most other media filters, will perform best if dosed using a pressure distribution system.

Pressure distribution is the typical application method by which a pump introduces effluent at the top of the watertight filter. Pressure distribution is used to apply the effluent to the filter surface, allowing uniform loading over the entire filter surface and thus maximizing treatment.

Typically the pressure distribution is in the form of a small diameter pipe, similar to that used in a mound system, so that the effluent can be uniformly applied in small, frequent doses. Pressure distribution systems are typically contained within a pea stone or coarse stone layer with sufficient cover over the pipe so that the applied effluent does not reach the top of the stone layer. The depth of gravel bed will be a minimum of nine inches if a one and one half inch diameter lateral is used.

Ideally, the filter will receive effluent evenly over its surface at regular time intervals. Timed dosing and a two-foot spacing of inlet pipes are recommended. To be considered a standard pressure distribution system in Minnesota, anywhere from two- to three-foot spacing is allowed.

Perforations in the laterals can be 1/8 inch to 1/4 inch. Six to ten square feet per perforation is recommended for even distribution. While laterals with 1/4 inch perforations require a larger pump, smaller diameter sizes are gaining in popularity.

Daily Flow

Sewage flows from the house into one or several septic tanks depending upon the size of the home, Chapter 7080, and the local ordinance. Effluent from the septic tank(s) then flows into a pump or lift tank. An effluent screen is commonly located in the septic tank or dosing chambers. Chapter 7080 recommends the screen if a garbage disposal or pump in the basement is installed, but many manufacturers of media filters require that one be installed. The recommended daily design flow for dwellings is the number of bedrooms times 150 gallons per day. For other establishments, estimate the average daily design flows using Table 10.6. If the design flow is measured rather than estimated, a safety factor must be included when sizing the system.

TABLE 10.6 Estimated Sewage Flows in Gallons per Day

Number of Bedrooms	Class I	Class II	Class III	Class IV
2	300	225	180	60% of the values in the Class I, II, or III columns.
3	450	300	218	
4	600	375	256	
5	750	450	294	
6	900	525	332	
7	1050	600	370	
8	1200	675	408	

Class I: The total floor area of the residence is over 800 square feet per bedroom or more than two of the following water-using appliances are installed: dishwasher, automatic clothes washer, water softener, garbage disposal, self-cleaning furnace.
Class II: The total floor area of the residence is between 500 and 800 square feet per bedroom, and no more than two water-using appliances are installed.
Class III: The total floor area of the residence is less than 500 square feet per bedroom, and no more than two water-using appliances are installed. Use this estimate **only** when designing a system with flow control, such as trenches and a holding tank, or a timer to dose the system at a designed volume.
Class IV: Class I, II, or III home, but with no toilet wastes discharged into the system.

Sizing

SPSFs are typically designed to accept about one gallon per day per square foot of filter surface, as shown in Table 10.7. This loading rate assumes a biomat has formed at the infiltrative surface and that a long-term application rate will occur. The biomat will form if sewage has the quality expected from single-family residences. If the loading rate is higher, two to six gpd/ft^2, the system must be accessible at the surface as it will require maintenance, raking, and eventual replacement of the medium. These loading rates are not common in the upper Midwest due to our cold climate. A high rate SPSF is shown in Figure 10.11. When the loading rate is less then 1.5 gpd/ft^2, the system will operate properly for longer without needing media replacement.

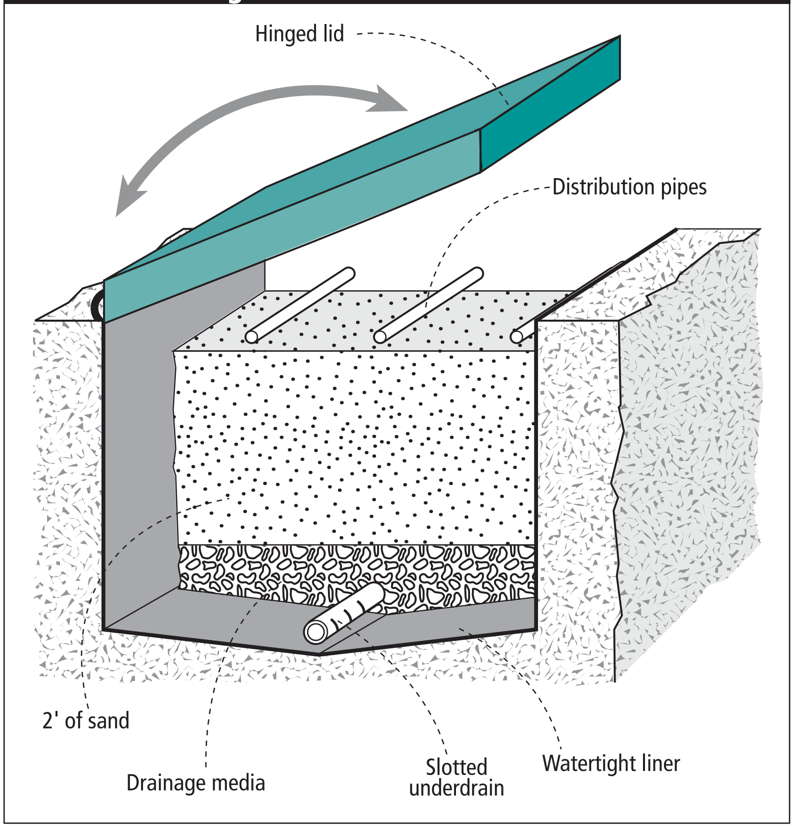
TABLE 10.7 Typical Design Values for Sand Filters on Single Family Dwellings

Design Factor	Single Pass	Recirculating
Hydraulic loading (forward flow)	0.8 - 1.0 gpd/ ft^2	2.0 - 5.0 gpd/ ft^2
Organic loading	< 5 x 10-3 pounds of BOD/day/ ft^2	
Pretreatment	Septic tank as required in 7080 with effluent screen	
Media		
a. Material	Washed, durable granular material	
b. Effective size	< 1.0 mm	1.5 - 2.5 mm
c. Uniformity coefficient	< 4.0	
d. Depth	24 inches	
Dosing frequency	8 or more doses per day	48 or more doses per day
Recirculation ratio	NA	3:1 – 7:1

To determine the design size of the filter, the volume of effluent flow from the residence is divided by the loading rate. Sizing criteria for SPSFs are similar to those used for the rockbed in a mound system.

Media

FIGURE 10.11 High Rate Sand Filter Cross Section



Clean sand is used in single-pass filters, often the same size as is used in mound systems. Clean sand must be free of organic impurities and contain less than three percent deleterious substances. **Minnesota Rules Chapter 7080.1100, Subp. 16 defines "Clean sand" as a soil fill material required to be used in mounds. The standards for clean sand are outlined in part 7080.2220, subpart 3, item C.** The media specification for sand used in SPSF is critical and is shown in Tables 10.8 and 10.9. Most single-pass units contain a single gradation of media in the treatment layer. Fine sediment, if present in the media, will be congregated in specific locations and reduce flow, which may eventually result in system failure. Somewhat coarser sand, such as ASTM C-33, provides adequate treatment of the effluent as well as better aeration and hydraulic acceptance; however, phosphorous removal will be less compared to removal rates of finer-sized sand. Figure 10.12 indicates the jar test field procedure conducted to verify sand quality.

TABLE 10.8 Clean Sand

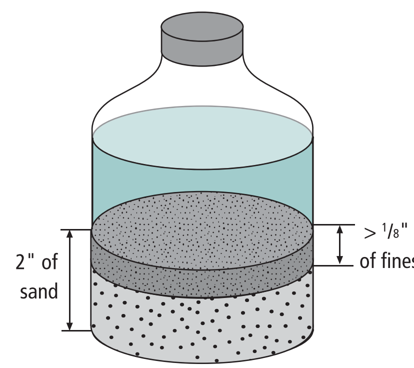
sieve number	sieve size (mm)	percent passing
4	4.75	95 to 100
8	2.0	80 to 100
10	0.85	0 to 100
40	0.425	0 to 100
60	0.212	0 to 40
200	0.075	0 to 5

7080.2220, Subp. 3 (C)

The bottom of the filter media should be level or slightly sloped to the underdrain. The minimum and optimum depth of the filter media is 24 inches. The pea gravel depth is typically three inches, and the underdrain gravel depth should be a minimum of six inches, with the gravity underdrain sufficient depth to provide adequate storage volume when using a pump well/vault to pump sand filter filtrate to the next component. The gravel depths may be greater to provide additional storage volume if filtrate will be pumped from the SPSF to the next system component. This washed gravel should be 7/8-inch to 2-1/4-inch.

Commonly, a shallow layer, six to eight inches deep, of sandy or loamy sand soil is added over the stone of SPSF. The soil is usually sod-covered. However, improved aeration of the sand media can be achieved if the sand filter is covered with decorative stone or some other porous covering material instead of sod. Stone covering is preferred from a functional standpoint. Deep rooting plants must be kept away from the SPSF, and nothing that would reduce air movement into the SPSF should be placed over the surface. Sand filters must be located and placed at an elevation such that they are not subject to surface water run-on. Traffic over the SPSF must be avoided so that the surface does not become compacted.

FIGURE 10.12 Jar Test



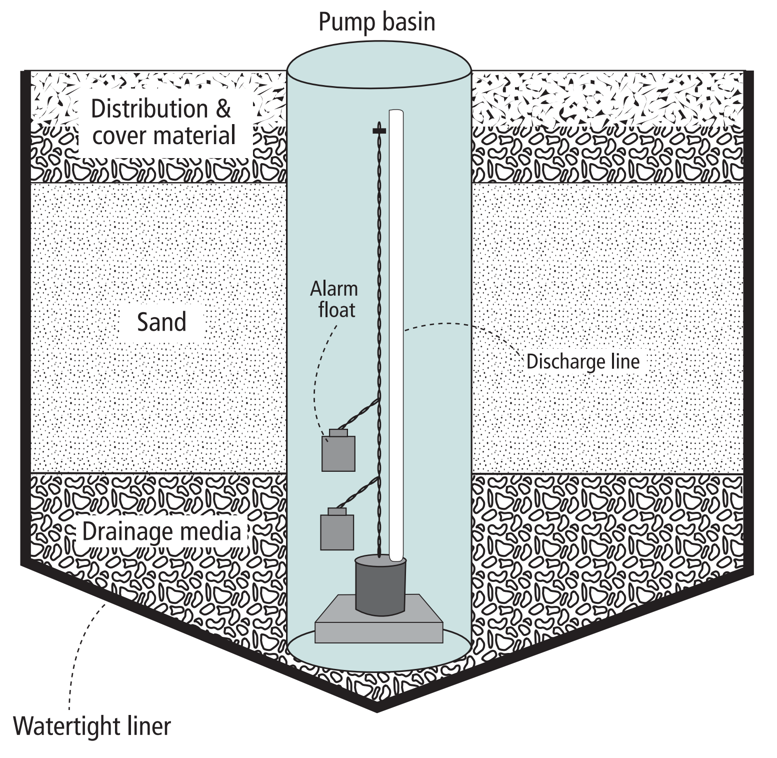
If the fines that settle out in 30 minutes accumulate to a depth of greater than 1/8", then the percentage of fines is too great and the sand **should not** be used for mound or sand filter construction.

Underdrain and inspection ports

There are several options for the underdrain method and the effluent means of transmitting to the dispersal component. In the simplest designs, effluent flows by gravity from the SPSF to a pump station. It is generally more economical to place a pump basin in the center of the filter.

There are a variety of ways to design the underdrain. Typically, three inches of pea gravel is placed over a six-inch layer of 3/4-inch gravel containing the underdrain collection pipe. If effluent is pumped directly from the sand filter to the soil dispersal area, the filtrate is collected in a gravel bed underlying the filter media and is discharged into a pump basin within the filter. The basin in which the pump will sit is deeper, usually by eight to 18 inches, than the SPSF bottom so that filtrate flows towards the pump. If a synthetic membrane is used, the pump basin must be adequately supported with a base on both sides of the synthetic membrane. The pump basin must allow the pump to stay submerged at all times. A large-diameter underdrain pipe or riser is placed in the basin. The bottom edges of the pipe or riser should be flat with no sharp edges. The diameter of the pipe or riser should be sufficient to allow room for the pump and floats to operate and for monitoring and maintenance to be performed. The pipe or riser should extend upwards to at least surface grade, where a tight-fitting, secure cover is placed. The pipe or riser should be one piece, from the floor of the pump basin to the top, and be made of a noncorrosive material.

FIGURE 10.13 Sand Filter Drain Setting



Float must be located and set so the sand layer does not become saturated.

The filtrate cannot be allowed to rise in the bottom of the filter to a level where it can saturate any portion of the filter media. As a rule of thumb, specify that the floats be set so the liquid level never rises any higher than the crown of the underdrain pipe. The pump-off float position will then be somewhere above the invert of the underdrain pipe. See Figure 10.13. A single "on-off" float switch will facilitate this function. A typical intermittent sand filter for a three-bedroom home will have a draw-down of one and one half to two inches and will deliver about 80 to 140 gallons per dose to the dispersal component.

An inspection port from the surface down to the bed-sand media interface should be installed. One may also be placed to the sand-distribution media interface. The inspection ports, in addition to the pump basin if one is used, will permit ponding levels within the filter to be monitored.

Outflow drainage from the filter is provided by a four-inch pipe surrounded by pea rock. This pipe should be slotted four-inch ASTM 3034 pipe or stronger. The slots should not be directly against the liner; they should be facing 12 o'clock or, if facing six o'clock, have a few inches of gravel under the pipe and slots. Depth of the outflow should be from one foot below the bottom of the media so the effluent can drain freely out of the media, since saturated conditions in the filter greatly reduce its treatment effectiveness.

The layout of the filter, in terms of length to width ratios, is not as critical as a good distribution system for applying effluent to the filter surface. Ideally, the filter will receive effluent evenly over its surface and at even time intervals. Timed dosing and a two-foot spacing of inlet pipes are recommended in many states using this system. In Minnesota, three-foot spacing and 1/4-inch perforations in the inlet pipes are allowed. Inlet pipes with 1/4-inch holes require a larger distribution pump than they would if the perforations were smaller, but smaller perforations are more likely to become plugged.

Choosing the containment vessel

Synthetic membrane liners can only be used in a lined excavation below the ground surface. Liner material specifications are:

- 30 millimeter thickness
- Manufactured per National Sanitation Foundation Standard 54
- One-piece construction, without holes. See construction media filter section for more information

TABLE 10.9 Typical Design Values for Sand Filters

Design Factor	low-rate	high-rate	recirculating
Hydraulic Loading (based on forward flow)	0.8 - 1.0 gpd/sqft	2.0 – 5.0 gpd/sqft	3.0 – 5.0 gpd/sqft
Organic Loading	——————— $< 5 \times 10^{-3}$ lbs. BOD/day/sqft———————		
Pretreatment	——————— must include settling and removal of solids———————		
Media			
material	——————— washed, durable granular material ———————		
effective size	< 1.0 mm	0.3–1 mm	1.5 - 2.5 mm
uniformity coefficient	< 4.0	< 4.0	< 4.0
depth	24 inches	24 inches	24 inches
Media Temperature	> 5 C	> 5 C	> 5 C
Dosing Frequency	——————— 8 doses or more per day ———————		
Recirculation Ratio	NA	NA	3:1–7:1

Peat Filters

A peat filter is a media filter in which septic tank effluent is applied to a two-foot thick layer of sphagnum peat. Peat is an organic material made up of partially-decomposed plants. It has a high water-holding capacity, large surface area, and chemical properties that make it very effective in treating effluent. Unsterilized peat is also home to a number of microorganisms, including bacteria and fungi. All of these characteristics work together to make peat a very reactive and effective filter media.

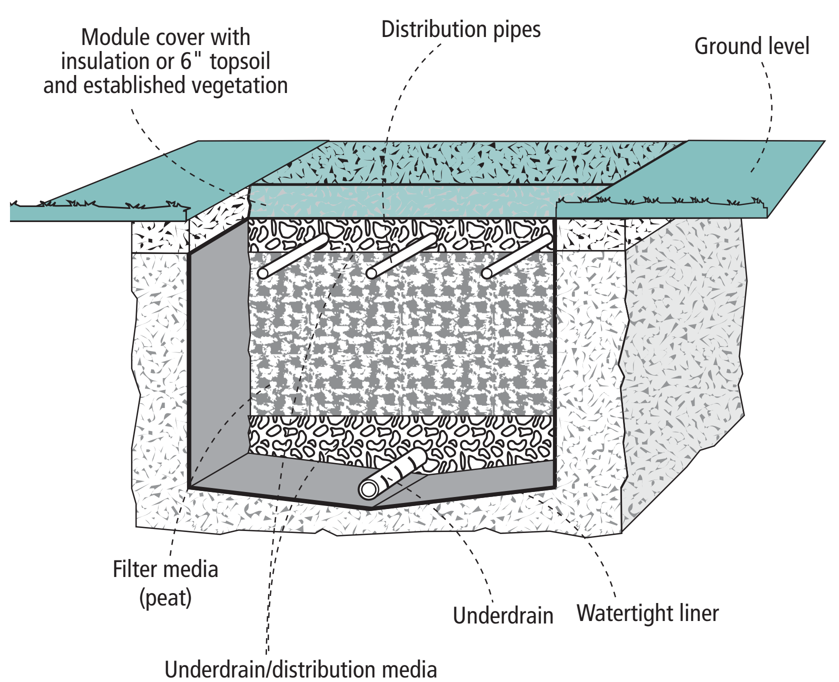
In research, peat filters have removed high concentrations of nutrients, BOD, TSS, and fecal coliform bacteria. Research sites were established in northern and southern Minnesota in the fall of 1995 to treat septic tank effluent from a single family home with peat filters.Replicate in-ground (lined excavation) intermittent peat filters with gravity distribution, experienced hydraulic failure after 15 months at the northern site, but were later modified with pressure distribution, and have operated successfully since 2004. Removal efficiencies were 98% TSS, >99% BOD_5, >99.99% fecal coliform bacteria, >42% TP, and >17% TN. Similarly constructed in-ground intermittent peat filters at the southern site also experienced hydraulic failure. However, a peat filter with pressure distribution is still in operation and functioning (since 1996) in a partial anaerobic condition. During the summer and winter of 1998, the in-ground intermittent peat filters at the northern site were spiked with *Salmonella choleraesuis*, and had an overall nine log removal efficiency. Modular recirculating peat filters (Puraflo®) were installed at the northern site in the summer of 1998 to compare a proprietary Irish peat with a Bord Na Móna specified proprietary Minnesota peat. Removal efficiencies for both have been >92% TSS, >96% BOD_5, >99% fecal coliform bacteria, 3-20% TP, and 29-41% TN. Both the in-ground and the modular peat filters performed well and consistently exceeded secondary levels of treatment (Monson Geerts et al., 2001).

A peat filter can be designed and installed in one of two primary methods: with pre-manufactured modules or constructed onsite like a sand filter. Either way, both types of peat filter have three typical components:

- The septic tank with effluent screen and dosing chamber
- The media filter containing the peat
- The soil treatment system

The distribution system for a peat filter such as the one shown in Figure 10.14 should be pressure distribution. Research has shown that gravity distribution is not an effective method by which to load a peat filter. Another option may be gravity distribution, such as a tipping tray. The biggest problem with uneven gravity distribution is ponding of effluent in pools on top of the peat. The weight of the effluent compresses the peat, resulting in a slower infiltration rate, significantly reducing the flow of effluent through the filter. The effluent must move through the peat under unsaturated conditions. In pressure distribution, effluent is sprayed evenly over the peat surface, so it does not pond on top of the filter, and the peat is not compressed. Filters using a pressure distribution system are long-lasting and provide good treatment of effluent.

FIGURE 10.14 Peat Filter Cross Section



There are a number of different designs available from peat filter suppliers. The peat layer is typically two feet in depth. It is harvested from large natural beds, and then screened for the right consistency. Table 10.10 provides information about the consistency of peat used for research by the University of Minnesota. Proprietary differences in peat typically relate to media coarseness and surface area.

TABLE 10.10 Characterization of Peat Used for U of MN Research Filters

Fiberous Composition	
Sphagnum & Bryopsida	30%
Ligneous (woody)	30%
Herbaceous & rootlets	5%
Charcoal	3%
Detritus	32%
Unrubbed fiber content	69%
Rubbed fiber content	42%
Coarse fiber (8.50–15 mm)	34%
Medium fiber (2.36–8.50 mm)	37%
Fine fiber (< 2.36 mm)	29%
Other Characteristics	
Organic content	88%
Ash content	12%
Von Post º of decomposition	H4
pH (water)	4.4
pH (CaCl)	3.6
Moisture content	60%

Final treatment and dispersal

As with any media filter, the effluent from a peat filter should be followed by a shallow drainfield, at-grade, mound, or drip distribution system, depending upon the site conditions. A peat filter modular systems for a four-bedroom dwelling followed by pressure trenches is shown in Figure 10.15. Some modular peat filters are installed to disperse directly out of the bottom of the peat filter, as show in Figure 10.16. The UMN OSTP does not recommend downsizing soil treatment systems unless a Type I soil loading rate and vertical separation can not be achieved on the available soil and site conditions. It is important to recognize the different loading rates of peat models and the natural soil that must disperse and treat the peat filter effluent. Bottomless peat filters should only be used where site conditions do not allow for a Type I soil treatment system to be installed.

FIGURE 10.15 Peat Filter Schematic

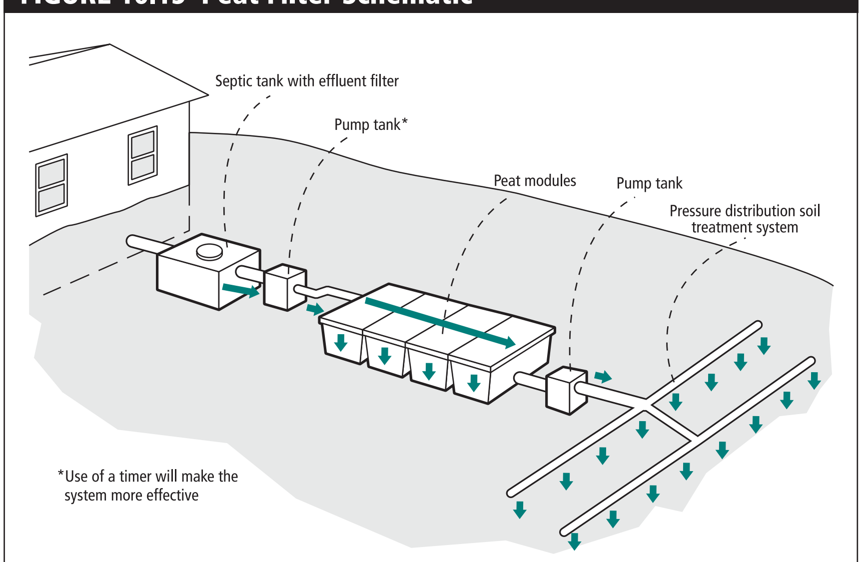
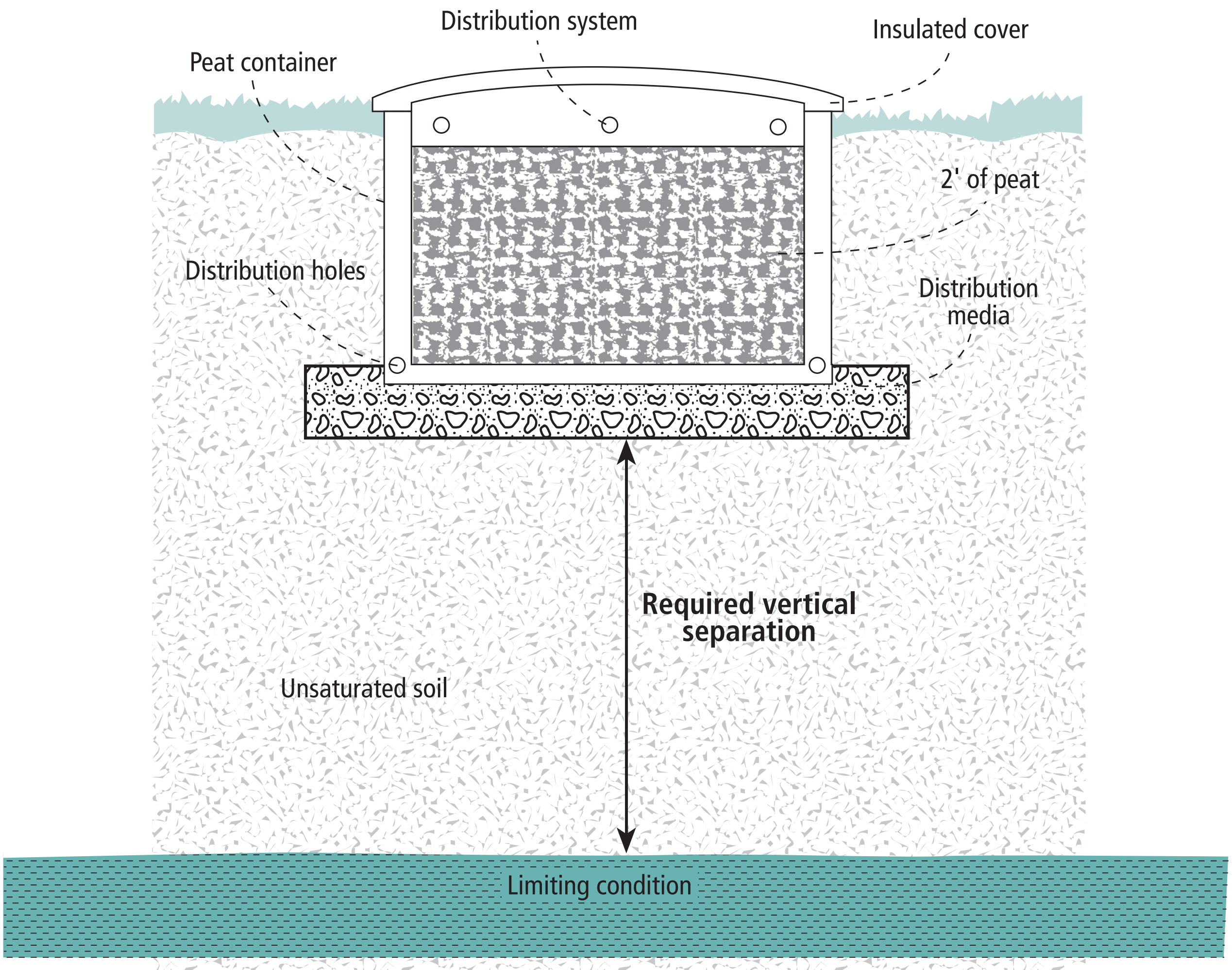


FIGURE 10.16 Bottomless Peat Filter



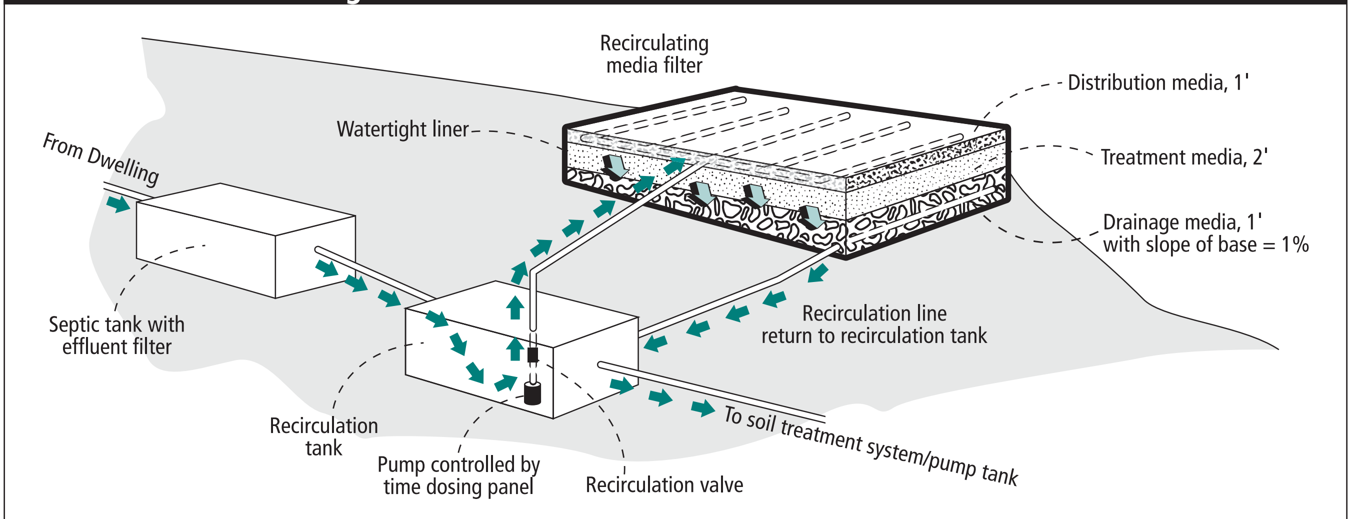
Design

Peat filters are typically designed in single-pass mode. If modules are used they are typically sized at one module per bedroom. The design of peat filters constructed on site is similar to that of SPSFs typically loaded at one gallon per square foot per day.

Recirculating Media Filters

Recirculation entails bringing effluent through a filter a number of times, allowing for continued filtering and increased bacterial decomposition. Effluent moves from the house or building into a septic tank with an effluent screen; in the septic tank, where solids settle out and some organic matter is decomposed. Liquid effluent moves, usually by gravity, to the recirculation tank. Here effluent that has been recirculated through the filter is mixed with septic tank effluent. Effluent is pumped repeatedly through a lined filter and then back by gravity or pump to the recirculation tank as shown in Figure 10.17. In the filter, biological treatment occurs as the effluent passes the surfaces of the filter media. Treated effluent is collected at the bottom and returned to the recirculation tank, where the cycle begins again. After the effluent has cycled through the filter several times, it goes to the soil for final treatment. Depending on the site the soil treatment area could be shallow trenches, a mound, at-grade, or drip distribution. A RMF followed by pressurized trenches is shown in Figure 10.18.

FIGURE 10.17 Recirculating Media Filter



The filter is encompassed in a watertight liner or container. Although the liner can be made from a number of materials, 30 millimeter polyvinyl chloride (PVC) is the most common and probably the most reliable liner material. The filter is usually composed of 12 inches of drainage media. Outflow from the filter is usually provided by a four-inch pipe surrounded by drainfield rock. The depth of the outflow should be from one foot to 18 inches below the bottom of the treatment media. It is critical that the effluent drain freely out of the media since saturated conditions in the filter will reduce its effectiveness. Above the drainage media are the treatment media. This is commonly two feet of coarse sand (0.05 - 2.0 mm in diameter). The top layer is the distribution media, where the pressure distribution system is located. This is commonly drainfield rock. See Figure 10.19.

FIGURE 10.18 Recirculating Media Filter Schematic

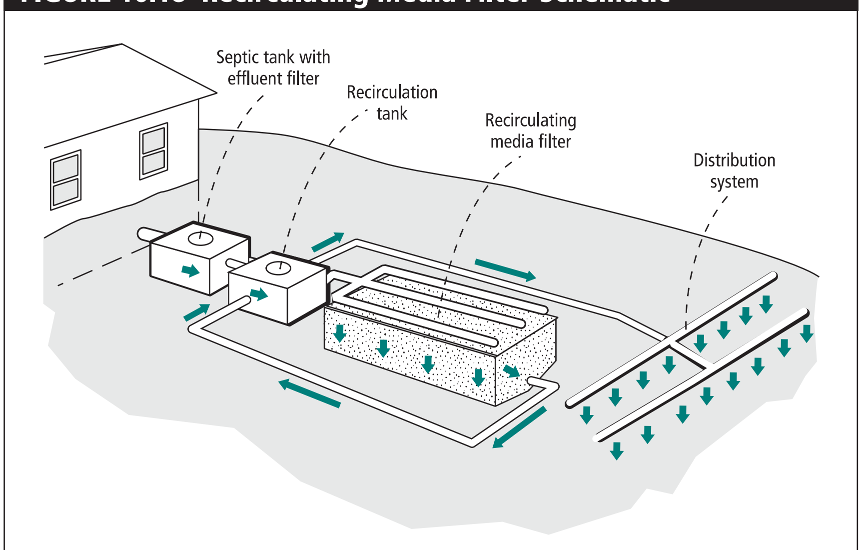
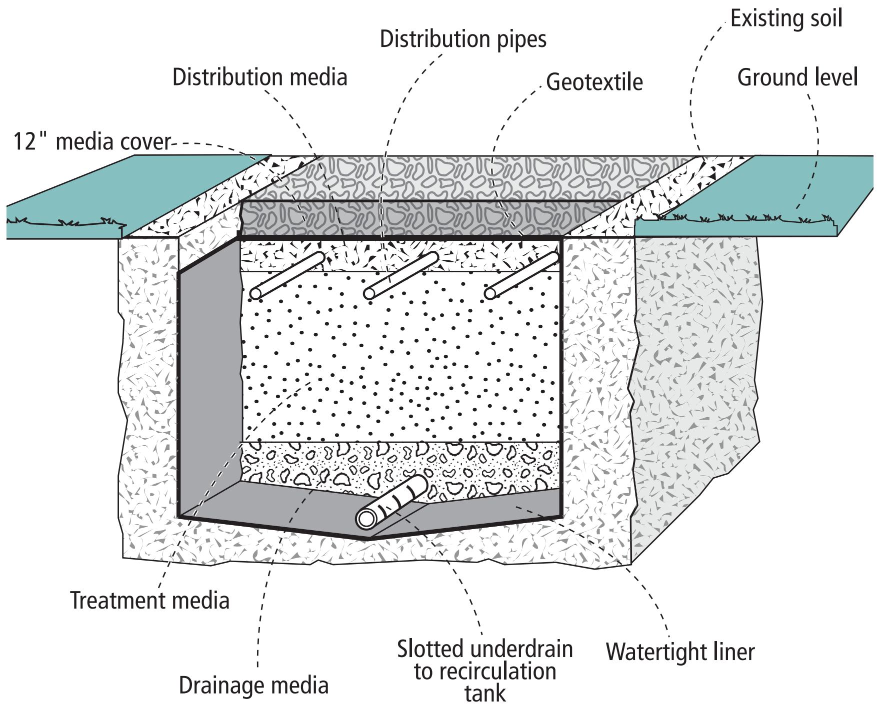


FIGURE 10.19 Recirculation Tank and Pump



When designed, installed, and managed properly, a RMF can achieve the treatment levels shown in Table 10.11. These results are typical for a RMF using sand as the treatment media. The major considerations when designing a RMF are loading, recirculation rate, media, and timer. The loading rate is a variable that describes how much effluent is applied per square foot. In a RMF, the loading rate can range from one to 20 gallons per day per square foot. The most widely used and researched loading rate is four to five gallons per day per square foot (Loudon et al., 2003).

TABLE 10.11 Typical Domestic Strength Septic Tank Effluent and Recirculating Media Filter Effluent *

	BOD (mg/L)	TSS (mg/L)	Nitrate-N (mg/L)	Ammonium-N (mg/L)	DO (mg/L)	Fecal Coliform Org/100 mL
Septic Tank Effluent	130-250	30-130	0-2	25-60	<2	$10^5 – 10^7$
Media Filter Effluent	5-25	5-30	15-30	0-4	3-5	$10^2 - 10^4$

* Total Phosphorus (P) content depends on the type of media used, but over time all media will reach its capacity of P removal

The recirculation rate describes how many times the effluent goes through the filter before being released to the soil treatment area. This rate is generally in the range of two to ten. To achieve acceptable treatment levels is four.

In the recirculation mode, many other medias are utilized that can handle the higher loading rates:

Coarse sand: 0.5 – 2.0 mm sand media constructed on site in a watertight liner

Foam: two to three-inch cubes of open-cell polyurethane foam material that are randomly arranged in prefabricated modular units.

Textile: non-rigid, synthetic material of varying shapes and configurations; typically packaged as prefabricated modular units.

If higher loading rates are necessary, recirculating the effluent is an attractive alternative to the single-pass design.

A RMF uses coarse sand, gravel, peat, or textile as a medium for effluent treatment, along with a septic tank and soil treatment area. Recirculating sand filters (RSFs) have been used since the 1970s for small communities with flows of more than 5,000 gpd, but use with small flow application (less than 1200 gpd) has been growing.

Recirculation systems require coarser media to accommodate higher loading rates; sand used for a single-pass sand filter would be too fine for a recirculating filter. For this reason, RSFs are also called **gravel filters.** A medium of 0.05 to 2.0 mm in diameter, such as bird grit #2, is a better choice. Advanced treatment ideas for recirculation systems include expanded shale, expanded peat media, or textile.

Recirculation systems also require constantly circulating water. Designs for recirculating filters must include a timer to regulate the loading of the system. The loading rate is usually four to five gallons per day per square foot, and the effluent flows through the filter four or five times before leaving the system. This allows a smaller RMF surface area to produce a similar pretreated effluent quality as a larger single-pass filter.

Recirculating Sand Filter Specifications

It is recommended that RSF media meet these criteria:

- Particle size distribution complies with Table 10.9
- Effective particle size: 1.5 - 2.5 mm
- Uniformity coefficient (D60-D10): ≤ 4
- Filter media must be clean

The uniformity coefficient is defined as the ratio of D60 (grain diameter for which 60 percent of the sample by weight is finer) to D10, the effective grain size (grain diameter for which ten percent of the sample by weight is finer).

The following section describes the general process for designing a RSF. See the Single-Pass and Recirculating Sand Filter Worksheet at septic.umn.edu/ssts-professionals/forms-worksheets.

1. Determine the infiltrative surface area.

   The loading rate is calculated on the basis of the BOD of the septic tank effluent. While the maximum septic tank influent BOD for a SSTS receiving only domestic waste is typically 300 mg/L, Washington State guidelines suggest that recirculating gravel filters may satisfactorily treat sewage with a BOD as high as 720 milligram per liter (Washington State, 2000).

   Calculate the loading rate (gallons per day per square foot) by dividing 1,150 by the BOD of the tank effluent. For residential applications, the maximum loading rate is five gpd/ft^2. If the effluent BOD is suspected to be greater than 170 mg/L, the loading rate will be lower. For repairs, alterations, or expansions to existing systems or where effluent BOD is suspected to exceed 170 mg/L, sampling of the septic tank is recommended to obtain reliable information. For new developments, especially for nonresidential development, BOD should be estimated on the basis of the best available comparative information from similar facilities. Determine the required surface area for the sand filter bed by dividing the average daily flow by the loading rate.

2. Select the type of containment vessel to be used. This will affect whether the RMF is above or below ground.
3. Determine the distribution, treatment, and collection methods and materials. The total depth of the filter depends on the media used for each layer.
   a. The top of the RMF may be a fiberglass/plastic cover such as with prefabricated modular units, exposed rock or gravel, or covered with geotextile and six to twelve inches of sandy or loamy cover material.
   b. If gravel is used for the distribution media, the depth will be approximately one foot. This is typically pea gravel or drainfield rock.
   c. The minimum and optimum depth of the filter media is 24 inches.
   d. Select the underdrain methodology and how the effluent will be transmitted back to the recirculating/mixing tank. This will usually be done via a gravity flow from the filter, so it is critical that the elevations of the filter drain and the recirculation tank are evaluated.

      The collection media depth with a gravity underdrain is a minimum of six inches with a gravity underdrain, and is typically one foot. The depth may be increased to provide additional storage volume if filtrate will be pumped from the RMF back to the recirculation tank. The top of the collection media depth should be level.

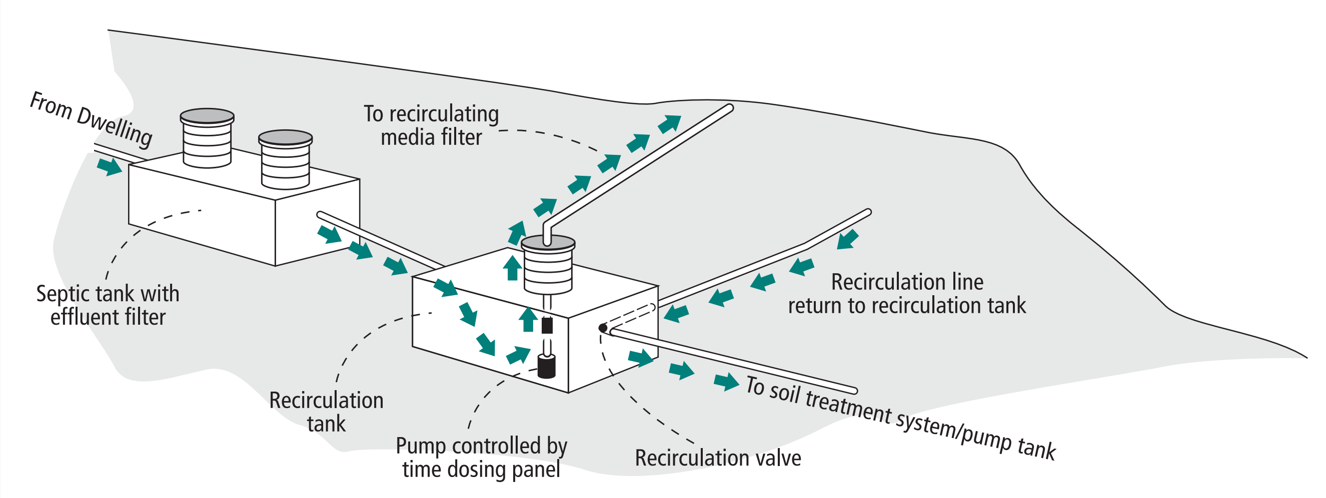
      An underdrain pipe is typically installed at the same level as or an inch or two above the bottom of the filter. In a RSF, this pipe should be a slotted four-inch ASTM 3034 pipe or stronger. The slots should not be directly against the liner and should either be facing 12 o'clock or six o'clock. If facing six o'clock, the slots and pipe should have a few inches of gravel underneath.

The return line returns the effluent back to the recirculation tank and is typically four inches in diameter. For larger flows, larger diameter pipe may be needed.

4. Design pressure distribution system (unless pre-designed by manufacturer). The recommended number of doses per day is at least 48 for ISTS systems and higher for MSTS systems. (See Section 11: Pressure Distribution and Section 9 Pumping Systems.)
5. Size the recirculating tank and pump as shown in Figure 10.20. The recirculation tank is a dosing chamber that doses the filter and receives a combination of septic tank effluent and recirculated effluent. This tank facilitates enhanced nitrogen removal due the combination of anoxic conditions, carbon from the septic tank effluent, and the nitrified RMF effluent. For residential systems, the minimum recommended volume of the recirculating/mixing tank should be 100 percent to 150 percent of the estimated average daily flow. For other establishments, tank volume should be 100 percent of the estimated average daily flow. The recirculating pump should be located at the opposite end of the tank from both the inflow from the septic tank and the return line from the filter. Unless some other recirculating process is used, the tank

will usually contain a buoyant-ball check valve. The elevation of this valve (typically 80 percent of the liquid depth) will control whether effluent flows back into the recirculating/mixing tank or out to the drainfield. The ball must be sufficiently buoyant that it creates a good seal.

FIGURE 10.20 Recirculation Tank and Pump



6. Design the control panel. Doses are controlled by a timer. Floats are wired in parallel with the timer to control the pump during periods of excessive effluent flow and/or in the event of timer malfunction. The recirculation ratio is the proportion of effluent returned to the treatment component compared to the amount of forward flow to the next component of the treatment train. Each unit of effluent is designed to flow through the media filter from three to 20 times before it flows to the dispersal component. This results in a recirculation rate of 3:1 or 5:1 (read as "five to one").

Timer example

1. Based on a 5:1 recirculation ratio, determine the filter flow through: the actual volume of effluent going through the filter each day:

   Flow through = daily design flow (gpd) x 5

   It is more accurate to use peak measured flow for this daily design flow if the goal is to achieve a 5:1 ratio.

2. Assuming 48 cycles/day, determine the gallons per dose, in gallons per cycle:

   Gallons per dose: Flow through (step 1)/ 48 cycles/day

3. Then add in drainback from the media filter:

   Total gallons per dose = gallons per dose (step 3) + drainback

4. Once you know the total dose volume, and the gallons per minute of your pump, you can determine the amount of time the timer needs to run. Assuming 25 gallons per minute:

   Timer on time = Total gallons per dose/ 25 gallons per minute.

5. To determine the time off, take 30 minutes minus the timer on time:

   Timer off time = 30 minutes – timer on time (step 4)

Installation of Media Filters

Flexibility in terms of siting is probably the single biggest advantage of a media filter system. Because the filter is watertight and uses a medium for treatment, the type of soil on which or in which it is constructed is not critical. What is critical is the ability of the system to transfer oxygen, because without adequate oxygen, bacterial action will be seriously compromised. Landscaping rock from the media filter surface to the soil surface can be used to maximize gas exchange/oxygen transfer. The site must be graded to avoid excessive surface runoff being introduced into the system.

Existing soil conditions for media filters are usually not critical; more critical is that the filter site is stable. Additionally, care must be exercised to ensure that seasonal high water tables or surface water does not enter the top of the media filter. Soil and site conditions are critical for the dispersal component following the media filter. There are many options for the soil dispersal system, including trenches, mounds, and drip distribution. Figure 10.8 depicts a SPSF system with pressurized trenches.

Containment Vessels

If a synthetic membrane liner is being used, cover the bottom of the pit with sand to a minimum depth of two inches (which is adequate to protect the liner from puncture) or use a nonwoven, needle-punched synthetic geotextile fabric, in a thickness that will protect the liner. The bedding layer of sand in the bottom of the pit must be graded to provide a sloping liner surface, from the outer edge of the filter toward the point of underdrain collection. The slope should be one inch of fall per foot of run.

The liner should extend vertically to the top of the gravel bed. In areas with high water tables, the liner may extend into a berm above the original grade to prevent water from flowing into the media filter. Refer to Table 10.12 for specifications if a boot is used. Plywood or other wood product can be used to line the excavation, so that the liner can be placed on a vertical surface.

Watertight concrete, plastic or fiberglass tanks/vessels may be used. These watertight vessels must meet all the setbacks of septic tanks.

TABLE 10.12 Using a Boot

If a synthetic membrane liner is used, a boot will be required
The boot outlet is to be bedded in sand.
The boot is to be sized to accommodate a four-inch underdrain outlet pipe.
The boot is to be secured to the four-inch outlet pipe with two stainless steel bands and screws and sealant strips as recommended by the manufacturer.
An inspection port shall be installed at the outlet of the underdrain pipe from the sand filter to the drainfield to facilitate checking if leakage is occurring and injecting air if needed.
The trench from the filter to the drainfield shall be backfilled with a minimum of five lineal feet clay dam to prevent the trench from acting as a conduit for groundwater movement towards the drainfield.
Test the sand filter and boot for leakage: 1. Block the outlet pipe. 2. Fill the underdrain gravel with water. 3. Measure the elevation of the water through the inspection port. 4. Let the water stand for a minimum of 24 hours. 5. Measure the elevation of the water through the inspection port. There must not have been any drop in the water level.

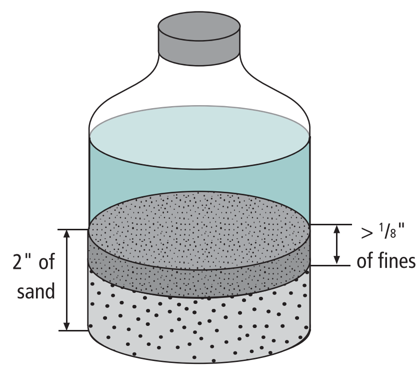
An important part of the design package is the construction plan. It contains specific instruction to the installer to help assure quality installation. In addition to step-by-step installation instruction, the construction plan should include the following:

- Routes of entrance and exit of construction vehicles
- Identification of reserve area and instructions to stay away from it
- Instructions as to when the system can be constructed in terms of time of year, moisture content
- Instructions for proper grading, diking, ditching, and subsurface drainage
- Instructions for fencing the dispersal component and reserve areas if they are located in areas where vehicular, livestock, or pedestrian traffic could cause problems
- Instructions for cleaning

For sand filters, clean sand should be verified using the jar test:

1. Place exactly two inches of sand in the bottom of a quart jar and then fill the jar three-fourths full of water.
2. Cover the jar and shake the contents vigorously.
3. Allow the jar to stand for 30 minutes and observe whether there is a layer of silt or clay on top of the sand.
4. If the layer of these fine particles is more than 1/16 inch thick, the sand is probably not suitable for use. Too many fine particles tend to cause the soil to compact during the construction process. Also, the long-term acceptance rate of this soil will be slower than the long-term acceptance rate of clean sand, which is used for sizing sand filters. See Figure 10.21. Sand uniformity is not confirmed through the jar test, and further material testing may be necessary.

FIGURE 10.21 Jar Test



If the fines that settle out in 30 minutes accumulate to a depth of greater than 1/8", then the percentage of fines is too great and the sand **should not** be used for mound or sand filter construction.

Media Filter System Management

All of the routine operation and maintenance practices suggested for any SSTS apply to media filters (Consult the Septic System Owner's Guide, Item # 06583, for details.) Media filters require more maintenance than a conventional SSTS does. Whether quarterly to annual maintenance is required depends on the local governmental unit and manufacturer. Maintenance includes inspecting all components: septic and dosing chambers flow recording devices, pumps, distribution, media, and effluent quality, and cleaning and repairing when needed. A visual inspection of the effluent is always done as a regular maintenance task, and often a laboratory analysis of effluent is required. A flow meter, event counter, or running time clock timer are required to be installed and periodically checked to assure the appropriate amount of effluent is being applied to the filter and soil treatment system. A maintenance contract is strongly recommended.

Over time, the upper layer of the media may become plugged with solids or build up of organic matter. If this occurs, the upper layer may be cleaned or removed and replaced with new media. Adding an air supply to the system may minimize this aspect of operation. With peat filters, the peat media will break down over time and will need replacement within seven and 15 years, depending on the type of peat and how frequently the system is used. The spray heights on the pressure distribution system should be inspected to assure that even distribution is continually achieved over time.

For the SSTS to operate properly, its various components need periodic inspection and maintenance. Maintenance is typically the responsibility of the homeowner, but is best performed by an experienced and qualified service provider. During a service visit, the management plan tasks should be implemented.

Management plan

All the routine operation and maintenance practices suggested for any onsite treatment system apply to a media filter. (Consult the Septic System Owner's Guide, PC-6583, for details.)

The system design will also include the management plan, which should include specific instructions to the system owner. The OSTP website contains a number of product-specific and public domain filter Management Plans. The management plan should contain:

- Diagrams of the system components and their locations
- Explanation of general system function, operational expectations, and owner responsibilities
- Specifications of all electrical and mechanical components installed
- Names and telephone numbers of the system designer, LGU, component manufacturer, supplier/installer, and the management entity to be contacted in the event of a failure
- Information on the periodic maintenance requirements of the sewage system's components: septic tank, dosing and recirculating/mixing tanks, media filter unit, pumps, switches, alarms, and dispersal unit
- Information on the final landscaping of the site, including limitation of future plantings and identification of activities that can not occur around the system and reserve area
- For proprietary media filter devices, a complete maintenance and operation document should be developed and provided by the manufacturer and made available to the system owner. A copy of this document should also be provided to the local health authority, prior to the issuance of the local installation permit.

It is recommended that the following are evaluated during maintenance visits:

1. Age of system: describe concerns about pump calibration and parts that may need replacement due to wear.
2. Nuisance factors: describe possible factors, such as odors or user complaints.
3. Septic tank: inspect yearly for structural integrity, proper baffling, screen, groundwater intrusion, and proper sizing. Inspect and clean effluent baffle screen and dosing chamber as needed.
4. Dosing and recirculating/mixing tanks: rinse the effluent screen (spray with hose), and inspect and clean the pump switches and floats yearly. Pump the accumulated sludge from the bottom of the dosing chamber, whenever the septic tank is pumped.
5. Pumpwell: inspect for infiltration, structural problems, and improper sizing. Check for pump malfunctions, including problems related to dosing volume, pressurization, breakdown, clogging, burnout, or cycling. Pump the accumulated

sludge from the bottom of the pumpwell whenever the septic tank is pumped, or every three years, whichever is sooner.

6. Check monitoring ports for ponding. Unless the filter has just been dosed, ponding in a media filter is indication of a problem and should be further evaluated.
7. Inspect distribution system and flush and clean laterals as needed.
8. Annually inspect and test for malfunctions in the electrical equipment such as timers, counters, control boxes, pump switches, floats, alarm system or other electrical components, and repair as needed. System checks should include improper settings or failures of electrical, mechanical, or manual switches.
9. Pump and pump screen: inspect yearly and clean as needed.
10. Mechanical malfunctions (other than those affecting sewage pumps) including problems with valves or other mechanical plumbing components.
11. Material fatigue, failure, corrosion problems, or use of improper materials, as related to construction or structural design.
12. Neglect or improper use, such as loading beyond the design rate, poor maintenance, or excessive weed growth.
13. Installation problems, such as improper location or failure to follow design.
14. Overflow or backup problems where sewage is involved.
15. Exposed-surface media bed: weed and remove debris from the bed surface.
16. Specific chemical/biological indicators, such as BOD, TSS, and/or fecal coliform bacteria sampling and testing, may be required by the LGU.

Operation Costs of Media Filters

The running costs for a media filter are all based on running times for the small submersible pump, which for an individual home will be less than five dollars per month. Overall operational cost will run $200 to $500 per year for a single family residence, including pumping, repairs, maintenance, and electricity.

Abandonment of Media Filters

Whenever used media is removed from a media filter, removal and dispersal of the contaminated media must to be done in a manner approved by the LGU. This material should be handled carefully, using adequate protective sanitation measures. This material may be applied to the soil, according to Table 10.13, only when approved by the LGU.

TABLE 10.13 Land Application Timetable for Used Filter Media

Crops	Restrictions
Low-growing vegetables, root crops, fruits, and berries used for human consumption.	Contaminated material must be stabilized and applied 12 months prior to planting.
Forage and pasture crops for consumption by dairy cattle.	Crops not available until one month following application of stabilized material.
Forage and pasture crops for consumption by livestock other than dairy cattle.	Crops not available until two weeks following application of stabilized material.
Orchards or other agricultural areas where the media will not directly contact food products, or where stabilized material has undergone further treatment, such as pathogen reduction of sterilization.	Less severe restrictions may be applicable.

Troubleshooting Media Filters

There are numerous reasons why a media filter may experience operational issues. See Table 10.14 for some of the more common challenges and potential causes.

TABLE 10.14 Common Challenges and Potential Causes

Challenge	Possible Cause
Experience slow flush in home but electronics are in good working order	■ Unacceptable level of solids in septic tank ■ Effluent screen blocked
Treatment below design goals	■ System hydraulically or organically overloaded ■ Recirculation device or timer improperly adjusted ■ Poor installation including leaky components ■ Distribution piping needs cleaning ■ Chemicals have killed the system
Effluent ponding on surface	■ Media clogged ■ Media at end of useful life ■ Underdrain piping clogged or not operating properly ■ Soil treatment system not operating properly
Effluent screen clogging frequently	■ Homeowner is not controlling inputs correctly, including using chemicals that may have killed the system ■ Septic tank needs cleaning or is too small
Production of odor	■ Media filter experiencing a disruption ■ Anaerobic conditions exist ■ Media cell flooded ■ Lids not gastight ■ Roof vent odor could be confused with filter odor ■ System not maintained correctly
System aesthetics poor	■ Landscaping not finished properly ■ Rodents burrowing ■ Landscaping not maintained causing erosion or accumulation of weed growth
Pump not operating properly- alarm condition	■ Control and electrical problems ■ Float switch or timer incorrectly set ■ Incorrect or low voltage ■ Pump mechanical problems ■ Defective electrical components ■ Debris on or under float switch ■ Panel fuses and breakers tripped
Pump operates but delivers little or no water	■ Media filter clogged ■ Clogged pipe or perforations ■ Timer set incorrectly ■ Increased pipe friction ■ Shut off valve closed ■ Low or incorrect voltage ■ Discharge head exceeds pump capacity ■ Clogged or worn out pump

Compliance Inspections for Media Filters

The monitoring or management plan for media filters must be evaluated before physically inspecting the system to determine the system performance requirements. If the unit does not meet these requirements, the unit is determined to be in non-compliance and the LGU needs to work with the system owner, designer, and service provider to determine what steps are required to bring the system back into compliance.

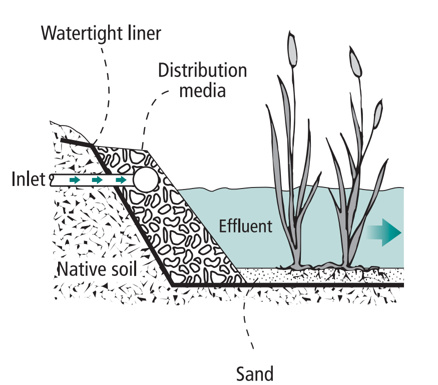
Constructed Wetland Systems

Definition and Description

A constructed wetland (CW) system treats effluent by the processes of filtering, settling, and bacterial decomposition in a large, lined, constructed wetland cell. As effluent moves through the CW system, the solids are removed through physical filtering and settling. The organic matter is broken down by bacteria, both aerobically, with the oxygen supplied through diffusion from the air or by plants, and anaerobically. A majority of the treatment occurs under anaerobic conditions. Historically, CWs have been used world-wide for over 30 years, in both warm and cold climates. In Minnesota, constructed wetlands are being used to treat effluent from both residential and commercial establishments. As of the publication of this manual, no constructed wetlands have been registered for use, which means that all CWs are considered Type V systems that must be designed by a PE and Advanced Designer.

Types of Constructed Wetland Systems

FIGURE 10.22 Open Water Constructed Wetland

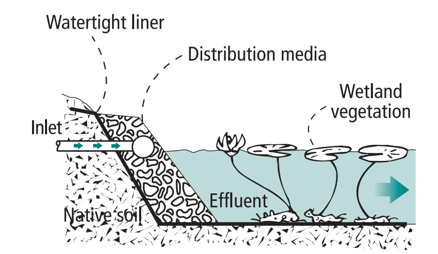


Open water

Three wetland designs are common: open water, hydroponic, and subsurface flow.

Open water systems as shown in Figure 10.22 often look like ponds. Wetland plants grow from the bottom, and the water moves through the system at its surface. Because the water is fairly deep, the surface area required for this design is the smallest of the varying types of CWs. Water evaporates off of the surface and oxygen from the air is dissolved in the water, so bacteria can break down the effluent aerobically. Unwanted plants and animals, including insects, can take up residence in an open-water constructed wetland. These systems should be fenced to prevent people from coming in contact with the effluent and the pathogens it is likely to contain. These systems are not common in Minnesota because biological decomposition rates are temperature dependent, decreasing in direct proportion with water temperature.

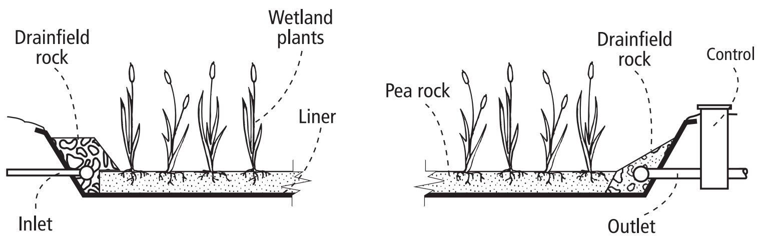
FIGURE 10.23 Hydroponic Constructed Wetland



Hydroponic

Hydroponic systems are shallow, with most of the water flowing in the root zone of the plants as depicted in Figure 10.23. In these systems, as in open water systems, water evaporates off the surface allowing oxygen to become available in addition to what the plants produce. The plants tend to take up nutrients from the water more efficiently in hydroponic systems than in open water systems. These systems are very shallow, however, so their surface area has to be much larger than that of open water designs, and they are more likely to freeze in winter. Fencing to prevent human contact with effluent is essential in these systems as well. These systems are not common in Minnesota.

FIGURE 10.24 Subsurface Flow Constructed Wetland



Subsurface flow

Subsurface flow (SSF) systems are the type recommended for use in Minnesota. They are constructed so all effluent moves through a media (such as pea rock) in which the plants grow. All the effluent flow occurs below the surface of the media and does not pond on the surface. Because there is no free water surface, SSF systems are less likely to freeze during the winter than either open water or hydroponic systems. These systems typically require more space than open water systems, but less space than hydroponic systems. The material and installation costs for SSF CW are typically higher than for the other two types. A subsurface flow wetland is shown in Figure 10.24.

Treatment Processes

A CW system treats effluent by a variety of physical, chemical, and biological processes that also occur in natural marshes. As effluent moves through the wetland, solids are removed by vegetative uptake and through physical filtration, settling, and decomposition. Organic matter (measured as BOD) is reduced as it is consumed by bacteria and other microbes (biodegradation), both aerobically (in the presence of oxygen supplied by the atmosphere and by plants growing in the wetland) and anaerobically (no oxygen present).

Nutrients that may cause eutrophication, such as phosphorus and nitrogen, may also be reduced. Phosphorus removal is largely due to chemical adsorption (essentially an ion exchange) to plant litter and to the gravel substrate. Iron-rich materials are particularly good for P-removal. Nitrogen removal, on the other hand, is much more complicated. It begins as bacteria decompose proteins and other forms of organic nitrogen to ammonium. This ammonium can then be converted to nitrate by certain aerobic bacteria via a process called nitrification. In a constructed wetland, nitrification is accomplished by oxygen diffusing from the atmosphere (if there is open water) or by certain wetland plants. Cattails, reeds, bulrushes, wild rice, pickerel weed, arrowhead, and many other species survive being submerged by actually pumping oxygen down to the roots. Excellent N-removal can be obtained by allowing the nitrified (high nitrate) water to become anaerobic again. This facilitates the growth of denitrifying bacteria that convert the nitrate to nitrogen gas (N2), which makes up almost 80% of the air we breathe. The root zone, therefore, provides an excellent habitat for the diverse groups of aerobic and anaerobic bacteria that are needed to treat effluent. Although the plants do take up some of the nutrients in the effluent, including nitrogen and phosphorus, this is typically a small fraction of the total effluent load reduction.

