Chapter VI
Enhanced/Advanced Treatment

TABLES

FIGURES

INTRODUCTION

When suitable for the site and soil conditions, a traditional septic tank and soil absorption field is the ideal onsite wastewater system choice because of low cost, simplicity, no energy requirement, and low maintenance. Site limitations such as small lot, poor soil, high or perched groundwater, shallow soil depth to rock, or topography, may mean a traditional system is not a good or suitable choice. Other options include enhanced/advanced treatment; absorption field alternatives like pump-dosed, low pressure pipe or drip dispersal; lagoon; and off-site treatment.

Enhanced or advanced treatment units further treat the wastewater before it is discharged to the soil absorption field for final treatment. These components reduce the total suspended solids (TSS), biochemical oxygen demand (BOD), and stabilize the wastewater, and some also reduce nutrients. Treatment occurs by supplying oxygen to aerobic bacteria, which grow either in suspension or attached to a substrate. These bacteria consume dissolved and suspended organic wastes. Suspended growth is achieved by injecting air into the wastewater to mix and supply oxygen. Attached bacteria grow on a structure whether submerged, bathed, or dipped in wastewater.

Components that provide enhanced or advanced wastewater treatment are among those often termed "alternative systems." Alternative systems include aerobic treatment units (ATUs), sand filters, mounds, rock-plant filters, or other media such as peat, plastic foam, or textile that support attached bacteria growth. Alternative systems also include pump systems that distribute effluent to the absorption field through drip lines or low pressure pipe network.

Figure VI-1 illustrates where enhanced treatment fits with conventional onsite treatment components. Most absorption field options can be used with any alternative system or with septic tank effluent when it provides adequate treatment for the site and soil conditions. However, three alternative systems (engineered mound, unlined sand filter, and unlined wetland) are hybrids accomplishing both treatment and absorption.

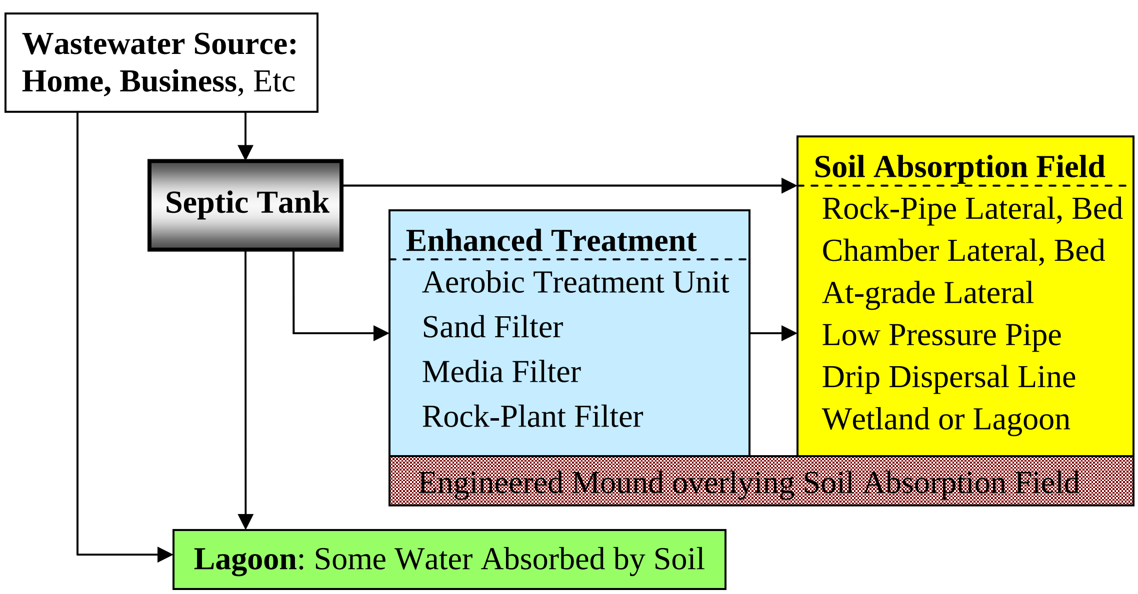


Figure VI-1. How Enhanced Treatment Options Relate to Other Onsite Treatment and Soil Absorption Components

Enhanced treatment provides much of the wastewater treatment that normally occurs in the soil absorption field. An enhanced/advanced treatment unit ahead of the absorption field substantially increases the options for field design and a reduced organic load (BOD) may allow a smaller field. An enhanced treatment system completes much of the treatment before the wastewater is delivered to the soil absorption field. Effluent from an enhanced treatment component is still sewage, has considerable bacteria, and therefore, is not suitable for surface discharge. Surface discharge from any onsite system is illegal in Kansas so use of an appropriate absorption field is a viable option.

AEROBIC TREATMENT UNITS (ATUs)

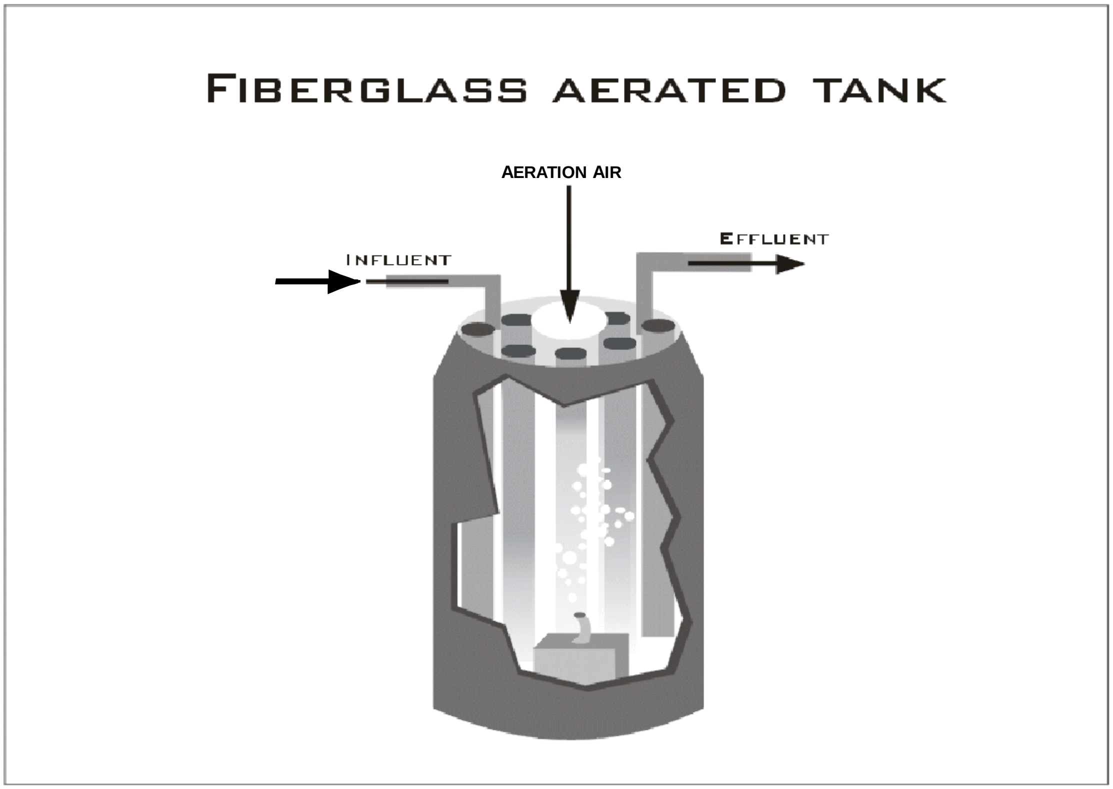
Like other enhanced treatment options, aerobic treatment units (ATUs) depend on aerobic bacteria that require oxygen to decompose organic material in wastewater. Aerobic treatment typically produces a substantially higher quality effluent than is produced by a septic tank alone. ATU systems are frequently used with drip systems but this may be because many equipment distributors market both products and not because of any requirements. Sand filters and other media filters are equally appropriate with drip systems. The effluent from many rock-plant filters may not consistently be clean enough for use with drip systems.

ATUs are available in several different designs from numerous manufacturers. By design, an ATU may follow the septic tank or incorporate a “trash” tank to function as a septic tank. Figure VI-2 shows the typical configuration of two types of aerated tanks. The most common ATU design uses three chambers or tanks to treat sewage. The first chamber functions like a septic tank to remove solids and scum. Air is pumped in the second chamber to supply oxygen and mix the contents. Aerobic bacteria decompose the organic material producing an effluent much lower in biochemical oxygen demand (BOD). The final chamber slows the flow of the water so solids settle before the clarified effluent exits the tank. Some of these units also use a filter to retain solids in the tank and thus further improve effluent quality. ATUs without three chambers typically use a filter system to remove solids before effluent exits the unit.

NSF International and ANSI have adopted Standard 40 for Residential Wastewater Treatment Systems. NSF and Baylor University have established testing protocols to evaluate the performance of ATUs. NSF Class 1 designation means that under a range of operating conditions representative of individual homes (including stress loading and interrupted use), the unit produced an effluent that averaged 25 mg/l or less of BOD and total suspended solids (TSS). Maintenance for the first 2 years of operation must be provided by the manufacturer’s representative. Because of uncertainty of treatment results, only manufacturer’s models meeting Standard 40 as shown on the NSF web site at <www.nsf.org> are recommended. About 30 manufacturers market Class 1 units that meet this standard.

