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Town and Country
SEWAGE TREATMENT

Agricultural Extension Service, University of Minnesota

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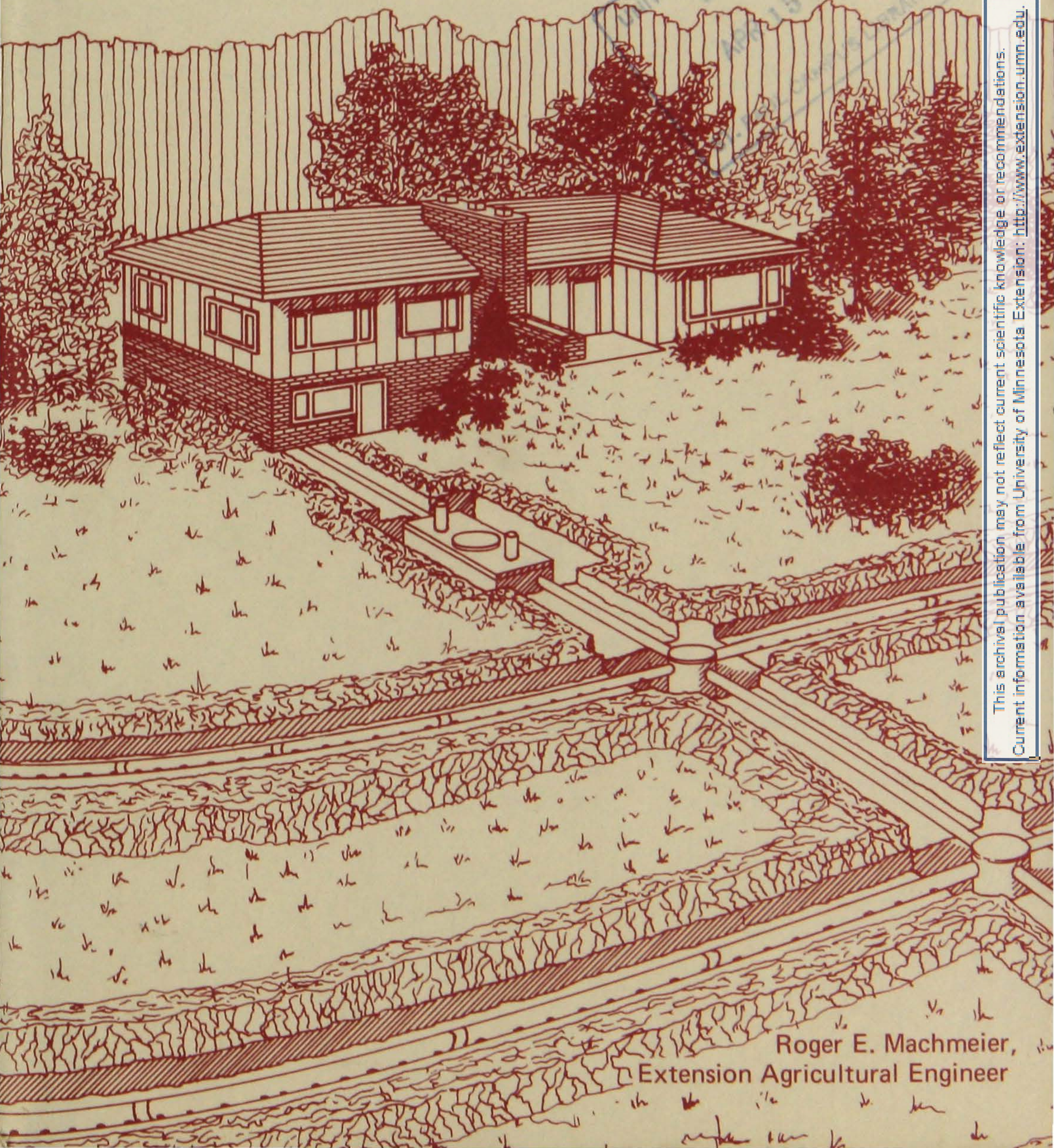

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Roger E. Machmeier,
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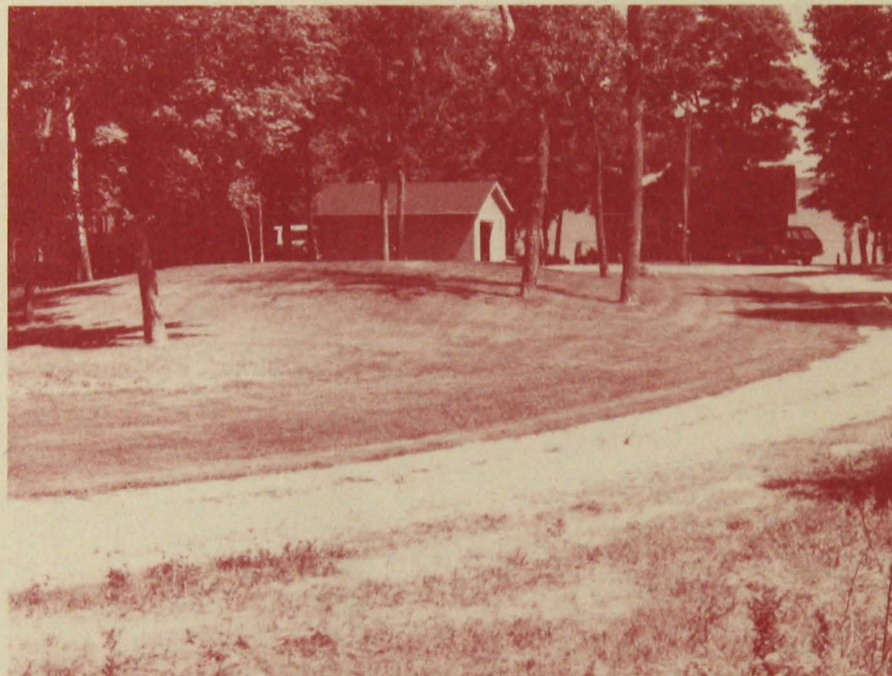

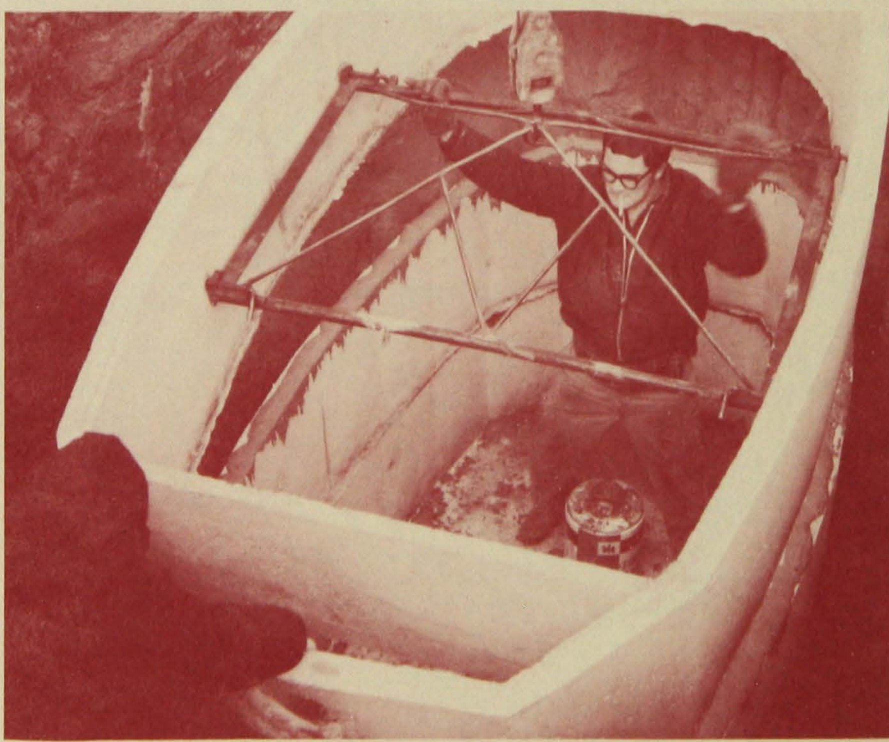

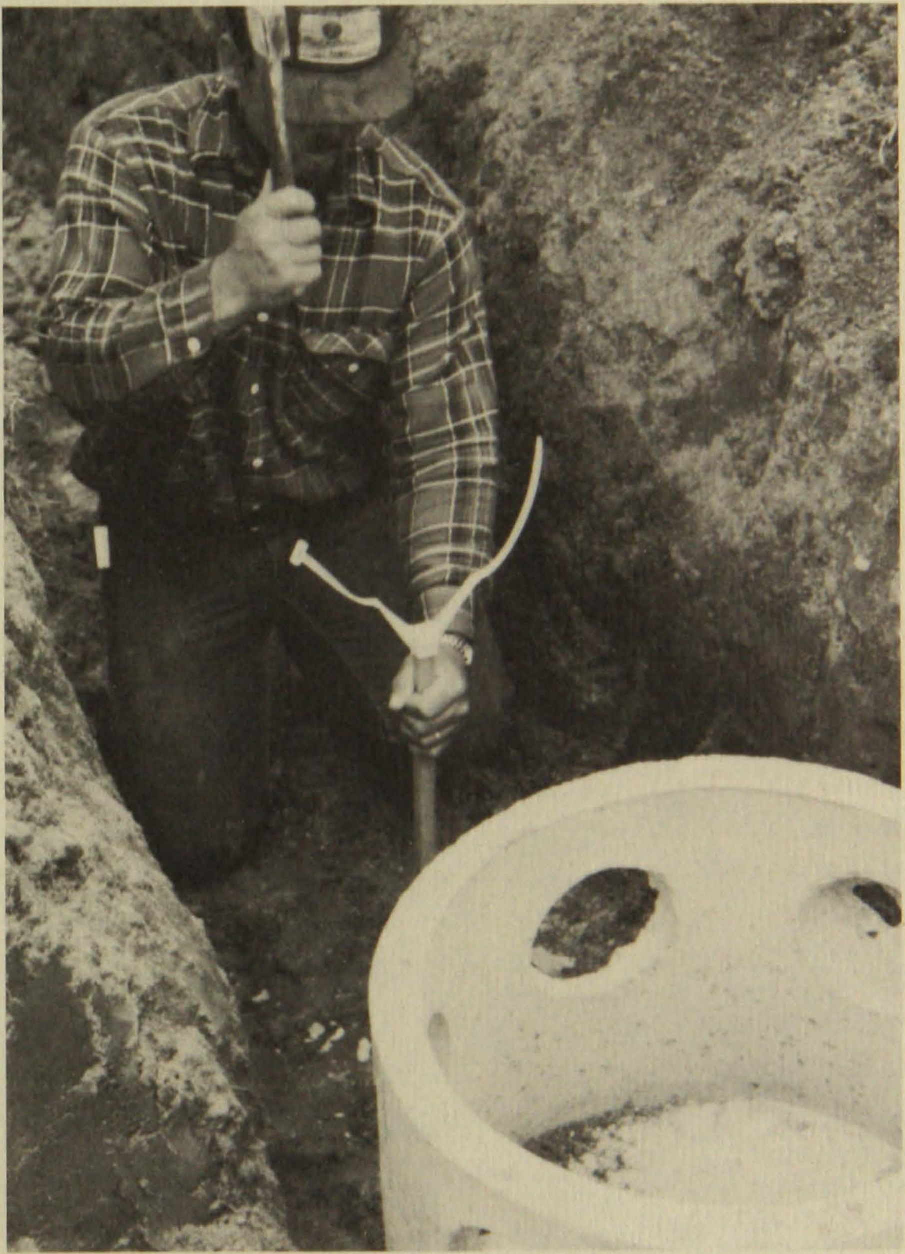

Modern sewage treatment systems in Minnesota include sewage treatment mounds, prefabricated septic tanks, and drop boxes. A sewage treatment mound blends into the landscape between existing trees in the yard (upper left). Septic tank effluent is pumped into the mound for adequate treatment in order to protect the lake in the background. A 1,500-gallon prefabricated concrete septic tank cast in three sections requires special equipment to transport and set in place (left). A drop box is being installed to distribute effluent to a drainfield trench. The workman is installing a pipe saddle to hold the trench distribution pipe on an even grade.

Clean rock placed carefully in the drainfield trench to avoid disturbing the distribution pipe supported at the proper grade. Note the drop box.

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INTRODUCTION

This publication contains comprehensive information on the proper design, installation, use, and maintenance of onsite sewage treatment systems. It is intended primarily for homeowners, but contractors and installers, administrators of sanitary ordinances, consultants, government officials at the local, regional and state levels, and anyone involved with onsite sewage treatment systems should find the material useful.

Readers are encouraged to consult the index to find sections relating to their specific interests and needs. While each section will not be of equal interest to each reader, the total publication is intended to present sewage treatment solutions for all site and soil conditions.

An *onsite sewage treatment system* includes the house sewer, the sewage tank (septic or aerobic), the outlet sewer, and the soil treatment unit, usually a drainfield trench but may be a seepage bed or pit.

Sewage flows to the sewage tank through the house sewer. Solids are separated from liquid in the sewage tank. Sewage effluent flows from the tank through a watertight pipe called the outlet sewer to the soil treatment unit. The appropriate type and quantity of soil will filter the effluent, removing bacteria, fine particles, and some nutrients.

An onsite sewage treatment system can be far more than "temporary." A properly designed, installed, and maintained sewage treatment system will adequately treat and dispose sewage for many years. But certain proven guidelines must be followed in the design and installation of a sewage treatment system.

The concept of back yards "loaded with sewage" is a misrepresentation. If the lawn is wet and spongy with sewage, the system is not working correctly. A properly designed and installed soil treatment unit will treat and filter sewage for as long as its effluent quality can be maintained. Soil is a self-renewing filter which does not become "loaded with sewage." A sewage treatment system never "fails"; it is either improperly installed or overloaded with sewage.

If you intend to plan and design your own sewage treatment system, use a drawing. Record and follow design specifications closely during construction. After the system is built, mark its location on the original drawing by measuring the distance from two corners of the house, garage, or other stationary landmark. Also mark the septic tank manhole, drop boxes, and inspection wells for the drainfield trenches on this drawing. Finally, file the drawing and design specifications with the deed to the property for future reference for you or subsequent owners.

HOUSE SEWER

The house sewer carries raw sewage from the house to the sewage tank. A house sewer should have at least a 4-inch diameter sewer pipe. Absolutely watertight joints are necessary to prevent root penetration. Concrete masonry joints will not be watertight, because mortar contracts as it cures.

The house sewer should have a slope of at least 1 inch for 8 feet of distance (1.0 percent). For house sewers longer than 50 feet, the sewer pipe should not slope more than 1 inch in 4 feet (2.0 percent). On too flat a grade, the liquid will slow down, allowing the solids to settle out in the sewer pipe. On too steep a grade, the liquids will flow away from the solids.

Therefore, the house sewer must be on a grade ranging between 1 inch in 4 feet and 1 inch in 8 feet.

Don't make sharp bends in the house sewer system. When 45 or 90 degree bends are necessary, use long sweep (long radius) elbows to allow a plumber's snake to go through the sewer line. If long sweep elbows are not available, use several 22½ degree (sixteenth bend) elbows.

Basement footing drains

Never, under any circumstances, allow footing drains to drain into the sewage treatment system. Footing drains are routinely used to prevent wet basements. The water from these drains, which does not need to be treated, will overload and cause failure of the sewage system. The overflowing sewage could then flow back into the drain tile, causing a serious and long-time odor problem in the basement.

When you must pump the footing drain water, discharge it in an area other than where the soil treatment unit is located.

Never use a single pump for both drain water and basement sewage wastes. If the laundry tub and floor drain wastes do require pumping, *a separate pump must be installed.* Using a single pump will overload the sewage treatment system.

SEWAGE TANKS

The house sewer carries raw sewage to the sewage tank, which may be either a septic tank or an aerobic tank. The purpose of the sewage tank is to separate the sewage solids from the sewage liquids. Sewage liquid discharged from a sewage tank is called effluent. Effluent from a properly maintained septic tank is slightly cloudy, while it is almost clear from a properly maintained aerobic tank. However, both types of effluent contain fine suspended solids, disease-causing bacteria, and the nutrients nitrogen and phosphorus. Sewage tank effluent *must not be discharged directly to the ground surface or into surface waters.* The effluent must be discharged to a properly designed and constructed soil treatment system.

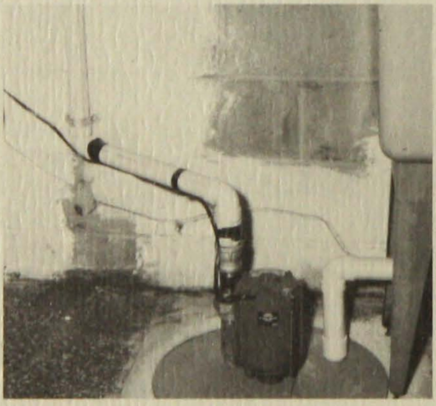
No reduction in soil treatment area size can be allowed for the use of an aerobic tank. The same size soil treatment unit must be used with an aerobic tank as with a septic tank.

Run all sewage wastes from the laundry, bath, kitchen, and toilet into the sewage tank. Do not let wash water and other similar wastes bypass the sewage tank. Soapy or greasy water sent directly into the soil treatment unit will quickly plug the soil pores and ruin the soil system.

Tank location

Place your sewage tank where it can be reached and maintained and cleaned easily. Most sanitary codes specify that the tank must be at least 10 feet from the house to protect against possible sewage flow into the basement.

Keep the sewage tank at least 50 feet from the water supply well. An even greater distance is preferable, if possible. Place the sewage tank where about 1 foot of earth can cover it. If the basement cannot be drained by gravity, install a sump pump to lift basement wastes up to the house sewer line.



A sump pump lifts laundry-tub and floor-drain wastes up the level of the house sewer. Sewage then flows by gravity to the septic tank.

Having the sewage tank close to the ground surface makes it readily accessible for cleaning. Extend the inspection pipes to the ground surface and cap them with airtight and rustproof covers. Do not allow automobiles or any heavier vehicular traffic to drive over the septic tank unless the cover is adequately reinforced.

Septic tanks

Solids separate from the liquid as the sewage flows slowly through the septic tank. Some solids settle to the bottom of the tank, and others float in the scum layer at the top. Bacterial action partially decomposes the solids.

The material in the septic tank separates into three distinct layers:

1. Scum at the top
2. A middle zone with no solids
3. A bottom layer of sludge

The scum layer consists of cooking fats and oils, soap scum and other materials that float. The greatest amount of bacterial decomposition occurs in the sludge layer which consists of those solids heavier than water. Effluent flows from the middle zone into the soil treatment system.

The most important feature of any septic tank is adequate *liquid capacity*. Select a size at least as large as is indicated in table 1. A 1,000-gallon tank is normally adequate for a three-bedroom house. Unless local regulations require a larger tank size, a good rule to follow is 1,000 gallons for a three-bedroom house or smaller, and 250 gallons of additional liquid capacity for each bedroom over three.

Table 1. Recommended septic tank liquid capacities

Number of bedrooms	Minimum liquid capacity, gallons[a]
2	750
3	1,000
4	1,250
5 or 6	1,500
7, 8 or 9	2,000

[a]Liquid capacity is the tank volume below the outlet. An additional internal volume equal to 20 percent of the liquid capacity is needed for floating scum storage.

Extra tank capacity can be purchased for a modest additional cost. A larger tank will have a longer sewage detention time. It will do a better job of removing solids. This increases the life of a soil treatment unit. The larger tank provides more volume for storing solids, so tank pumping is not required as often. Any added cost for installing a larger tank is repaid by lower maintenance cost.

It's not necessary to add any special material to "start" a septic tank. Simply use your plumbing facilities in a normal manner and the septic tank will begin to function.

The U.S. Department of Health, Education, and Welfare says over 1,200 products — many containing enzymes — are being sold for use in septic tanks. Extravagant claims are made for some of them. However, none have been proven advantageous in properly controlled tests.

Some septic tank additives cause the accumulated sludge to "bulk" and be flushed out and plug the soil treatment unit. Other additives, particularly degreasers, may be carcinogens (cancer causing) or suspected carcinogens and will flow directly into the groundwater.

So *never* put any special additives or chemicals into the septic tank. However, ordinary amounts of bleaches, lyes or caustics, soaps, detergents, toilet bowl cleaners, and drain cleaners (except degreasers) normally used in the average household do not harm the system. If the septic tank is large enough, dilution of these materials overcomes any harmful effects.

Whether or not a garbage disposal can be used depends on the size of the septic tank and the maintenance program of solids removal from the tank. Experience has shown that solids accumulate about twice as fast in a septic tank when a garbage disposal is used. Therefore, an annual maintenance program is essential. Also, select a septic tank larger than the minimum values suggested in table 1.

Never place materials into the sewage treatment system that will not decompose readily. Coffee grounds, cooking fats, bones, wet strength towels, disposable diapers, facial tissues, filter cigarette butts, and similar materials should not be discharged into the septic tank.

However, waste brined from a household water softener has no effect on a well maintained 1,000-gallon or larger septic tank. Sewage effluent having additional sodium will have little or no adverse effect on the soil treatment unit. Nevertheless, the extra water used to recharge the softener may be enough to overload an undersized soil treatment unit.