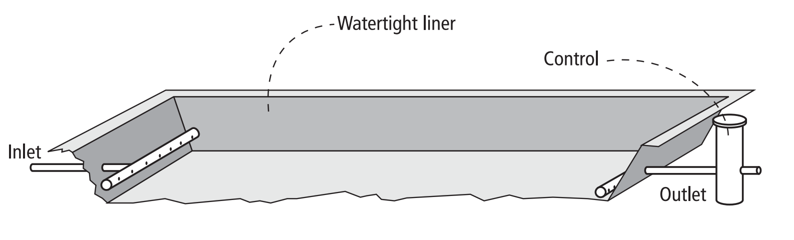
Treatment processes are both aerobic, with oxygen being supplied by plant root systems, and anaerobic at microsites within the pea rock media where there is no dissolved oxygen. Anaerobic decomposition reduces nitrogen levels in the discharge. This double aerobic-anaerobic action also allows for excellent removal of bacteria and phosphorus if adequate time is provided for effluent to move through the system.

Design

A septic tank is the first component of any CW system. An effluent screen with an alarm is recommended to further reduce suspended solids and protect downstream components. Timed dosing of the wetland is also recommended; this allows treatment to be maximized by controlling the inflow and flow through the system by periodically delivering doses of effluent. This requires a dosing chamber and pump in the system prior to the installation of the CW.

The CW itself has four main parts: an impermeable liner, media, wetland plants, and an effluent-level control structure. The impermeable liner prevents effluent from prematurely seeping out of the wetland and groundwater from entering the wetland. Although the liner can be fabricated from various materials, 30-mil PVC is common. Clay liners can crack, allowing the effluent to move into the soil and contaminate groundwater, so they are not recommended. The liner and controls are shown in Figure 10.25.

FIGURE 10.25 Constructed Wetland Liner



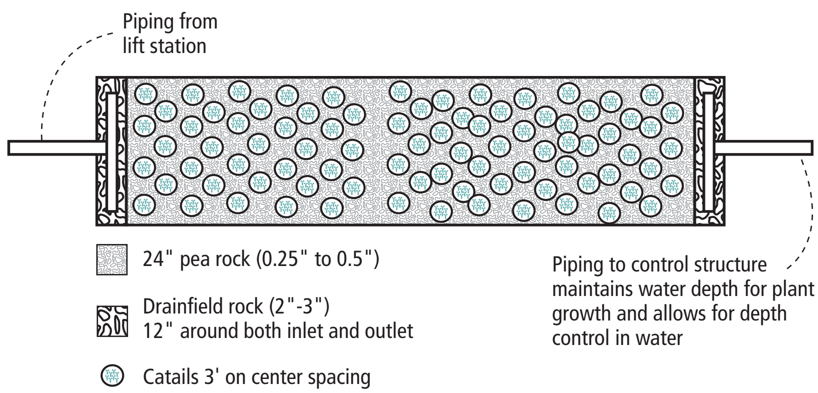
The second component of the wetland, the media, is composed of distribution, treatment, and collection media. The distribution media are typically two- to three-inch rock and are located at the inlet of the wetland, where effluent enters from a septic tank. The piping that carries sewage into the wetland is buried with this coarse rock of the media so that the incoming effluent is spread across the width of the wetland. Both gravity and pressure distribution can evenly spread the effluent over the system, allowing the effluent to flow evenly through the length of the system. Vegetation is rooted in the treatment media. Sized pea rock (sized 1/4 to 1/2 inch) is typically used to a depth of 18 to 24 inches. The depth is a tradeoff: it must be shallow enough for the roots to extend to the bottom of the bed yet provide sufficient volume to prevent problems related to freezing. The surface of the pea rock is raked level to ensure that plant roots can reach the effluent below the surface. The collection media, typically drainfield rock, move the treated effluent out of the wetland. Some wetland designs place tubing similar to that used for drip distribution in the bottom of the wetland. This tubing can then be hooked up to a blower, which bubbles air and provides oxygen to the wetland.

The third part of the CW system is the vegetation. Wetland plants are planted directly to the pea rock (or in a mulch layer spread over the pea rock) at the surface of the media with cattails, bulrushes, reeds, and other water-loving plants. An important function of wetland plants is to transport oxygen through their root systems into the wetland, supplying oxygen to bacteria that grow on plant roots; these bacteria improve the decomposition of organic matter and convert ammonium to nitrate. The wetland vegetation that dies off in the fall will serve as a natural insulating blanket, providing some insulation to prevent the wetland from freezing during the winter months by functioning as a snow fence to accumulate an insulating blanket of snow. Harvesting the vegetation removes phosphorus from the system.

The control structure is the last component of the wetland, where effluent flows out of the wetland and typically into a dosing chamber, which delivers the effluent to SSTS. The control structure regulates the depth of the effluent in the wetland and is typically set to maintain the effluent one to two inches below the top of the bed. It should also provide for flow measurement and sampling.

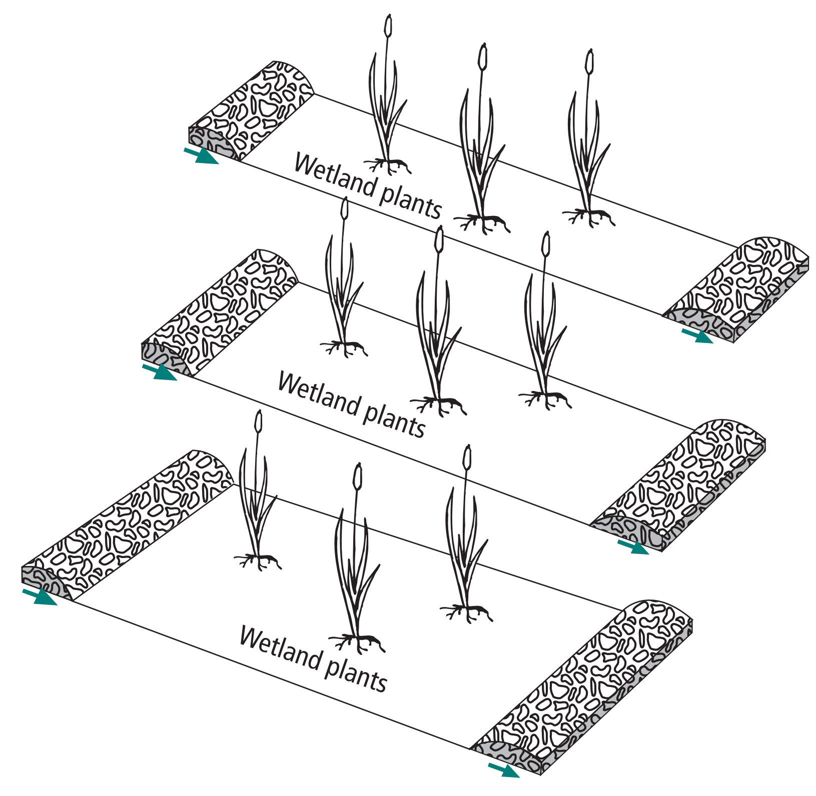
The size of the system is based on the volume of wastewater remaining in the wetland for ten to 13 days. The more time the effluent spends in the wetland, the more treatment will occur. A design example of SSF CW is shown in Figure 10.26. Some designs include the addition of air into the wetland to provide oxygen and reduce the size. An aerated system out performed the conventional SSF systems in terms of organic and ammonia removal (Lockart, 1999). For SSF systems, the space occupied by the rock medium must be included in calculations for the system size; a 40 percent porosity ratio takes the rock volume into account, increasing the system volume necessary for adequate retention time. The shape of the system is not critical except that it should prevent effluent from flowing too quickly through the system. The typical shape is rectangular with a length-to-width ratio of not less than 2:1. A high ratio can short-circuit the CW, while too low a ratio (greater length than width) can lead to uneven distribution of effluent down the length of the bed. See Figure 10.27.

FIGURE 10.26 Constructed Wetland Schematic



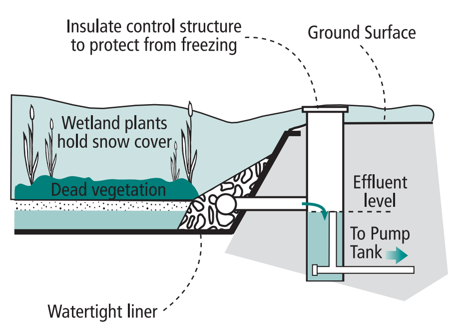
Surface area: 600 sqft, calculated as:
13 days x 40 cuft ÷ day ÷ 2 depth ÷ 40% porosity
Dimensions: 16' x 60' Liner: 30 mil PVC
BOD loading 0.2 pounds per day

FIGURE 10.27 Constructed Wetland Dimensions



A CW system is designed to run level, so the system should be located on the contour. Surface water inflow can cause overloading problems, so drainage should be directed away from the system. A barrier to soil erosion into the wetland, such as rock landscaping or sod, is needed to minimize sediment problems. The discharge of effluent pollutants can be greatly reduced by the evapotranspiration of water during warm periods; in fact, the effluent may be reduced to a trickle for most of the day. Conversely, rainstorms and snowmelt can flush higher than average volumes out of the system. To reduce the inevitable impact of climate, the excavation walls should be as vertical as possible to minimize rainwater collection.

FIGURE 10.28 Insulated Controls



The CW may be covered with a thin layer of mulch to assist in rooting the vegetation and protecting the system from freezing. The depth of cover should be limited to six inches as a deep cover will reduce oxygen transfer into the wetland. It is important to insulate the control structure (with vegetation as mentioned above, for instance) to avoid freezing problems. See Figure 10.28.

Performance

A healthy stand of wetland vegetation is one of the most important factors that influence the overall performance of constructed wetlands. The best time to plant is in the spring or early summer. It will probably take three years for plants like cattails and bulrushes to become fully established. Plants may be purchased from a number of regional nurseries or harvested locally after a permit is obtained from the county or DNR. To maximize performance, the stems should be cut back to about six inches and the root-rhizome planted in a scooped out hole. About one plant per one to three square feet is reasonable, and by the end of the first growing season the plants will likely have sent out subsurface runners that will sprout new shoots. Therefore, constructed wetlands in Minnesota do not achieve their most efficient performance until the third growing season.

The best performance of CWs occurs during the growing season (about May through September in Minnesota), with decreased performance during winter. Secondary treatment standards for the removal of solids (TSS) and organic matter (BOD) were achieved for most periods of time. BOD removal efficiency may average about 80% in winter and about 90-95% in summer. Fecal Coliform bacteria (indicators of disease-causing organisms) are generally reduced by 96-99% in winter to >99% percent during the snow-free season. CWs also remove nitrogen and phosphorus with efficiencies of about 25 - 30% in winter and 65-80% in summer. CWs is a viable, year-round onsite wastewater treatment option in Minnesota based on their performance at three research sites encompassing five subsurface flow wetlands from 1995-2000. These were small flow (<1000 gpd) subsurface flow gravel beds located at the NERCC, Grand Lake, and Lake Washington, MN. The systems were generally able to achieve design criteria of 30 mg BOD5/L, 25 mg TSS/L and 200 fecal cfu/100mL, although the NERCC CWs required 30 cm. of unsaturated soil to achieve consistent disinfection. High strength (~300 mg BOD/L and 100 mg TN/L) influent at NERCC probably limited system performance, particularly N-removal, which was ~40% in summer and ~20% in winter (mass-based). Declining P-removal at the oldest sites suggest substrate saturation. Although CWs remain a viable option for homeowners in terms of performance, ease of operation, and cost, performance may be affected by inconsistent vegetation growth (which affects freezing). In addition, the substantial variability of rain events, partial freezing, spring snowmelt, and summer evapotranspiration may complicate consistent attainment of concentration-based regulatory standards (Henneck et al., 2001).

Applications

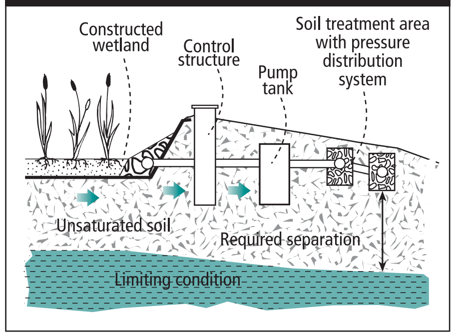
Since effluent leaves a constructed wetland pretreated, the soil in the trench or mound SSTS may be better able to accept the effluent, and the system should last longer. SSTSs receiving pretreated effluent can be downsized if they are on the MPCA registered product list. The UMN OSTP does not recommend downsizing soil treatment systems unless a Type I soil loading rate and vertical separation can not be achieved with the available soil and site conditions. Even though additional pretreatment of the septic tank effluent can be achieved with a media filter, the soil treatment system should be located in the most suitable, natural soil conditions to promote overall system longevity.

Lined SSF CW, can be placed on locations on a property that have been compacted, cut, or filled in as the natural soil conditions under lined wetlands is not critical as long as the site is level and uniformly packed.

Final Dispersal of Effluent

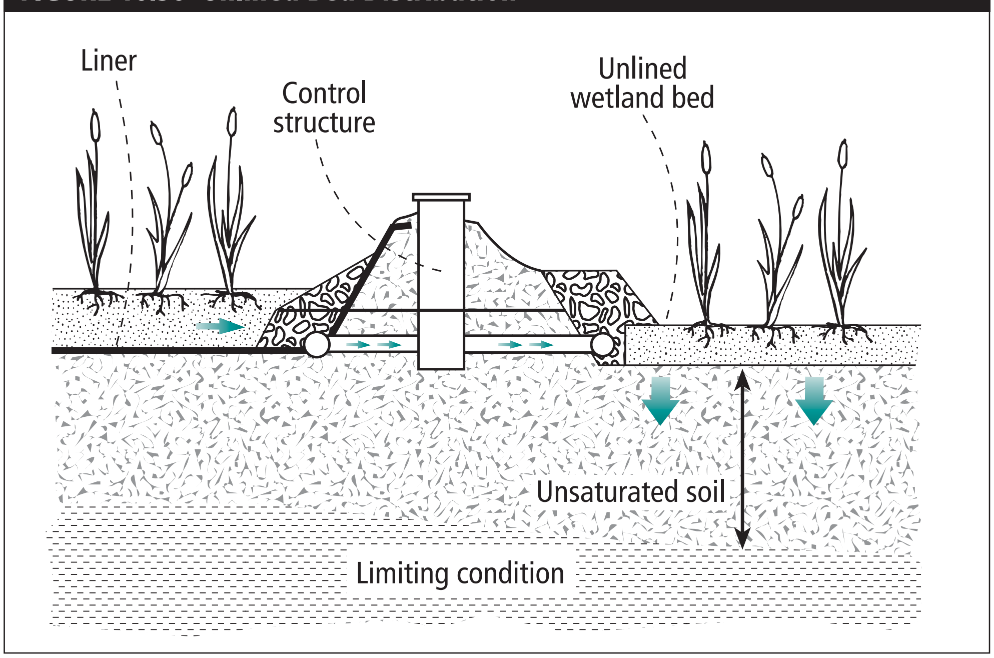
Effluent from the CW system is dispersed into the soil for final treatment. Depending on specific site conditions, there are several options for the final treatment and dispersal of wetland effluent into the soil. In an unlined wetland, a pressure distribution system is an option. Shallow trenches, drip distribution, an at-grade system, and a mound system are other options for various site conditions. A SSF CW to pressurized trenches is shown in Figure 10.29.

FIGURE 10.29 Pressurized Trench Distribution



SSTSs with less than three feet of separation below the soil treatment system are allowed in Minnesota if the LGU allows Type IV and Type V systems. UMN OSTP does not recommend downsizing soil treatment systems unless a Type I soil loading rate and vertical separation can not be achieved on the available soil and site conditions. An unlined wetland bed is also a possibility, as shown in Figure 10.30. In this case, the final cell of the wetland is unlined, and the treated effluent is allowed to pass into the soil. This is only an option if there is sufficient separation from the bottom of distribution media to the limiting condition below the wetland.

FIGURE 10.30 Unlined Bed Distribution



Installation

The hydraulic performance of constructed wetlands can be significantly influenced by improper construction activities. Initial excavation and grading must be carefully controlled to avoid low spots and preferential flow down one side of the cell or erratic cross flow within the cell. Past experience has shown that even with careful initial grading, the cell profile can be disrupted by uncontrolled truck traffic bringing the gravel or rock media to the bed. Construction vehicle access to the cell should be limited during wet conditions. It is suggested that the native soils at the bottom of the wetland cell be compacted to provide a uniform bottom surface. The liner goes on top of the compacted soil, and the bed media is placed on top of the liner. A layer of sand is suggested to prevent puncture of the liner.

The media type and size is critical to the successful performance of the system. Unwashed crushed stone has been used on a large number of projects; however, during delivery of this material, the fines may become segregated, so when the load is dumped, the fines will be deposited in a single spot. This can result in numerous small blockages in the flow path and internal short circuiting within the system. Because of these complications, washed stone or gravel is preferred. Coarse aggregates for concrete construction are commonly available throughout the U.S. and are suitable for use in the construction of wetland systems.

The vegetation on most of the existing SSF CW systems has been planted by hand, with the initial spacing ranging from one to three feet. The use of locally available individual root/rhizome material with a growing shoot at least eight inches in length is recommended. The root/rhizome material should be placed in the media at a depth equal to the expected operational effluent level. The growing shoot should project above the surface of the media. If mature plants are used, they can be separated into individual root/rhizome/shoot units with the stems cut back to be shorter than one foot before planting.

The effluent level in the bed should be maintained slightly above the media surface during planting and for several weeks thereafter to suppress weed development and promote growth of the planted species. Effluent applications can commence soon after planting if growth is observed. An early spring planting is preferred whenever possible. The plants, and therefore, system performance , may not begin to reach maturity and equilibrium for nitrogen removal until late in the second growing season.

Troubleshooting

There are challenges occasionally experienced with constructed wetlands. Common challenges are described in Table 10.15.

TABLE 10.15 Common Challenges and Causes in Constructed Wetlands

Challenge	Possible Cause
Sewage backs up into home	■ Excess water into system ■ Improper design ■ Roots clogging pipes ■ Improper operation or blockage in plumbing
Sewage overflow in wetland (See Figure 10.31)	■ Excess water use ■ System blockage ■ Improper system elevations ■ Undersized wetland bed ■ Pump failure
Treatment below design goals	■ System hydraulically or organically overloaded ■ Recirculation device or timer improperly adjusted ■ Poor installation including leaky components ■ Distribution piping needs cleaning ■ Chemicals have killed the system
Vegetations not healthy (see Figure 10.32)	■ Lack of effluent ■ Plugged media ■ Toxics ■ Lack of nutrients ■ Weeds
Sewage odors near wetland	■ Wetland not providing proper treatment ■ Overflow of sewage in wetland ■ Lids not gastight ■ Roof vent odor could be confused with filter ■ System not maintained correctly
Dosing chamber alarm	■ Pump failure ■ fuse break tripped ■ Excess water use ■ Controls malfunction
Freezing of wetland	■ Lack of cover material ■ Lack of flow into system ■ Control structure and other sensitive locations not insulated

FIGURE 10.31 Excessive Flow

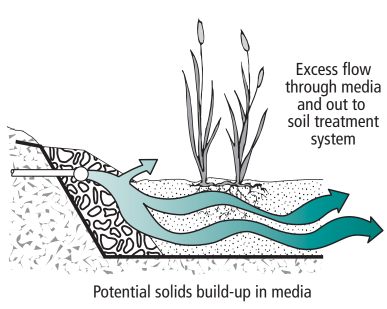
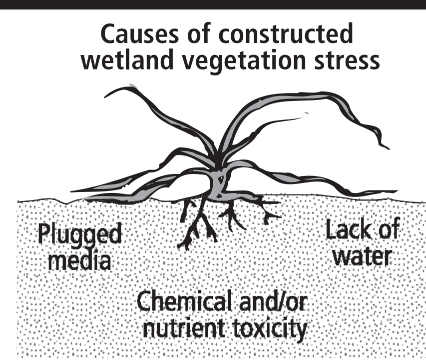


FIGURE 10.32 Wetland Plant Stress



Management Plan

There are several issues beyond those associated with typical SSTSs that should be covered in the management plan.

1. Effluent levels

Periodic regulation of the control structure may be needed to ensure that ponding of effluent at the surface does not occur. Effluent flow to the wetland should be monitored using a water meter, pump run time, or event counters on a pump. Periods of time without sufficient flow may cause the system to dry up or freeze. Conversely, excessive effluent flows from the home, leaky septic tanks, heavy rains, and rapid snowmelt may lead to long-term reduction in treatment efficiency.

2. Vegetation

Several times throughout the growing season, the wetland must be weeded for invasive species, weeds, and small brush and trees. Without this weeding, the proper vegetation will not be established or maintained. It may be necessary to replant the appropriate, vegetation depending on the initial success of and stress on the vegetation. Dead vegetation should be removed when it gets thicker than two inches in depth to remove phosphorus from the system and promote oxygen transfer.

3. Effluent quality

Influent quality can affect the system. Toxic chemicals can harm or kill plants and bacteria in the wetland. In commercial applications, plugging of the media by excess solids, undecomposed organic matter, and/or grease is a concern.

4. Air supply

If an air supply is provided to the wetland, it should be alarmed to indicate failure and checked twice per year to assure performance.

5. Control of nuisance pests and insects.

The primary concern in Minnesota constructed wetlands is burrowing animals. Burrowing animals use the wetland's vegetation for food and nesting materials, which can seriously damage the vegetation system. Control measures include raising and lowering the operating effluent level, and live trapping, and, if necessary, eliminating the animals. An inspection of any pest-related symptoms should be conducted annually.

6. Maintenance of berms and dikes.

This activity includes the routine maintenance of berms and dikes: mowing, controlling erosion, and inspecting for damage from burrowing rodents. Periodic removal of trees may be necessary.

Winter Operation

Unlike most systems, constructed wetlands must be winter-proofed in the fall. This includes insulating the piping systems, allowing ice to form, and then lowering the effluent depth by as much as six inches. The space between the ice and the effluent is an insulating barrier, maintaining a higher temperature in the wetland and ensuring system operation through the winter. Mulch or cover may also be added over the wetland for additional insulation.

Compliance Inspections

The monitoring or management plan for constructed wetlands must be evaluated before physically inspecting the system to determine the required system performance requirements. If the system does not meet these requirements, it is in non-compliance, and the LGU needs to work with the system owner, designer, and service provider to determine what steps are required to bring the system back into compliance.

Abandonment

Whenever used media is removed from a wetland or other media filter, removal and dispersal of the contaminated media must be done in a manner approved by the LGU. This material should be handled carefully, using adequate protective and sanitation measures. This material may be applied to the soil, according to Table 10.16, only when approved by the LGU.

TABLE 10.16 Land Application Timetable for Used Filter Media

Crops	Restrictions
Low-growing vegetables, root crops, fruits, and berries used for human consumption.	Contaminated material must be stabilized and applied 12 months prior to planting.
Forage and pasture crops for consumption by dairy cattle.	Crops not available until one month following application of stabilized material.
Forage and pasture crops for consumption by livestock other than dairy cattle.	Crops not available until two weeks following application of stabilized material.
Orchards or other agricultural areas where the media will not directly contact food products, or where stabilized material has undergone further treatment, such as aspathogen reduction or sterilization.	Less severe restrictions may be applicable.

Final Treatment and Dispersal of Effluent After Pretreatment Units

ATUs, media filters, and CW systems have the potential to produce effluent with lower contaminant concentrations compared to the effluent produced by a septic tank, but the effluent must be dispersed into a SSTS for final treatment. Pretreatment units can be:

1. Added to a Type I SSTS to increase the system's life expectancy
2. Used as part of a Type IV system along with a registered pretreatment unit
3. Used as part of a Type V system if the pretreatment unit is not registered

Type IV systems are allowed to have reduced vertical separation and sizing. The UMN OSTP does not recommend downsizing soil treatment systems unless a Type I soil loading rate and vertical separation can not be achieved based on the available soil and site conditions. Type IV and Type V systems must be operated under an operating permit and include flow measurement.

Sending this pretreated effluent through a SSTS adds to safety concerns. Uniform and pressurized distribution to the SSTS is required since the effluent from pretreatment units contains very little organic matter. **Uniform distribution is defined as a method that distributes effluent evenly over the entire absorption area of a component over**

both space and time (MN Rules Chapter 7080.1100, Subp. 89a). Because of this lack of organic material, a biomat layer may not form as it does in SSTSs that receive effluent from a septic tank. A biomat layer makes the soil less permeable, so effluent flows through the full length of the trench. Without a biomat, effluent tends to percolate through the soil only at the beginning of the trench unless pressure distribution is used to apply effluent evenly throughout the entire soil treatment system.

When designing the SSTS, the designer should maximize the soil treatment area's ability to treat and hydraulically accept effluent and limit impacts from ground and surface water by:

- Making the SSTS as long and narrow as possible
- Minimizing the number of laterals down slope from each other
- Running the laterals of the SSTS so they are parallel with the slope contours
- Siting the soil treatment system in areas with the most suitable natural conditions for treatment and dispersal
- Evaluating the landscape loading rates

Dispersal becomes more challenging as the soil separation becomes shallower, finer-textured, and as the design flows increase. A crested site where subsurface flow can occur in multiple directions is desirable for soil dispersal areas. Areas with convex rather then concave slopes are better for dispersal. The soil treatment area should be located on the upper part of a slope rather than at the bottom of a slope away from drainage ways, depressions, and areas subject to flooding.

Strictly observing setback requirements and paying special attention to downslope geologic or soil conditions and land use activities will help mitigate challenges with using systems on small lots. As the density of SSTS increases, especially on sites with shallow soils and where systems are placed down-gradient from each other, concerns become greater. Especially on small lots, site evaluation should include assessment of the impacts that surrounding lot developments may have on the design and performance of a system.

Just as for other systems, a reserve area with suitable site conditions for installation of a Type I system must be set aside. The area should be available to handle 100 percent of the daily design flow and must meet all requirements that apply to the primary area. For a mound system, the reserve area must be totally separate from the initial mound area.

Disinfection Systems

Definition and Rules

According to Minnesota Rules Chapter 7083.4060 manufacturers of disinfection units may register products that use disinfection for treatment Levels A (fecal level 1,000 org/100mL) and B (fecal level 10,000 org/100 mL). Products that use disinfection may be registered by manufacturers as a component of the process in treatment Level A or B.

Generally, disinfection is the process of destroying or inactivating microorganisms in effluent. **According to Minnesota Rules Chapter 7083.0020, Subp. 7. "Disinfection" means the process of destroying or inactivating pathogenic microorganisms in sewage to render them noninfectious.**

> A majority of the following text was taken from the Disinfection section of the Consortium's University Curriculum (Gross and Farrell-Poe, 2005).

Disinfection is considered to be the primary mechanism for the inactivation/destruction of pathogenic organisms to prevent the spread of waterborne diseases to downstream users and the environment. The organisms of concern in domestic effluent include pathogenic enteric bacteria, viruses, helminthes and their eggs, and protozoan cysts. In order for disinfection to be effective, effluent must first be adequately pretreated to remove suspended solids and organic material. If an attempt is made to disinfect inadequately treated effluent, the organic compounds can "steal" the disinfectant and allow pathogens to survive. Pathogens are associated with suspended solids, and removing the suspended solids is quite an effective way to remove pathogens. Pathogens can also "hide" within the suspended solids, making it more challenging for the disinfectant to come into contact with the pathogens.

In some cases the level of disinfection may affect the allowable (regulated) vertical separation between soil treatment areas and groundwater, seasonal water tables, fractured rock, or other restrictive or sensitive layers. Chlorination is not particularly effective as a disinfectant for Giardia cysts and Cryptosporidium oocysts; UV disinfection is not particularly effective on helminth eggs. If the effluent is disinfected to the level of primary contact water or drinking water microbial standards, the vertical separation may be shallower than if the effluent is not disinfected.

Disinfection is the destruction and inactivation of pathogenic organisms, and should not be confused with sterilization, which frees the effluent stream of **all** life. The goal of disinfection is to reduce the number of pathogens in the treated effluent so that the risk of disease is minimized.

Some of the specific water-borne diseases associated with the organisms of concern in domestic effluent (mentioned above) include typhoid and paratyphoid fever, cholera, bacillary dysentery, Giardiasis, Crytosporidiosis, Amoebic dysentery, Poliomyelitis, Infectious Hepatitis, Aseptic meningitis, Encephalitis, Gastroenteritis, and chronic anemia. Although it is an unpleasant thought, all of these diseases are transmitted by the fecal-oral route.

Time is a critical factor with all of the disinfection processes. In fact, simply allowing the organisms time to die is one way to disinfect effluent. In cases where a disinfecting agent is used, the appropriate disinfectant dose can be determined by finding the CT value. CT stands for concentration of disinfectant multiplied by time, and this product is sometimes considered the disinfectant "dose."

Dose = Concentration of disinfectant x Time (or intensity of energy)

"Recommended Standards for Effluent Facilities" (ten states' standards published by the Great Lakes Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers) requires a minimum of 15 minutes of contact with pathogens following chlorine injection and mixing at peak flow. Following this recommendation, a very high concentration of disinfectant in contact with the pathogen for a very short time may be as effective as a low concentration of disinfectant in contact with the effluent for a long time. The product of concentration and time may be numerically the same. This concept is discussed later in this section.

One of the factors affecting the recommendation above is the variability of flow of this recommendation is the variability of flow in an effluent system. In all effluent systems, whether municipal or individual SSTSs, a diurnal variation occurs. This variation may be exacerbated in an individual SSTS, since the variation is not buffered by multiple homes using water on a varied schedule. Since the CT value is a function of the effluent's detention time in the disinfection system and also a function of the effluent's flow rate. The disinfection processes may need to be sized for the peak hourly flow expected in the home rather than the average daily flow. All of the hydraulic considerations for sizing the disinfection system and all treatment systems downstream of the septic tank should take into account the flow attenuation of the septic tank. If the system is dosed, the detention time may be governed by the dosing mechanism, whether a pump, a dosing siphon, or other method. The flow rate from the dosing mechanism will be used to calculate the detention time in the CT value.

The goal of disinfection is for the pathogens to be removed or inactivated to an acceptable level before the treated effluent returns to the hydrologic cycle. In all cases, it is desirable for residential sewage to be disinfected. However, it may not be desirable to chemically disinfect all residential sewage. When treated effluent is discharged to surface water, chemical disinfection may be acceptable. When treated effluent is discharged to SSTSs, chemical disinfection with a chemical that stays in the water (residual disinfectant) is not particularly desirable because the disinfectant could potentially harm the beneficial organisms providing treatment in the soil. The following material includes a discussion of disinfectants and their residual effects.

As in centralized effluent treatment, several processes can be employed in decentralized effluent treatment to remove pathogens from the effluent stream. Among these disinfection processes are sedimentation, filtration, oxidation, dessication, cell-wall destruction, and disruption of biological processes and reproduction. Looking at some of the processes in a simple SSTS may help in the understanding of the treatment system's role in the disinfection process. As raw sewage moves into the septic tank, the heavier-than-water solids settle to the bottom (sedimentation) and the lighter-than-water solids float to the top (flotation). Pathogens tend to be associated with solids. The organisms may be attached to the solid particles, and "clumps" of organisms may even make up small settleable or floatable solids. As the solids are removed, the first step in disinfection is taking place in the septic tank. The discussion of the processes in the septic tank (see "Septic Tanks" section) will help to clarify the concept of sedimentation and flotation.

In onsite and decentralized effluent treatment systems, pathogen removal can occur as septic tank effluent moves from the tank, into the soil absorption system, and through the biomat at the soil-gravel interface. Some of the larger organisms are physically filtered out by the soil and the biomat. Other processes such as adsorption and absorption occur, and may be responsible for the removal of pathogens, including viruses. The biomat is an extremely active environment, and predation also occurs in that zone. Again, as the effluent moves through the soil relatively slowly, and over a large surface area, die-off, starvation, and physical filtration occur. The natural transport and transportation processes in soil effect the disinfection of the effluent.

The method of dispersal of the effluent over the soil treatment area may increase or decrease the effectiveness of the soil's disinfection process. A fuller understanding of these dispersal processes may be gained by reviewing the section on Soil Treatment in Section 3 as well as reviewing the sections on dispersal in Section 12.

Leaving the operation and management of disinfection systems to the homeowner has not proven to be effective. When a treatment system requires adding chemicals, changing components, or monitoring performance, a responsible management entity (RME) other than the homeowner is the reliable method for management. The U.S. EPA has provided management models for decentralized effluent systems. In most cases, secondary treatment unit manufacturers' representatives provide operation and management services for their products. Contracting with these same service providers can be one option for reliable operation and maintenance of the disinfection system. Again, homeowner management, in general, has simply proven unreliable or ineffective in the past.

Disinfection Processes and Design Considerations

Effective disinfection of effluent is influenced by (1) contact time, (2) pH, (3) concentration and type of disinfecting agent, (4) effluent demand, (5) temperature of effluent, (6) flow rate, and (7) concentration of interfering substances. Although it is impractical to accurately identify all effluent characteristics due to differences in location, water use, seasonal variations, waste-stream make-up, and other factors, it is important to have a general knowledge of the effluent characteristics if the disinfection system is to perform its intended purpose.

In addition, disinfection methods for systems using soil treatment areas should not leave a residual disinfectant, as the residual has the potential to destroy the beneficial soil organisms that provide additional treatment when the effluent enters the soil. For example, chlorination without subsequent dechlorination leaves a chlorine residual. Neither UV radiation nor ozone disinfection leaves a residual disinfectant in the effluent stream. When using soil-based dispersal, dechlorination should be used if UV or ozonation are not the disinfection methods.

Methods of Disinfection

There are basically three methods of disinfection for SSTSs: chlorination, ultraviolet (UV) radiation, and ozone. In general, UV radiation and tablet chlorinators seem to be the most effective methods for disinfecting small effluent flow.

Chlorination

Chlorine is used in three forms in the disinfection of effluent:

1. As a clear amber liquid or a greenish-yellow gas (elemental chlorine)

2. As a solid (calcium hypochlorite)

3. In solution (sodium hypochlorite) form

Most large sewage treatment facilities, greater than one million gallons per day (mgd), use chlorine gas or liquid because of cost and availability. Chlorine is by far the most used disinfectant for effluent in the United States today.

Chlorine destroys microorganisms by destroying the cell's enzymes once the disinfectant migrates through the cell wall. This process generally requires 30 to 60 minutes of contact time for typical concentrations used to treat effluent, depending on effluent flow and characteristics. If applied properly, chlorine can be quite effective in the destruction of bacteria, although it lacks the same success against viruses, Giardia cysts, and Cryptosporidium oocytes.

For optimum performance, a chlorine disinfection system should display plug flow and be highly turbulent for complete initial mixing in less than one second. The goal of proper mixing is to enhance disinfection by initiating a reaction between the free chlorine in the chlorine solution stream with the ammonia nitrogen. This prevents prolonged chlorine concentrations from existing and forming other chlorinated compounds.

Among other considerations for chlorine disinfection, is the interference of BOD with chlorine. BOD can exert a chlorine demand since chlorine is an oxidizer. The chlorine may be used to oxidize the organic matter that exerts the BOD. TSS can interfere with the chlorination process by exerting a chlorine demand, as well as by providing hiding places for the pathogens. The chlorine must come into contact with the pathogenic organism in order to destroy the cells. The TSS may shield the pathogens from contact with the disinfectant. Humic materials may exert a chlorine demand since they are organic compounds. Nitrite is oxidized by chlorine, and therefore may exert a chlorine demand. Chlorine may react with iron, manganese, and hydrogen sulfide in the treated effluent.

Not only will these substances exert a chlorine demand, but oxidation of these compounds results in precipitates that have the potential to clog downstream processes or to cause otherwise unexpected or undesirable colors in the treated effluent. These precipitates do not represent harmful compounds, and they may be removed readily. Planning for their appearance gives the designer the flexibility to implement their removal (filtration or sedimentation are some removal options).

Ultraviolet

Disinfection by ultraviolet (UV) radiation is a physical process that occurs when electromagnetic energy from a source (e.g., a lamp) is transferred to an organism's genetic material (i.e., DNA and RNA). UV radiation destroys microorganisms by preventing their replication and eventually causing death. UV radiation, generated by an electrical discharge through mercury vapor, UV radiation penetrates the genetic material of microorganisms and retards their ability to reproduce. There is some evidence that exposing the organisms to full-spectrum light following UV irradiation may allow the organisms to regenerate (akin to "self-healing"). Therefore the effluent stream should be covered or kept in darkness by other means immediately following the UV irradiation. Some have theorized that sunlight can provide adequate disinfection by UV radiation. However, the evidence of full-spectrum lighting allowing the organisms to regenerate would appear to dispel this theory.

The main components of a UV disinfection system are mercury arc lamps, a reactor, and ballasts. The source of UV radiation is either a low-pressure or a medium-pressure mercury arc lamp with low or high intensities. The optimum wavelength to effectively inactivate microorganisms is in the range of 250 to 270 nanometers (nm). The intensity of the radiation emitted by the lamp dissipates as the distance from the lamp increases.

The ideal lamp wall temperature is between 95 and 122 °F. Today, the most widely used source of UV light is the low-pressure mercury arc lamp. Approximately 85 percent of its energy output is at a wavelength of 253.7 nm, which falls within the optimum wavelength range of 250 to 270 nm for germicidal effect. Low-pressure mercury vapor lamps are long, thin, transparent tubes (1.5 - 2 cm in diameter). The lamps are typically 0.75 and 1.5 meters in length. Ballasts are used to provide starting voltage and to maintain constant current.

In addition to low-pressure mercury vapor lamps, medium-pressure mercury vapor lamps have been developed for use in higher-capacity UV disinfection systems. The lamps produce 25 to 30 times greater output than do low-pressure lamps and use permanent transformers instead of ballasts to provide starting voltage. Medium-pressure lamps cost three to four times more than low-pressure lamps but operate half as long.

Presently, two general types of reactors are in use. The first is a quartz tube (or contact reactor), which has its lamps submerged in effluent. The lamps are sheathed in quartz jackets that are transparent to UV wavelengths and slightly larger than the lamps. Flow can be either parallel or perpendicular to the lamps. The quartz tube reactor can be further classified as the enclosed-vessel or open-channel system. In the enclosed vessel system, liquid flows under pressure through a sealed reaction chamber, which contains one or more lamps. In the open channel system, a group or battery of lamps are submersed into a plant's effluent channel.

The second general type of UV disinfection system is the Teflon tube reactor. In this reactor system, UV lamps are suspended outside Teflon tubes which transport the effluent to be disinfected. The Teflon tubes used to transport effluent are transparent to UV wavelengths, thus allowing disinfection to occur. Open channel quartz tube and Teflon tube reactor systems are typically used for large sewage treatment facilities. The effectiveness of a UV disinfection system depends on the characteristics of the effluent, the intensity of UV radiation, the amount of time the microorganisms are exposed to the radiation, and the reactor configuration. For any one treatment plant, disinfection success is directly related to the concentration of colloidal and particulate constituents in the effluent.

Ozone

Like chlorine, ozone is a powerful disinfectant that destroys microorganisms through oxidation. Unlike chlorine, it does not have to penetrate the cell wall to be effective. Ozone is also much more effective against viruses than chlorine. The mechanisms of disinfection using ozone include:

- Direct oxidation/destruction of the cell wall with leakage of cellular constituents outside the cell
- Reactions with radical by-products of ozone decomposition
- Damage to the constituents of the nucleic acids (purines and primidines)
- Breakage of carbon-nitrogen bonds leading to depolymerization

When ozone decomposes in water, the free radicals hydrogen peroxy (HO_2) and hydroxyl (OH) that are formed have great oxidizing capacity and play an active role in the disinfection process. It is generally believed that bacteria are destroyed because of protoplasmic oxidation, which results in cell wall disintegration (cell lysis).

Ozone is produced when oxygen (O_2) molecules are dissociated by an energy source into oxygen atoms and subsequently collide with oxygen molecules, forming ozone (O_3), an unstable gas that is used to disinfect effluent. Production of ozone in quantities of more than one gram per hour is done by passing an electrical current through air or oxygen in a controlled environment. This method of production is known as *electric discharge* or *corona discharge* and is used at effluent treatment plants. Where large amounts of ozone are required, intake air must be dried to prevent damage to production equipment. The equipment required to dry intake air can be as expensive as the ozone production equipment itself. Many larger treatment facilities use pure oxygen to produce ozone at a higher rate than can be achieved by using ambient air. Generally, production of under 500 lbs/day is not economically feasible using oxygen.

Ozone can also be produced by a low-pressure mercury arc lamp operating at 190 to 270 nm. Quantities of less than one gram/hour can be produced by this method, which is a sufficient quantity to provide disinfection for small sewage treatment systems. Ozone disinfection is generally used at medium- to large-sized plants after at least secondary treatment. Manufacturers of ozone production lamps suggest a bulb life of 7,000 hours; excessive starts reduce this time. Ozone disinfection is the least used method in the U.S., although this technology has been widely accepted in Europe for decades. Ozone treatment has the ability to achieve higher levels of disinfection than either chlorine or UV; however, the capital costs as well as maintenance expenditures are not competitive with available alternatives. Ozone is, therefore, used only sparingly, primarily in special cases where alternatives are not effective.

In addition to disinfection, another common use for ozone in effluent treatment is odor control. Other ancillary benefits when using ozone to disinfect treated effluent include reduction of the organic and inorganic content through oxidation and the addition of oxygen to the effluent.

The effectiveness of disinfection depends on the susceptibility of the target organisms, the contact time, and the concentration of the ozone. The components of an ozone disinfection system include feed-gas preparation, ozone generation, ozone contacting, and ozone destruction. Air or pure oxygen is used as the feed-gas source and is passed to the ozone generator at a set flow rate. The energy source for production is generated by electrical discharge in a gas that contains oxygen. Ozone generators are typically classified by their:

- Control mechanism (either a voltage or frequency unit)
- Cooling mechanism (either water, air, or water plus oil)
- Physical arrangement of the dielectrics (either vertical or horizontal)
- Inventor's name

Applications

Choosing a suitable disinfectant for a treatment system is dependent on the following criteria:

- The disinfectant's ability to penetrate and destroy infectious agents under normal operating conditions
- The disinfectant's safe and easy handling, storage, and shipping

- The absence of toxic residuals and mutagenic or carcinogenic compounds after disinfection
- Affordable capital and operation and maintenance costs

Management

Management Plans for registered proprietary disinfection units can be found on the OSTP web page.

Chlorine

A routine operation and maintenance (O&M) schedule should be developed and implemented for any chlorine disinfection system. Regular O&M activities include:

- Disassembling and cleaning the various components of the system, such as meters and floats, once every six months
- Removing iron and manganese deposits with, for example, muriatic acid
- Maintaining booster pumps
- Inspecting and cleaning valves and springs annually
- Compliance with all manufacturer's O&M recommendations should be required
- Testing and calibrating equipment as recommended by the equipment manufacturer
- Developing an emergency response plan for onsite storage of gaseous chlorine

Because chlorine gas collects in the tablet container, the container should be opened in a well-ventilated area. Chlorine gas can escape from the tablets and container, reducing the effectiveness of the tablets and possibly corroding metal products stored near the container.

When using chlorine, it is very important to properly and safely store all chemical disinfectants. The storage of chlorine is strongly dependent on the compound phase. For further details on the safe use and storage of chlorine, refer to the chemical's Material Safety Data Sheets (MSDS). Chlorine gas is normally stored in steel containers (150-pound or 1-ton cylinders) and transported in railroad cars and tanker trucks. Sodium hypochlorite solution must be stored in rubber-lined steel or fiberglass storage tanks. Calcium hypochlorite is shipped in drums or tanker trucks and stored with great care.

UV

In a UV disinfection system, target organisms must come into direct contact with UV light if the disinfection is to be effective. The hydraulic properties of the reactor, the age and configuration of lamps, time frame and procedures for cleaning, the flow rate, contact time, and water quality all affect the system's efficiency.

Inadequate cleaning is one of the most common causes of a UV system's ineffectiveness. The quartz sleeves or Teflon tubes need to be cleaned regularly by mechanical wipers, ultrasonics, or chemicals. The cleaning frequency is very site-specific, i.e., some systems need to be cleaned more often than others.

Chemical cleaning is most commonly done with citric acid. Other cleaning agents include mild vinegar solutions and sodium hydrosulfite. A combination of cleaning agents should be tested to find the agent most suitable for the effluent characteristics without producing harmful or toxic by-products. Non-contact reactor systems are most effectively cleaned by using sodium hydrosulfite. Any UV disinfection system should be pilot tested prior to full-scale operation to ensure that it will meet discharge permit requirements for a particular site.

The average lamp life ranges from 8,760 to 14,000 working hours, and the lamps are usually replaced after 12,000 hours of use. Operating times should be adjusted to reduce the on/off cycles of the lamps, since their efficacy is reduced with repeated cycles. The ballast must be compatible with the lamps and should be ventilated to protect it from excessive heating, which may shorten its life or even result in fires. Although the life cycle of ballasts is approximately ten to 15 years, they are usually replaced every ten years. Quartz sleeves will last about five to eight years but are generally replaced every five years.

Ozone

Ozone generation uses a significant amount of electrical power. Thus, constant attention must be given to the system to ensure the power is optimized for controlled disinfection performance. There must be no leaking connections in or surrounding the ozone generator. The operator must, on a regular basis, monitor the appropriate subunits to ensure that they are not overheated. The operator must check for leaks routinely, since a very small leak can cause unacceptable ambient ozone concentrations. The ozone monitoring equipment must be tested and calibrated as recommended by the equipment manufacturer.

Like oxygen, ozone has limited solubility and decomposes more rapidly in water than in air. This factor, along with ozone reactivity, requires that the ozone contactor be well covered and that the ozone diffuses into the effluent as effectively as possible.

Ozone, in gaseous form, is explosive once it reaches a concentration of 240 g/m^3. Since most ozonation systems never exceed a gaseous ozone concentration of 50 to 200 g/m^3, this is generally not a problem. However, gaseous ozone will remain hazardous for a significant amount of time, so extreme caution is needed when operating ozone gas systems. It is important that the ozone generator, distribution, contacting, off-gas, and ozone destructor inlet piping be purged before opening the various systems and subsystems. When entering the ozone contactor, personnel must recognize the potential for oxygen deficiencies or trapped ozone gas in spite of best efforts to purge the system. The operator should be aware of all emergency operating procedures required if a problem develops.

Troubleshooting

Problems with disinfection units are often related back to effluent quality levels and proper operation of the disinfection unit. Make sure that power to the disinfection unit remains on at all times, that the unit is cleaned when necessary, and that bulbs and chemicals are replaced as needed.

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SECTION 11: Distribution of Effluent

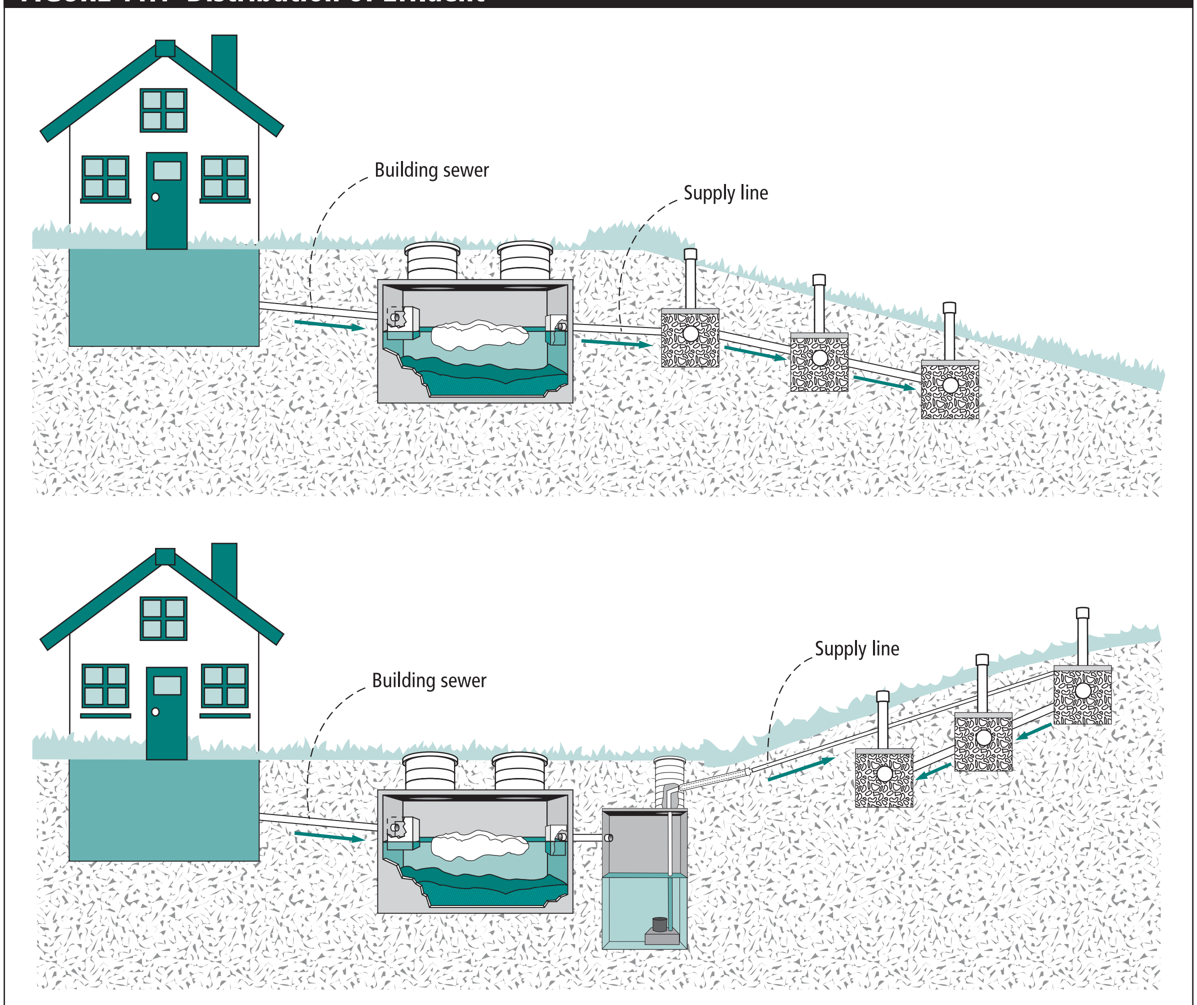
DISTRIBUTION OF EFFLUENT

Distribution

Distribution is defined as *the process of conveying wastewater or effluent to one or more components or devices* (CIDWT Glossary, 2009). All decentralized wastewater treatment systems (whether simple or complex) include components that distribute effluent to and among various components. The goal of distribution is to spread wastewater and effluent over space and time to allow physical, biological, and chemical treatment processes to effectively remove contaminants.

The distribution of effluent includes all the piping and distribution media through which effluent passes after it leaves the septic tank. The supply line transports sewage from the tank to the soil treatment area; the distribution system, operating under gravity or pressure, distributes the effluent into the soil. Piping is an important part of all onsite SSTSs. Both the type of system and method of application determines the necessary pipe characteristics and installation. Distribution applications can be divided into several categories, two of which are shown in Figure 11.1.

FIGURE 11.1 Distribution of Effluent



1. The supply pipe from the septic tank via gravity distribution to either a:
   a. Pump tank/dosing chamber
   b. Pretreatment device for secondary treatment
   c. Soil treatment system
2. The supply pipe from a pump tank to either a:
   a. Collection line to a cluster system
   b. Pretreatment system or gravity soil treatment system
   c. Pressure distribution system to another
   d. Pre-treatment device, pump tank or the distribution system for final dispersal.
3. The piping in a gravity distribution network in a trench or bed system
4. The piping in a pressure distribution network

Each application needs a specific type, size, and strength of pipe.

Supply Pipes

According to MN Rules Chapter 7080.2050, Subp. 2(B), supply pipes must:

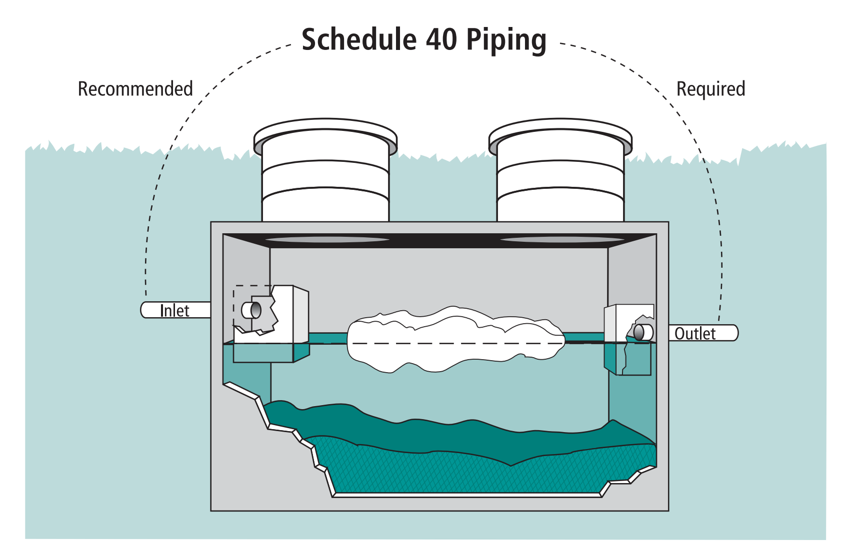
- Be made from materials resistant to breakdown from sewage and soil
- Be watertight, including all joints
- Be durable throughout the design life
- Not deflect, buckle, crush, or longitudinally bend
- Be resistant to pressures, fatigue, and strain for the application
- Be installed according to American Society of Testing and Materials (ASTM), Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications, ASTM D2321 (2005)
- Be designed, installed, and operated to minimize the danger of freezing in the pipe
- Not be closer than six inches from final grade. Pipes susceptible to freezing shall be insulated
- Be set back from water supply wells and water service pipes according to Chapter 4715

Materials

In the past, materials such as cast iron, clay tile, or other materials were used, but plastic is now required due to its durability, ease of handling, and economics. Now, the rules specify that **the supply pipe extending from the septic tank to the undisturbed soil beyond the tank excavation must meet the strength requirements of ASTM, Schedule (Sch) 40 Pipe, contained in Standard Specification for PolyVinyl Chloride (PVC) Plastic Pipe, Sch 40, 80, and 120, ASTM D1785 (2006) (7080.2050 Subp. 2.(A)).**

Ease of handling includes the ability to make watertight connections between pipe sections to reduce root intrusion or leaking.

FIGURE 11.2 Building Sewer and Supply Pipe Materials



Schedule 40 and ASTM 3034

The two most common pipe grades used are Schedule 40 and ASTM 3034. These pipes have different wall thicknesses, which give them different lateral strengths. Schedule 40 has a thicker wall and is stronger than 3034. It was designed to be the plastic equivalent of cast iron pipe. This strength also makes it the required pipe to use at the inlet and outlet of the septic tank or any other span across excavated soil. ASTM 3034 pipe should only be used if it is well supported and the effluent will flow by gravity.

You may ask: If Schedule 40 plastic pipe was designed as the equivalent of cast iron pipe, why not use cast iron? Cast iron is not used because it is more difficult to connect and, more importantly, it tends to develop plugging related to a number of common detergents. Schedule 40 pipe, as shown in Figure 11.2, is required to be used in areas of non-native soil where a stronger pipe can help reduce sagging in pipes along with proper backfilling techniques.

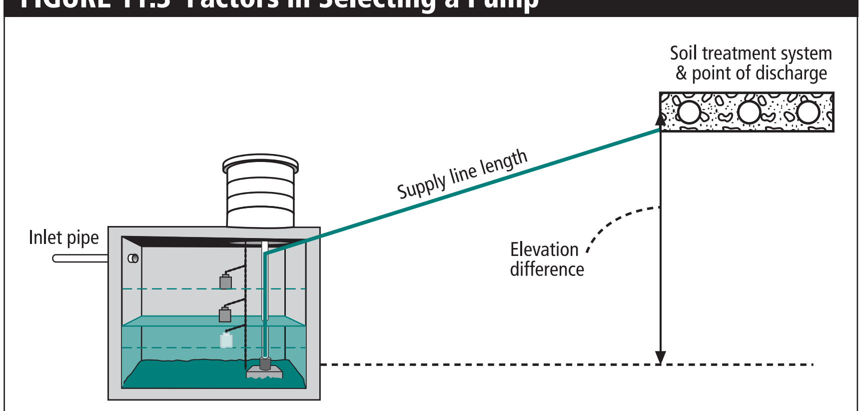
Existing Piping

If existing pipe is to be used, be sure to examine the piping materials. As mentioned above, cast iron can be a problem because of reactivity with some detergents. Problems with clay and orangeburg pipes are also common, as both these materials are likely to crack, and cracking leads to troubles with roots. If there is excessive root infiltration or cracks in the piping, it is not watertight and therefore sewage is leaking out of the pipe or groundwater is leaking in. Either situation creates problems.

Size

In pressure applications where grinder pumps are feeding into a collection line for a cluster system, pipe one to three inches in diameter is used as the solids are ground or ejected by a pump (see Section 8 for more information on pumps), while a four inch diameter is common with gravity distribution where the solids are intact. In pressure applications, when smaller diameter pipes are used, there will be more energy lost to friction in the pipe, which requires more total dynamic head from the pump to over come the friction loss. As shown in Figure 11.3, the length of the supply line as well as the elevation difference from the pump to the point of discharge will affect the size of pump needed.

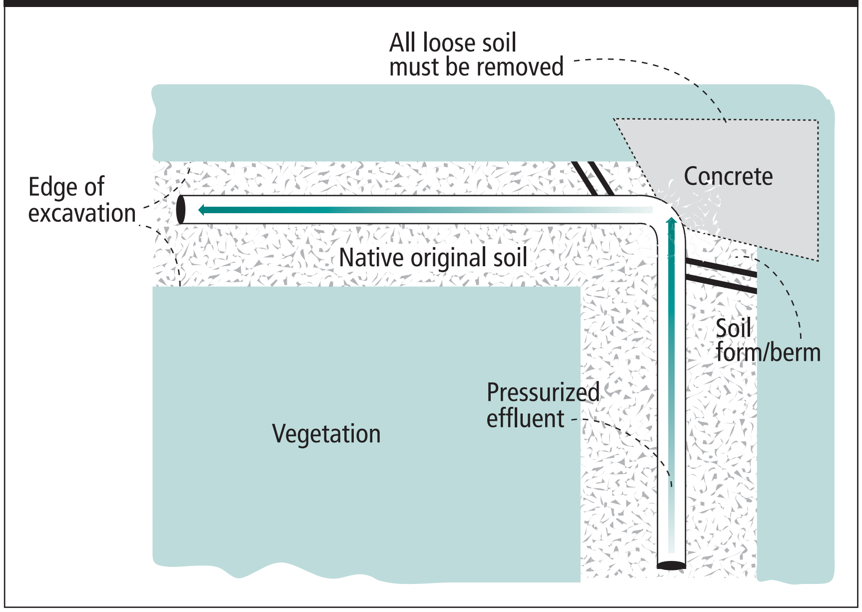
FIGURE 11.3 Factors in Selecting a Pump



Slope

The minimum slope for gravity supply pipes is one percent (1/8 inch per lineal foot). There is no maximum slope (7080.2050 Subp. 2 (C)). No maximum slope is required because there will not be any large solids to transport, while the minimum slope is there to assure that effluent travels through the pipe at an appropriate velocity and does not freeze. **For pressure systems, a minimum slope of one percent is required for drainback and other frost protection measures must be employed. Pipe restraints must be used for slopes greater than 20 percent or where fluid velocities in the pipe exceed 15 feet per second.** Thrust forces in pressurized pipelines should be restrained or anchored to prevent excessive movement and joint separation under all projected conditions. Common methods include thrust blocking and various types of restrained joints as shown in Figure 11.4.

FIGURE 11.4 Thrust Block Placement



In a theoretical continuous straight run of pipe, the forces at one joint are balanced by the equal and opposite forces at the adjacent joints. No restraint is necessary. When a bend, tee, reducer, valve, or other flow-altering fitting is introduced, the forces no longer balance each other. The hydrostatic forces created at the joints on both ends of the fitting combine to form a single reaction. This reaction is the resultant thrust force, which is the force attempting to move the fitting away from the bend and its attached piping. This is the force to be restrained.

The typical acceptable method of restraint for PVC would be Uni-flange or Mega-lug type restraints. All restraint devices must have a water working pressure rating equivalent to the full rated pressure of the pipe on which they are installed, with a minimum 2:1 safety factor in any nominal pipe size. Restraining devices should provide full (360 degree) support around the circumference of the pipe. See the 2007 ASTM Standard F1674, "Standard Test Method for Joint Restraint Products for Use with PVC Pipe," for more information.

Installation

By following three simple rules, excavation problems with supply pipes can be avoided:

Rule 1: Avoid over-excavating the trenches when possible. If effluent is to flow properly, the pipe must be supported. Unsupported pipe can lead to clogging and freezing problems. Minimizing unexcavated soil under the pipe reduces the potential for low spots developing where water can collect.

In general, natural soil provides a solid base (unless you work in organic or peat soils). If the trench is over-excavated, the soil will need to be compacted before the pipe is put into place. When placing pipe in organic soils, remove the original organic material and replace it with a solid material or aggregate. Organic soils—peat and muck—do not provide a solid base, and settling and heaving are likely to take place. This movement puts pressure and stress on the pipe and will cause leaks at the joints. More importantly, the pipe will not maintain the proper pipe slope. See Section 7 for installation of septic tanks in these situations.

Rule 2: Support the pipe over deep excavations. If you removed material, like organic soil, or if you installed a septic tank and the piping going in and out of the structure, the pipe will be at least partially on fill, and this material can settle. To minimize problems, use a granular fill material and compact it as the material is installed. Sand or pea rock is most typically used as fill. If rock is used, silting into the rock is a form of settling that can cause an aesthetic problem. Rock can also create a drain system that channels groundwater into septic tanks. Soil which is in large clumps does not make for a stable base which will support the pipe.

Another aspect of support in these situations is the pipe material choice. Using a heavier pipe such as Sch 40 helps minimize sagging but does not remove the requirement of proper backfilling. In pressure supply pipes where two-inch pipe is used, the two-inch pipe can be placed inside a four-inch pipe, adding strength and decreasing the potential for bows as shown in Figure 11.5. Be sure that the four-inch pipe is sealed to avoid having the pipe fill with soil or groundwater.

Rule 3: Backfill with good material. The backfill material has two functions: protecting the pipe system and maintaining the slope. Protection means the pipe is surrounded by and covered with the backfill material, providing some protection from freezing.