ATU Design

ATUs are designed to handle a specific volume of flow and strength of wastewater. Aerated tanks are intended to treat typical domestic wastewater. High strength wastewater with a high BOD and/or TSS loading requires a special design. A typical average unit is designed to treat up to 500 gallons of wastewater per day. When the wastewater flow is more than 500 gpd, then a larger unit, a second unit, or special design features may be required.



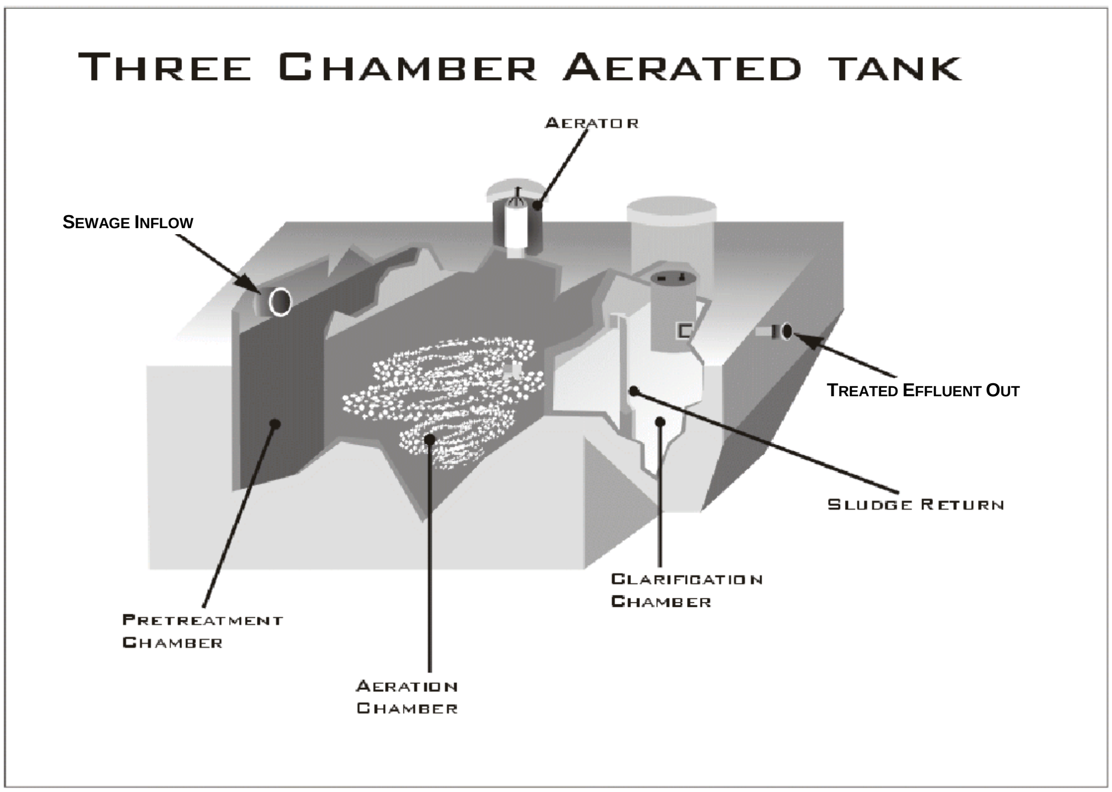


Figure VI-2. Common Styles of Aerobic Treatment Units

The aerobic unit may provide a high level of treatment to remove BOD and TSS, however, the effluent requires further treatment to destroy or deactivate pathogens. The unit may be followed by any of the soil absorption fields shown in Figure VI-1. Soil absorption systems provide further treatment of the waste to destroy pathogens and in some cases, remove nutrients. Research has shown that because of changes in conditions small aerated tanks used for single-family residences do not produce consistent water quality. Surface discharge from these units is not legal in Kansas.

ATU Performance Evaluation

A well designed and maintained ATU produces an effluent which is much lower in BOD. This means that much less treatment is required in the soil absorption field. Additionally, aerobic treatment of organic material does not produce the odors characteristic of anaerobic treatment in the septic tank. With plenty of aeration, ammonia is oxidized to nitrite and then nitrate. Microorganisms (or microbes) are responsible for the decomposition, as summarized in Table VI-1. For treatment to be successful, an environment must be maintained in the aerobic system that allows these microbes to thrive. Total suspended solids (TSS) removal by an ATU depends to a large degree on the design as well as operating conditions.

Table VI-1. Microbial Processes in Aerobic Treatment

Biochemical Oxygen Demand (BOD) Decomposition

$$\text{Organic Matter} + \text{Oxygen} + \text{Nutrients} \xrightarrow{\text{microorganisms}} O_2 + NH_3 + C_5H_7O_2 \text{ (new cells)}$$

Microbial Decomposition

$$C_5H_7O_2 \text{ (microbial cells)} + 5O_2 + N \xrightarrow{\text{microorganisms}} 5CO_2 + 2H_2O + NH_3 + \text{energy}$$

Nitrification – Conversion of Ammonia to Nitrite and Nitrate

$$2NH_3 + 3O_2 \xrightarrow{\text{microorganisms}} 2NO_2 + 2H + 2H_2O$$

$$2NO_2 + O_2 \xrightarrow{\text{microorganisms}} 2NO_3$$

Table VI-2 compares the average concentrations of septic tank effluent (the wastewater quality entering the ATU), ATU effluent, and two different sand filter effluents following different pretreatment systems. This data is based on typical household sewage treated in an aerated tank that receives regular maintenance and is operating properly.

Table VI-2. Performance Comparison of Effluent Water Quality for Septic Tank, ATU, and Sand Filters Following a Septic Tank and ATU System

Parameter	Septic Tank	Septic Tank and ATU	Septic Tank and Sand Filter[a]	Septic Tank, ATU, and Sand Filter[b]
BOD_5* (mg/L)	123	26	9	2-4
TSS (mg/L)	48	48	6-9	9-11
Ammonia-N (mg/L)	19.2	0.4	0.8-1.1	0.3
Nitrate-N (mg/L)	0.3	33.8	19.6-20.4	36.8
Orthophosphate (mg/L)	8.7	28.1	6.7-7.1	22.6
Fecal Coliform (#/100mL)	5.9×10^5	1.9×10^4	$(0.5\text{-}0.8)\times 10^3$	1.3×10^3
Total Coliform (#/100mL)	9.0×10^5	1.5×10^5	1.3×10^3	1.3×10^4

* Biochemical Oxygen Demand (5-day)
[a] Receiving septic tank effluent dosed at 5gpd/ft^2; [b] Receiving aerobic tank effluent dosed at 3.5gpd/ft^2
Source: Adapted from Kellam, Boardman, Hagedorn, and Reneau, *Evaluation of the Performance of Five Aerated Package Treatment Systems*, Bulletin 178, 1993, Virginia Water Resources Research Center, Virginia Polytechnic Institute and State University.

ATU Components

The wastewater treatment atmosphere is highly corrosive even when treated aerobically. All mechanical and electrical components must be protected from corrosion and water intrusion. The components of the aeration unit should be stainless steel or plastic. The motor housing should be mounted outside the tank or enclosed with watertight seals. Corrosion of the motor housing may eventually contribute to motor failure. The power supply to the tank should be grounded and all connections should be inside watertight junction boxes using water resistant wire nuts or other water resistant method. All electrical wiring must have water tight connections and be done in accordance with the manufacturer's instructions and local wiring codes.

Aerobic treatment units are either buried or are otherwise protected from freezing. The aeration tank must be vented to the outside air, usually with an air tube on top of a riser or lid to bring in air which contains the oxygen. Easy access (riser to the surface) must be provided to the first compartment where the solids accumulate so that this chamber can easily be checked and pumped when needed. Some ATUs that have multiple compartments may also have an effluent filter at the outlet or in the line from the unit. Easy surface access (port) must be provided for service (cleaning) of the filter and any other components that require regular service.

The aerator provides a source of oxygen for the microbes and promotes mixing of the wastes being aerated. Mixing of suspended growth systems is essential so the microbes come into contact with both the organic material and the air and to keep them in suspension. The aeration compartment contains a mixed blend of particles (or floc) containing organic and inorganic solids and microbes that do the decomposition. In the final (or clarifier) chamber floc particles settle to the bottom and some particles are returned to the aeration chamber. The returned floc particles keep the microorganism population high in the aeration tank providing more complete decomposition. Some ATU systems have only one compartment so the water must pass through a filter before exiting the tank. In these systems the floc accumulates on the surface of the filter so that the population of microorganisms is contained in the aeration compartment.

ATU Electrical Considerations

ATUs require an uninterrupted electrical supply to power the controls and aeration pump. The power source should be wired to a separate circuit in the home electrical panel. This prevents overloading the circuit, prevents the homeowner from unknowingly turning off power to the unit, and assures safety when working on the unit. The control box and all electrical connections for the aerobic unit must be watertight and must be outside the tank, above ground, or in a separate dry well. Because motor vibration in some aerobic units can wear and fray electrical wiring, it is important to carefully route wiring during installation to prevent unnecessary wear. During maintenance all wiring should be carefully checked for wear and realigned if necessary.

ATU Required Operating Conditions

An ATU must maintain an environment that is beneficial to the microbial population. The system should have a pH between 6.0 and 9.0 to keep the microbes healthy. Dissolved oxygen in the aerated tank should be a minimum of 1.0 mg/L. The actual dissolved oxygen will vary depending upon the loading, time of day, rate of oxygen transfer, and location in the tank. The tank will contain aerobic, facultative, and some anaerobic microbes. The accumulated sludge in the bottom of the tank will contain most of the anaerobic and facultative microbes.