Liquid capacity

Before buying a tank, be sure the manufacturer of the tank rated it in *liquid* capacity. Tank capacity depends on liquid depth and surface area. Liquid depth cannot be less than 3 feet and should not be greater than 6½ feet. For floating scum storage, an additional tank height must be allowed above the liquid level equal to 20 percent of the liquid depth.

To determine the liquid capacity of a septic tank, measure the inside length, inside width, and the height of outlet above the tank floor. For example, consider a tank having 54 inches of liquid depth which is 4 feet wide and 8 feet long on the inside. This tank has 32 square feet (4×8 feet) of liquid surface area. Thus, the tank has 32 cubic feet of liquid volume for each foot of liquid depth. Since each cubic foot of water is equal to 7.5 gallons, the tank has 240 gallons per foot of depth (7.5×32).

With 4.5 feet (54 inches) of liquid depth, the total tank liquid capacity is 1,080 gallons (4.5×240).

Inlet and outlet baffles

Proper baffles are essential for correct performance of a septic tank. The inlet baffle directs the raw sewage downward into the middle zone of the septic tank. The outlet baffle allows the sewage effluent to flow out of the tank while retaining the scum in the tank.

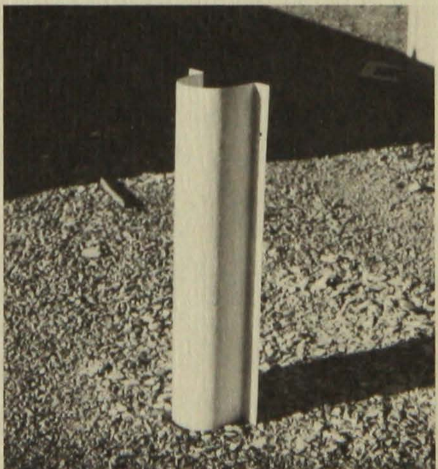
Baffles are available in different shapes. Some baffles extend across the width of a rectangular tank and are fastened to the tank walls. Baffles fastened to the end wall of a tank are usually semi-circular. Sanitary tees of plastic or cast iron are often used for baffles. A sanitary tee has one side curved to minimize the chance of plugging. Do not use the standard tees as they have a sharp edge which will tend to hold sewage solids that may plug the tee. Elbows are not suitable for inlet or outlet baffles because gases which are generated by bacterial action cannot escape the septic tank. Gases from the septic tank move through the house sewer and into the plumbing stack vent.

Baffle materials should be durable and corrosion proof. Fiberglass or acid-resistant concrete baffle materials are suitable. Suitable materials for sanitary tees are cast iron and plastic. Some septic tank servicemen report that cast iron at the outlet may corrode shut. Apparently the corrosion relates to water quality. Check conditions with local installers or the zoning administrator. Cast iron sanitary tees are suitable for inlet baffles.

Do not use coated metal baffles; the metal will corrode, even if it is covered with corrosion-resisting material. Concrete used for inlet and outlet devices must be of the proper mix and be properly cured. Porous concrete baffles made with a dry mix which cannot be properly compacted will soon be decomposed by the gases in the septic tank. Such baffles will fall off and solids will flow into and plug the drainfield.

Baffles must have the proper submergence and proper height above

Metal septic tank baffles corrode easily. Avoid using them.



Fiberglass septic tank baffles do not corrode.

the tank liquid level so the septic tank can effectively trap the sewage solids. Also, the elevation of the inlet pipe to the tank must be at least 3 inches higher than the liquid level (outlet pipe). This elevation is required to provide free flow from the house sewer into the tank to minimize any chance of plugging.

The inlet baffle directs the raw sewage downward and also prevents the floating scum layer from plugging the inlet pipe. The inlet baffle must be submerged at least 6 inches below the liquid level, but must not penetrate any deeper than 20 percent of the liquid depth. A deeper submergence will cause the bottom sediments to be disturbed when sewage flows into the tank.

The submergence of the outlet baffle is critical to proper retention of both sludge and scum in the tank. The bottom of the outlet baffle must be submerged at a point which is equal to 40 percent of the liquid depth of the tank. This elevation will provide for the maximum storage of scum and sludge.

The upper part of both the inlet and outlet baffles must extend above the liquid level a dimension equal to 20 percent of the liquid depth to provide for scum storage. However, the tops of the inlet and outlet baffles must be open and extend no closer than 1 inch to the inside top of the tank. This allows for movement of gases through the tank. For complete tank specifications, contact the local zoning administrator. Also, personally check that the septic tank has the proper inlet and outlet baffles with the proper dimensions.

The following examples will help you figure inlet and outlet baffle length, submergence below liquid level, and extension above liquid level.

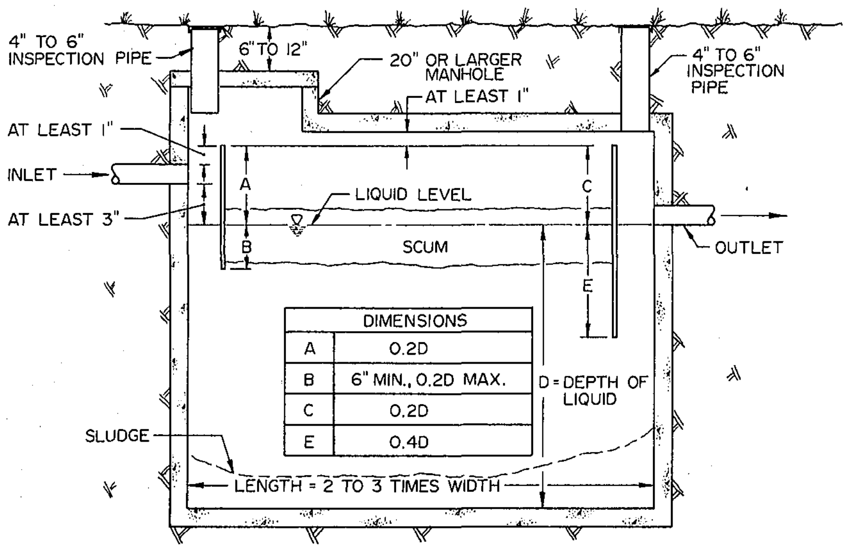
If a tank measures 54 inches from the floor to the bottom of the outlet hole, the inlet and outlet baffles should have these dimensions (figure 1):

Table 2. Inlet and outlet baffle length for vertical sidewall septic tanks

Liquid depth, D, in inches	Lengths in inches (see figure 1)					
	A	B		C	E	C+E
		Min	Max			
30	6	6	6	6	12	18
36	7	6	7	7	14	21
42	8	6	8	8	17	25
48	10	6	10	10	19	29
54	11	6	11	11	22	33
60	12	6	12	12	24	36
66	13	6	13	13	26	39
72	14	6	14	14	29	43
78	16	6	16	16	31	47

Note: At least 1 inch of clearance must be above both the inlet and outlet baffles. The invert (bottom) of the inlet pipe must be 3 inches higher than is the invert of the outlet pipe.

Figure 1. Dimensional requirements, inspection pipes, manhole access and baffle submergence of a rectangular septic tank



INLET BAFFLE

Submergence (dimension B) — at least 6 inches below the liquid level, but no more than 11 inches (0.2 × 54 inches).

Top extension (dimension A) — at least 11 inches (0.2 × 54 inches) above the liquid level and no closer than 1 inch to the underside of the tank cover. Also, the top of the inlet device should be at least 1 inch above the top of the inlet pipe which is the house sewer.

OUTLET BAFFLE

Submergence (dimension E) — 40 percent of 54 inches, to the nearest inch, 22 inches (0.4 × 54 inches).

Top extension (dimension C) — at least 11 inches (0.2 × 54 inches) above the liquid level and no closer than 1 inch to the underside of the tank cover.

Thus, for the 54-inch liquid depth, the inlet baffle must be at least 17 inches (6 + 11 inches) long but not longer than 22 inches (11 + 11 inches). The outlet baffle must be 33 inches (22 + 11 inches) long. The inlet and outlet baffles both must be properly submerged for proper tank operation and performance. Use table 2 to determine inlet and outlet baffle lengths for other liquid depths.

Access

Access to the septic tank must be provided by either a manhole or an inspection pipe located over both the inlet and outlet devices. At least one manhole, with a lesser dimension of at least 20 inches is needed for solids removal. The edge of the manhole must be within 6 feet of any wall of the tank. At least 6 inches but not more than 12 inches of earth must be over the manhole cover. The minimum earth cover is to prevent unauthorized or accidental entry into the tank.

Inspection pipes at least 4 inches in diameter should be installed directly above and in line with the openings of the tank inlet and outlet devices. A downward projection from the inspection pipes should not hit the inlet or outlet devices. The top of the inspection pipes should be flush with or above final grade and capped with airtight and corrosion-proof covers. The inspection pipes should not be used to remove accumulated solids from the septic tank. Use the manhole for this.

Construction

The septic tank must be watertight. Do not allow the liquid level to fluctuate. If the liquid level drops below the bottom of the outlet device, the scum layer will spread out and get inside the outlet device. When the liquid level rises, the scum will flow into the outlet sewer. This may clog the outlet sewer, the distribution pipes in the trenches, or the soil pores. A watertight tank bottom also prevents soil from decreasing the tank volume. Certain soils tend to enter the tank from the bottom as the liquid level fluctuates or when the tank is pumped to remove the accumulated solids.

Septic tank materials must be strong and be able to resist corrosion and decay. Some authorities report that metal tanks rust through and begin to leak in 5 years. Fiberglass does not corrode or decay, but it is generally more expensive than concrete. However, the weight of fiberglass tanks permits easier handling for remote sites. Careful installation of fiberglass tanks is required, however, to prevent structural damage. Fiberglass tanks are not able to withstand surface loads such as heavy vehicles.

Precast concrete tanks are suitable and economical and the most often used in Minnesota. Rectangular tanks constructed with concrete blocks should have mortar joints and be sealed with two coats of concrete plaster on the inside. Circular block tanks may be laid with loose joints, but they must be plastered on the inside with two coats of concrete plaster. A watertight, poured, or precast concrete bottom is required for all block tanks.

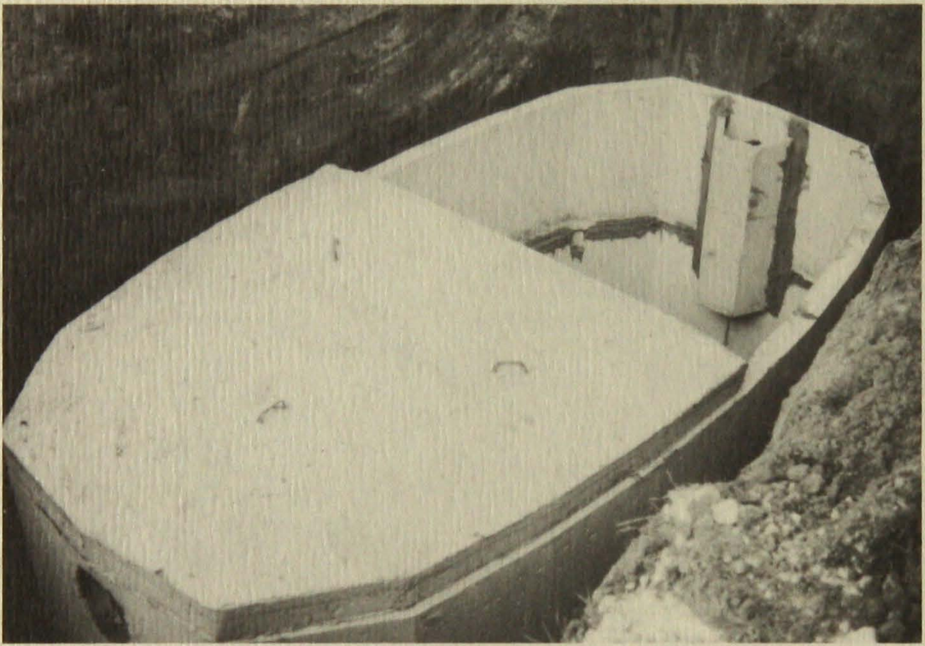
A rectangular septic tank should be two to three times as long as it is wide. A circular tank should have at least a 5-foot inside diameter.

Tank compartments

Research has shown that compartments are not a major advantage unless the septic tank is larger than 3,000 gallons. It is more important to maintain tank volume by periodic removal of solids.

When a septic tank is divided into two compartments, the first compartment must be not less than one-half nor more than two-thirds of the total tank liquid volume. When a septic tank is divided into three or more compartments, one-half the total volume should be in the first compartment, and the other half of the volume should be equally divided into the other compartments.

Effluent should flow between compartments through submerged baffles or sanitary tees. Adequate ventilation between compartments should be provided by baffles or tees or by an opening of at least 50 square inches near the top of the compartment



This precast concrete septic tank is ready to be connected to the house sewer. Note the outlet baffle and the mortar joint between tank sections.

wall. Each compartment must have adequate manhole access as explained in the previous section.

Up to four tanks may be connected in a series to obtain the required liquid volume. Each tank must comply with all the provisions for a septic tank.

Aerobic tanks

In aerobic tanks, air mixed into the sewage promotes the oxygen-using (aerobic) bacteria. Aerobic bacteria are more rapid decomposers than anaerobic (non-oxygen-using or septic) bacteria. A stirring agitator or an air pump supplies oxygen to the aerobic bacteria in the tank.

Aerobic tank effluent contains disease-causing organisms and nutrients. Thus, aerobic tank effluent cannot be discharged to the ground surface or into surface waters. Any surface discharges will endanger the public health and violate the regulations of the Minnesota Pollution Control Agency and the Minnesota Department of Health.

Aerobic tank size is based on the amount of sewage that can be treated daily. Thus, for a given sewage flow, the liquid volume of an aerobic tank is less than is a properly sized septic tank. However if the aerobic tank agitator or air compressor fails and is not repaired, the quality of effluent discharged from an aerobic tank will not be as good as that from an adequately sized and maintained septic tank.

Aerobic tanks require considerable maintenance. A continuous service agreement must be maintained with the dealer or installer. Any aerobic tank installed in Minnesota must be a model tested by the National Sanitation Foundation (NSF). The unit must meet all specifications of NSF Standard No. 40.

OUTLET SEWER

The outlet sewer carries sewage tank effluent either to the soil treatment unit or to a pumping station which then transfers the effluent to the soil treatment unit. The outlet sewer should be a watertight pipe at least 4 inches in diameter and laid on a grade of at least 1 inch in 8 feet. There is no maximum grade for the outlet sewer since it does not transport solids. The solids have been retained in the sewage tank.

SOIL TREATMENT UNITS

The soil treatment unit provides the final treatment and disposal of the sewage tank effluent. A properly designed and installed soil treatment unit will filter out all disease-causing bacteria and the fine solids contained in the sewage tank effluent. The nutrient phosphorus will be adsorbed (attached to) by fine soil particles and nutrient nitrate — nitrogen will move with the water. In the summer a shallow drainfield trench supplies water (and nutrients) to grass and trees. The nitrates that remain in the downward percolating water will be either changed to nitrogen gas by soil bacteria or diluted by precipitation. Nitrates are rarely a problem when the soil treatment unit is a drainfield trench system or the well is deeper than 50 feet.

The three types of soil treatment units commonly used are drainfield trenches, seepage beds and seepage pits. Drainfield trenches perform the most adequate job of treating sewage tank effluent and should be used whenever possible.

A drainfield trench is constructed by making a level excavation 18 to 36 inches wide and up to 100 feet long. Clean rock is placed in the bottom 12 inches of the excavation, then a 4-inch diameter perforated distribution pipe, 2 inches of rock over the top of the pipe, a layer of hay or straw and untreated building paper, and the soil backfill to a depth of 6 to 12 inches, above the rock.

Sewage effluent flows through the distribution pipe holes into the rock layer and into the soil. Bacteria and fine sewage solids are removed by soil of suitable texture. Soil must not be too coarse or too fine. A coarse soil cannot adequately filter bacteria and a fine soil may be too tight to allow water to pass through. Soils having percolation rates between 0.1 and 60 minutes per inch (MPI) are suitable for treating sewage. Trench rock must never be placed in contact with soils having a percolation rate faster than 0.1 minute per inch or slower than 60 minutes per inch.

Seepage beds are constructed like trenches but are wider than 3 feet. A seepage bed requires less lawn area than drainfield trenches but has much less sidewall area available for treating sewage. Beds may require the removal of trees and can't be located on slopes steeper than 6 percent. Contractors often smear or seal the bed bottom during construction destroying the bed's ability to treat effluent.

A seepage pit (dry well) is the least desirable soil treatment unit. A tank with holes along the sidewalls is placed in an excavation. Rock is placed along the outside of the tank before the soil is replaced. The effluent is placed too deep in the soil for adequate treatment. There is no evaporation or use of effluent by plants. Seepage pits often contribute to well water contamination and deep soil borings must be made to determine if the pit will pollute ground water. Seepage pits are not allowed if the soil is suitable for trenches or beds.

Location

Maintain a safe distance between the soil treatment unit and the water supply source. The distance that nitrates travel underground and their concentration depend upon numerous geologic factors, including characteristics of subsoil formations and quantity of sewage discharged. It is not always safe to specify minimum distances. The greater the distance, the greater the safety provided. All trench and bed soil treatment units should be at least 100 feet from any water supply well unless the well is deeper than 50 feet or is protected by an impervious layer at least 10 feet thick. Then the separation distance can be 50 feet.

A seepage pit should be located at least 150 feet from a water supply well unless the well is deeper than 50 feet or is protected by an impervious layer at least 10 feet thick. Then the minimum separation distance between the well and the pit can be 75 feet.

The setback distance for the soil treatment unit is 20 feet from buildings and 10 feet from property lines. However, check these setbacks with your county zoning administrator. The minimum setback distances from lakes or streams is 50, 75, or 150 feet, depending upon the lake classification. For additional details on shoreland, refer to Extension Bulletin 394, *Shoreland Sewage Treatment*.

Locate the soil treatment unit where good grass cover is possible. Don't allow automobiles or other large vehicles onto the area. In the winter, keep all traffic off — including snowmobiles and foot traffic.

Locate the soil treatment unit in order to protect it against surface runoff water. Don't allow runoff from roofs, patios, driveways, or other paved areas to flow across the area over the soil treatment unit. Construct a small diversion or grassed waterway on the upslope side of the area and lead the excess surface water away from the soil treatment unit. Never discharge the water from basement footing drains or other sources over the area where the soil treatment unit is located. Establish a grass cover as soon as possible after installation to prevent erosion and to promote evapotranspiration during the summer.

Site evaluation

Suitable soil is necessary for a successful sewage treatment system. A suitable soil texture has a percolation rate between 0.1 and 60 minutes per inch. Sandy loam or loam soils are the best for your soil treatment unit. Heavy clay soils with high seasonal water tables are not suitable since sewage will not flow through them at an adequate rate. Very coarse-textured sand and gravel are not suitable since sewage flows through them too rapidly and is not filtered properly. Bacteria may reach the ground water table if sewage is applied to coarse soil.

Experience is needed to properly evaluate soils and their suitability for treating sewage. Check with the local Soil Conservation Service (SCS) office about the soils on your property. Even if the county does not have a complete soil survey, the SCS personnel will probably be familiar with your area. Soil interpretation sheets are available for the soils on your lot and will provide information on soil texture as well as high seasonal water tables that will interfere with your sewage system.

Fractured bedrock, like this limestone rock exposed in a highway grade, does not provide adequate treatment of sewage unless at least 3 feet of suitable soil exists between the trench rock and the limestone bedrock.

Table 3. Minimum lawn area in square feet required for soil treatment trench system

Soil texture	Area required for a 3-bedroom home (square feet*)	Add for each additional bedroom (square feet)
Fine to medium sand	940	312
Fine sand and silt	1,425	475
Silty sand, little clay	1,875	625
Silty sand, some clay	2,250	750
Considerable clay	2,475	825

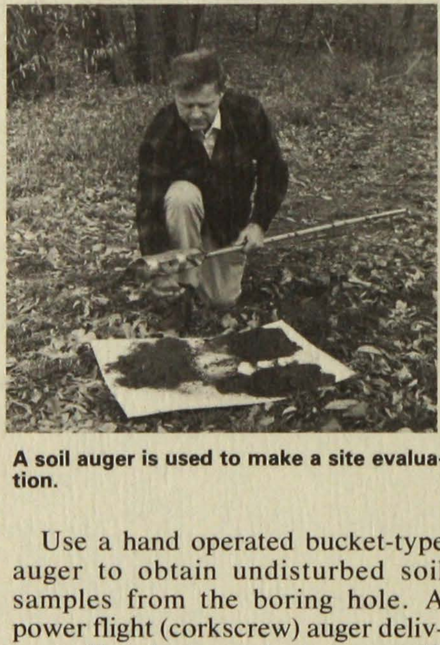
*Based on 3-foot wide trenches spaced 7.5 feet center to center.

On a developed lot, you must consider the locations of all improvements including the well. An inexpensive, but dependable, pumping station can be installed if the suitable soil area is located at a higher elevation than your house. Therefore, investigate all areas of the lot either higher or lower than your house.