FIGURE 11.5 Pump Tank with Supported Supply Pipe

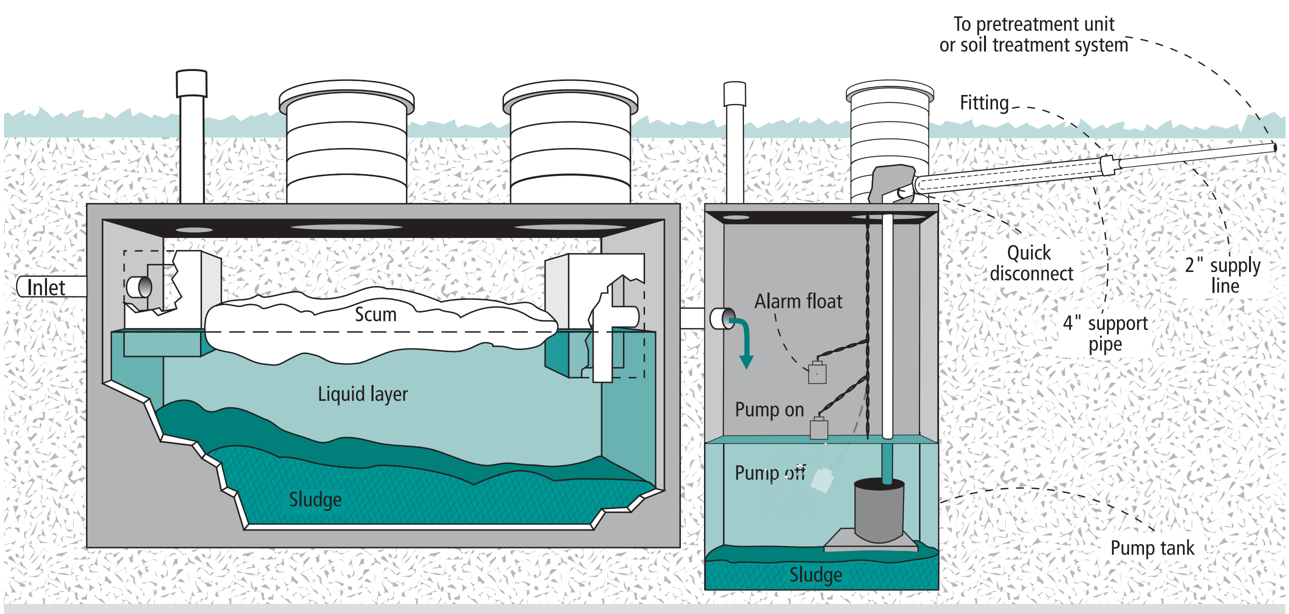
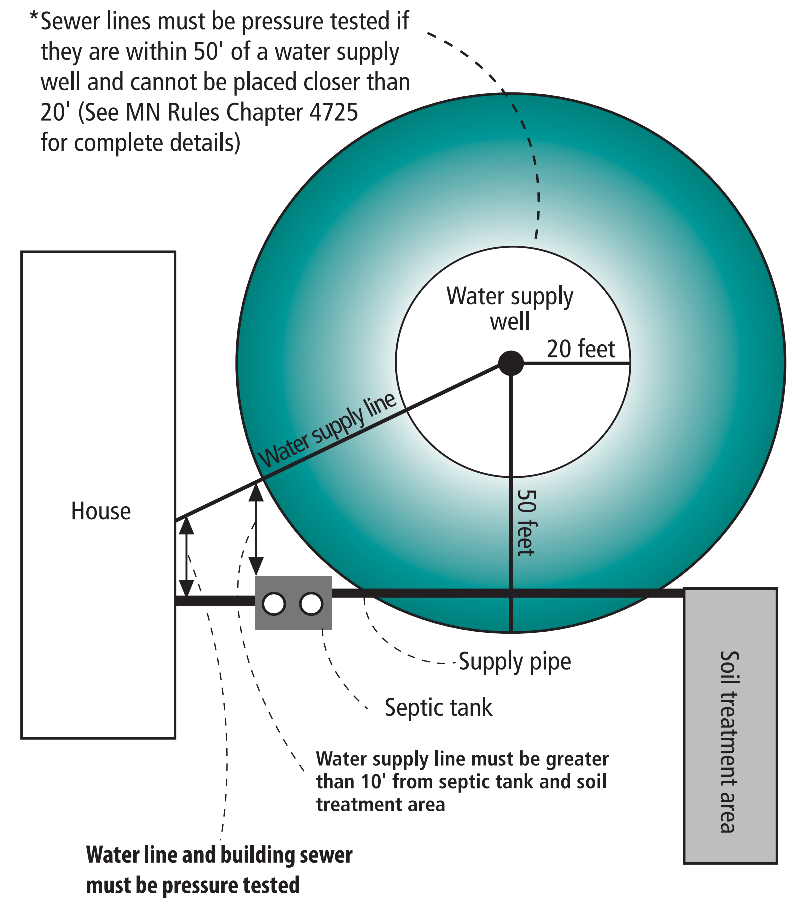


FIGURE 11.6 Pressure Testing Requirements



For this to be true, the backfill must surround the pipe. The strength of the pipe is related to its round shape. If the shape is deformed, the strength is reduced, which can lead to failure. The minimum total burial depth is six inches. To minimize the weight of the cover and the potential for collapse, apply granular backfill at least to the midway point of the pipe. Plastic pipe needs to be covered to protect it from UV rays and other surface activities that can cause failure. Lawn mowing and traffic over excavations can break and crack the pipe. The potential for these problems can be minimized by a backfill system that properly supports the pipe. Avoid using large stones, as these also can damage the pipe during backfilling. Large rocks should not be returned to the trench in contact with the piping. In heavier clay soils, dry soil clods can act like rocks, so do not use them to backfill the excavation. A granular material in contact with the pipe will minimize the impact of soil clods.

During septic system installations it is important to assure the sewer line and supply do not leak if they are within 20-50 feet of the well or water line as shown in Figure 11.6. This requires a pressure test, which must be done after the pipe is installed but before the piping has been backfilled. This simplifies any required repairs, but also means an installer needs to be careful backfilling the trench to avoid any breaks. A pressure test is conducted by plugging the pipe at both ends and adding compressed air for a period of time. It is important to have a method of adding air and measuring the pressure in the pipe. Air pressure is raised to a set level, typically three to five pounds. The pipe then should hold this pressure for an extended period, typically five to ten minutes. **In MN Rule 4715.2820, Subp. 2 on the pressure testing requirements are 5 pounds for 15 minutes.** If the pipe and joints can hold this pressure, it is considered watertight. When the Installer is **performing the pressure test they must fill out the required air test paperwork. This form can be found at septic.umn.edu/ssts-professionals/forms-worksheets.**

Freeze Protection

Supply pipes must be designed, installed, and protected so that they are not closer than six inches from final grade and so that effluent will not freeze in the pipe. **According to 7080.2050 Subp. 2(B) 8, pipes susceptible to freezing shall be insulated.** In cold-weather areas, pipes installed with minimal cover (fewer than one to two feet), or in areas with compacted soil or lack of snow cover such as driveways, must be protected from freezing. In city sewer systems, this protection is often achieved by ensuring that the pipe is installed deep (six to eight feet) underground, but in onsite systems this depth is not typically achievable.

If the bury depth is shallow (fewer than one to two feet), the pipe is minimally sloped for drainage, or if the pipe is under a driveway or sidewalk, it should be insulated. There are two methods of insulation: 1. pipe with insulation already attached (Figure 11.7) or 2. install foam sheets over the pipe (Figure 11.8). Make sure you choose insulation rated for use underground. Fiberglass battings are not designed for such applications. Another critical issue for freeze protection is that the supply pipe must drain after the pump shuts off. This is typically done through a weep hole in the pump tank.

FIGURE 11.7 Insulated Pipe

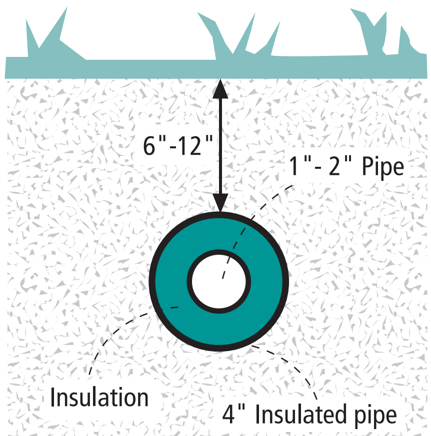
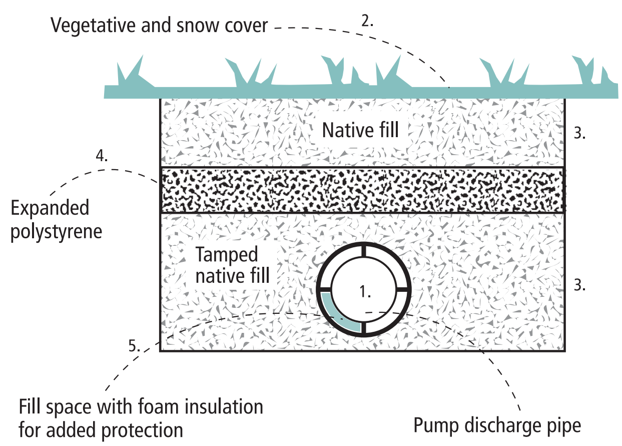


FIGURE 11.8 Frostproofing an Excavation



5 Options to Reduce Frozen Pipes:

1. Keep discharge pipe on a grade back to pump, and do not allow low spots in discharge line
2. Vegetative and snow cover. When snow cover is light, place
3. Proper cover and backfill
4. Sheets of expanded polystyrene
5. Pipe sleeved in larger diameter pipe with or without foam insulation

Cleaning, Priming, and Gluing Joints

Upon installation, the pipe must be clean and clear of debris and PVC cuttings. During construction, protect the ends of the pipe to keep dirt and rodents out. All pipes and fittings must be properly joined together with primer and glue, which is discussed in more detail in Section 6.

Cleanout Requirements and Maintenance

7080.2050 Subp. 2 (D) requires access to each supply pipe must be provided for cleanout. The cleanout point must be accessible from the final grade. Installing a cleanout at the wall outside the home or business is a good idea should the system ever need to be jetted or cleaned. This cleanout allows all work to be done outside, so any mess stays outside. Inside the home, there is potential for the cleanout to be hidden and the possibility of a major spill.

Maintenance of the sewer should be a design and installation consideration. As the pipe is installed close to structures or decks, it becomes more difficult to maintain the proper slopes and to make good connections. The need to clean and replace pipe is the reason for specifying setback requirements from structures. Typically, ten to twelve feet will allow for the excavator to work on the piping around the structure. Decks present bigger problems because they are often built after the pipe is installed. The pipe can be crushed or broken during installation of the deck footings. Installers must work with homeowners so that they understand the importance of avoiding the pipes and planning for access in case future repairs are needed.

Gravity Distribution

Flow to gravity distribution systems is directly related to use at the source: effluent from the septic tank flows to the soil treatment area (STA) whenever sewage enters the septic tank. In pressure-dosed gravity distribution, wastewater flows out of the septic tank into a dosing tank and is stored before being intermittently applied to the STA in demand- or timed-doses of equal volume. Pressure-dosed gravity distribution adds a "dose and rest" regime that spreads the effluent out over time relative to conventional gravity distribution but not necessarily over space; effluent is still applied to the beginning of the trench or bed and subsequently flows by gravity within it. Regardless of the trench media, the effluent moves rapidly to the soil infiltrative surface in a localized area at the beginning of the trench.

Gravity distribution of septic tank effluent has been the most common design over the history of onsite treatment in Minnesota. Less expensive to install and maintain than systems in which effluent is pumped, gravity distribution systems take advantage of natural elevation differences. Effluent flows down from its sources to the septic tank, then on to the soil treatment system in either serial or parallel distribution (discussed below).

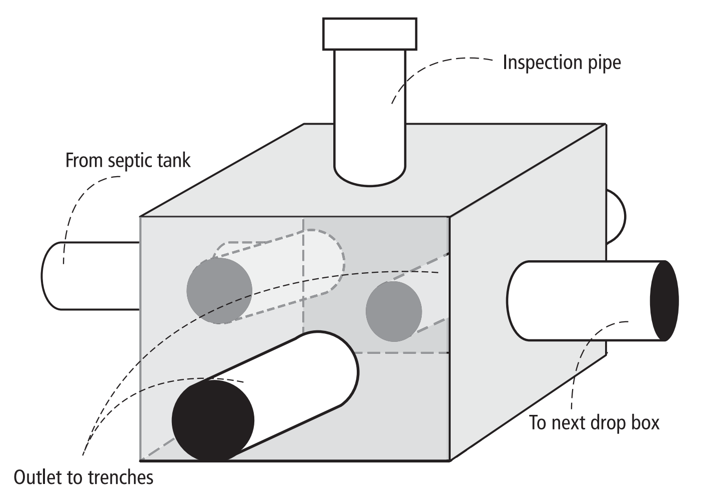
Today, gravity distribution systems for conveying septic tank effluent are used in two types of systems: either trench and seepage bed systems. Trenches are narrow (less than or equal to three feet wide), long (typically greater than 25 feet), level ditches dug in soil of suitable texture, filled with distribution media, covered with a fairly shallow (maximum allowable depth of four feet to the bottom of the media) layer of topsoil, and planted/seeded with a dense vegetative cover. Seepage beds are basically wide (greater than three to 25 feet) trenches. The rate at which sewage is generated and the rate at which soil will absorb effluent will vary throughout the year. A change in the number of people using a system will affect the daily sewage flow. High soil moisture conditions will decrease the rate at which the soil will absorb effluent, while hot, dry weather will increase the ability of the soil to accept effluent. Less trench bottom area may be required during warmer, drier months than during winter when evapotranspiration is negligible. Thus, the trench bottom area not being used will automatically rest and dry out. This resting and drying will increase the soil's ability to absorb effluent over time.

Rule Requirements, Definition and Description

There are several types of gravity distribution devices that receive and transfer effluent from the supply pipes to distribution pipes or down slope components **(Chapter 7080.1100, Subp, 21)**: drop boxes, distribution boxes, valve boxes, and manifolds. The primary purpose of flow distribution devices is to control the flow of the effluent into the drainfield.

Some site conditions require a pump to deliver the effluent to the distribution device as shown in Figure 11.9. In these instances, the pump discharge must be directed into the distribution device against a wall, the side of the box on which there is no outlet, or against a deflection wall, baffle, or other energy dissipater. The pump must discharge at a rate at least ten times greater than the water supply flow rate but no

FIGURE 11.9 Pressurized Delivery to a Drop Box



faster than the rate at which effluent will flow out of the distribution device. The distribution device must be placed on firm and settled soil and covered by a minimum of six inches of soil. If the top of the device is deeper than six inches, access must be provided within six inches. The type of distribution device used depends on whether effluent is distributed by serial or parallel distribution.

Serial Distribution

In MN Rules Chapter 7080.1100, Subp. 71, serial distribution is defined as the distribution of septic tank effluent by gravity flow that progressively loads one section of a soil treatment and dispersal system to a predetermined level before overflowing to the succeeding section and does not place a dynamic head on the lower section of the soil treatment and dispersal system. The distribution media may function as a conveyance medium to the next section (see “Continual Distribution Systems,” below).

According to 7080.2050, Subp. 3(A) serial distribution must be used to distribute effluent to individual trenches in a soil treatment and dispersal system. If the necessary elevation differences between trenches for serial distribution cannot be achieved by natural topography or by varying the excavation depths, parallel distribution may be used. Serial distribution must not create a pressure head on trenches at lower elevations.

Application

Serial distribution are highly recommended to be used in gravity flow trenches whenever possible as it encourages biomat formation and unsaturated flow.

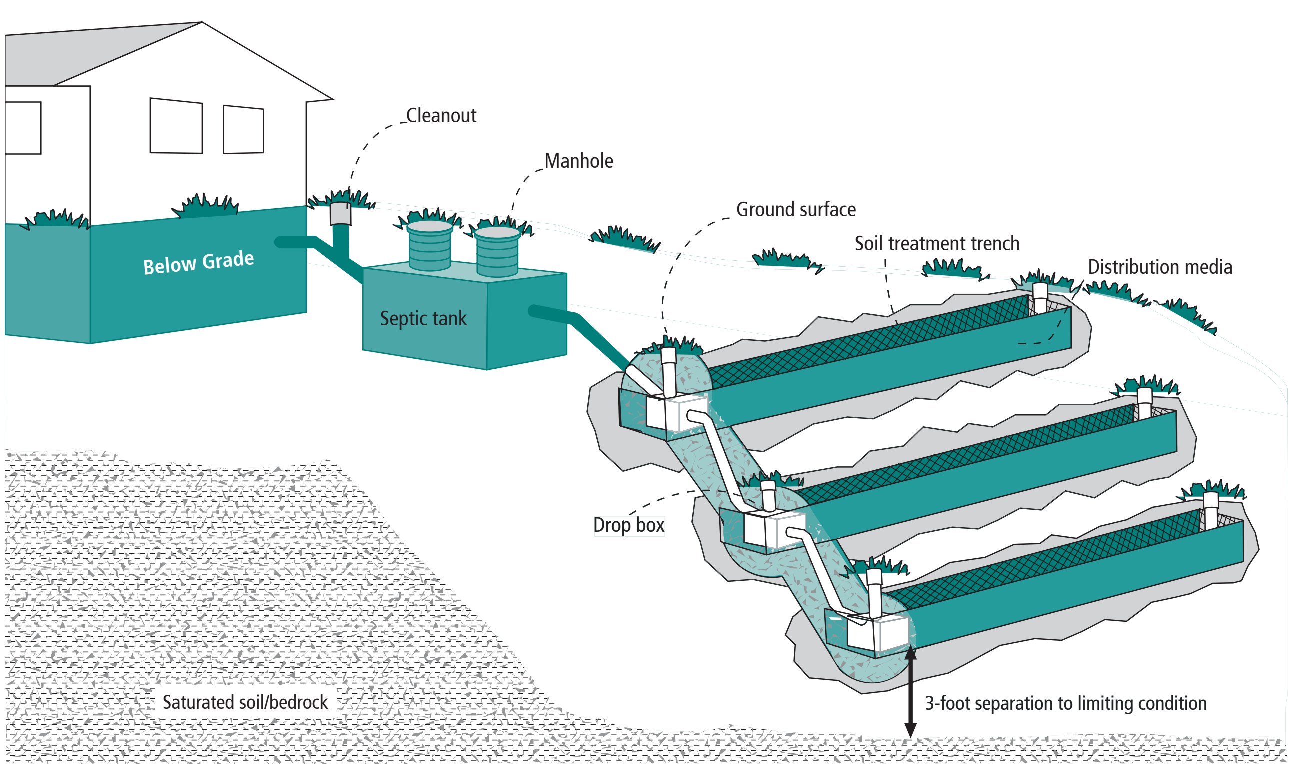
Drop Boxes

Drop boxes are used to achieve serial distribution. **A drop box is a distribution device used for the serial gravity application of sewage tank effluent to a soil dispersal system (Chapter 7080.1100, Subp. 24).**

With drop box distribution, septic tank effluent flows into the first trench until effluent has ponded and the trench reaches capacity. Then, the effluent flows into the second trench until it, too, reaches capacity, then into the third. The first trench should be at capacity before effluent is delivered to the second trench. Figure 11.10 shows the layout of a SSTS using drop box distribution. Effluent flows through a watertight pipe from the septic tank to the first drop box. An outlet, near the bottom of the drop box, connects to the distribution pipe of the trench. Another outlet near the top of the drop box connects to a watertight pipe leading to the drop box of the lower trench.

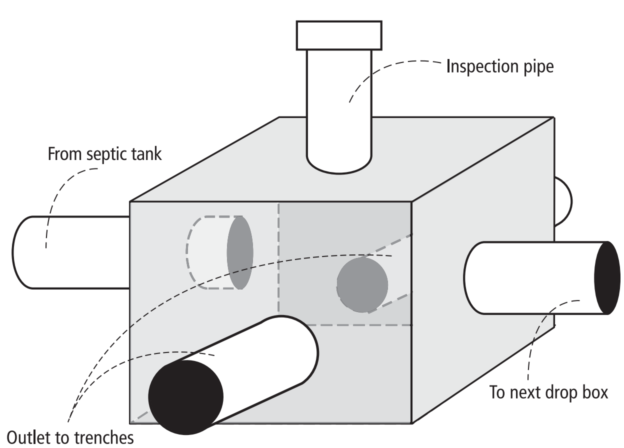
Aside from the order in which effluent reaches them, the trenches function independently, each receiving effluent at the rate it is accepted in that trench. If one is draining more slowly than the others, perhaps because it is located in less permeable soil, it will accept less effluent. If one tends to drain quickly, perhaps because it receives more sunlight on the surface and more water is lost through evaporation in the warmer months, it will receive more effluent. Since the trenches are not directly connected, there is no hydraulic head from trench to trench - effluent does not move more quickly into or through the second or third trenches because they are downhill from the first one.

FIGURE 11.10 Serial Distribution Using Drop Boxes



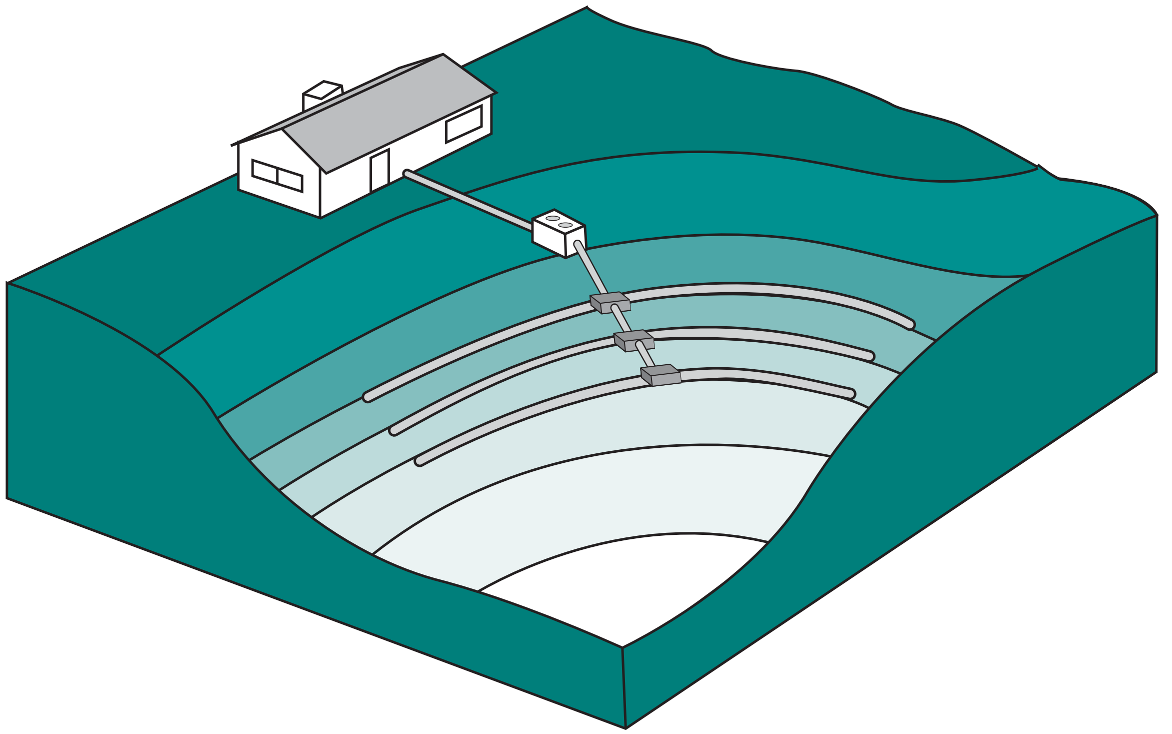
Drop boxes are most suitable for sloping sites as shown in Figures 11.10 and 11.11, but can be used on level sites by positioning the downstream boxes two inches lower than the up slope unit, as shown in Figure 11.13. The first inch is for the elevation difference between the inlet pipe and the supply pipe to the next drop box, and the second inch is for the slope of the supply pipe to the next drop box. Effluent flows through a watertight pipe from the septic tank to the first drop box, where all the effluent enters the first trench. Outlets near the bottom of the drop box connect to the distribution pipe of the trenches as shown in Figure 11.12.

FIGURE 11.11 Drop Box Outlets



Another outlet near the top of the drop box connects to a watertight pipe leading to the drop box of the next trench. When a trench will no longer accept the effluent, the liquid level increases in the drop box and flows to the second drop box where the effluent enters the second trench. When the first and second trenches cannot handle the flow, the effluent enters the third drop box/trench.

FIGURE 11.12 Drop Boxes on a Sloped Site



The drop box distribution system allows for flexibility. If additional soil treatment system capacity becomes necessary, or if one of the trenches clog, additional trenches can be added, assuming there are suitable soils and space on the lot. This system can also be constructed on steeper slopes than can other distribution methods. Although use of very steep slopes may be impractical because construction machinery cannot safely be operated on steep hills, the serial distribution system itself has no maximum slope limits. This site flexibility may allow these systems to be constructed on the most suitable soils on a lot, or at an ideal distance from other improvements, such as wells, driveways, or surface water bodies. As shown in Figure 11.13, a watertight pipe is connected to the last drop box of the existing system, and additional drop boxes and trenches can be added without disturbing the existing SSTS. Each trench can be any length to accommodate structures and trees as long as the total trench length is adequate for the wastewater source and site conditions, as shown in Figure 11.14.

Features of drop box distribution:

- No slope maximum
- No need for even lengths of trenches (See Figure 11.14)
- Flexibility to construct and connect new trenches as needed
- Quick inspection at the box and ends of the trenches
- No standing effluent in solid pipe between septic tank and drop boxes

See Figures 11.13 and 11.14 on the next page.

FIGURE 11.13 Drop Boxes and Piping

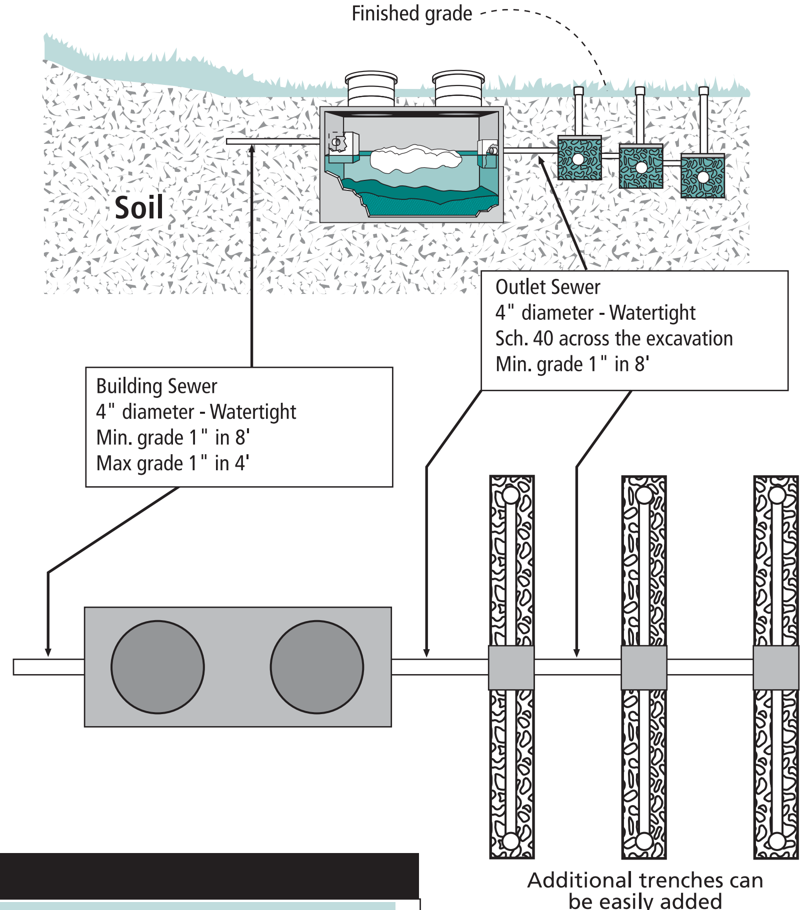
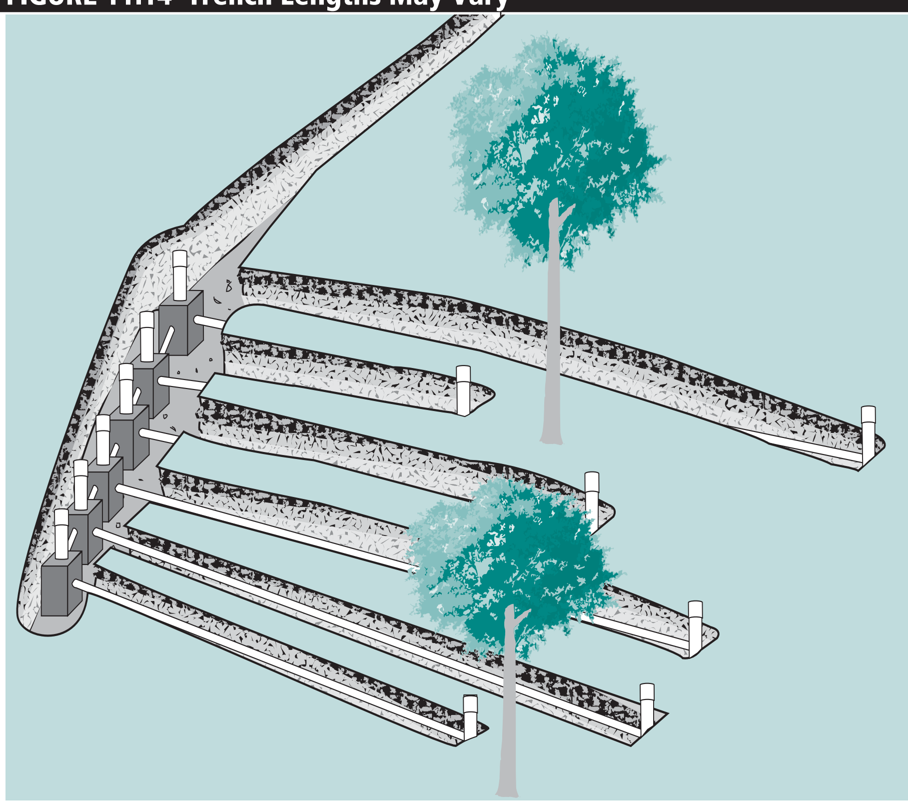


FIGURE 11.14 Trench Lengths May Vary



According to Chapter 7080.2050 Subp. 3 (B), when drop boxes are used for serial distribution, the drop box meet the requirement in Table 11.1.

TABLE 11.1 Drop Box Specs
1. The drop box must be watertight and constructed of durable materials not subject to corrosion or decay.
2. Drop boxes must have an invert of the inlet supply pipe at least one inch higher than the invert of the outlet supply pipe to the next drop box.
3. Drop boxes must have an invert of the outlet supply pipe to the next drop box no greater than two inches higher than the crown of the distribution pipe serving the trench in which the box is located.
4. When sewage tank effluent is delivered to the drop box by a pump, the pump discharge must be directed against a wall or side of the box on which there is no outlet or directed against a deflection wall, baffle, or other energy dissipater. The discharge rate into the drop box must not result in surfacing of sewage from the drop box. The supply pipe must drain after the pump shuts off.
5. The drop box must be covered by a minimum of six inches of soil. If the top of the box is deeper than six inches, access must be provided above, at, or within six inches of finished grade.
6. The drop box must be placed on firm and settled soil.

A detailed view of the drop box is shown in Figure 11.11 on page 10. A drop box should be installed in each trench. In addition to providing for loading of the soil treatment area, drop boxes also allow inspection of the system. Drop boxes may be constructed of concrete, fiberglass, or polyethylene. For installations where the drop box will have minimal soil cover (less then 1 foot), the installer should consider insulating the box. Drop box strength is a factor to consider when backfilling the SSTS.

The liquid level in a trench is established by the elevation of the supply line pipe leading to the next drop box. If the elevation of the bottom of the supply pipe is approximately equal with the top of the rock in the trench, this will achieve a liquid level that will maximize the trench sidewall, develop the maximum hydraulic head on the bottom of the trench, and maximize the potential for evapotranspiration during warmer months. When the first trench is accepting effluent at its long-term acceptance rate, any additional effluent will flow to the drop box of the second trench. Only the portion of the soil treatment unit required to treat the effluent is used.

Management of systems with drop boxes

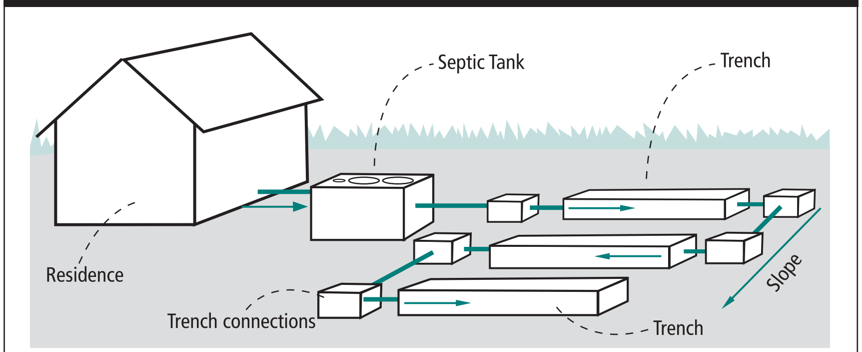
Drop boxes can be managed by the homeowner or an onsite professional. To rest the system, after a year or more of use, plug or cap the outlet pipe from the first box, or place an elbow on the outlet pipe. The effluent will then flow into the second drop box, by passing the first trench. The first trench will rest; the infiltrative surface may assist with the recovery of a trench segment if a clogging biomat has formed. The following year, after the first trench has been rested, the second trench can be rested. The first one may be reinstated or allowed to rest depending on the number of unused trenches. In a 2004 study by Owens et al., ten year old trenches were rested during the summer months. Following these rest periods, the effluent absorption rates increased 70-280%. These results indicate that resting improves the hydraulic function of soil treatment systems.

The drop box provides a convenient point at which to inspect the soil treatment unit. The drop box inspection pipe can be installed at the ground surface or covered with a few inches of soil to prevent it being hit by a lawn mower. Opening and inspecting the drop boxes will show if a trench is being used. By evaluating the inspection port at the end of the trench, it can be determined how much of the drainfield trench system is being used.

No drop box

Serial distribution can be achieved with out the use of drop boxes, but it is more challenging because management and expansion is more difficult. In serial distribution systems without drop boxes, the pipe from trench to trench is often dropped, with a 90º elbow or a T, into the top of the media, such as a chamber, with an outlet pipe at a higher elevation in the media.

FIGURE 11.15 Continual Distribution



Continual Distribution

In continual distribution (also known as "in-line distribution"), trenches are connected so that all effluent passes through the first trench on its way to the second, which it passes through on its way to the third as shown in Figure 11.15. This means that the first trench in the series will see all of the effluent unless another distribution/management option exists.

Effluent entering the second or third trench may have had some solids removed by passing through the length of the previous trench. High levels of organic matter or suspended solids tend not to reach the last trench. The biomat at this end of the system is expected to be a thinner layer, since there is little in the effluent for the bacteria to consume,and the effluent will drain more quickly. The soil pores at the end of the last trench will take a long time to develop a biomat. The first trench, however, is fairly likely to have problems, including:

- Soil pores becoming clogged
- The buildup of an impermeable biomat layer
- Hydraulic overload

The first trench of a continual distribution system must handle more than its share of suspended solids and organic matter.

When any part of the system gets clogged or otherwise fails, the rest of the system goes without having been used to its full potential. The primary features of continual distribution are:

- No slope maximum
- No limits on trench length
- Easy expansion

Valve Boxes

Valve boxes are another distribution option, similar to drop boxes. **MN Rules Chapter 7080.1100, Subp. 90 defines a valve box as a watertight structure designed for alternate distribution of septic tank effluent to segments of a soil treatment system.** Valve boxes have valves that open and close the outlets. **All the requirements of drop boxes apply to valve boxes (Chapter 7080.2050, Subp 3 (C)**. Valve boxes are often used with dual field systems.

Parallel Distribution

Parallel distribution is the distribution of septic tank effluent by gravity flow, loading all sections of the soil treatment and dispersal system equally at the same time. The parallel distribution system directs effluent flow into all trenches in the soil treatment unit simultaneously. Trenches are constructed to be of equal length and depth and to be suited for the same type of soil, so treatment occurs at the same rate in each trench. In theory, this allows for equal use of all parts of the system. However, in practice this rarely, if ever, happens. In practice, the trenches are never identical to each other, so the result is unequal flow.

Differences between the trenches are unavoidable: one trench may be dug in slightly more permeable soil or be slightly deeper or longer. Effluent will enter all the trenches at the same time and at the same rate; however, since it won't all be treated and leave the trenches at the same rate, the result can be backflow, as effluent leaves a full trench and moves to one that is emptying faster.

The parallel distribution system can freeze in winter since the solid pipes between the trenches and the distribution box sometimes contain standing effluent. Even when there is no backflow problem, there may be significant hydraulic head between the top of the system (the distribution box) and the trenches, with effluent in lower trenches being forced up to the soil surface—a surface failure. These systems must, therefore, be sited where the slope is not very steep (typically less than 5%), often not steep enough to take advantage of gravity.

To evenly distribute effluent to the soil, a pump is required to deliver the effluent to the trenches. Depending on elevation differences, parallel distribution systems can fail when a single trench fails if the trenches are not fed completely levelly and equally. Unlike the continual distribution system, in which a failure at one part of the system can also mean failure of most or all of the system, the parallel system offers no benefit in terms of improved effluent quality. Features of parallel distribution include:

- Common application
- Best for level sites

Application

Parallel distribution is only used when serial distribution is not an option due to site limitations. Parallel distribution spreads the effluent equally between all the trenches, which can limit the development of a biomat.

Distribution Boxes

A distribution box is defined in Minnesota Rules Chapter 7080.1100, Subp. 22, as a device designed to distribute septic tank effluent concurrently and equally by gravity to multiple segments of a soil treatment and dispersal system and must meet the requirement in Table 11.2. Distribution boxes are made of concrete or plastic and typically have one inlet and multiple outlets, with the outlets available in a variety of configurations. They work best on level or nearly level sites. In operation, septic tank effluent enters the box and flows out one or more of the outlets. The outlet pipes leaving the distribution box should have equal slopes for at least five feet beyond the box. Distribution boxes will rarely provide equal distribution to each outlet pipe.

TABLE 11.2 Distribution Box Specs
1. They must be water tight and constructed of durable materials not subject to corrosion or decay.
2. The distribution box shall be covered by a minimum of six inches of soil. If the top of the box is deeper than six inches, access must be provided above, at, or within six inches of the finished grade.
3. Inverts of all outlets must be set and maintained at the same elevation.
4. The inlet invert must be either at least one inch above the outlet inverts or sloped such that an equivalent elevation above the outlet invert is obtained within the last eight feet of inlet pipe.
5. Each trench line must be connected separately to the distribution box and must not be subdivided. Distribution boxes must not be connected to one another if each box has distribution pipes.
6. When sewage tank effluent is delivered to the drop box by a pump, the pump discharge must be directed against the wall or side of the box on which there is no outlet, or directed against a deflection wall, baffle, or other energy dissipater.

The condition necessary for the use of a distribution box is that the ground surface at the lowest trench be at least 12 inches higher than the outlets of the distribution box, this will prevent any effluent from surfacing until all of the trenches have been loaded with effluent. All trenches must be exactly the same length, and each must be able to treat the same amount of effluent as the others throughout its operational life. All of the outlets of the distribution box must be at exactly the same elevation when installed and after the system has been backfilled.

A study by the Federal Housing Authority showed that distribution boxes were rarely installed properly and recommended that their use be discontinued (Coulter and Bendixen, 1958). The theory of distribution box operation is difficult to realize in the field because all the trenches are often not the same length, at the same elevation, are not able to treat a like amount of effluent, and may settle over time, with the freeze thaw cycle. This situation is rarely true in practice.

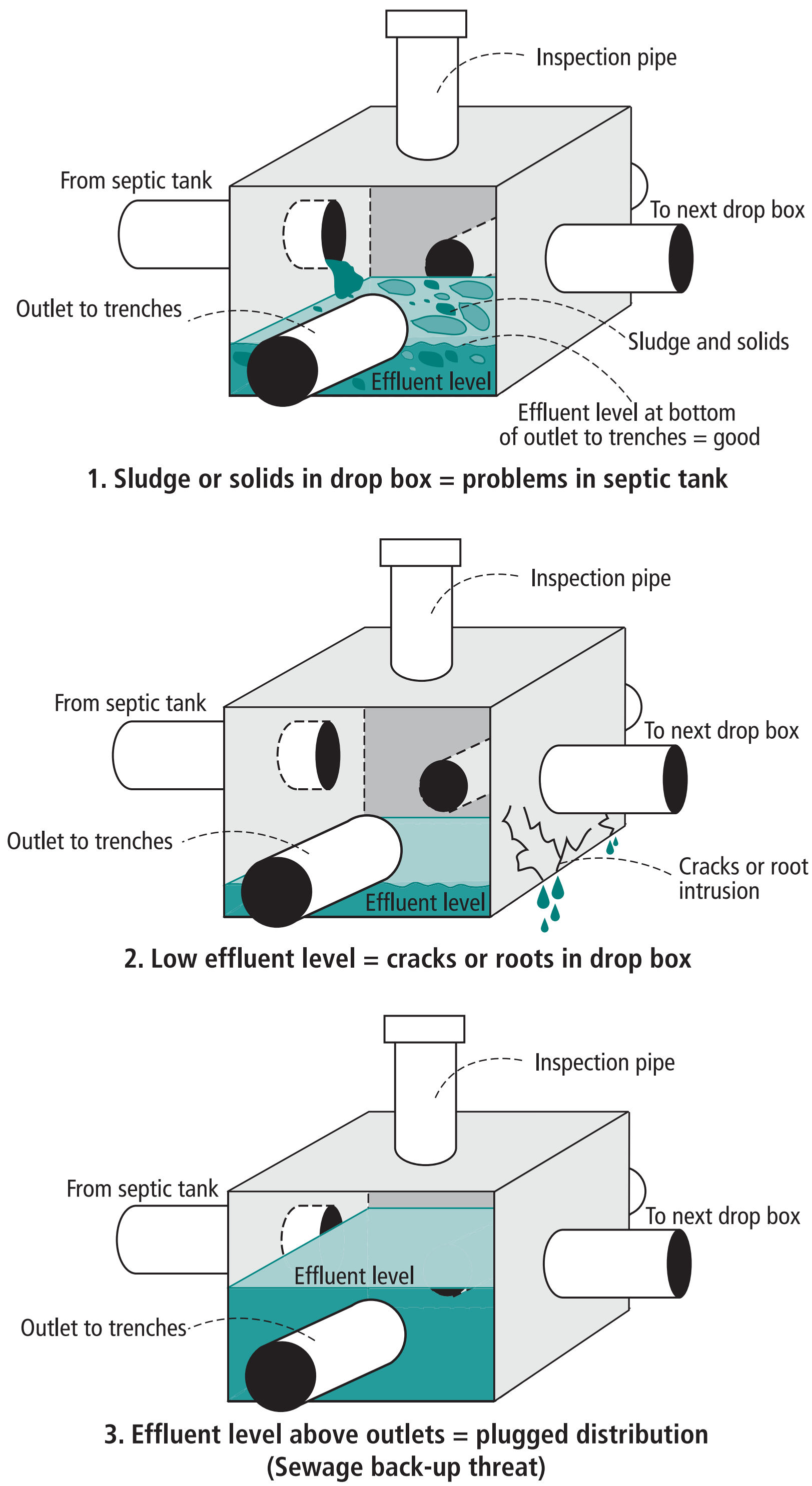
Distribution Box Modifications

Many devices have been developed to overcome the problems associated with distribution boxes. Some manufactures have developed distribution boxes that can be leveled after they are installed. A leveling device can be inserted in the end of the four-inch outlet pipes, which makes the outlet inverts somewhat level. These levelers need to be adjusted periodically. The distribution box outlet adjuster is a device that can be placed inside the distribution box into each pipe leaving the distribution box. These adjusters can be turned or dialed so that the inverts of the small openings are at exactly the same elevations or at different elevations to provide trench resting. The advantage of this approach is that it allows readjustments to be made when one side of the distribution box settles or when freeze-thaw activity or shrink-swell in the soil causes the distribution box to become slightly out of level.

Instead of trying to get equal flow to all trenches, it may be more appropriate to direct the flow to a given trench. This can be done by adjusting the levelers to different invert elevations or by placing an elbow on the outlet end of the pipe with the invert set at one-inch increments, with the lowest elbow invert set at the outlet pipe invert. In this case, all the effluent enters the trench with the lowest elbow or adjuster invert, causing the clogging mat to develop, and resulting in ponding at some time depending on loading rate, soil conditions, and other factors. If this trench cannot handle the flow, the effluent goes out through the next highest elbow (or leveler) to the second trench. If neither trench one nor two can handle the flow, the effluent goes out through the next highest elbow to the third trench, and so on. Once a year or so, the trench receiving the effluent for the longest time can be shut off and allowed to rest. The resting may reduce the biomat.

There are other proprietary devices available that can distribute the effluent somewhat equally to each trench, such as a tipping D-box.

FIGURE 11.16 Inspecting Drop Boxes



Management

There is limited management of systems with distribution boxes. Some boxes may have access to shut off and rest individual runs of the trench. The inspection ports at the end of each trench can tell you how much ponding is in the system and if the system may be reaching the end of its useful life. The distribution or drop boxes should be evaluated to assure that clean water is not entering or sewage leaking out as shown in Figure 11.16.

Manifolds and other distribution methods

Manifold pipe distribution is totally buried and connects several distribution pipes in parallel trenches or in beds. In trench systems, the septic tank effluent will flow into one trench as the header pipe is incapable of dividing the flow equally to all trenches. When that trench can no longer handle the flow, the effluent will back up and flow into another trench. Manifold distribution is easy and inexpensive to install. Header systems cannot be managed as individual trenches because the trenches cannot be taken out of service. Lines can potentially be added on if site and soil conditions are appropriate.

Installation of Gravity Distribution Components

Installation activities can greatly impact how closely gravity systems come to achieving even application. Distribution boxes and drop boxes must be properly bedded to remain stable over time. The proper bedding is a thin layer of washed rock placed on a level foundation of native soil. Alternately, they can be placed directly on a smooth, level foundation of native soil. Pipes exiting the device must be securely installed and stabilized or they will settle over time and may negatively affect distribution or allow infiltration. The elevation and orientation of any distribution device (distribution box, drop box) is critical because it determines the depth of the succeeding trench bottom. If trenches are installed too deeply, there may be inadequate separation to a limiting condition, resulting in inadequate treatment of effluent before it rejoins the hydrologic cycle.

Distribution boxes and drop boxes must be rendered watertight to prohibit infiltration by water and roots. Boxes that include pipe penetrations that remain watertight after installation are the best choice. Using concrete to seal pipes to boxes is ineffective and results in significant problems over time.

It is absolutely critical that distribution boxes be installed level because they are used on flat sites. If all trenches are installed at equal elevations, the pipes exiting the d-box should theoretically be on the same grade. If the pipes exit the box with different grade, unequal distribution will result. Pipes exiting a distribution box should be installed on identical grade. Otherwise they will not provide even distribution.

While leveling drop boxes is not as critical as leveling distribution boxes, they must still be installed so that they remain stable. The proper bedding is a thin layer (3 - 6 inches) of rock or pea gravel placed on a level foundation of native soil. Alternatively, they can be placed directly on a smooth level foundation of native soil.

Pressure Distribution

This section examines the distribution system that conveys the septic tank effluent to the soil treatment system for treatment and dispersal under pressure through a series of perforated pipes.

With pressure distribution, effluent is delivered either to taps in a pressure manifold (pressure-dosed gravity systems) or to multiple points across an infiltrative surface (low pressure or drip distribution). By definition, pressure distribution systems incorporate a pump or siphon to provide the energy needed to overcome the forces of gravity. Pressure distribution systems using pumps can be dosed either on demand or at specific times. Those with siphons are inherently demand-dosed. Use of a siphon is limited to sites where the soil treatment area (STA) is downhill from the siphon tank, but systems can still be pressurized because of the energy they provide. Effluent can thus be distributed along the entire length of an infiltrative surface without using electricity.

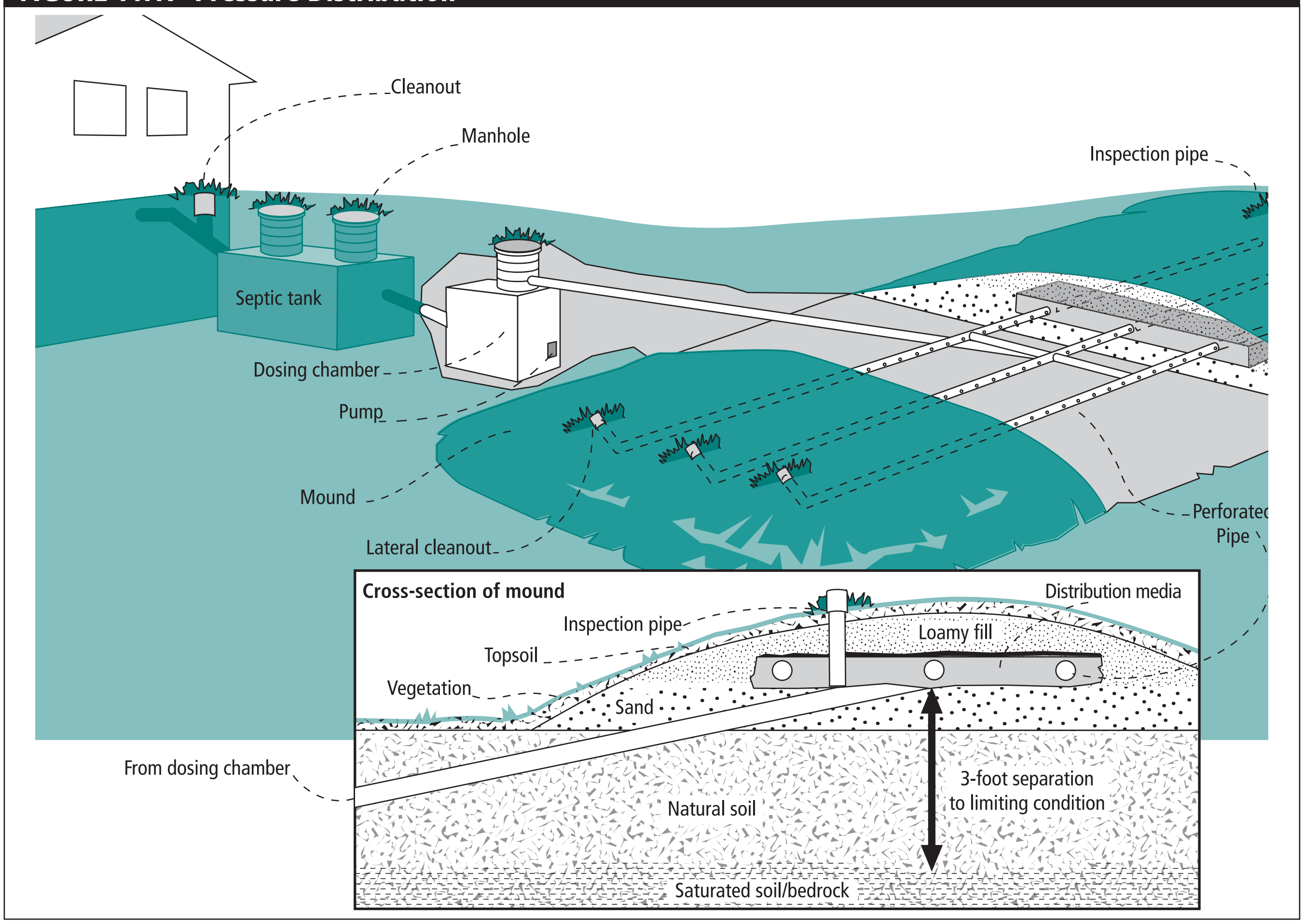
Chapter 7080.1100, Subp. 61 defines pressure distribution as a network of distribution pipes in which effluent is forced through orifices under pressure. Pressure distribution has been used for more than 40 years to apply septic tank effluent to soil treatment systems. In 1974, Converse et al. published a paper documenting the application and performance of pressure distribution systems particularly in sandy soils. Today, media filters and many other advanced treatment units rely on pressure distribution. Because this trend is sure to grow, professionals need to understand how pressure distribution works.

Pressure distribution substitutes for the biomat in gravity systems to distribute effluent across the infiltrative surface. It provides increased treatment efficiency on sites with soil and size limitations. A pump typically controls the application, which proceeds at a rate determined by the long-term acceptance rate of the soil or media. Pressure distribution at the proper rate maintains an aerobic (oxygen rich) environment that allows for effective treatment.

Any pressure distribution system has four interdependent components, as shown in Figure 11.17:

- Pump tank and pump that pressurizes the system
- Pump controls
- Pipes that deliver the effluent
- Orifices that discharge effluent into the treatment area

FIGURE 11.17 Pressure Distribution



Each has important design and installation requirements.

Pressure distribution applies effluent uniformly over the entire infiltrative surface such that each square foot of bottom area receives approximately the same amount per dose at a rate less than the saturated hydraulic conductivity of the soil. This application promotes soil treatment performance by maintaining vertical unsaturated flow and also may reduce the degree of clogging in finer-textured soils. Pressure distribution closely approaches uniform distribution. In a field study, the more uniform distribution of effluent offered by pressure distribution resulted in better aeration and nitrification during system start-up. Fecal coliform removal was significantly lower in pressure-dosed systems over the course of the study (Bomblat et al., 1994). Uneven distribution of effluent can result in localized overloading and the system failure.

One often overlooked benefit of pressure distribution is that it ensures resting periods between applications, allowing time for the soil or media to recover. Designs should allow for a number of resting periods. A typical pressure distribution system is designed with four dosing and resting periods per day. Equally spaced applications allows resting between doses and more uniform application, resulting in more consistent oxygen transfer and better treatment potential. A timer can further assist in spreading out the application of effluent. Typical demand dosing, by comparison, which turns the pump on whenever sufficient effluent is available. Pressure distribution is usually used in locations where it is either desirable or required to:

- achieve uniform application of effluent throughout the soil treatment area;
- disperse effluent higher in the soil profile;
- avoid potential contamination of groundwater beneath excessively permeable soils;
- improve the treatment performance and extend the life expectancy of a drainfield or other component;
- reduce the potential for breakout or seepage on slopes;
- distribute effluent to all above ground-systems;
- avoid potential contamination on sites in aquifer-sensitive areas;
- avoid potential contamination on sites with limited soil depth;
- disperse effluent evenly for larger drainfield systems; and
- disperse effluent evenly in conditions where pumping is needed due to elevation problems.

One disadvantage of pressure distribution is that it needs a pump tank, pump, controls, and an alarm. This means the owner has to pay for these components along with electrical service and usage.

Another issue with pressure distribution is that the orifices must be kept clear for the system to work properly. Septic tank effluent inevitably contains some solids, which can plug the system. Effluent screens which are increasingly popular, further limit the size of suspended solids leaving the pump tank. Maintenance of the septic tank and distribution system is critical for long-term performance.

Purpose and Application

Under Chapter 7080.2050, Subp 4 (A), pressure distribution is required in several situations:

1. Mound systems
2. At-grade systems
3. All seepage beds with a width greater than 12 feet
4. Systems receiving pretreated effluent (levels A, A2, B, or B2)
5. All systems where the distribution network is installed above the original grade
6. All MSTS systems (7081.0250)

MN Rules Chapter 7080.2210 Subp. 4 (F) (1) identifies pressure distribution as one of three treatment options for trenches or seepage beds in which the distribution media is in contact with any sand textured soils with a percolation rate of 0.1 to 5 minutes per inch.

Pressure distribution systems are designed so that the volume of septic tank effluent flowing out of each orifice of the distribution pipe is nearly identical. The pipe diameters and orifice diameters must be appropriately sized to achieve uniform distribution. A pump placed in a pump tank is used to deliver the septic tank effluent. **A pump tank is defined as a tank or a separate compartment following the septic tank that serves as a reservoir for a pump (MN Rules Chapter 7080.1100, Subp. 64).** For more information on pump tanks and pumps, see Section 8.

Pipe Specifications

The distribution piping system includes supply pipe, which carries effluent from the septic tank to the pressure distribution system, and laterals, which actually distribute the effluent. The volume necessary to fill the pipe—the amount of effluent needed to charge the system before even distribution occurs—is an important variable. The dose volume must be four times the amount to pressurize the system (7080.2100, Subp. 4 (D)). In cold climates, another issue is the volume that drains back to the pump tank when the pump turns off. Drain-back is necessary to prevent freeze-ups. However, if this volume is too great, the system becomes less efficient because the pump must move a significant amount of effluent more than once. The size and kind of supply piping determine friction loss, which affects the pressure requirement. Larger diameter pipe has less friction loss, and thus requires less total dynamic head and may allow for a smaller pump. On the other hand, more materials costs are incurred when larger pipes are employed.

Supply Pipe and Manifold Requirements

The supply pipe delivers the effluent from the dosing chamber to the manifold. The supply pipe diameter is dependent on the system flow rate. From the head loss values given in Table 11.3, select a pipe diameter that will have a low head loss at the given flow rate. The head loss in this pipe affects the sizing of the pump; see Section 9: Pumping Systems for more information. Note that the head losses listed are for a 100-foot length of pipe. After the main diameter is selected, compare it with the chosen manifold diameter. If the manifold is smaller than the supply pipe, increase the manifold diameter to match the supply pipe.

The supply line for pump systems must be properly bedded and the connection between the discharge assembly and the supply line should be secure and stable. The supply line must be appropriately sized and pump capacity must be considered if changes are made. If the elevation of the supply line changes between the pump tank and the next component, air may become trapped in the line during rest periods and affect performance. In this situation, an air release valve should be specified for installation at the highest elevation of the line or pipe. The valve should be housed in a vault that comes to final grade to allow for inspection and maintenance. If the installer determines that any such device should be added to a system, the affect on pump performance must be assessed.

TABLE 11.3 Head Loss per 100 Feet, Based on Flow Rates: C = 130

	Nominal Pipe Diameter						
FLOW RATE (GPM)	1”	1.25”	1.5”	2”	2.5”	3”	4”
10	9.1	3.1	1.3	0.3			
12	12.8	4.3	1.8	0.4	0.1		
14	17.0	5.7	2.4	0.6	0.2		
16	21.8	7.3	3.0	0.7	0.3	0.1	
18		9.1	3.8	0.9	0.3	0.1	
20		11.1	4.6	1.1	0.4	0.2	
25		16.8	6.9	1.7	0.6	0.2	
30		23.5	9.7	2.4	0.8	0.3	
35			12.9	3.2	1.1	0.4	
40			16.5	4.1	1.4	0.6	0.1
45			20.5	5.0	1.7	0.7	0.2
50				6.1	2.1	0.9	0.2
55				7.3	2.5	1.0	0.3
60				8.6	2.9	1.2	0.3
65				10.0	3.4	1.4	0.3
70				11.4	3.9	1.6	0.4
80				14.6	4.9	2.0	0.5
90				18.2	6.1	2.5	0.6
100					7.5	3.1	0.8
125					11.3	4.6	1.1
150					15.8	6.5	1.6
175						8.6	2.1
200						11.1	2.7

According to MN Rules Chapter 7080.2050, Subp. 4 (H), pressure distribution laterals must be connected to a header or manifold pipe that is of a diameter such that the friction loss in the header or manifold will be no greater than five percent of the average head at the orifices. The manifold connects the laterals and distributes the septic tank effluent to each lateral. Manifolds and supply pipes are usually PVC pipe with appropriate ‘L’ or ‘T’ fittings. The manifold pipe should be connected to the supply pipe from the pump, and sloped toward the supply pipe. The manifold should be the same diameter as the supply pipe. The size and position of the manifold and main will vary for each pressure distribution system.

Depending on the site conditions and the design of the pressure distribution system, the manifold may be run along one end or down the center of the distribution system. See Figure 11.18 for an end manifold and Figure 11.19 for a center manifold connection. The benefit of a center manifold is that it allows more orifices per lateral while maintaining the required minimum friction loss.

FIGURE 11.18 End Manifold

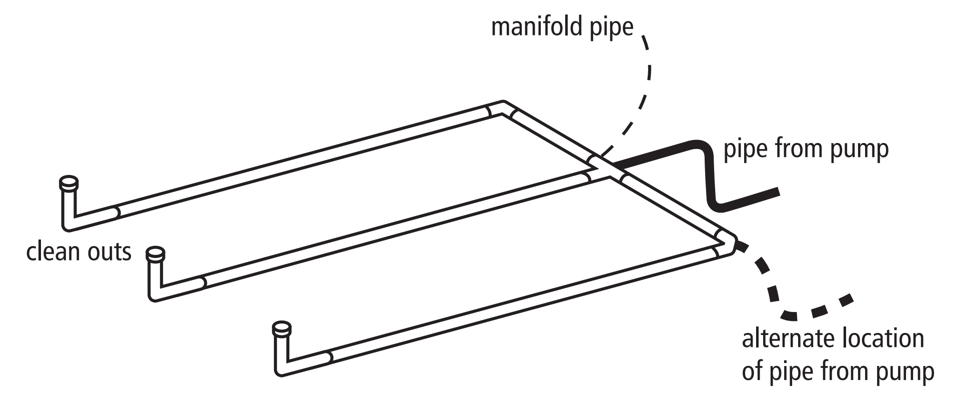
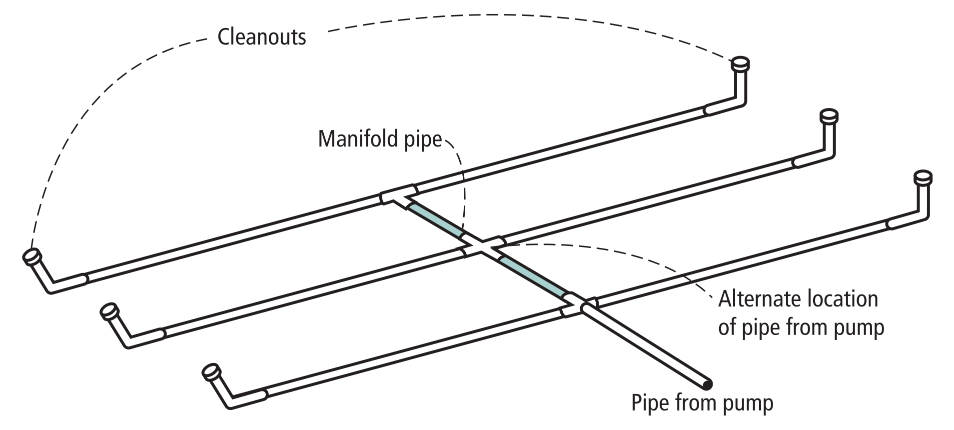


FIGURE 11.19 Center Manifold



The manifold must be installed level. If it is not level, effluent will flow by gravity to laterals at the lowest elevations during filling (pressurizing) and draining (de-pressurizing) stages of the dosing cycle. Use proper bedding materials and techniques to ensure a stable installation.