The hydraulics of an ATU are similar to a septic tank. As flow enters the tank, wastewater in each compartment is displaced to allow the new wastewater to enter. The tank should have a total detention time of 24 hours or more, with at least 3 hours detention time in the final compartment to allow settling to occur. ATUs are very susceptible to hydraulic surges (high flow rates) that may wash solids out of the tank, reduce treatment efficiency, and can eventually cause a failure in the soil absorption field. Water conservation though important for all in-ground onsite wastewater systems is especially important for ATU Systems. Users with ATU systems should avoid high water use in a short period of time by spreading water using activities (laundry, bathing, showers, etc) over a longer time period of the day.

An aerated treatment tank depends on a healthy population of aerobic microorganisms to remove pollutants. Sudden changes in waste characteristics (shock loading) such as pH, toxic chemicals, or the concentration of organic material may negatively affect the microbial population. A decline in the microbial population may cause a decline in the treatment efficiency of the system. An aerated tank should have a steady supply of organic wastes to keep the microbe population in the best condition. If the tank is not used, the microbial population begins to decline. If non-use continues for several weeks or months the microbe population may decline to a critically low level.

When tank use resumes after a long idle period, it may take several days for the microbial population to become large enough to provide adequate treatment. Additionally, when the family returns after a vacation and runs several loads of laundry in a short period of time, the hydraulic surge may wash much of the bacteria out of the system. The homeowner should be informed about how the system works and be encouraged to use the system properly to maintain good treatment. Arranging for some use of the system during long absences helps ensure good operation when occupants return.

Harmful chemicals that change the pH of the tank or contain toxic substances may cause the microbial population to decline with a corresponding decline in treatment efficiency. Exclude toxic chemicals from the waste stream of ATUs just as in a septic system. Solids that do not readily decay such as sand, clay, cigarette butts, kitty litter, bones, and grit do not decompose and accumulate in the tank, reducing the tank's capacity to accumulate sludge. Grease and oil are not easily decomposed in an aerated system so should be excluded from the wastewater as much as possible. Inert materials or those slow to degrade, accumulate in the tank and increase the required sludge pumping frequency.

ATU Maintenance

Aerobic treatment units use mechanical and electrical components that require maintenance. Maintenance should include a check of overall operation, the aeration motor and pump, air lines, orifices, alarms and controls, and accumulation of debris in piping, shafts and filters. Hair, lint, and other debris must be removed from the aerator shaft. Accumulation of debris on the aerator shaft increases the load on the aerator motor and wear on the bearings and may cause a premature motor failure. The air intake vent must be open to provide air for the system.

Distributors of ATUs often provide service contracts for the system. Homeowners are strongly encouraged to keep a service contract on these systems. The tank should be equipped with an alarm to alert the owner when there is a failure of mechanical or electrical equipment. The alarm should be both visual and audio and must be placed so the homeowner can readily detect failing conditions. The homeowner should call the qualified, trained service provider when an alarm is activated.

In addition to mechanical equipment maintenance, treatment tanks must be pumped to remove solids, and filters, if present, must be periodically cleaned. The power supply to the system must also be kept operational so the tank has a constant supply of air.

ATU System Summary

A well designed, tested, and manufactured ATU can achieve a higher level of wastewater treatment than is possible with a septic tank. However, to consistently achieve this level of treatment, the system must be properly installed, operated, and maintained. The homeowner is responsible for the operation of the system and must understand how to use it properly and respond quickly when problems develop. The system should be equipped with an alarm that automatically notifies the homeowner when problems exist. Good maintenance requires that the system receive routine checks and repairs by a qualified, trained technician. When all requirements are met, an aerated tank can provide effective treatment.

ENGINEERED MOUND SYSTEM

Traditional septic tank-absorption field systems require suitable soil and site conditions to adequately treat wastewater. Mound systems are only slightly different in principle from a wastewater treatment aspect. Mound systems are elevated absorption beds that utilize suitable sand fills to partially treat wastewater before it reaches natural soil. Mound systems are used to augment natural soil for complete treatment and disposal. Figure VI-3 demonstrates the cross section of a conventional soil absorption lateral and the mound system in relation to ground surface and limiting conditions.

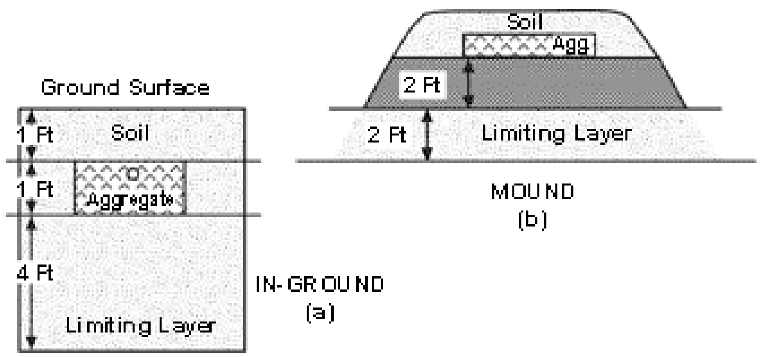


Figure VI-3. Cross Section of Traditional Soil Absorption Lateral (A) and Mound (B) in Relation to Ground Surface and Limiting Condition (After Converse and Tyler, 1990)

A mound must be positioned in the landscape along the contour of the lot. Minimum separation distances of 50 feet from drinking wells and of 10 feet from property lines are required for the mound system, as shown in Figure VI-4. Mounds are long and narrow to insure that wastewater can infiltrate the soil beneath and move away from the mound without surfacing. Ideally the mound should be as long and narrow as possible along the contour, but no shorter than is prescribed for the design linear loading rate. Constructing a mound shorter and wider than recommended, results in a risk of partially treated wastewater coming to the surface. Cost of an engineered mound increases with site slope. Design is dependent on the slope and slopes greater than 15 percent are normally not suitable for a mound.

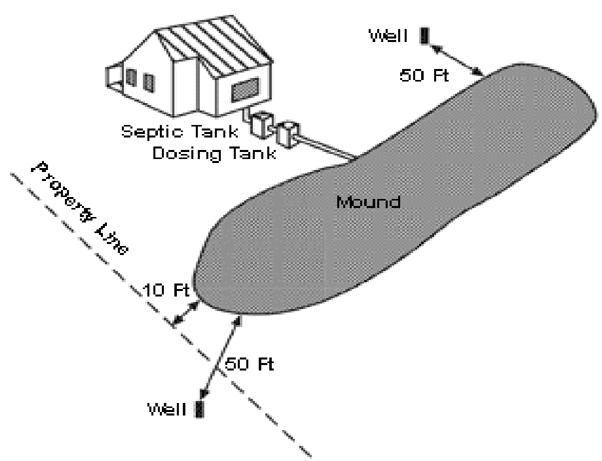


Figure VI-4. Minimum Separation Distances for the Mound System

A mound system consists of a septic tank, dosing tank with pump, distribution pipes, and mound, as shown in Figure VI-5. The septic tank allows the solids in wastewater to separate by settling or floating and to degrade. The septic tank effluent should discharge through an effluent filter to a dosing chamber (tank). The dosing tank is equipped with a pump to deliver the septic tank effluent through the distribution system in the mound. The distribution system normally consists of small diameter pipes and allows for low pressure, even distribution of effluent to the absorption area in the mound.

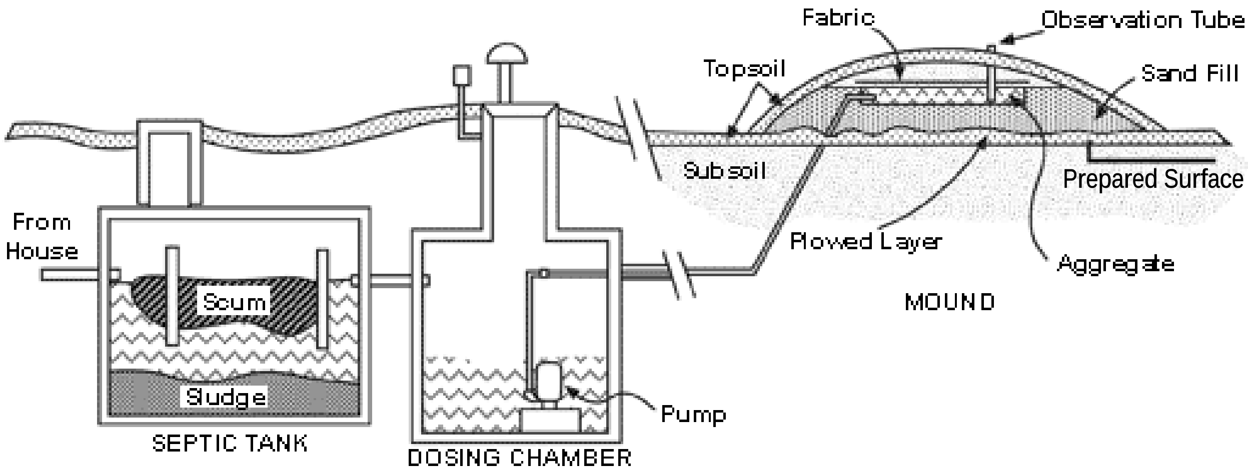


Figure VI- 5. Schematic of the Mound System (Converse and Tyler, 1990)

Most of the pollutants are removed as the wastewater percolates through the sand fill in the mound. The natural soil beneath absorbs the partially treated wastewater that trickled through the mound and removes pathogens to complete treatment and dispersal. To enhance infiltration into the soil, the surface is roughened by tillage along the contour before the sand fill is placed.