The size of the surface area required for the soil treatment unit depends on the soil texture and the size of the proposed or existing residence that generates the sewage. Table 3 estimates required area in relation to these two factors. Be sure to consider setback distances from property lines, buildings and other improvements. Consult with your zoning administrator on the local sanitary code.

Soil borings

Soil borings are necessary to locate an area suitable for the soil treatment unit. Boring holes should be at least 3 inches in diameter and 3 feet deeper than the bottom of the proposed soil treatment unit. Six feet is an appropriate depth, unless you encounter the water table or impermeable layers at a shallower depth. You can stop boring at the water table or other barrier.



A soil auger is used to make a site evaluation.

Use a hand operated bucket-type auger to obtain undisturbed soil samples from the boring hole. A power flight (corkscrew) auger delivers a disturbed sample and you will not be able to identify the presence of mottled soil. A backhoe is sometimes used to make excavations for evaluating soil for an onsite sewage treatment system.

Leave the boring holes open. After 24 hours, check for the presence of a water table. In clay soils, a water table that will prevent the soil treatment unit from working may be within 1 to 3 feet of the surface. In the spring, the water table can be observed directly. In late summer or fall, the water table may not be physically present, but its former location can be identified by mottled soil. Mottling is a distinctive multicoloration of grey with splotches of red and yellow indicating a high water table during wet seasons. Such a soil is unsuitable for a soil treatment unit. A high seasonal water table will cause the soil treatment unit to fail or to inadequately filter the sewage tank effluent. The bottom of the drainfield trenches or the seepage bed *must not be closer than 3 feet* to mottled soil.

Number the soil boring holes and locate them on a scale map of the building site or lot. To identify a suitable area, take at least four soil borings over a representative area.

Describe and record the soil texture (fine sand, medium sand, silt loam, clay, etc.) for every foot or where there is a change in texture. If you encounter the water table or an impervious layer, such as rock or clay, at a depth less than 3 feet, the area is not suitable for a standard subsurface soil treatment unit. Evaluate the soils on the list to determine what type of sewage treatment system can be installed. Alternative systems appear in later sections of this bulletin.

Percolation tests

A percolation test is a standard test procedure used to evaluate soil porosity and the soil's ability to treat sewage effluent. Percolation test results will identify which soils are too porous to properly filter bacteria and which soils are too tight to accept sewage. For the soils which are suitable to treat sewage, percolation test results will provide information on the required size of the soil treatment area.

After the soil borings have identified an area of soil which is likely to be suitable for the soil treatment system, make at least two percolation test holes in each soil texture and space them uniformly over the area. Make each test hole diameter at least 6 inches, but no larger than 8 inches. To fill a hole 6 inches in diameter requires about 1½ gallons of water per foot depth. Dig the test hole as deep as you intend to dig the proposed soil treatment unit. The bottom of the percolation test hole must be at least 3 feet above the highest known level of the water table (mottled soil) or an impervious layer as identified by the soil borings.

1. **Preparation of the percolation test hole:** Scratch the sides and bottom of the percolation test hole with a sharp-pointed instrument to provide open natural soil into which water may percolate. Nails driven into a 1-inch thick by 2-inch wide board will provide a good instrument to scarify the sides of the hole. Remove all loose soil from the bottom of the hole. Add 2 inches of pea-sized gravel to protect the soil bottom from scouring when water is added.
2. **Saturation and swelling of soil:** You must distinguish between saturation and swelling. Saturation means that void spaces between soil particles are full of water; saturation can be accomplished in a short time. Swelling is caused by intrusion of water into individual soil particles. This is a slow process, especially in clay soils, requiring prolonged soaking. Carefully fill the hole with clear water to a depth of at least 12 inches above the bottom of the hole. Keep water in the hole for at least 4 hours, and preferably overnight. Refill, if necessary, or supply a surplus reservoir of water maintaining the 12-inch depth with an automatic siphon ("chicken feeder" type device). Use a hose or similar device to add water to the hole to prevent washing down the sides of the hole.

   Measure the percolation rate after at least 16 hours, but no more than 30 hours, after water was first added to the hole. This insures that the soil has ample opportunity to swell and to approach its natural condition during the wettest season. Therefore, the test gives comparable results in the same soil, whether made in a dry or wet season.

   Sandy soils containing little or no clay do not swell. The sandy soil percolation test is described under 3C below. It is to be used if water from one completely filled hole seeps away in less than 10 minutes. However, if time is available, soak the hole and perform the percolation test the following day for more reliable results.
3. **Measurement of rate:**
   A. If water remains in the percolation test hole after the overnight swelling period, adjust the water depth to 8 inches above the soil bottom of the hole (6 inches above the pea-sized gravel). Use a bail can to remove excess water. Measure the drop in water level to the nearest $^1/_{16}$ inch over approximately 30-minute periods. A percometer is a convenient device to measure the depth of water in a percolation test hole. (Details on making and using a percometer can be found in Extension Folder 261, *How to Run a Percola-*

The percometer sets vertically with the adjustable tripod.

tion Test). Or use a measuring stick with a hook gauge and the top of a level batterboard as a reference point. The hook can be made of stiff wire or an 8d nail. Continue to test until three consecutive percolation rate measurements vary by a range of no more than 10 percent.

B. If no water remains in the hole after the overnight swelling period, add clear water to bring the water depth in the hole to 8 inches above the soil bottom of the hole (6 inches over the gravel).
Measure the drop in the water level to the nearest 1/16 inch at approximately 30-minute intervals. Continue to run the test until three consecutive percolation rate measurements vary by a range of no more than 10 percent. Refill the hole with water to 6 inches above the pea gravel as necessary.

C. In soils in which the first 6 inches of water seeps away in less than 30 minutes after the overnight swelling period, allow approximately 10 minutes between measurements. Continue the test until three consecutive percolation rate measurements vary by no more than 10 percent.

4. **Calculate percolation rate:** Determine the percolation rate in minutes per inch (MPI) by dividing the time intervals in minutes by the drop in water level in inches. Calculate the percolation rate for each reading, and use the slowest value for each test hole to obtain the average percolation rate to be used to design the soil treatment unit.

Drainfield trenches

Use drainfield trenches in preference to other soil treatment units. Drainfield trenches provide the most adequate treatment of sewage effluent by the soil.

Don't cut down all the trees in the area proposed for the drainfield.

Sample calculations:

Hole 1: $= \frac{30 \text{ minutes}}{7/8 \text{ inch}} = 30 \times \frac{8}{7} = 34.3$ MPI

Hole 2: $= \frac{33 \text{ minutes}}{15/16 \text{ inch}} = 33 \times \frac{16}{15} = 35.2$ MPI

Average $= \frac{34.3 + 35.2}{2} = \frac{69.5}{2} = 34.8$ MPI $=$ 35 MPI

Trees will be able to utilize your waste water. Run the trenches on the contour between the trees. To avoid serious root damage, avoid placing trenches much closer than 10 feet to large trees. Place 12 inches of rock below the distribution pipe. Tree roots will grow into the bottom 3 to 4 inches of this trench rock to absorb the water and nutrients.

Where soil backfill may be needed over shallow trenches, protect trees by placing retaining walls around the trunks to prevent soil from contacting the bark. If fill soil is placed against the bark of most trees, they will develop disease and die.

Install trenches with 6 to 12 inches of soil cover whenever possible. Sometimes, you may need to pump the sewage tank effluent to an area or an elevation where the soil is suitable. However, this is the most effective way to properly treat and dispose of your sewage.

Freezing rarely occurs in a properly constructed drainfield trench system kept in continuous operation. Establish a good grass cover and allow snow to accumulate naturally. Pedestrian or snowmobile traffic will compact the snow and allow frost to penetrate to the drainfield.

Bottom area required

The amount of trench bottom area required depends on the porosity of the soil as measured by the percolation rate, the daily amount of sewage liquids, and the depth of rock placed below the distribution pipe.

As the soil filters sewage effluent, a biological mass (biomass) develops on the soil at the trench bottom and sidewalls. The rate at which the biomass is able to filter sewage depends upon the size of the pores in the soil. The pore size index is evaluated by the percolation test.

The daily amount of sewage wastes must be estimated to size the soil treatment unit. For residences, the daily amount of sewage wastes is based on the number of bedrooms and the type of residence. A luxury 3-bedroom house likely will generate more sewage than a more modest house. Sewage flows for different types of houses can be estimated from table 4. Using a large sewage flow provides a factor of safety in sizing the soil treatment unit. Also consider future house expansion.

Conserve water whenever possible. Reducing the amount of water used will increase the life of your sewage treatment system. See pages 55 and 56 for water-saving ideas.

To illustrate the use of table 4, determine the amount of trench bottom area required for a 3-bedroom type I dwelling. The soil percolation rate, as measured by the percolation data presented on page 20, is 35 MPI. From table 4, a 3-bedroom type I dwelling is estimated to generate 450 gallons of sewage per day. The trench bottom area required for a percolation rate in the range of 31 to 45 is 2.00 square feet per gallon waste daily.

Thus, the total required bottom area is $2.00 \times 450 = 900$ square feet for trenches with 6 inches of rock below the distribution pipe. If 12 inches of rock are used, the bottom area can be reduced by 20 percent. The required trench bottom area is then $0.80 \times 900 = 720$ square feet.

The trench bottom area can be reduced by 34 percent for 18 inches of rock below the distribution pipe and by 40 percent of the maximum of 24 inches. As rock depth increases, the required trench bottom area decreases because more soil is exposed along the trench sidewall and a greater liquid depth increases the flow through the trench bottom.

Table 4. Sewage flows and soil treatment areas

Number of Bedrooms	Estimated sewage flows in gallons per day — Type of residence[a] I	II	III	IV	Soil treatment areas in square feet — Percolation rate, minutes per inch	Soil treatment area in square feet per gallon of waste per day[c]
					Faster than 0.1[b]	Soil too coarse for sewage treatment[b]
2	300	225	180	60% of	0.1 to 5	0.83
3	450	300	218	values	6 to 15	1.27
4	600	375	256	in	16 to 30	1.67
5	750	450	294	Type I,	31 to 45	2.00
6	900	525	332	II or	46 to 60	2.20
7	1050	600	370	III	Slower than 60[b]	Refer to section on mounds and alternative systems
8	1200	675	408	Columns		

[a]Type I : The total floor area of the residence divided by the number of bedrooms is more than 800 sq. ft. per bedroom, or more than two of the following water-use appliances are installed: automatic washer, dishwasher, water softener, garbage disposal, or self-cleaning humidifier in furnace.
Type II : The total floor area of the residence divided by the number of bedrooms is more than 500 sq. ft. per bedroom, and no more than two of the water-use appliances are installed.
Type III: The total floor area of the residence divided by the number of bedrooms is less than 500 sq. ft. per bedroom, and no more than two of the water-use appliances are installed.
Type IV: No toilet wastes into sewage system.
[b]Soil is unsuitable for standard soil treatment units. Refer to sections on mounds and alternative systems.
[c]For trenches only, the bottom areas may be reduced if more than 6 inches of rock is placed below the distribution pipe: for 12 inches of rock below the distribution pipe the bottom areas can be reduced by 20 percent; a 34 percent reduction for 18 inches; and a 40 percent reduction for 24 inches.

Bottom area reductions are *for trenches only*; they cannot be used for seepage beds, since there is relatively little sidewall area in a seepage bed compared to a trench system.

The minimum trench width is 18 inches, the maximum width is 36 inches. Using 36-inch wide trenches on the above example, total trench length with 12 inches of rock below the distribution pipe is 240 lineal feet (720 ÷ 3). No single trench can be longer than 100 feet. Thus, the 240 lineal feet should be divided into three or more trenches.

Trench construction

A drainfield trench may be installed only where the trench rock will be in contact with soil having a percolation rate between 0.1 and 60 MPI and where the bottom of the rock will be at least 3 feet above a high seasonal water table, permeable bedrock or a hardpan clay layer. The excavation depth can vary from a maximum of 5½ feet to no excavation where the trenches are constructed by placing the rock on the top of the existing ground surface and backfilling the trench area with sandy loam soil.

If the soil has a suitable texture with no barrier layers, excavate the trench 24 to 30 inches deep. This depth allows for 12 inches of rock below the distribution pipe, the 4-inch distribution pipe covered with 2 inches of rock, and 6 to 12 inches of soil cover above the rock.

If the subsoil is heavy clay or there is a barrier layer within 3 feet of the ground surface, do not make any excavation. Place the trench rock on the ground surface, lay the distribution pipes and backfill the trench area with sandy loam soil. On some heavy soils, the only soil treatment unit that will function properly is a shallow trench system with the entire area backfilled after the trenches are installed.

Where a high seasonal ground water table occurs, it may be necessary to install an interceptor or curtain drain tile as shown in figure 2. Install the curtain drain 5 to 6 feet deep and 10 to 15 feet upslope of the top drainfield trench. Since the curtain drain is removing excess soil water, it should outlet to the surface at a protected location. Install a ¼-inch mesh screen over the outlet end of the curtain drain to prevent entry

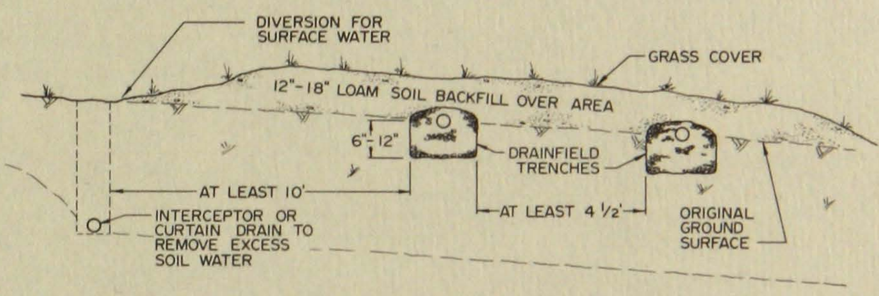


Figure 2. Interceptor or curtain drain installed to remove excess soil water in order to allow shallow drainfield trenches to adequately treat sewage

A back hoe is used to properly excavate drainfield trenches. Shallow trenches provide the most effective sewage treatment.

of small animals which could plug the tile line. The curtain drain and the drainfield trenches must not be connected in any way.

When a high seasonal water table is a problem, make the drainfield trenches as long as the lot area and shape permits. These trenches can extend 200 feet along the slope by using a drop box to supply effluent at the center so each individual trench is only 100 feet long.

Some soils may have more suitable percolation rates at 4 to 5 foot depths than near the soil surface. The maximum depth of excavation is 5½ feet. This allows for a maximum rock depth of 24 inches below the distribution pipe and a maximum soil cover of 34 inches above the top of the rock layer.

Careful excavation for the soil treatment unit is essential. Excavating clay soils when wet will lead to severe compacting and puddling, destroying the soil's ability to absorb and treat effluent.

Soil containing clay should be excavated only when the moisture content is less than the plastic limit. Soil is wetter than the plastic limit if a piece of soil taken from a depth where the bottom of the proposed trench will be located can be easily rolled into a wire or thread ⅛ inch in diameter. Any construction activity when the soil is wetter than the plastic limit will severely compact and smear the soil, resulting in early failure of the soil treatment unit. The soil will never regain its ability to absorb water, and the system may fail in 3 to 6 months.

If the soil is friable or dry enough for construction, it will crumble when you try to roll it into a wire. Construction can take place with little danger of compacting or smearing the soil.

However if the soil at the bottom of the trench contains more than 20 percent silt and clay particles (loam texture or percolation rate slower than 15 MPI), do not allow any construction equipment to drive on the bottom surface of the soil treatment area. Construction equipment wheels or tracks cause severe soil compaction and smearing, even under relatively dry soil conditions.

Use a backhoe to excavate for drainfield trenches or seepage beds. Backhoe bucket widths usually range from 18 to 36 inches. Do not allow the soil treatment area to be excavated with a front-end loader bucket or bulldozer blade. The scraping action of the bucket or blade will severely smear the soil, and the wheels or tracks will compact the bottom of the soil treatment area. Any soil treatment unit constructed in this matter will usually have a very low capacity to treat sewage.

The bottom and sidewalls of any soil treatment area exposed to rock should be in as natural condition as possible to readily accept sewage effluent. Many sanitary ordinances specify hand raking or scarifying the trench or bed sidewalls and bottom if the soil is smeared or compacted by excavation equipment. However, this is difficult and rarely done. Ask the contractor to use a backhoe bucket with raker teeth along the side as well as along the bottom. This type of bucket will leave both the bottom and sidewalls in a natural soil condition requiring very little, if any, hand labor. It is the contractor's responsibility to have the trench bottom and sidewalls in natural soil condition before the rock is placed.

Figure 3 shows trench construction details. The bottom of the trench must be "level" throughout the length of the trench. This means that the trench should approximately fol-

A tripod surveying instrument is essential for the sewage contractor. The trench bottom must be level through the length of the trench.

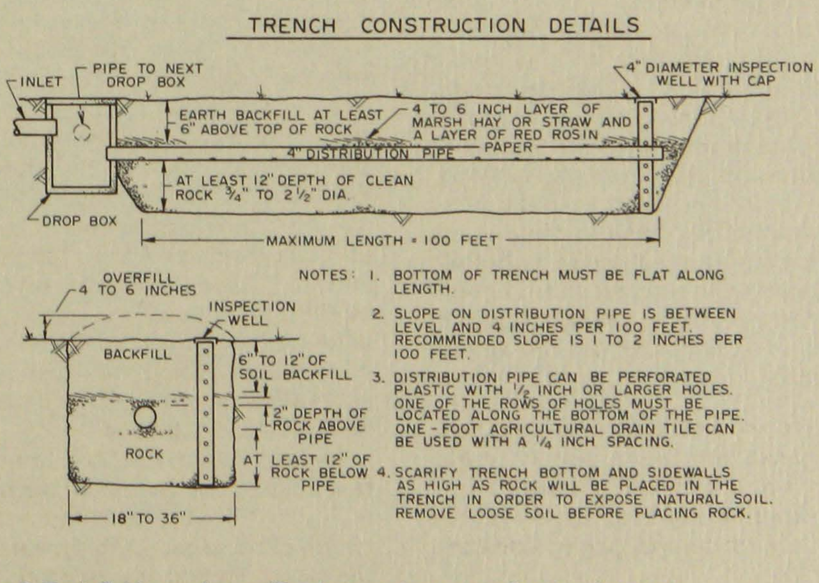


Figure 3. Drainfield trench specifications and construction requirements

low the contour of the land. The maximum trench length from the drop box or distribution box is 100 feet. Trenches will need to be spaced 7½ to 8 feet on centers for the convenience of construction equipment. However, a wider spacing will disperse the effluent over a larger area and should be used if space is available. Each soil treatment unit should have at least two trenches, unless total required trench length is less than 50 feet. A trench should be no narrower than 18 inches and no wider than 36 inches.

After the bottom and sides have been carefully prepared, place at least 12 inches of rock into the trench. While some standards suggest a minimum 6 inch rock depth, use at least 12 inches of rock under the distribution pipe for all trenches, if trees or shrubbery are present or will possibly be planted in the future.

The rock must be clean and free of dust, dirt, and debris. The diameter of the rock should be at least ¾ inch, but no greater than 2½ inches. Do not use pea-sized gravel or "pit-run" gravel, as this size will clog in a short time. The system will fail. Don't use crushed calcite limestone because it contains fine dust which clogs the soil. Also if the effluent is slightly acid, the limestone may dissolve, clogging the soil. Crushed dolomite limestone may be used if crushed to the proper size and then screened and washed.

Rigid plastic pipe, 4 inches in diameter and having perforation holes at least ½ inch in diameter and with at least 1,200 pounds per lineal foot of crushing strength is commonly used for distribution pipe in the trench. (Do not use plastic drain tubing constructed for agricultural drainage because the small holes will clog with sewage.) Corrugated plastic pipe may be used, but the perforation hole size must be at least ½ inch in diameter. Lay the pipe with one row of holes located at the bottom.

Agricultural drain tile in 1-foot lengths may be used if it is of suitable quality. Standard quality clay tile is suitable, but concrete tile must be of "special quality" or it will break down and need to be replaced in as little as 5 years. Space the agricultural tile ¼ inch apart, and cover the upper half of the joints with tar paper to keep soil from filtering into the tile.

Other devices may be used to distribute sewage tank effluent over the soil treatment area upon approval of the local zoning administrator. However, no reduction in treatment area can be allowed. The values in table 4 must be used to size the soil treatment unit.

While no slope is required on the distribution pipe, a grade of 1 to 2 inches per 100 feet is recommended to assure that the pipe slopes down from the drop box or distribution box. The maximum slope for the distribution pipe is 4 inches per 100 feet. Several methods can be used to maintain a uniform slope on the distribution pipe. For agricultural drain tile in 1-foot lengths, a 1-inch × 4-inch board staked on grade is recommended. Rock is placed into the trench up to the top of the grade board. The tile are placed on the board, and rock is placed around the sides and over the top of the tile. The grade board remains in the trench after the placement of the trench rock.