The size of the taps in the manifold affects the system flow. For a long manifold on a level site, the taps should be spaced to correspond to the trench spacing to eliminate the need for additional elbows that will increase friction losses (and costs). Use a string line to mark the manifold to ensure the taps are drilled in a straight line. This provides the proper orientation for connections.

With a Schedule 40 PVC manifold, the taps will consist of reducing tees which should be joined to the pipe using appropriate adhesives. Do not attempt to drill and tap a Schedule 40 manifold. A Schedule 80 PVC manifold has a wall thickness sufficient to allow the installer to drill and tap the fittings without compromising pipe strength. The correct diameter drill and associated tap is critical for these activities to avoid changing system flow. All burrs should be removed from the drilled and/or tapped orifices, and the assembled network should be flushed through open cleanouts using clean water to remove all debris. This prevents clogging of taps in the manifold or orifices in the field after startup.

Designing the Pressure Distribution System

This section presents steps to design and construct components of the pressure distribution system. These steps can be used to design pressure distribution systems where each lateral is at the same elevation. A reference can be found online at septic.umn.edu. To develop a pressure distribution system for a series of laterals at different elevations, consult the “Non-Level Distribution” section and worksheet.

In a pressure distribution system, small-diameter pipes are used to distribute the effluent. The four-inch perforated pipe used in conventional soil absorption systems is not suitable because it is too large, and the orifices are not appropriately sized and spaced to provide even effluent distribution.

Sch 40 PVC pipe and fittings are used in pressure distribution systems. The pipe and connections must be able to withstand a pressure of at least 40 pounds per square inch. Pressurized distribution laterals must be installed level, and the orifice must be free of burrs. Orifices may be spaced no more than three feet apart, and a method to introduce air into the pipe after dosing must be provided. The pipes must completely drain after the pump turns off.

The pipe diameter, orifice diameter, and orifice spacing must be determined for each pressure distribution system. As the lateral diameter increases, the maximum allowable length increases, but as lateral diameter decreases, the velocity in the pipe increases. Increased velocity is a benefit, as it helps keep solids suspended. The length of the laterals is related to the number and size of the orifices.

For uniform distribution, the discharge from each orifice must be effectively the same or within ten percent of the others. Table 11.5 (page 11-27), from MN Rules Chapter **7080.2050, Subp. 5 (E),** meets this requirement, so as long as the spacing, pipe diameter, and orifice size you have chosen produce a sufficient number of orifices, you can proceed.

Table 11.5 is calculated by using the friction loss over the laterals. By using the friction loss or F factor for pipes with multiple outlets (shown in Table 11.4), the friction loss is calculated as if the entire flow were moving through the entire pipe. To assure the discharge is within ten percent, the friction loss in the pipe should not be greater than two percent of the average operating pressure head. The pressure head should be between one and five feet at the end of each lateral. For a system with a design pressure head of one foot, the maximum allowable friction loss would be 0.20 foot. By using the F factor and

TABLE 11.4 “F” Factors for Pipe with Multiple Outlets

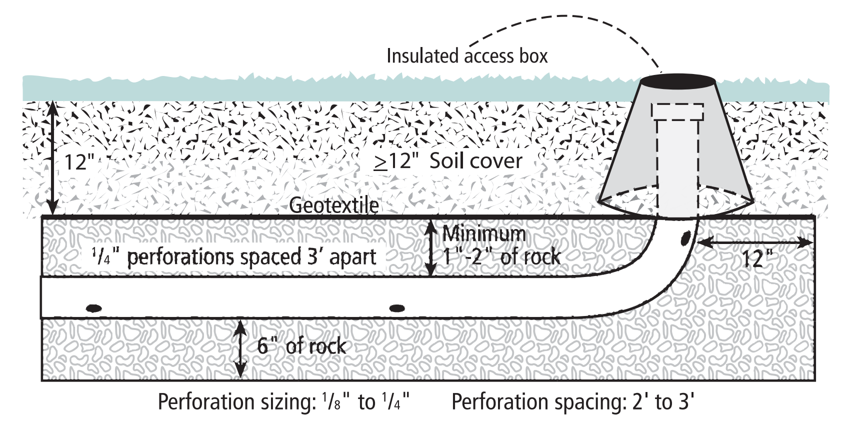
Number of Perforations	“F” Factor
6	0.432
8	0.409
10	0.396
12	0.387
14	0.380
16	0.376
18	0.372
20	0.370
30	0.360

the friction loss for plastic pipe, a designer can determine if any pressure distribution design will meet the requirement.

Pressure systems have many components, but none are more important than the orifices in the distribution pipe. Taking the role of orifices lightly can lead to disastrous consequences. Proper design and installation of orifices is critical to creating a system that uniformly distributes effluent. Key design parameters include the size of the orifices, location, and spacing in the pressure distribution lateral. Friction losses relate to the diameter of the pipe and the flow. The larger the orifices and length of pipe, the more flow is necessary to properly charge the pipe. This translates into a maximum length for the laterals based upon the size of orifices and the size or diameter of the pipes. All pressurized laterals should be the same size.

The number of orifices may be adjusted slightly to match the available pump capacity and head. The orifices should be staggered between adjacent laterals, if possible. The last orifice should be drilled at the end of the lateral, at least one foot from the media edge, and in the elbow or sweep of one of the cleanout accesses (see Figure 11.20 for specifications). It is important that this orifice be below the media to assure that effluent does not freeze in the access box. This final orifice facilitates venting as the pipe fills and drains. If rock is used as the distribution media, at least six inches must be placed under the pipe and two inches over the pipe.

FIGURE 11.20 Lateral End Specification



The designer needs to balance the diameter of the pipe with the size of the orifices to provide the necessary lateral length to maintain equal distribution across the area. The larger the orifice size, the greater the capacity the pump must be able to deliver. Large orifices allow fewer orifices per lateral to achieve even distribution, resulting in shorter maximum lateral lengths. The smaller diameter orifices have smaller flow requirements, smaller pumps, and greater maximum allowable lengths. Smaller orifices create additional management requirements because they are more subject to plugging. This issue can be addressed in one of three ways:

1. Include a screen or filter upstream from the pressure distribution system. Removal of solids from the effluent reduces the risk of plugging. Effluent screens are only required when the dwelling includes a garbage disposal or pump in the basement, but is advantageous for all systems.
2. Increase the pressure at each of the orifices. The higher the pressure at the orifice, the less likely it is that solids will hang up and plug the orifice. Typical designs using quarter-inch orifices operate at a pressure of one to two feet of head. For smaller orifices (1/8 or 3/16 inch) a greater operating pressure is beneficial.
3. Provide access for maintenance. Even if all solids are removed from the effluent by filtration, the growth of solids in the distribution system remains a threat **(Chapter 7080.2050, Subp. 4 (J)).**

Steps to designing the pressure distribution system

1. First, establish the dimensions of the system from estimated daily flow rate and soil conditions.
2. Next, determine the length of the laterals and the distance between laterals. At this time the designer also chooses an orifice diameter, although it may be adjusted later in the design if modifications are needed. The laterals do not all need to be the same length. **One foot should be subtracted from each edge of the distribution media because perforated laterals must not be installed closer than 12 inches from the edges of the absorption bed, and perforations must not be installed closer than 12 inches from the ends of the absorption bed, as shown in Figure 11.20. Pressure distribution laterals must be spaced no further than 36 inches apart in seepage beds and mound absorption beds, and no further than 24 inches from the outside edge of the bed.** The lateral length is measured from the distribution manifold to the end of the lateral.
3. Select a perforation spacing from two to three feet. Previous to the 2008 rule change, spacing was allowed up to five feet, but with smaller perforations spacing and higher density, the effluent is more uniformly distributed. The perforations can not be more than three feet apart.
4. Select a perforation size from 1/8 to ¼ inch in diameter. For systems serving single-family homes, ¼ inch perforations are typically used. Perforations larger then ¼ inch in diameter require larger pipe diameters and greater pump capacity and are not allowed.
5. Determine total number of perforations per lateral. This is equal to the number of spaces plus one additional perforation in the cleanout access. The number of orifices is calculated by taking the length of each lateral and dividing it by the spacing, then rounding down and adding one. Table 11.5 shows the maximum number of 1/8 – ¼ inch perforations per lateral to guarantee less than ten percent discharge variation for various pipe diameters (from **MN Rules Chapter 7080.2050, Subp. 4 (D)).** If the number of perforation designed is greater then the amount allowed in Table 11.5 the orifice diameter can be decreased, the pipe diameter increased, the spacing increased, or the system may be fed with a center manifold. The total number of perforations allowed across the length of a system is double the amount in Table 11.5, if the system is fed with a center manifold.
6. Next, determine the total number of perforations in the system. This is done by taking the number per lateral and multiplying by the number of laterals if they are all the same length. If they are not, you must determine the number in each lateral and add them together. At this time you can determine the square feet per perforation, which should be less than 10 ft^2 / perforation.
7. The next step is to determine the required discharge of the pump in gallons per minute (GPM). Select the **pressure head** to be maintained at the end of each lateral. The head should be between one foot and five feet. **The pump discharge capacity must be based on the perforation discharges for a minimum average head of 1.0 foot for 3/16-inch to 1/4-inch perforations and 2.0 feet for 1/8-inch perforations for dwellings. The minimum average head must be 2.0 feet for other establishments with 3/16- to 1/4-inch perforations and 5.0 feet of head for 1/8-inch perforations (Chapter 7080.2100, Subp. 4 (B)). For MSTS the minimum average**

head is two feet for 1/4 inch and 3/16 inch perforations and five feet for 1/8 inch perforations (Chapter 7081.0260 (C)). Using the selected head and the perforation diameter, the flow rate per perforation can be determined from Table 11.6. The figures in this table are calculated from the equation found in Chapter 7080, Subp. 4 (B). Calculate the lateral flow rate by multiplying the flow rate per perforation by the number of perforations in the lateral.

TABLE 11.5 Maximum Number of Perforations per Lateral

Perforation Diameter in (inches)	Perforation Spacing (feet)	Pipe Diameter (inches)				
		1	1.25	1.5	2	3
1/4	2.0	10	13	18	30	60
	2.5	8	12	16	28	54
	3.0	8	12	16	25	52
3/16	2.0	12	18	26	46	87
	2.5	12	17	24	40	80
	3.0	12	16	22	37	75
1/8	2.0	21	33	44	74	149
	2.5	20	30	41	69	135
	3.0	20	29	38	64	128

TABLE 11.6 Perforation Discharges in GPM

Head (feet)	Perforation Diameter (inches)			
	1/8	3/16	7/32	1/4
1[a]	0.18	0.42	0.56	0.74
1.5	0.22	0.51	0.69	0.90
2[b]	0.26	0.59	0.80	1.04
2.5	0.29	0.65	0.89	1.17
3	0.31	0.71	0.98	1.28
4	0.36	0.82	1.13	1.47
5	0.41	0.94	1.26	1.65

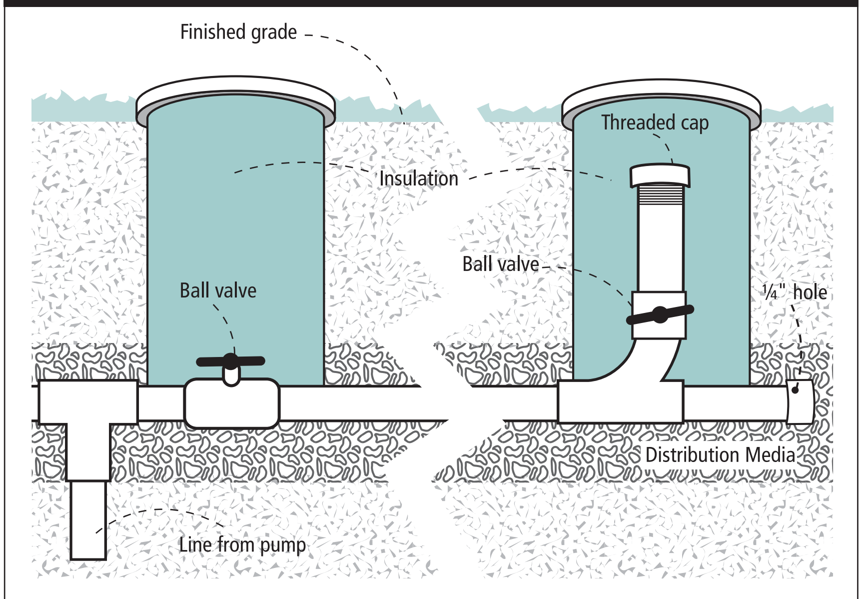
[a] Use 1.0 foot for 1/4 inch and 3/16 inch perforations
[b] Use 2 feet of head for 1/8 inch perforations for dwellings and for all other establishments

8. Select a maximum pipe diameter based on either a center or end manifold. Effluent is distributed by one to three inch diameter perforated pipe under pressure. Based on the lateral flow rate, manifold length, and lateral spacing, determine the minimum pipe diameter. If the desired pipe length or spacing is not listed, use the next greater length listed.

9. Based on the pipe diameter chosen, calculate the volume of effluent required to charge or fill the pipes. This is the amount of effluent that is required to be delivered by the pump before even pressure distribution is achieved. From Table 9.3, select the gallons per foot of pipe based on the distribution, manifold, and supply pipe diameters in inches. Then take the total length of each diameter of pipe and multiply by the length of each section. When added together, this volume in gallons is the amount to fill all the pipes. The dose volume can then be calculated by taking four times the amount of effluent to fill the distribution pipes only (Chapter 7080.2100, Subp. 4 (D)).

10. Pressure distribution pipe cleanouts must be provided to check the system for proper operation and cleaning of plugged perforation. According to MN Rule Chapter 7080.2050, Subp 4 (J), cleanouts must be accessible from the final grade. These clean-outs should:
    - Have threaded removable caps or plugs on the ends of the laterals to allow for cleaning the laterals and for monitoring the lateral pressure
    - Be large enough to allow access to caps or plugs with hands, tools, etc.
    - Be accessible from the ground surface

FIGURE 11.21 Lateral End Clean-outs



Cleanouts are placed at the distal end of pressurized laterals to allow flushing of the system prior to startup, measurement of operating pressure and regular flushing of solids. The pipe configuration of the cleanout varies, but the most basic and convenient cleanout consists of a 90 degree turn up. Two 45 degree elbows or one sweep 90 degree elbow may be used. Using these allows the service provider to use a pressure washer or bottle brush for cleaning purposes because the gentle turn allows easy insertion of the pressure line. If a cap assembly is used, a female screw cap is easier to remove during O&M activities. Alternately, ball valves may be installed at the distal end of the lateral in a vertical position. These can be opened to flush laterals using pump pressure. Figure 11.21 is an example of a cleanout with a ball valve.

There does need to be a perforation part way up the elbow to make sure that air is able to re-enter the pipe after the pump shuts off. The clean-out is then brought to grade and covered with a landscaping box. It is recommended that rock be placed in the box to cover the perforation so effluent isn't spraying freely in the box. UMN OSTP recommends the larger sized boxes as with the small ones it is difficult to get your hand inside to remove the threaded cap. Insulation is also recommended on the lid of this box. Some installers also place removable insulation around the cleanout.

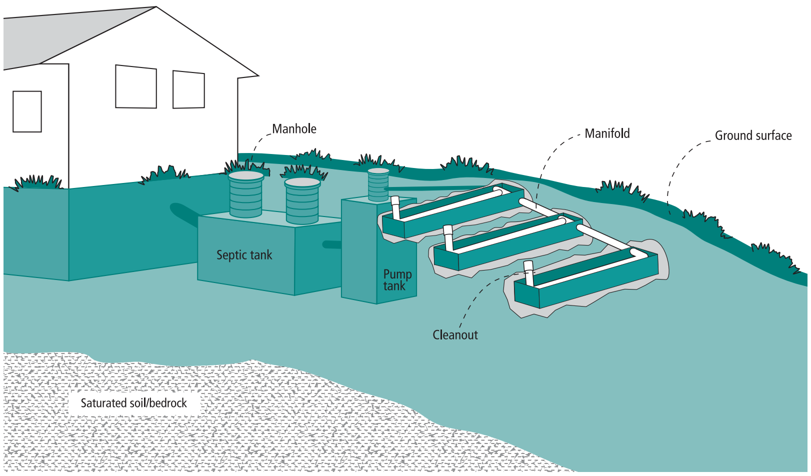
Make sure that the access is completely stabilized to prevent shifting during backfill activities. Its location and orientation should be verified during installation to ensure the cleanouts are ultimately located in the center of the access upon completion of the installation.

Inspection ports to the infiltrative surface are also required in pressure distribution systems. They should be

- Accessible from the surface
- Open and slotted at the bottom
- Void of gravel to the infiltrative surface to allow visual monitoring of standing effluent in the trench or bed

Design for pipes at different elevations

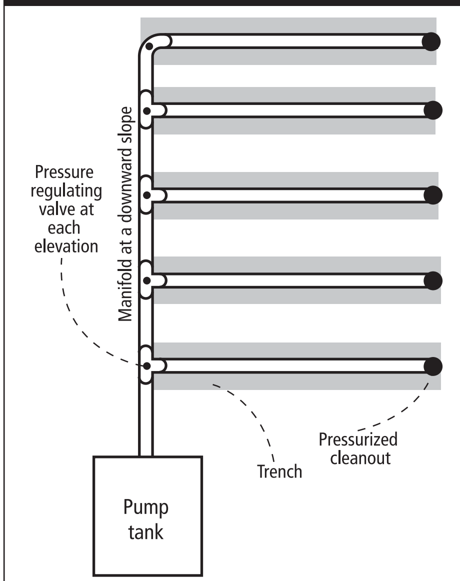
FIGURE 11.22 Non-level Pressure Distribution



Local program requirements or site conditions may dictate the use of pressure distribution in trenches. Trenches cannot be installed level and meet vertical separation requirements in many sites. Figure 11.22 shows non-level trenches down a hillslope. To design a pressure distribution system with laterals at different elevations, there are four methods from which to choose:

1. Have a separate pump for each lateral/zone at a different elevation. This option may be more applicable with larger flow systems split into several zones. Switching valves can also be used to dose several zones within a system with one pump.
2. Use valves to regulate the pressure head in each lateral/zone so it is equal. This option requires squirt height testing at system start up and adjustment over the life of the system as shown in Figure 11.23.
3. Some types of drip distribution are pressure compensating and can account for pipes at differing elevation (see Drip Distribution Section).
4. Vary the perforation size, spacing, and pipe length to assure even distribution from one lateral/zone to the next.

FIGURE 11.23 Non-level Pressure Distribution



The nonlevel pressure distribution worksheet found at septic.umn.edu can be used to complete this design using the following steps:

a. Determine the elevation and length of each lateral.
b. Calculate the difference in elevation from the lateral at the highest versus the lowest elevation.
c. Add in the required head at the perforation (one to two feet.)
d. Calculate the pressure head at each elevation.
e. Estimate a perforation size and determine the flow rate per orifice for each lateral.
f. Calculate gallons per minute per foot for lateral at highest elevation with an estimated spacing.

g. Balance gallons per minute per lateral for each of the other elevations by varying the length of pipe, perforation size, and spacing so equivalent gallons per minute per foot are being delivered.

h. Add gallons per minute for each lateral to determine the total gallons per minute required.

Installation

Manifold construction

The connections elevations between the manifold and the laterals and between the manifold and the supply pipe determine how the system drains. If the manifold and laterals are connected at the same elevation with staggered tees, the manifold volume will drain through the perforation. If the manifold and laterals are connected at different elevations, with the manifold higher, and using tee-to-tee connections, the manifold volume will be part of the delivery pipe system, because effluent will drain back to the pump tank. The supply pipe should be sloped back to the pump tank so that effluent drains back to the tank between doses. This helps minimize the potential for freezing in cold climates.

Distribution piping construction

According to MN Rules Chapter 7080.2050, Subp. 4, (C), pressure distribution pipes and associated fittings must be properly joined together. The pipe and connections must be able to withstand a pressure of at least 40 pounds per square inch. Care during the connection of the pressure distribution system will ensure proper system operation. All connections in the pressure distribution system must be properly primed, glued and tight in order to prevent leakage and to withstand pressure. Proper connection of the pipes is a critical element of system construction. Pressure-rated PVC pipes and connections are installed using glue, and proper gluing requires the use of a cleaner. In fact, many codes recommend that the cleaner be purple so that inspectors can verify that the cleaner was used. The cleaner prepares for the glue that welds the pipes together. Once the pipe is clean, the next step is to apply the glue. A ¼ turn of the pipe, once glued, helps solidify the connection. Pressure fitting means that twice as much area is exposed to the glue, creating a better connection. Cleaner and glue are applied using an applicator supplied with the materials. The applicator should be kept clean. Users should avoid excessive glue, because when the glue hardens, it can actually break into particles that can contribute to plugging of the perforation. When cutting the piping, be sure that the filings do not go into the pipe as they can cause a perforation restriction.

Temperature is also critical when constructing the system. Cold pipe can be brittle and crack during transport. Installers must use the proper glue for the temperature at the time of installation. Temperature also affects the speed at which the glue sets. The colder the weather, the longer it takes for the glue to set up. Holding the sections longer allows for a better connection. Also, be very careful that rock, soil, and other debris do not get in the pipe as these can plug the perforations.

Perforations

Perforations are drilled perpendicular to the pipe in a straight line, typically along the underside of the pipe. An orifice drilled at an angle creates an oval-shaped opening that has more area than a round one, increasing the flow through the perforation. This change in flow in turn affects the uniformity of distribution. Again, the smaller the perforation, the more critical this becomes. Being a "little off" and expanding a ¼ inch perforation will have a smaller impact than if a 1/8 inch perforation is expanded. In fact, for drilling smaller perforations, using a drill press is a good idea. The perforations should be drilled as uniformly as possible. A good, sharp drill bit should be used, and the plastic material removed should be cleaned from inside the pipe. Great care should be used to keep plastic shavings from entering the system, as these can easily become permanent plugs once effluent begins flowing through the laterals. Any burrs or rough edges must be removed from the orifices so they do not collect debris and become clogged. Sliding a rod or small-diameter pipe along the inside of the lateral pipe works to remove burrs. During construction, protect the ends of pipe to keep dirt and rodents out of pipes.

Perforated laterals must be installed level with either all of the orifices pointing downward or with a small percentage (10-20%) facing upward to drain the pipe of all the effluent. In systems utilizing rock as the distribution media and ¼ inch perforations, all the perforations are typically pointed downward, but in the case of installations with smaller perforations or with other distribution media, having a majority of orifices pointing upwards has advantages. The advantages include a more even distribution of effluent and reduced likelihood of perforation being blocked by the media. A method to introduce air into the pipe after dosing must be provided. This is typically achieved by a perforation in the elbow or sweep of one of the cleanout accesses to assure a vacuum is not created. **The pipes must completely drain after the pump turns off (Chapter 7080.2100, Subp. 4 (F)).**

A requirement under an increasing number of state codes is the installation of perforation/orifice shields—removable coverings that protect each orifice from media. This protection is important because if the perforation is covered or partially covered by the distribution media or rock, the actual flow from that perforation will be less than designed. This can contribute to plugging with solids, resulting in non-uniform distribution on the treatment surface. Shields become more critical as perforation size decreases. The smaller the perforation, the more easily the media can affect the flow and the greater the potential for varying distribution. A number of orifice shields are commercially available.

Management

Experience with pressure distribution has indicated that laterals have the potential for plugging. Even with large perforation and high pressure, it is possible for solids to plug up the perforations. Providing maintenance access is probably the single most important component for long-term operation of a pressure distribution system. If proper access, which has been required since 2008, is provided at installation, regular maintenance can be an easy job. When lateral ends are buried, the only time maintenance takes place is after the system fails. To ensure long-term system performance, the laterals must be periodically flushed or cleaned. Typically, access for maintenance is provided by putting a valve box at the end of the pressure distribution lateral and bringing it near the surface. A threaded cap allows easy removal and access. This access is located in a valve box at the end of each lateral.

The best way to provide access is to bring a pipe off the end of the lateral using sweep 90-degree fittings or two 45-degree-angle elbows. A threaded cap in which an orifice is drilled is used at the end. The orifice should be drilled to the side to avoid spraying directly up to the top of the valve box. However, in cold weather, spray into the valve box can cause freezing, so this method should be used cautiously, and if used, insulation should be provided around the box. A preferred method would be to install a ball valve at the end of each lateral. During normal operation, these valves are turned off, but they can be accessed one at a time when flushing the distribution laterals. The distal pressure at the end of each lateral can be checked by threading in a cap with an orifice pointing upwards on each lateral. The height to which the effluent squirts up should be the same in each lateral. If it is higher in one lateral versus another, this indicates that the lateral with a greater squirt height has plugging in some of the orifices and that flushing and cleaning is needed.

Partial plugging of the distribution piping may also be detected by long dosing times, such as 25% extra run time per dose, or a decreased drawdown following the dose event (decrease from original settings). The ends of the distribution laterals should be exposed and the pump activated to flush out any solid material. If necessary, the pipe can be cleaned. Any visible solids or effluent which discharge from the pipe should be removed from the site and properly disposed of.

Under normal operation the inspection ports in pressure distribution system should be dry unless the pump has just delivered a dose to the system. If prolonged ponding exists, further investigation of the system is required to determine if it is being hydraulically or organically overloaded.

Drip Dispersal

Drip dispersal is a method of distributing effluent into the soil with pressure distribution. As of the publication of this manual, no drip dispersal products have been registered for use in Minnesota, meaning that any application would be considered a Type V system and must be designed by a PE and Advanced Designer. Typically drip dispersal systems use pretreated effluent as a source of nutrients and moisture for plant growth. The pretreated effluent is piped under pressure to the soil treatment site, where it “drips” out of tubing at regular intervals. In this way, a small amount of effluent irrigates a large vegetative area, maximizing both uptake of water by plants and evaporation. Topsoil with vegetation is an excellent environment for treatment. Treatment of septic tank effluent is maximized, and the risk of untreated effluent flowing quickly through the soil is minimized. Suitable soils, separation, and area are required.

Drip irrigation has been used for many years in agricultural settings but has only been employed successfully in the United State to distribute wastewater effluent since the late 1980s. Most of the initial experience with drip technology has been in the south-eastern United States. In the past years, the technology has been of national interest, and there are now a number of states, including Minnesota, which are conducting research, developing standards, and/or actively permitting these systems. See Bohrer and Converse, 2001 for more information on cold weather design and installation.

A subsurface drip system is an efficient pressurized effluent distribution system that can deliver small, precise doses of effluent to shallow subsurface dispersal/reuse fields. Drip distribution piping is small diameter, flexible polyethylene tubing (*drip line*) with small in-line *emitters* (orifices that can discharge effluent at slow, controlled rates, usually specified in gallons per hour). Drip line can be trenched (by hand or with a trenching machine) into narrow, shallow trenches or plowed (with a vibratory plow or other insertion tool) directly into the soil and backfilled without gravel or geotextile.

Freezing is an issue in cold climates, since most product development has occurred in warm climates. Initial operation of a drip system installed near Duluth, MN showed that while parts of the system (most notably the filters) worked well in the winter, other portions froze (McCarthy et al.,2001). To assure that the system would not freeze, the following steps were taken:

1. The drip field was located in a wooded area, and it was covered with 12 inches of hay immediately following installation in October 1997 while the ground was still fairly warm.
2. The entire drip network was constructed to drain back to the dose tank.
3. The manifolds and air release valve were also insulated with 12 inches of hay.

With these measures, the system did not freeze after two winters with limited snow cover.

The filter portion must be both well-insulated and heated. Depth of placement is an important consideration. Systems installed in colder climates, and only used during the summer, often place the tubing six inches deep, while in climates where freezing is not a concern, six inch burial depths are common in all applications. A minimum depth of twelve inches is recommended for all other systems in Minnesota to minimize freezing problems. A research site near Hastings had freezing problems attributed to compaction of snow cover by foot traffic over the area (Gustafson, 1999). Repeated walking or driving over the system reduces the insulating ability of the snow. A thick vegetative cover will also assist with freeze protection of the system. If the system is located over a manicured lawn, it should not be mowed later in the summer to ensure additional protection.

Outlined below are some additional measures to reduce the risk of a drip system freezing:

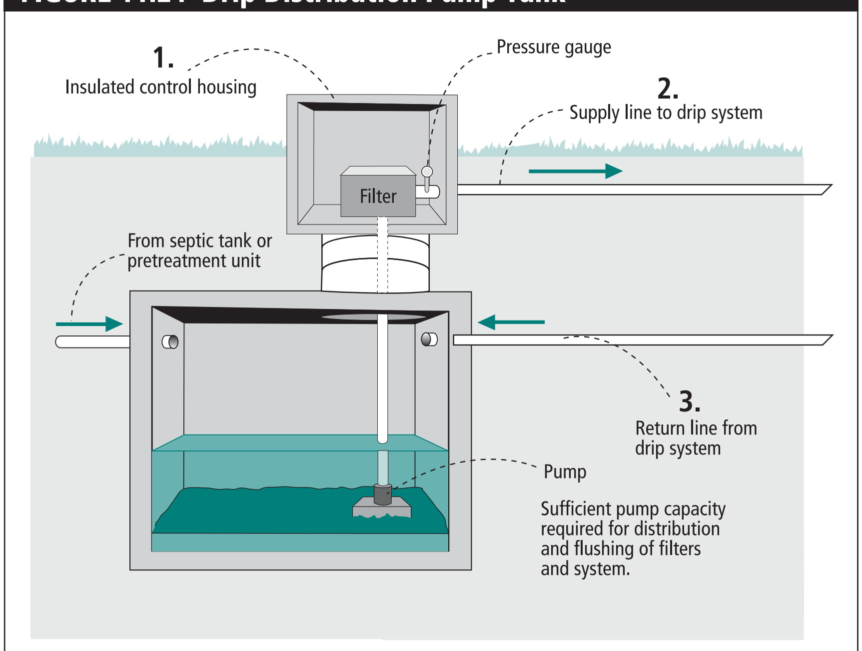
- Manifolds, supply lines, and return lines should be sloped back to their respective dosing or treatment tanks to drain between doses.
- Insulating the return and supply manifolds is recommended for systems which will be used year round in MN.
- Be sure the drain valve on the flush line remains open for long enough for the entire field to drain.
- Remove the check valve at the pump.
- Insulate all equipment boxes, including headworks box or filter and field flush valve boxes as well as zone dosing valves, and air vacuum relief valves. Use closed-cell insulation such as perlite in a plastic bag.
- The top of air vacuum relief valves must be no higher than the soil surface.
- If using an index valve to split field zones, be sure it is capable of self-draining.
- Drip line will self-drain through the emitters into the soil. If the cover crop over the drip field is not yet adequately established, add hay or straw over the field for insulation.
- Mark valve boxes with a metal pin so you can find it in the winter when covered in snow.

Definition and Description

A drip dispersal system as a small diameter pressurized effluent distribution system that can deliver small, precise doses of effluent to the soil surrounding the drip distribution piping. Drip dispersal works on the same basic principles as any other soil based treatment system: filtering and bacterial decomposition of the effluent. However, the method of application of the effluent to the soil is different. The goal in a drip distribution system is to distribute the effluent evenly over a large area, so no single location receives excess effluent. A drip distribution system has four parts: a pretreatment device, a pump tank, a filtering/flushing device, and the distribution system as shown in Figure 11.24.

All drip systems will have plugging problems without a good filtering system. The filtering system depends on the drip tubing and the manufacturer's recommendations. Some drip systems require advanced pretreatment, but others have been put in with only a septic tank. The type of pretreatment will in part determine the type of filter necessary. Pretreatment devices include aerobic treatment systems, sand, peat, textile, single pass recirculating filters, and constructed wetlands. Most of these pretreatment devices use a septic tank for primary treatment. In a research study by Rowan et al., (2004) sand filter effluent caused significantly less reduction of flow rates (2%) than did septic tank effluent (11%).

FIGURE 11.24 Drip Distribution Pump Tank



The pump tank as shown in Figure 11.24 stores the effluent until the drip field is ready for a dose of effluent. A high head pump is required for even application of the effluent to the soil. Pump selection and installation follows typical onsite treatment system design practices.

The filters in drip systems remove all particles larger than 100 microns. Some filters have automatic cleaning systems. Flushing capacity and the total dynamic head are two important design parameters to assure that effluent passes through the emitters in the tubing. Even with excellent filtration, algal growth in the tubing can cause plugging. Flushing the system removes the growth and minimizes plugging.

Two types of filters are commonly used: spin and disc. A disc filter diagram is shown in Figure 11.25. Both filters will function adequately with the proper pretreatment, so the designer and owner must weigh the advantages and disadvantages of each type.

- Disc filters use serrated discs as the filtering medium. The manufactured medium allows flexibility in application waste strength. The initial investment in materials is greater, but O&M will be less intensive and can be completely automated with pressure gauges and control panels.

FIGURE 11.25 Disc Filter Diagram

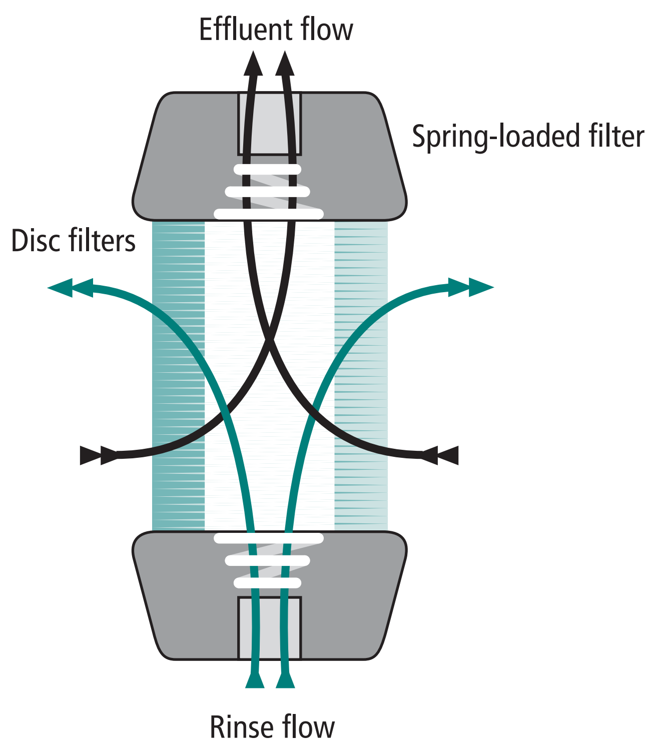
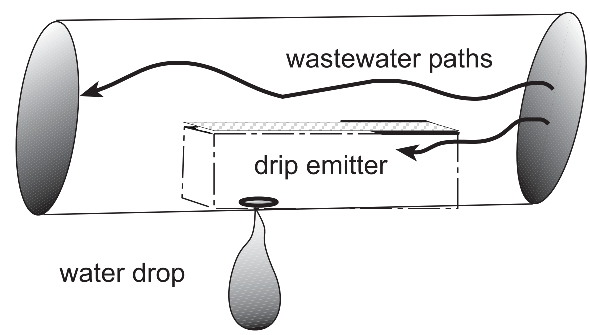
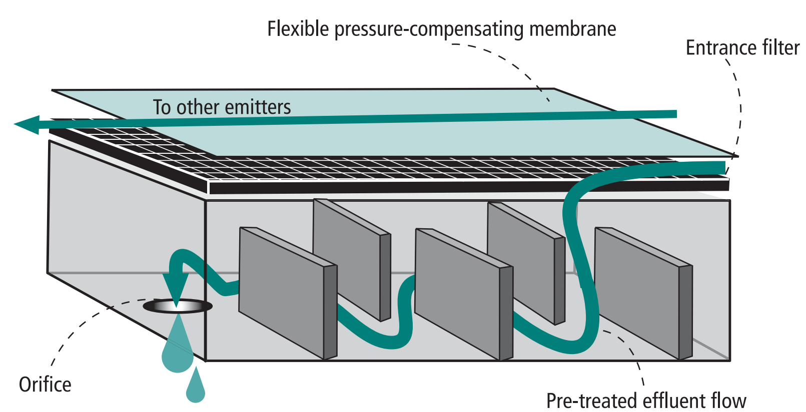


FIGURE 11.26 Drip Tubing



- Spin filters have a stainless steel screen that filters the effluent, and most are self-cleaning. The effluent is forced through a directional nozzle plate onto the inside of the screen. This creates a centrifugal action that rotates debris down the screen wall to a large debris-holding basin.

FIGURE 11.27 Drip Emitter



The distribution system includes the components that carry effluent from the pump to the soil treatment area. This is the drip part of the system, which is complex and has seen the most design changes over the last twenty years. At one end, the tubing is connected to the pump. Along its length, tiny orifices, or emitters, allow the effluent to drip out into the soil. The tubing is generally 1/2 inch in diameter with an emitter in the tubing wall. See Figure 11.26 and 11.27. The pressure inside operates at 15 - 20 pounds per square inch. The collection manifold for the drip system is connected back to the tank for flushing solids in the drip tubing. Typical drip line installations are six to twelve inches deep, have emitters spaced two feet apart and are installed on two-foot centers (with increased separations on sloped sites). Distribution networks are often laid out with the lines running parallel to one another, but due to its flexibility, drip line can be installed to accommodate irregularly shaped sites and to run parallel to contours on sloped sites. The two-foot spacing is convenient for installation, and has been used in many areas as a basis of drip distribution system sizing.

Soil application rates have been established empirically and generally assume each emitter will wet an area of four square feet. This assumption is not valid in all soil types. Research conducted for agricultural applications has shown that wetting patterns around emitters are impacted by soil/site characteristics, emitter discharge rate, and dosing regime. Site characteristics and installation methods also affect distribution patterns, particularly in fine, textured soils. Care must be taken to apply effluent at a rate that the soil can accept it. A complete soil investigation, including soil texture, structure, and redoximorphic features, must be performed to determine the appropriate size and necessary pretreatment. Emitter discharge rates should be matched with soil conditions (slower discharge rates are required in finer textured soils) to avoid effluent surfacing during dosing.

Tubing is where most problems can occur, including plugging of the tubes or the emitters by dissolved or suspended solids or roots, resulting in uneven distribution of effluent. Each brand of tubing is unique and tubing suppliers approach problems differently; system designers or operators should research tubing choices thoroughly before making a selection. Tubing with pressure compensation automatically increases flow if an emitter starts to plug. It is also designed for systems installed on non-level sites, so even distribution is provided with no additional design requirements.

Rule Requirements

Currently in Minnesota, drip distribution can be used as a Type I system if it is on the registered product list, designed with three feet of separation, and sized with 7080 loading rates **(7080.2200).** If three feet of separation to the limiting layer are not present below the tubing, the system is classified either a Type IV system with a registered pretreatment system in front of it **(7080.2350)** or as a Type V **(7080.2400)** with a non-registered pretreatment unit. **Chapter 7080.4070 (E) has requirements for subsurface drip dispersal products:**

1. **be warrantied by the manufacturer for use with sewage and for resistance to root intrusion;**
2. **have a means to inhibit the accumulation of slime and bacterial growth within the drip line and plugging of the emitters. Emitter discharge rate must be controlled by the use of either pressure compensating emitters or a pressure regulator.**

Purpose and Application

Drip distribution is commonly used in areas where other soil treatment distribution systems may be difficult to install, such as on steep slopes and forested areas. They are also used for resorts and golf courses that only operate during the warmer months of the year. Drip distribution systems are often used after a pretreatment system, such as an aerobic treatment system or sand filter. Drip distribution systems have also been used to place the rock and pipe in mound systems (Gustafson, 1999).

Advantages of subsurface drip systems include:

- Installation of drip line is less site-intrusive when plowed in.
- Flexible drip line can be installed in grid or irregular patterns as needed to accommodate contours on sloped sites, irregularly shaped areas, difficult site conditions, or landscape irrigation applications.
- Small diameter drip line can be pressurized quickly, resulting in even distribution.
- Low flow rates allow for long lateral runs to take advantage of site contours typically longer than can typically be obtained with conventional piping.

- Shallow placement of drip line can enhance treatment by maximizing soil depth and vertical separation and delivering effluent to a point in the soil profile where there is more oxygen and organic material.
- A vegetative cover over the drip field (usually turf) provides additional treatment and reuse through plant evapotranspiration.
- Slow, controlled emitter discharge combined with multiple daily dosing enhances aerobic conditions in the soil and results in frequent soil treatment system resting periods.

Design Basis and Operational Theory

Like all soil treatment systems, drip distribution systems require primary wastewater treatment prior to receiving effluent at the pump tank. Depending on the application and manufacture, after primary treatment the effluent stream enters a pretreatment unit or the pump tank. Pump and dosing controls are required to operate the dosing cycles and alarm system. The effluent stream is discharged from the pump tank to filters that are located prior to the supply line discharging to the distribution field. The effluent stream should be treated so as to remove solids greater than 1/8 inch in size prior to entering the drip line filter. The filters that receive the discharged effluent stream from the pump tank must be designed to prevent solids greater than 100 microns in size from entering into the drip line effluent dispersal component. The filters should be flushed no less than the minimum frequency required by the drip line manufacturer.

Two connections are made to the filter discharge: the supply line, which feeds the manifold, and a return discharge line. The supply line discharges the effluent stream to the supply manifold. The supply manifold should be installed at the highest elevation in the distribution field or within each zone. The return discharge line should be connected to the filters to carry the flushed filter effluent back to the primary treatment tank. The return discharge line should be sloped at a minimum of 1/8 inch per foot. The discharge line may be connected to the return manifold line from the distribution field or directly connected to the building sewer at a distance of greater than four feet from the primary treatment tank.

After receiving the effluent flow from the supply line, the supply manifold discharges the effluent stream to the drip line laterals through pressure-rated pipe and fittings, which are connected to the supply manifold and to the drip line laterals. The pressure-rated pipe and fittings must be able to withstand the pressures to which the piping will be subjected. The pressurized pipe and fittings should be able to withstand deformation when covered by backfill materials. The pressure-rated piping typically extends from the supply manifold into the distribution field greater than one foot prior to connecting to the drip line lateral.

The drip line laterals consist of tubing typically installed in parallel lines within one or more zones. Emitters can be either:

1. pressure compensating to give an even flow through a range of pressures or
2. non-pressure compensating with pressures controlled by pump selection, pressure compensating valves, or by some other means within the system design.

At the distal end of the drip line, laterals connecting to a return manifold are again made with pressure-rated pipe and fittings able to withstand the pressures to which the piping will be subjected. The pressurized pipe and fittings should be able to withstand deformation when covered by backfill materials. The pressure-rated piping should extend from the return manifold into the distribution field greater than one foot prior to connecting to the drip line lateral. The drip line laterals should not be connected directly to the return manifold. The return manifold should be installed at a lower elevation than the supply manifold. The drip line's distal end is connected to the return manifold to allow periodic line flushing. The drip line laterals should be flushed no less than the minimum frequency required by the drip line manufacturer. The effluent stream flushed from the laterals is collected in the return manifold. From the return manifold a return manifold discharge pipe is connected to the building sewer. The return manifold discharge pipe should be sloped at a minimum of 1/8 inch per foot. The return manifold line should be connected to the building sewer at a distance of greater than four feet from the primary treatment tank.

Sizing

The sizing of the system is based on the effluent flow and the soil acceptance rate. See septic.umn.edu/ssts-professionals/forms-worksheets: Forms for a step-by-step guide to designing a drip system. A manufacturer of drip systems gives a range of system sizes based on soil acceptance rates; these values are similar to existing long-term acceptance rates. The area is somewhat larger than a conventional soil treatment system, since the goal is to maximize the area loaded by a given volume of effluent.

Location of the system depends on soil conditions, including depth of soil to bedrock or zone of saturation, texture, and winter climate. The tubing type dictates siting requirements. These may include equal length runs, a level distribution field, equal distance from the pump, and equal manifold heights. Pressure compensating tubing has the fewest siting restrictions; in particular, a level field is not required and the system-dosing controller allows for different lengths of tubing runs. In warmer climates and for systems used seasonally in MN, it is recommended that systems be located in open areas where exposure to sun and wind increases evaporation and transpiration. In cold climates where the system will be used year round, it is recommended that the system be placed where a good vegetative cover or thick layer of leaf litter can be relied upon to help protect the systems from freezing. It is recommended that a drip line design should not be installed in areas where all the laterals would have elevation differences exceeding six feet.

Installation

Procedures used in the construction of a drip system are just as critical as the design of the components. A good design with poor construction can result in component failure. Installations are to be made only when the soil is below the plastic limit and therefore, dry enough to prevent compaction and smearing of the infiltrative surface. Proper equipment includes tractors or other equipment that will not compact the infiltrative surface.

At all times, no equipment should cross the field areas during rainfall events, when the site is above field capacity, or when water is standing over the site. Minimize traffic on infiltrate surface and avoid equipment traffic on or over infiltrate surface.

Construction procedures

1. Check the moisture content and condition of the soil. If the soil at the infiltrative surface can be rolled into a 1/4-inch wire, the site is too wet and construction cannot proceed until it dries out. If the soil at or below the infiltrative surface is frozen the construction should not occur. If the soil moisture content and the condition of the soil allows, the distribution field area should be prepared in a manner that minimizes site disturbance. The distribution field site should be cleared of all obstructions prior to bringing materials on site. The lateral lines can be directed around trees or bushes. The site should be prepared as needed to enable a grass cover to be established and maintained prior to drip line lateral installation.
2. Set up a construction level, engineer's, or laser level and tape to assure conformation with natural contours and design requirements for sizing, location, and separations to determine all relative elevations in relationship to the system benchmark.
3. It is suggested that the four corners of the distribution field or of each zone within the distribution field be marked. The top two corners should be at the same elevation and the bottom two corners should be at a lower elevation. Because of freezing conditions, the bottom drip line must be higher than the supply line connection at the dosing chamber and the return flushing line connection to the building sewer. Lay out the distribution area(s) on the site so that the distribution field runs parallel with the land surface contours and is within the designated area.
4. Consult with the manufacturer of the drip line tubing regarding appropriate trenching techniques.

O&M and Troubleshooting

Primary treatment tanks and pump tanks are to be inspected routinely and maintained when necessary. Recommended maintenance tasks of the drip system depend on the manufacturer and specific components of the system. The manufacturer should be consulted and maintenance performed in accordance with the manufacturer's recommendations. Inspections of the drip system components should be performed at least twice every year by a licensed professional. Maintenance of a drip distribution system is similar to maintaining other systems. The tubing and emitters themselves are designed to self-clean, but will still need periodic cleaning, even though they have the automatic self-flushing feature.

Inspections will include:

- If the filters are plugging and pretreatment is working correctly, you need bigger filters
- Checking the system to ensure flush and alarm systems are functioning properly
- Checking flush valves and vacuum release valves and cleaning if necessary
- Checking pressure-reducing valves to see if cleaning is needed
- Ensuring that dose volumes registered on the water meter are acceptable in accordance with the system design dose
- Checking pump discharge capacity
- Ensuring that wet or damp spots do not appear on the surface of the distribution field

Rodents are active in some areas and can damage drip system components. Gophers have been reported to eat through drip lines and burrow into valve boxes and other enclosures, where they can damage components or simply fill the valve box up with soil. One drip line manufacturer reports that rodents will not burrow towards a drip line when the ground is kept continuously moist (one reason for high-frequency dosing). This still could pose a problem during system dormancy—when a drip system is charged and tested and then left out of service for a period of time, such as with seasonal usage, or where a system has been in continuous use, but is temporarily shut down during a family vacation. Ideally, a drip system should be tested shortly before it is placed into continuous service. Another means of discouraging rodents is to add enough butyric acid to the pump chamber to achieve a two-ppm solution. Butyric acid is the substance that gives spoiled butter its rancid smell. This substance is relatively harmless but creates an unpleasant odor. Possible ways to prevent rodents from burrowing into valve boxes are to line the bottom of the valve box with bricks, drain rock, or other hard material to create a barrier to digging, or to sprinkle butyric acid or powdered boric acid at the bottom of the enclosure, creating an unpleasant odor. Avoid sprinkling anything corrosive on wires or other drip components.

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SECTION 12: Soil Treatment Systems

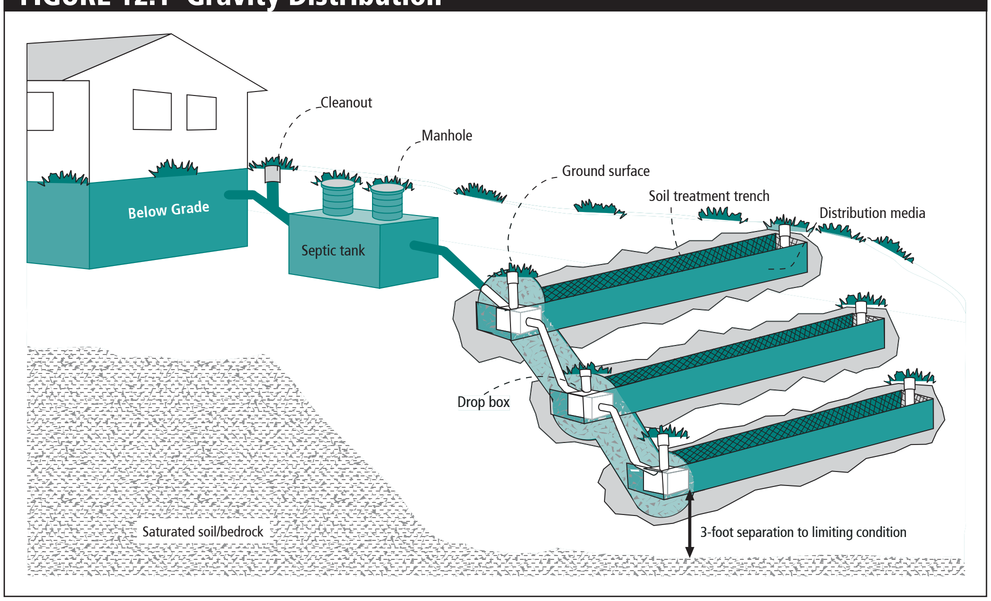
SOIL TREATMENT SYSTEMS

Overview

The soil treatment system is the primary barrier between the septic tank effluent and the environment before the treated effluent is recycled back into the environment. The treatment system must be located where suitable conditions for final treatment and dispersal are available. The typical soil dispersal system consists of a piping network to receive septic tank effluent, with distribution media, rock, or manufactured media to assist in distributing effluent to the soil. Design of soil treatment systems should consider the volume of septic tank effluent, the method of distribution, and soil conditions in the treatment and distribution areas.

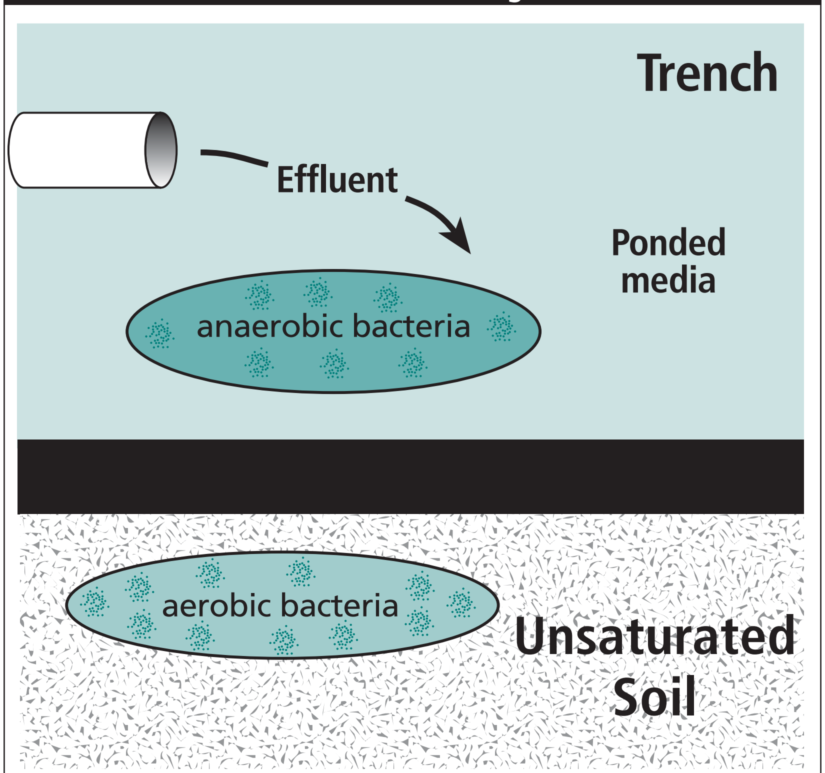
In a typical gravity soil treatment system, such as a trench system, effluent from the septic tank flows into large diameter distribution pipes and down through distribution media (such as rock) to the soil and media interface as shown in Figure 12.1. The rate at which effluent infiltrates to the soil depends upon the volume and character of the effluent as well as the soil properties, including texture, structure, moisture content, depth from the soil surface, micropores, macropores, and consistence. The interplay of these factors affect the formation of a biological layer, often referred to as a biomat, at the soil/media interface. The biomat is formed by microorganisms that secrete a sticky substance and anchor themselves to the soil-media interface. This biomat forms first along the trench bottom, and as liquid begins to pond, it forms along the trench sidewalls. This is a normal condition that occurs over time in nearly all soil dispersal systems, which has both positive and negative impacts.

FIGURE 12.1 Gravity Distribution



Biomat development begins when the combination of effluent flow and the load of suspended solids overwhelm the infiltrative capacity of the soil at the bottom of the trench. Effluent accumulates or ponds above the infiltrative surface, creating a zone of anaerobic (oxygen-deprived) conditions that lead to biomat development. The biomat acts as a valve to slow the flow of effluent into the soil, creating a "trickle" flow in the soil beneath the biomat. The biomat can slow effluent movement to as much as 100 times less than the normal flow in saturated soil (Bouma, 1975). Slowing effluent movement is necessary to maintain unsaturated, aerobic conditions below the biomat and maximize the contact time between the effluent and the soil particles. Maintaining an unsaturated zone surrounding the trenches is the single most important factor in preventing transmission of pathogens. A mature gravity-fed soil treatment system, with biomat formed on its bottom and sidewalls, will frequently have effluent ponded in the trench while the soil a few inches outside of and below the trench will be unsaturated. As ponding continues to increase, the infiltrative surfaces of the trench sidewall become involved with the biomat development and the resulting regulation of effluent flow into the surrounding soil. The balance between flow out of the trench through sidewalls and the bottom area is influenced by the vertical and horizontal hydraulic conductivities and gradient in the soil, the biomat resistance, and the soil moisture of the surrounding soil. Therefore the percentages will vary over time and from site to site (Otis et al., 1977).

FIGURE 12.2 Effluent Movement Through a Biomat



Slowed by the biomat, the effluent trickles through the soil and around the soil particles, encountering air pockets and soil particles as shown in Figure 12.2. The air pockets allow aerobic bacteria, which are much more efficient than the anaerobic bacteria in the septic tank, to continue treatment. Additionally, the soil particles' negative charge attracts positively charged pathogenic bacteria and viruses in the effluent. This process is called adsorption. Other bacteria then grow using the nutrients in the sewage, producing slimy films over the soil particles. The slime acts as a filter to grab additional bacteria and viruses, which then die off due to temperature changes and lack of moisture and food. Physical entrapment, increased retention time, and conversion of pollutants in the effluent are important treatment objectives accomplished under unsaturated conditions. Pathogens contained in the effluent are eventually deactivated through filtering, retention, and adsorption by the soil. In addition, many pollutants are converted to other chemical forms by oxidation processes.

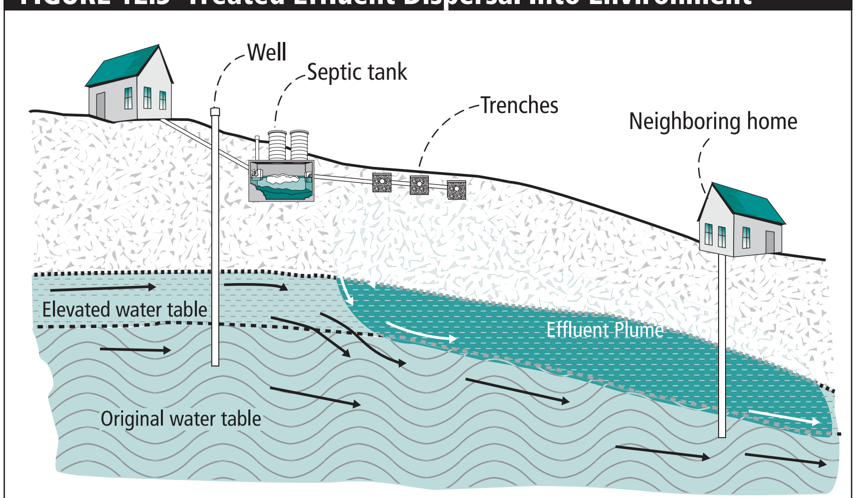
If the bottom of the system is at or near the water table (periodically saturated zone), the soil underneath the system may be saturated, reducing oxygen availability. Lowered oxygen levels reduce treatment efficiency and increase the risk of contamination. Being at or near the periodically saturated zone without proper treatment allows pathogens to move quickly though the soil without being adsorbed, filtered, or treated, potentially contaminating surface or groundwaters. These waters can then move into deeper aquifers, contaminating wells or discharging into lakes and streams, where the public can come into contact with disease-causing organisms.

The anaerobic conditions induced by the ponding effluent contribute to a thicker, denser biomat, which in turn further retards effluent flow. In most soil dispersal systems, a point of equilibrium is achieved, with a well-developed biomat that is in balance with the effluent flow into the system and the soil which surrounds the soil treatment system. Over time, however, this condition of equilibrium may be upset, resulting in soil treatment system problems.

A biomat can have positive and negative effects on a soil treatment system. On the positive side, the developing biomat retards the flow of effluent, contributing to unsaturated soil conditions below the soil treatment system, which are conducive to improving effluent treatment. Without an established biomat to regulate effluent flow into the surrounding soil, saturated flow conditions exist at and below the soil treatment system trench bottom infiltrative surface. These saturated flow conditions, as explained above, reduce the treatment efficiency of the soil below and around the soil treatment system. On the negative side, particularly in finer textured soils, the biomat can become so restrictive that the soil treatment system exhibits continual, increasing ponding conditions, possibly resulting in the soil dispersal system malfunctioning.

The last step in the treatment process is the final treatment and dispersal of wastewater recycled back into the environment through the soil as shown in Figure 12.3. Several options are available for distributing and recycling wastewater into the soil. Gravity flow distribution to below-grade soil treatment areas (STA) are the most widely used soil treatment system. These systems are typically used in areas where the soil separation distances can be met and because they are the least expensive alternative.

FIGURE 12.3 Treated Effluent Dispersal Into Environment



The type of STA utilized at a site is largely dependent on soil conditions. Each STA technology has horizontal and vertical setback distances that it must adhere to. In some areas, with shallow soil available for treatment and acceptance, the vertical separation from groundwater or restrictive layers is achieved by importing soil fill and raising the infiltrative surface above the natural grade. Pressurized distribution, which provides even distribution of wastewater, is often used to overcome a variety of site conditions such as shallow depths to limiting conditions, coarse soils with limited surface area, and clay soils with lower acceptance rates.

General Requirements

According to MN Rules Chapter 7080.2150 Subp. 3 (C and D):

C. For acceptable treatment of septic tank effluent by soil, the soil treatment and dispersal systems must meet the requirements of subitems (1) and (2).

(1) A minimum three-foot vertical soil treatment and dispersal zone must be designed below the distribution media that meets the criteria in units (a) to (c):

(a) the zone must be above the periodically saturated soil and bedrock. The zone must be continuous and not be interrupted by seasonal zones of saturation;

(b) any soil layers that are any of the United States Department of Agriculture (USDA) soil textures classified as sand with 35 to 50 percent rock fragments or loamy sand with 35 to 50 percent rock fragments must be credited at only one-half their thickness as part of the necessary treatment zone. Soil layers, regardless of soil texture, with greater than 50 percent rock fragments must not be credited as part of the necessary treatment zone. Layers that are given full, partial, or no credit must, in any layering arrangement in the soil profile, be cumulatively added to determine the amount of soil treatment zone in accordance with other soil treatment zone provisions; and

(c) the entire treatment zone depth must be within seven feet from final grade.

(2) The distribution system or media must not place a hydraulic head greater than 30 inches above the bottom of the bottom absorption area.

D. The system's absorption area must be original soil.

In addition to the requirements above it is critical that surface water be dealt with as many soil treatment systems have the potential to be significantly affected by the addition of water due to site characteristics. Since it is expected that our systems will accept several hundred gallons of water a day, the addition of any other water, regardless of its source, will affect performance. In accounting for water flow, the first consideration is to determine where on the natural landscape each piece of the system should be installed. One common mistake is installing parts of the system at the base or toe of a slope. This is the point where the slope begins to flatten out and surface runoff will slow down and infiltrate. If the septic tank or pump station is installed here and all connections are not absolutely watertight, water will infiltrate into the tank, from which it will ultimately be delivered to the soil dispersal area, potentially creating hydraulic overload. Concave sloping sites are sites that have convergence of surface and subsurface drainage. Landscape topography that retains or concentrates subsurface flows, such as swales, depressions, or potholes, is considered an unacceptable above-ground system location. Over-land surface flow is to be diverted from the site, or other methods should be employed to allow surface flow around the system. Remember here to look even beyond the lot boundaries of the system you are installing for the potential for water to be added from lots up slope of where you are working. This concern is common in Midwest landscapes that are glacial in origin and can have long and gradual slopes. **All soil treatment systems located in areas subject to excessive run-on must have a diversion constructed upslope from the system (7080.2150, Subp. 2).** There is no slope restriction on trench systems in Chapter 7080, but systems on slopes greater than 25% are susceptible to severe erosion, can present difficulties establishing the required cover, are more likely to have surface seepage, and can present serious safety concerns relating to equipment operation.