Mound Design Example

Designing a mound system is a site-specific process thus the following steps must be completed to fit the components of the mound to the features of the site. The configuration of the mound is based on the volume of the wastewater to be treated, the characteristics of the site, natural soil profile, and the depth to a limiting condition. These steps show the design procedure and an example of a mound design for a typical three-bedroom Kansas home is also included. The following 15 design steps described here are adapted from Ohio State University Extension, Bulletin 813. (Chen and Mancl, 2004)

Design Step 1. **Site and Soil Evaluation**

Conduct a site and soil evaluation as outlined in Chapter IV making note of the soil profile and the depth of the limiting condition; slope of the site; and the location of trees, etc. Mound systems are suitable for areas of Kansas with shallow depth to a restrictive soil layer, shallow bedrock, or seasonal high water tables. A minimum depth of at least 12 inches of unsaturated, permeable soil is a prerequisite for a mound system. The permeability of the soil must be at least 0.5 inch per hour (perc no greater than 120 minutes/inch) and no more than 20 inches per hour. Table VI-3 gives some recommended minimum and maximum criteria for mound systems.

Table VI-3. Recommended Minimum/Maximum Soil and Site Conditions for Mounds

Minimum depth to permeable restriction such as fractured or weathered rock	1 foot
Minimum depth to impermeable soil or rock	1.5 feet
Minimum depth to permanent or seasonally perched water table	1.5 feet
Minimum perc rate for soil horizons on the site (no greater than)	120 min/inch
Maximum site slope	15 percent

Before designing a mound system for a site, evaluate and record the site description and soil profile. The natural soil would not be reshaped. If the site meets the recommended soil and site criteria, establish the contour of the lot in and adjacent to the proposed mound area as shown on Figure VI-6. Measure and mark the required set back distances for wastewater systems. Mounds must be on the contour to maintain constant mound height and to ensure even distribution of effluent. This means that mounds typically curve to follow the natural soil surface contour.

Example:

A summary example of the soil and site information is presented here.

1. Soil Profile (summary of three soil profile excavations based on shallowest values):
   a. 0-7 inches: silt loam texture; moderate fine and medium angular structure; slightly hard / friable consistence
   b. 7-24 inches: silty clay texture; moderate fine blocky structure; extremely hard / very firm consistence (layer of poorer drainage)
   c. 24-30 inches: silty clay texture; common fine and medium distinct grayish brown and few fine distinct strong brown mottles (poor to very poor internal drainage); weak medium and fine blocky structure; extremely hard / very firm consistence; few fine black concretions
   d. Greater than 30 inches: silty clay texture; few fine distinct strong brown mottles that increase with depth; very weak fine blocky structure grading to massive at greater depths; extremely hard / very firm consistence (very poor internal drainage)
2. Site slope is 3 percent or 0.03.
3. The suitable area available on the site is 180 feet along the contour and 50 feet parallel to the slope. Three medium-sized trees are near the mound area. A small tree just above the available area could be removed to prevent root interference with the mound fill material.
4. Depth to restrictive soil layer or limiting condition is 24 inches due to the silty clay texture with weak blocky structure that has poor drainage. Mottles below 24 inches indicate a seasonal high water table indicative of poor drainage.

Site slope = 3 percent or 0.03

Suitable area = 180 feet long (on the contour) by ***50 feet wide*** (with the slope)

Depth to restriction = 24 inches (layer of poor internal drainage)

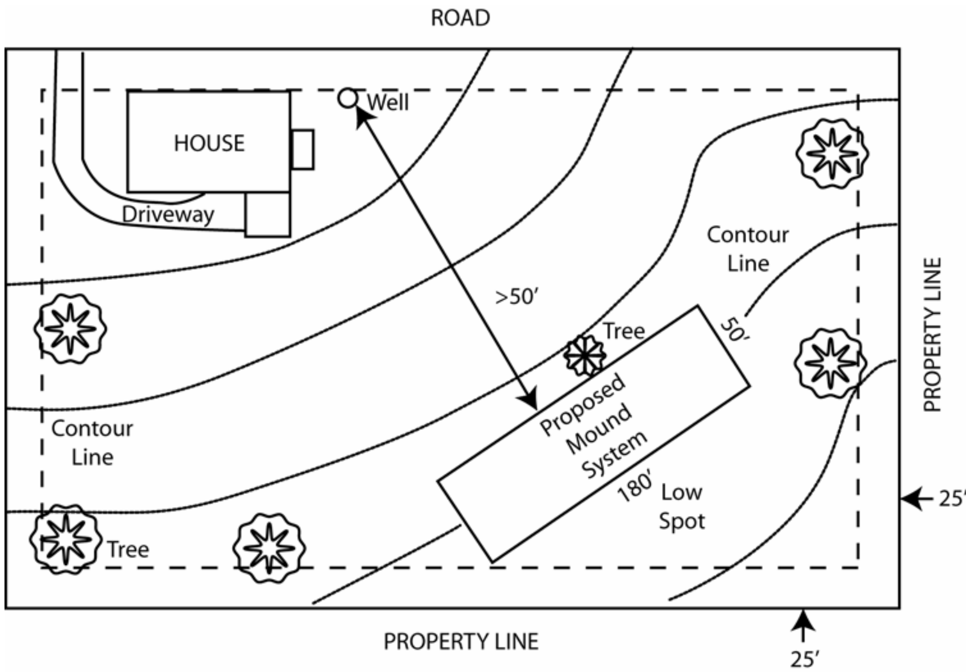


Figure VI-6. Site Evaluation Example for Locating an Engineered Mound

Design Step 2. **Determine Wastewater Flow Rate.**

The wastewater flow rate for individual homes is estimated by multiplying the number of bedrooms by 150 gallons per day (gpd). This is based on 2 people per bedroom and 75 gallons per person per day as outlined in KDHE Bulletin 4-2. Other types of wastewater sources can be estimated from tables of typical flows.

Wastewater Flow Rate = 150 gpd/bedroom x number of bedrooms

Example:

Wastewater Flow Rate = 150 gpd/bedroom x 3 bedrooms

Wastewater Flow Rate = 450 gallons/day (gpd)

Design Step 3. **Select the Linear Loading Rate**

The linear loading rate shown in Table VI-4 controls the hydraulic loading along the contour and prevents overload. The rate controls the mound length. Based on soil and site evaluation, identify the nature of the limiting condition. In Table VI-4 a range of values is given, use the conservative value when possible. The space-limited value is less conservative and should be used only when the suitable area available is limited by the lot size and the site features.

The linear loading rate is selected from Table VI-4 using the rate for the limiting condition that corresponds to the site. Use the conservative value when space permits.

Table VI-4. Linear Loading Rates Based on Limiting Conditions

	Linear Loading Rate Range (gpd/linear ft)	
Limiting Condition	Conservative Value	Space-Limited Value
Solid bedrock	3	4
Impermeable soil layer	3	4
Seasonal high water table	3	4
Semi-permeable soil layer	5	6
Fractured compacted till	5	6
Creviced or fractured bedrock	8	10
Sand and/or gravel layer	8	10

Note: The values in this table are the same values shown on Figure VI-7.

Example:

The soil evaluation revealed the limiting condition as a soil layer with fine texture and weak structure that has poor drainage. The soil mottles are an indication of a seasonal perched water table. The area available seems large enough to accommodate the conservative linear loading rate of 3 gpd/lf (Table VI-4) so this will be used.

Linear Loading Rate = 3 gpd/lf (the conservative value)

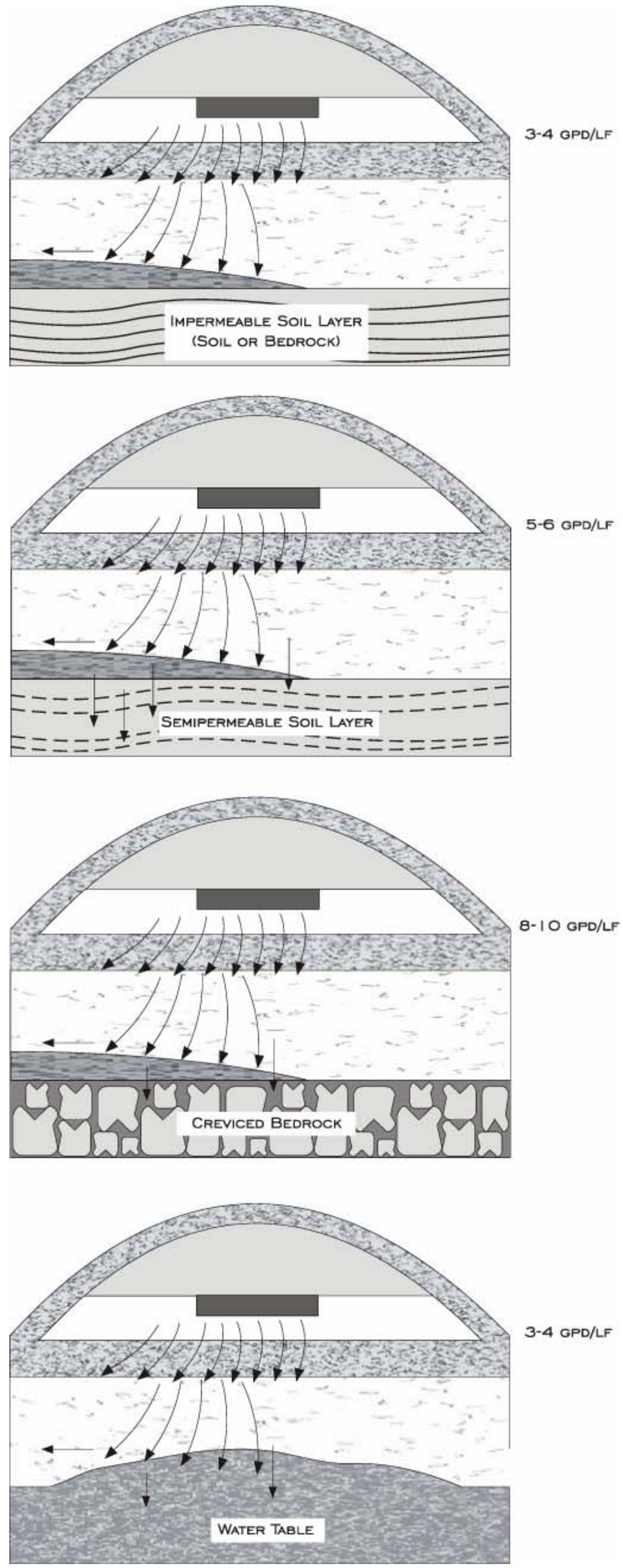


Figure VI-7. Linear Loading and Lateral Movement of Percolate Through Soil and Geologic Materials

Adapted from Converse and Tyler, 1990.