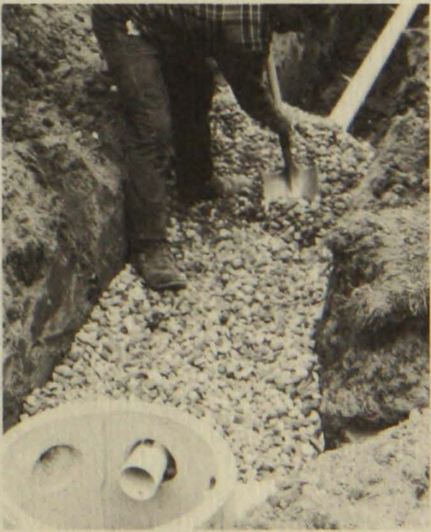
For rigid perforated plastic pipe, saddles are often used to establish a uniform grade. The saddles are fastened to 1-inch square wooden stakes which are pounded into the bottom of the trench every 5 feet. The distribution pipe is strapped in the pipe saddle, and the rock is placed into the trench to a depth of 2 inches over the

Pipe saddles installed in a drainfield trench hold the distribution pipe on a uniform grade. A tripod level is used to set grade for the trench distribution pipe which will connect to the drop box in the foreground.

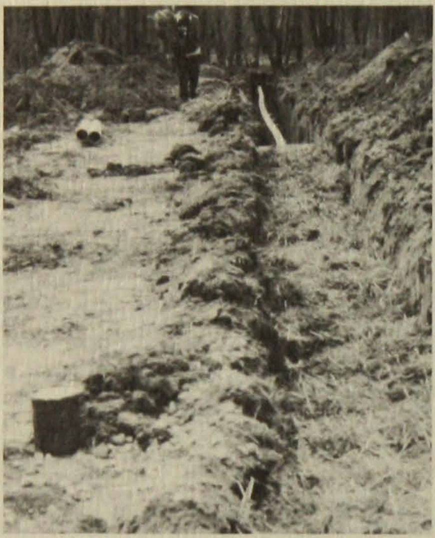
top of the pipe. Pipe grade is established before rock placement, and the rock is placed in one operation, saving considerable labor.

For corrugated plastic pipe with ½-inch or larger holes (not plastic agricultural drain tubing) several techniques may be used. Because the corrugated pipe is flexible, special techniques are required to hold a uniform grade. A grade board may be used together with large staplelike holders to keep the pipe on grade until the rock is placed. The large staple holders are removed after the rock is placed over the pipe, but the grade board remains in the trench.

Another technique used to keep corrugated plastic pipe on grade is a temporary grade board inside the pipe. A 2 by 4 at least 12 feet long, necessary for 10-foot pipe lengths, can be inserted into the pipe for rigid-



Clean rock is carefully placed in the drainfield trench around the supported pipe.



Hay or straw cover prevents soil backfill from filtering down into the trench rock.

ity during installation. The 2 by 4 is slid through the pipe, holding a 10-foot length rigid while rock is placed around it.

Many installers simply place rock into the trench to the elevation of the pipe bottom. The rock must be shoveled level to establish the grade for the pipe. Then, more rock must be carefully placed over the pipe. With this method, no additional construction materials are needed, but considerable time and care is required to install the pipe on a uniform grade.

Regardless of which method is used to install the distribution pipe on a uniform grade, the care and precision used by the contractor is most important. A tripod level or transit must be used to establish the grade of the trench bottom and the grade of the distribution pipe. Hand levels or carpenter levels are not adequate to establish grades in a drainfield trench. The tripod surveying instrument can also be used to accurately and quickly establish elevations and grades for the other components of the sewage treatment system.

The contractor should avoid as much foot traffic as possible in the bottom of the trench. Natural or undisturbed soil allows the sewage tank effluent to most easily percolate into the soil. Smeared or compacted soil will accept sewage only at a reduced and perhaps inadequate rate.

Cover the top of the distribution pipe with at least 2 inches of the clean rock. Over the top of the rock place a 4- to 6-inch layer of marsh hay or straw, and then a layer of untreated building paper, or newspapers, or other permeable material. This covering helps prevent the rock from becoming clogged by the soil backfill.

Don't use an impervious cover, such as tar paper, plastic, cement bags, fertilizer bags, or similar materials over the rock. This will interfere with upward movement of water vapor. Transpiration and evaporation are important for year-round operation of a drainfield trench system.

However, total evapotranspiration sewage treatment systems cannot be designed for Minnesota's climate. During winter, radiant energy is insufficient to evaporate sewage tank effluent fast enough to be of value to sewage treatment. Snow cover also retards evaporation from the soil surface.

But during summer, evapotranspiration can utilize a significant amount of effluent. With a properly designed soil treatment unit using drop box distribution, a portion of the trench bottom area will dry out as evapotranspiration contributes to the treatment and disposal of the effluent. During winter, the entire bottom area of the soil treatment unit will be available to treat and dispose of the sewage.

Place 6 to 12 inches of soil backfill over the top of the trench rock (34 inches is the maximum cover permitted). Select a backfill of the same texture as the topsoil in the trench area. Crown the backfill 4 to 6 inches above finished grade to allow for settling. Sandy soil is not suitable backfill where the topsoil is clay because the trenches will collect and be overloaded with surface water. Rainfall will run off the clay soil between the trenches and will rapidly percolate down through the sand backfill into the trenches.

Install an inspection well at the end of each drainfield trench. The inspection well can be a section of 4-inch perforated pipe extending to the bottom of the rock and with a cap at the ground surface (figure 3). This pipe will allow inspection of the far end of the trench to determine if effluent is reaching that point and also to determine how high the effluent is in the trench rock.

Establish a grass cover over the soil treatment area as soon as possible. Protect the soil treatment area from runoff water from paved driveways, eaves, and similar areas. This extra surface water will overload the soil.

Distribution of effluent

When the total length of drainfield trench has been determined, the choice of trench layout and distribution of effluent depends upon topography. The three options available to distribute effluent to the drainfield trenches are drop boxes, a distribution box, or the closed or continuous system.

The most desirable method to distribute effluent to the drainfield trenches is with drop boxes. While the distribution box and the continuous system are allowable under certain conditions, they are not preferred methods. Use drop boxes whenever possible.

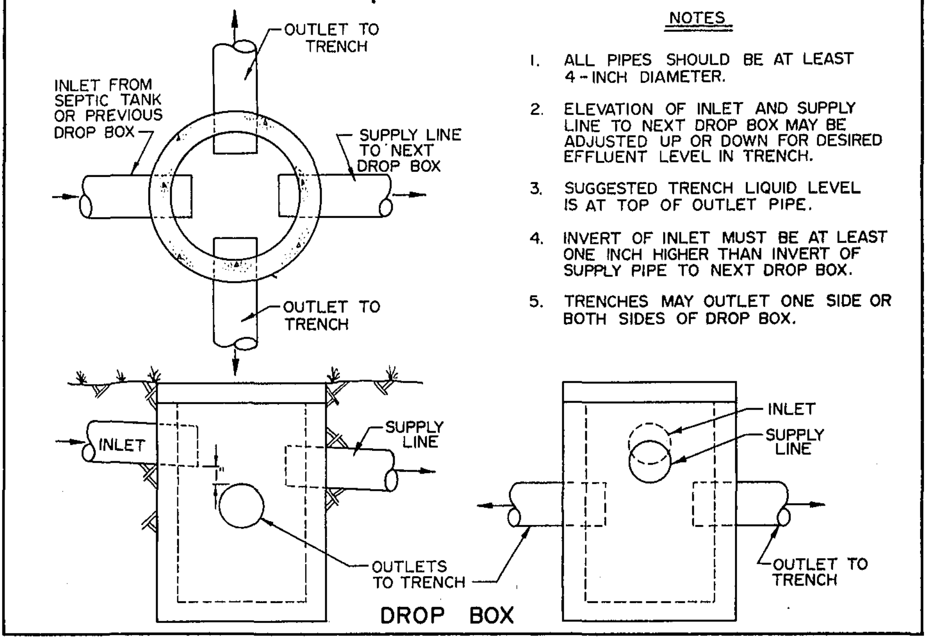
There are many advantages to the drop box distribution of effluent. Drop boxes can be installed on any topography. Installation is simple and the trench system can conveniently be added to at a later date should water use increase. Only that portion of the soil treatment unit required to treat the effluent is actually used. The drop box system can be managed by the homeowner who wants to periodically rest part of the system. The drop box provides a convenient access point to evaluate the performance of the soil-treatment unit. These advantages make drop boxes the preferred method of effluent distribution in a drainfield trench system.

Drop boxes: A drop box is usually constructed of concrete, 12 to 18 inches in diameter or square and about 18 inches deep. A drop box must be installed at the head end of each trench.

Effluent flows through a watertight pipe (outlet sewer) 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 next drop box. The inlet pipe to the drop box should be 1 inch higher than the outlet pipe leading to the next drop box. A detailed view of the drop box is shown in figure 4.

The liquid level in the trenches is established by the elevation of the supply pipe leading to the next drop box. If the elevation of the bottom of the supply line pipe is approximately at the top of the rock in the trench, this liquid level will utilize the entire trench sidewall, will develop the maximum hydraulic head on the bottom of the trench, and will provide a supply of liquid to the capillary tubes

Figure 4. Dimensional requirements and installation recommendations for drop boxes



of the soil, maximizing evaporation and use by plants.

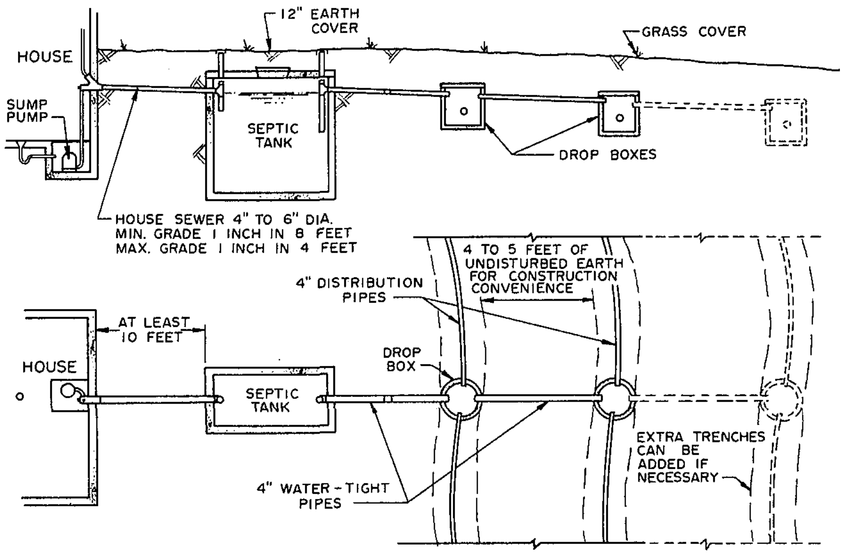
When the first trench is treating effluent at maximum capacity, any additional effluent will flow to the drop box of the second trench. Only that portion of the soil treatment unit required to treat the effluent is used. The rate at which sewage is generated and the rate at which the soil will absorb the effluent will vary throughout the year. Guests or a change in the number of people in a family will affect the amount of 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 treat effluent. Less trench bottom area will be required during summer when evapotranspiration is high 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.

The drop box system can be managed by the homeowner. The first trench would not be rested in the normal operation of the system. However, the first trench can easily be rested by plugging the outlet. Then, the effluent will flow through the first drop box and into the second drop box.

No surface seepage will occur with a drop box system unless the total sewage treatment system is used at greater than its design capacity. And then, seepage will occur only at the lowest trench. If this happens, the amount of drainfield trench will need to be increased.

Additional trenches can be easily added to a drop box system if increased daily sewage flow requires them. As shown in figure 5, a watertight pipe is connected to the last

Figure 5. Sewage treatment system using drop box distribution of effluent



drop box of the existing system, and additional drop boxes and trenches can be added without disturbing the existing treatment system.

The drop box provides a convenient point to inspect the soil treatment unit. The drop box cover can be installed at the ground surface or covered with 4 to 6 inches of soil to prevent unauthorized entry. Opening the drop boxes will show how much of the drainfield trench system is being used. Installation of inspection wells at the end of each trench (figure 3) is another convenient and inexpensive way to inspect the operation of the soil treatment unit.

Installation of the drop box is simple and does not require great precision. If two trenches are supplied from one drop box, the outlets should be approximately at the same elevation.

The drop box method of effluent distribution can be used on any topography from level to the maximum slope on which construction equipment can operate. An elevation difference of 2 inches between successive trenches is all that is needed for the installation of drop boxes. One inch is for the elevation difference between the inlet pipe and the supply pipe to the next drop box and 1 inch is for the slope of the pipe to the next drop box.

Distribution box: A distribution box is a round or rectangular watertight box constructed of durable materials not subject to corrosion or decay and having one inlet from the septic tank and an outlet to each trench of the soil treatment unit. The inlet invert should be 1 inch higher than the outlet inverts, which must all be at exactly the same elevation and at least 4 inches above the bottom of the box.

The distribution box must have a removable cover. Each outlet should have at least 8 inches of sidewall space, and the edge of any outlet should be at least 6 inches from any corner. The box can be rectangular or round. The bottom of the box must be watertight.

Extreme care is required to install a distribution box. The box must be carefully placed on a firm foundation so it will not settle during or after backfilling. To ensure that all outlet pipes are at the same elevation, water is poured in the bottom of the box and the invert of each outlet pipe is located by measuring from the liquid surface. Each drainfield trench must be connected separately and directly to the distribution box.

As shown in figure 6, distribution boxes can be used only when the elevation of the final ground surface at the lowest trench is at least 1 foot higher in elevation than are the distribution box outlets. If the outlet to the lowest trench is lower than the other outlets of the box, it will draw the most effluent. Unless the lowest trench is at a high enough elevation to back up the effluent to the distribution box, surface seepage may occur. Surface seepage, in this case, does not mean the entire trench system is being used to capacity. Sewage surfacing on slopes is most often because of improperly installed distribution box systems.

Closed or continuous system: The closed or continuous trench system (figure 7) can be used on level or nearly level ground. Effluent can flow to any point by at least three paths. The bottom of the excavation for the trenches must be level throughout the system.

Since the maximum soil cover is 34 inches and the minimum cover is 6 inches above the trench rock, the allowable ground slope in any direction over the drainfield trench area is 28 inches.

A distribution box, a tee, or a cross may be used at the beginning of the closed system. An inspection well should be installed so the performance of the system can be evaluated. It is difficult to add trenches to a closed system.

Seepage beds

A seepage bed is a soil treatment system having a bottom area wider than 36 inches (figure 8). Drainfield

Figure 6. Sewage treatment system using distribution box to distribute effluent

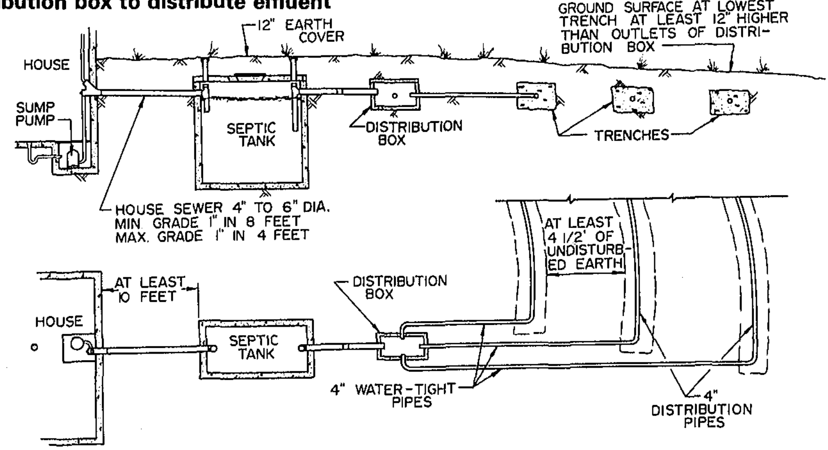
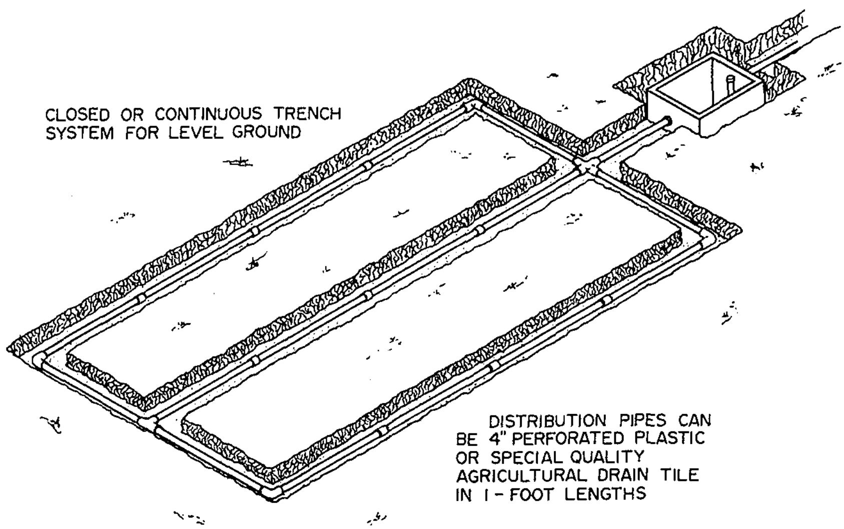


Figure 7. Closed or continuous trench system for level ground



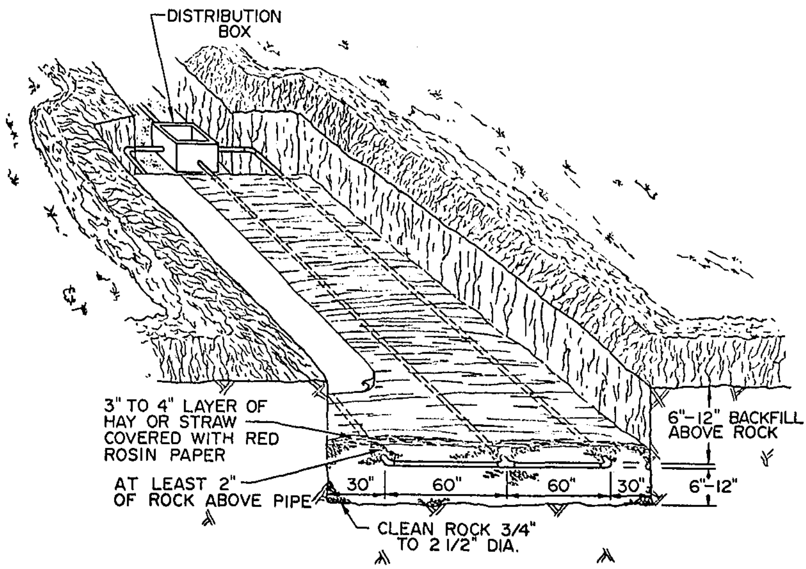


Figure 8. Seepage bed for level ground and limited lawn area

trenches are the preferred soil treatment unit and should be used whenever adequate lawn area is available. This is because trenches have more sidewall area than does a bed having the same bottom area.

If the area of suitable soil is limited, install more rock below the distribution pipe and decrease the amount of undisturbed earth between trenches rather than install a seepage bed.

The location of the seepage bed is limited to relatively flat areas. Never locate a seepage bed where the natural ground slope is greater than 6 percent. The excavation gets too deep on the upslope side, resulting in poorer sewage treatment and less chance for summer evapotranspiration. On the downslope side, the bed may be too shallow, resulting in surface seepage as the effluent level rises in the bed. Seepage beds require an area of original soil that slopes no more than 28 inches, the difference between the maximum and minimum soil cover.

Construction of a seepage bed is much the same as for a drainfield trench. The maximum length of a bed is 100 feet. The bottom of the bed must be level in all directions.

When the percolation rate of the soil at the bottom of the bed is slower than 15 MPI, excavation must not be made with a front end bucket or bulldozer blade. No equipment wheels or tracks can be allowed on the bottom of the bed. Excavation for the bed must be by back hoe or other construction equipment that does not require wheels or tracks on the bottom of the bed.

The bottom of the bed must be in a natural soil condition and should not be walked or driven on before the rock is placed. Place at least 6 inches of rock in the bottom of the bed. The required bottom area of the bed is presented in table 4. No reduction in bottom area can be made if more than 6 inches of rock is placed below the distribution pipe. This is because the bed has relatively little sidewall area compared to trenches.

Distribution pipes should be placed on the rock and spaced no more than 60 inches apart and no more than 30 inches from the sides of the bed. Distribution pipes can be connected to a distribution box, a tee, or a cross at the head end of the seepage bed. The distribution pipes should be connected together at the far end of the bed as shown in figure 8.

Rock should be added to cover the distribution pipe to a depth of at least 2 inches. The rock should then be covered with a 4- to 6-inch layer of marsh hay or straw, and then a layer of untreated building paper (red rosin), or newspaper, or other permeable material to prevent soil backfill from filtering down into the rock and clogging it.

The seepage bed should be backfilled with at least 6 inches, but not more than 34 inches, of excavated topsoil. The backfill should be slightly crowned to allow for settling and to promote runoff from the bed area. The backfill should not be mechanically compacted to a density greater than the original soil.

Never locate a bed where excess surface runoff can flow across the bed. This extra water will overload the soil, and the bed will not accept sewage. Establish a grass cover as soon as possible to prevent erosion and to promote evapotranspiration during the summer.