Locate the soil treatment system where a good vegetative cover can be established. Generally, sites with large trees, numerous smaller trees, or large boulders are less desirable for installing a system because the surface is difficult to prepare, and there is a reduced infiltration area beneath the mound. Areas that are occupied with rock fragments, tree roots, stumps, and boulders reduce the amount of soil available for proper treatment. Surface preparation is an important step in mound installation, especially for mounds that must be placed on less desirable sites. **MN Rules Chapter 7080.2220, Subp. 3 (I - K) state these requirements:**

I. Vegetation in excess of two inches in length and dead organic debris including leaf mats must be removed from the original soil mound absorption area. Trees must be cut nearly flush with the ground and stumps must not be removed.

J. The original soil mound absorption area must be roughened by backhoe teeth, moldboard, or chisel plow. The soil must be roughened to a depth of eight inches. Discing is allowed if the upper eight inches of soil has a texture of sandy loam or coarser. If plowed, furrows must be thrown uphill and there must not be a dead furrow in the original soil mound absorption area. A rubber-tired tractor is allowed for plowing or discing. Rototilling or pulverizing the soil is not allowed. The original soil must not be excavated or moved more than one foot from its original location during soil surface preparation.

K. Prior to placement of six inches of clean sand, vehicles must not be driven on the original soil mound absorption area before or after the surface preparation is completed. The clean sand must immediately be placed on the prepared surface.

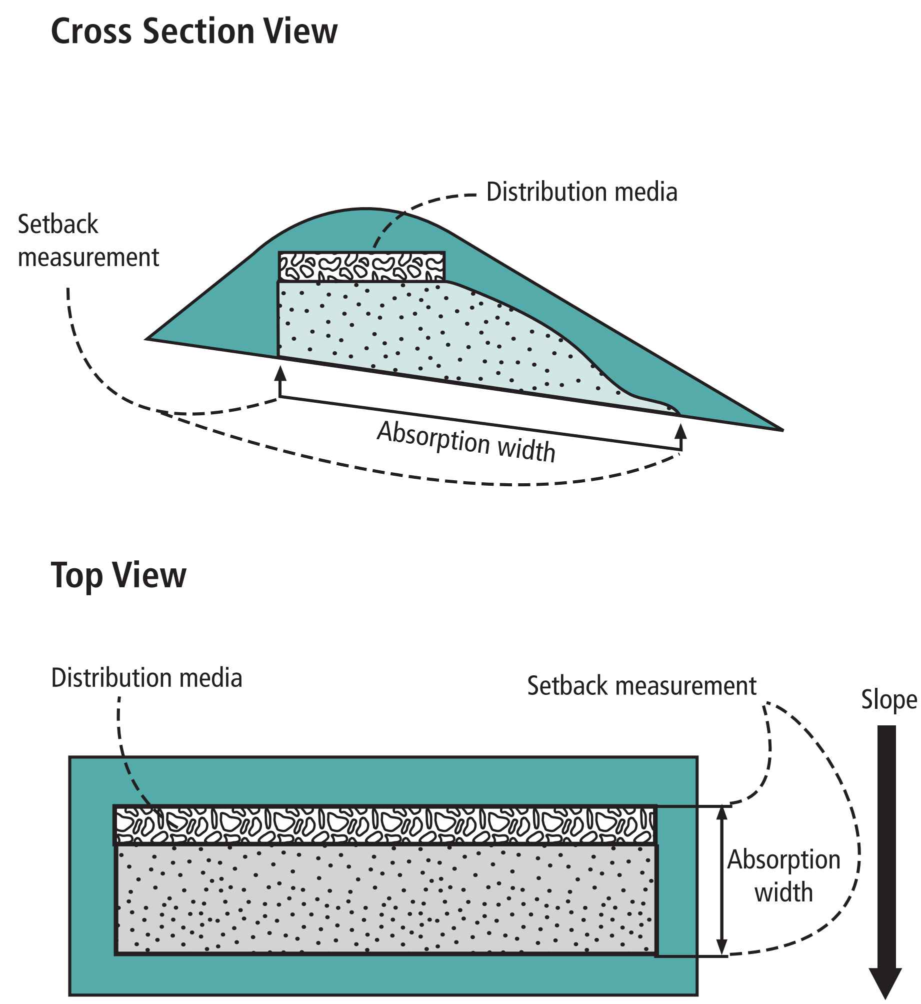
Setbacks

The soil treatment system provides the final treatment and dispersal of septic tank or pretreated effluent. When properly designed and installed, the soil treatment system should treat disease-causing bacteria and fine solids contained in the effluent. Some of the phosphorus and nitrogen will be utilized by vegetation, the amount depending on the rooting depth and season. Phosphorus can be adsorbed and attached to soil particles. Nitrogen will undergo nitrification, and, if an anaerobic environment is encountered below the biomat, denitrification may also occur. The remaining nitrogen will be in the nitrate-nitrogen form and transportable by water. The nitrate may then be diluted by precipitation and groundwater. The extent of the dilution is dependent upon the design of the system and the properties of the groundwater.

Refer to Section 2 for the setbacks for the soil treatment system with respect to water supply wells, bodies of water, and buildings as set by the Minnesota Department of Health (MDH), the Department of Natural Resources (DNR), and Chapter 7080.

These setbacks are measured from the absorption area of the system. **In Chapter 7080.1100, Subp. 2, absorption area is defined as the design parameter that is associated with the hydraulic acceptance of effluent. The absorption area for mound systems is the original soil below a mound system that is designed to absorb sewage tank effluent. The absorption area for trenches, seepage beds, and at-grade systems is the soil area in contact with the part of the distribution medium that is designed and loaded to allow absorption of sewage tank effluent. This includes both bottom and sidewall soil contact areas.** Figure 12.4 (next page) shows the an example of the absorption area in a mound system.

FIGURE 12.4 Mound Absorption Area

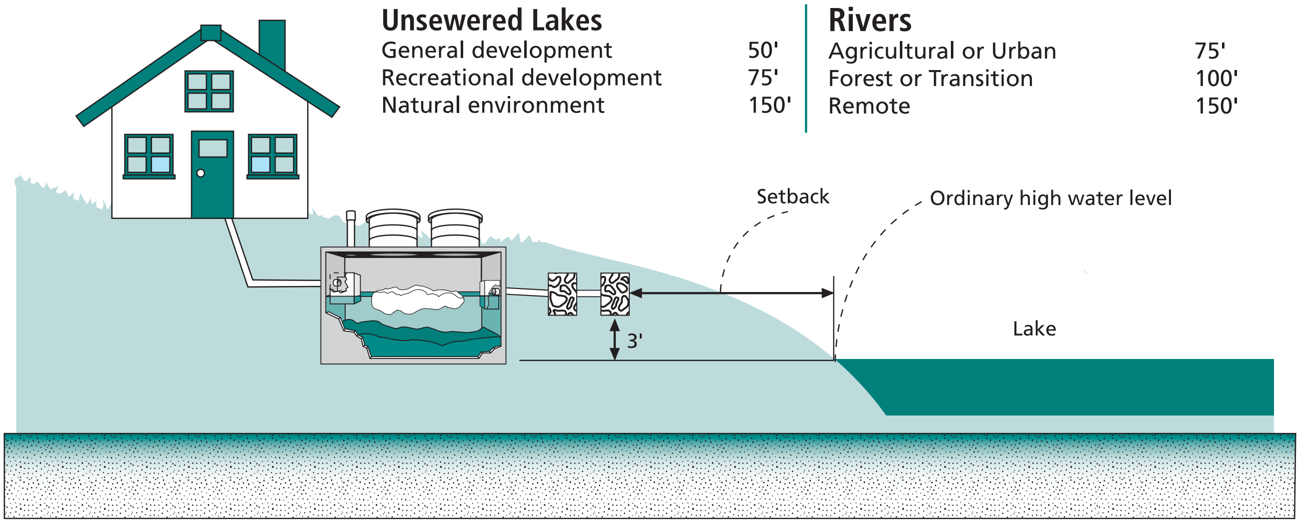


Distribution medium is defined in Chapter 7080.1100, Subp 22 as **the material used to provide void space in a dispersal component, through which effluent flows and is stored prior to infiltration. Distribution media includes, but is not limited to: drainfield rock, polystyrene beads, chambers, and gravelless pipe.** The greater the setback distance, the greater the safety provided. All soil treatment systems should be at least 50 feet away from any water supply well, unless the well is a shallow well with less than 50 feet of casing or an impervious layer of less than ten feet. In these cases, the separation distance is 100 feet. The setback distance for the soil treatment unit is 20 feet from any building and ten feet from property lines. The minimum setback distances from lakes or streams are 50, 75, or 150 feet, depending upon the lake or stream classification set by the Department of Natural Resources. Setbacks should be verified with the local unit of government (LGU) as they may be more restrictive. These setbacks are measured from the ordinary high water mark as shown in Figure 12.5. From MN Statutes 103G.005, Subd. 14, ordinary high water level is defined as an elevation delineating the highest water level that has been maintained for a sufficient period of time to leave evidence upon the landscape, commonly the point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial.

FIGURE 12.5 Setback Distances from Lakes and Rivers

Minimum Setbacks

Unsewered Lakes		Rivers	
General development	50'	Agricultural or Urban	75'
Recreational development	75'	Forest or Transition	100'
Natural environment	150'	Remote	150'



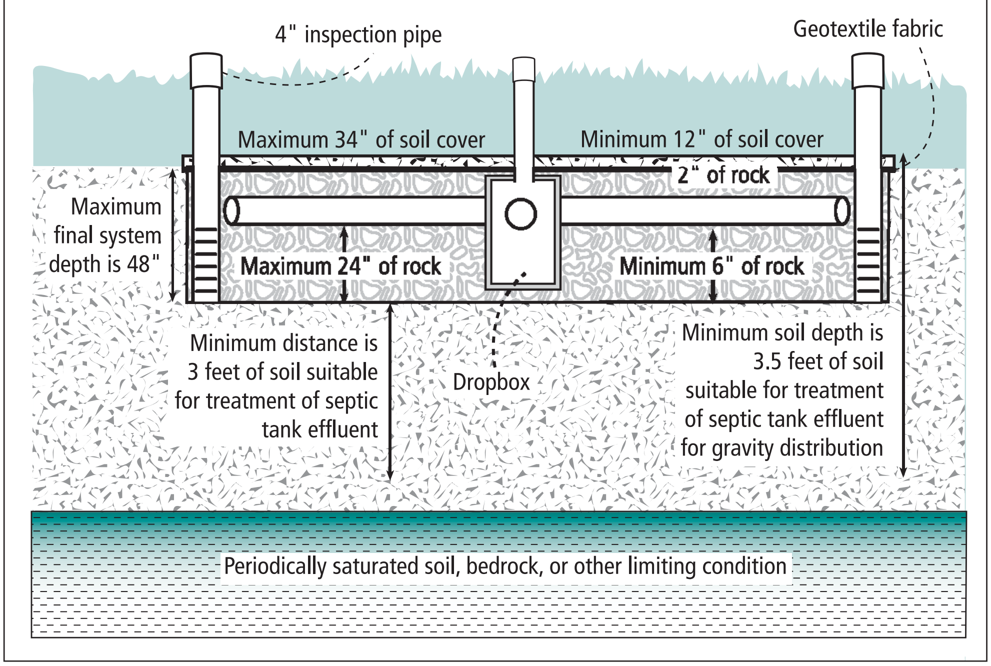
Below-grade Systems

Below-grade systems are constructed in original soil with distribution of effluent occurring below the soil surface. With below grade systems the soil treatment area is designed and installed such that the infiltrative surface is below the original ground elevation and a final cover of topsoil stabilizes the completed installation, supports vegetative growth, and sheds runoff. It is the underlying soil that treats the many harmful components in the effluent before it reaches surface or groundwaters. The two types of below-grade soil treatment systems commonly used are trenches and seepage beds.

Trenches have better oxygen transfer then beds and are recommended whenever the site conditions allow, although seepage beds are often more attractive due to reduced land area requirements. In addition, the cost and time of construction, trenches are preferred because they have greater infiltrative surface for the same bottom area, and less damage typically occurs to the infiltrative surface during construction (Otis et al, 1977).

Figure 12.6 shows minimum depths and separation requirements for trenches or seepage beds. For systems without pretreatment, at least three feet of soil suitable for treatment should be located below the bottom of the distribution media. The minimum depth of distribution media is six inches, followed by a minimum soil cover of twelve inches, so that the total distance from the periodically saturated or other limiting condition to the final grade is approximately 4.5 feet. Note that this total could be made up of 3.5 feet of original soil and one foot of soil (7080.2150, Subp. 3) over the distribution media of the system.

FIGURE 12.6 Range of Depth for Trenches and Seepage Beds



From MN Rules 7080.2210, Subp. 4 F (1-3) state that trenches and seepage beds in which the distribution media is in contact with any of the United States Department of Agriculture soil textures classified as sand or loamy sand or soils with a percolation rate of 0.1 to 5 minutes per inch must employ one or more of the following measures:

(1) employ pressure distribution according to part 7080.2050, subpart 4;

(2) divide the total dispersal area into multiple units that employ serial distribution, with each dispersal unit having no greater than 15 percent of the required bottom absorption area; or

(3) have a vertical separation distance of at least five feet.

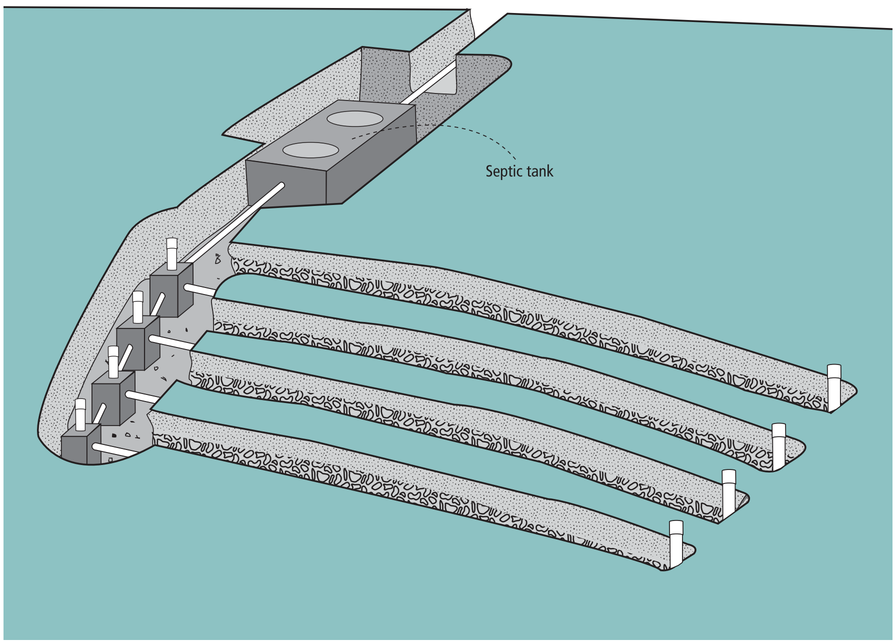
Below-Grade Systems: Specifications

Trenches

The trench is the most common of the soil treatment systems. **According to MN Rules Chapter 7080.1100, Subp. 89 a trench is defined as a soil treatment and dispersal system, the absorption width of which is 36 inches or less.** Trenches are narrower than they are wide, no wider than three feet, and are laid out along the contours of the soil. The method of distributing the septic tank effluent can be either pressure or gravity. There are a number of different configurations by which the trenches can be connected with each other and with the septic tank: parallel, serial, and continual. A typical trench is constructed by making a level excavation 18 to 36 inches wide. A typical layout for a trench system is shown in Figure 12.7.

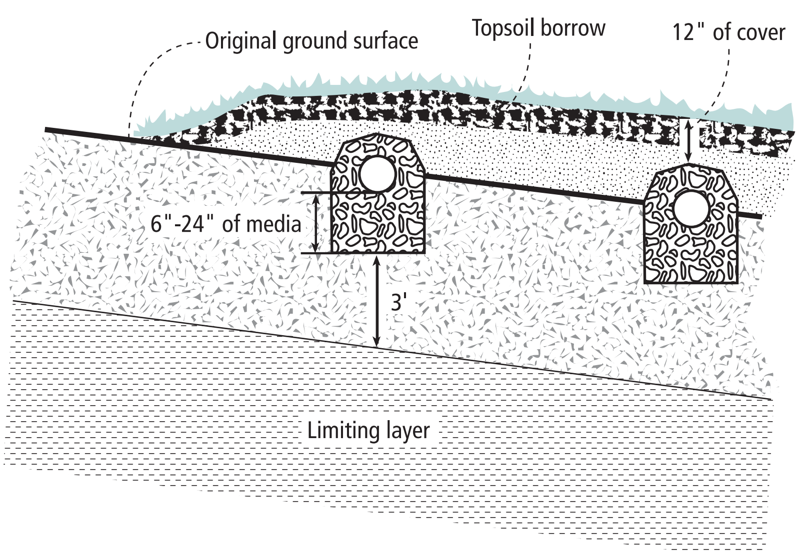
The soil around and beneath the trench must be neither too coarse nor too fine. A coarse soil may not adequately filter pathogens, and a fine soil may be too tight to allow water to pass through. Soils with percolation rates between 0.1 and 60 mpi or soils with a listed loading rate on Table IX in Chapter 7080.2150 are suitable for treating sewage using a Type I below-grade design. **The distribution media must not be in contact with soils with any of the USDA soil textures classified as sand with 35 percent or more rock fragments or loamy sand with 35 percent or more rock fragments or any soils that have a percolation rate of less than 0.1 minute per inch (7080.2150, Subp. 3 (L)). Absorption areas for seepage beds and trenches must not be placed in soils with a loading rate of less than 0.45 gallons per day per square foot or as shown in Table IX or IXa in part 7080.2150, subpart 3, item E (7080.2210 Subp. 2).** A typical trench is constructed by making a level excavation 18 to 36 inches wide and is shown in Figure 12.7.

FIGURE 12.7 Typical Trench Layout



The trench soil treatment system consists of distribution media, covered with a minimum of 12 inches of soil and a close-growing and vigorous vegetation. Many trench systems utilize a pipe and gravel distribution system where effluent passes through the pipe and is stored within the media until it can be absorbed into the soil. Partial treatment is achieved as effluent passes through the biomat. The biomat also distributes effluent across the soil surfaces and maintains aerobic conditions outside the trench.

FIGURE 12.8 Shallow Trenches



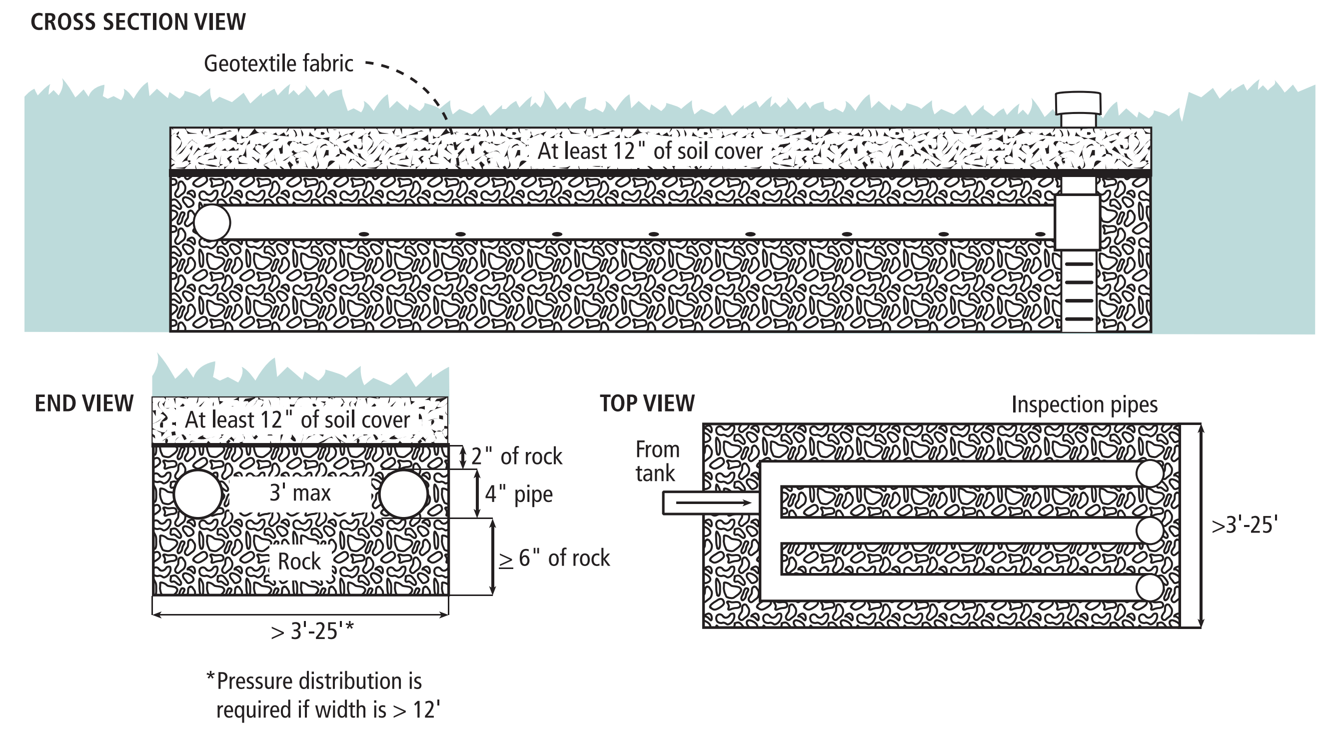
Shallow trenches

Shallow trenches may be used in areas of periodically high water tables. **The system's absorption area must be original soil (7080.2150, Subp. 3 (D))** and therefore placed within six inches of grade to maintain the required three-foot separation distance. To provide a suitable soil covering over the top of the trench, the soil must be mounded above the original soil surface **(7080.2210, Subp. 4 (E))**. The portion of the distribution media delivering the effluent must be below the natural soil surface to be a Type I system as shown in Figure 12.8. Shallow trenches follow Type I trench design, installation, and maintenance requirements.

Seepage Beds

A bed system is a wide area (wider than three feet) prepared to accept septic tank effluent that is created below the surface of the soil, and built the same way as a trench system. The beds treat the effluent effectively as long as they are located in appropriate soils. **A seepage bed is defined in MN Rules Chapter 7080.1100, Subp. 67 as a soil treatment and dispersal system, the absorption width of which is greater than three feet but no greater than 25 feet.** Figure 12.9 shows design and installation specifications of a seepage bed.

FIGURE 12.9 Seepage Bed Specifications



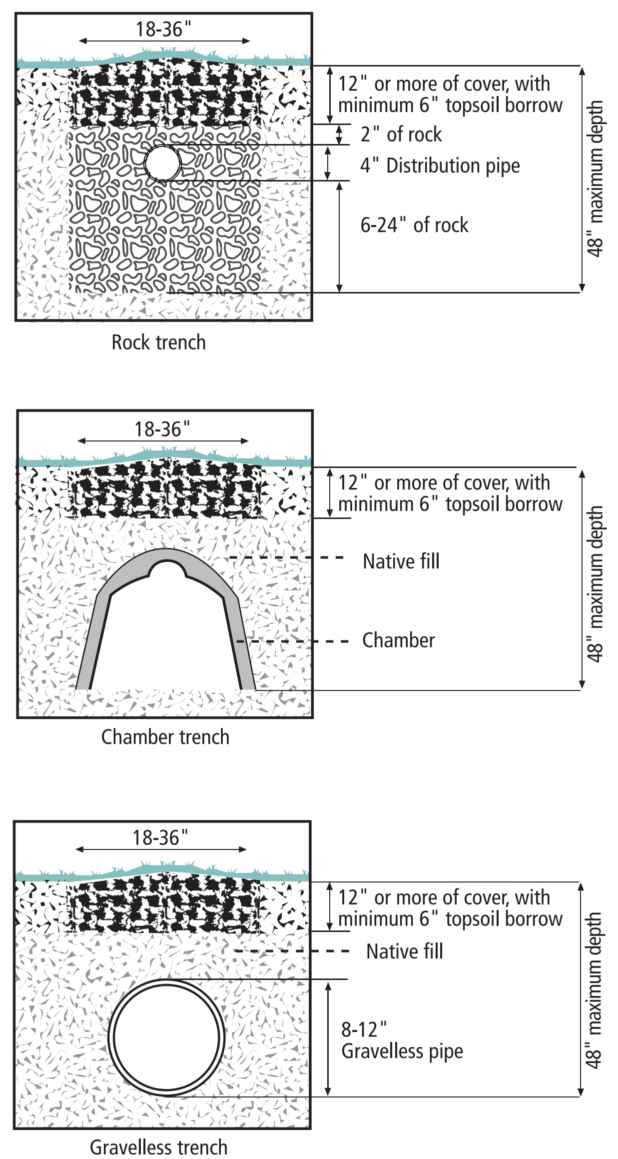
Beds are more prone to problems due to reduced oxygen transfer than are trenches as trenches have more sidewall. The sidewalls are sometimes too far apart to provide sufficient oxygen for the entire seepage bed bottom area, and the biomat may increase in thickness. The thicker the biomat, the more slowly the water will leave the system. Another cause of seepage bed failure is the reduced sidewall surface area available for biological growth. Therefore, sizing of beds is critical, and designers should size beds with greater surface area than trenches receiving the same flow. Alternatively, a bed system could use pressure distribution to apply the effluent to the soil. This would allow for better transfer of oxygen and would not require the seepage bed to be any larger than a trench system.

Any distribution media can be used in a seepage bed as long as it is listed for that use on the MPCA Product Registration List.

If gravity distribution pipes are used they must not be more than 30 inches from the sidewalls of the bed (7080.2050, Subp. 3 (E) 4). Very little effluent is distributed through the distribution pipe. Effluent flows through the orifices in the first length of pipe into the media and is distributed over the soil absorption area to the biomat. **Distribution pipes are defined in 7080.1100, Subp 23 as the perforated pipes that distribute effluent within a distribution medium.**

The construction of a seepage bed is essentially the same as that for a trench, except that the bed is wider. Chapter 7080 requires that the bottom area of seepage beds with gravity distribution be 50% greater than that of trenches to allow for the fact that there is very little sidewall with a seepage bed and low oxygen transfer. **Seepage beds may not be used where soils have percolation rates slower than 60 mpi, on slopes of greater than 6%, and must not be located in floodplains (7080.2210, Subp. 2).**

FIGURE 12.10 Distribution Media



Pressure distribution must be used for all seepage beds where the width is greater than 12 feet.

If pressure distribution is used, the absorption bed area is sized equal to trenches **(MN Rules Chapter 7080.2210, Subp. 3 (A).**

General Specifications

Media Choices

Distribution media is defined in Chapter 7080.1100, Subp. 22, as the material used to store and distribute sewage tank effluent within a soil treatment and dispersal system. The function of the media in trenches and beds is five-fold: distribution, storage, energy dissipation, insulation, and prevention of root penetration (Otis et al., 1977). The available media have advantages and disadvantages as far as meeting these functions. Any distribution media used needs to be registered in Minnesota. The media itself does little treatment; rather, it distributes the effluent to the soil where the treatment and dispersal will take place. Figure 12.10 shows a trench system with rock, chambers and gravelless pipe for distribution. The MPCA maintains a list of products which are registered distribution media. See their website at http://www.pca.state.mn.us for the most current list. The distribution media included in this manual were approved for use under the pre-2008 rules. Gravelless pipe has not been registered for use in Minnesota as of the publication of this manual (2017).

Soil treatment system size & long-term performance

The length of time a soil treatment system functions satisfactorily depends on many factors, including:

1. Accuracy of initial soil treatment system design, matching the site and soil characteristics to the anticipated facility use and wastewater generation

2. Quality of materials and methods used in the installation of the soil treatment system

3. Care of use (operation) and timeliness of maintenance on the system

The selection of an appropriate effluent-to-soil application rate is critical to the soil treatment system's performance and lifespan. Gravelless soil treatment system manufacturers commonly encourage the use of their products in reduced configurations when compared to conventional gravel-filled soil treatment systems. These smaller soil treatment systems may impact the life of the soil treatment system. Soil treatment system performance over the long-term (20 to 30 years) needs to be observed and analyzed as additional field experience with these systems is gained. In a field study conducted in Minnesota in 2006, systems from five to ten years in age which use chambers or rock as distribution media were compared. There was no observed benefit in the systems evaluated that utilized chambers (Christopherson et al., 2007).

Distribution pipe

Distribution pipe means the perforated pipe that distributes effluent within a distribution medium according to 7080.1100 Subp. 23.

As shown in Figure 12.11 from Chapter 7080.2050, Subp. 3 (E), if a distribution pipe is part of a gravity trench or bed distribution system, it must:

Be made from materials resistant to breakdown from sewage and soil
Be durable throughout the design life
Not deflect, buckle, crush, or longitudinally bend
Be resistant to pressures, fatigue, and strain for the application
Be at least four inches in diameter
Have at least one row of orifices of no less than one-half inch in diameter spaced no more than 40 inches apart
Be laid level or on a uniform slope oriented away from the distribution device of no more than four inches per 100 feet
Be uniformly spaced no more than five feet apart and not more than 30 inches from the side walls in seepage beds

Rock/Geotextile

The function of the rock in soil treatment systems is to maintain a space within the trench, bed, mound, or at-grade system. The rock holds the sides of the system apart, providing space for the effluent. Rock used as a distribution medium must:

1. Be insoluble, durable rock

2. Be between three-fourths inch and 2-1/2 inches in size

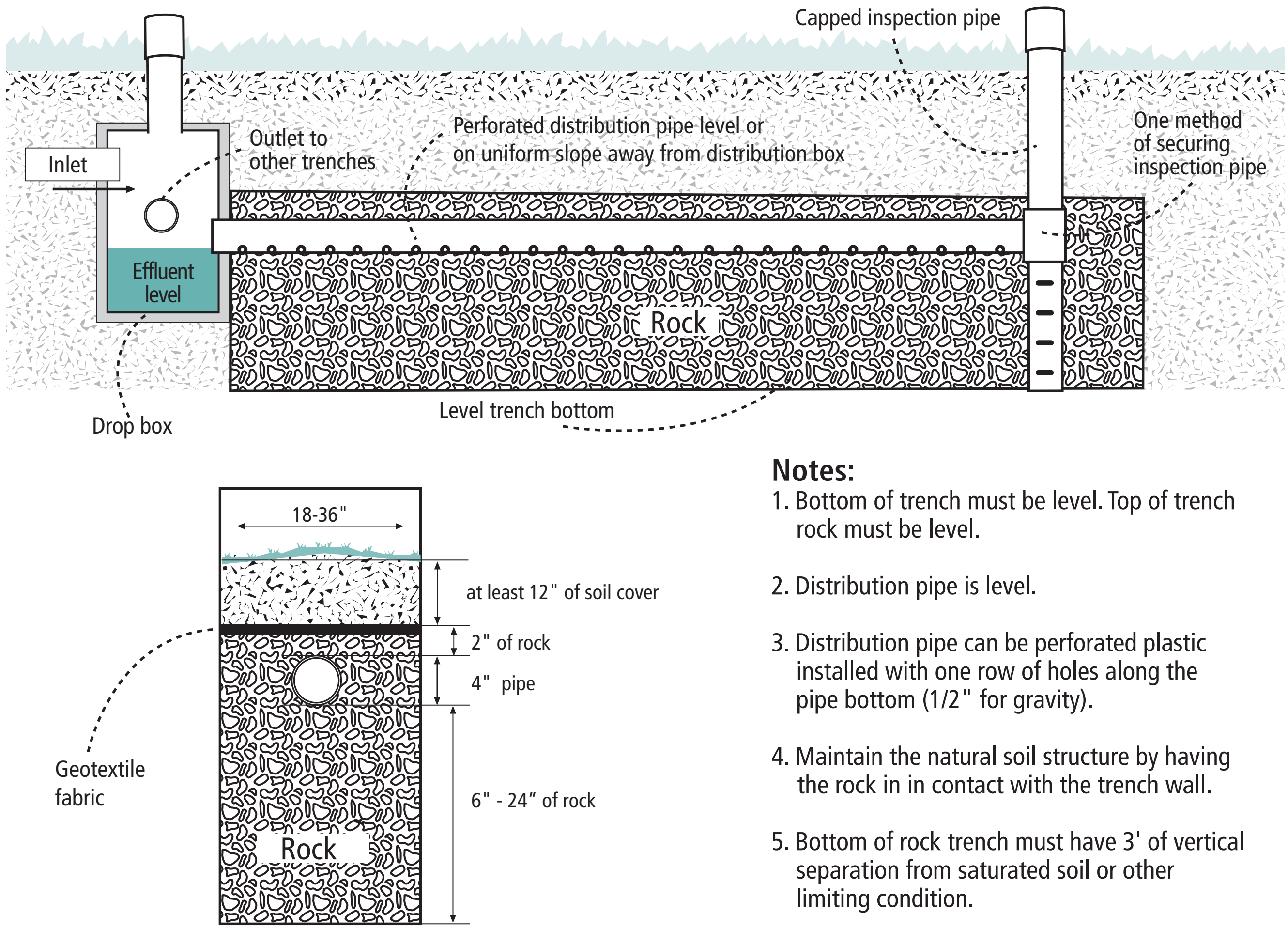
3. Have no more than five percent by weight able to pass through a three-fourths inch sieve

4. Have no more than one percent by weight able to pass through a No. 200 sieve

5. Have no more than five percent by weight of materials greater than 2-1/2 inches in size

Chapter 7083.4070 (A) requires drainfield rock distribution media shall meet requirements contained in the recommended standards and guidance for public domain distribution products before local units of government are allowed to permit its use. As shown in Figure 12.11, a soil treatment system trench is constructed by making a level excavation 18 to 36 inches wide. The bottom of the trench must be

FIGURE 12.11 Trench Specifications



Notes:
1. Bottom of trench must be level. Top of trench rock must be level.
2. Distribution pipe is level.
3. Distribution pipe can be perforated plastic installed with one row of holes along the pipe bottom (1/2" for gravity).
4. Maintain the natural soil structure by having the rock in in contact with the trench wall.
5. Bottom of rock trench must have 3' of vertical separation from saturated soil or other limiting condition.

level, as must the top of the rock in the trench. A minimum of six inches of clean rock is placed in the bottom of the excavation; then, a four-inch diameter perforated distribution pipe; next, rock around and covering the pipe; finally, a layer of permeable synthetic fabric and soil backfill to a depth of 12 inches above the top of the rock. The upper six inches of the cover material must be topsoil borrow and must have the same texture as the adjacent soil (7080.2210 Subp. 4(E)).

Geotextile Fabric

Durable non-woven geotextile fabric must be used to cover rock distribution media. The fabric must be of sufficient strength to undergo installation without rupture. The fabric must permit the passage of water without passage of overlying soil material into the drainfield rock medium (7080.2150, Subp. 3(F)).

There are also ASTM standards for the fabric:

- Unit weight of at least 3.0 oz./yd^2 (ASTM D-5261)
- Permittivity of at least 1.0 sec^{-1} (ASTM D-4491)
- Trapezoid tear strength of at least 35 lbs. (ASTM D-4533)
- Mesh size equal to U.S. Sieve No. 70 (A.O.S.) (ASTM D-4751)

Nonrock Soil Treatment System Media

For nonrock distribution media, manufacturers shall register their distribution media, including gravelless distribution media and subsurface drip dispersal products, with the MPCA before local units of government are allowed to permit their use (7083.4070 (B)). The list of registered distribution products will be maintained on the MPCA website. **MN Rules Chapter 7083.4070 (D) state that distribution media must:**

1. **be constructed or manufactured from materials that are nondecaying and nondeteriorating and do not leach unacceptable chemicals when exposed to sewage and the subsurface soil environment;**
2. **provide void space at least equal to the void space provided within a 12-inch layer of drainfield rock in a drainfield rock-filled distribution system. The void space must be established by the distribution medium, system design, and installation. The density of the media must be maintained throughout for the life of the system. This requirement is allowed to be met on either a lineal foot basis or on an overall system design basis;**
3. **support the distribution pipe and provide suitable effluent distribution and infiltration rate to the absorption area at the soil interface; and**
4. **maintain the integrity of the trench or bed. The material used, by its nature and manufacturer-prescribed installation procedure, must withstand the physical forces of the soil sidewalls, soil backfill, and weight of equipment used in the backfilling.**

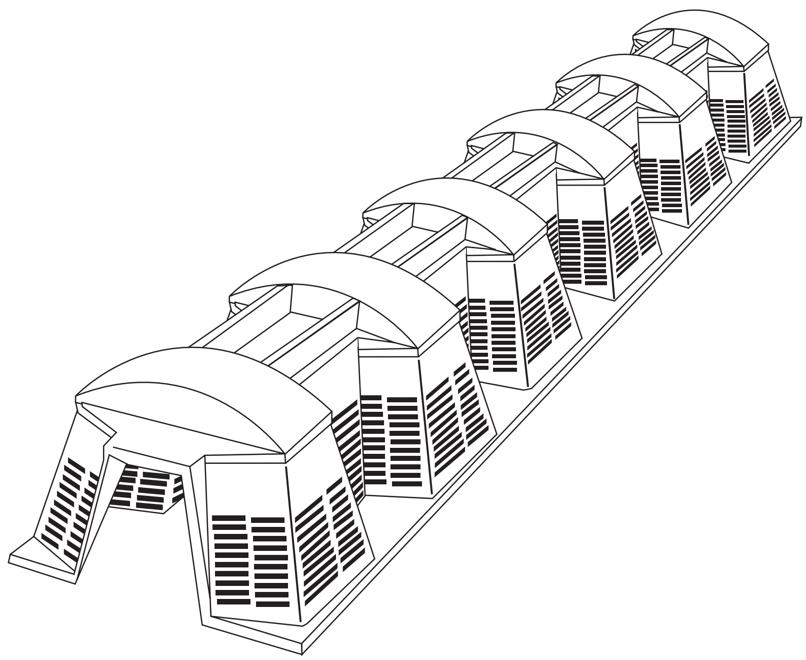
The advantage of a gravelless soil treatment system becomes clear when and where suitable gravel is either unavailable, expensive, or where site conditions make moving gravel about difficult or time consuming. In addition to these benefits, the use of gravelless soil treatment systems addresses some of the concerns presented with gravel. Among these are:

- If the quality of the gravel washing process is poor, the silt particles remaining on the surface of the gravel may be washed off when the soil treatment system is placed into use, resulting in a silt layer on the infiltrative surface and reducing its infiltrative capacity.
- Transportation of gravel across yards can have a damaging effect on lawns, flowerbeds, shrubs, etc. due to the weight of the material and the size of the heavy equipment needed to effectively move it from the stock pile to the soil treatment system area.

Chambers

The chamber system, sometimes called leaching chamber, is technology that uses something other than gravel to fill the trench or bed. A chamber refers to the open-bottom pipes used in these systems. They are commercially available and usually constructed of high-density plastic. A number of chamber systems have been developed out of plastic materials, featuring a plastic dome with orifices or slots (or both) cut in the sides (Figure 12.12). Typically, the design and construction of the chambers minimize the movement of fines into the chamber area.

FIGURE 12.12 Chamber System



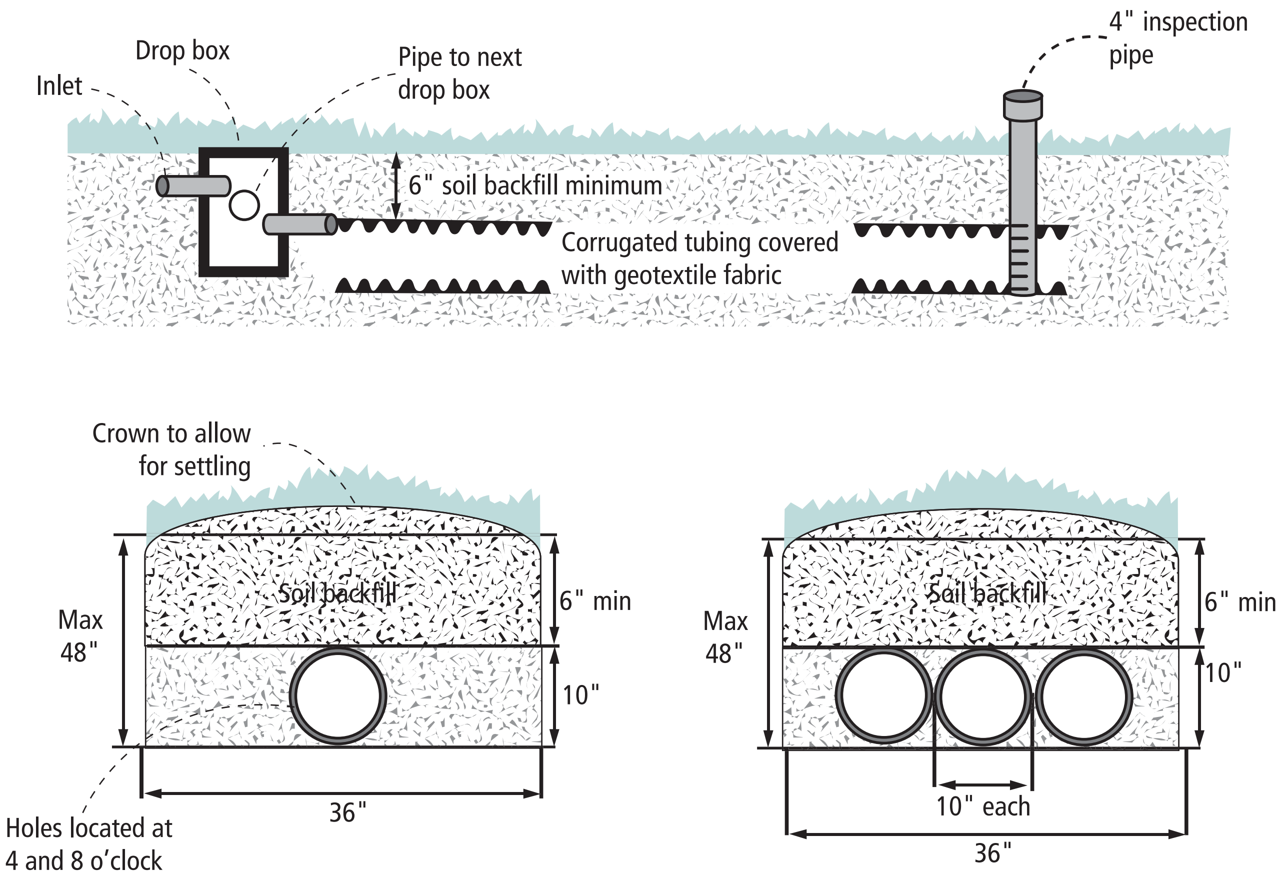
Chamber technology can also be used with gravity or pressure distribution. With pressure distribution, the pipe is installed either at the top of the dome or laid across the bottom. Concerns with these applications include settling of the pipe or media, which can result in uneven loading. Freeze protection can be accomplished either by placing all the holes downwards with orifice shields or 10% downward to assure drainage of the pipe. Scouring of the soil is another concern. Some manufacturers include splash plates or recommend paving blocks or bricks to protect the bottom of the trench from the effluent stream.

Chamber systems are excavated like standard soil dispersal systems. If any smearing of the bottom or sidewalls has occurred, they need to be raked. Chamber systems also need to be level. The chambers are then placed in the trench applying minimal foot pressure and the sidewall area is backfilled with the excavated soil. The fill is packed down by walking along the edges of the trench and chambers. The area is overfilled to allow for settling and to ensure that runoff water is diverted away from the system. The manufacturers' requirements for installation that are required to be provided with the Product Registration Process (7080.1645, (F)) should be followed.

Gravelless pipe

Gravelless pipe is a corrugated pipe used in place of drainfield rock for a trench system as shown in Figure 12.13. This pipe typically has an inside diameter of eight to ten inches. The corrugations are usually 1/2-inch, with 3/4-inch separations. The corrugated pipe also has 1/2-inch orifices in the pipe bottom. Typically, manufacturers place the orifices at four o'clock and eight o'clock. Gravelless pipe systems are designed to be surrounded by soil. The excavation should not be backfilled with drainfield rock. If an excavation has been filled with rock around the pipe, the biomat will not develop at the pipe-rock interface, but will instead develop at the rock-soil interface. The manufacturers' recommendations should be followed for installation. This product has been used extensively in Minnesota. As of October, 2011, it has not been registered for use and as such, would be considered a Type V system that requires designs to be submitted by a PE and Advanced Designer.

FIGURE 12.13 Gravelless Pipe Specifications



NOTES:

1. Bottom of trench must be level. Top of tubing must be level.
2. Scarify trench bottom and sidewalls at least 12 inches above trench bottom to expose natural soil.
3. For proprietary products consult manufacturers for performance and installation criteria.
4. Place at least 6" of backfill on top of the system with the top 6" having the same texture as the surrounding soil.

Polystyrene beads

Expanded polystyrene is one type of manufactured distribution media designed to replace drainfield rock and pipe soil treatment systems. This type of media is typically manufactured in ten-foot sections and is comprised of four-inch corrugated polyethylene pipe surrounded by extruded polystyrene held together with durable polyethylene netting.

Other soil treatment media

Recycled crushed aggregate (Sherman et al., 1994) and tire chips (Burnell & McOmber, 1997) along with many other media have been used successfully across the US and may become registered for use in Minnesota.

Design Basis and Operational Theory

A typical soil treatment system consists of two to five trenches that are three feet wide by one to four feet deep, installed on six to ten-foot centers. Shallow excavations are better than deeper for treatment and access. Trenches are only effective if the sidewalls do not interfere with each other in transferring oxygen. If the center-to-center distance is reduced too much, the trenches will behave like a bed.

Table 12.1 shows the soil treatment areas in square feet required for various soil properties. Note in the footnotes that, for trenches only, the bottom area may be reduced if more than six inches of distribution media is utilized for acceptance of effluent. If the soil characteristics are suitable, an increased depth of distribution media provides more soil exposed to the effluent along the side of the trench, and consequently less bottom area is required. The bottom area reduction is allowed for trenches, but not for seepage beds. Chapter 7080 requires that seepage beds using gravity distribution be sized at 1.5 times the values shown when six inches of distribution media is used without pressure distribution.

TABLE 12.1 Drainfield Trench Bottom Area (ft^2) for Class I Dwellings[(a)]

	2-bedroom				3-bedroom				4-bedroom				5-bedroom			
percolation rate, minutes per inch	inches of media[(b)]				inches of media				inches of media				inches of media			
	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24
faster than 0.1[(c)]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0.1 to 5	250	200	165	150	375	300	248	225	500	400	330	300	635	500	412	375
0.1 to 5*	500	400	330	300	750	600	495	450	1000	800	660	600	1250	1000	825	750
6 to 15	380	304	250	228	570	456	376	342	760	608	502	456	950	760	627	570
16 to 30	500	400	330	300	750	600	495	450	1000	800	660	600	1250	1000	825	750
31 to 45	600	480	396	360	900	720	594	540	1200	960	792	720	1500	1200	990	900
46 to 60 c	660	528	436	396	990	790	653	594	1320	1056	871	792	1650	1320	1089	990
slower than 60[(c)]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

* Soil having greater than 50% fine or very fine sand
(a) Class I: The total floor area of the residence divided by the number of bedrooms is more than 800 square feet per bedroom, and more than two of the following water-use appliances are installed: automatic washer, water softener, dishwasher, garbage disposal, or self-cleaning humidifier in furnace.
(b) For trenches only utilizing gravity distribution, the bottom areas may by reduced if more than six inches of distribution media is available for absorption of effluent; for 12-18 inches of media the bottom areas can be reduced by 20 percent; a 34 percent reduction for 19-24 inches; and a 40 percent reduction for more then 24 inches.
(c) Soil is unsuitable for drainfield trenches or seepage beds.

Design of Trenches and Seepage Beds

See the forms and worksheets page on the OSTP website septic.umn.edu/ssts-professionals.

The size of soil treatment systems is based on the amount of wastewater and the characteristics of the soil. All soil has a set capacity for accepting wastewater, that depends on the soil properties and also on the strength of the waste. The greater the waste strength beyond typical residential levels, the larger the system should be sized unless advanced pretreatment is designed. This is true for all system types; although each type of system introduces water into the soil differently, sizing for the system you choose is critical. If mistakes are made in design, the system will have difficulty performing properly. The configuration of the system—its layout with respect to the contour of the land—is the second consideration in sizing a soil treatment system.

All water use, and thus the total amount of wastewater, should be accounted for when sizing the system. Users of the system (household residents) should know that reductions in water use will benefit the system. It is a good idea to build some extra capacity into the system because household water use can increase as well as decrease.

1. The estimated flow rate is determined using Table 12.2, unless measure flow rates are available for other establishments. With a Class I residence, the estimated water use is equal to 150 gallons per day (gpd) per bedroom. This assumes an occupancy of two people per bedroom, each using 75 gallons per day. The footnote in Table 12.2 suggests a classification for residences according to size and number of water-using appliances. While the individuals who occupy a residence use the water, the number of bedrooms is still considered a good index of the potential water use. **See Section 5: Source** for a more detailed discussion of flow determination.

TABLE 12.2 Estimated Sewage Flows in Gallons per Day

Number of Bed-rooms	Class I	Class II	Class III	Class IV
2	300	225	180	60% of the values in the Class I, II, or III columns.
3	450	300	218	
4	600	375	256	
5	750	450	294	
6	900	525	332	
7	1050	600	370	
8	1200	675	408	

Class I: The total floor area of the residence is over 800 square feet per bedroom or more than two of the following water-using appliances are installed: dishwasher, automatic clothes washer, water softener, garbage disposal, self-cleaning furnace.
Class II: The total floor area of the residence is between 500 and 800 square feet per bedroom, and no more than two water-using appliances are installed.
Class III: The total floor area of the residence is less than 500 square feet per bedroom, and no more than two water-using appliances are installed. Use this estimate **only** when designing a system with flow control, such as trenches and a holding tank, or a timer to dose the system at a designed volume.
Class IV: Class I, II, or III home, but with no toilet wastes discharged into the system.

a. Determine the required septic tank capacity, compartments, effluent screen, and alarm based on bedrooms and use of garbage disposal and pump in the basement as shown in Table 12.3. For more information on septic tanks, see Section 7.

b. Based on elevations, determine if a pump tank will be needed: if so, specify the minimum size required for the pump tank. See Section 9 for more information on pump tanks.

2. Determine the maximum depth of the system by subtracting three feet from the depth to the limiting condition, or use four feet, whichever depth is less. The bottom of the system can not be greater then 4 feet from final grade.

TABLE 12.3 Septic Tank Capacity for Dwellings (gallons)

Number of bedrooms	Septic tank capacity (gallons)	*Septic tank with garbage disposal and/or pump in basement capacity (gallons)
3 or less	1,000	1,500
4 or 5	1,500	2,250
6 or 7	2,000	3,000
8 or 9	2,500	3,750

* must include either multiple compartments or multiple tanks. An effluent screen with an alarm is recommended.

3. Determine the soil loading rate based on the field data collected. If difficulty arises choosing a loading rate, always go with the more conservative value (the smaller number). Seepage beds and trenches must not be placed in soils that have percolation rates greater than 60 mpi (Chapter 7080.2200, Subp. 3 (A).

   Please see Tables IX and IXa in the Forms section.

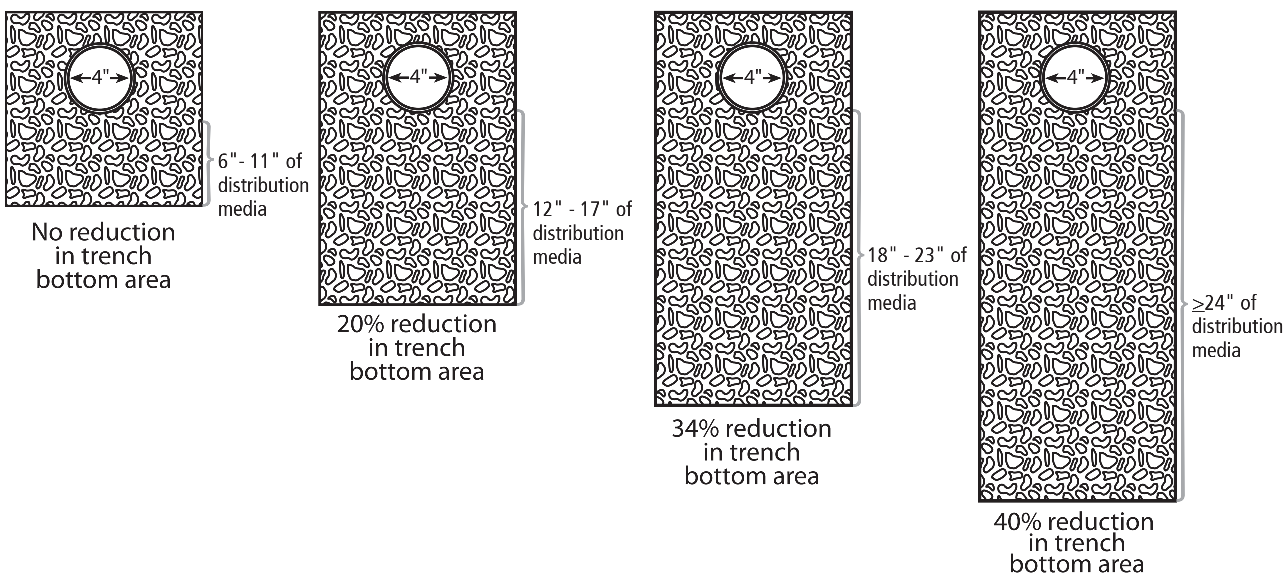
4. Now divide the design flow (1) by the soil loading rate (5). The result is the required bottom area (BA). This square footage BA is based on six inches of side wall area of distribution media. The sizing of trench systems can be looked at in two ways: bottom area and sidewall area.

5. If 12-17 inches of sidewall media are used in a trench system, the BA can be reduced by 20 percent. Now, the required trench bottom area is 80 percent of the BA. The trench bottom area can be reduced by 34 percent for 18-23 inches of media sidewall pipe and by 40 percent for the maximum of 24 or more inches of media sidewall. See Figure 12.14. **A 40 percent reduction is not allowed with a loading rate of 1.2 gpd/ft^2 (7080.2210 Subp. 3 (B)).** Using both the sidewall and the bottom for sizing allows less lawn area to be used. You will note that effluent will move through the soil sidewalls as well as the bottom no matter how the size of the system is calculated.

FIGURE 12.14 Trench Bottom Area Reduction

Reductions in trench bottom area dictated by 7080.2210 Subp. 3 (B)

Note: A 40% reduction is not allowed with a loading rate of 1.2 gpd/ft^2



6. If a seepage bed is the chosen design, the BA must either be multiplied by 1.5 or pressure distribution must be used. If the bed will be wider than 12 feet, pressure distribution is required.

7. Select the distribution media to be used. Refer to the MPCA product registration list to determine the appropriate bottom and sidewall sizing. For most distribution media the square footage required is based on exposed bottom and sidewall area.

8. Select the width of the trench or bed based on the design and media. Then, to determine the lineal feet required, take the required bottom area divided by the width chosen.
9. If rock is used as the distribution media, the amount of rock required is determined by adding the below-pipe depth of rock chosen and the depth of rock needed to cover the pipe. The amount of cover estimated is usually six inches. This total depth is then multiplied by the bottom area. Table 12.4 shows the calculated rock for soil treatment system trenches in cubic yards. The trench bottom area is presented in the first column, and the remaining column headings are the various rock depths. An additional 10% should be added for practicality in construction.

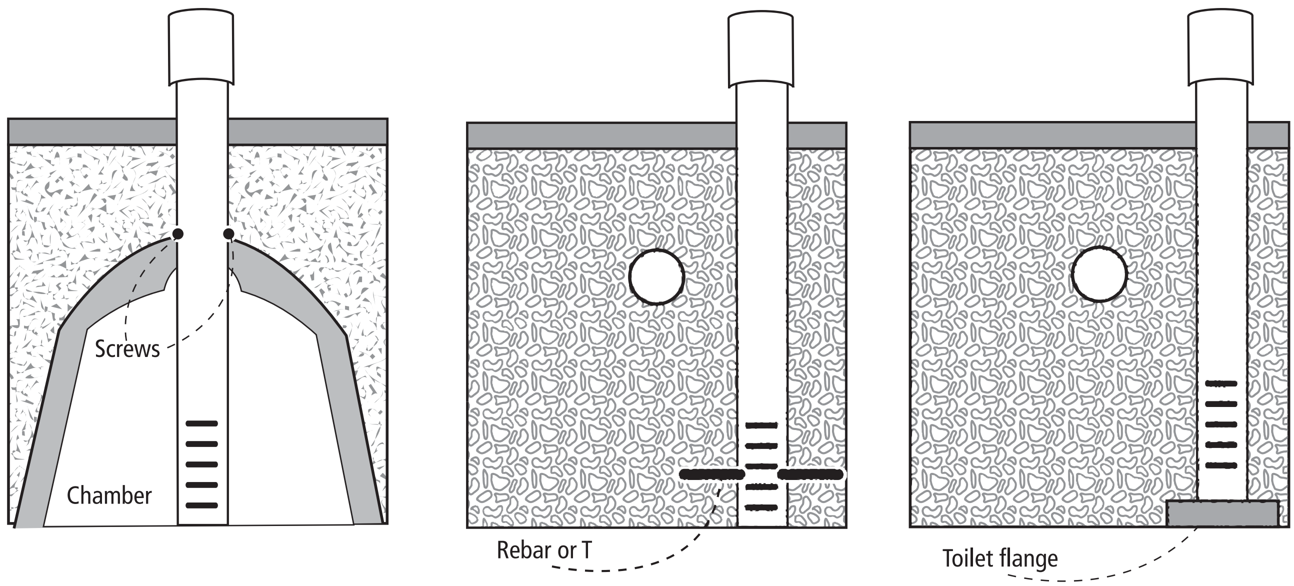
TABLE 12.4 Rock Required for Drainfield Trenches (cubic yards)

trench bottom area (sq. ft.)	depth of rock below distribution pipe (total rock depth)			
	6” (12”)	12” (18”)	18” (24”)	24” (30”)
50	1.8	2.8	3.7	4.6
100	3.7	5.6	7.4	9.3
150	5.6	8.3	11.1	13.9
200	7.4	11.1	14.8	18.5
250	9.3	13.9	18.5	23.1
300	11.1	16.7	22.2	27.8
350	13.0	19.4	25.9	32.4
400	14.8	22.2	29.6	37.0
450	16.7	25.0	33.3	47.1
500	18.5	27.8	37.0	46.3
600	22.2	33.3	44.4	55.6
700	25.9	38.9	51.9	64.8
800	29.6	44.4	59.3	74.1
900	33.3	50.0	66.7	83.3
1000	37.0	55.6	74.1	92.6
1100	40.7	61.1	81.5	101.9
1200	44.4	66.7	88.9	11.1
1300	48.1	72.2	96.3	120.4
1400	51.9	77.8	103.7	129.6
1600	59.3	88.9	118.5	148.1
1800	66.7	100.0	133.3	166.7
2000	74.1	111.1	148.1	185.2

Values of rock volume include another six inches, the depth required to cover a four-inch distribution pipe with two inches of rock. Table values include no waste. To calculate rock quantity in tons, multiply table values by 1.4.

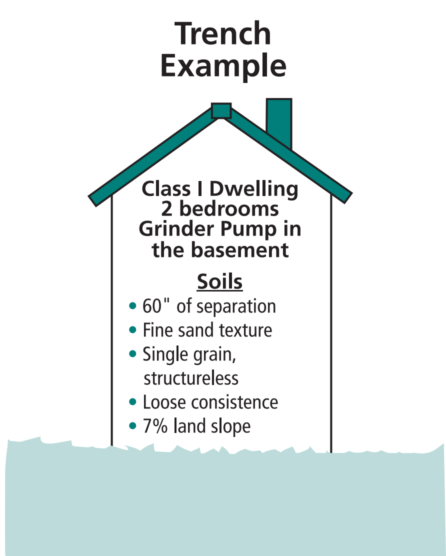
Rock is specified by weight, rather than volume. While there is some variation in rock density, multiplying the table values of cubic yards by 1.4 will result in a reasonably accurate estimate of the rock weight in tons.

FIGURE 12.15 Methods for Securing Inspection Pipes



10. A vertical inspection pipe at least 4 inches in diameter must be installed and secured in the distribution media of every trench or seepage bed. The inspection pipe must be located at an end opposite from where the sewage tank effluent enters the medium. The inspection pipe must have three-eighths inch or larger perforations spaced vertically no more than six inches apart. At least two perforations must be located in the distribution medium. No perforations may be located above the geotextile cover or wrap. The inspection pipe must extend to the bottom of the distribution medium, be secured, and be capped flush with or above finished grade (7080.2150 Subp. 4 (B)). Examples of securing methods are shown in Figure 12.15.

Trench Example



Example Trench Design

The following example is an oversimplification for EXAMPLE CALCULATION purposes ONLY!

A trench system is being designed for a two-bedroom Class I dwelling with the following characteristics:

- Pump in the basement
- Soil: 60 inches of vertical separation, is fine sand, single grain structure
- Land slope of 7%

1. The estimated flow rate is 300 gallons per day.
   a. The minimum septic tank capacity is 1,500 with multiple tanks or compartments. An effluent screen and alarm is added as a best practice.
   b. The minimum size of pump tank required is 500 gallons.