***Design Step 4.* Select the Sand Fill Loading Rate**

The selection of sand fill material is critical to long-term performance of the mound system. The purpose of the sand fill is to accept effluent from the distribution system and provide much of the treatment of the wastewater before infiltration into the natural soil. Suitable sand is a type that can be loaded at a reasonable rate and will provide satisfactory treatment. Generally, the finer the sand the better the treatment but the slower the wastewater infiltration will be from the absorption bed. However, too fine sand cannot be loaded at an acceptable rate and may become severely clogged, which may result in failure of the mound system. Too coarse sand will allow effluent to pass through the mound with inadequate treatment.

Following the USDA Soil Textural Classification, coarse sand is suitable. However, this is subject to the following two conditions: (1) no more than 20% by weight is gravel (> 2 mm), and (2) no more than 5% by weight is silt and clay (< 0.053 mm). To achieve a fines content this low usually requires that the sand material be washed to remove the fines. Note: Request a sieve analysis report from the aggregate supplier for the proposed sand to verify the criteria specified here are met.

Concrete sand is produced by many sand and gravel quarries in Kansas and generally meets the criteria for the very coarse and very fine fractions. The fine aggregate specified by the Kansas Department of Transportation will meet the mound sand requirements. The specification is detailed in Section 703.02 of Aggregate for Portland Cement Concrete, Office of Construction Administration, 2002 Construction and Material Specifications. Although mason sand is also commonly available, it is finer sand than concrete sand and is not recommended. Limestone sand is not suited although it may meet size requirements. Limestone sand can dissolve over time, reducing the system's useful life.

Sand specifications are also given in terms of effective size and uniformity coefficient. When using these criteria, select sand with an effective size in the range of 0.15-0.30 mm, and with a uniformity coefficient in the range of 4-6. When the sand meets these guidelines, the recommended design sand fill loading rate is 1.0 gpd/ft^2 when the wastewater is typical domestic septic tank effluent. If the septic tank effluent has a higher than normal strength such as from a restaurant, the wastewater quality should be evaluated and the sand fill loading rate should be reduced accordingly. When treating higher strength wastewater, the sand fill loading rate should either be reduced, or additional pretreatment installed in order to achieve a waste strength comparable to domestic effluent before distribution to the sand fill material.

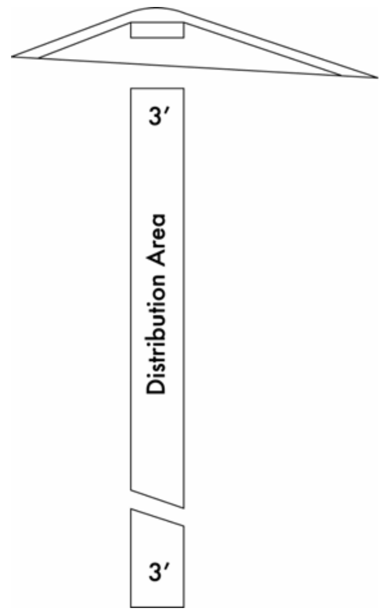
Sand Fill Loading Rate = 1.0 gpd/ft^2 (unless a sand is used that does not meet the specifications defined above).

Example:

The engineered sand fill specified for a mound will be used and the recommended sand fill loading rate of one gallon per square foot per day. (1.0 gpd/ft^2) will be used.

Sand Fill Loading Rate = 1.0 gpd/ft^2

Design Step 5. **Determine the Distribution Area Width.**



The distribution area runs the length of the mound at the top of the sand fill as shown in the diagram to the right. The distribution area is where wastewater is applied at the surface of the sand fill material. It is similar to the bottom of a lateral trench. The distribution area width is obtained by dividing the linear loading rate from step 3 by the sand fill loading rate from step 4.

$$\textit{Distribution Area Width} = \frac{\textit{Linear Loading Rate (gpd/lf)}}{\textit{Sand Fill Loading Rate (gpd/ft}^2)}$$

Example:

Distribution Area Width = $(3\ gpd/lf)/(1\ gpd/ft^2)$ *= 3 ft*

Distribution Area Width = 3 ft = 36 inches

Design Step 6. Determine the Distribution Area Length

The distribution area length is obtained by dividing the wastewater flow rate (gpd) from step 2 by the linear loading rate (gpd/lf) from step 3 as shown in the following equation.

Distribution Area Length = Wastewater Flow Rate (gpd) / Linear Loading Rate (gpd/lf)

Example:

Distributon Area Length = (450 gpd)/(3 gpd/lf) = 150 feet

Distributon Area Length = 150 feet

Design Step 7. **Select Basal Area Loading Rate**

Wastewater percolates through the sand fill by gravity. When the partially treated wastewater reaches the natural soil it can not move as quickly through the soil as in the more porous sand above. The wastewater begins to spread out and flow downslope. The purpose of the basal loading rate is to assure that there is adequate area at the base of the mound for the water to spread out when it contacts the soil surface. The properties of the surface soil horizon determine the basal loading rate. However, when there is a less permeable layer within the top 2 feet of soil below the mound, a more conservative basal loading rate may be selected.

Choose the basal loading rate from Chapter IV, Table IV-4 (reproduced here for convenience as Table VI-5).

Example:

The surface soil layer (top 7 inches) is a silt loam texture with moderate granular structure. Because a mound gives better treatment (BOD=30), a suitable basal loading rate from Table VI-5 is 0.8 gpd/ft^2. However, because the internal drainage in the next lower soil layer is poorer and there is adequate area it is advisable to use a lower basal area loading rate. A rate of only 0.3 gpd/ft^2 is appropriate for a silty clay texture with moderate structure (BOD=30).

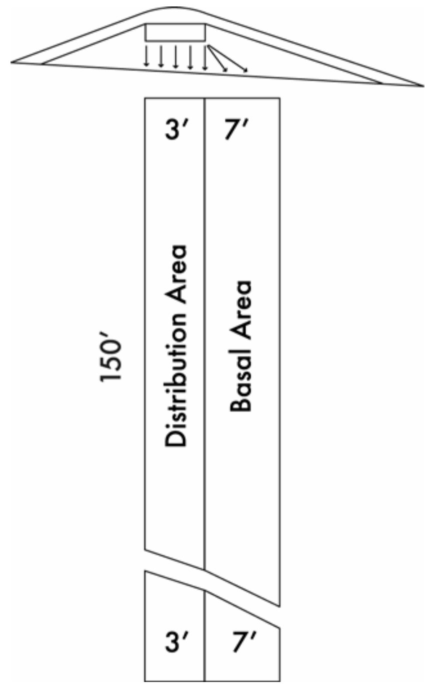
The Basal Area Loading Rate = 0.3 gpd/ft².

Table VI-5. Recommended Design Loading Rate for Various Soil Texture, Structure, and Effluent Quality

Texture	Structure		Hydraulic loading (gpd/ft²)	
	Shape	Grade	BOD=150[1]	BOD=30[2]
Coarse sand, sand, loamy coarse sand, loamy sand	Single grain	Structureless	0.8	1.6
Fine sand, very fine sand, loamy very fine sand	Single grain	Structureless	0.4	1.0
Coarse sandy loam, sandy loam	Massive	Structureless	0.2	0.6
	Platy	Weak	0.2	0.5
		Moderate, Strong		
	Prismatic, blocky, granular	Weak	0.5	0.7
		Moderate, Strong	0.6	1.0
Fine sandy loam, very fine sandy loam	Massive	Structureless	0.2	0.5
	Platy	All grades		
	Prismatic, blocky, granular	Weak	0.2	0.6
		Moderate, Strong	0.4	0.8
Loam	Massive	Structureless	0.2	0.5
	Platy	All grades		
	Prismatic, blocky, granular	Weak	0.4	0.6
		Moderate, Strong	0.6	0.8
Silt Loam	Massive	Structureless		0.2
	Platy	All grades		
	Prismatic, blocky, granular	Weak	0.4	0.6
		Moderate, Strong	0.6	0.8
Sandy clay loam, clay loam, silty clay loam	Massive	Structureless		
	Platy	All grades		
	Prismatic, blocky, granular	Weak	0.2	0.3
		Moderate, Strong	0.4	0.6
Sandy clay, silty clay, clay	Massive	Structureless		
	Platy	All grades		
	Prismatic, blocky, granular	Weak		
		Moderate, Strong	0.2	0.3

[1] *typical septic tank effluent BOD concentration*
[2] *typical enhanced (advanced) treatment component effluent*
Source: *Table IV-4 page IV-7of the Environmental Health Handbook; reproduced here for user convenience.*

Design Step 8. **Determine the Basal Width**



The basal area is critical for a mound because the wastewater that moves through the mound must be absorbed by the natural soil surface. To ensure that water will infiltrate, surface compaction must be avoided in this area. The mound basal area length and width should be outlined on the site and protected from construction traffic and equipment. (Note: The basal width is normally less than the mound side widths, which are required to provide a mound side slope as selected but no steeper than 3:1.)The minimum basal width is the linear loading rate (gpd/ft) divided by the basal loading rate (gpd/ft^2).