Seepage pits

Seepage pits are called dry wells and are often incorrectly called cesspools. They are the least desirable soil treatment system. They must not be used:

- where the soil is suitable for drainfield trenches or seepage beds;
- where domestic water supplies are obtained from wells shallower than 50 feet;
- where limestone or other faulty rock is closer than 50 feet to the ground surface;
- in any soil where the percolation rate of any layer that will contact the pit sidewall is faster than 0.1 minute per inch; and
- in soils where the percolation rate is slower than 30 minutes per inch.

Location

Locate the seepage pit as far as possible from water supply wells. The type of subsurface soil formations is more important to protect a water supply than is the separation distance. For example, a layer of coarse sand and gravel with a percolation rate faster than 0.1 minute per inch may transmit contamination much farther than the recommended minimum separation distances.

If your water supply well (or your neighbor's) is less than 50 feet deep and does not penetrate an impervious layer at least 10 feet thick, the seepage pit should be located at least 150 feet away. For all other water supply wells or buried water suction pipes, the minimum separation distance is 75 feet.

A seepage pit should be located no closer than 20 feet to buildings or 10 feet to property lines. When two or more seepage pits are installed, they should be separated edge to edge a distance of three times the diameter of the largest pit.

Site evaluation

The site and soils must be carefully evaluated before construction begins. Geologic information should be used to determine if limestone or similarly faulty bedrock occurs at depths less than 50 feet from the ground surface. If so, seepage pits cannot be used because they will likely contaminate underground waters.

The maximum excavation depth for a seepage pit is 10 feet below the ground surface. Thus, the soil borings required to evaluate the soil profile should extend to at least a 13-foot depth. The bottom of the seepage pit must be at least 3 feet above the highest known level of the ground water table or other barrier layer, such as clay or nonfractured bedrock.

If any layer of soil is encountered which has a percolation rate faster than 0.1 minute per inch, a seepage pit cannot be used. This coarse soil will not adequately treat the sewage effluent, and underground waters may be contaminated.

Perform percolation tests at the depth of each layer of different soil texture along the sidewall of the proposed pit. Compute a weighted average of the suitable percolation rates. Do not include the depth of any soil layers where the percolation rate is slower than 30 MPI.

As an example, calculate the weighted average percolation rate from this data:

0 — 1 foot	Loam top soil
1 — 3 feet	Sandy loam, percolation rate = 8 MPI
3 — 6 feet	Loam, percolation rate = 25 MPI

6 — 8 feet Silty clay, percolation rate = 55 MPI

8 — 10 feet Loam, percolation rate = 28 MPI

Soil borings to a depth of 14 feet show no evidence of water table or other barrier layer. The inlet to the seepage pit will be 2 feet below ground surface.

Compute the weighted average percolation rate:

Depth of soil below ground surface, in feet	Thickness of soil layer in feet		Percolation rate		Weighted value
2 to 3	1	×	8 MPI	=	8
3 to 6	3	×	25 MPI	=	75
6 to 8 (Do not include because percolation rate is slower than 30 MPI)	0				0
8 to 10	2	×	28 MPI	=	56
Totals	6 feet				139

Weighted average $= \frac{139}{6} = 23$ MPI

The value of 23 MPI should be used for design purposes, and the sidewall depth is 6 feet. Note that this soil is suitable for trenches and that they are the preferable soil treatment unit.

Design

Use the areas presented in table 4 (page 22) to determine the required sidewall area. The above weighted percolation rate of 23 falls into the 16 to 30 MPI range. The amount of sidewall area required per bedroom is 250 square feet. For a three-bedroom house, the total required sidewall area is 750 square feet.

The total depth of sidewall depends on the excavation diameter. If the outside diameter of the pit wall is 6 feet and 12 inches of rock is placed outside the wall, the excavation diameter will be 8 feet. For a diameter of 8 feet, there will be 25.1 square feet (8 × 3.14) of wall area per foot of depth. This value can also be obtained from table 5.

The total depth of sidewall required is 30 feet (750 ÷ 25.1). Because each seepage pit has 6 feet of usable sidewall depth, a total of 5 pits will be required to provide the necessary 750 square feet of sidewall area.

The seepage pits should be separated a distance of 3 times the diameter edge to edge. Thus, they should be at least 3 times 8 or 24 feet apart edge to edge or 32 feet on centers. If the pits are connected in series and spaced 32 feet on centers, an area of 16 ft. wide × 144 ft. long = 2,304 sq. ft. of lawn area will be required.

For the same soil conditions, 190 lineal feet of 3-foot-wide trench would treat the sewage more effectively and require only 1,425 square feet of lawn area with the trenches spaced 7.5 feet on centers.

Construction

When two or more seepage pits are needed, you may use a distribution box if the inlet inverts of the pits are

Table 5. Vertical wall areas of round seepage pits in square feet

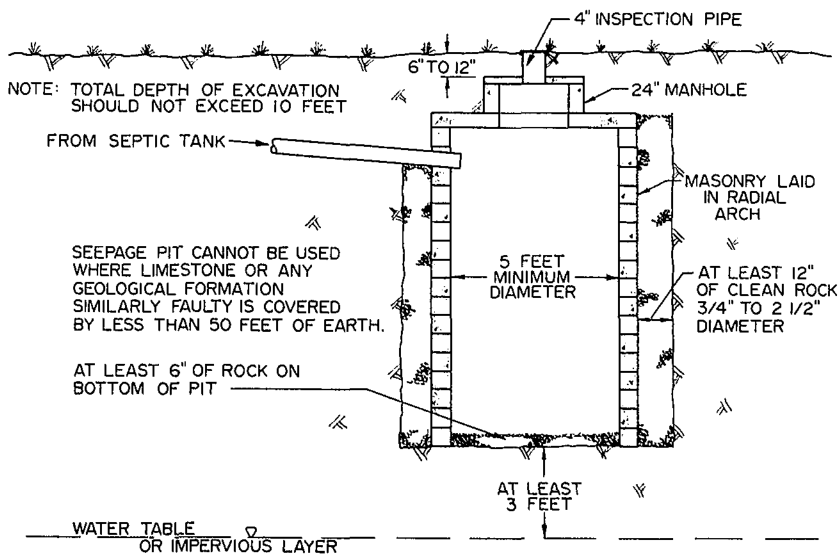
Diameter[a] of seepage pit in feet	Effective strata depth below inlet in feet									
	1	2	3	4	5	6	7	8	9	10
4	12.6	25	38	50	63	75	88	101	113	126
5	15.7	31	47	63	79	94	110	126	141	157
6	18.8	38	57	75	94	113	132	151	170	188
7	22.0	44	66	88	110	132	154	176	198	220
8	25.1	50	75	101	126	152	176	201	226	251
9	28.3	57	85	113	141	170	198	226	254	283
10	31.4	63	94	126	157	188	220	251	283	314
11	34.6	69	104	138	173	207	242	276	311	346
12	37.7	75	113	151	188	226	264	302	339	377

[a]Diameter of excavated soil in contact with rock.

within 1 foot of the same elevation. When the elevation difference of the inlet inverts of the pits is more than 1 foot, connect the pits in series.

Construct the seepage pit as shown in figure 9. The inside diameter of the pit wall should be at least 5 feet. The pit wall should be precast concrete or bricks, stones, or blocks at least 4 inches thick and laid in a radial arch to support the pit walls. The pit should have openings below the inlet to provide adequate passage of liquids, but should be watertight above the inlet.

Figure 9. Seepage pit construction and location requirements



Place at least 12 inches of clean rock ¾ inch to 2½ inches in diameter between the outside of the pit wall and the excavated soil. Place 6 inches of rock in the bottom of the pit to prevent removing the bottom soil if the pit is pumped.

The top of the seepage pit must be within 12 inches of the ground surface and strong enough to support the earth cover and any other reasonable surface load. Provide access to the pit by either an inspection hole or a manhole. If a manhole is used, place it where at least 6 inches, but not more than 12 inches, of soil can be put on the cover. Don't extend the manhole to the surface, because children and others could fall into the pit.

If an inspection pipe is used for access to the pit, it should be at least 4 inches in diameter, and the top should be flush with the final ground surface. Cover the top of the inspection pipe with a corrosion-proof and easily removable watertight cap.

Problem soil conditions

The most suitable soils for treating sewage tank effluent are those with percolation rates ranging between 5 and 60 MPI and located where the water table or other barrier layer is at least 3 feet below the bottom of the soil treatment unit. Problem soil conditions include extremely fast percolation rates, extremely slow percolation rates, water table proximity, and bedrock proximity.

Sewage can be adequately treated and disposed of even though you have problem soils, but properly designed and carefully installed systems are required. When soils have extremely fast percolation rates, fill soil having a slower percolation rate can be placed in contact with the trench rock. When soils have extremely slow percolation rates, fill soil can be used between the rock and original soil, or trenches can be installed on the original ground surface with soil backfill over the trench area.

When the water table or bedrock is too close to the existing ground surface, fill soil can provide adequate separation distance before the soil treatment system is built. The fill soil must have the proper texture to treat the sewage effluent. Usually a sandy loam to loam texture is most suitable.

Percolation rates faster than 0.1 MPI: Sewage effluent should never be placed directly in contact with soils having little or no fine material to filter bacteria and fine sewage solids. Thus, trench rock should never be placed in contact with such soils. You can place a 6-inch layer of soil having a percolation rate between 6 to 15 MPI between the rock and the existing soil, or you can construct a mound and use the natural top soil to filter the sewage effluent. Details on proper mound construction are presented on page 42.

Percolation rates between 0.1 and 5 MPI: Soils in this percolation rate range can have a standard soil treatment system installed in them. However, the soil treatment system can treat the sewage effluent more effectively if special considerations are taken in the layout of the trench system or in the distribution of effluent.

As the sewage effluent moves into the soil from the trench rock, a black layer begins to form. This layer, called the biomass, is an effective bacteria filter. However until the biomass forms, bacteria will move through the soil.

Three techniques can be used to make soils having percolation rates between 0.1 and 5 MPI more effective in treating sewage. They are: dividing the total soil treatment area into smaller parts; using pressure distribution over the entire area; and adding a layer of finer soil between the trench rock and the original soil.

The first method is the simplest and can be done at little or no extra cost. Divide the total treatment area into at least four equal parts connected serially. The first part will receive all of the sewage effluent; as the biomass forms, it will become an effective filter. As the biomass slows down the flow of sewage into the soil of this first part, some sewage will flow into the second part. But the first part will continue to effectively filter sewage at its maximum capacity.

As an example, a three-bedroom house would require 100 lineal feet of 3-foot wide trench with 12 inches of rock below the distribution pipe. Divide the 100 lineal feet into four 25-foot lengths with each connected to a drop box. This layout will more effectively treat sewage than would two 50-foot trenches or one 100-foot trench.

The second method uses small-diameter perforated plastic pipe to distribute effluent evenly over the entire soil treatment area. Use 100 square feet of trench bottom per bedroom to size the soil treatment system. Divide the total treatment area of 300 square feet into two 50-foot trenches, each 3 feet wide. The bottom of both trenches should be at the same elevation. Place 12 inches of trench rock in the bottom of the trench. On top of the rock, lay 1¼-inch diameter plastic pipe with perforation holes drilled every 36 inches. Perforation diameters should be no smaller than 3/16 inch and no larger than ¼ inch. For proper distribution of effluent, the length of the perforated lateral pipes should not be longer than 50 feet. If more area is needed, as for a larger house, add another trench.

Cap the far end of the 1¼-inch laterals and connect the laterals to a 2-inch supply line. Install the lateral pipes level with the perforations downward.

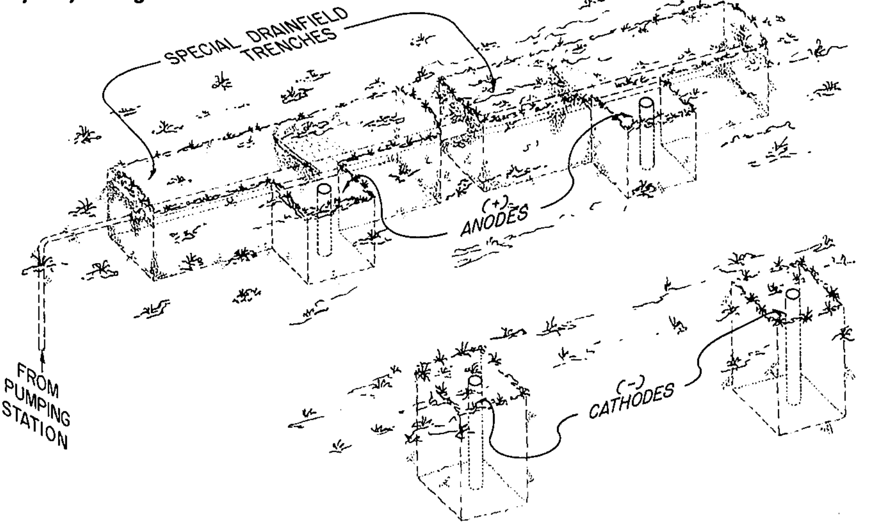
Connect the 2-inch supply pipe to a sump pump installed into a separate tank beyond the septic tank. The tank should be large enough so the pump can deliver at least 75 gallons per cycle. For good sewage treatment the dose should not exceed 25 percent of 1 day's estimated sewage flow.

Pump capacity is extremely important, and depends on amount of trench bottom area and perforation diameter. The pump must deliver at least 7.5 gallons per minute for each 100 square feet of trench bottom area when ¼-inch perforations are drilled in the laterals. Thus, for a three-bedroom type I house the required flow rate is about 22.5 gallons per minute. The pressure head should be at least 5 feet greater than the head required to overcome the pipe friction loss and the elevation difference between the pump and the trenches. Pump capacities for 3/16- and 7/32-inch perforations can be determined by referring to page 48 in the section on mounds.

Cover the 1¼-inch plastic lateral pipes with 2 inches of rock. Cover the rock with 3 to 4 inches of hay or straw and a layer of red rosin paper. Backfill the trench with top soil, and crown it slightly to allow for settling. Establish a grass cover over the trench area as soon as possible.

The entire perforated pipe system will be under pressure when the pump is running, and sewage effluent will be evenly distributed throughout the entire treatment area. The even distribution will allow the soil to effectively filter bacteria and fine sewage solids.

Figure 10. Sewage osmosis system using cathodes and anodes to treat sewage in heavy clay or high water table soils



The third method is the same as described for soils having percolation rates faster than 0.1 MPI. Between the trench rock and the trench bottom and sidewalls place at least 6 inches of sandy loam-textured soil having a percolation rate between 6 and 15 MPI after placement. The soil treatment area should be designed for a percolation rate of 6 to 15 MPI.

Percolation rates slower than 60 MPI: Water moves very slowly through soils having percolation rates slower than 60 MPI. However, if a high seasonal water table is not present, as would be evident by the presence of mottled soil, these soils provide excellent sewage treatment if careful construction practices are followed.

Soils with a percolation rate slower than 60 MPI have a high proportion of silt and clay particles. While the natural soil structure will allow water movement, any compaction, puddling, or smearing of the soil during construction will destroy the natural structure.

Excavation for a sewage treatment system should never be made in any soil having a percolation rate slower than 120 MPI. Excavation of this soil will destroy the natural structure. Do not attempt to excavate for a pit or bed and backfill with other soil. The clay soil structure will have been destroyed and will not absorb water. Construct the soil treatment unit by adding sandy soil fill above the clay soil before placing the trench rock.

Soils having percolation rates between 60 and 120 MPI can be excavated, but only when the soil moisture is less than the plastic limit. The plastic limit is the soil moisture when a small cube of soil taken from the depth of the proposed excavation can be easily rolled into an 1/8-inch thread or wire. When the soil moisture is at the plastic limit or wetter, severe puddling or compaction of the soil structure will occur if the soil is excavated or manipulated in any way.

Only when soil moisture is less than the plastic limit can construction take place. However, do not allow any construction equipment wheels or tracks at the bottom of the excavation. Severe soil structure damage from wheels and tracks can extend much deeper into the soil than the bottom of the track.

Do not place trench rock in contact with soils having percolation rates slower than 60 MPI. Between the rock and the original soil along the trench bottom and sidewalls, place at least 6 inches, but no more than 12 inches, of fill material having a percolation rate no slower than 5 MPI after placement. The fill should be a medium to coarse sand with no more than 10 percent of the particles larger than fine sand (0.05 mm).

Size the soil treatment area based on a percolation rate of 60 MPI. Determine the required area from table 4.

Sewage osmosis: The Sewage Osmosis system can be useful for heavy clay and seasonal high water table soils. This patented system using a set of cathodes and anodes, together with special drainfield trenches, must be installed by licensed dealers. A diagram is shown in figure 10.

The Sewage Osmosis system establishes an electrical potential in the soil without the use of any outside power source and is claimed to help water move through heavy and slowly permeable soils. Check with your zoning administrator to see if your county will allow this system on an experimental basis.

Water table proximity: Where the water table is closer than 3 feet to the ground surface, a standard soil treatment system cannot be installed. There are two solutions. One is to install agricultural drain tile to lower the ground water table and the other is to install a mound.

To lower a high seasonal water table, install agricultural drain tile around the area proposed for the drainfield trenches. On sloping ground, the tile should be installed upslope of the trenches to intercept the soil water as shown in figure 2. Be sure there is at least 10 feet of undisturbed soil between the sidewall of the soil treatment unit and the agricultural drain tile.

Take special care installing drain tile on shorelands of public waters. Drain tile may be used to intercept a seasonal high ground water table only if the water table slopes at least 2 feet per 100 feet toward the surface water. The agricultural drain tile must be installed at least 20 feet upslope of the soil treatment system.

Where the water table cannot be lowered by tiling, a sewage treatment mound can be installed. The procedure for installing a mound is described in detail in the following section. Sufficient soil fill must be hauled to the treatment area so the bottom of the rock layer is at least 3 feet above the water table.

Bedrock proximity: Never place the rock for a soil treatment unit closer than 3 feet to creviced bedrock, such as limestone, or to permeable bedrock, such as sandstone. Where consolidated impermeable bedrock is covered by a soil having a percolation rate slower than 60 MPI the rock layer of the soil treatment unit can be no closer than 7 feet to the bedrock. This depth is needed to allow lateral movement of the water after the solids and bacteria have been filtered out of the effluent.

When adequate natural soil cover does not exist above the bedrock, place fill soil before constructing the soil treatment system. A maximum depth of 24 inches of sand may be used under the trench rock. When you need additional fill to achieve the required separation distance, use a soil which will have a percolation rate between 5 and 45 MPI (textures ranging from loamy sand to silt loam) after 12 months of settlement. Allow the soil fill to settle for 12 months before constructing the soil treatment system. If you can't wait 12 months for the soil to settle, use water settlement or other mechanical methods to settle the soil to within 10 percent of natural density.

After the soil fill has been carefully placed and settled, construction of the soil treatment unit can proceed. The least volume of fill is required for a sewage treatment mound. However, if a large enough area is filled with suitable soil, standard drainfield trenches can be installed.

Sewage treatment mound

A sewage treatment mound is a seepage bed elevated by fill to provide an adequate separation distance between the rock layer in the mound and a barrier layer such as the water table or bedrock. The mound must be carefully constructed to provide adequate sewage treatment. Important factors are location, size and shape, soil surface preparation, construction procedures, distribution of effluent, and dosing quantity. The cross section of a sewage treatment mound is shown in figure 11.

Location and ground slope: Whenever possible, locate the mound on a flat area or the crest of a slope. Such a location will have the least interference from surface water and ground water.

Mounds may be located on slopes up to 12 percent if the natural soil under the mound has a suitable percolation rate. The soil fill under the rock layer of the mound can be as much as 24 inches of sand. The percolation rate of the remainder of the soil depth required for separation from the barrier layer must be fast enough to prevent side seepage. Also, to provide for adequate sewage treatment there must be at least a 12-inch depth of soil under the mound with a percolation rate no faster than 5 minutes per inch.

As the slope gets steeper, the percolation rate of the soil under the mound must be faster to prevent sidehill seepage. To locate a mound on a natural ground slope up to 3 percent, the percolation rate in all layers of natural or fill soil to a depth of at least 24 inches below the sand fill must be faster than 120 MPI.

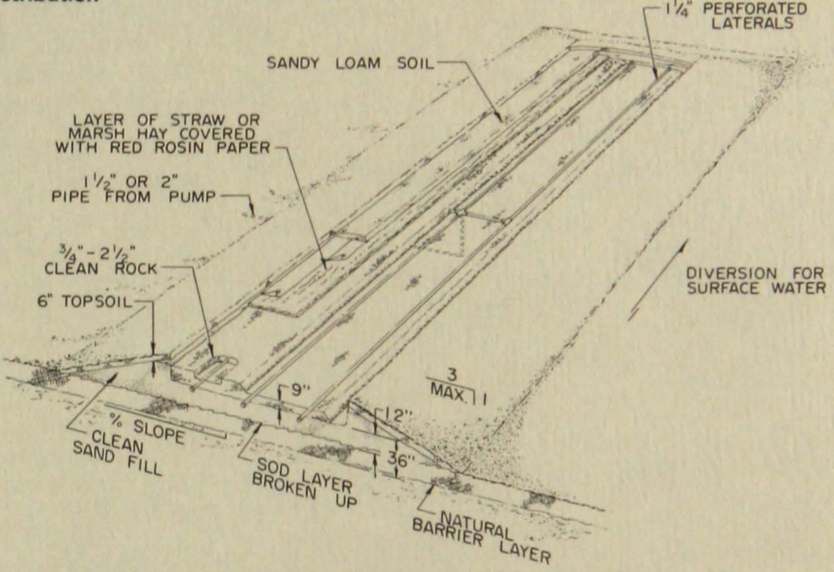
For slopes of 3 to 6 percent the percolation rate in all layers of natural or fill soil to a depth of 24 inches below the sand fill must be faster than 60 MPI. For slopes of 6 to 12 percent the percolation rate must be faster than 30 MPI (but not faster than 5 MPI). Don't locate a mound on natural slopes exceeding 12 percent under any soil conditions. And don't move or grade soil to change the ground slope.