2. The maximum depth of the system is determined by subtracting: 5 feet - 3 feet = 2 feet.
3. The fine sand/single grain soil loading rate is selected for the system from the texture and structure of 0.60 gpd per square feet.
4. The design flow of 300 gpd is divided by the soil loading rate of 0.60 gpd/ft^2 which results in a required BA of 501 ft^2. This square footage for a BA is based on six inches of side wall area of distribution media. If 12 inches of sidewall media are used in a trench system, the BA can be reduced by 20 percent, which results in a BA of 401. Twelve inches of media will be installed.
5. A seepage bed is not appropriate for this site due to the 7% slope.
6. Rock is chosen as the distribution media.
7. A width of the trench is selected as three feet. The lineal feet of trench needed is found by taking the BA of 401 and dividing by the width of the trenches and is equal to 134 lineal feet.
8. The amount of rock required is determined by taking the depth of rock under the pipe of one foot, adding 0.5 feet above the pipe, and multiplying by the BA of 401 ft^2, which results in 602 cubic feet of rock, or 32 tons. Adding in 10% for constructability results in 35 tons of rock.
9. A vertical inspection pipe at least 4 inches in diameter must be designed and installed in each trench or seepage bed at the media/soil interface. The pipe must be located at the end of the soil treatment unit appropriate from the end where the sewage tank effluent enters and be secured to remain in place over the life of the system (Chapter 7080.2200, Subp. 4 (B).
10. Since this system is being designed in fine sand, either pressure distribution, five feet of vertical separation, or the dispersal area must be divided into multiple units with no trench having >15% of the required bottom area.

Dual Field Systems

Dual field systems allow for the septic tank effluent to be dispersed in one of two or more systems. Dual field systems are designed with two or more soil absorption areas, used alternately. While one field is accepting effluent, the other is resting. Dual field systems can be installed as Type I systems, but when downsized below standard capacity during loading, they are considered Type III systems. Periodically a valve is switched and the second soil treatment system is placed into use while the first one is allowed to rest. This resting period allows the soil treatment system to have a break and should allow for aerobic conditions to predominate and reduce the clogging potential of the biomat and rejuvenate the soil for phosphorus removal.

Once the first section of the system has developed a mature biomat, it can be diverted to the second section. Often times, people manually turn a valve on July 4th to let the trench system that was receiving effluent recover, while the second system receives the septic tank effluent. Advantages of dual field systems:

- Relatively low cost
- Easy to install
- Allow periodic resting of infiltrative surface, increasing the soil's absorptive ability

Disadvantages of dual field systems:

- Front end of trench can overload
- Require larger soil treatment system than do conventional systems
- Diversion valve should be evaluated every six to twelve months

In larger systems, this design has been found useful in system management. It also allows some protection in case flows become higher than those for which the system was designed. If a system has low seasonal flows, a dual field system allows for a smaller portion of the system to be used. Dual field systems are sized, designed, and constructed as other standard systems are, except that:

- the soil treatment area is divided into two or more parts, and
- a device to alternate between the zones is designed and installed.

Each zone can be used for up to one year, unless the effluent level indicates that a longer duration is feasible. Managing the development and existence of the biomat in the soil treatment system can contribute greatly to both the treatment performance and the lifespan of the soil treatment system.

The use of alternating gravity soil treatment systems in coarse soils may be counter-productive, particularly in terms of effluent treatment. The development of a biomat in the soil treatment system is beneficial even though too much of good thing can lead to problems. In coarse-textured soils, the biomat is much slower to develop than in fine textured soils. During the time it takes the biomat to develop in coarse soils, effluent flow in the soil below the soil treatment system is often in saturated flow conditions, which reduces the effluent treatment capacity of the system. If alternating soil treatment systems are used in this setting, an annual succession of slowly developing biomat can ensue in each of the soil treatment systems. The two soil treatment systems perform well hydraulically (disposing of the effluent) but poorly in terms of treating the effluent.

One approach to addressing the slow or poor development of a flow-restricting biomat in medium-to-coarse soils is the use of pressure distribution. The design of pressurized soil treatment systems, with frequent dosing of small volumes of effluent uniformly throughout the soil treatment system, simulates the flow-restrictive nature of a well-developed biomat. This is why, for coarse soils, the on-site rules require the use of pressure distribution: the mechanical system of pressurizing and dosing replaces the biomat as a flow regulator in soils where the natural development of a biomat is slow and uncertain. For long-term management of effluent treatment and dispersal, alternating soil treatment systems link well with pressure distribution.

In all soil conditions, the frequency of valve switching depends upon the rate of biomat development, which in turn is dependent upon the biological load and hydraulic flow of the effluent being treated and disposed at the site. In any case, proper management of the biomat—development, existence, and resting/drying—is based upon observations of the soil treatment system ponding levels. These routine observations will lead the operator to select a valve switching schedule or frequency that matches the particular system site, soil, and effluent characteristics. Such an approach, depending upon conditions, could result in a relatively frequent valve switching cycle (every six months) to a relatively infrequent valve switching cycle (every three or four years).

Zoning of Cluster Systems

In some applications it is advantageous or required to zone a soil treatment system into several separate components. The goal may be to facilitate management, keep pump size reasonable or be due to site limitations. Regardless of the reason there are control panels and splitting devices a designer may choose to facilitate a zoned system.

Type II – V Trenches and Seepage Beds

Many times the site available for onsite wastewater treatment will not allow a Type I system. In other instances, the designer or property owner may be interested in utilizing technology beyond those allowed under Type I systems. Chapter 7080 classifies these systems as Type II, III, IV or V. The reasons may include:

1. Locating the system in a floodplain (Type II)
2. Reducing the bottom area beyond what is allowed in Chapter 7080 (Type III)
3. Designing and installing all or part of the system in non-natural/disturbed soil, including installing the system so not all the distribution media is in native soils (Type III)
4. Using pretreatment with a registered product and pressure distribution (Type IV) with difficult soil and site conditions
5. Pretreating with a reduced-size trench or bed with a registered product (Type IV)
6. Using non-registered pretreatment to a trench system located in fill (Type V) and
7. Using non-registered distribution media (Type V)

MN Rules Chapter 7080 allows the reduction in vertical separation in 7080.2350, Subp. 2, provided that certain conditions are met as shown in Table 12.5.

TABLE 12.5 Treatment Component Performance Levels and Method of Distribution by Texture Group[1]

Vertical Separation (inches)	Texture Group[2]		
	All sands and loamy sands	Sandy loam, loam, silt loam	Clay, clay loams
12 to 17[3]	Treatment level A Uniform distribution Timed dosing	Treatment level A Uniform distribution Timed dosing	Treatment level A Uniform distribution Timed dosing
18 to 35[3]	Treatment level B Uniform distribution Timed dosing	Treatment level B Uniform distribution Timed dosing	Treatment level B Uniform distribution
36+[3]	Treatment level A-2 or B-2 Uniform distribution Treatment level C	Treatment level A-2 or B-2 Uniform distribution Treatment level C	Treatment level A-2 or B-2 Uniform distribution Treatment level C

[1] The treatment component performance levels correspond with those established for treatment components under the product testing requirements in Table III in part 7083.4030.
[2] With less than 50 percent rock fragments
[3] Additional vertical separation distance is required as determined in part 7080.2150, subpart 3, item C, subitem (1), unit (b).

Above–ground Systems

Above-ground systems are used when the natural soil will not accomplish the necessary acceptance or treatment below grade. The construction of these systems is a more exacting process than construction of below-grade systems. Many times, an above-ground system is the only choice for proper treatment on a site. When we think of above-ground systems, we usually think of either a sewage treatment mound system or an at-grade system. Unless the soil under the above-ground system has the ability to transmit liquid both vertically and horizontally, it will not function properly. If the site has unnatural soil or does not have 12" inches for a mound or 36 inches for an at-grade of unsaturated soil, a mound or at-grade may still be an option for the site; however, it will be a Type III system, which dictates additional permitting and management requirements. Above-ground systems applications include sites with high water tables, bedrock, excessively permeable soils and slowly permeable soils.

Above-ground systems are designed based on the principle of an absorption area. The absorption area is the area necessary to treat and accept the wastewater before dispersal into the natural soil conditions. This principle was first seen in the literature in a 1977 paper by Converse et al.

Above-ground Rule Requirements

All above-ground systems must utilize a pump and pressure distribution (7080.2050, Subp. 4 (1 &2)). Flow measurement is also required (7080.2220, Subp. 1 (D) and 7080.2230, Subp. 1 (D)).

Above-ground System Siting

When possible, above-ground systems should be located on the summit or shoulder of a slope. On a crested site, the distribution system can be situated such that the effluent can move laterally down both slopes. A level site allows lateral flow in all directions, but may present problems as the water table beneath the absorption bed may rise in slowly permeable soils. Sloping sites allow the liquid to move only in one direction away from the absorption bed. On sloping sites and sites with slowly permeable soils, soil components rely on lateral effluent movement through the upper soil horizons. Lateral movement becomes more important as soil permeability decreases. It is best if these systems are sited in open areas with exposure to sun and wind, which increases the assistance of evaporation and transpiration in the dispersal of the effluent. In fact, locating above-ground systems on some slope is preferable. **The upslope edge of the absorption bed must be installed along the natural contour (Chapter 7080.2230, Subp. 3(D).**

The setbacks specified for soil subsurface treatment/dispersal component apply to mound and at-grade systems. The distances are measured from the absorption area.

At-grades

Definition and Description

An at-grade, as its name implies, is a system installed with the distribution media placed at the original soil surface. It is designed to solve similar problems as the mound, but where the soil conditions are somewhat more favorable. According to Minnesota Rules Chapter 7080.1100 , Subp. 6 an at-grade system is a pressurized soil treatment and dispersal system where sewage tank effluent is dosed to an absorption bed that is constructed directly on original soil at the ground surface and covered by loamy soil materials. The operation of the at-grade component is a two-stage process involving both effluent treatment and dispersal into the underlying soil. Treatment is accomplished predominately by physical and biochemical processes within the soil. These processes are affected by the physical characteristics of the effluent wastewater, influent application rate, temperature, and the nature of the receiving soil.

The at-grade system is an option to consider as a Type I system when there are between 36 and 42 inches to the limiting condition, or when you have soils you do not want to excavate, such as clay. **Chapter 7080.2230, Subp. 2 (A) requires that the upper 12 inches of the absorption area of the at-grade must be original soil with a loading rate of 0.45 gallons per day per square foot as shown in Table IX or IXa in 7080.2150, Subp. 3(E).** One of the advantages of using an at-grade system compared to a mound is the potential for cost savings on material. The material used to cover the media bed should be a loamy material and need not be the same clean sand used below the media in the construction of a mound. At-grades can also be used as part of a Type III – V system with reduced areas and vertical separations allowed with additional permitting and management requirements. Another advantage of an at-grade system is that the effluent is spread out across the slope (long and narrow), offering better potential treatment of the nutrients and other contaminants found in the effluent as well as better acceptance of the effluent. Type I at-grade systems cannot be used if the distance to the limiting condition is less than three feet.

General Specifications

The at-grade component contains a distribution system that consists of distribution media and a pressure distribution system, which is installed directly on top of the plowed natural soil and covered by loamy or sandy cover material and topsoil borrow, as shown in Figure 12.16. Effluent flows into the soil, where it undergoes biological, chemical, and physical treatment and dispersal into the environment. The natural soil serves as the treatment medium and disperses the effluent into the environment.

FIGURE 12.16 At-Grade Specifications

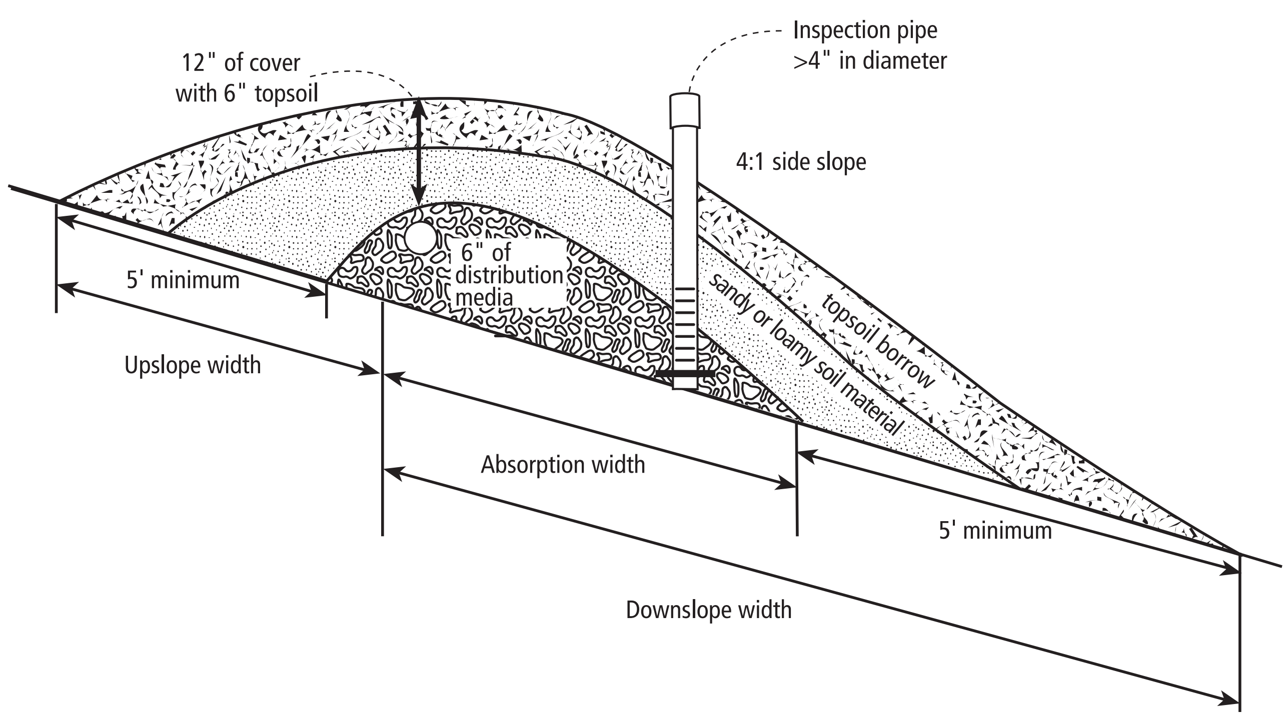


TABLE 12.6 Contour Loading Rates

perc rate (mpi) at 12 inches	loading rate	soil texture (0-12 inches)	other characteristics in the upper 48"	contour loading rate (CLR) (gpd/ft)
faster than 0.1	0.00	coarse sand	no textural change	6
			saturated soil (<3')* bedrock (<4')	5
0.1 to 5	1.60	sand loamy sand fine sand (50% or more fine sand plus very fine sand)	no textural change	8
			layers of other textures	6
			banding	4
			saturated soil (<3')*	5
			bedrock (<4')	5
6 to 15	1.00	sandy loam	strong to moderate structure, no textural change	7
			weak structure layers of other textures	6
			massive or platy structure* saturated soil (<3')* bedrock (<4')	5
16 to 60	0.6 – 0.78	loam silt loam silt sandy clay loam silty clay loam clay loam	strong to moderate structure, no textural change	6
			weak structure layers of other textures	5
			massive or platy structure* saturated soil (<3')* bedrock (<4')	4
61 - 120 slower than 120	0.0 – 0.3	sandy clay clay silty clay	strong to moderate structure, no textural change	3
			weak structure layers of other textures	2
			massive or platy structure* saturated soil (<3')* bedrock (<4')	2

* Total Design CLR < 8 gal/ft

Design of At-Grade Systems

The design of the at-grade system is based on sewage flow as estimated for other systems, soil flow patterns as dictated by the contour loading rate (CLR), and the general geometry of a system built above-ground. **MN Rules Chapter 7080.1100 Subp. 18a defines Contour Loading Rate as the amount of effluent loaded to the soil per the length of the dispersal unit or units along the single hillslope along the contour. The contour loading rate is determined on the relationship between the vertical and horizontal water movement in the soil and is based on the permeability difference between the absorption area and any deeper horizons, the depth between the absorption area and the change in permeability, and the land slope.** CLR refers to potential horizontal and vertical flow patterns in the soil. MN Rules Chapter 7080 does not provide CLRs; therefore, it is the professional responsibility of the designer to choose the appropriate CLR for a system. Taking into account soil texture, soil structure, and any limiting layers existing in the soil, the University of Minnesota has developed recommended CLRs (see Table 12.6), which range from two to twelve gallons per foot. The two-gallon per foot minimum accounts for nearly all horizontal flow of effluent. This minimum should be used for a system limited by impermeable bedrock or very heavy clay soils, or in any situation where horizontal movement of contaminants is a concern. The twelve gallon per foot loading rate (the maximum) would be used when water moves down through the soil much faster than it moves sideways, as in a sandy soil profile. Design values should be somewhere between these two. For a "typical" soil horizon made up of a variety of soil textures, a CLR of four to twelve gallons per foot should be used. Using the soil texture, structure and percolation rate, if available, a CLR should be chosen based on the most limiting condition. Sites with steep slopes may also want to consider lower CLRs as horizontal movement is more likely.

Discussion of CLRs first began appearing in the literature with regards to large or cluster effluent absorption systems. Tyler and Converse (1984) describe CLRs as being important design criteria for large systems from which system width and length are calculated, and Converse and Tyler (1987) showed that mounds can be placed on much more restrictive sites if the system is designed using CLRs that fit the site, provided the installer follows correct construction and siting procedures. When laying out soil treatment areas it is critical to make the systems long and narrow along the contour when soil and site conditions encourage lateral movement of effluent. Two systems can have the same square footage, but one can have a CLR much greater if the system is not situated appropriately as shown in Figure 12.18.

FIGURE 12.18 System Layout Affects CLR

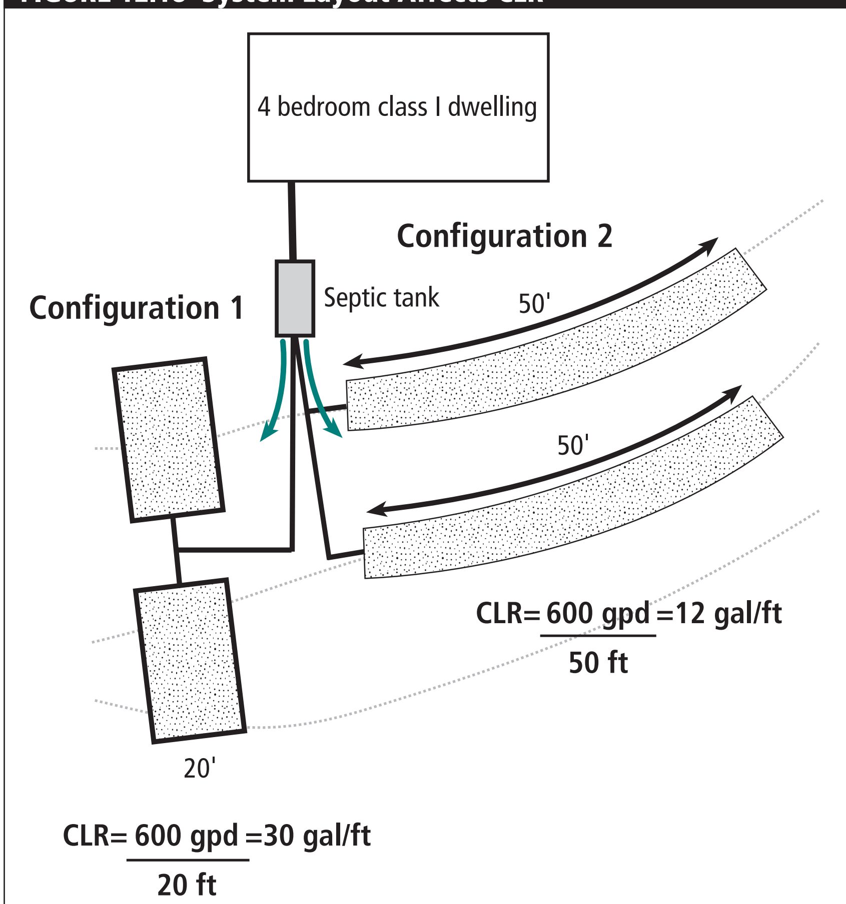


Table 12.7 highlights the appropriate loading rates used to determine the required area for a soil treatment system.

Table 12.7: Loading Rates for Determining Bottom Absorption Area and Absorption Ratios Using Percolation Tests

Percolation rate (MPI)	Treatment level C		Treatment levels A, A-2, B, and B-2	
	Absorption area loading rate (gpd/ft^2)	Mound absorption ratio	Absorption area loading rate (gpd/ ft^2)	Mound absorption ratio
<0.1	-	1.0	-	1.0
0.1 to 5	1.2	1.0	1.6	1.0
0.1 to 5 (fine sand and loamy fine sand)	0.6	2.0	1.0	1.6
6 to 15	0.78	1.5	1.0	1.6
16 to 30	0.6	2.0	0.78	2.0
31 to 45	0.5	2.4	0.78	2.0
46 to 60	0.45	2.6	0.6	2.6
61 to 120	-	5.0	0.3	5.3
>120	-	-	-	-

Design of the at-grade system includes the following three steps (described in more detail below), (1) calculating the design wastewater flow, septic tanks, and dosing tanks (2) design of the absorption bed, including the pressure distribution system and (3) design of the entire at-grade component. See the At-Grade Design, Pressure Distribution, Pump Tank, and Pump Selection worksheets at septic.umn.edu.

TABLE 12.8 Estimated Sewage Flows in Gallons per Day

Number of Bed-rooms	Class I	Class II	Class III	Class IV
2	300	225	180	60% of the values in the Class I, II, or III columns.
3	450	300	218	
4	600	375	256	
5	750	450	294	
6	900	525	332	
7	1050	600	370	
8	1200	675	408	

Class I: The total floor area of the residence is over 800 square feet per bedroom or more than two of the following water-using appliances are installed: dishwasher, automatic clothes washer, water softener, garbage disposal, self-cleaning furnace.
Class II: The total floor area of the residence is between 500 and 800 square feet per bedroom, and no more than two water-using appliances are installed.
Class III: The total floor area of the residence is less than 500 square feet per bedroom, and no more than two water-using appliances are installed. Use this estimate **only** when designing a system with flow control, such as trenches and a holding tank, or a timer to dose the system at a designed volume.
Class IV: Class I, II, or III home, but with no toilet wastes discharged into the system.

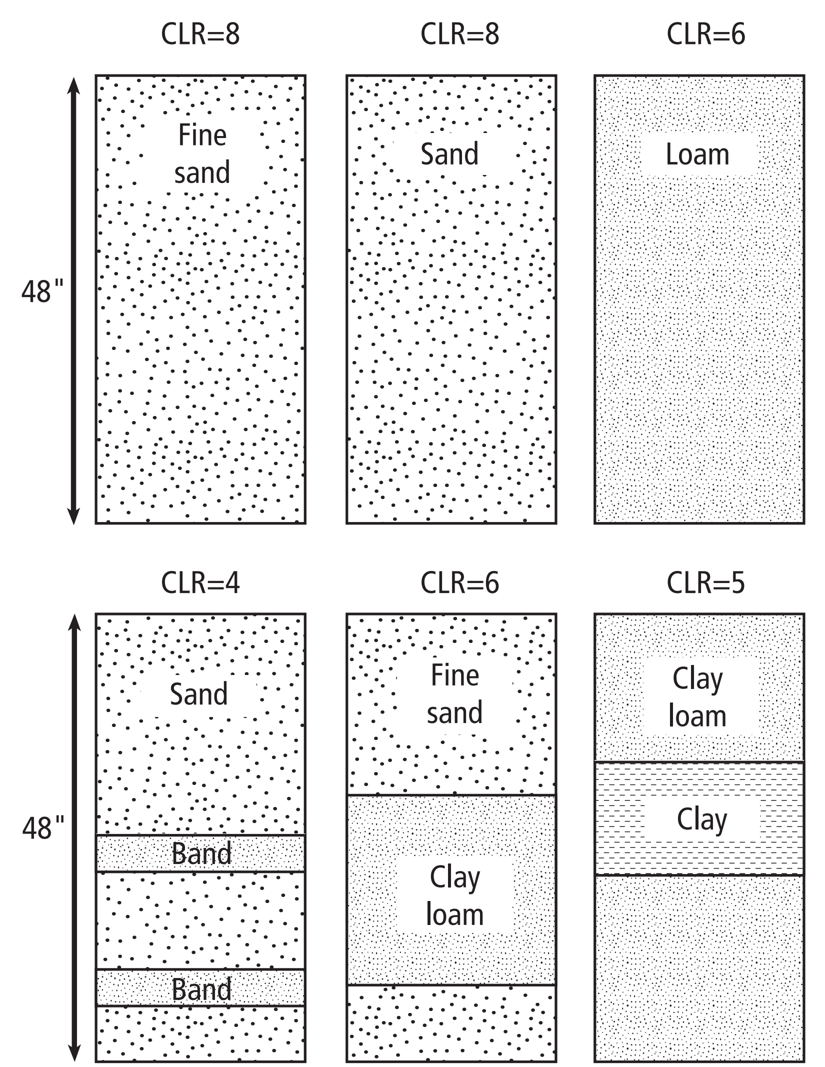
1. The estimated flow rate is determined using Table 12.8, unless measured flow rates are available for other establishments. With a Class I residence, the estimated water use is equal to 150 gallons per day (gpd) per bedroom. This assumes an occupancy of two people

TABLE 12.9 Septic Tank Capacity for Dwellings (gallons)

Number of bedrooms	Septic tank capacity (gallons)	*Septic tank with garbage disposal and/ or pump in basement capacity (gallons)
3 or less	1,000	1,500
4 or 5	1,500	2,250
6 or 7	2,000	3,000
8 or 9	2,500	3,750

* must include either multiple compartments or multiple tanks. An effluent screen with an alarm is recommended.

FIGURE 12.19 Contour Loading Rates by Soil Texture



per bedroom, each using 75 gallons per day. The footnote in Table 12.8 suggests a classification for residences
according to size and number of water-using appliances. While the individuals who occupy a residence use the water, the number of bedrooms is still considered a good index of the potential water use. See Section 5: Source for a more detailed discussion of flow determination.

a. Determine the required septic tank capacity, compartments, effluent screen, and alarm based on bedroomsand use of garbage disposal and pump in the basement, as shown in Table 12.9. For more information on septic tanks, see Section 7.

b. Determine the minimum size pump tank required. See Section 9 for more information on pump tank.

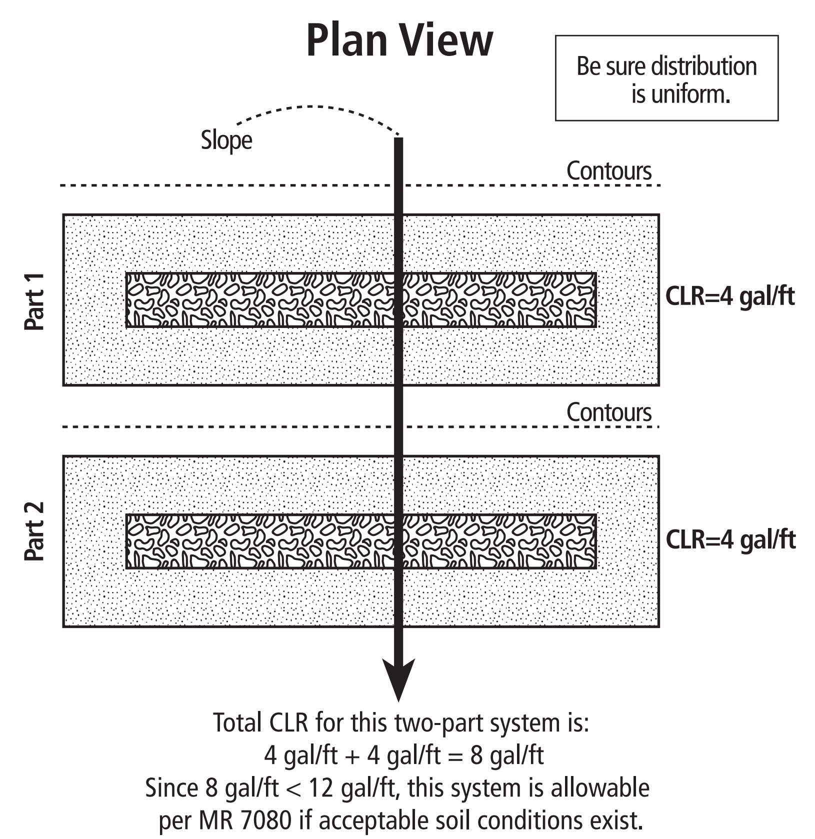
2. Determine the width and length of the at-grade absorption bed. This begins by selecting the appropriate soil loading rate (Table 12.7) and CLR/absorption ratio. **According to 7080.2150 Subp. 3. (M), the contour loading rate for soil dispersal systems must be between 1 and 12 gallons per lineal foot per day.**

The University of Minnesota has developed recommended at-grade CLRs, which are provided in Table 12.6.

Figure 12.19 demonstrates various CLR for different soil texture conditions. In both at-grades and mounds the required absorption area based the contour loading rates can be split into several parts. The total CLR must be less then twelve gallons per foot to be considered a Type I system. Figure 12.20 represents a system with a total CLR of eight split between two sections. It is critical if these parts are at different elevations that the design of the pressure distribution system account for the difference.

a. The at-grade absorption width is calculated by dividing the CLR by the soil loading rate for the upper 12 inches of soil. This width cannot exceed 15 feet. The at-grade bed absorption width for slopes of one percent or greater does not include the width of the media necessary to support the upslope side of the pipe.

FIGURE 12.20 Contour Loading Rate Example



b. The CLR is also used to size the length of the system. System length is calculated by dividing the design flow by the CLR.

c. The total amount of distribution material should be specified in the design. If drainfield rock is used as the distribution material, the amount of rock is determined by:

i. Determine the area covered by rock by taking the rock layer length multiplied by the rock layer width, adding in an additional foot on the upslope portion to support the pipe.

ii. Determine the volume of rock by taking the area calculated above (i) times the height of rock (one foot) and dividing in half since the shape of the distribution area is triangular. This will give you the amount of rock in cubic feet. The volume can be converted to cubic yards by dividing by 27. Ten percent of additional rock for constructability should be added in.

d. Design the pressure distribution system. **At-grade systems located on slopes of one percent or greater require only one distribution pipe located on the upslope edge of the distribution media, with the absorption bed width being measured from the distribution pipe to the down slope edge of the media. Multiple distribution pipes may be used to provide even distribution, if necessary, based on site conditions (Chapter 7080.2230, Subp. 3 (C)).**

3. Design the entire at-grade component, including landscaping.

a. The total height of an at-grade is the height of the distribution media plus the cover material. Rock is typically the distribution media in at-grades. For most

TABLE 12.10 Bermslope Multipliers

% Slope	Upslope Multiplier	Downslope Multiplier
0	4.00	4.00
1	3.85	4.17
2	3.70	4.35
3	3.57	4.54
4	3.45	4.76
5	3.33	500
6	3.23	5.26
7	3.12	5.56
8	3.03	5.88
9	2.94	6.25
10	2.86	6.67
11	2.78	7.14
12	2.70	7.69
13	2.62	8.26
14	2.55	8.92
15	2.48	9.57
16	2.41	10.24
17	2.35	10.94
18	2.29	11.67
19	2.23	12.42
20	2.18	13.19
21	2.13	13.99
22	2.08	14.02
23	2.03	15.67
24	1.98	16.54
25	1.93	17.44

at-grades the total height of two feet is assumed. **Six inches of loamy or sandy cover material must be installed over the distribution media and be covered by six inches of topsoil borrow.** Cover must extend at least five feet from the ends of the distribution material and be sloped to divert surface water **(Chapter 7080.2230, Subp. 3 (G)).**

b. To determine the upslope berm, start by selecting an upslope berm multiplier based on the land slope. See Table 12.10. **Side slopes must not be steeper than four horizontal units to one vertical unit (Chapter 7080.2230, Subp. 3(G)).**

i. If land slope is greater than 1%, the upslope berm width is calculated by taking the at-grade height (two feet) multiplied by the upslope multiplier.

ii. If land slope is less then 1%: due to the absorption width being split equally on both sides, the upslope berm width is calculated by taking half of the absorption width and adding five feet.

c. To determine the downslope berm, start by selecting the downslope berm multiplier based on the land slope. See Table 12.10. The downslope width is then calculated by multiplying the downslope multiplier by the height (two feet) or by adding five feet to the absorption width (calculated in 2a).

i. For slopes greater than 1%, the downslope width equals the larger value calculated above.

ii. If land slope is less than 1%: due to the absorption width being split equally on both sides, the downslope berm width is calculated by taking half of the absorption width and adding five feet.

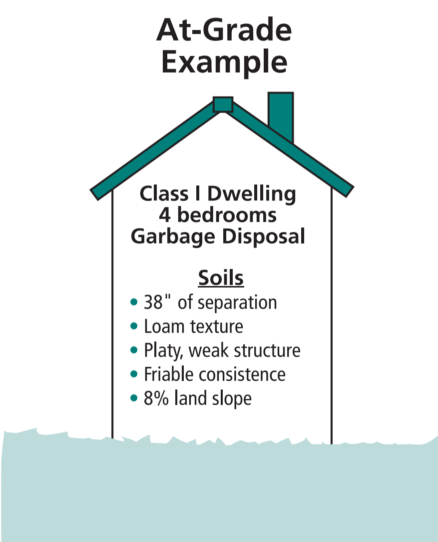
d. The total at-grade width is then calculated by adding the upslope berm (b) and the downslope berm (c).

e. The total at-grade length is the sum of two times the upslope berm (b) and the absorption length (4b).

f. **One vertical inspection pipes of at least 4 inches in diameter must be installed and evenly spaced along the downslope portion of the absorption bed. The inspection pipes must have three-eighths inch or larger perforations spaced vertically no more than six inches apart. Perforations must not exist above the distribution medium. The inspection pipes must extend to the absorption bed/soil interface and must be secured and capped flush with or above finished grade (Chapter 7080.2230, Subp. 3 (H)).**

g. The setbacks specified in MN Rules Chapter 7080 for soil subsurface treatment and distribution components apply to at-grade components. The distances are measured from the absorption area.

At-grade Example



Example at-grade design

The following example is an oversimplification for EXAMPLE CALCULATION purposes ONLY!

An at-grade system is being designed for a four-bedroom Class I dwelling with the following characteristics:

- Garbage disposal installed
- Soil: 38 inches of vertical separation, loam soil with a platy structure, using a CLR of four gallons per foot
- 8% land slope

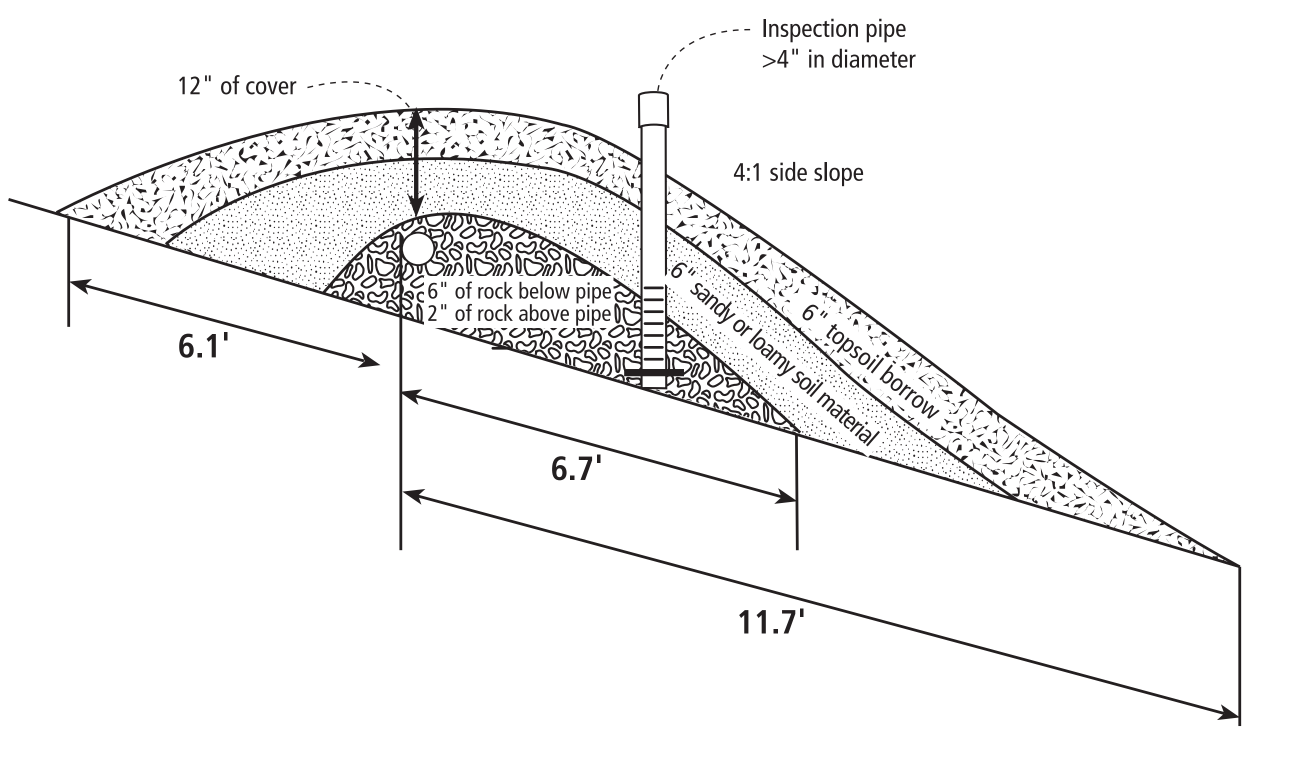
1. The estimated flow rate is 600 gallons per day.
   a. The minimum septic tank capacity is 2,250 with multiple tanks or compartments. An effluent screen and alarm is included as a best practice.
   b. The minimum size pump tank required is 500 gallons.
2. Choose a CLR and find the size of the adsorption bed. The CLR for this site was chosen to be 4 gallons/feet and the soil loading rate is 0.60 gallon per day per square foot. The at-grade absorption width is therefore 4 gal/ft / 0.60 gpd/ft^2 = 6.7 feet. System length is 600 gpd / 4 gal/ft = 150 feet. So, the absorption bed would be seven feet by 150 feet. If the necessary length cannot be found on the slope in one continuous section, this system can be broken into smaller pieces using the same dimensions. When the system is divided into pieces, the total CLR should be calculated. The total CLR is the sum of the pieces (see Figure 12.20) which can not be greater then twelve gallons per foot for the entire system.
3. The total amount of distribution material by determining the area covered by rock = (6.7 + 1) feet x 150 feet = 1152 ft^2
4. The volume of rock is calculated by taking 1152 ft^2 x 1 foot / 2 = 576 ft^3, dividing in half as the shape of the distribution area is triangular. Multiplying by 0.052 and adding in 10% for constructability yields 33 tons of rock.
5. Designing the pressure distribution system with one pipe results in a pipe length of 150 feet – 2 feet (one foot from each end) = 148 feet. A three foot spacing and ¼ perforations are selected, which yields 50 orifices and 37 gallons per minute. In order to achieve even distribution, this system must be center-fed with two-inch pipe. A center feed creates two laterals, meeting the specifications of Table 12.11. There must be a clean out provided for the lateral.

TABLE 12.11 Maximum Number of Perforations per Lateral

Perforation Diameter in (inches)	Perforation Spacing (feet)	Pipe Diameter (inches)				
		1	1.25	1.5	2	3
1/4	2.0	10	13	18	30	60
	2.5	8	12	16	28	54
	3.0	8	12	16	25	52
3/16	2.0	12	18	26	46	87
	2.5	12	17	24	40	80
	3.0	12	16	22	37	75
1/8	2.0	21	33	44	74	149
	2.5	20	30	41	69	135
	3.0	20	29	38	64	128

6. Design the entire at-grade component as shown in Figure 12.21 (next page).
   a. The total height is two feet.
   b. To determine the upslope berm, start by selecting an upslope berm multiplier of 3.03. Since the land slope is greater than 1%, the upslope berm width is 2 feet x 3.03 = 6.1 feet.

FIGURE 12.21 At-Grade Example Specifications



c. To determine the downslope berm, start by selecting the downslope berm multiplier of 5.85. The downslope width is then calculated by taking 5.85 x 2 feet = 11.7 feet or 6.7 + 5 feet = 11.7.

d. The total at-grade width is 6.1 +11.7 = 17.8.

e. The total at-grade length is the sum of (2 x 6.1ft) + 150 ft = 162.2 feet.

f. Specify one, four inch inspection port.

g. Assure that the layout of the system meets all setbacks.

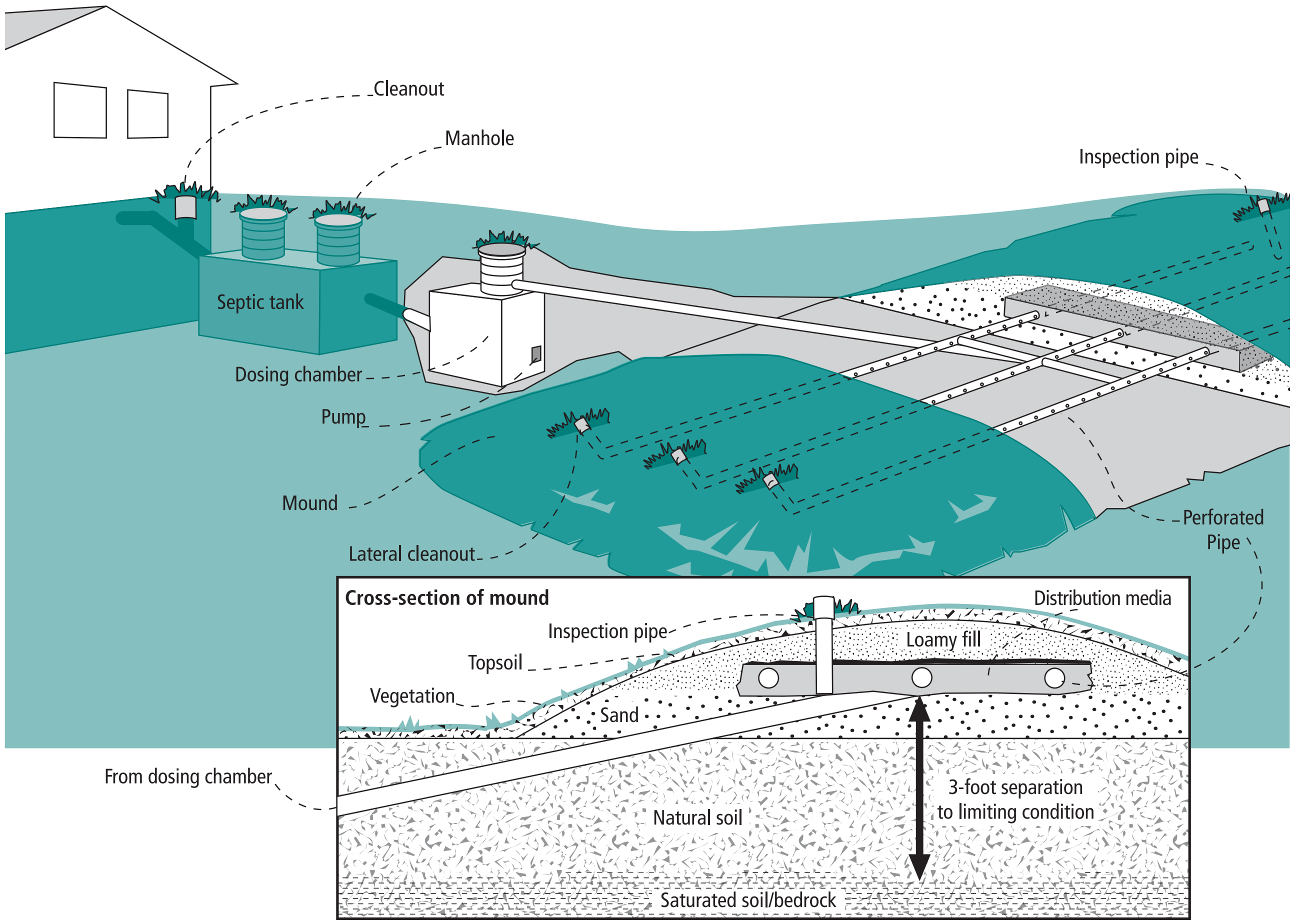
Mound Systems

Definition and Description

Mound systems are defined in Chapter 7080.1100, Subp. 50, as a soil treatment and dispersal system designed and installed such that all of the infiltrative surface is installed above grade, using clean sand between the bottom of the infiltrative surface and the original ground elevation, utilizing pressure distribution and capped with suitable soil material to stabilize the surface and encourage vegetative growth. A sewage treatment mound is nothing more than a seepage bed elevated by clean sand fill to provide adequate separation between where sewage effluent is applied and a limiting soil layer as shown in Figure 12.22. Mounds were developed in the early 1970s to overcome soil and site conditions, which limit the use of trenches and beds (Converse et al., 1977). Limiting conditions include high water tables, shallow soil depth to bedrock, slowly permeable soil, or soil too coarse for treatment.

A mound system is a two-stage process involving both effluent treatment and dispersal. Treatment is accomplished predominately by physical and biochemical processes within the clean sand material and native soil. The physical characteristics

FIGURE 12.22 Mound System



of the influent wastewater, influent loading rate temperature, and the nature of the receiving fill material and in situ soil affect these processes.

Physical entrapment, increased retention time, and conversion of pollutants in the effluent are important treatment objectives accomplished under unsaturated conditions. Pathogens contained in the effluent are eventually deactivated through filtering, retention, and adsorption by the fill material. In addition, many pollutants are converted to other chemical forms by oxidation processes.

The mound system addresses high water table conditions by elevating the infiltration bed to achieve the needed vertical separation. By using uniform distribution and adequate vertical separation in the selected sand media, vertical unsaturated flow is maintained, thus ensuring the maximum treatment permitted by this technology. On sites with slowly permeable soils, the mound system helps assure a known level of effluent treatment before effluent is discharged to the native soil. These soils are subject to severe damage from smearing and compaction, especially during the construction of conventional systems, which drastically reduces the permeability of the soil by destroying water-moving pores and channels. As a result these sites present a high potential for site and soil interface damage in addition to the need for large soil treatment systems to provide adequate infiltration area. For these sites, mound systems provide the following advantages:

- The mound effluent enters the more permeable natural topsoil over a larger area where it can move laterally until absorbed by the less permeable subsoil.
- The biomat that develops at the bottom of the media/sand infiltration area will not clog the filter media as readily as it would the less permeable natural soil.
- The infiltration area within the filter media is much smaller than it would be if placed in the more slowly permeable subsoil, yet the total mound area is probably larger than it would be for a conventional soil treatment system, if one could be used.

Mound systems are used primarily in shallow soils overlying a restrictive layer or elevated groundwater table. The shallower the soil, the more attention must be paid to transporting the treated effluent away from the point of application. Fifteen mound systems in Wisconsin were found to have a total nitrogen reduction of at least 55% from the pretreatment effluent to mound toe effluent (Blasing and Converse, 2004). Sufficient numbers of mounds have been installed in Minnesota and elsewhere to prove that the mound treatment system is a Type I technology. There are more than 50,000 single-family mounds successfully treating sewage in Minnesota.

Dispersal is primarily affected by the depth of the unsaturated receiving soils, their hydraulic conductivity, land slope, and the area available for dispersal. The mound consists of sand material, an absorption bed, and cover material. Effluent is dispersed into the absorption bed, where it flows through the fill material and undergoes biological, chemical, and physical treatment. It then passes into the underlying soil for further treatment and dispersal to the environment as shown in Figures 12.25 and 12.26.

TABLE 12.12 Clean Sand

Sieve Number	Sieve Size (mm)	Percent Passing
4	4.75	95 to 100
8	2.0	80 to 100
10	0.85	0 to 100
40	0.425	0 to 100
60	0.212	0 to 40
200	0.075	0 to 5

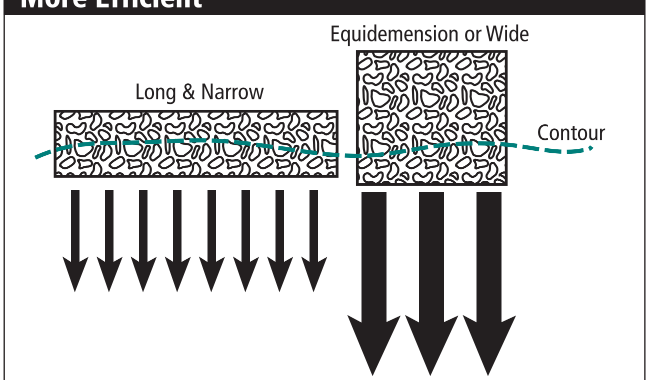
Clean sand is required for mounds to effectively treat and disperse effluent. Clean sand is defined in Table 12.12 (7080.1100, Subp. 16).

Cover material consists of material that provides erosion protection, a barrier to excess precipitation infiltration, and allows gas exchange. The native soil serves, in combination with the fill, as treatment media, and it also disperses the treated effluent.

Locating Mounds

Suitable soil provides excellent treatment of sewage tank effluent, and the natural topsoil should be utilized for treatment wherever possible. However, some locations do not have soils or soil profiles suitable for treatment of sewage using below-grade or at-grade systems. For instance, some soils do not have the ability to accept effluent, an ability that is necessary for the proper operation of the soil treatment system. In other soils, there is seasonal saturation at depths closer than three feet to the ground surface, such that adequate vertical separation of the soil treatment system is not possible under "natural" conditions. Soils with a hardpan layer that restricts downward movement of liquid, or with fractured or permeable bedrock, present problems for adequate treatment and/or acceptance of septic tank effluent.

FIGURE 12.23 Long and Narrow Layout is More Efficient



Mounds should be located on slopes whenever possible, because as a slope increases, the ability of the topsoil to accept and treat effluent increases. A sewage treatment mound will operate more effectively if it is relatively long and narrow as shown in Figure

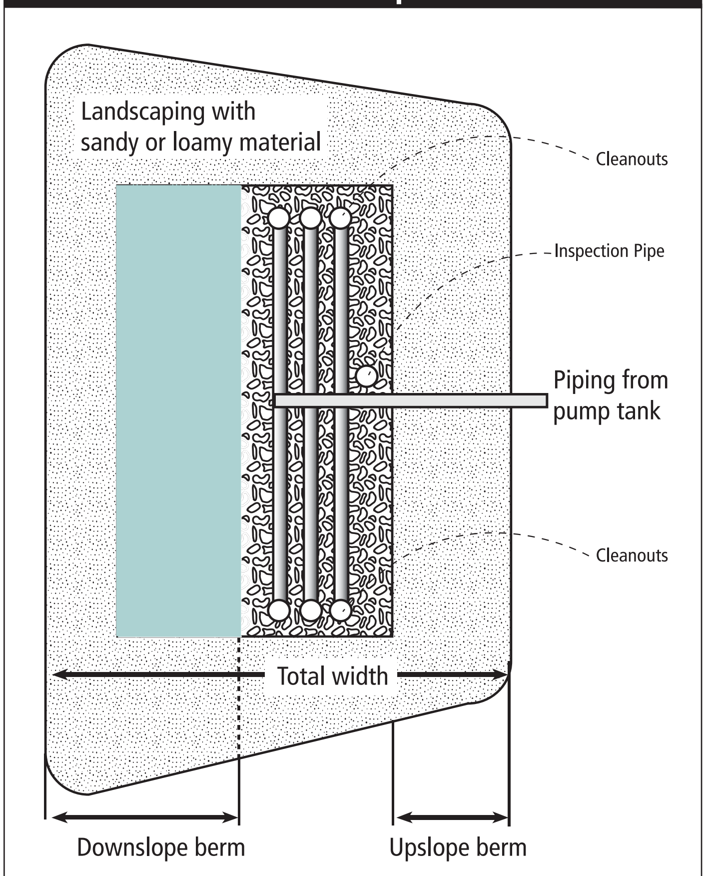
12.23. Mounds are designed with CLR of up to 12 gallons per foot resulting in ten-foot-wide absorption beds. When difficult soil conditions are present, the CLR should be reduced to narrow the beds and lengthen the mound.

The upper twelve inches of the original soil absorption area can be any soil texture as long as it has a mound absorption ratio of one or greater in Tables IX or IXa in 7080.2150 Subp. 3 item (E). Refer to Table 12.13 or see Table IX in the Forms section.

Table 12.13: Loading Rates for Determining Bottom Absorption Area and Absorption Ratios Using Percolation Tests

	Treatment level C		Treatment levels A, A-2, B, and B-2	
Percolation rate (MPI)	Absorption area loading rate (gpd/ft^2)	Mound absorption ratio	Absorption area loading rate (gpd/ft^2)	Mound absorption ratio
<0.1	-	1.0	-	1.0
0.1 to 5	1.2	1.0	1.6	1.0
0.1 to 5 (fine sand and loamy fine sand)	0.6	2.0	1.0	1.6
6 to 15	0.78	1.5	1.0	1.6
16 to 30	0.6	2.0	0.78	2.0
31 to 45	0.5	2.4	0.78	2.0
46 to 60	0.45	2.6	0.6	2.6
61 to 120	-	5.0	0.3	5.3
>120	-	-	-	-

FIGURE 12.24 Mounds are Trapezoids

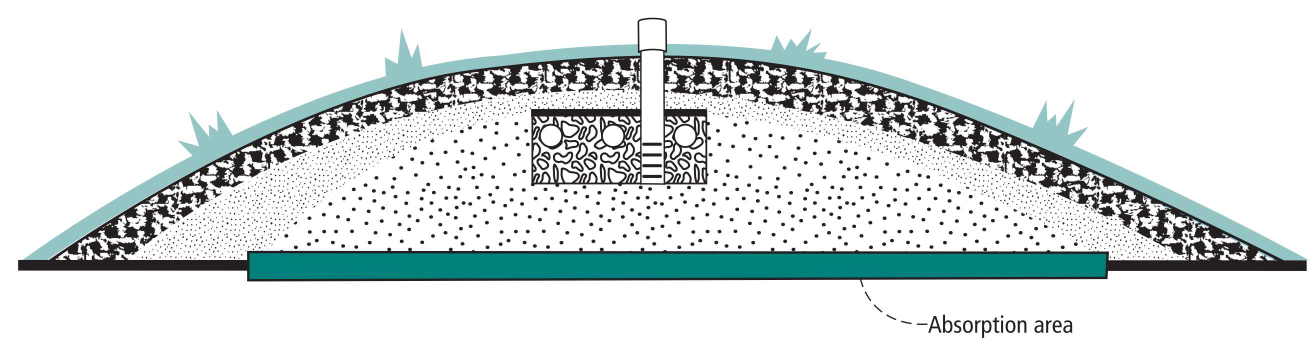


The upper twelve inches of the absorption area must also be above the periodically saturated soil or bedrock (Chapter 7080.2220, Subp. 2 (A)). **Mounds must never be located in swales or draws where the radius of curvature of the contour lines is less than 50 feet. On slopes of one percent or greater and where the original soil mound absorption is 5.0 or greater in Table IX or IXa in part 7080.2150, Subp. 3 (E), mounds must not be located where the ground surface contour lines that lie directly below the long axis of the distribution media bed represent a swale or draw, unless the contour lines have a radius of curvature greater than 100 feet (7080.2220, Subp. 2 (C)).**

It is recommended that mounds should be trapezoidal in shape as it lies on the slope, narrower at the top and wider at the bottom, as shown in Figure 12.24. This shape can be modified to fit with landscaping plans if necessary, as long as adequate absorption area is provided for the sewage effluent. The total lawn area for the mound will depend on the size of the bed, the height of the mound, and the side slopes of the mound landscaping. In any case, the side slopes should be no steeper than a 3:1. The "rectangular" mound, with parallel upslope and down slope sides, is the most commonly used shape, since it is the easiest to construct, but several shapes are possible, including C or S curves. While the mound location depends upon soil suitability, every effort should be made to fit the mound into the landscape plan.Mounds can be used as privacy berms or to highlight a certain portion of the outdoor living area. While the mound must be functional for sewage treatment, the location and shape should also be functional in the landscape plan.

According to Minnesota Rules Chapter 7080.2150, setbacks shall be measured from the absorption area. "Absorption area" means the area on original soil below a mound that is designed to absorb sewage tank effluent. The absorption area is not the total foot print of the mound but only the area that was designed to accept sewage. As can be seen in Figure 12.26, on slopes greater than 1%, the sewage will travel vertically and horizontally downslope, in the sand on the native soil. Therefore, on the upslope edge, the setback should be measured from the absorption bed, and on the downslope edge, from the clean sand layer, which extends past the absorption bed to the required absorption area. On flat sites, the effluent will move equally in both directions; therefore, the absorption width is split equally on each side as shown in Figure 12.25.

FIGURE 12.25 Flat Mound Absorption Width



General Specifications

A vertical separation of at least three feet is required between the bottom of the absorption bed and any restricting layer in order to maintain aerobic conditions and treat the effluent. When aerobic conditions exist in the clean sand, the long-term acceptance rate will be 1.2 gallons per day per square foot. If the depth to the restricting layer is inadequate or the absorption bed is too wide, anaerobic conditions may exist and cause a much slower acceptance rate. The possibility of anaerobic conditions occurring in the clean sand, and subsequent hydraulic failure, is a major design consideration when mounds larger than those required for single-family residences are required for the system. Figure 12.27 shows the recommended design and construction techniques for clean sand in the system. MN Rules Chapter 7080 does allow the sand to just come to the bottom of the distribution media as shown in Figure 12.27, though UMN OSTP does not recommend this technique.

Mound absorption beds are being constructed with alternative distribution media, such as chambers or gravelless pipe. The distribution media in a mound has historically been drainfield rock, but other media maybe approved for use under the product registration process.

FIGURE 12.26 Sloped Mound Absorption Width

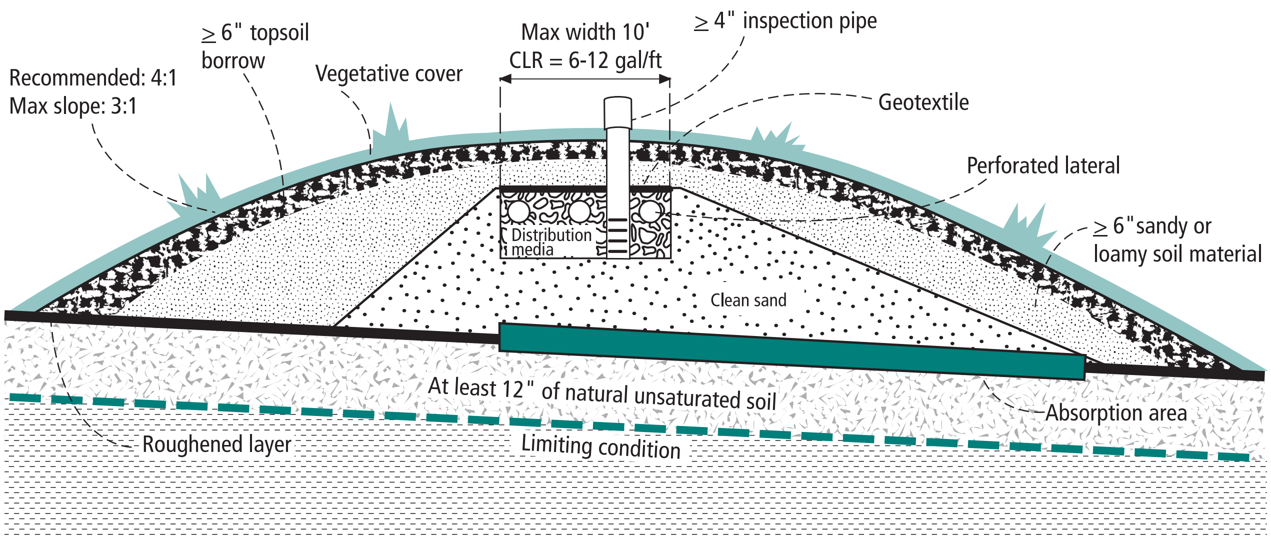
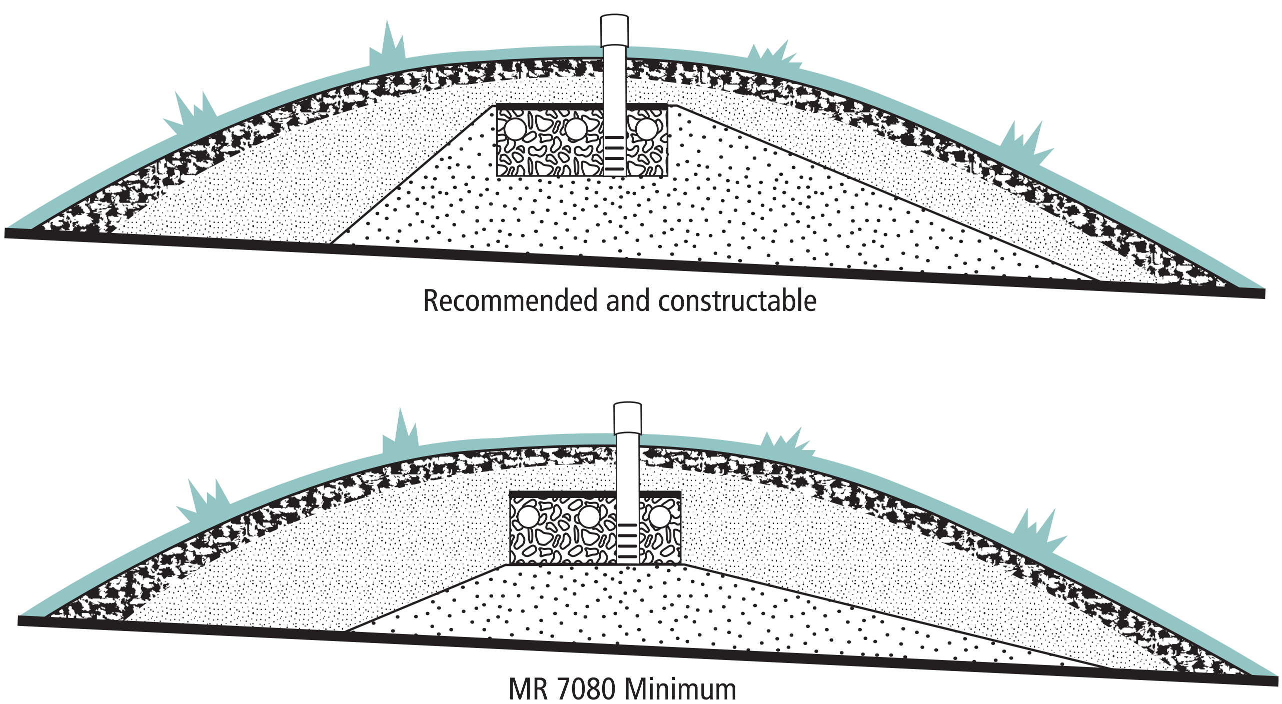


FIGURE 12.27 Recommended and MN Minimum Mound Profiles



Mound Design

Design of a mound system includes the following three steps, which are detailed below: (1) calculating the design wastewater flow, septic tanks, and dosing tanks; (2) design of the absorption bed, including the pressure distribution system; and (3) design of the entire mound component. See the Mound Design, Pressure Distribution, Pump tank and Pump Selection worksheets at septic.umn.edu/ssts-professionals/forms-worksheets.