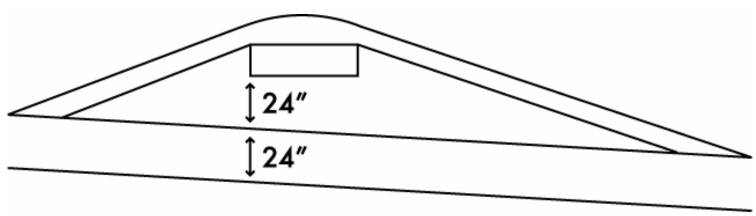
$$\textit{Basal Width} = \frac{\textit{Linear Loading Rate (gpd/lf)}}{\textit{Basal Loading Rate (gpd/ft}^2\textit{)}}$$

Example:

Basal Width = (3 gpd/lf) /(0.3 gpd/ft^2) = 10 ft

This basal width is 10 - 3 = 7 feet wider than the distribution area width.

Design Step 9. **Determine Upslope Sand Fill Depth**



Bulletin 4-2 states 4 feet of suitable soil is required beneath soil absorption systems. The mound sand fill combined with the existing suitable soil must be at least 4 feet. The available suitable soil depth is obtained from the soil profile evaluation conducted within the proposed area, step 1.

The depth of required sand fill is determined by subtracting the available suitable soil on the site from the required 4 feet or 48 inches of aerated soil required in Kansas.

Example:

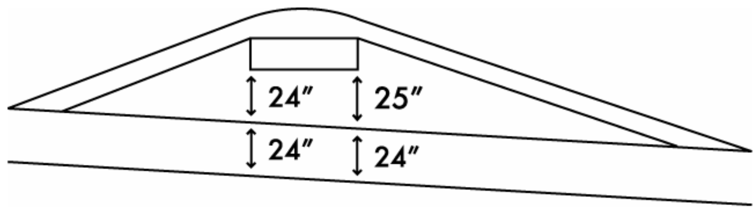
In the design example, the silt loam top layer (0-7 inches) and the silty clay with moderate structure second layer (7-24 inches) could be considered suitable. The deeper part of the soil profile is not suitable due to its silty clay texture and weak or massive structure. The soil profile shows 24 inches of suitable soil. The mound sand fill combined with the existing suitable soil must total at least 4 feet.

Upslope Sand Fill Depth = (48 inches) - (Depth of Suitable Soil to Limiting Condition)

Upslope Sand Fill Depth = (48 inches) - (24 inches) = 24 inches

***Design Step 10*. Determine Downslope Sand Fill Depth**

The bottom of the distribution area (small rectangle at the top of the mound) must be constructed level. Therefore, sloping sites must have a deeper sand fill on the downslope side of the distribution area.



The depth at the downslope edge of the distribution area is the upslope depth plus the site slope times the width of the distribution area.

Example:

The site slope is 3 percent (0.03) for the design example (step 1). The downslope fill depth is obtained by adding the slope times the width and to the upslope fill depth.

Downslope Sand Fill Depth = (Mound Sand Fill Upslope Depth) + (Site Slope) x (Distribution Width)

= (24 inches) + (0.03) x (36 inches) = 24 + 1.08

Downslope Sand Fill Depth = 25.08 or 25 inches

***Design Step 11*. Mound Cover Depth, Distribution Area Depth, and Distribution Cap Depth**

A mound cover depth of 6 inches of soil is required to protect the mound side slopes, the sand fill, and to ensure proper performance. This soil cover supports grass roots needed for erosion control and also provides frost protection. Because the mound soil cover must have specific properties, it can be an expensive construction component. The preferred materials for a mound cover are sand loam, loamy sand, or silt loam. The soil must be adequate to support grass growth preventing soil erosion. Generally high clay soils are not suitable without significant amendments to improve properties. Do not compact the mound cover soil because the microbial community treating the wastewater entering the mound and the grass growing on the mound need air. Natural settling of the mound cover and cap will occur over time and will not interfere with mound operation.

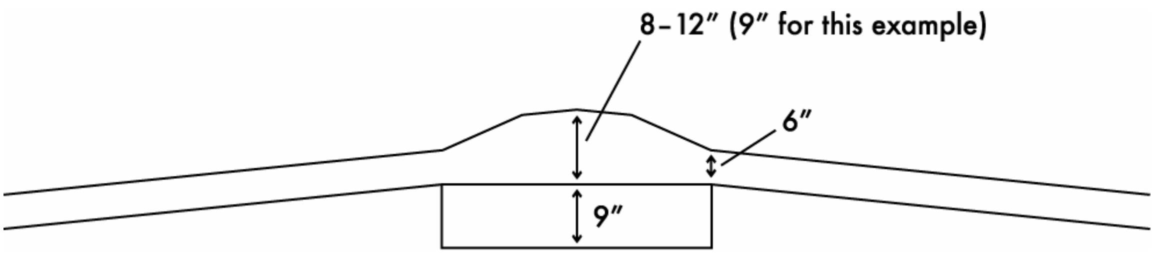
The distribution area fill should be clean, washed, coarse aggregate to surround and protect the distribution lines and assure good contact with the sand fill. At least 6 inches of coarse aggregate base should be beneath the distribution laterals, 1½ more inches of aggregate depth for pipe depth, and 1½ inch of aggregate covering the distribution laterals. Thus the total aggregate depth should be 9 inches. The distribution aggregate should be covered with geotextile filter fabric to keep soil from working down into and filling voids of the distribution aggregate. In some areas chambers are used in place of aggregate for the distribution area.

A distribution area cap must cover the distribution area with adequater soil to drain water off the top of the mound and to provide freeze protection for the distribution area. This cap should be more than the 6 inches used for the mound cover but should be no greater than 12 inches deep. The wider the distribution area the deeper the cover will need to be. Often 8 to 10 inches is adequate.

Distribution Area (Aggregate) Depth = 9 inches

Mound Cover Depth = 6 inches

Distribution Cap Depth = 8-12 inches Note: the wider the distribution area the thicker the cap should be to ensure adequate slope for drainage.



Example:

Because the distribution area is narrow, the depth selected for the distribution cap was 9 inches. Other depths used for this example are as described in the discussion of this section.

Distribution Area (Aggregate) Depth = 9 inches.

Mound Cover Depth = 6 inches.

Distribution Cap Depth = 9 inches.

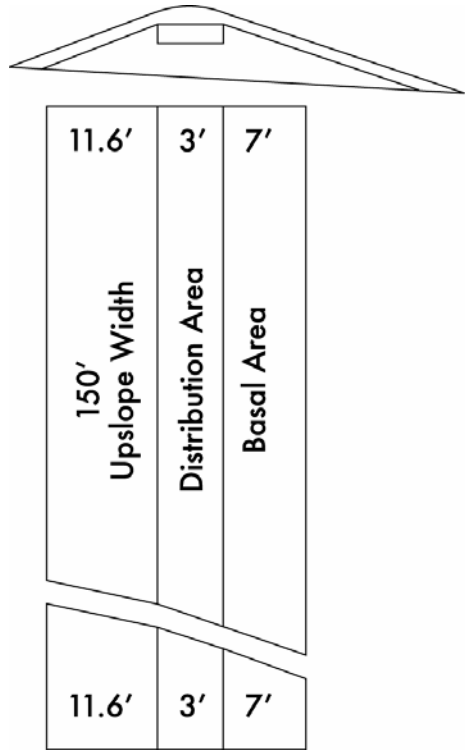
Design Step 12. Determine the Upslope Fill Width

The mound side slope ratio (run:rise) should not be steeper than 3:1 for safe mowing, with 4:1 or flatter preferred. The larger the ratio, the flatter the slope. Flatter side slopes require more fill to construct resulting in a larger mound footprint, but generally blend better with the landscape. The mound footprint extends in all directions beyond the distribution area. On level sites the mound side slope ratio is used to calculate the distance the sand fill will extend to the sides of the distribution area. On sloping sites the upslope width intersects the site slope making the distance less than calculated using the side slope ratio. An upslope width correction factor must be used for the width adjustment. Upslope width correction factors are provided in Table VI-6 for a range of site slopes and mound side slope ratios.

Table VI-6. Mound Upslope Width Correction Factors

Site Slope, %	Mound Side Slope Ratios 3:1	4:1	5:1	6:1	7:1
0	1	1	1	1	1
1	0.971	0.962	0.952	0.943	0.935
2	0.943	0.926	0.909	0.893	0.877
3	0.917	0.893	0.870	0.847	0.826
4	0.893	0.862	0.833	0.806	0.781
5	0.870	0.833	0.800	0.769	0.741
6	0.847	0.806	0.769	0.735	0.704
7	0.826	0.781	0.741	0.704	0.671
8	0.806	0.758	0.714	0.676	0.641
9	0.787	0.735	0.690	0.649	0.613
10	0.769	0.714	0.667	0.625	0.588
11	0.752	0.694	0.645	0.602	0.565
12	0.735	0.676	0.625	0.581	0.543
13	0.719	0.658	0.606	0.562	0.524
14	0.704	0.641	0.588	0.543	0.505
15	0.690	0.625	0.571	0.526	0.488

Note: This table is based on the upslope width correction factor = 1/[1+(Mound side slope ratio, or run) x (Site slope as a decimal)].