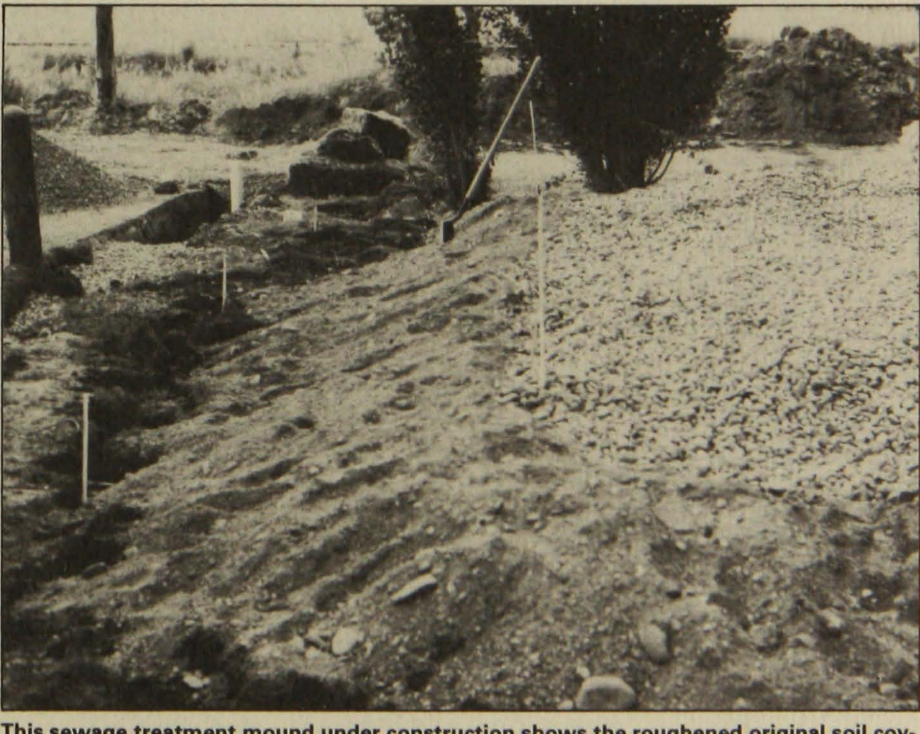
Size and shape: A sewage treatment mound more effectively absorbs water if it is relatively long and narrow. This is particularly true when the soil percolation rate is slower than 60 MPI.

The width of the rock bed in the mound should be no greater than 10 feet. The bottom area of the rock should be based on 125 square feet per bedroom or 0.83 square feet per gallon of waste per day.

Select the size and dimensions of the rock bed or the mound from table 6. Don't make the rock bed any wider than 10 feet.

Figure 11. Construction requirements of a sewage treatment mound utilizing pressure distribution





This sewage treatment mound under construction shows the roughened original soil covered with a 12-inch layer of clean sand. The layer of clean, ¾-inch rock is ready for placement of distribution pipes. Careful construction procedures are essential for successful mound performance.

Table 6. Required area and length of rock bed for sewage treatment mound

Number of bedrooms	Rock bed area required, square feet	Maximum width of rock bed, feet	Length of rock bed, feet
2	250	10	25.0
3	375	10	37.5
4	500	10	50.0
5	625	10	62.5
6	750	10	75.0

Note: Table is based on 0.83 gallons per day per square foot of rock bed area and 150 gallons per day per bedroom.

Figure 12 shows three different shapes for mounds. View A shows a mound constructed on level ground or on a uniform slope. A mound constructed along a contour is shown in view B. Whenever a mound is constructed on a slope, divert any surface water away from the upper side of the dike.

View C shows a mound constructed in the corner of a lot. Sewage treatment mounds can be many shapes and can be part of the landscape architectural plan. Shrubs or trees should not be planted directly above the rock bed, but low-growing shrubs can be planted along the side slope and toe of the dike.

If the shape of the available area won't allow a long, narrow mound, two rock beds can be built side by side if the soil percolation rate is faster than 60 MPI in all layers of natural or fill soil to a depth of at least 24 inches below the sand fill. Separate the two rock beds with at least 4 feet of sand.

The total lawn area required for the mound depends on size and shape of the rock bed, height of the mound, and the side slope of the dike. Don't make the side slopes of the dike any steeper than 3 feet horizontally to 1 foot vertically (3:1). This slope is required to spread out the water, particularly on clay soils. Make the dike side slope 4:1 if you plan to mow the grass cover.

Construction equipment: A rubber-tired tractor can be used to prepare the soil surface, but never use a rubber-tired tractor after the soil surface is prepared. Always use a crawler or track-type tractor for mound construction because the pressure of the equipment on the soil is not as great.

Soil surface preparation: If there is grass where the mound is to be constructed, the sod must be roughened to provide a good bond with the sand fill of the mound. If the sod is not broken up, lateral seepage will occur along the original grass surface.

The grass layer must be broken up without smearing or compacting the soil. One method is to use backhoe teeth to break up the sod and leave the surface rough.

Another method to prepare the soil surface would be to use a moldboard plow or chisel plow. However, plow the soil only when the moisture content at an 8-inch depth is less than the plastic limit. Plow along the slope and turn all the furrows upslope. Don't have a deadfurrow under any part of the mound.

If the top soil is sandy loam to a depth of at least 8 inches, a disk can be used instead of a plow.

Install the 1½- or 2-inch diameter discharge pipe from the pump to the center of the mound area before preparing the surface soil. Backfill the trench carefully, and compact the

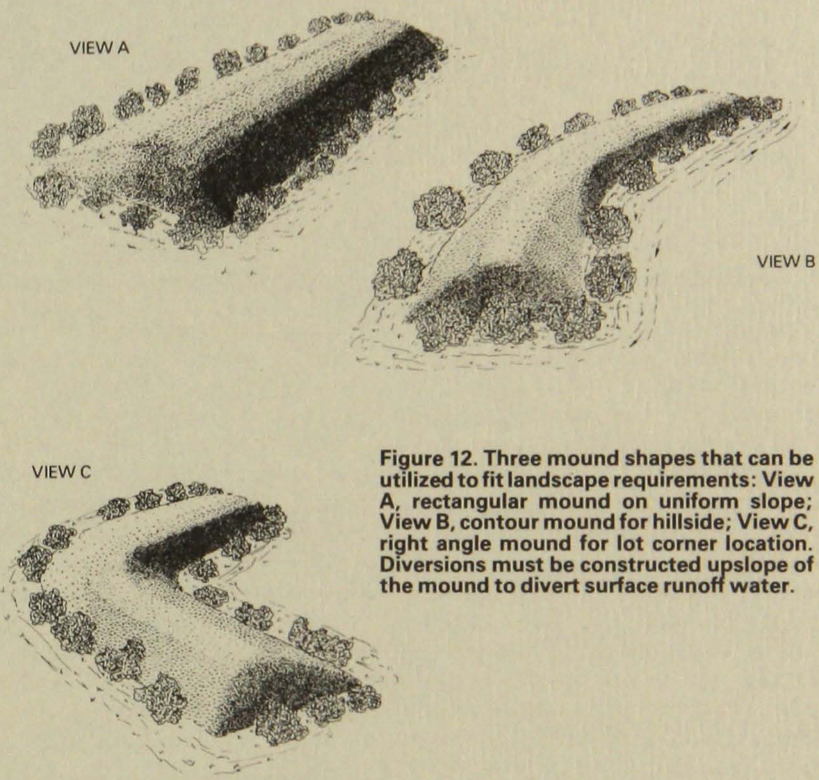
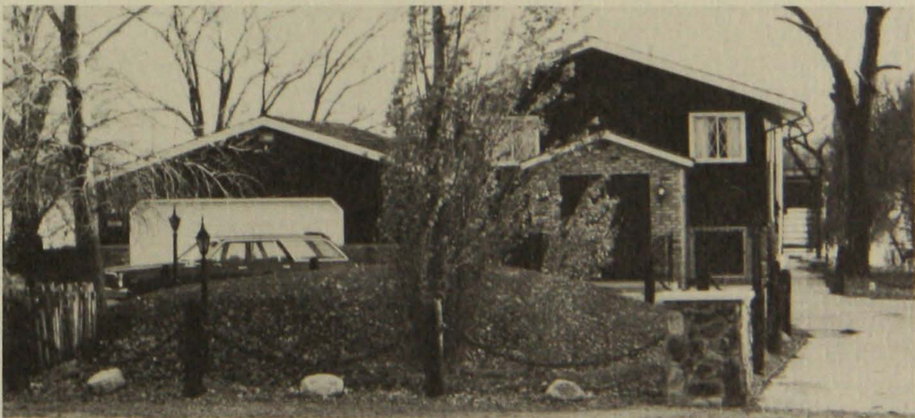


Figure 12. Three mound shapes that can be utilized to fit landscape requirements: View A, rectangular mound on uniform slope; View B, contour mound for hillside; View C, right angle mound for lot corner location. Diversions must be constructed upslope of the mound to divert surface runoff water.



This completed sewage treatment mound might easily be mistaken for a berm commonly used in landscape architecture. The top of the berm is crowned to promote runoff of heavy rains. This berm adds interesting relief to an otherwise flat landscape and serves as a privacy barrier.

soil to prevent effluent seepage along the trench.

Start the mound construction on a day when rain is not likely. Cover the prepared soil surface with sand fill as soon as possible. Make every effort to prevent rain from falling onto the prepared soil surface. A successful mound depends on careful preparation and protection of the soil.

Construction procedure: Place at least 12 inches of clean sand over the mound area, and level it out to the edges of the dike. Use a crawler tractor to push the sand into place. Always keep at least 6 inches of sand under the crawler tracks to prevent compaction of the prepared soil surface. The top of the sand layer must be level.

Clean sand is required to distribute the effluent over the soil surface and to provide initial filtration. Use sand that is composed of at least 25 percent particles ranging in size from 0.25 to 2.0 millimeters (mm), less than 50 percent between 0.05 to 25 mm, and no more than 10 percent of the particles smaller than 0.05 mm.

After the proper depth of sand is placed and leveled, use a front end loader on a track-type tractor to place the rock bed. At least a 9-inch depth of trench rock should be placed for the rock bed. The dimensions of the rock bed should be selected from table 6.

Distribute effluent over the rock bed with perforated plastic pipe under pressure. Perforation size should be no smaller than 3/16 inch, so they will not plug, and no larger than ¼ inch, so friction loss will be kept to a minimum in the lateral pipes. Drill a perforation hole every 36 inches in a straight line along the pipe. Use a sharp drill and try not to leave any burrs inside the pipe.

Use good quality trench distribution pipe. The pipe shown will likely collapse in the trench.

Lay the perforated pipe laterals on the level rock bed with the holes down. Three laterals are required for a 10-foot-wide rock bed. Center one lateral down the length of the bed, and space the other two 40 inches on each side. Cap the far end of the laterals, and connect the head end to a 1½-or 2-inch diameter manifold pipe. All connections must be watertight and able to withstand a pressure head of at least 40 feet.

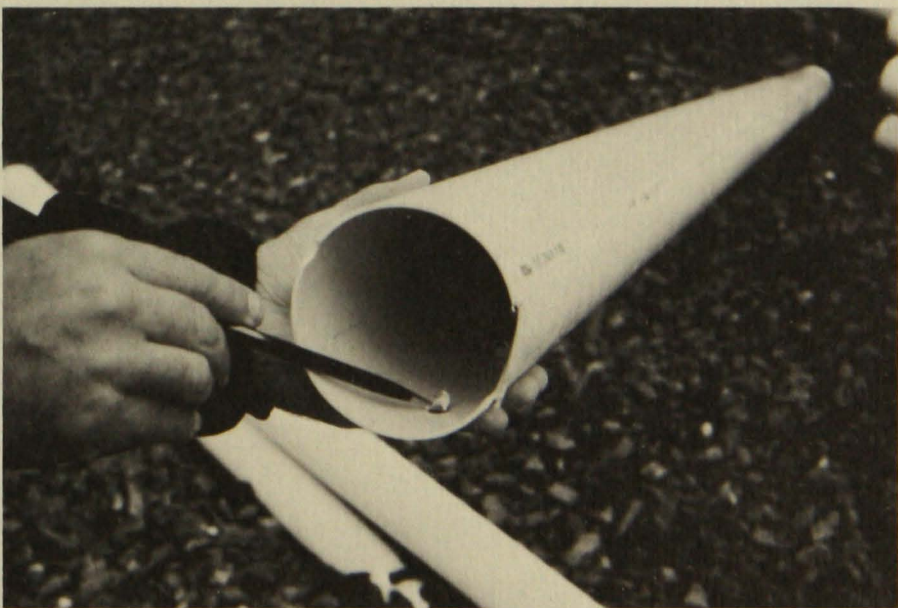
For proper effluent distribution, no perforated lateral should be longer than 50 feet. The 2-inch manifold pipe in the center allows up to a 100-foot-long bed. Do not perforate the manifold pipe, but slope it slightly toward the supply line from the pump.

Place at least 2 inches of rock carefully over the lateral and manifold pipes. Straw or marsh hay to an uncompacted depth of 6 to 8 inches should be placed on top of the rock to prevent the soil backfill from filtering down into the rock. As an extra precaution use a layer of red rosin paper over the marsh hay or straw.

Place sand along the edge of the rock bed up to the level of the top of the rock. Place sandy loam soil on top of the hay and paper above the rock using a lightweight crawler tractor with a dozer blade. Place the sandy loam soil 12 inches deep at the center of the rock bed and 6 inches deep at the sides. If two rock beds are installed side by side, place the sandy loam backfill 18 inches deep at the center of the mound and 6 inches deep at the sides.

The sand fill should extend out from the top of the rock bed on a side slope no steeper than 3:1. Using a

Holes in the distribution pipe must be open and free of burrs which will cause plugging.



lightweight crawler tractor, place 6 inches of topsoil over the entire mound and establish a grass cover as soon as possible.

Dosing quantity and rate: The amount of effluent pumped into the mound each time must be adequate to fill all the lines under pressure and to supply the proper quantity for adequate treatment of the effluent. Thus, for a residence the quantity of effluent delivered each pump cycle should be at least 75 gallons but no more than 25 percent of 1 day's sewage flow. This range of quantities provides for even distribution of effluent and proper treatment by the soil. Larger doses would overload the soil with effluent resulting in less adequate treatment.

The rate of pumping is also important. The pump must supply effluent to all of the perforations in the lateral pipes. To do this requires both pressure and flow rate. The pump must deliver at least 7.5 gallons per minute for each 100 square feet of rock bed area when ¼-inch perforations are used in the laterals. For a three-bedroom type I house, the required flow rate is about 28 gallons per minute. The pressure head should be at least 5 feet greater than the head required to overcome the pipe friction loss and the elevation difference between the pump and the mound. If 7/32-inch perforations are used in the lateral pipes, the pump must deliver at least 6 gallons per minute to each 100 square feet of rock bed area in the mound. For 3/16-inch perforations the minimum required flow rate is 5 gallons per minute for each 100 square feet.

PUMPING STATIONS

Don't hesitate to install a pumping station where required for a shallow soil treatment unit. A pump delivering sewage effluent to a shallow drainfield trench system located in suitable soil will be far more trouble-free than deep trenches or pits using gravity flow. If you follow proven design guidelines, the pump will operate for many years.

A pumping station consists of two parts, a pumping tank and a pump. Never install a pump directly in the septic tank to pump to soil treatment units. The sewage solids will plug either the pump or the soil treatment unit, causing the system to fail. Install a watertight tank for the pump beyond the septic tank. Then the solids will be separated in the septic tank, and the pump will handle only sewage effluent, a relatively clear liquid.

Select a reliable pump dealer and ask for a quality pump. Expect to pay $75 to $125 for a dependable sump pump. The average annual cost of a pump of this quality will be far less than for pumps costing less initially but which need frequent replacement.

The size of the dose or amount of effluent pumped per pump cycle is important for two reasons. First, the dose size may be selected for the soil treatment unit to function properly. As an example, for a mound to treat sewage adequately, the dose size should not exceed 25 percent of 1 day's estimated sewage flow.

Second, a minimum dose size is needed to keep the number of pump cycles per day to a reasonable number. The pump will "wear out" sooner by repeated starting and stopping than by running continuously. Pump experts suggest that the pump should start only 3 or 4 times a day for long pump life. For the average three- or four-bedroom house, this is equivalent to 150 to 200 gallons per pump start or cycle. Never pump less than 75 gallons per cycle.

The amount of effluent pumped per cycle depends on the surface area of the pumping tank and the setting of the pump start and stop controls. A relatively large pumping tank surface area is needed with a small pump out depth.

Pumping tank

The pumping tank must be watertight and constructed of materials that will not corrode or decay. Install a manhole to the ground surface and securely fasten the cover so that unauthorized persons can't get into the pumping tank. The manhole's smallest dimension should be at least 20 inches, preferably 24 inches for easy access. Details on the pumping station are shown in figure 13.

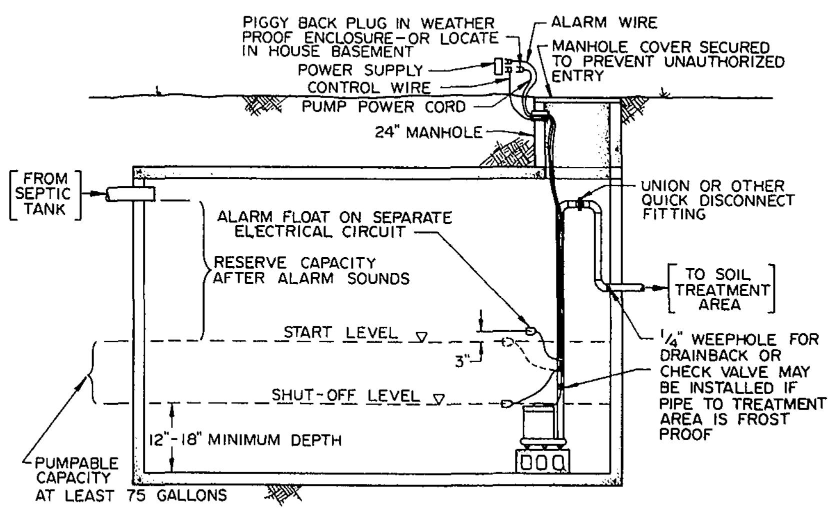
Never go down into the pumping station unless you have an air hose, a rope tied around your chest, and someone on the ground surface strong enough to pull you up. Sewage gases can asphyxiate you, and you may fall into the liquid and drown.

When the pumping tank is installed where the water table is high enough to be alongside the tank, consider the buoyancy problem. Consult with your contractor and be sure the weight of the tank will be adequate to prevent flotation after the pump has run. Otherwise, the contractor must install anchors into the earth to prevent tank flotation.

Flotation usually is not a problem with a concrete tank but it may be with a tank constructed of fiberglass or similar lightweight material. Also, be sure the pumping tank is completely watertight because ground water could flow into the tank, be pumped, and overload the soil treatment unit, causing failure.

The size of the pumping tank depends on the amount of daily sewage flow and the amount of reserve tank capacity in case of pump failure. If the daily sewage flow from a three-

Figure 13. Specifications on a pumping tank and pump for a single family residence



bedroom house is 450 gallons per day and the pump is to start no more than four times, then 112 gallons must be delivered to the soil treatment unit each time the pump runs.

In case the pump should fail to start, have a warning device and some reserve pumping tank capacity so the sewage system can be used on a limited basis until the pump is replaced or repaired. A reasonable reserve capacity is 1 day's estimated sewage flow.

A pump also will not pump a tank completely dry; pump operation requires a minimum liquid depth. In a pump tank with a large surface area do not allow the shut-off level to be lower than the top of the pump since submergence is required for proper cooling of the pump motor. Also, it is good design to set the pump on a concrete block 6 to 8 inches off the tank bottom to provide some additional volume for sludge settlement. The minimum liquid depth in the tank may be 12 to 18 inches which may amount to several hundred gallons in a tank designed to be a 1,000-gallon septic tank.

Thus, the pumping tank capacity for a three-bedroom house may total 700-800 gallons: 100 or more gallons to be pumped, 450 gallons reserve capacity, and 200 gallons remaining in the bottom of the tank.

The shape of the tank depends on the amount to be pumped and the pump-out depth as determined by the pump start and stop controls. The pump-out depth for submersible sump pumps is usually about 8 to 12 inches.

As an example, assume the pump-out depth is 10 inches and the desired pumping quantity is 125 gallons. The required surface area of the pumping tank can be determined from these values. First, convert the quantity of 125 gallons to cubic feet. One cubic foot is equivalent to 7.5 gallons. Thus, 125 gallons are equivalent to 16.7 cubic feet (125 ÷ 7.5).