1. **Calculate design wastewater flow, septic tanks, and dosing tanks.** The estimated flow rate is determined using Table 12.14 unless measure flow rates are available for other establishments. (Measured values are multiplied by a safety factor of 1.5 to determine the flow rate.) With a Class I residence, the estimated water use is equal to 150 gallons per day (gpd) per bedroom. This assumes an occupancy of two people per bedroom, each using 75 gallons per day. The footnote in Table 12.14 suggests a classification for residences according to size and number of water-using appliances. While the individuals who occupy a residence use the water, the number of bedrooms is still considered a good index of the potential water use. **See Section 5: Source** for a more detailed discussion of flow determination.

TABLE 12.14 Estimated Sewage Flows in Gallons per Day

Number of Bed-rooms	Class I	Class II	Class III	Class IV
2	300	225	180	60% of the values in the Class I, II, or III columns.
3	450	300	218	
4	600	375	256	
5	750	450	294	
6	900	525	332	
7	1050	600	370	
8	1200	675	408	

Class I: The total floor area of the residence is over 800 square feet per bedroom or more than two of the following water-using appliances are installed: dishwasher, automatic clothes washer, water softener, garbage disposal, self-cleaning furnace.
Class II: The total floor area of the residence is between 500 and 800 square feet per bedroom, and no more than two water-using appliances are installed.
Class III: The total floor area of the residence is less than 500 square feet per bedroom, and no more than two water-using appliances are installed. Use this estimate **only** when designing a system with flow control, such as trenches and a holding tank, or a timer to dose the system at a designed volume.
Class IV: Class I, II, or III home, but with no toilet wastes discharged into the system.

TABLE 12.15 Septic Tank Capacity for Dwellings (gallons)

Number of bedrooms	Septic tank capacity (gallons)	*Septic tank with garbage disposal and/or pump in basement capacity (gallons)
3 or less	1,000	1,500
4 or 5	1,500	2,250
6 or 7	2,000	3,000
8 or 9	2,500	3,750

* must include either multiple compartments or multiple tanks. An effluent screen with an alarm is recommended.

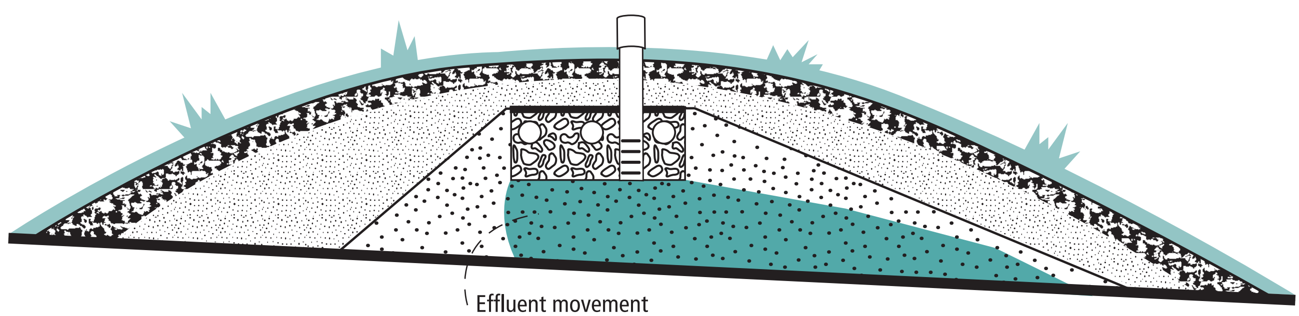
a. Determine the required septic tank capacity, compartments, effluent filter, and alarm based on bedrooms and use of garbage disposal and pump in the basement as shown in Table 12.15. For more information on septic tanks, see Section 7.

b. Determine the minimum size pump tank required. See Section 9 for more information on pump tanks.

2. **Design the mound distribution media system bed and pressure distribution system.** Determine the area, length, and width of the bed. The mound distribution media bed area should be as long and narrow as practical. The bed must completely encase the top and sides of the distribution pipes to a depth of at least one inch above the pipe. The bed must have at least six inches of storage below the pipe. The sidewalls of the mound distribution media bed must be as vertical as practical and not intentionally sloped. The top of the bed must be level in all directions and on slopes of one percent or greater; the upslope edge of the bed must be placed on the contour.

a. The mound distribution media bed area consists of bottom area only and is calculated by multiplying the estimated flow rate by 1.2 gpd/square foot per gallon per days as is shown in Table 12.16.

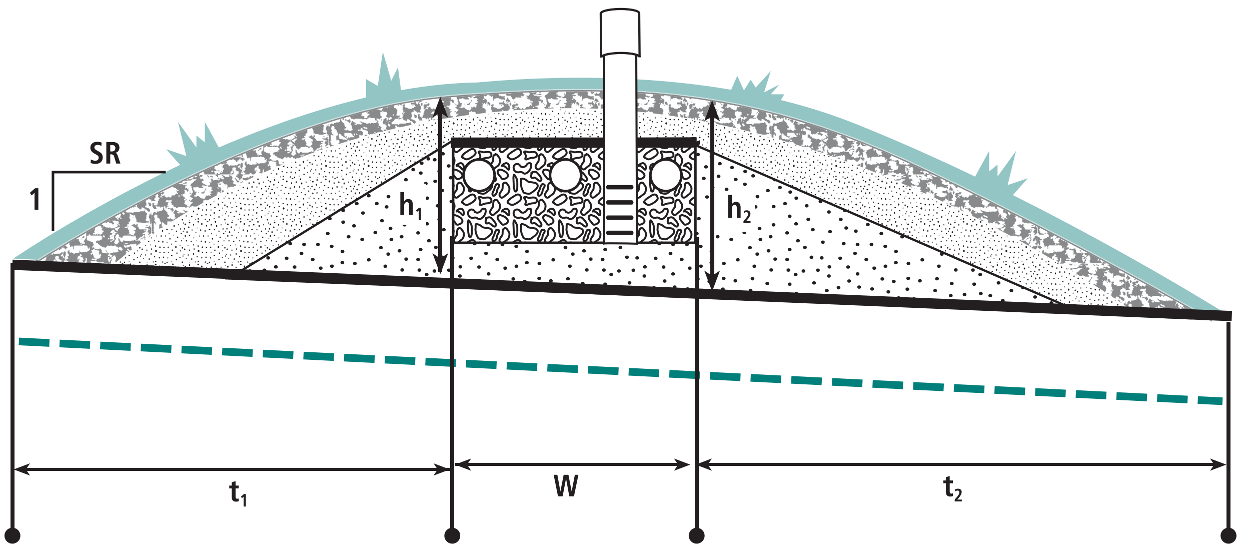
FIGURE 12.28 Effluent Movement Through a Mound Absorption Width



b. The width of the bed of a mound is the width of soil under the sand layer that receives effluent (Figure 12.28) where the soil receiving effluent must have the capability to absorb this effluent; otherwise, berm toe surfacing will occur. Mound absorption media bed widths must be determined by the relationship between the vertical and horizontal water movement (CLR) and must be between one and twelve gallons per foot.

The mound bed width is calculated by dividing the CLR by 1.2 gal/square foot. The width of the bed is designated as W in Figure 12.29. A CLR of 12 is typically chosen for sites which do not have soil layers that would cause likely lateral movement of effluent and results in the maximum bed width of ten feet. On challenging sites where lateral movement is a concern, this width should be reduced. This will reduce the CLR. To achieve sufficient bed width, it is occasionally necessary to use a narrower and longer length.

FIGURE 12.29 Mound Specifications



SR = Slope ratio of horizontal distance per 1.0 foot vertical (unitless)
S = Landslope (percent)
h_1 = Depth of mound on upslope edge of rock bed (feet)
h_2 = Depth of mound on downslope edge of rock bed (feet)
W = Width of mound bed (feet)
t_1 = Upslope width (feet)
t_2 = Downslope width (feet)

$$t_1 = \frac{h_1 * SR}{1 + (S \div 100 * SR)} \qquad t_2 = \frac{h_2 * SR}{1 - (S \div 100 * SR)} \qquad h_2 = h_1 + W\,(S \div 100)$$

c. The mound bed length is calculated by taking the area and dividing by the width.

d. The total amount of distribution media should be specified in the design. If drainfield rock is used as the distribution media the amount of rock is determined by taking the area calculated above in (a) times the height of rock (one foot). This will give you the amount of rock in square feet. The volume can be converted to tons by multiplying by 0.052. 10% for constructability should be added in.

e. Design the pressure distribution system. Mound systems can not have spacing on laterals or perforations greater then three feet. Cleanouts are required on the pressure distribution laterals. See Section 11: Distribution of Effluent for more information on the design of pressure distribution systems.

3. Determine the absorption area of the mound. Adequate absorption area is essential to the successful operation of a mound system. The required absorption area depends upon the allowable loading rate of the soil under the clean sand layer

of the mound. The allowable loading rate depends upon soil texture, structure, and the percolation rate of the soil in contact with the clean sand layer of the mound. Allowable soil loading rates for various soil textures and structures are presented in Table 12.16 and Tables IX and IXa in the Forms Section. The distribution media bed is sized on the basis of 1.2 gal/square foot of effluent per day, so unless the soil under the mound has the same properties and absorption capability as clean sand, the effluent must be spread out over additional soil area.

Another way to express the absorption width requirement is to use the absorption width ratio, which is defined as the area of soil required to absorb the effluent percolating downward from one square foot of the distribution media layer. As long as sufficient mound width is available so that all of the liquid is accepted into the soil and pressure distribution is used, berm toe surfacing should not occur. One of the major causes of berm toe surfacing has been inadequate down slope berm widths. Another cause is compaction of the soil, which changes its ability to accept effluent.

Table 12.16 Loading Rates for Determining Bottom Absorption Area and Absorption Ratios Using Percolation Tests

	Treatment level C		Treatment levels A, A-2, B, and B-2	
Percolation rate (MPI)	Absorption area loading rate (gpd/ft^2)	Mound absorption ratio	Absorption area loading rate (gpd/ft^2)	Mound absorption ratio
<0.1	-	1.0	-	1.0
0.1 to 5	1.2	1.0	1.6	1.0
0.1 to 5 (fine sand and loamy fine sand)	0.6	2.0	1.0	1.6
6 to 15	0.78	1.5	1.0	1.6
16 to 30	0.6	2.0	0.78	2.0
31 to 45	0.5	2.4	0.78	2.0
46 to 60	0.45	2.6	0.6	2.6
61 to 120	-	5.0	0.3	5.3
>120	-	-	-	-

The required original soil absorption width for mounds constructed on slopes from zero to one percent must be centered under the mound distribution media bed width; where the absorption width is equal to the sum of the upslope berm width, the distribution bed width, and the downslope berm width. The required original soil absorption width for mounds constructed on slopes greater than 1% must be measured downslope from the upslope edge of the mound distribution media bed in the direction of the original land slope and perpendicular to the original contours. On ground sloping more than 1%, all of the effluent is assumed to move down slope and the absorption width is calculated as the rock layer width plus the down slope berm width (Table IX and IXa).

The soil absorption width is calculated by multiplying the mound distribution media bed width by the absorption ratio. The absorption ratio of the upper 12 inches of soil in the proposed absorption area can be determined according to Table 12.16.

TABLE 12.17 Slope Multiplier Table

Land % Slope	Upslope Multipliers for Common Slope Ratios		Land % Slope	Downslope Multipliers for Common Slope Ratios	
	3:1	4:1		3:1	4:1
0	3.00	4.00	0	3.00	4.00
1	2.91	3.85	1	3.09	4.17
2	2.83	3.70	2	3.19	4.35
3	2.75	3.57	3	3.30	4.54
4	2.68	3.45	4	3.41	4.76
5	2.61	3.33	5	3.53	5.00
6	2.54	3.23	6	3.66	5.26
7	2.48	3.12	7	3.80	5.56
8	2.42	3.03	8	3.95	5.88
9	2.36	2.94	9	4.11	6.25
10	2.31	2.86	10	4.29	6.67
11	2.25	2.78	11	4.48	7.14
12	2.21	2.70	12	4.69	7.69
13	2.17	2.62	13	4.95	8.29
14	2.13	2.55	14	5.24	8.92
15	2.09	2.48	15	5.55	9.57
16	2.06	2.41	16	5.88	10.24
17	2.03	2.35	17	6.24	10.94
18	2.00	2.29	18	6.63	11.67
19	1.97	2.23	19	7.04	12.42
20	1.95	2.18	20	7.47	13.19
21	1.93	2.13	21	7.93	13.99
22	1.91	2.08	22	8.42	14.82
23	1.89	2.03	23	8.93	15.67
24	1.87	1.98	24	9.46	16.54
25	1.85	1.93	25	10.02	17.44

4. **Landscaping and finishing of the mound.** The side slopes on the mound must not be steeper than three horizontal units to one vertical unit (3:1) and shall extend beyond the required original soil absorption area, if necessary. A slope ratio of three indicates three feet horizontal to one foot vertical, and is equivalent to a slope of 33 percent. A side slope ratio of 4:1 (four feet horizontal, one foot vertical) is recommended, particularly for mounds constructed on soils having a percolation rate of 61 to 120 mpi, in order to expose sufficient soil to effluent. A 4:1 berm slope ratio or flatter, however, is desirable for landscaping and maintenance. A slope ratio of four is a flatter slope, and is equivalent to a 25 percent slope.

Table 12.17 presents multipliers used to determine upslope and downslope berm widths. It will also allow calculation of down slope berm width for distribution media bed widths narrower than ten feet. A minimum of six inches of sandy to loamy soil material must be placed on the top of the mound distribution media bed and sloped upwards toward the center of the mound a minimum of ten horizontal units to one vertical unit. A minimum of six inches of topsoil borrow must be placed over the entire mound.

a. Calculate the downslope absorption width (area beyond distribution media bed required to be covered with clean sand).

i. On slopes greater than 1%, the downslope absorption width is equal to the absorption width calculated above (in 3) minus the distribution media bed width.

ii. On slopes less than 1%, the downslope absorption width is split equally on both sides of the mound and is calculated by taking the absorption width minus the distribution media bed width and dividing by two.

b. To determine the upslope berm:

i. Determine the height of the mound at the upslope by the depth of clean sand to meet separation requirements, plus the height of distribution material (typically one foot), plus the amount of cover material (typically one foot). The height of the mound above the original soil at the upper edge of the distribution media layer is designated as h1 in Figure 12.26. The dimension h1 at a minimum is usually three feet, consisting of one foot of clean sand, one foot of distribution media, and one foot of soil cover over the distribution media. Select an upslope multiplier based on slope (a 4:1 multiplier is recommended).

ii. Calculate the upslope width by taking the height of the mound times the multiplier. Dimension d1 is the upslope berm width.

c. To determine the downslope berm:

i. To determine the height of the mound at the downslope, you need to determine the amount of sand at the downslope edge of the distribution media bed, which is greater if there has been a drop in elevation over the width. This depth is calculated by taking the height at the upslope and adding in the distribution media bed width times the slope across the width. Then the total height is equal to depth of clean sand at the downslope portion of the distribution media bed, plus the height of distribution material (typically one foot), plus the amount of cover material (typically one foot). The height at the down slope edge of the distribution bed is designated as h2. On level ground, h2 equals h1, but on sloping ground, h2 is greater than h1 because the top of the sand layer and the bottom of the distribution bed layer must be level.

ii. Select a downslope multiplier based on slope (a 4:1 multiplier is recommended).

iii. Calculate the downslope berm by taking the height of the mound times the multiplier. Dimension t2 is the down slope berm width. As shown in Figure 12.26, on level ground, t1 equals t2. On sloping ground, t2 becomes longer than t1 when the slope ratio is the same for both berms.

d. The total width is calculated by adding the upslope berm, the distribution media bed width, and the downslope berm and is shown on Figure 12.29.

e. The total length of the mound is found by adding the endslope berm, the distribution media bed length, and the endslope berm. The length can vary depending upon where it is measured as shown in Figure 12.24 in the plan view.

The mound shape can be installed as a trapezoid. The berms located at the short ends of the distribution bed are necessary for mound construction, but the soil area under these berms is not considered part of the total absorption area.

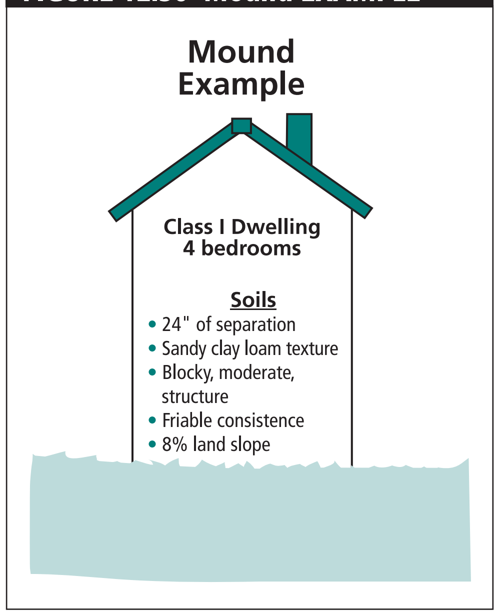
f. A vertical inspection pipe at least four inches in diameter must be installed and secured at the distribution media and sand interface. The inspection pipe must have three-eighths inch or larger perforations spaced vertically no more than six inches apart. At least two perforations must be located in the distribution medium. The perforation must not be located above the permeable synthetic fabric, if used. The inspection pipe must extend to the bottom of the distribution medium, be secured, and be capped, flush with or above finished grade.

Example mound system design

The following example is an oversimplification for EXAMPLE CALCULATION purposes ONLY as shown in Figure 12.30! A mound system is being designed for a four-bedroom Class I home with the following characteristics:

- No garbage disposal or pump in the basement
- Sandy clay loam texture with moderate structure.
- Redoximorphic features are located at the two-foot depth.
- 8% land slope

FIGURE 12.30 Mound EXAMPLE



1. The estimated flow rate is 600 gallons per day.
   a. The minimum septic tank capacity is 1,500.
   b. The minimum size pump tank is 500 gallons.
2. The CLR for this site was chosen to be 12 gallons/feet, and the absorption ratio is 2.6 square feet per gallon per day. To determine the area of distribution media bed, divide the flow rate by the sand soil loading rate:
   a. 600 gpd / 1.2 gpd/ft^2 = 498 ft^2 approximately 500 ft^2
   b. Distribution media bed width = 12 gal/ft / 1.2 gpd/ft^2 = 10 feet
   c. Distribution media bed length = 500 ft^2 / 10 feet = 50
   d. If rock is used as the distribution media, the rock must be at least six inches deep below the distribution pipe and two inches above. Find the total amount of distribution material by determining the area covered by rock: 1 foot x 500 ft^2= 500 ft^3, multiplying by 0.052, and adding in 10% for constructability yields 29 tons of rock.
   e. Designing the pressure distribution system with one lateral results in a pipe length of 50 feet – 2 feet (1 foot from each end) = 48 feet. A three foot spacing and ¼ perforations are selected, which yields 51 orifices and 38 gallons per minute. In order to achieve even distribution this system can be fed with a

manifold either in the center or at the end with 1.5 inch pipe. There must be cleanouts provided for the laterals.

3. Landscaping and finishing the mound.
   a. Determine the total absorption width by taking the absorption ratio times the distribution media bed width = 2.6 x 10 feet = 26 feet.
   b. On a landslope greater than 1%, only the width of the rock layer and the down slope berm are included in determining the distribution bed width. So, the width of the down slope berm past the distribution bed is: 26 - 10 = 16 feet.
   c. Determine upslope berm:
   i. Determine height of mound along upslope
      1. Depth of sand = 3 feet – distance to restricting layer = 3 feet – 2 feet = 1 foot
      2. Total height = depth of sand (fi) + depth of distribution media + cover depth = 1 foot + 1 foot + 1 foot = 3 feet
   ii. Select upslope berm multiplier based on slope of 8% and 4:1 sideslopes. Upslope width = upslope berm multiplier (fii) x height (fi2) = 3.03 x 3 feet = 9.1 feet
   d. Determine downslope berm:
   i. Determine height of the mound along downslope
      1. Drop in elevation = rock layer width x slope = 10 x 0.08 = 0.8 feet
      2. Downslope mound height = 3 feet + 0.8 feet = 3.8 feet
      3. Select downslope berm multiples of 5.88 based on slope and 4:1 sideslopes = 5.88 x 3.8 feet = 22.3 feet
   e. Total mound width is the sum of upslope + distribution media bed width + downslope width = 9.1 + 10 + 22.3 = 41.4 feet.
   f. Total mound length is the sum of two times the upslope width + length = 2 x 9.1 + 50 = 68.2 feet.
   g. Specify an inspection pipe of at least 4 inches with a method for securing specified.

Type III Above-ground

Type I above-ground systems must have at least twelve inches of natural unsaturated soil without bedrock with approved permeability. If a system is being installed on a site where the soil has been impacted or where twelve inches are not available, the system would be classified as a Type III system. It is recommended that the design of these systems use CLRs less than twelve gallons per foot.

If two above-ground systems are going to be placed side by side, the total absorption width of each system must be installed. If the resulting design exceeds a CLR of 12 gpd/ft, the system will be a Type III mound. The use of two ten-foot wide distribution media beds installed side by side is not recommended particularly if the soil has a large percentage of clay or has a depth of less than 24 inches of natural unsaturated soil due to issues of groundwater mounding and acceptance of the effluent. If two absorption areas are installed side by side, one downslope from the other, the distribution media beds should be separated by at least four feet of clean sand. The reason for this requirement is to provide adequate absorption width and a sufficient depth of permeable soil to allow the liquid to move laterally.

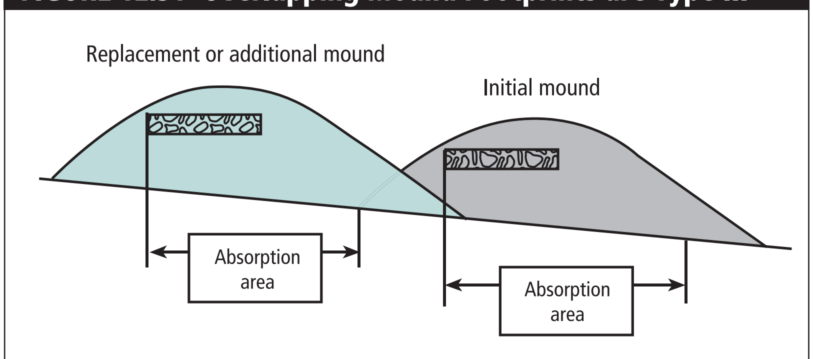
Box Mounds

A box mound is a vertical sidewall mound design based on the perceived over-design of the absorption area and the additional unnecessary area needed to accommodate mound side-slopes. The design of these systems has two defining characteristics: the addition of pretreatment to decrease the size requirement and the corresponding reduction in needed landscaping area. If pretreatment is installed before a mound system, much of the treatment requirement will not occur in the mound. In this design, the mound will primarily serve as dispersal mechanism. When a box mound is constructed, the landscaping berms of 3:1 or 4:1 can be cut off, and the remaining area is the absorption area. Hybrid systems have been installed which use both of these options. Care should be taken so that the treated effluent is still provided sufficient area to disperse into the soil. These systems would be classified as a Type III or V, depending on the design.

Replacing Mounds

If the distribution media bed of the mound is no longer accepting effluent at an acceptable rate, can the old distribution media bed be removed and replaced? The answer is maybe, depending on the reason for the malfunction. If the ponding were due to dirty sand, then a good portion of the sand would need to be removed and added back. Rather than doing this, it may be better to construct a new mound on the second site. If the excessive ponding occurred due to dirty rock or dirty sewage, then a few inches of the plugged sand should be removed and replaced when the new distribution media bed is installed.

FIGURE 12.31 Overlapping Mound Footprints are Type III



If a new mound is going to be placed in close proximity to an existing mound that is longer performing, it is recommended that the absorption width of the new mound be on natural soil as shown in Figure 12.31.

Installing Soil Treatment Systems (STA)

General Soil Treatment Installation Principles

1. Keep the installation dry (KID)

Compaction and smearing are more likely to occur with installations on sites with high water tables and soil textures with high clay content; therefore, the soil surface must be treated carefully. The surface should be maintained in as natural condition as possible because soils that are wet at the time of construction are more likely to have problems with acceptance of wastewater due to compaction and smearing. Compaction is the compression of soil particles, which closes the pore spaces. Smearing is spreading and smoothing soil particles by sliding pressure.

Excavation is only allowed when the soil moisture content is at or less than the plastic limit and is not frozen or freezing. The exposed areas must be immediately covered with media or the designed coverage materials. If the areas are exposed to direct rainfall, they must be allowed to dry and must be re-prepared accordingly.

The soil surface should be treated very carefully. It needs to be maintained in as natural condition as possible. This means that the system be constructed only when the soil is dry enough to work. If the soil is wetter than the plastic limit, or if considerable construction activity has caused compaction, then the ability of the soil to transmit liquid will have been seriously reduced due to compaction and smearing. The plastic limit is the soil moisture content below which the soil may be manipulated for purposes of installing a soil treatment system, and above which manipulation will cause compaction. **In 7080.1100, Subp. 60 the plastic limit is defined as the soil moisture content above which manipulation will cause compaction or smearing.**

Check the moisture content of the soil to the depth you will be digging or eight inches for an above-ground system. If a fragment of soil can easily be rolled into a wire 1/8 inch in diameter, the moisture content is above plastic limit. If the soil is dry enough to be friable and falls apart when rolling it into wire, the moisture content is below the limit and soil may be manipulated. The standard method of determining the plastic limit is specified by the American Society for Testing and Materials, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils, ASTM D4318 (2005).

During repair and replacement of system components on sites with existing dwellings, construction can damage landscaping and driveways, particularly if the construction occurs in wet conditions. This may result in unsightly tire ruts and compaction. For general site construction, soil must be dry enough so equipment for site preparation, installation, and materials handling can safely and effectively access and operate on the site.

The higher the clay content of the soil, the greater the likelihood that the soil will hold water. Soils that are saturated, meaning all the pore spaces are filled with water, or nearly saturated have lower soil strength, and they will compact and smear more than the same soil under dry conditions. To limit impacts to the natural soil structure, excavation is only advisable when the soil is below the plastic limit and when the soil is dry enough to be worked. If considerable construction activity has caused compaction, then the ability of the soil to transmit liquid will be seriously reduced and failure is more likely.

2. Keep the installation natural (KIN)

All excavation into the absorption area, or surface preparation of the upper twelve inches of absorption area, must be done so that the original soil structure is exposed in an unsmeared and uncompacted condition. Excavation equipment or other vehicles must not be driven on the excavated or prepared absorption area. Foot traffic on these areas must be minimized and not cause undue compaction. Care should be taken when media is being placed to avoid compaction due to the heavy weight of some distribution and treatment materials.

Maintaining natural soil structure is critical when installing the STA. All excavation to the infiltrative surface or surface preparation must be done so that the original soil structure is not smeared or compacted. Generally, the soil located at or near the soil surface is the best soil for treatment and dispersal due to its structure and oxygen-transfer potential. In addition, evapotranspiration and natural biological activity is greatest near the surface. Compacted soil has reduced void space; therefore, compacted sites are less permeable and are more likely to have problems with water movement.

To limit compaction in the STA, do not drive excavation equipment or other vehicles on the infiltrative surface. Foot traffic on these areas must be minimized to reduce the risk of compaction. Raking sidewalls of trenches and beds may help expose the natural soil structure which may have been slightly smeared by the bucket. Place media working upslope of the system with low ground pressure to avoid compaction due to the heavy weight of distribution and treatment materials. This distributes the weight over as large an area as possible.

Installing Systems in Cold Climates

In cold climates, installers must pay special attention to several issues to ensure proper system installation and performance. Special care must be taken with placement of components to ensure all piping drains. Shallow pipes, tanks, and pretreatment components may require insulation. The soil infiltrative surface should not be frozen when the system is being constructed, as smearing and construction problems may result due to the large clumps of soil. These large clumps should not be used to backfill around system components as they can cause settling and result in improper support. Due to the reduced void space, freezing issues are more common in compacted soil. In areas of known compaction such as driveways, insulation should be installed over or around components. See Section 8 for insulation methods for piping and tanks. STAs installed late in the fall may need protection from frost by covering the area with loose straw or mulch.

Sheet insulation should never be placed permanently above a STA as it will limit oxygen transfer and evaporation.

3. Keep the installation level (KIL)

The top and bottom of the distribution medium must be level in all directions. Sidewalls must be as vertical as practical and not intentionally sloped.

Several of the components in an onsite wastewater treatment system must be installed level for the system to properly treat and disperse wastewater:

- Tanks must be installed level to achieve the necessary treatment and drainage out of the tanks.
- Advanced treatment systems must be level to achieve even distribution and drainage out of the component.

In the STA:

1. In gravity systems, the distribution device and bottom of the distribution medium should be level in all directions to achieve even distribution of effluent. Along the length of a trench or bed, the maximum recommended difference in elevation is one inch per 25 feet. The difference in elevation across an entire level system should be no more than two inches. This is to ensure that, for a system at a level site, the entire system will be completely loaded before any back-up occurs into the septic tank.
2. In pressure distribution systems, the bottom of distribution media and piping must both be installed level to achieve even distribution across the site. A maximum of ½-inch across the entire pressure system network is recommended. Verify the maximum allowable difference in your local code.

4. Keep the installation shallow (KIS)

Generally the soil located at or near the soil surface is the best soil for treatment and dispersal due to its structure and oxygen transfer. In addition, evapotranspiration and natural biotic activity is greatest near the surface.

On sloping sites, you must identify the elevation(s) of the bottom of the trench or bed in relation to the limiting condition before construction begins. These elevations are then used throughout the excavation of the trenches to ensure the required separation is maintained.

If tracked equipment is used, you need a pad in order to dig a level excavation. Wheeled backhoes can self-level through the use of stabilizers. The construction techniques for these sites are greatly impacted by the depth of soil available for excavation. If the soil is deep, you can make a bench by cutting out soil on the upslope of the first trench and placing the excavated material downslope to create a bench for the second trench excavation.

Cover, Topsoil and Vegetation Requirements

Whenever above-ground systems are located on slopes, a diversion must be constructed immediately upslope from the above-ground system to intercept and divert runoff.

A minimum of six inches of topsoil borrow should be placed over all soil treatment systems. In Minnesota Rules Chapter 7080.1100, Subp. 88, topsoil borrow means a loamy soil material having:

- **Less than five percent material larger than two millimeters, no. 10 sieve**
- **No material larger than 2.5 centimeters**
- **A moist color value of 3.5 or less**
- **Adequate nutrients and pH to sustain healthy plant growth**

The soil cover must be placed over the system with minimal compaction.

A close-growing, vigorous vegetative cover must be established over the soil treatment and dispersal system; other vegetation establishment should begin immediately after the placement of the topsoil borrow. The soil treatment and dispersal system must be protected from erosion and excessive frost until a vegetative cover is established. The vegetative cover established must not interfere with the hydraulic performance of the system and should provide adequate frost and erosion protection. Trees, shrubs, deep-rooted plants, or hydrophilic plants should not be planted on the system. See Landscaping Septic Systems (AG-FO-6986) for more information about plantings on soil treatment systems.

It is good to determine before installation begins who is responsible (in the contract) for the seeding of the system. Either the property owner or the contractor can seed the site, but the property owner will be responsible for assuring that vegetation is established.

If the system is installed late in the year, frost and erosion protection may be needed throughout the first winter.

Trench and Seepage Bed Installation

Care should be taken when a trench or bed absorption area is being constructed to assure the natural structure of the site is maintained. Trenches or seepage beds must be backfilled and crowned above finished grade to allow for settling. The top six inches of the backfill must have the same texture as the adjacent soil. The minimum depth of soil cover over the distribution medium, including topsoil borrow, is 12 inches. The top six inches of the backfill must have the same texture as the adjacent soil and be considered topsoil borrow.

When excavating the trench or bed infiltrative surface minimize foot traffic on infiltrative surface and avoid equipment traffic on or over infiltrative surface. During the planning process, you will determine the equipment or method to use for the excavation. When constructing the trench/bed bottom, be sure it is graded to the specifications in the design. Excavate the trench or bed to the correct bottom elevation(s) taking care not to smear the infiltrative surface. If the infiltrative surface is smeared, loosen it with the use of a rake or similar device. The infiltration surface can be left rough and should not be raked smooth.

If rock trenches are being installed: Table12.18 shows the depth that the soil replaced by the trench rock would be if it were spread over and between the trenches. For example, if 30-inch trenches are installed on eight-foot centers with a total of 18 inches of rock, there will be a 5.6-inch depth of soil spread over each eight-foot wide strip. This value should be added to the total soil cover over the trench rock. If the trench were excavated 24 inches deep, the top of the rock would be six inches below the original soil surface. The additional 5.6 inches of soil replaced by the rock would provide a total cover of 11.6 inches over the rock in the trench.

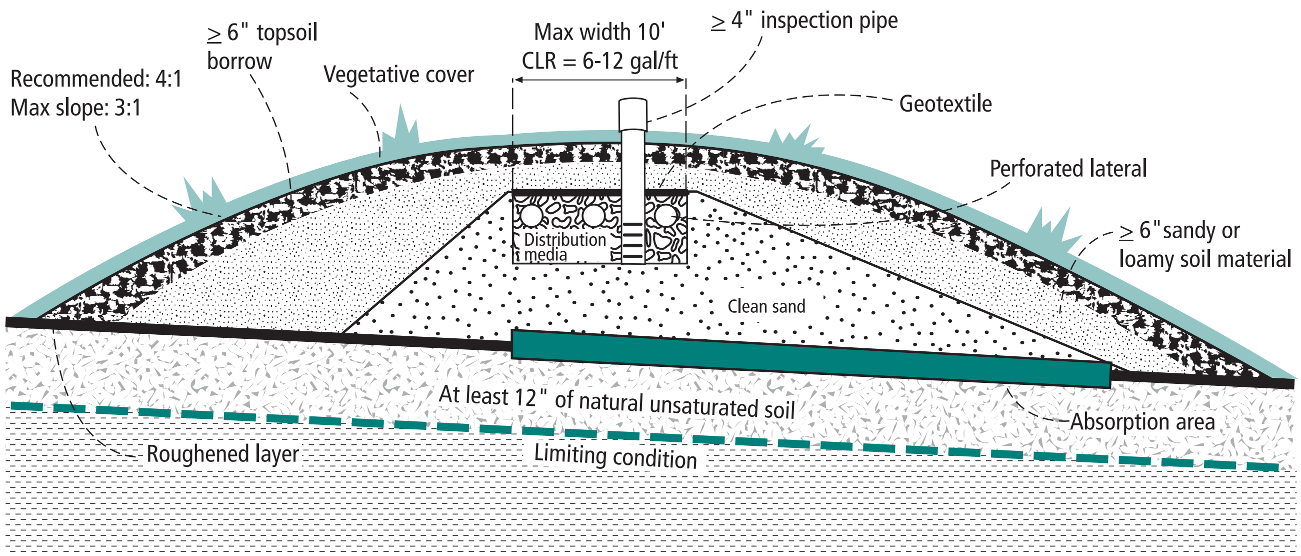
TABLE 12.18 Amount of Soil Replaced by Rock (inches)

trench width (inches)	trench spacing on centers (feet)		
	6.0	8.0	10.0
6 inches of rock below pipe (12 inches total):			
24	4.0”	3.0”	2.4”
30	5.0”	3.8”	3.0”
36	6.0”	4.5”	3.6”
12 inches of rock below pipe (18 inches total):			
24	6.0”	4.5”	3.6”
30	7.5”	5.6”	4.5”
36	9.0”	6.8”	5.4”
18 inches of rock below pipe (24 inches total):			
24	8.0”	6.0”	4.8”
30	10.0”	7.5”	6.0”
36	12.0”	9.0”	7.2”
24 inches of rock below pipe (30 inches total):			
24	10.0”	7.5”	6.0”
30	12.5”	9.4”	7.5”
36	15.0”	11.2”	9.0”

Above-ground System Installation

Installation considerations are very similar for all above-ground systems. Important factors to consider include location on the landscape, size and shape of the system, soil surface preparation, construction procedures, distribution of effluent, and dosing quantity.

FIGURE 12.32 Mound Specifications



Construction Equipment

While a rubber-tired tractor can be used in the initial surface preparation, it is necessary to use a crawler or tracked-type tractor for mound and at-grade construction to protect the soil surface and keep it as natural as possible.

Wheeled equipment has greater ground pressure then tracked equipment due to the reduced ground contact area and therefore should not be used in areas where compaction is a concern. Wheels do provide quicker movement and do not damage roads as much as tracks, but they provide less traction in muddy soils. Tracked equipment has lower ground pressure due to the larger footprint of the tracks and is more stable. Tracked equipment can be driven over a small spoil pile, whereas the material has to be moved out of the way with wheeled equipment.

When installing STA on sites with significant slopes, care must be taken to ensure the safety of the operator and laborer while achieving a level excavation. Check your local codes for maximum slope installation requirements. No matter what method is used to install the system, it is critical to maintain the required vertical separation and in some instances the installation can only be performed by hand.

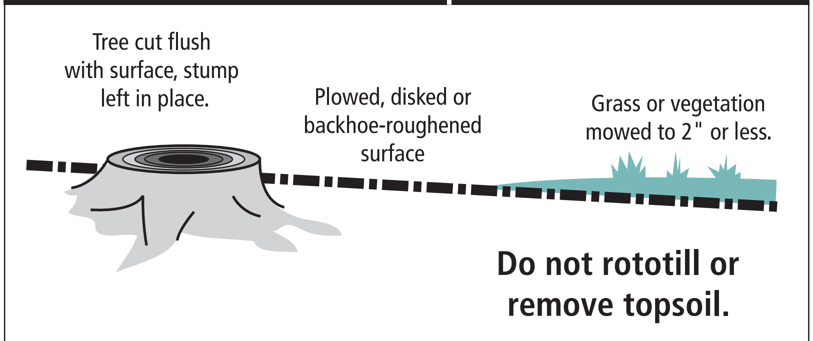
Soil Surface Preparation

For proper hydraulic performance, there should be at least three feet of unsaturated natural soil or clean sand above the limiting soil condition. This could be three feet of natural soil above a saturated layer in an at-grade, two feet of natural soil plus one or two feet of clean sand plus one or two feet of natural soil in a mound system. A Type I mound needs at least twelve inches of unsaturated and natural soil, while an at-grade requires 36 inches, as shown in Figure 12.32.

First, lay out the system on the contour. Establish the original grade elevation (surface contour) along the up slope edge of the absorption bed. This elevation is used throughout the mound construction as a reference to determine the bottom of the absorption bed, lateral elevations, etc., and is the permanent bench mark for the project.

If any trees are present on the site, they should be cut off at the soil surface and the stumps left. Removing the stumps will likely result in damaging the soil. The surface area taken up by the stumps is relatively small, so they will not affect the water infiltration under the system. If there is long grass, it should be cut off and removed so that the remaining grass is no taller than two inches. All vegetation in excess of two inches in length, as well as any dead organic debris, must be removed from the surface of the total area under the above-ground system (see Figure 12.33).

FIGURE 12.33 Mound Surface Preparation



Soil surface preparation should be carefully studied. A soil surface that has been smeared, compacted, or otherwise made unsuitable for the movement of liquid will never recover its capacity to transmit liquid. For instance, effluent will probably seep out of the above-ground system at the berm toe or at the distribution media edge. Once the clean sand layer is in place, it will be extremely difficult for the inspector to determine how the soil surface was prepared prior to sand placement. It is required that the soil only be plowed when it is not frozen.

Determine where the supply from the pump tank will connect to the distribution system in the absorption bed. The supply line from the pump to the above-ground system area should be installed prior to soil surface preparation. The trench excavated to install the discharge pipe should be carefully backfilled and compacted to prevent seepage of effluent.

The total area selected for the above-ground system, including that under the berms, should be roughened to thoroughly break up any existing sod layers and to provide a suitable transition zone between the original soil and the soil that will be placed to construct the above-ground system. Prepare the site by breaking up, perpendicular to the slope, the top seven to eight inches so as to eliminate any surface mat that could impede the vertical flow of liquid into the in situ soil. The best way to do this is to work around the perimeter of the system with the backhoe, using the bucket teeth to leave the surface rough. It is important that the grass be turned over so there is not a lot of grass at the surface. This grass can "slime off" and create a pathway for water to flow out of the mound dike. Surface preparation or roughening may be performed with a moldboard plow, a disk plow, or a backhoe using only the teeth. Moldboard plow furrows should be at least eight inches deep, should be thrown upslope, and should run perpendicularly to the slope. There should be no dead furrow under the above-ground system. *Never* use a rototiller to prepare the surface. Disking may be used to roughen the soil surface and break up the sod layer. Care must be taken not to compact or puddle deeper soil layers. In no case should any surface soil be excavated and moved more than one foot from its original location.

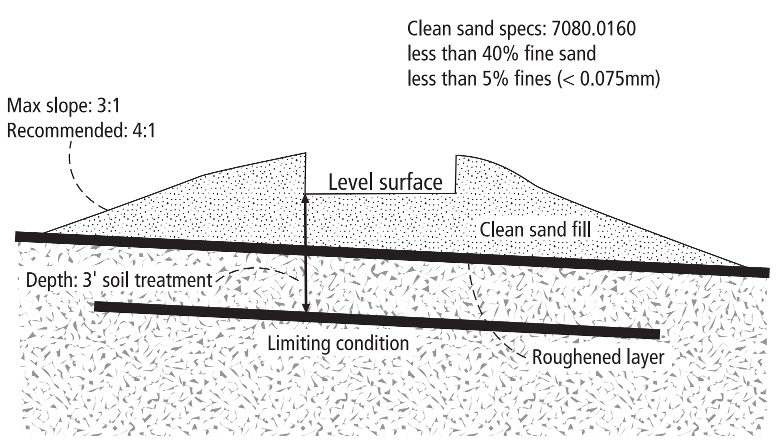
Above-ground system construction should proceed immediately after surface preparation is completed. The prepared surface should be kept free of all traffic, and every effort should be taken to prevent rain from falling on the prepared soil surface. Above-ground system construction should not take place when rain is expected. Cover the area with clean sand and/or media to protect the soil as soon as possible.

If it rains after the tilling is completed, wait until the soil dries out before continuing construction, and contact the LGU for a determination regarding the damage done by rainfall. At least six inches of sand should be kept under the tracks of the transport vehicle to minimize compaction of the plowed layer. Maintaining the soil's ability to accept effluent is a critical piece of the installation procedure.

Media Placement

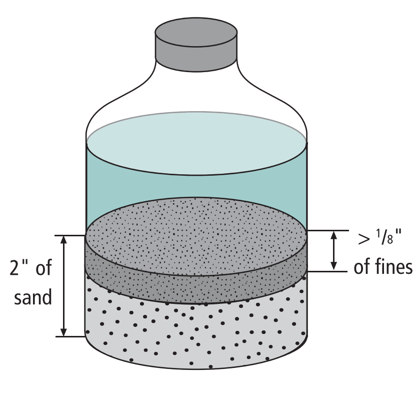
The next step in the construction of a mound system is placement of the sand and, in an at-grade, the distribution media. If a mound is being constructed, a minimum of twelve inches of clean sand must be placed where the absorption bed is to be located and must cover the entire absorption area. A crawler tractor with a blade or bucket should be used to move the sand in to place. The sand layer upon which the absorption bed is placed must be level in all directions (see Figure 12.34). On level sites, the media should initially be placed around the perimeter of the site with a low-ground pressure machine. On sloping slights, the media should be installed from the upslope side.

FIGURE 12.34 Level Surface for Media Placement



Clean sand, as defined by state rule, is a soil texture composed by weight of at least 25 percent very coarse, coarse, and medium sand varying in size from 2.0 to 0.25 millimeters, less than 50 percent fine or very fine sand ranging in size between 0.25 and 0.05 millimeters, and no more than five percent of particles smaller than 0.05 millimeters. Clean sand can be verified using the jar test (Figure 12.35).

FIGURE 12.35 Jar Test



If the fines that settle out in 30 minutes accumulate to a depth of greater than 1/8", then the percentage of fines is too great and the sand **should not** be used for mound or sand filter construction.

Conducting a Jar Test

1. Place exactly two inches of sand in the bottom of a quart jar and then fill the jar three-fourths full of water.
2. Cover the jar and shake the contents vigorously.
3. Allow the jar to stand for 30 minutes and observe whether there is a layer of silt or clay on top of the sand.
4. If the layer of these fine particles is more than 1/8 of an inch thick, the sand is probably not suitable for use in mound construction, because too many fine particles tend to cause the soil to compact during the construction process and future operation. Also, the long-term acceptance rate of this soil will be slower than the long-term acceptance rate of clean sand, which is used for sizing the absorption bed area.

When evaluating various sources for clean sand, it is worthwhile to observe the moisture line in the sand piles. A sand pile with a high moisture line has more fine particles due to the capillary forces in the soil pore space wicking moisture up. In addition, wet soil weighs significantly more then dry soil; therefore, the moisture content of materials must be considered when ordering media.

A rubber-tired tractor may be used for plowing or discing to prepare the soil surface, but after the surface preparation is completed, only a crawler or track-type tractor should be used. Move the fill material into place using a small track-type tractor with a blade or a large backhoe that has sufficient reach to prevent compaction of the tilled area. Do not use a tractor or backhoe with tires. Always keep a minimum of six inches of fill material beneath tracks to prevent compaction of the in situ soil. Place the sand material to the required depth and then form the absorption bed.

On slopes of one percent or greater, the upslope edge of the level absorption bed must be placed on the contour. Construction vehicles must not be allowed on the absorption bed until backfill is placed. The distribution media must completely encase the top and sides of the distribution pipes. In a mound, the top of the media must be level in all directions. Hand level the bottom of the absorption bed. See Figure 12.34.

The next step is to excavate/construct the trench or bed infiltrative surface. Minimize foot traffic on infiltrative surface and avoid equipment traffic on or over infiltrative surface. This is typically a bed constructed in/on top of the sand material. During the planning process, you will determine the equipment or method to use for the excavation. When constructing the trench/bed bottom, be sure it is graded to the specifications in the design. Excavate the distribution cell(s) to the correct bottom elevation(s) taking care not to smear the infiltrative surface. If using chambers, hand tamp fill where chambers will be located. Install the leaching chambers and pressure distribution piping as instructed by the leaching chamber manufacturer's instructions and the pressure distribution design.

If rock is used as a distribution medium, it should be igneous rock or a similar insoluble, durable, and decay-resistant material between three-fourths of inch and 2.5 inches in size, with no more than five percent by weight passing a three-fourths inch sieve and no more than one percent by weight passing a No. 200 sieve. Materials greater than 2.5 inches in size should not exceed five percent by weight. This media should conform to the MPCA document, "Drainfield Rock Distribution Media Recommended Standards and Guidance". The rock bed must be covered with a durable nonwoven geotextile fabric designed for this purpose, of sufficient strength to undergo installation without rupture. In addition, the fabric must permit passage of water, without passage of overlying soil material, into the soil treatment system rock bed. This should be done with a front-end loader on a track-type tractor. At least six inches of rock should be placed under the distribution pipe and two inches of rock above.

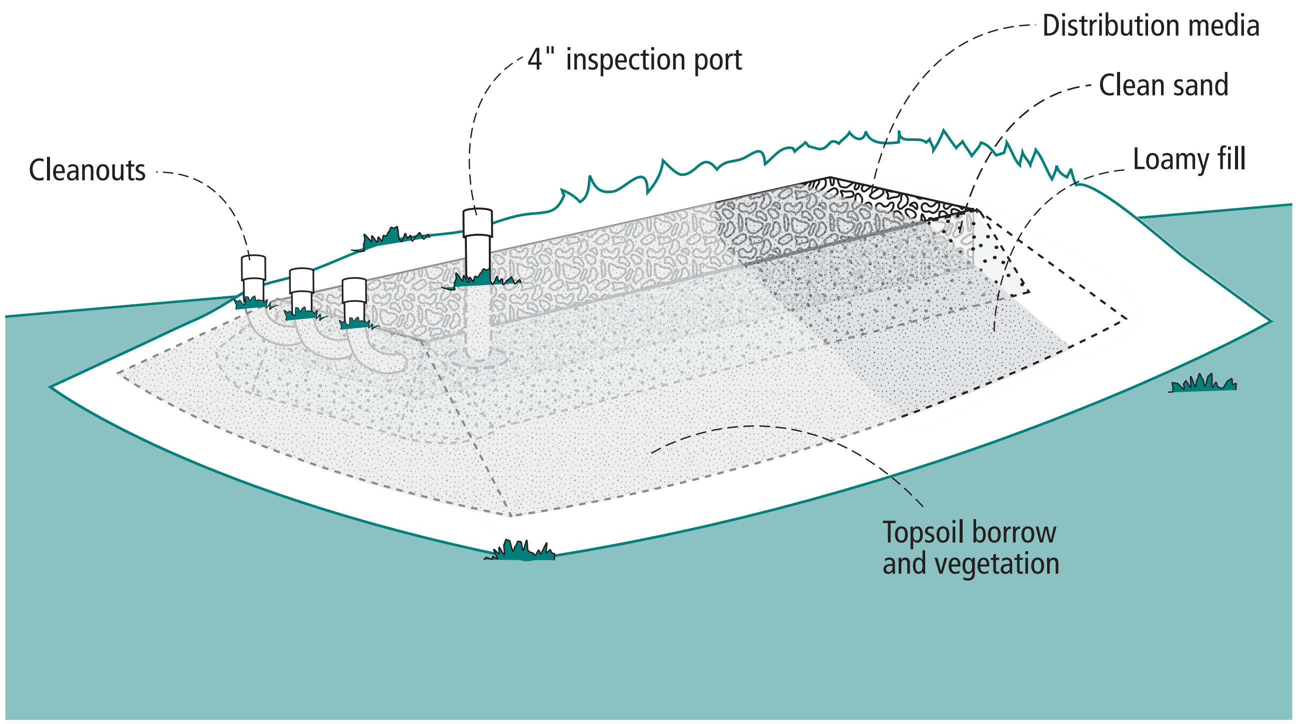
The pressure distribution laterals can be placed in the absorption bed with the orifices down or with orifice shields; whichever method is chosen, make sure that all the effluent drains from the pipe. An orifice should be placed three-fourths of the way up the end cap to allow air to flow back into the pipe after the pump turns off.

Typically, the inspection ports are installed next. The inspection ports provide a location for the monitoring of ponding in soil treatment systems and are typically installed at the infiltrative surface (interface where effluent moves from distribution media or a distribution device into treatment media). Inspection ports extend from the infiltrative surface to a point at or above finished grade. The portion of the observation pipe below the distribution pipe for rock systems is slotted, while the portion above the distribution pipe is solid wall. The inspection port can be placed in a valve box without a cover. However, if a slip cap is used on the inspection port, it must be secured so the pipe does not come out when the cap is removed. Inspection ports for chamber systems are attached to the chambers. With rock systems, a 12-18 in section of rebar can be placed in the pipe, a pipe T installed or a toilet flange installed at the end to hold it in place.

Cover Material

Sandy loam soil should be placed over the absorption bed with a 10:1 slope from the center of the media bed to the edges. In a ten-foot wide media bed, this is twelve inches in the center and six inches at the sides. The purpose of this sandy loam cap is to avoid undue soil compaction so that the pore spaces are maintained and soil air and moisture can move freely. At least six inches of the cap must be topsoil borrow, which is a loamy soil material having less than five percent material larger than 2.0 mm (#10 sieve); no material larger than 2.5 cm; a moist color value of 3.5 or less; and adequate nutrients and pH to sustain healthy plant growth. Figure 12.36 indicates what type and where each type of media must be installed in a mound.

FIGURE 12.36 Mound Cross-Section



Side slopes of four feet horizontal to one foot vertical (4:1) are suggested for the berms of the above-ground system. This gentle slope will allow easy mowing of the grass cover. If area is limited, steeper side slopes of 3:1 can be used. In no case, however, should the berm slope be steeper than 3:1.

Inspection of Soil Treatment Systems

New Systems

During an inspection of a new installation there are several key items to check:

1. Proper construction techniques - observe the excavated trench or bed for evidence

of compromised soil conditions such as excavation during plastic conditions or compaction due to excessive foot traffic. Check the absorption area preparation: vegetation removal, soil moisture content below plastic limit, and proper rough-up techniques.

2. Verify the system was sited/located properly along the contour and not in a swale or drainageway.
3. Design verification - verify that the design is being followed, particularly that the distribution media installed matches the design sizing requirements.
4. Verify system depth and elevations. It is important that the system not be too deep. "Too deep" for trenches and beds means three feet of cover or four feet to the bottom of the system. Soil treatment systems should be relatively shallow to maximize oxygen transfer to the bottom of the system. "Too deep" for mounds may mean that twelve inches of unsaturated soil is not present or not enough sand is installed to meet the three foot requirement. The bottom elevation of the system should be verified as specified in the design.
5. Examine material used in installation, paying particular attention to rock and sand quality. A jar test or sieve analysis can be requested if questionable materials are on-site (see process on previous page).
6. Examine the building sewer materials. If existing pipe is used, be sure to verify that it does not have cracks or root infiltration in the piping.
7. Verify proper distribution system:
    a. Verify that the distribution media is level at the top and bottom.
    b. Proper sizing and connections (i.e., properly primed and glued, pressure fittings where needed, etc.).
    c. If a drop or distribution box is used to distribute effluent to individual lines in a soil treatment system, and if it is accessible, inspection should include levelness of the inverts of outlets of the d-box.
    d. Verify pipe size, orifice size, spacing, and orifice shields as per design.
    e. Verify proper installation of drop or distribution boxes if required in the design.
    f. Be sure to check that the inspection pipes are secured properly.
    g. Install clean-outs, as required, and covers.
    h. Verify squirt height, equal distribution.
8. Soils verification - many local units of government perform a field verification of the soil conditions at the time of inspection to verify that the proper soil interpretation was made.
9. Verify cover, topsoil depth, and presence of erosion control protection prior to establishment of vegetative cover
10. Check setback distances. Figure 12.5 shows the critical setbacks from a trench system. The most critical, in terms of possible contamination, are the setbacks from the well. The setback from the well to the system is based on the construction of both well and system. Setbacks from lakes, rivers, and streams should be verified as well as from buildings or property lines and any other local requirement such as wetlands, easements, or roads.

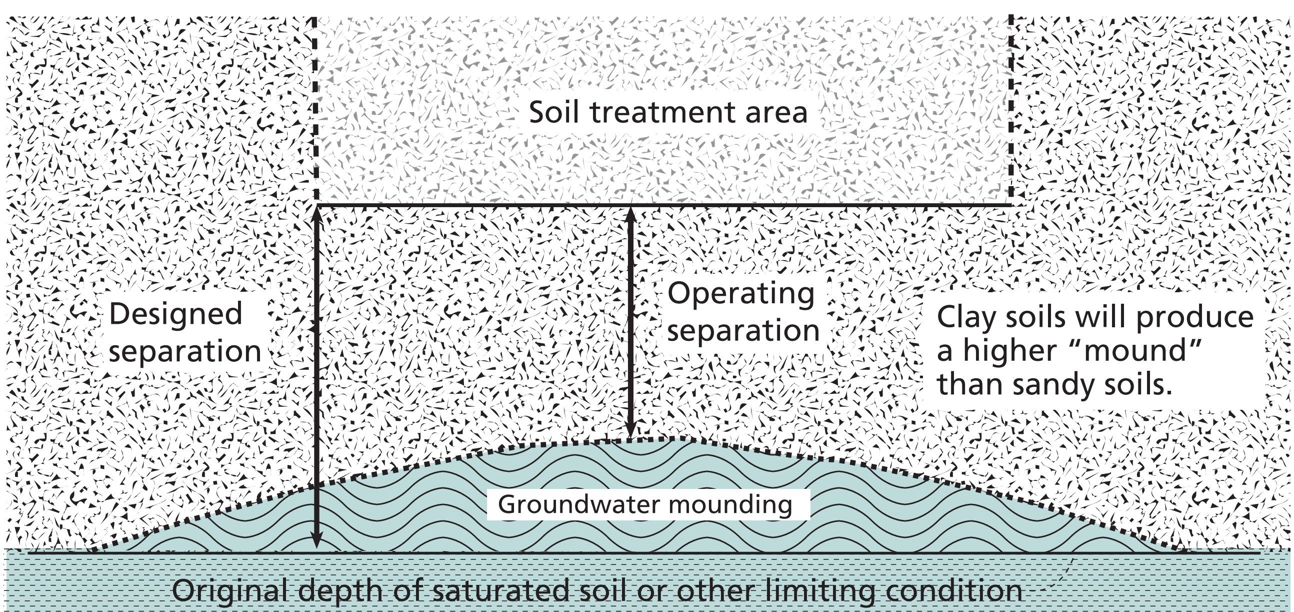
Existing Systems

With existing systems the soil treatment unit does not need to meet all the requirements of Chapter 7080. The system does need to have a watertight septic/pump tank, should not be surfacing, must have a least two to three feet of vertical separation (depending on when and where the system was built), and be in compliance with management requirements for the system. An inspection should verify the following:

1. Septic tank verification – the septic tank must be verified for watertightness. If the septic or pump tank leaks effluent, it is considered to be failing to protect groundwater and the upgrade time line is set in the local ordinance.
2. Soil separation – verify the soil limiting condition, either redoximorphic features or bedrock. Check the distance from the bottom of the system to the limiting layer (bedrock or saturated soil). The system should have been designed and constructed with a "design depth" of at least three feet of soil between the system and the limiting layer. Take a boring of soil and use the Munsell color book to classify the soil. This boring should be located near but not in the system, because the system can change the soil colors, giving a false reading of the separation depth. If a system was built after 1996, is located in shoreland, a wellhead protection area, or serves a food, beverage, or lodging establishment, the required separation is three feet. For all other Type I systems, the required separation is two feet.

   Once the system has been constructed and has begun accepting effluent, the depth to saturated soil will change, which is why the boring is performed outside the area of influence. The new separation is called the "operating depth": the actual depth of the water table under the working system. Operating depth can be less than design depth (see Figure 12.37). How much less depends on a number of factors, including surface water drainage, soil texture, and system application rates. However, if a system is properly designed with three feet of separation, the operating depth should be sufficient to maintain treatment. Although shallower systems perform better, a deep system is not necessarily failing.

FIGURE 12.37 Groundwater Mounding Below Soil Treatment



If a system lacks separation, it is considered to be failing to protect groundwater and the upgrade time line is set in the local ordinance.

In the past under certain conditions, the installation of agricultural draintile was allowed as a way to deal with excessive moisture on a site. These systems were designed to increase the separation from redoximorphic features to the bottom of the system to at least three feet. That being said, studies (Nieber et al., 1998, Goff et al., 2001) have shown performance issues due to limiting soil conditions (restrictive textures, structures, bedrock, etc.) and new systems are now required to get an NPDES permit to be installed.

Existing SSTS currently employing drainage systems which are lowering the groundwater in an attempt to meet the required vertical separation distance do not need to obtain a NPDES permit. However, if water quality monitoring of the discharge indicates a violation of surface water quality standards, the system must be replaced within ten months as the agency considers the system to be an imminent threat to public health or safety. If monitoring of groundwater elevations indicates a violation in the required vertical separation distance, the system is considered failing to protect groundwater and must be upgraded per local ordinance requirements. These systems are not to be confused with those that have a diversion which intercepts groundwater as an enhancement, but whose function is not relied upon to provide the required unsaturated treatment zone, and is placed at least ten feet upslope of the soil dispersal system.

3. Verify system hydraulic performance. If the soil treatment system is overly full, effluent will come to the soil surface. If effluent is surfacing, the system is failing and is an imminent public health threat. Odor and spongy ground over the top of the system are indicators. Check for cattails or other landscaping that may hide surfacing effluent. The property owner or agent should verify in writing that the system has not backed up into the home or surfaced in the yard, as these types of failures can be cleaned up and hidden by a creative owner.

   Dye testing is one way to identify failures, but because it will miss some failing systems, its result cannot be used as the only criterion. There are a number of new dyes that are available for use. They include the use of optical brighteners for the identification of sewage. The process for using brighteners includes collecting a sample on a cotton swab and having the cotton analyzed. This method is still being researched.