Example:

For the design example a side slope ratio of 4:1 is used because that shape is easier to maintain (mow) than steeper sides slopes. Compared with larger ratios this ratio also minimizes the footprint of the mound and the quantity of fill materials required. However, slopes this steep (4:1) are not easy to mow so when possible it is desirable to use a slope ratio of 5:1 or flatter. The upslope correction factor from Table VI-6 for the 3 percent site slope and 4:1 side slope ratio is 0.893.

Upslope Fill Width = (Side slope ratio or run) x (Upslope sand fill depth + Aggregate depth + Mound cover depth) x (Upslope width correction factor)

= (4) x (24 inches + 9 inches + 6 inches) x (0.893) = 139.31 in

Upslope Fill Width = 139 inches or 11.6 feet

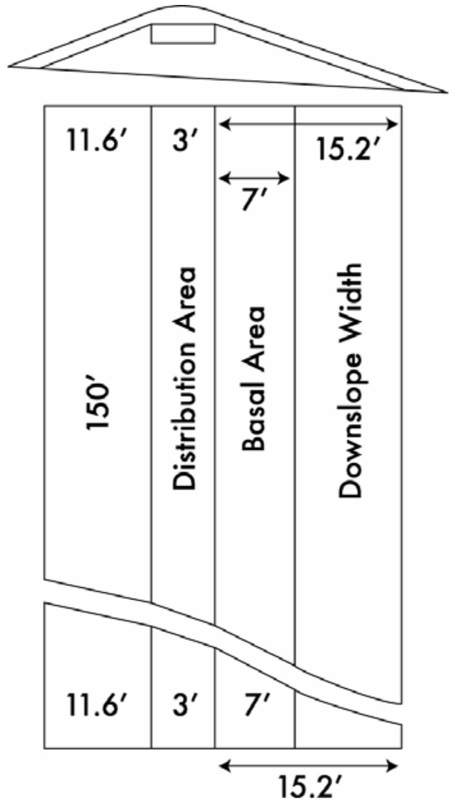
Design Step 13. **Determine the Downslope Fill Width**

Since the site slopes away on the downslope side, a downslope width correction factor is required for the width adjustment. Downslope width correction factors are provided in Table VI-7 for a range of site slopes and mound side slope ratios. Note: Downslope width plus the distribution area width (Step 5) must be at least as much as the basal width.

Table VI-7. Mound Downslope Width Correction Factors

Site Slope, %	Mound Side Slope Ratios 3:1	4:1	5:1	6:1	7:1
0	1	1	1	1	1
1	1.031	1.042	1.053	1.064	1.075
2	1.064	1.087	1.111	1.136	1.163
3	1.099	1.136	1.176	1.220	1.266
4	1.136	1.190	1.250	1.316	1.389
5	1.176	1.250	1.333	1.429	1.538
6	1.22	1.316	1.429	1.563	1.724
7	1.266	1.389	1.538	1.724	1.961
8	1.316	1.471	1.667	1.923	2.273
9	1.370	1.563	1.818	2.174	2.703
10	1.429	1.667	2.000	2.500	3.333
11	1.493	1.786	2.222	2.941	4.348
12	1.563	1.923	2.500	3.570	6.250
13	1.639	2.083	2.857	4.545	11.111
14	1.724	2.273	3.333	6.250	50
15	1.818	2.500	4.000	10.00	xx

Note: This table is base on the downslope width correction factor = 1/[1 - (Mound side slope ratio, or run) x (Site slope as a decimal)].



Downslope Fill Width = (Side slope ratio or run) x (Downslope sand fill depth + Aggregate depth + Mound cover depth) x (Downslope width correction factor)

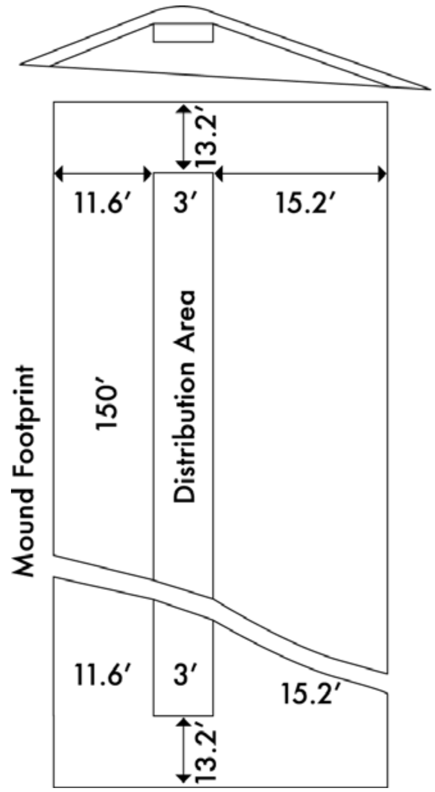
Example:

The design example uses the side slope ratio 4:1. The downslope correction factor for the 3 percent site slope and 3:1 side slope ratio is 1.136.

Downslope Fill Width = (4) x (25.1 inches + 9 inches + 6 inches) x (1.136) = 182.21 in

Downslope Fill Width = 182 inches or 15.2 feet

Design Step 14. **Determine the End Slope Length.**



The mound ends have the same slope as the side slope ratios used for the sides of the mound.

End Slope Length = *(Side slope ratio or run) x (Average depth of sand fill under absorption area [average of Steps 9 and 1] + Aggregate depth + Mound cover depth)*

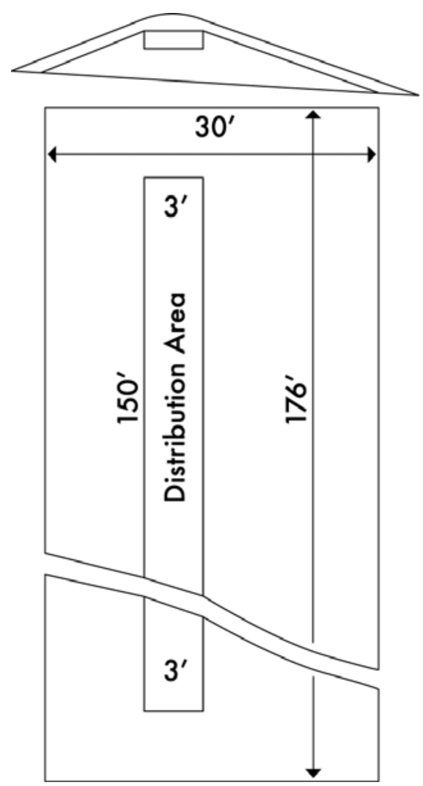
Example:

The mound side slope is 4:1 for this design example.

End Slope Length = *4 x ([24 + 25]/2 + 9 + 6 in)*
= *158.2 in*

End Slope Length = 158 inches or 13.2 feet

Design Step 15. **Overall Mound System Length and Width.**



The overall length and width of the mound is also called the mound footprint and is the area covered by the completed mound. Add the end slope length (step 14) to both ends of the distribution area (step 6) to determine the overall mound length. Add the upslope fill width (step 12) and downslope fill width (step 13), to the distribution area (step 5) to obtain the overall mound width. Knowing both length and width of the mound, the footprint can be located on the site.

Overall Length = *(Distribution area length) + (2) x (End slope length)*

Overall Width = *(Distribution area width) + (Upslope fill width) + (Downslope fill width)*

Example:

Overall Length = (150 ft) + (2) x (13.2 ft) = 176.4 feet

Overall Length = 176 feet

Overall Width = (3 ft) + (11.6 ft) + (15.2 ft) = 29.8 ft

Overall Width = 30 feet

Stake out the mound so all parts are parallel to the contour. The length of this mound system (176 ft) will fit within the proposed site area (50 x 180 ft). However, wastewater is applied only to the distribution area (3 by 150 ft) which is smaller than the site area available. Because wastewater should not move into the ends of the mound to any appreciable extent in restricted space conditions it may be acceptable for the mound end to extend into the setback width (beyond the mound end location shown in Figure VI-6).

Engineered Mound Design Summary

Following the 15 design steps described above will result in the appropriate size for a mound to adequately fit site conditions. The volume of fill materials must still be calculated based on the dimensions obtained. Be sure the site plan and design specifications require that there be no trees in the mound footprint area. Because it is not acceptable to build a mound on a site that has been disturbed by the mechanical removal of trees, cut any existing trees flush with the ground surface. The remaining tree root system will then be covered by the mound. Avoid placing the distribution area directly above the remains of a tree.

In some cases a valuable tree within the footprint near the edge of a mound could be preserved with a shallow retaining wall placed out several feet around the tree; using mound fill to the retaining wall. Do not attempt this on the downslope side of the mound because the toe could leak at this location. Soil mounded around the base of a tree may cause the tree to die.