The pump-out depth of 10 inches is equivalent to $\frac{10}{12}$ or 0.83 of a foot. Thus, to have a tank capacity of 16.7 cubic feet in a 10-inch depth, the surface area must be 20.0 square feet (16.7 ÷ 0.83). This could be rectangular tanks 4 feet wide by 5 feet long inside dimensions or 3 feet wide by 6 feet 8 inches long, etc. The tank could be circular with a 5-foot inside diameter.

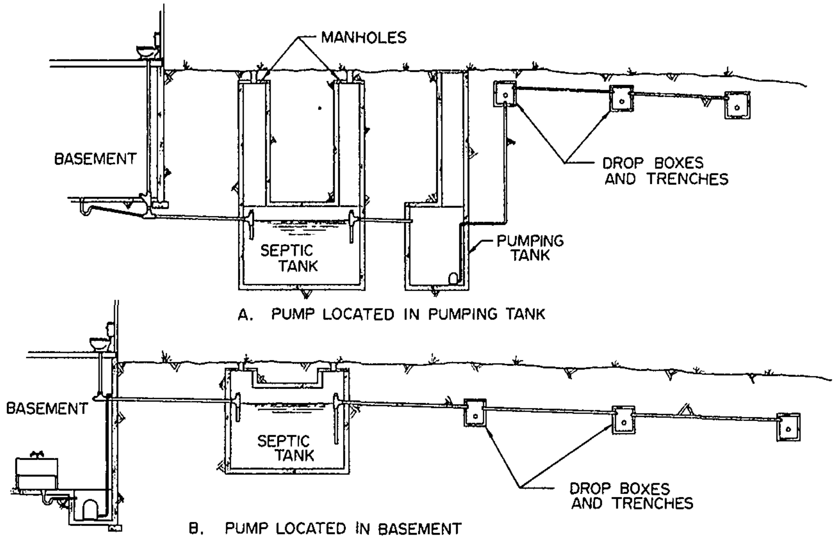
A tank with 20 square feet of surface area contains 150 gallons per foot of depth. If the tank is 5 feet deep below the inlet, it will have a capacity of 750 gallons. This tank will provide an adequate pumping quantity for long pump life and a reasonable reserve capacity when the pump needs maintenance.

Pumps

The pump materials should be durable and corrosion resistant. A cast iron or bronze-fitted pump with stainless steel screws will not be corroded by sewage effluent. Plastic can be a suitable material if the pump is properly designed and constructed. Buy your pump from a reputable local dealer who stocks pumps and is qualified to service them. Usually the smallest size sewage pump available will be more than adequate for a house.

There are a number of pumping situations, and a specific pump is needed for each situation. Whenever possible, pump settled sewage. The most trouble-free pumping situation is to pump the sewage effluent after the solids have been separated in the septic tank. Effluent is essentially

Figure 14. Pump locations: A — in separate pumping tank; B — in house basement



water, except for the corrosive effects. A submersible sump pump is all that is needed to pump sewage effluent. Pumps that will handle sewage solids will also pump effluent. However, these pumps are more expensive, require more maintenance, and are not needed if the sewage doesn't contain large solids.

For easy removal of the pump, use a union or other quick-disconnect coupler as shown in figure 13. The piping extends up to where it can be reached without going down into the tank. A ¼-inch weep hole will provide drainback to prevent freezing of the pipe to the soil treatment unit.

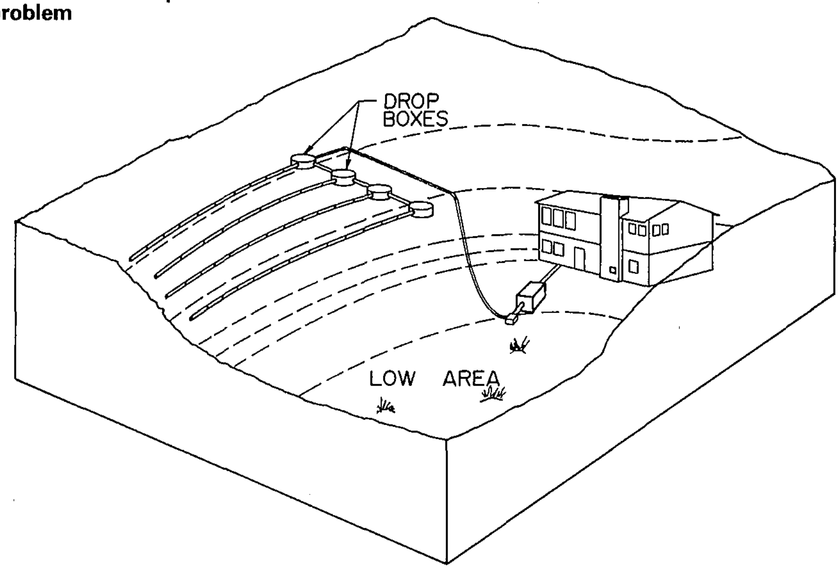
The submersible pump might be installed in a pumping tank beyond the septic tank (figure 14A) or in a small basement sump to lift the sewage from the laundry tubs and floor drain to an elevation where it will flow into the house sewer (figure 14B).

If a flush toilet is located in the basement, a sewage ejector pump will be needed to handle the solids. The sewage ejector pump must be installed in a sealed sump vented into the plumbing stack.

There are advantages to locating the pump in the basement (figure 14B). The pump is readily accessible for service. If the pump fails, most of the plumbing system can still be used (except the basement). The septic tank is shallow and readily accessible for removal of solids and other maintenance or repairs.

If the sewage effluent can flow by gravity from the sewage tank to the soil treatment unit, the sewage treatment system is complete. In some cases, it is necessary to pump the effluent to an elevation higher than the house (figure 15). Pump sewage effluent rather than raw sewage whenever possible. If space is not

Figure 15. Using pumping station and trenches with drop boxes to solve low area problem



available for a septic tank or if it will be inaccessible for service, use a *sewage ejector pump to* deliver all sewage wastes to a septic tank located at an elevation where the effluent can flow by gravity to the soil treatment unit.

If a sewage ejector pump must be used for all the sewage wastes, select a holding tank large enough so the pump does not start and stop more often than the manufacturer recommends.

Unless a specific flow rate is required by the soil treatment unit, as with a mound, the pump should deliver at least 600 gallons per hour, but not more than 2,700 gallons per hour. The minimum rate is so that the pump can keep up with high discharge appliances, such as automatic washers. The limit on the maximum rate is so the sewage effluent will have time to flow out of the drop box, or if raw sewage is pumped to a septic tank, there will not be excessive turbulence caused by the inflow of sewage.

Pump controls

The parts of the pumping station requiring the most maintenance will be the start and stop controls for the pump. Many control devices are available, such as pressure diaphragm switch within the pump case, small float attached to pump, liquid level sensing devices (such as electrodes and mercury floats), and manual float switch.

The most dependable and easily serviced combination is a manually controlled pump connected to a mercury switch control encased in plastic or neoprene. The pump-out depth can be adjusted by changing the length of wire between the float and where the wire is attached to the discharge piping (figure 13). Either the pump or the control can be removed easily for service.

The pressure diaphragm switch must be installed in the pump body at the factory. While these switches are usually vented, moisture accumulation is a problem and often causes failure. The pump-out depth cannot be adjusted conveniently by other than experienced pump service personnel. Repair of this pump control requires removal of the entire pump.

A small float attached to the outside of the pump case activates a switch inside the case. A leak-proof connection must be made through the pump case. Pump-out depth normally is not adjustable and the pump must be removed for service to the control.

When a relay is used to control the pump, the liquid level sensing devices may be either electrodes or mercury switches encased in a plastic float. Electrodes are normally brass or stainless steel shielded by a plastic case. Electrodes fouled by sewage can be cleaned by dipping in a weak acid or toilet bowl cleaner. The mercury switch is totally enclosed in a plastic or neoprene float and is not subject to fouling.

The relay and the liquid level sensing devices, either electrodes or mercury switches, can be serviced without removing the pump. Also, either the start or stop levels can be changed easily by adjusting the electrodes or mercury switches.

Never locate the relay inside the pumping tank or tank manhole. Humidity will soon cause this electromechanical device to corrode and fail. Also, never install an electrical plug-in or socket inside the pumping tank. Locate these devices in an above-ground weatherproof box or in the house basement. Use all watertight or soldered electrical connections within the pumping tank.

The manual float switch control requires the most maintenance and most frequent replacement. A brass or plastic float slides up and down around a metal or plastic rod. This activates a mechanical switch to start and stop the pump. As the liquid level rises, the hollow float slides along the rod to a stop button. The buoyancy of the float raises the rod to activate a lever which activates the pump. As the liquid level drops with the pump running, the float slides down along the rod to another stop button. The weight of the float pulls down on the rod, activating the lever that stops the pump.

The float start and stop depths are adjustable within limits. Scum may build up on the rod, causing the float to stick. The switch is an electromechanical device and must be located in the pumping tank, where it will be subject to the corrosive atmosphere. Frequent maintenance and replacement of the switch will be required.

Install an alarm to warn if the pump does not start. The alarm should be on an electrical circuit separate from the pump circuit (figure 13). A buzzer or an easily visible light is often used for the alarm signal. With a reserve capacity based on 1 day's average sewage flow, you will have time to get the pump serviced. By using water conservatively, the reserve capacity can be adequate for several days.

ALTERNATIVE SYSTEMS

When adequate lot area is available, a soil treatment unit usually can be constructed on the site to adequately treat and dispose of sewage. Unfortunately, many small lots do not have an adequate area to treat and dispose of the sewage. This is particularly true of shoreland property, but small developments with inadequately sized lots also exist in other areas where municipal sewage treatment is not available.

The alternative solutions available for the problems of small lot size are water use reduction and subsequent reduction of soil treatment area, collector systems, and holding tanks. Each of these alternatives can provide adequate sewage treatment and disposal.

However, the alternative solutions of sewage treatment will usually be considerably more expensive than a septic tank with a standard drainfield trench system. A continuing economic penalty will be required when there is inadequate area or unsuitable soil on a lot for the proper treatment of sewage. The original low price paid for the lot will likely be small consolation for the increases in investment and annual costs of an adequate sewage treatment system.

In addition to the increased costs of sewage treatment, a change in lifestyle may also be required. One of the most realistic alternative methods is to reduce the daily sewage flow. But this may necessitate a change in lifestyle or a transfer of costs to another function.

Year-round use of an outdoor privy would reduce water use about 40 percent in the average house, but would be a rather drastic change in lifestyle for most Minnesota residents. Thus, chemical, incinerating or composting toilets would likely be used to reduce the amount of toilet wastes, but at an increased cost.

Laundry might be washed at a laundromat, but the cost would include transportation unless combined with a necessary trip. A wringer-type or suds-saver washer will use less water than an automatic washer, but will require more labor and time.

Other water-saving techniques include using a fine spray shower nozzle with a shut-off valve, eliminating the bathtub, keeping a container of drinking water in the refrigerator rather than allowing a faucet to run a long time to get a cold drink, manually starting the water softener cycle when regeneration is needed, repairing all leaky faucets and valves, and having a general awareness for the need to save water.

Recognize the need to practice water use economy regardless of the type of sewage treatment system. Water is still a relatively inexpensive commodity and is wasted far too often. The unnecessary water flowing into the sewage treatment system will need to be disposed of and may overload the system.

Soil treatment area reduction

As noted earlier, the size of the required soil treatment area depends on the soil and amount of daily sewage flow. If the sewage flow can be substantially reduced, the soil treatment area can be reduced about the same proportion.

However, the amount of sewage discharged to the soil treatment unit must be accurately measured and recorded. The amount of sewage can be measured either by a watermeter installed in the water supply pipe beyond the pressure tank and outdoor sillcocks or, if a sewage pump is used, by a cycle counter installed on the pump.

For installing a reduced area soil treatment unit, table 7 presents the values of estimated sewage flow for type III residences.

Table 7. Estimated values of sewage flow for type III residences with water metering devices

Number of bedrooms	Estimated sewage flow, gallons per day
2 or less	180
3	218
4	256
5*	294

*For more than 5 bedrooms, use the formula $Q = 66 + 38\,(BR + 1)$.

The following values are the average proportions of daily water use: toilet, 40 percent; bath, 30 percent; laundry with automatic washer, 15 percent; kitchen, 10 percent; and miscellaneous, 5 percent. While water saving should be practiced for all uses, the greatest saving in water can be realized by eliminating the flush toilet.

Alternatives to the flush toilet include the outdoor privy, incinerating toilet, chemical toilet, biological decomposition or composting toilet, and low water use toilet. The outdoor privy is the least costly, but also least desirable alternative to a flush toilet for a year-round residence in Minnesota's climate. However, an outdoor toilet can be maintained relatively odor-free and constructed to be usable year round.

Incinerating toilets can also completely eliminate liquid wastes from the toilet and are available both in electric- and gas-fired models. An initial cost from $600 to $1,200 includes electric wiring and a fireproof vent for the waste gases. In addition, the average energy use is 1.5 pounds of gas or 1.0 kilowatt hour for each cycle of the toilet. Energy costs may continue to rise.

A cool-down period is required after each incineration cycle. Therefore, an incinerator toilet is not a particularly desirable device for a large family where demands on the toilet may come in short spans of time. The waste gases have some odor and, under certain atmospheric conditions, may settle to the ground and be objectionable to the occupants or neighbors. The fire pot requires regular cleaning to remove ashes and other residue. The fire pot must be replaced periodically, depending on amount of use.

Chemical toilets are available in many models. 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 the holding chamber. The initial charge of chemical is adequate for from 40 to 160 uses, depending on the model.

When the holding chamber is full, a valve can be opened to discharge the wastes into a septic tank. On some chemical toilets, the holding chamber can be removed for waste disposal. Wastes are reduced to about 2 percent of those from a conventional flush toilet.

The initial cost of chemical toilets varies greatly, but will range from $100 to $600 plus installation. The cost of the chemical is about 1½ to 2 cents per toilet use. Because most chemical toilets are plastic, they should not corrode. Maintenance should be minor.

Some toilets use biological decomposition with enzyme additives to break down the wastes. A small amount of liquid, depending on the number of uses, is drawn off each week. This liquid contains disease-causing bacteria and nutrients, so it must be disposed of in a safe and sanitary manner.

The cost of biological toilets ranges from $300 to $500, not including installation. Maintenance and replacement of a biological toilet will vary with the model and should be discussed carefully with the dealer.

Composting toilets are also available in models costing from $650 to $1,600, plus installation. In some models, organic wastes from the kitchen can also be composted. Some models require a ventilation fan to minimize odors, while others also need electricity for heat to aid the composting process. Electric energy use may average 100 kilowatt hours per month. At 4 cents per kilowatt hour, this is an additional $4 per month. Obtain accurate cost estimates from the supplier on costs of energy consumption, installation, maintenance, and replacement.

Low water use toilets may be another convenient means to reduce water use. An average toilet uses from 4 to 6 gallons per flush. The design of the toilet bowl requires this amount of water to remove the solid wastes. The amount of water in the toilet tank can be decreased simply by adjusting or bending the float arm. However, the reduced amount of water may not remove all the solids with a single flush. If two flushes are needed, more water may be used than before the adjustment.

Water-using toilets are available with a sliding gate at the bottom rather than a trap. The sliding gate toilet uses as little as ½ pint of water per use. However, it requires more frequent cleaning than a regular flush toilet. The plumbing should have other water-using appliances upstream on the sewer line so the wastes will be transported to the septic tank. Otherwise, sewer line plugging may occur.

Other low water use toilets are available from various suppliers. The cost is slightly higher than for a conventional flush toilet.

Other water saving practices should be followed. A shower can be taken with 3 gallons of water if a fine spray is used and the water is shut off at the showerhead while lathering. A wringer or sudsaver washer with a wash day once or twice a week will save 50 to 75 percent of the water required by daily use of an automatic sequence washer.

Water from humidifiers or dehumidifiers should not be discharged into the sewage system. Some humidifiers that attach directly to the heating system use a flow of water to clean the evaporating pads. This extra water can overload an undersized sewage treatment system.

The soil treatment area can be reduced if the water used is reduced and a water-measuring monitor is installed to measure the amount of sewage wastes. Table 8 presents the

Table 8. Soil treatment areas required for type III residences when water use is reduced 40 percent

Percolation rate, minutes per inch	Required trench or bed bottom area per residence[a, b]				
	Number of bedrooms				
	2	3	4	5	6
0.1 to 5 [c, d]	90	109	127	146	165
6 to 15	137	166	195	224	253
16 to 30	180	218	257	295	333
31 to 45	216	262	307	353	398
46 to 60[e]	238	288	338	388	438

[a]Estimated daily sewage flow is 60 percent of [66 + 38(BR + 1)], where BR is number of bedrooms.

[b]Bottom areas based on at least 6 inches of rock below the distribution pipe. If more than 6 inches of rock is used, the bottom area for trenches only may be reduced by the following percentages: 20 percent for 12 inches; 34 percent for 18 inches; and 40 percent for 24 inches.

[c]The soil is unsuitable if its percolation rate is faster than 0.1 minute per inch. See page 38.

[d]Consider solutions to improve sewage treatment for soils in this range. See page 38.

[e]The soil is unsuitable for standard trench if the percolation rate is slower than 60 minutes per inch. See page 40.

trench or bed bottom area required when water use is reduced 40 percent.

For a three-bedroom house and a soil percolation rate ranging from 16 to 30 MPI, the required bottom area for a seepage bed or trenches having 6 inches of rock is 218 square feet. Bed size could be 10 feet × 22 feet, 8 feet × 28 feet, etc. For a 3-foot-wide trench, 73 lineal feet is required.

Additional bottom area reduction is allowed for trenches when more than 6 inches of rock is placed below the distribution pipe (footnote b, table 8). For example, if there is no water table or other barrier layer within 6 feet of ground surface, the trench can be excavated 36 inches deep and 24 inches of rock placed on the bottom. The required bottom area is 40 percent less than 218 square feet, which is 131 square feet. If the trench is constructed 36 inches wide, 44 lineal feet will be adequate if water-saving techniques are used.

Tables similar to table 8 can be developed for type I and II houses if the toilet wastes are eliminated. However, whenever the soil treatment area is reduced, the sewage discharged into the system must be measured.

Greywater system

A greywater system has a 2-inch diameter house sewer, too small for a flush toilet. Also, a garbage disposal cannot be used.

Because no toilet wastes or garbage wastes can be discharged into a greywater system, liquid capacity of the septic tank can be less than presented in table 1 (page 8). Septic tank liquid capacities in table 9 can be used. However, whenever possible, tank volumes larger than the minimum values in table 9 can and should be used.

Table 9. Septic tank capacities for greywater systems[a]

Number of bedrooms	Minimum liquid capacity, gallons[b]
2 or less or hand pump	300
3	500
4	625
5 or 6	750
7, 8 or 9	1000

[a]No toilet wastes or garbage wastes can be discharged into the septic tank.
[b]Liquid capacity is the tank volume below the outlet. An additional internal volume equal to 20 percent of the liquid capacity is needed for floating scum storage.

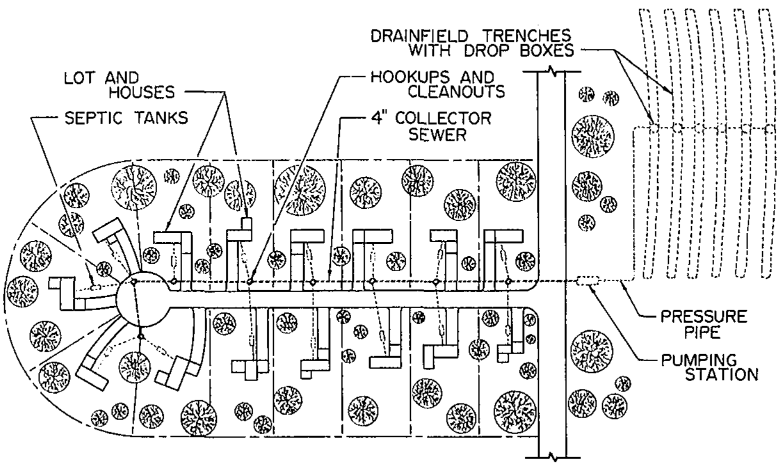
Baffle submergence, length-width ratio, distance between inlet and outlet devices, access, and other septic tank features should be the same as for a regular-sized tank.

The soil treatment unit can be sized according to the values in table 8. The site for the soil treatment unit must be carefully evaluated and the soil treatment unit must be carefully designed, recognizing possible soil limitations. Proper construction procedures must be followed, as described earlier.

Collector systems

Collector systems are used by two or more property owners jointly owning and using a single soil treatment unit (figure 16). When lot sizes are small and the soil is not suitable for adequate sewage treatment, as it often is on developed shoreland, the collector system may allow a group of property owners to solve their sewage treatment problem. However, collector systems should rarely be used to develop new plats. Better sewage treatment will result and fewer problems will develop if adequate area of suitable soil is provided on each lot for the installation of an individual sewage treatment system. Newly platted lots should be of ade-

Figure 16. A collector sewer system with a common soil treatment unit



quate size and have soils suitable for proper sewage treatment.