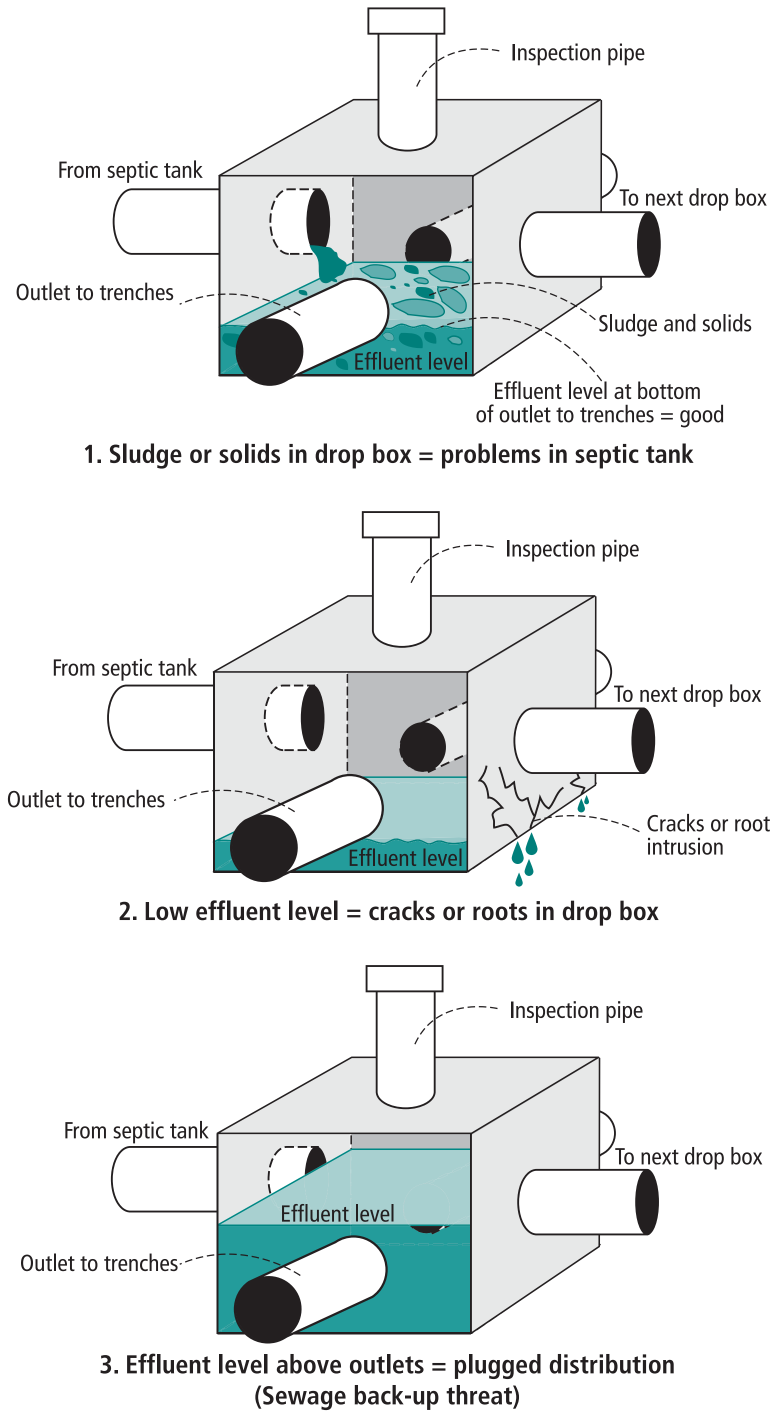
   It is important to identify the cause of the failure. It may be due to plugging of soil pores, sewage flows in excess of the soil's ability to accept effluent, soil compaction, or malfunction or plugging of the distribution system. You may already have found the cause of the problems in your inspection of the tank or lift station.

   Look at the impact of surface water on the system. Another issue in terms of surface water is the location of the system in the landscape. Trenches should be located along contours. They should not be located in drainage areas such as the bottom of a drainageway, or in the middle of or transecting a drainage swale.

Troubleshooting Below-ground Systems

As shown in Figure 12.38 (system inspection) there are several parameters to evaluate when troubleshooting below ground soil treatment systems. Inspect the distribution system that brings effluent to the soil treatment area, either drop

FIGURE 12.38 Inspecting Drop Boxes



boxes, valve boxes, or distribution boxes. (These are also good places to check the performance of the tank.) Verify that drop boxes have solid walls and bottoms. Although drop boxes need not be absolutely watertight, they should be constructed in such a way as to minimize outflow. They should have minimal side seepage, so the presence of roots may indicate a problem. (Figure 12.38.)

Check distribution boxes for structural soundness and watertightness. Root infiltration is a definite indication of a problem. Inspect piping for bows, drops, or ponding water, which indicate possible settling of the soil.

If the distribution system is overly full, it's an early sign of problems, possibly due to lack of maintenance or sludge flow-through. There may be sludge in the maintenance box or plugging in the soil system itself.

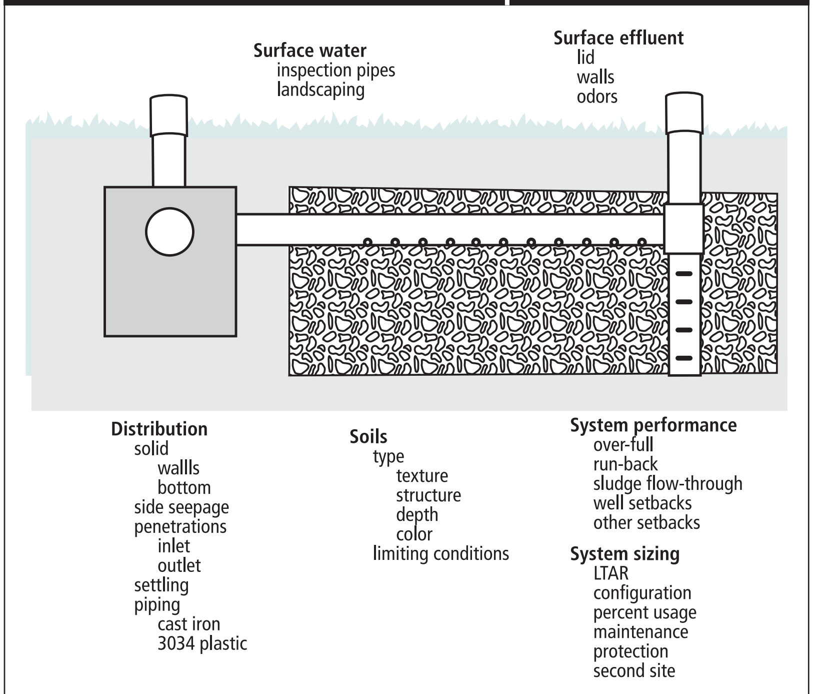
If possible, note the percentage of the soil treatment system being used, and make a record of it. How much of the system is used can be observed through the inspection pipes, which are, therefore an important component of the soil treatment system. They must be watertight and have watertight lids to minimize the addition of water to the system.

The maximum upgrade time period for a system that is an imminent threat to public health and safety (ITPHS) is ten months and may be reduced in the local ordinance.

4. Verify system operation and maintenance – the users of the system should understand that proper maintenance of their tank and protection of their soil treatment site in terms of drainage, mowing, and avoiding compaction is very important. The system's owners should also make an effort to protect the auxiliary or second site for the system.

If the management requirements for the system are not being followed, the system is out of compliance, and the time line and requirements necessary to bring it back into compliance are determined by the local unit of government.

FIGURE 12.39 Soil Treatment Area Inspection



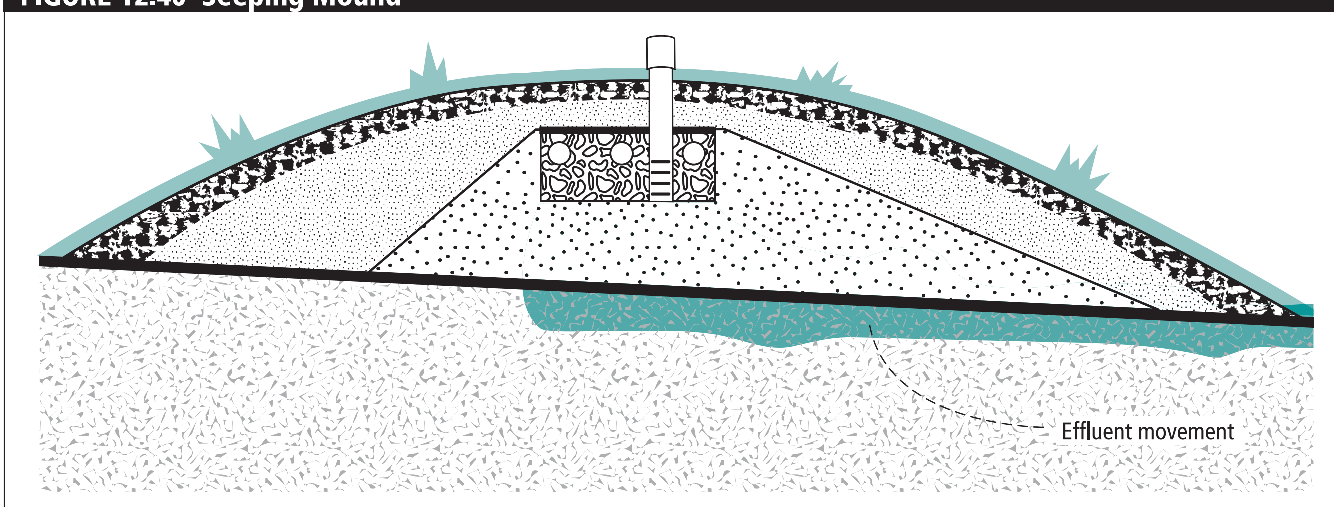
Troubleshooting Above-ground Soil Treatment Systems

It has been estimated that mounds and at-grade systems should perform hydraulically for 25 to 35+ years. However, some systems do not perform as they should for that long. Soil treatment system problems are often traced to improper design and construction practices, but improper operation and maintenance of the system also contribute to problems with systems.

Reasons for system malfunctions

The materials with which systems are constructed can lead to malfunction. Systems' siting, design, construction, and homeowner misuse also commonly contribute to malfunction. Some common problem situations are described below, including, in parenthesis, where the seeping problem occurs (toe or side/top) in the system. Figure 12.40 shows a mound on a sloping site which is leaving out the toe.

FIGURE 12.40 Seeping Mound



Malfunction due to poor-quality materials

Common cause for seeping mounds is poor-quality materials.

- Sand with too many fines: there should not be over 5% silts and clays (side/top).
- Sand with too much fine sand: this is a problem when there is more than 5% fines (side/top).
- Soil treatment system rock with too many fines: there should not be more than 1% fines (side/top).

Malfunction due to poor siting

Poor siting is the second most common cause for seeping mounds. Common siting problems are:

- Mounds placed on soils that do not have one foot of soil above the periodically saturated soil or bedrock (toe)
- At-grades, trenches, and beds placed on soil that does not have three feet of soil above the periodically saturated soil or bedrock (toe)
- Systems placed on disturbed or compacted soils (top/toe)
- Soil treatment systems not placed on the contour (top/toe)
- Soil treatment systems placed in swales/upland drainageways (top/toe)

Malfunction due to errors in design

Errors in system design can result in seepage. The errors include:

- Mis-estimation of the soil texture and structure or percolation rate (top/toe)
- Miscalculation of slope (a system designed for a flat site instead of a sloping site) (toe)
- Miscalculation of the bottom area/absorption area — the area where sewage enters original soil (top/toe)
- Upslope drainage not designed; soil treatment systems receives upslope runoff (top/toe)

Malfunction due to construction errors

- Construction errors are of two types: (1) poor-quality materials (discussed previously) and (2) errors in installation. Installation-related construction errors include:
  - Sewage absorption area compacted during construction, reducing infiltration (toe)
  - Sewage absorption area smeared during excavation or scarification because the soil moisture was over the plastic limit (toe)
  - Excess vegetation was not removed, reducing infiltration from vegetative mat (toe)
  - Cracked pipe or pipe that became disconnected (toe or side)
  - Nonwatertight joints in tanks (excess infiltration) (toe)
  - Incorrect float adjustment (toe or side/top)
  - Water stands in sagging pipe and freezes in winter (side or problems at pump tank)

Malfunction due to system misuse by homeowners

- Excessive water use or leaky fixtures (toe/top)
- Clean-water source hookups to the septic system, such as the sump pump (toe)
- Lack of pumping solids from septic tank or other cause of high-strength waste (side/top)
- Improper landscaping causing compaction around system (toe)
- Rooftops or impervious areas draining to the tank or system areas (toe)
- Disposal of chemicals in system (side/top)

Management of All Soil Treatment Systems

Management Plans

According to MN Rules Chapter 7080.1100 Subp. 46, every system designed since the enactment of the 2008 Rules must have a management plan. **A management plan requires the periodic examination, adjustment, testing, and other operational requirements to maintain system performance expectations, including a planned course of action in the event a system does not meet performance expectations.**

In Minnesota Rules Chapter 7082.0600, Subp.(1), local units of government (LGUs) shall require management plans for all new or replacement systems. These plans must be submitted and approved before issuance of a construction permit. It is recommended that the management plan be reviewed and signed by the owner.

Management plans must include:

1. **Maintenance requirements, including frequency of assessment**
2. **Operational requirements, including which tasks the owner can perform and which tasks a licensed service provider or maintainer must perform**
3. **Monitoring requirements**
4. **Requirements that the owner notify the LGU when management plan requirements are not met**
5. **Disclosure of the location and condition of the additional soil treatment and dispersal area on the lot or serving the residence**
6. **Other requirements as determined by the LGU**

For Type I soil treatment systems, the management plan should include:

1. An assessment frequency of at least every three years
2. Recommendations for water usage, conservation, and other key behaviors within the house or establishment that will help assure that the at-grade component will not be overloaded
3. Recommendations for vehicle and animal traffic across the system
4. An evaluation of usage if a water meter, event counter, or running time clock is available
5. Evaluation of septic and dose tanks along with related screens, pumps, and alarms
6. An evaluation of the liquid levels in the observation pipes and examination for any seepage around the soil treatment component
7. Evaluation to verify that surface water is not collecting on the soil treatment system site
8. Evaluation to verify that the site is not being driven on or compacted in any other manner
9. Evaluation of a suitable, non-invasive, shallow-rooted vegetative cover over the soil treatment system site
10. Evaluation of the secondary soil treatment area site

Example management plans for trench, bed, and mound systems are provided and updated on the OSTP website: septic.umn.edu/ssts-professionals/forms-worksheets.

For a Type II-V soil treatment system, the management plan should include all the components above, in addition to an evaluation of any additional features such as piezometers.

Site planning, preparation, documentation, and contracting

Reading a Drawing

The first step in constructing any onsite system is reading the system plan and locating the components. Measure the site locations using tapes and the elevations using a laser. The elevation of each component must be related to or measured from a fixed point. This point can be designated as your laser elevation (but this is hard to locate again) or set in relationship to a benchmark, a permanent reference point.

Component locations must be measured in three dimensions and be located from a fixed reference point (called the benchmark) which should appear on the plans. Because this point is key for all measurements, it has to be a permanent location. Often the benchmark is a dedicated lot corner stake or even an official survey point. Be sure that this point can be readily found and will remain after construction. A piece of lath stuck in the middle of the construction site is not a good choice for a benchmark because it will certainly be lost. On existing sites, the wellhead or electrical box can be a good benchmark because these structures typically do not move.

Be sure to place the laser out of the way of construction equipment and at a elevation where you can read the rod from all locations onsite. Do not set the laser so tall that the rod is always stretched past the maximum. If you do this, you will not have enough rod to complete the measurement when you dig a deeper excavation for installing the tank.

A few tips to remember: When the numbers are getting larger on the rod, you are going downhill. And, for your laser to work, you need good batteries. It is a good practice to check your equipment on a regular basis. With the right tools and a little planning, you can easily and quickly complete the all-important act of surveying the site.

Equipment

To properly survey and install the system, you need a number of tools:

1. Tape measures to determine horizontal measurements
2. A laser level or a surveyor's level and a surveyor's rod for elevations
3. Twelve-inch stakes, four-foot lath and wire flagstone to mark the locations for the components being installed. Sometimes these are also helpful for identifying setback distances

Tapes should measure at least 100 feet. They come in a variety of materials. Non-metal tapes seem to be the most typical choice, but over time the numbers can become unreadable from wear and weathering. Make sure your tapes are readable. Also, take note of the units on tapes. Some measure in inches and others in tenths of a foot. A tape with units that match those used on the design plan minimizes the number of calculations you'll have to do at the site. It is a good idea to have two tapes: you'll have a spare if one gets lost, and using two tapes can speed up the surveying job. By laying one tape on a reference point, such as along the property line, and using the other to measure setback distances and system component locations, you can quickly and easily create a grid. This makes recording and drawing the system much easier and faster.

Another critical tool is the surveying rod, a graduated rod used to measure elevation differences. You will use it with the level or laser target to establish component elevations. The units are identified on the rod. Typically they are in tenths of a foot, but some are in inches. Just be careful not to confuse the units in which you are working. In setting elevations, a laser level delivers a level plane of light, and a target picks up the light, allowing you to determine when you are reading the same elevation.

The laser light can be visible (typically red) or invisible to your eye but picked up by the receiver. Set the laser at an elevation that is not at your eye height during your working day. This will avoid exposing your eyes to excessive laser light.

The laser is set atop a tripod and adjusted to level by setting the legs and using the fine adjustment system. Newer self-leveling models can make life easier for your crew. Another useful feature is the ability of the laser to set a desired grade or slope on the piping and to allow that grade to be followed without changing the location of the receiver. (Be careful and double check that the grade feature is not on when you are trying to level the system.) The big advantage of a laser level is that the level portion does its work with no help so that one person can check the elevations. When a surveyor's level is used, a second person must operate the rod. A number of manufacturers provide laser levels. When choosing one, look beyond price to the features that will make your work easier. Once you are accustomed to using a laser level, you will hardly be able to imagine working without it.

A surveyor's level has a scope and a crosshair. To use this device, one person sights through the level and another operates the rod. This can be an effective layout tool, but the laser is more efficient.

Survey Techniques

Stake out the system area on the site according to the system design, so the system runs parallel to the contours. Reference stakes offset from the corner stakes are recommended in case corner stakes are disturbed during construction. If the site conditions do not allow for layout according to the approved design, contact the designer and/or the LGU.

In establishing elevations, remember that even though water runs downhill and gravity distribution is used, there must be enough drop in the system to move the effluent between the system parts. Be sure you take into account the two to three-inch elevation drop from the inlet pipe to the outlet pipe inside the septic tank. Sluggish flow out of the septic tank can result in freezing problems. Component locations must be measured in three dimensions and must be located from a fixed reference point—called the benchmark—which should appear on the plans. Because this point is key for all measurements, it has to be a permanent location. Often, the benchmark is a dedicated lot comer stake or even an official survey point. Be sure that this point can be readily found and will remain after construction. A piece of lath stuck in the middle of the construction site is not a good choice for a benchmark, because it will certainly be lost. On existing sites, the wellhead or electrical box can be a good benchmark, since these structures typically do not move. Once you set the benchmark, you can start the installation.

If you were not the designer of the system be sure to discuss expectations the property owner may have about the installation. The designer may have promised protection of trees, plantings, or out buildings. These are important points to address before construction begins.

The installer should verify that the site conditions are appropriate for construction and lay out the system. The installation plan should be thought of before construction begins to avoid problems with material delivery and spoil pile storage. During the installation the installer should be watching for any unusual soil or obstructions. Often the designer will have performed only a few soil borings across the site and may not have had a good view of the variability across the site. If, for any reason there are questions regarding the appropriateness of the design for the site, the designer should be contacted.

As-Builts

After any system has been constructed, an as-built is required to be completed by the installer and submitted to the local unit of government. **Chapter 7083.0020, Subp. 4, defines as-builts as the drawings and documentation specifying the final in-place location, elevation, size, and type of all system components.** These records identify the results of materials testing and describe conditions during construction. Information provided must be verified by a certified statement. **Chapter 7080.1100, Subp. 15, defines a Certified statement as statement signed by a certified individual, apprentice, or qualified employee under Chapter 7083, certifying that the licensed business or qualified employee completed work in accordance with applicable requirements.**

The as-built must include drawings and documentation specifying:

- The final in-place location of all system components, including maintenance, access, and location
- The size of all system components (this should include the pump gpm and tdh)
- The type of all system components
- The results of materials testing
- The construction conditions

Chapter 7083.0760, Subp. 2, (C) requires that the as-built drawings be provided to the owner and local unit of government within 30 days of system installation. An example as-built form is provided at septic.umn.edu/ssts-professionals/forms-worksheets.

Photographing Installation

A camera can be used as part of a designer's and installer's equipment. It is recommended that photographs be taken showing features of the system before and during construction. These photographs may be valuable in the future, in case there is a question about the proper siting or construction of the system.

Notating Your Photographs

Make notes of the following:

- Elevations of the outlet from the house
- Elevation going into the septic tank
- Elevation of the manhole on the septic tank
- Elevation of the first drop box or pressure distribution system
- Elevation of the top and bottom of distribution media
- Elevations of subsequent drop boxes and cover material

Building Sewer and Tanks

First, photograph the building sewer area. This should include the placement of the building sewer, the connection to the house, the cleanout location, the connection to the tank, and if possible, the type of pipe used for the connection. Photograph the building sewer and tanks in the same manner as in the previous section.

Pump Tank

The series of photographs for the dosing chamber will include:

- All wiring
- The control panel
- The lift pump with both gpm and tdh recorded
- The connection of the pipe to the pump
- The wiring of the floats onto the pipe
- The entire set-up before placing it into the tank
- The pump in place, so you can have a record of where it was located in the tank

Soil Treatment Site

Take pictures of the construction site as a whole. Begin by taking photos before construction begins, so that an overall view of the site will be available. Next, photograph the site after the vegetation has been cleared. Be sure to include any trees (before and after), highlighting that they were cut off and not grubbed.

Soil Separation

If a soil pit or boring is evaluated during construction of the system, photos should be taken, including tape measures alongside the soil to indicate where the limiting condition was identified.

Site Preparation

Your next set of photographs should depict the site preparation. These photos should include the staking, but more importantly, should show the site after the ground has been roughened by backhoe or plow. One of the shots of this portion of the construction should include the equipment actively engaging in work.

Sand

Photograph the clean sand if it is part of the installation. Take a picture of the sand itself, and include a photo of the jar test after it has been run. Photograph the placement of the sand; include a photo of the equipment used for placing it.

Distribution Media

Take photos of the placement of the media. Your photos should show the depth of the media and how it was placed. If rock is used, a close-up of the rock should be taken to show the size and quality.

Pressure Laterals

Photograph the placement of the pressure laterals. Be sure to include a picture of the gluing and a picture of the orifices.

Special Considerations

Were there any unusual or special considerations on the site? If so, photograph them. These may include tile drainage, special sloping for placements, and special soil conditions. Another concern may be identifying and protecting a second site. Take a picture of that site when all work is completed. Photos showing setbacks, such as those from wells, buildings, and property lines, may also be appropriate.

The goal is to complete a good record of the construction job. This record can be a benefit to you and your client for years to come.

Finished Product

Now you are ready to photograph the finished product. In these pictures, include how the soil treatment system was finished. Take pictures of equipment to show what the system looks like in its completed state.

Contracts

First and foremost, recognize that any contract or agreement should be reviewed by your attorney. Business contracts are too important to enter casually. The scope-of-service document should begin where you propose to start and needs to spell out the general terms, conditions, and limitations of the agreement. You may want a separate agreement about your expectations for the client—this would be contained in a separate client consent form. If you will do the site evaluation and design work as well as the installation, this needs to be made clear. It is probably advantageous in most areas to keep this separate, also. That is, have a separate scoping document for what it will cost to do the preliminary survey, soil borings, and percolation tests that result in a system design and layout. It makes sense to provide a separate price solely for this work because, during the site evaluation, you may find conditions that alter the system design and in turn affect the installation price.

Once you have a design or plan in hand (whether it's done by you or someone else) the scope of services can cover what happens at installation. The plan should be specific to the site and should include a to-scale drawing of the system location and detailed specifications of what will be installed. Specifications include the type and size of the septic tank or tanks, the presence of a pump chamber and pump (if necessary) any additional pretreatment devices (such as a media filter or ATUs), and a description of the final treatment and soil dispersal system: trenches, mound, at-grade, or drip irrigation. These specifications can be referred to in the specific agreement. For example: "I will install 300 lineal feet of 3-foot wide trench with 18 inches of clean 3/4-inch to 2-inch diameter rock, with 4-inch schedule 3034 distribution pipe, covered with a filter fabric, and backfilled with existing soil."

There should also be provisions to cover the potential for additional work, how the cost of added tasks will be determined, and whether the client will pay for them. For example, consider stumps. Usually, you can visually estimate the cost to remove a stump, but it is important to be specific about what happens to the stumps after they come out of the ground. We've heard more than one homeowner complain, "I came home to find a pile of stumps next to my driveway, and now what am I supposed to do?" The time to negotiate this point is before the contract is signed. Large rocks are sometimes not so easy to detect. In areas where rocks might be located, it's a good idea to decide with the customer up front on what will be done about them and who will pay any removal expenses. Your agreement should also describe what the area will look like at completion of the job. Will topsoil be added? Will the site be smoothed and seeded? Will sod be laid? How will the cleanup be handled? In some areas, particularly on heavily wooded sites, it once was a common practice to install trenches or beds and simply let the natural vegetation grow back. Today, however, when more attention is given to system longevity, operation, and maintenance, this practice is not acceptable. If the client is expected to do the finishing work, it needs to be documented in your agreement.

The agreement also should specify payment terms. Is some of the money due up front, before work begins? Or is the entire sum due when the work is completed? Usually, payment is split, with some (but not the entire) amount paid up front to cover the cost of materials. Final payment is often made after system has been issued a Certificate of Compliance (COC) by local unit of government, and work approved by the client.

Your agreement should include a disclaimer statement covering what you are obligated to fix if problems develop with the system and over how long a time you are responsible. In many states, this statement is part of the onsite treatment or building code, and the period involved is often one year. In addition, be sure to specify problems for which you are not responsible, such as those caused by owner misuse. If your company also maintains systems, you should offer another agreement covering the operation and maintenance of the system. Again, this agreement should describe clearly what you will and will not do for the stated price.

By having these agreements in place at the start of the design or installation process, you get the project off to a good start. A good agreement increases the likelihood that your client will be happy and will give you good word-of-mouth advertising for many years.

Landscaping Septic Systems

Introduction

Landscaping near, around, and on septic systems is of concern to many homeowners. This anxiety can be eased by involving the homeowner in the placement of the septic system and by what is appropriate to plant.

To ensure a properly functioning soil-based septic system, whether below-grade or mound, a suitable vegetative cover must be established. The right vegetation cover helps keep the soil stay in place, lets the septic system function at its best by removing moisture and nutrients from the soil, provides as an insulating layer, and makes the area more attractive. However, planting the wrong cover can do irreparable damage to the area. Trees, shrubs, and any herbaceous plants that have extensive root systems should not be placed on or near the system. These roots can interfere with and possibly destroy the distribution system. Herbaceous plants such as turf grasses, wildflowers, and native grasses are suitable cover for septic systems in Minnesota (see Table X for specific suggestions). Turf grasses have fibrous root systems that hold soil in place, require maintenance similar to a lawn, and are available in numerous varieties, including shade-tolerant, to suit site conditions. Wild flowers and native grasses are an attractive alternative to turf grass and provide, many of the same benefits, including fibrous roots, low maintenance (once established), and tolerance of dry soil conditions. Careful consideration should be given to planting any vegetation so that the soil does not get compacted; when the soil is compacted, it loses its structure and therefore loses free water movement.

The correct landscaping of mound systems can minimize the aesthetic intrusion and maximize protection of the system. The actual shape of the mound can be changed to incorporate individual landscaping desires. Landscaping around the mound can serve as a privacy barrier, a windbreak, or as a screen to block unsightly views.

Guidelines for Planting On and Near Septic System

- Topsoil on the mound should be a minimum of six inches and a maximum of 18 inches.
- Use minimal tilling when planting and establish a cover as soon as possible to limit erosion.
- Always wear gloves when working around a septic system to minimize your contact with soil.
- Use plants that prefer dry soils near the septic system. This will prevent their root systems from interfering with the septic system. The larger the plant, the more extensive (though not necessarily deeper) the root system.
- Do not place trees and shrubs on the mound; they may be planted at the foot or on the side slopes. Frame the mound with trees and shrubs at a distance, but use only herbaceous (non-woody) plants on the mound itself. Trees should be planted a minimum of 20 feet from the edge of the mound. Trees known for seeking water reservoirs, such as poplar, maple, willow, and elm, should be planted at least 50 feet from the mound. Shrubs should not be planted on top of the mound.
- Minimize traffic on the mound, both human and animal, to avoid soil compaction. Do not exercise pets or allow them to play on septic mounds. Never drive a car or other vehicle across the mound, and do not mow when the soil is wet. Compacted soil can lead to soil erosion and impedes the flow of air around the systems. In winter, activities on a mound can cause frost to penetrate, resulting in freezing problems.
- Do not plant edible plants such as vegetables and herbs on the mound or drainfield.

- Annually inspect the mound for animal damage such as burrowing and tunneling. Control animals at the first sign of tunneling or burrowing before damage is extensive.
- Root barriers (geotextile impregnation with a long-lasting herbicide that kills plant roots) have been used around mounds. Installation is expensive and can be avoided with proper plant selection.

(University of Minnesota Extension, 1998. Landscaping Septic Systems. FO-06986.)

Frequently working the soil on the septic area is not a good idea. The plants in the following tables are low maintenance, grow well on dry soil, and have a fibrous root system to help hold the soil in place. Use the tables to chose plants that are right for your preferences and needs.

Vegetation tables

TABLE 12.19 Wild Flowers/Native

Common Name	Botanical Name	Height	Color	Bloom Time	Comments
Prairie onion	Allium stellatum	1-2'	Purple	late	Flower heads 1 to 2" wide
Pussytoes	Antennaria negkecta	3-6"	White	mid	Flower heads resemble compact tufts of white hair
Butterfly weed	Asclepias tuberosa	2-3'	orange	late	Butterfly favorite
Heath aster	Aster ericodes	1-3'	white/purple	mid	One of the last flowers lasting in Fall
Prairie clover	Delea spp.	1-2.5'	white	late	Dainty stems
Purple cone-flower	Echinacea purpurea	2-4'	purple	late	Showy flowers
Prairie smoke	Genum triflo-rum	6-12"	pink	early	Attractive foli-age and unique flower
Oxeye, false sunflower	Helianthus helianthoides	3-5'	yellow	mid	Easy to grow
Blazing star, Gayfeather	Liatris aspera	2-5'	purple	late	Butterfly favorite
Wild bergamont, Bee balm	Monarda fis-tulosa	2-4'	pink/lavender	mid	Distinct showy flowers
Pasqueflower	Pulsatilla pentens	6-8"	white/lavender	early	Showy flowers
Penstemon, Beardtongue	Penstemon spp.	2-3'	white	mid	Favorites for bees and hum-mingbirds
Rattlesnake master	Eryngium yac-cifolium	3-4"	bluish/sliver	late	Unique looking

TABLE 12.20 Ornamental

Common Name	Botanical Name	Height	Color	Bloom Time	Comments
Daylily	Hemerocallis spp.	1-3’	several colors	mid	Minimal care
Sedum	Sporoblus het-erolepis	1-3’	several colors	late	Tough plant for dry sites
Peonies	Paeonia spp.	2-3’	several colors	early	Large showy fragrant flowers

TABLE 12.21 Shade Tolerant

Common Name	Botanical Name	Height	Color	Bloom Time	Comments
Bigleaf aster	Aster macro-phyllus	2-3’	white/purple	late	Hardy
Pennsylvania sedge	Carex pensyl-vanica	6-12”	green and brown	late	Low clumped grass
Wild geranium	Geranium maculatum	1-2’	purple/pink	mid	forms large clumps of flowers
Violets	Violets spp	6”	purple/white	mid	Will multiply

TABLE 12.22 Native Grasses

Common Name	Botanical Name	Height	Color	Bloom Time	Comments
Sideoat grama	Bouteloua curti-pendula	1-2’	light tan	mid	Tolerates hot and dry
Blue grama	Bouteloua gracilis	6-18”	bluish purple	fall	Tolerates hot and dry
Little bluestem	Schizachyrium scoparium	2-4’	bronze/orange	fall	Native
Prairie dropseed	Sporobolus heterolepis	2-3’	yellowish/orange	fall	Native, forms cloud-like flowers
June grass	Koeleria mac-rantha	2-3’	bluish/green	early	Tufted

Sources: University of Minnesota Extension. 1998. FO-06986. Tim Wedekind. Vance, F.R, etal.

While the plants are establishing (first two years after planting) it is important that either mulch or an erosion-control blanket is placed on the mound to reduce soil runoff. Mulch should be chosen if the mound is not too steep, but if the mound has steep, sloping sides, an erosion blanket should be used. Erosion-control blankets are composed of straw or coconut fiber layers, between two jute mesh layers. The blanket is staked in place, covering the entire surface of the mound; then, holes can be cut through the layers to create spots for the plants. The blanket is biodegradable, so it can be left in place. The material can be purchased at landscape supply stores.

Turf grasses have fibrous root systems that hold soil in place, require maintenance similar to a lawn, and are available in numerous varieties, including shade-tolerant, to suit site condition. Low maintenance lawn grasses such as fine fescues make a dense cover and only need to be mowed a few times a year. Fine fescues such as creeping red, hard, sheep's, and chewing fescues *(Festuca rubra, Festuca longifolia, Festuca ovina, and Festuca rubra var. commetata)* are shade tolerant. Fine fescues are often sold in mixes with Kentucky bluegrass for shady sites.

There are two primary means of establishing a new lawn: seeding and sodding. The following are advantages and disadvantages to seeding and sodding from the University of Minnesota Sustainable Urban Landscape Information Site (www.sustland.umn.edu):

Seeding

Advantages:	More grass types and varieties to chose from Less expensive than sodding Stronger root system development initially
Disadvantages:	Initial establishment is longer For best results, time of seeding is limited mainly to late summer and early fall Moisture is critical for the young seedlings

Sodding

Advantages:	Rapid establishment and relatively weed-free in the beginning Good for slopes or areas prone to erosion Can be laid anytime during the growing season
Disadvantages:	Expensive Less selection or control over kinds of grass, especially shade or drought tolerant

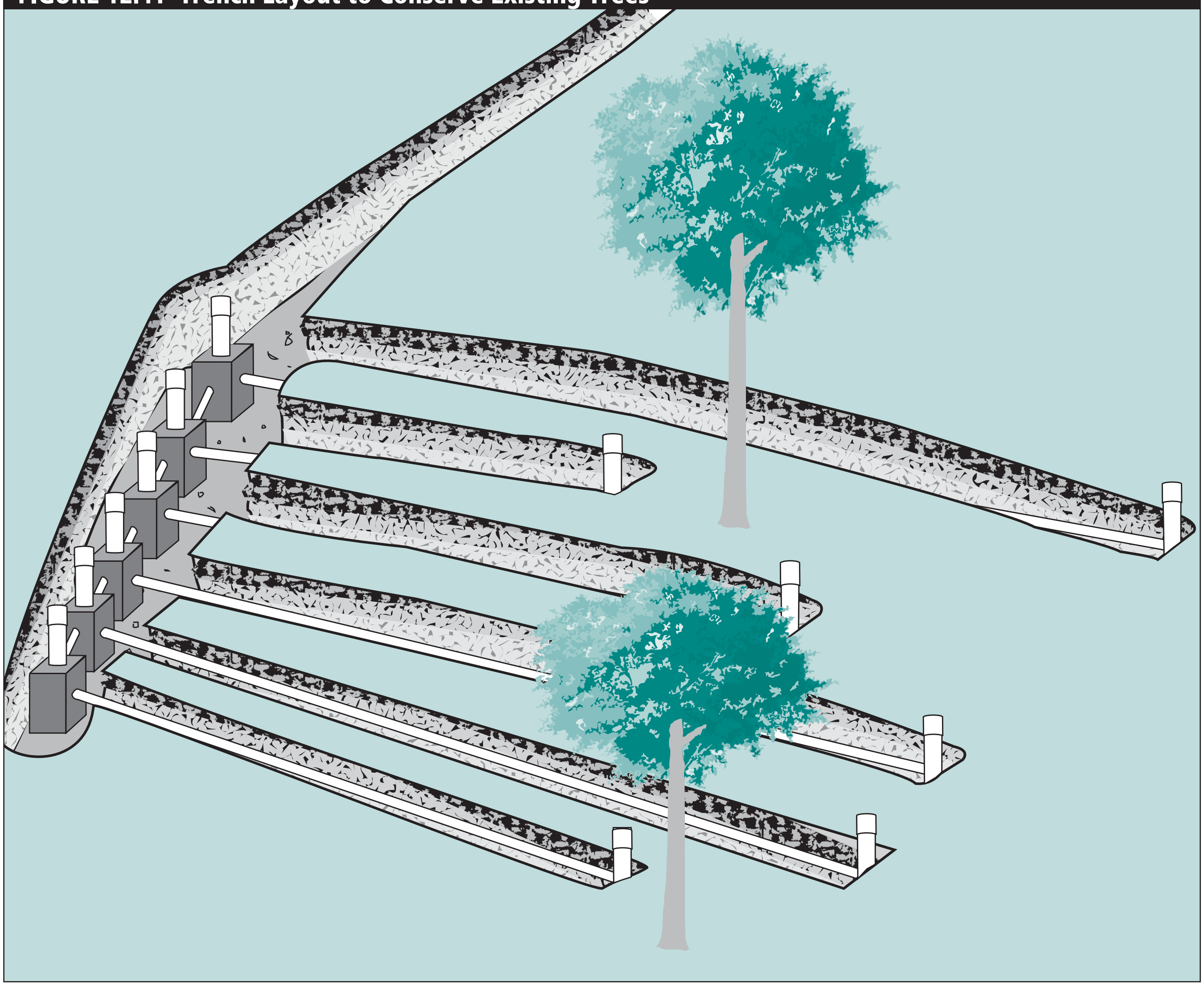
Erosion control is also important when establishing grass, particularly when seeding is the method. Again, an erosion-control blanket can be laid after the seeds have been put down. This will help retain moisture and protect the seeds and soil. Another product that can be found in landscape supply stores is an erosion-control blanket with seed. These are blankets made of organic material such as straw or coconut, which will decompose as the vegetation matures.

Vegetative cover is critical to insulating the system over the winter. Well-established vegetation helps hold snow close to the soil surface where it insulates the septic tank, piping, and soil treatment area. Snow helps keep the heat of the sewage and soil from escaping, keeping the frost depth shallow. In the absence of snow cover, a dense vegetative cover acts as an insulating layer, helping prevent the septic system components from freezing.

Trees and Shrubs

Shrubs and trees on and around septic systems in Minnesota present numerous limitations to the treatment and proper functioning of system components. For instance, they fail to provide adequate year-around erosion control, require additional homeowner maintenance (mulching, disease prevention, etc.), and interfere with septic system infrastructure with varying root depths and rooting structure that depends on site, soil, origin of the tree/shrub and tree/shrub species. The OSTP does not recommend planting trees or shrubs on or around septic systems due to these stated reasons, although the layout of new soil treatment systems often considers saving and protecting existing trees as shown in Figure 12.41. For additional recommendations and proper maintenance of septic systems, please refer to the Septic System Owner's Guide (Olson et al., 2008) or the University of Minnesota Onsite Sewage Treatment Program web site.

FIGURE 12.41 Trench Layout to Conserve Existing Trees



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SECTION 13: Forms and Reference

The MOST CURRENT version of forms are available electronically on the University of Minnesota OSTP website at: **septic.umn.edu/ssts-professionals/forms-worksheets**

Most of the forms found on website are interactive and include:

OSTP Design Forms
Inspection Forms
Installation Forms
Maintenance Forms
Management Plans
Community Septic System Owner's Guide - H20andM.com
Septic System Improvement Estimator

TABLE IX: Loading rates for determining bottom absorption area and absorption ratios using detailed soil descriptions.

		Treatment Level C		Treatment Level A, A-2, B, B-2	
USDA soil texture	Soil structure and grade	Absorption area loading rate (gpd/ft^2)	Mound absorption ratio	Absorption area loading rate (gpd/ft^2)	Mound absorption ratio***
Sand, coarse sand, loamy sand, loamy coarse sand, fine sand, very fine sand, loamy fine sand, loamy very fine sand, 35 to 50% rock fragments	Single grain, granular, blocky, or prismatic structure; weak grade	**	1.0	**	1.0
Sand, coarse sand, loamy sand, loamy coarse sand, <35% rock fragments	Single grain, granular, blocky, or prismatic structure; weak grade	1.2	1.0	1.6	1.0
Fine sand, very fine sand, loamy fine sand, loamy very fine sand, <35% rock fragments	Single grain, granular, blocky, or prismatic structure; weak grade	0.6	2.0	1.0	1.6
Sandy loam, coarse sandy loam, fine sandy loam, very fine sandy loam	Granular, blocky, or prismatic structure; weak to strong grade	0.78	1.5	1.0	1.6
Sandy loam, coarse sandy loam, fine sandy loam, very fine sandy loam	Platy with weak grade or massive	0.68	1.8	0.87	1.8
Loam	Granular, blocky, or prismatic structure; weak to strong grade	0.6	2.0	0.78	2.1
Loam	Platy with weak grade or massive	0.52	2.3	0.68	2.4
Silt loam, silt	Granular, blocky, or prismatic structure; weak to strong grade	0.5	2.4	0.78	2.1
Silt loam, silt	Platy with weak grade or massive	0.42	2.9	0.65	2.5
Clay loam, sandy clay loam, silty clay loam	Granular, blocky, or prismatic structure; moderate to strong grade	0.45	2.6	0.6	2.7
Clay, sandy clay, silty clay	-	**	**	**	**

* Only includes soil horizons with <50% rock fragments, with very friable and friable consistence, and loose noncemented sands. All USDA sands and loamy sands with 35% or more rock fragments or any soil horizons with >50% rock fragments must not come in contact with soil dispersal system media.
** Conduct percolation test and size under Table IXa. May need to be designed under part 7080.2300.
*** Assume a hydraulic loading rate to the sand at 1.6 gpd/ft^2.

Table IXa: Loading rates for determining bottom absorption area and absorption ratios using percolation tests

	Treatment level C		Treatment levels A, A-2, B, and B-2	
Percolation rate (MPI)	Absorption area loading rate (gpd/ft^2)	Mound absorption ratio	Absorption area loading rate (gpd/ft^2)	Mound absorption ratio
<0.1	-	1.0	-	1.0
0.1 to 5	1.2	1.0	1.6	1.0
0.1 to 5 (fine sand and loamy fine sand)	0.6	2.0	1.0	1.6
6 to 15	0.78	1.5	1.0	1.6
16 to 30	0.6	2.0	0.78	2.0
31 to 45	0.5	2.4	0.78	2.0
46 to 60	0.45	2.6	0.6	2.6
61 to 120	-	5.0	0.3	5.3
>120	-	-	-	-

Estimate of Waste Strengths from Other Establishments

Type of Facility	BOD_5 (mg/L)	BOD_5 (lbs/unit/day)
Airports		
Per passenger	400 - 500	0.02
Per employee	400 - 500	0.05
Apartment houses	240 - 400	0.175/multiple family
Assembly hall (no kitchen)	240 - 400	0.01/seat
Boarding school	240 - 400	0.208/student
Bowling alley (no kitchen)	240 - 400	0.15/lane
Camps		
Construction (Semi-permanent)	400 - 500	0.140
Country club (member)	400 - 500	0.052/member
Country club (resident)	240 - 400	0.208/resident
Day (no meals)	400 - 500	0.031
Luxury	400 - 500	0.208
Church (no kitchen)	240 - 400	0.02/seat
Country club	400 - 800	0.208/member
Personnel addition	240 - 400	0.04/employee
Day school	240 - 400	0.031/student
Add for showers	240 - 400	0.011/student
Add for cafeteria	500 - 700	0.031/meal
Factory		
No showers	240 - 400	0.073/employee
With showers	240 - 400	0.083/employee
Food service		
Ordinary restaurant	600 - 1500	0.35/seat
24-Hour restaurant	600 - 1500	0.50/seat
Freeway restaurant	600 - 1500	0.70/seat
Tavern (limited food)	400 - 800	0.10/seat
Carry-out (single service)	600 - 800	0.70/100 sqft
Carry-out	200 - 600	0.04/employee
Fast food chain	1000 - 2000	0.80/seat
Kitchen Waste	600 - 1500	0.015/meal
Toilet and Kitchen Waste	600 - 1500	0.021/customer
Additional for bars & cocktail lounges	600 - 1500	0.01/customer
Hospital (not including personnel)	400 - 600	0.518/bed
Laundromat	600 - 800	2.0/machine
Mobile home park	240 - 400	0.40/space
Mobile home park	240 - 400	0.140/person
Motel, Hotel	240 - 400	0.083/bed
Motel, Hotel	240 - 400	0.14/person
Nursing home (not including kitchen or laundry)	400 - 600	0.26/bed
Office building (per 8 hour shift)	240 - 400	0.05/employee
Park, toilets only	400 - 600	0.01/person
Park, bathhouse and flush toilets	240 - 400	0.021/person
Resort hotel, cottage	240 - 400	0.15/room
Add for self-service laundry	600 - 800	2.0/machine
Service station	240 - 400	0.50/toilet or urinal
Service station	240 - 400	0.021vehicle served
Shopping center (no food service or laundry)	400 - 600	0.30/1000 sqft
Shopping center (no food service or laundry)	400 - 600	0.050/employee
Sports Stadium	400 - 600	0.20/person

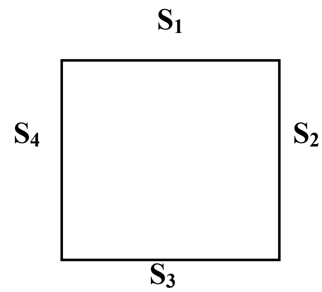
Equations and Constants

TABLE OF CONTENTS

PERIMETER/CIRCUMFERENCE

1. Rectangle or Square:

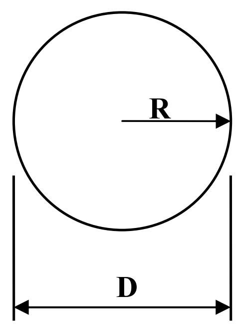
$$P = S_1 + S_2 + S_3 + S_4$$



2. Circle:

$$C = \pi \times D$$

Where: $\pi = 3.14$
$D = 2 \times R$



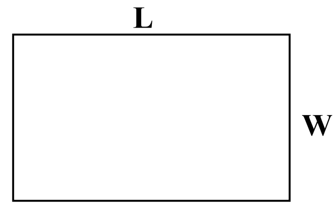
LENGTH CONVERSION FACTORS

1 inch	=	2.54 centimeters	=	25.4 millimeters
1 foot	=	12 inches	=	0.31 meters
1 yard	=	3 feet	=	0.91 meters
1 mile	=	5,280 feet	=	1,760 yards
1 meter	=	39.37 inches	=	3.28 feet
1 kilometer	=	0.62 miles	=	1,000 meters

AREA

1. Square or Rectangle:

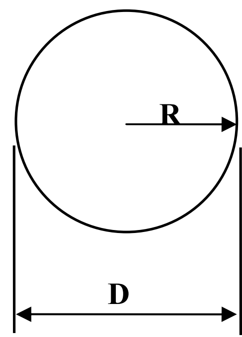
A = L x W



2. Circle:

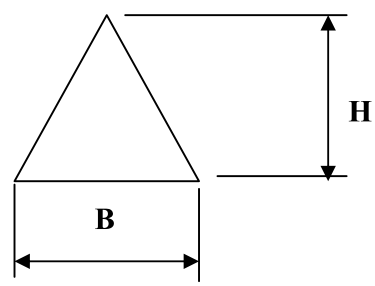
$$A = \pi \times R^2$$

Where: D = 2 x R



3. Triangle:

$$A = \frac{B \times H}{2}$$

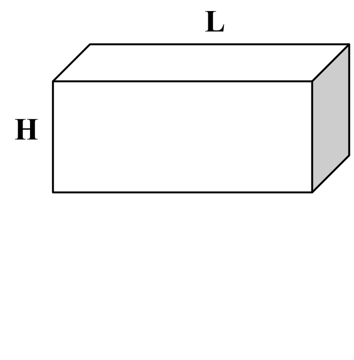


AREA CONVERSION FACTORS

1 square foot	=	144 square inches
1 square yard	=	9 square feet
1 square mile	=	640 acres or 1 section
1 square meter	=	10.76 square feet
1 square meter	=	10,000 square centimeters
1 acre	=	43,560 square feet
1 hectare	=	2.47 acres

VOLUME

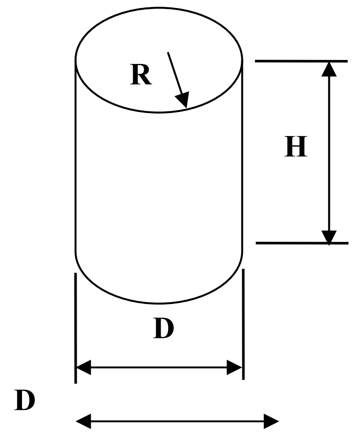
1. Rectangle



Volume = Area x Height

V = L x W x H

2. Cylinder:



Volume = Area x Height

$V = \pi \times R^2 \times H$

Where : $D = 2 \times R$

VOLUME CONVERSION FACTORS

1 cubic foot	=	1,728 cubic inches
1 cubic foot	=	7.48 gallons
1 cubic yard	=	27 cubic feet
1 acre-inch	=	27,152 gallons
1 acre-foot	=	43,560 cubic feet
1 acre-foot	=	326, 000 gallons
1 gallon	=	3.79 liters
1 gallon	=	231 cubic inches
1 gallon	=	4 quarts
1 cubic meter	=	35.3 cubic feet
1 cubic meter	=	1.3 cubic yards
1 liter	=	0.26 gallons
1 liter	=	1,000 milliliters

TEMPERATURE

1. Fahrenheit to Celsius:

$$°C = \frac{5\,(°F - 32)}{9}$$

2. Celsius to Fahrenheit:

$$°F = \frac{(°C \times 9)}{5} + 32$$

VELOCITY

1. $$\text{Velocity} = \frac{\text{distance traveled}}{\text{time}}$$

2. $$\text{Velocity(C)} = \frac{\text{flow rate}}{\text{area}} = \frac{Q}{A}$$

FLOW/PUMPING RATE

1. Flow Rate (Q) = velocity (V) x area (A)

2. $$\text{Pumping Rate} = \frac{\text{volume pumped}}{\text{time pumped}}$$

3. Calibrated Pumping Rate (gallons per minute):

$$= \frac{\text{drawdown volume (gallons)}}{\text{time to drawdown (minutes)}}$$

$$= \frac{\text{(Reading 1 in inches - Reading 2 in inches)} \times \text{gallon per inch of tank}}{\text{Time (min)}}$$

FLOW CONVERSION FACTORS

1 cubic foot/second	=	449 gallons/minute (GPM)
1 gallon/second	=	0.13 cubic feet/second (CFS)
1 gallon/second	=	8.03 cubic feet/minute (CFM)
1 gallon/minute	=	0.002 cubic feet/second (CFS)
1 gallon/minute	=	1440 gallons/day (GPD)

LOADING and SOLIDS

1. Loading (lb/day) = concentration (mg/L) x flow (gallons/day) x 8.34 lb/gallon/1,000,000

2. Organic Loading (lb/day) = population (people) x population equivalent factor (lb/person/day)

Note: **Population equivalent factors for: BOD = 0.17 lb/person/day**
TSS = 0.20 lb/person/day

WEIGHT CONVERSION FACTORS

1 gallon	=	8.34 pounds of water
1 cubic foot	=	62.4 pounds of water
1 foot of water	=	0.433 pounds per square inch
1 pound	=	0.454 kilograms
1 kilogram	=	2.2 pounds
1 kilogram	=	1,000 grams
1 pounds per square inch	=	2.31 feet of water
1 liter	=	1,000 grams
1 mg/kg or 1 ppm or 1 mg/l	=	0.0022 pounds/ton or 0.0001%
1 mg/l	=	1,000 µg/l

3. Total Suspended Solids (mg/L) = $\frac{\text{weight of suspended solids (mg)}}{\text{volume of sample (liter)}}$

4. Organic Nitrogen = Kjeldahl Nitrogen **-** Ammonia Nitrogen

SOILS

1. Percolation rate = min/in
2. Ksat =
3. Contour Loading Rate (CLR) = gal/ft

TANKS & CLARIFIERS

1. Surface Settling Rate (SSR): $\text{SSR} = \frac{\text{flow rate}}{\text{surface area}}$

2. Tank capacity in gallons $\text{TC= L(ft) x W (ft) x Liquid depth(ft) x 7.48 gal/ft}^3$

3. Detention Time (DT): $\text{DT} = \frac{\text{volume of tank}}{\text{flow rate to or from tank}}$

4. Percent Removal (PR): $\text{PR (\%)} = \frac{\text{influent - effluent}}{\text{influent}} \times 100\%$

FILTERS

1. Hydraulic Loading Rate (HLR):

$$HLR = \frac{\text{total flow to filter *}}{\text{surface area of filter}}$$

* Where total flow = influent flow + recirculation flow

2. Organic Loading Rate (OLR):
(lbs per day per 1000 cubic feet)

$$OLR = \frac{\text{pounds per day applied to the filter}}{\text{volume of filter media (in 1000 cubic feet units)}}$$

CALCULATING RECIRCULATION RATIOS AT SYSTEM STARTUP

To set recirculation at the time of system startup, the flowing information is needed:

- Forward flow through the system – this will be assumed from available records and/or interviews or design flow
- Pump delivery rate of the pump dosing the media filter (in gallons per minute)
- Dose volume
- Amount of pipe drainback to the pump after a dose
- Desired recirculation ratio, based upon forward flow (usually determined by the designer or manufacturer – 3:1 – 5:1)
- Number of minutes in a day = 1440

Before media filter startup occurs, it is important that the startup person understand how the regulatory jurisdiction and/or manufacturer determines recirculation volume to the filter. Most proprietary technologies use the following basic formula: [(forward flow) multiplied times (desired recirculation)] plus (forward flow) = volume to the filter. Other entities/manufacturers may calculate recirculation differently, for example [(desired recirculation) multiplied by (forward flow), so always verify before startup.

For the following example the manufacturer-determined pump dose volume per pump cycle (15 gallons) will not be altered. The pump off time needed to meet the desired recirculation ratio will be determined.

The following values will be assumed for this example:

- Forward flow = 200 gallons per day (gpd) -made by assumption
- Pump delivery rate (PDR) = 30 gallons per minute (gpm)
- Pump on time = 15 gallons/dose / 30 gpm = 0.5 minutes (min) on
- Pump dose volume = PDR X Pump run time = 30 gpm X 0.5 min = 15 gallons per dose
- No pipe drainback is assumed to simplify this example
- Desired recirculation ratio of 3:1 as required by manufacturer (Using the first formula noted above, the filter surface will see four times the amount of forward flow or [200 gpd x 3] + 200 gpd = 800 gpd

Given the above information, let's calculate what the pump off time needs to be:

Note, that to simplify the example, the entire pump dose volume (15 gallons) reaches the media filter surface with no pipe drainback.

Number of pump dose events needed to meet the 3:1 ratio = 800 gpd ÷ 15 gallons per dose event = 53.3 dose events per day. **Because we can't have a fraction of a dose event, this is rounded down to 53 events.** Note that for each dose event there is a corresponding pump rest cycle—or 53 rest cycles a day.

Number of minutes per day = 24 hours x 60 min per hour = 1440 min/day

Pump off time (minutes) = (number of minutes per day ÷ pump rest cycles per day) minus pump on time. Substituting in numbers, the math is: (1440 min/day ÷ 53 pump rest cycles) – 0.5 min = 26.7 min

Answer: 26.7 minutes off time between pump doses

To double check the math, the combined pump on and off times multiplied by the number of dose events per day should equal the total number of minutes in a day (or 1440 minutes).

Check: (0.5 min + 26.67 min) x 53 dose events = 27.2 min x 53 dose events = 1440 min

To double check the math on the timer settings; multiply the pump on time by the dose events per day, and multiply this number by the pump delivery rate (or PDR). The result should equal the total gallons needed to meet the desired recirculation ratio (or 800 gpd).

Check: (0.5 min per dose x 53 dose events/day) x 30 gpm = 795 gpd

Note that the answer above is very close to the 800 gpd needed to meet our desired recirculation ratio. The difference is because we could not utilize a portion (0.3) of a dosing event, so earlier in our calculations we decided to round down to 53 dose events per date.

COLLECTION

1. Hazen Williams Equation

$$V = 1.318 * C * R^{0.63} * S^{0.54}$$

V = Velocity in feet per second
C = Hazen-Williams Roughness Coefficient = 130
D = Diameter of pipe in inches
R = D/2
$S = H_f/L$
H_f = Friction head loss (feet)
L = Length of Pipe (feet)

$$H_f = (10.5/D^{4.87}) \quad X \quad (Q/C)^{1.85} \quad X \quad L$$

Q = Flow in gallons per minute

2. Manning Equation

$V = k/n(A/P)^{2/3}S^{1/2}$ where k = 1.486, and n = 0.013

n = 0.013 should be used for PVC pipe.

Inserting the constants in the equation:

$V = 114.3\ (A/P)^{2/3}S^{1/2}$

$A = \pi D^2/4$
P = Wetted Perimeter (assume full pipe) = πD

Simplifying the equation by inserting A and P in terms of D:

$V = 114.3(D/4)^{2/3}S^{1/2}$

S = Slope (feet/foot) (usually given, and assumed 1/8 inch per foot, which equates to 0.01 feet/foot)

Manning Equation Constants

Pipe Diameter	Velocity (V) ft/s	Area (A) ft^2	Q_f (GPM)
4”	2.18	0.087	85.2
6”	2.85	0.197	253.0
8”	3.46	0.349	542.2

Other Collection Constants
Minimum slope in pipe =1/8 inch per 1 foot ~ 1%
Maximum slope in pipe = 0.2 feet/foot = 2%
Maintains velocity below 15 feet/sec

OTHER FORMULAS

1. Convert Gallons Per Minute to Gallons Per Day:

Gallons/day = gallons/minute x 1,440 minutes/day

3. $\text{Percent Removal (\%)} = \dfrac{\text{influent concentration} - \text{effluent concentration}}{\text{influent concentration}} \times 100\%$

5. $\text{Slope or Grade (\%)} = \dfrac{\text{rise or drop (difference in height)}}{\text{run (difference in length)}} \times 100\%$

SYMBOLS/ABBREVIATIONS

A	= Area
Ac-Ft	= Acre-feet
B	= Base
BOD	= Biochemical Oxygen Demand
C	= Circumference
CEC	= Cation Exchange Capacity
CFM	= Cubic Feet per Minute
CFS	= Cubic Feet per Second
Cu In.	= Cubic Inches
°C	= Degree Centigrade
D	= Diameter
Ft	= Foot or Feet
Ft^2	= Square Feet
Ft^3	= Cubic Feet
°F	= Degree Fahrenheit
F/M	= Food to Mass
Gal	= Gallons
Gal/Min	= Gallons per Minute
Gal/Sec	= Gallons per Second
GPD	= Gallons per Day
GPM	= Gallons per Minute
GPS	= Gallons per Second
H	= Height
hr	= Hour
In.	= Inch
In^2	= Square Inch
In^3	= Cubic Inch
L	= Length
lb	= Pound
Mi	= Mile
Mi^2	= Square Mile
Min	= Minute
mg	= milligrams
ml	= milliliters
MG	= million gallons
MGD	= million gallons per day
mg/kg	= milligrams per kilogram
mg/L	= milligrams per liter
MLSS	= mixed liquor suspended solids
MLVSS	= mixed liquor volatile suspended solids
N	= Nitrogen
NH_3-N	= Ammonia Nitrogen
Org. N	= Organic Nitrogen
P	= Perimeter
PE	= Population Equivalent
ppm	= Parts per Million
ppb	= Parts per Billion
PSI	= Pounds per Square Inch
Q	= Flow
R	= Radius
RPM	= Revolutions per Minute
S	= Side
Sec	= Second
Sq. In.	= Square Inches
SVI	= Sludge Volume Index
SRT	= Solids Retention Time
SS	= Suspended Solids
TSS	= Total Suspended Solids
V	= Volume
Vel	= Velocity
W	= Width
Yd	= Yard
π	= pi or 3.14
/	= Per (as gallon/day)
%	= Percent
µL	= Microliters

METRIC SYSTEM

LENGTH	One kilometer (km)	=	1,000 meters
	One meter (m)	=	100 centimeters
	One decimeter (dm)	=	0.1 meter
	One centimeter (cm)	=	0.01 meter
	One millimeter (mm)	=	0.001 meter
WEIGHT	One kilogram (kg)	=	1,000 grams
	One gram (g)	=	1,000 milligrams
	One decigram (dg)	=	0.1 gram
	One centigram (cg)	=	0.01 gram
	One milligram (mg)	=	0.001 gram
VOLUME	One kiloliter (kl)	=	1,000 liters
	One liter (l)	=	1,000 milliliters
	One deciliter (dl)	=	0.1 liter
	One centiliter (cl)	=	0.01 liter
	One mililiter (ml)	=	0.001 liter
AREA	One hectare (HA)	=	10,000 square meters
	One square kilometer	=	1,000,000 square meters

MASTER LIST - CONVERSTION FACTORS

MULTIPLY	BY	TO OBTAIN
Acres	43560	Square Feet
Atmospheres	33.9	Feet of Water
Centimeters	0.40	Inches
Cubic Feet	7.48	Gallons
Cubic Feet	28.32	Liters
Cubic Feet/Second	449	Gallons/Minute
Cubic Meters	35.31	Cubic Feet
Cubic Meters	264.2	Gallons
Cubic Meters	10^3	Liters
Cubic Yards	27	Cubic Feet
Cubic Yards	202	Gallons
Feet	30.48	Centimeters
Feet	0.31	Meters
Feet of Water	62.43	Pounds/Square Foot
Feet of Water	0.43	Pounds/Square Inch
Gallons	3785	Cubic Centimeters
Gallons	0.13	Cubic Feet
Gallons	3.79	Liters
Gallons water	8.34	Pounds of Water
Gallons/Minute	2.2×10^{-3}	Cubic feet/Second
Gallons/Minute	1440	Gallons/Day
Gallons/ Minute	0.06308	Liters/Second
Gallons/Day	6.9×10^{-4}	Gallons/Minute
Gallons/Day/Square Foot	1.604	Inches/Day
Grams	2.21×10^{-3}	Pounds
Grams/Liter	1000	Parts/Million
Hectares	2.47	Acres
Horsepower	33,000	Foot-pounds/Minute
Horsepower	0.7457	Kilowatts
Inches	2.54	Centimeters
Inches/Day	0.62	Gallons/Day/Square Foot
Kilograms	2.21	Pounds
Kilowatts	1.34	Horsepower
Kilowatt-hours	2.66×10^6	Foot-pounds
Liters	103	Cubic Centimeters
Liters	0.04	Cubic Feet
Liters	0.26	Gallons
Meters	3.28	Feet
Milligrams/Liters	1	Parts/Million
Million Gallons/Day	1.55	Cubic Feet/Second
Parts/Million	8.34	Pounds/Million Gallons
Pounds	453.50	Grams
Pounds of Water	0.12	Gallons
Pounds/Square Inch	2.31	Feet of Water
Pounds/Square Inch	2.04	Inches of Mercury
Temperature (°C) + 17.78	1.8	Temperature (°F)
Temp. (°F) - 32	5/9	Temp. (°C)

SECTION 14: Detailed Directory

MANUAL FOR SEPTIC SYSTEM PROFESSIONALS IN MINNESOTA

DETAILED DIRECTORY