When collector systems are designed for existing developed lots, individual septic tanks are used for each home to separate sewage solids. The effluent generally flows by gravity into the collector line to the main pumping station. Sometimes additional lift stations are required along the collector line. The sewage effluent is pumped to where the soil is suitable for the installation of a soil treatment unit, preferably a drainfield trench system having drop boxes.

When property owners join together in a project, competent legal advice is needed to develop an agreement on easements for the collector and pressure sewer lines, mutual ownership of portions of the sewage treatment system, operation and maintenance responsibilities for mutually owned portions, maintenance schedule for individual septic tanks, assessment of initial costs to each lot, other uses for the common soil treatment area, and similar questions.

Property owners must agree on organizational and operational details before the sewage treatment system can be designed. Success of the group system depends on mutual cooperation and understanding by all participants as well as proper design, installation, and maintenance.

The most trouble-free collector systems are where each residence has an adequately sized septic tank based on the values in table 1. Then the collector line carries only effluent, and the pipe grades are not as critical as when the sewer carries raw sewage. Also, because the solids have been retained in the septic tanks, sewage ejector or sewage grinder pumps are not required. High-quality submersible sump pumps, which are relatively inexpensive, are adequate for the lift stations and the main pumping station.

The collector sewage line must be watertight and strong enough to withstand any forces placed upon it. Protect the collector line against freezing. If soil conditions prohibit burying the line deep enough to avoid freezing, either insulate or provide heat.

The diameter of the collector line should be at least 4 inches, which is usually adequate unless more than 25 houses are involved. If more houses participate, the relative location of the houses and the pumping tank determines if a larger diameter collector line is needed.

The collector sewer line must be watertight so that infiltration or exfiltration (leakage) is not greater than 200 gallons per inch of pipe diameter per mile per day. To illustrate, a 4-inch collector ½ mile long should have no more leakage than 400 gallons per day (200 × 4 × ½).

Install cleanouts on the collector sewer line. Cleanouts should extend flush with or above finished grade and must be located wherever an individual sewer connects to the collector line or every 100 feet, whichever is least. If manhole access is provided on the collector sewer, the manholes can be placed farther apart than 100 feet, depending upon the type of cleanout equipment.

When raw sewage flows into a centrally located septic tank, the sewer must give mean velocities of not less than 2 feet per second at full flow. Cleanout or manhole access to the sewer is important. A local contractor or plumber can help select sewer line diameters and grades.

The septic tank effluent is collected into a main pumping station. The pumping tank must be watertight. Manhole access must be provided for cleaning and maintenance.

Manhole access is necessary for septic tank and pumping tank maintenance. The manhole cover should be secured to prevent unauthorized entry.

The manhole cover must be flush with or above finished grade and secured to prevent unauthorized entry.

The septic tank effluent can also be collected and transported to the soil treatment area in a collector line under pressure. A pump station is located on each lot and discharges into a collector possibly 2 inches in diameter for a small group system. Since the collector pipe is under pressure, a double check valve system is required on each lot to prevent flow back into the septic tank and residence. The advantage of the pressure collector is that a constant uniform grade is not required as with a gravity collector line. Also, the small diameter pipe can be installed more easily under adverse soil conditions such as a high water table.

To estimate the amount of sewage flowing in a collector system, classify each house as type I, II, III, or IV (table 4). Estimate the sewage flow from each residence using table 4. Add a 3-bedroom type I house for each platted but undeveloped lot. Total the flows to determine the estimated daily sewage flow for the collector system.

Pumping tank capacity should include the pump-out quantity as well as reserve storage in case of power failure. A suggested minimum pump-out quantity is 10 percent of the daily sewage flow or 200 gallons, whichever is greater. A suggested reserve storage capacity is 25 percent of the daily sewage flow or 500 gallons, whichever is greater. The pumping tank capacity also must include the minimum submergence depth required for the pumps.

As an example, assume a collector system is to be designed for 20 homes; 5 are 3-bedroom type I (450 gallons per day per home, table 4); 10 are 3-bedroom type II (300 gpd); and 5 are 2-bedroom type III (180 gpd). The total estimated daily sewage flow is $5 \times 450 + 10 \times 300 + 5 \times 180 =$ 6,150 gallons.

For the 20 homes, the suggested minimum pump-out quantity would be 615 gallons (0.10×6150); the suggested reserve storage capacity would be 1,040 gallons (0.25×6150). A 6-inch minimum submergence depth for the pump might be another 250 to 300 gallons, the actual amount depends on tank surface area. Thus, the suggested pumping tank size is approximately 2,000 gallons. This volume could be obtained with a single tank or two or more tanks connected in series. Tanks in series must be connected by watertight pipe at both their tops and bottoms. One of the tanks must have a vent at least 2 inches in diameter to allow air to enter and leave the tank during filling and pumping.

For a group system, always install dual pumps that operate alternately. The pump control should have a warning device to advise of either pump failure. In addition, a liquid level warning device must be installed on a separate electrical circuit to warn of pump circuit failure.

In a collector system, use electrodes or mercury switches for pump controls. These allow for easy pump replacement and also simple adjustment of pump-out levels if the number of participants increases.

The pump will have to handle the maximum inflow rate of sewage to the pumping station. Sewage discharge data from residences suggest that the pump should be capable of pumping at least 25 percent of the total estimated daily sewage flow in a 1-hour period at a head adequate to overcome elevation and friction loss. The minimum pump capacity should be at least 1,200 gallons per hour. If

A collector sewer line for effluent serves these lakeshore cabins. Each cabin has its own septic tank.

the inflow becomes faster than a single pump can handle, the second pump will start.

Size the soil treatment unit based on the percolation rate of the soil and the estimated total daily sewage flow. For the example above with 20 houses and an estimated daily sewage flow of 6,150 gallons, assume that a site is available with a percolation rate of 10 MPI.

From table 4 on page 22, 1.27 square feet of soil treatment area is required for each gallon of waste per day. The total required trench bottom area is 7,810 square feet (1.27 × 6,150) if 6 inches of rock are used below the distribution pipe. If 12 inches of rock are used, the trench bottom area can be reduced by 20 percent to 6,260 square feet (0.80 × 7,810). This is 2,083 lineal feet of 3-foot wide trenches, or 21 trenches each 100 feet long.

The trenches could extend 100 feet each way from a drop box. Thus, 11 drop boxes would be required and it would be advisable to install 22 trenches providing a small factor of safety. If the trenches were spaced 10 feet from center to center, a lawn area 110 feet wide by 200 feet long (½ acre) would be needed for the soil treatment unit.

Place the soil treatment unit as far as possible from any drinking water supplies. Sewage tank effluent can easily be pumped a mile if there are no natural barriers, such as rivers and swamps. If an adequate area is available, space the trenches 10 to 12 feet apart. Use 6 to 12 inches of soil cover to maximize evapotranspiration during the summer.

Each member of the group should own an undivided share of the soil treatment site. Since grass cover must be maintained over the trenches, the treatment site can be used as a playground or picnic area. However, do not allow heavy vehicles on the drainfield trenches, and prohibit foot traffic and snowmobiles on the trenches in the winter. Establish a good grass cover, and allow natural snow accumulation to protect against winter freezing.

Several collector systems have been installed in Minnesota, and more are under construction. It is a technically sound and economical alternative for sewage treatment. Collector systems for small groups of houses can usually solve sewage treatment problems on small lots without the large expense of municipal sanitary sewer.

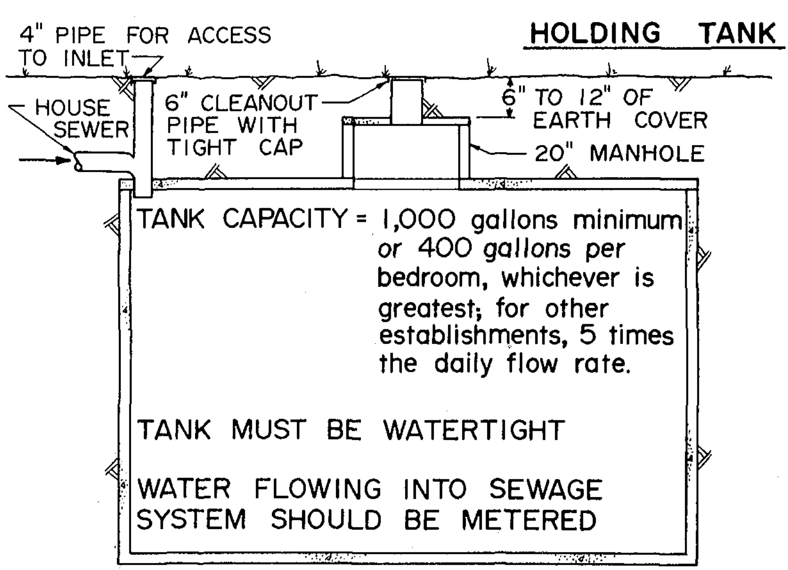
Among group systems installed in Minnesota, the cost per lot has been about the same as for adequately sized individual systems. Costs of collector lines and the common soil treatment unit have ranged from $800 to $1,200 per lot, depending on treatment site accessibility, land cost, and the soil percolation rate (which determines soil treatment unit size).

Holding tanks

For some existing residences on small lots too remote or isolated for a collector system, it may be necessary to discharge the sewage into a holding tank from which the sewage is pumped and transported to a treatment and disposal system. Holding tanks are usually allowed only on lots where a residence is already located, not for new houses. Check with your zoning administrator to determine the regulation in your county.

The high cost of hauling sewage makes the holding tank undesirable. Sewage hauling costs vary, but 3 cents per gallon is about average. Thus, a 5-gallon toilet flush costs 15 cents, a 40-gallon shower costs $1.20, and 50 gallons used for an automatic washer load cost $1.50.

Figure 17. Requirements for a holding tank



An average three-bedroom type III house with 4 people uses 218 gallons of water per day, not including outside uses such as car washing and lawn sprinkling. This annual use of 79,570 gallons would cost $2,387.10 to haul away each year!

Therefore, consider all other alternatives first. Don't urge your zoning administrator to allow you to install a holding tank so you can build on the small lot you own. At an annual hauling cost of $2,387.10, you will soon pay for a more suitable lot, but will never own it. Your zoning administrator will be doing you a favor by not allowing you to build a holding tank.

The high cost of a holding tank can be kept down by conserving water. However, prospective purchasers of your property may not want to do this, and the resale price will be sharply reduced because of the holding tank.

Whenever holding tanks are allowed for lots with existing houses, water conservation is necessary. However, as was discussed in "Soil treatment area reduction," the apparent savings in hauling costs will be transferred to other costs. Without a septic tank and an adequate drainfield trench system on your lot, sewage treatment will be expensive.

Certain definite procedures are required to build a holding tank. The tank must be watertight and constructed of the same materials and by the same procedures as for watertight septic tanks. The liquid capacity of the holding tank must be at least 1,000 gallons or 400 gallons times the number of bedrooms, whichever is greatest (see figure 17).

Locate the holding tank in an area readily accessible to the pump truck under all weather conditions and where accidental spillage during pumping will not be a nuisance. The tank must be at least 50 feet from the water supply well and 10 feet from buried pipe distributing water under pressure, from buildings, and from property lines. Place the tank on firm and settled soil capable of bearing the weight of the full tank.

Protect the tank against flotation under high water table conditions. It is usually best to locate the tank above the water table and to use a sewage ejector pump for sewage from the residence.

Access to the tank should be a clean-out pipe at least 6 inches in diameter which extends to the ground surface and which is capped tight enough to prevent odor and to exclude insects and vermin. Also install a manhole at least 20 inches in diameter and extend it to within 12 inches, but no closer than 6 inches, below finished grade. Be sure that the manhole is covered with at least 6 inches of earth to prevent unauthorized entry.

A water meter should be installed beyond the pressure tank and outside sillcocks to record all liquid wastes flowing into the holding tank. The charge for hauling the sewage should be based on the water meter reading. With a water meter, the owner knows he is not paying for hauling more sewage than he has discharged. The hauler also benefits by being able to "fill out" his load if he happens to be in the area.

The zoning administrator will probably insist that you maintain a contract with a hauler licensed by the county. He may also require that you and/or the hauler submit a quarterly report to his office.

OPERATION AND MAINTENANCE

Your onsite sewage treatment system requires minimum maintenance. But you can't just install it and forget it. The major maintenance is periodic removal of solids from the septic tank. The soil treatment unit can be maintained under certain soil conditions by resting portions of the unit.

Septic tank

Cleaning frequency of a septic tank depends on tank capacity, the number of people using the system and appliances such as a garbage disposal. Figure that the solids from 1 person will occupy about 50 gallons of tank capacity per year. Pump the tank when half of the initial liquid capacity is occupied by solids. Some tanks may need cleaning within 2 years, while others may go 10 or more years before they need cleaning. Tanks with a relatively short distance between 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.

Although it is difficult, actual inspection of sludge and scum accumulation is the only way to determine when to pump a septic tank. Inspect your tank annually, or have a qualified septic tank pumper do it for you. Have all the tank solids removed if:

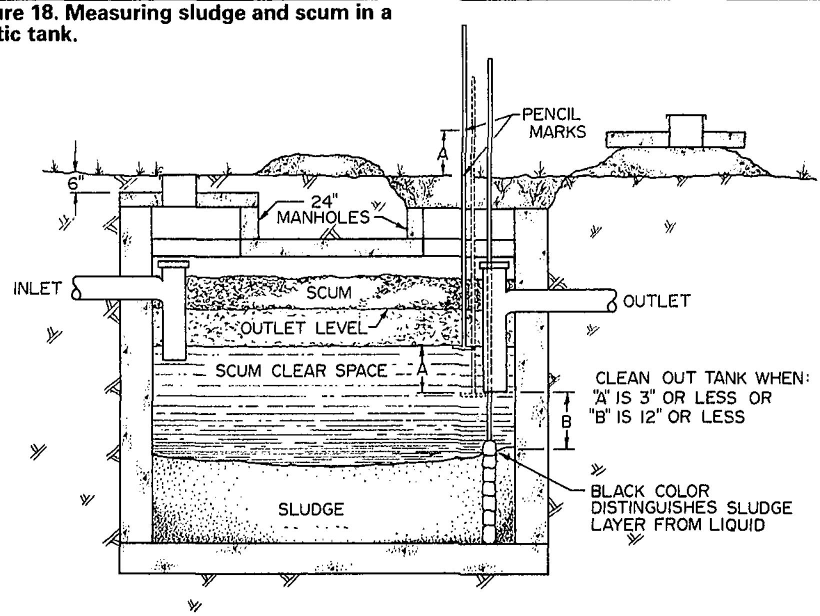
- The scum layer bottom is within 3 inches of the bottom of the outlet baffle;

  or
- The sludge top is within 12 inches of the bottom of the outlet baffle.

All septic tanks have three distinct layers of scum, liquid, and sludge. To determine scum accumulation, use a 3-inch square piece of wood attached to the bottom of a long stick (figure 18). Push the measuring device through the scum layer into the liquid layer. If the stick is carefully moved down and up, resistance on the "foot" should locate the bottom of the scum layer.

Mark the stick at a convenient reference point when you feel the bot-

Figure 18. Measuring sludge and scum in a septic tank.



tom of the scum layer. With the same stick, locate the bottom of the outlet baffle. Determine the distance between the bottom of the scum layer and the bottom of the outlet baffle by measuring the distance between the marks on the stick.

Wrap an old bath towel around the bottom 3 feet of a stick long enough to reach the bottom of the tank (figure 18). Push the stick to the bottom of the tank, and twirl it between your hands. Mark the stick on your reference point, and let it stay in the tank about a minute. When you withdraw the stick, you will find a distinct black layer representing the sludge depth. Measure the distance from the bottom of the outlet baffle to the top of the sludge layer.

Removing all the septic tank solids requires more than just pumping the tank. The job should be performed by a professional having adequate equipment. Some of the liquid is first pumped back into the tank under pressure to agitate all the solids into suspension. If the scum layer is hard, you may need to agitate the tank with air or to use a long-handled shovel through the manhole to break up the scum. When all the solids become suspended, the mixture is pumped out of the septic tank into the pumper tank.

It is usually necessary to open the manhole to remove all the solids from a septic tank. If the septic tank pumping technician services the tank through the inspection pipes over the inlet and outlet baffles he may break or dislodge them.

It is not necessary to leave solids in the septic tank to "start" it again. A septic tank pumping technician who tells you this is either misinformed, does not have adequate equipment to break up the scum layer, or does not have a large enough pumping tank to remove all the contents of your septic tank in one load. On the other hand, the septic tank should not be washed, scrubbed, or disinfected.

When the septic tank manhole is open, check the condition, length, and submergence of the inlet and outlet baffles. Have the septic tank serviceman replace them if they are the wrong length or in bad condition.

To repeat, *never* allow anyone to go down into a septic tank unless a continuous fresh air supply is pumped into the tank and a strong rope is tied securely around his chest. The person on the ground surface must have enough strength to pull the person out of the tank in case danger from asphyxiation becomes apparent. Fatalities have occurred during septic tank maintenance and repair.

Material removed from a septic tank is called septage and should be disposed of in a safe and sanitary manner. Septage discharged to a municipal treatment plant will likely overload the treatment system. The most appropriate treatment facility for septage is the soil. While septage does not have many nutrients (4 to 8 pounds of nitrogen for a 1,000-gallon load), the soil can assimilate what nutrients septage does have and make them available for plant growth. Also, soil and sunlight destroy any disease-causing organisms in a short time.

When spreading septage on agricultural soil, consider soil texture, land slope, vegetative cover, distance to surface waters, topography, season (winter or summer), and similar factors. Contact the Minnesota Pollution Control Agency for guidelines on the selection of appropriate sites for the treatment and disposal of septage.

Soil treatment unit

If the septic tank is properly maintained, little maintenance is required of the soil treatment unit. However, be aware of the importance of the soil treatment unit and monitor its performance. Check the drop boxes or inspection wells several times a year to see how much of the soil treatment unit is being used.

On loamy soils (percolation rates slower than 6 minutes per inch), it is desirable to "rest" a portion of the soil treatment unit. To do this, plug the inlet to a trench for a year to let the soil dry out. Drying out will allow the soil to recover much of its original percolation capacity.

A drop box distribution system for the soil treatment unit automatically provides resting for some of the trenches. During spring snow melt and rainfall, all the trenches may be needed to treat the sewage effluent. During the fall, particularly a dry fall, only 1 or 2 trenches may be needed. Thus, the portion of the trench system not needed is resting and drying out.

However, the first trench and possibly the second trench always receive effluent. To rest them, plug the pipe leading to the trench at the drop box.

Never rest a soil treatment unit located where soil percolation rate is between 0.1 and 5 minutes per inch. In soil of this texture, the biomass is necessary for effective filtration of the sewage effluent. Therefore, the soil treatment unit should not have a management program to rest it.

REPAIR

If your sewage treatment system backs up, it is probably too small for the amount of sewage you are using, or it hasn't been maintained properly. When a young family purchases and moves into a house previously occupied by two people, the sewage system will often be overloaded. Regardless of advertising claims to the contrary, there is no magic elixir that will rejuvenate or make an undersized sewage treatment system effective.

If the soil treatment unit can't accept as much sewage as you want to discharge into it each day, you will either have to enlarge it or use less water. When you enlarge the soil treatment unit, don't abandon the previous unit unless it is poorly constructed. Instead, use a drop box or distribution box and connect both the old unit and the newly installed one. However, plug the pipe leading into the old unit for a year or 2, allowing it to dry out and recover. If the soil was badly clogged because of a small or improperly maintained septic tank, it may not recover completely. But it will be to your advantage to restore some of the capacity of the unit.

It is usually not economical to make major repairs to a septic tank. A septic tank with no bottom, loose blocks, and improper baffles can be brought up to standard only at considerable expense. Most installers will refuse to do major work to an old tank because of the expense and danger involved. Install an adequately sized, properly constructed, quality, prefabricated septic tank for the most economical and effective sewage treatment.

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- Do select an adequately sized, watertight septic tank with proper baffles and access.
- Don't use septic tank additives; they may harm your system by clogging the soil treatment unit.
- Don't use a garbage disposal with a septic tank unless you plan to follow a rigid maintenance schedule.
- Don't go down into a septic tank.
- Don't run footing drain water into the sewage treatment system.
- Don't bypass the septic tank with washwater; run all sewage into the septic tank.
- Investigate the site and soils carefully; select the proper location for the soil treatment unit.
- Don't place trench rock into contact with coarse soil having a percolation rate faster than 0.1 minute per inch or clay soil with a percolation rate slower than 60 minutes per inch.
- Use drainfield trenches and drop boxes.
- Keep the sewage treatment system shallow, both the septic tank and the soil treatment unit.
- Use clean rock ¾ inch to 2½ inches in diameter; don't use crushed limestone.
- Use 12 inches of rock below the distribution pipe.
- Carefully prepare the soil surface, especially clay soils.
- Use a backhoe bucket that has side teeth to leave the trench sidewalls rough.
- Don't excavate with a front end loader or a bulldozer blade.
- Don't use distribution boxes on sloping ground.
- Don't install a holding tank for a new house.
- Don't install your system and forget it.
- Maintain your sewage treatment system regularly, even when it is working properly; it will be a lifetime installation.
- Have a contract to service your sewage treatment system.