Recommended Construction for Mound System

Because a large portion of mound system components are above-grade, some people say mound systems are easier to construct than conventional in-ground soil absorption systems. However, mound construction requires procedures and perhaps some equipment unique to its construction. Once the design has been completed and verified and the soil conditions are correct, construction is ready to begin. The most important things for a contractor to remember are outlined in the following 11-step procedure. It is strongly recommended that the following procedure be followed as closely as possible until the contractor has gained experience through installation of several systems. These construction steps are adapted from Ohio State University Extension, Bulletin 813. (Chen and Mancl, 2004)

***Construction Step 1.* Mark the Mound Site**

Lay out the proposed mound system along the contour of the lot in the area specified by the detailed soil and site evaluation. According to the design, outline and stake three areas: distribution area, basal area, and overall footprint of the mound.

***Construction Step 2.* Locate the Septic Tank and Dosing Tank**

Determine the septic tank and dosing tank locations based on the site layout. The tanks should be installed to the side or upslope of the mound.

Construction Step 3. **Prepare the Mound Site**

Prepare the site for the mound. Mow grass to a maximum 2-inch height and remove cuttings from the mound location. Trees should be cut flush with the ground surface leaving the base and roots undisturbed. Construction should be delayed if the soil is too wet. Dig a trench from the dosing tank to the side or upslope of the mound. The trench is for the pressure pipe carrying septic tank effluent to the center of the mound. The pressure pipe should be installed with an adequate slope so septic tank effluent drains back to the dosing tank after the pump shuts off. The trench should be adequately bedded and filled with granular backfill to reduce settling.

Construction Step 4. **Prepare the Soil Under the Mound**

Prepare the soil surface in the basal area. A chisel plow on a small tractor or special teeth fitted to a backhoe bucket can be used to scarify the soil surface. Scarifying the soil surface and breaking up the sod growing in the basal area will improve the contact of the mound sand with the natural soil. Avoid any traffic and equipment on the basal area or downslope of the mound. The basal area will be covered with a layer of sand that protects the soil under the mound from compaction during construction.

Construction Step 5. **Place the Sand Fill**

Apply the sand fill to cover the basal area and form the absorption area. Two methods are used to spread and shape the mound. In the traditional approach a backhoe moves sand to cover the basal area in the shape of the mound after the truck delivers sand to the upslope side. The alternative method is to use a truck equipped with a conveyor to distribute the sand over the basal area to the appropriate depth. This approach is especially suited to limited access sites. Spray paint markings on the ground to outline the basal area and use stakes to indicate the desired depth of sand at critical points to guide the operator in distributing sand to shape the mound.

Construction Step 6. **Place Absorption Rock**

Level the sand surface in the absorption area. Cut off the distribution main at least 4 inches above the sand surface and remove all bits of plastic and rough spots that can accumulate debris and clog the pipe. Place supports on the sand (sections of 6-inch pipe work well) to hold the distribution pipe at the desired level. Lay out the main, manifold, and laterals according to the designs. Cement all tees and joints to prevent leaks and pressure losses.

***Construction Step 7.* Layout Distribution Laterals**

Distribution laterals are typically small-diameter pipe with small orifices (holes) spaced evenly along the top. The distribution orifices should be mechanically drilled at the shop with a drill press. Hand drilling is discouraged. Mark the hole positions evenly on the top of the laterals according to the design calculations. Drill the design-size holes with a sharp drill bit to help create clean holes and minimize rough edges. Put one of the same size holes in the bottom at the end of each lateral as a drain. Slide a smaller diameter pipe back and forth inside each pipe to knock off any burrs of plastic around the drill holes. The pipe size, hole size, and hole spacing should be carefully calculated, laid out, and marked in the shop to avoid mistakes in assembly. Consult with the designer about necessary adjustments during the construction to be sure this will not affect performance. Guidance for designing pump and distribution systems will be covered in Chapter X.

Attach turn-ups to the end of each distribution lateral pipe with a removable cap to allow accumulated debris to be flushed from the pipes. The turn-up is supported with gravel to accept the flushed wastewater and allow it to flow back into the mound for treatment. An irrigation valve box (Figure VI-8) works well to house the turn-ups so they can be easily located and accessed for regular maintenance. To facilitate maintenance a ball valve is often used with a threaded plug or cap. The squirt height for the plug or cap with the correct size hole should be recorded for all new installations. During maintenance the squirt height is measured to verify that the system is functioning as planned and installed.

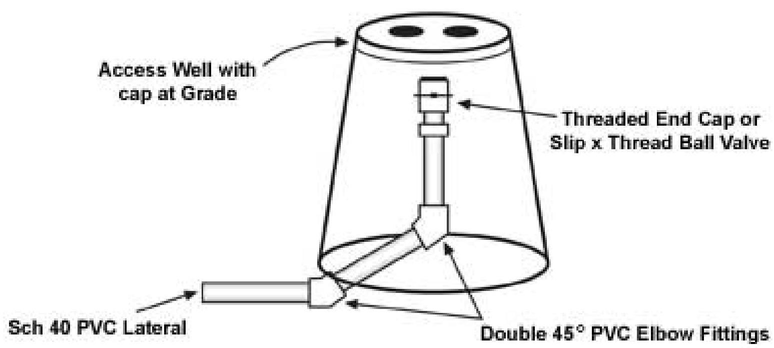


Figure VI-8. Valve Box for Access to Flush Lateral Lines (not to scale)

***Construction Step 8.* Install Observation Access**

Observation pipes extending from the absorption surface through the gravel to the top of the mound serve as a window and provide a convenient way to check the conditions and ponding of wastewater above the sand. At least two 4-inch observation pipes – one at either end of the distribution area – are recommended; three would be better. They are inexpensive to install at the time of construction. Three methods of anchoring observation pipes so they do not pull out are shown in Figure VI-9.

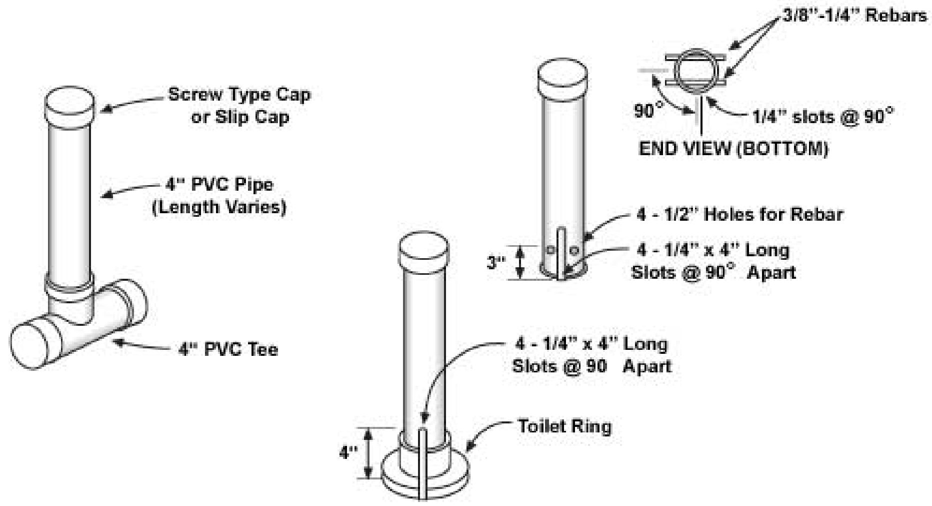


Figure VI-9. Three Methods of Anchoring Observation Pipes (Converse and Tyler, 1990)

Construction Step 9. Pressure Test and Cover the Distribution System

Conduct a pressure test for each line to check for leaks, plugging, broken pipes, drainback, and to record the squirt height of each line. The squirt height should be uniform for all distribution laterals. Cover the distribution system with clean, washed gravel. The holes on the top of the pipe must be shielded so they are not restricted by the gravel cover. A 4-inch perforated pipe slipped over the distribution pipe, or commercial deflectors make effective shields. Cover the gravel with geotextile fabric before placing the protective layer of soil on top of the mound. Chambers can also be used in place of gravel on top of the sand. The distribution laterals, as designed, are hung from the top of the chambers.

Construction Step 10. Cover the Mound with Soil

Cover the sand and gravel with an insulating layer of soil. Deliver soil cover material to the upslope side of the mound and cover the mound working from the upslope side. Never allow any heavy equipment on the area downslope of the mound before or during construction. On sloping sites the treated wastewater must be able to flow downslope through the soil. Heavy equipment will cause unnecessary soil compaction and lead to bleed-out at the toe or downslope of the mound. Properly grade the upslope side of the mound to divert surface runoff around the mound. Stay on the mound while shaping the downslope side to limit soil compaction. A small bulldozer works well to shape the mound. Seed the soil cover of the mound to limit soil erosion as soon as the construction is completed. If it is late in the season, additional erosion control measures may be necessary.

Construction Step 11. Complete and Deliver As-built Drawings

Preparation of as-built drawings is strongly recommended for good record keeping. The as-built drawings should include actual mound system layout, elevations, benchmark, and start-up date. They should contain pertinent information needed for reference during service, especially the initial squirt height for each lateral. The drawings should be kept for personal records with copies provided to the owner and inspector. Photos make an excellent verification record.

Mound Maintenance

Maintenance-free wastewater treatment systems do not exist. All systems require some regular maintenance. Because mound systems have mechanical pumps, electrical controls, small diameter laterals, and orifices, they require semi-annual maintenance. Each inspection and maintenance should take a trained professional approximately 30 minutes to complete. For systems with great distances between pumps and the mound, it may take as long as one hour to complete the necessary inspection and maintenance.

Important inspection and maintenance tasks include:

- Make sure no trees or shrubs are planted on the mound. Tree roots may clog the distribution pipes.
- Avoid sprinkler systems and irrigation on the mound. Plant ground-cover vegetation that tolerates dry conditions, if necessary.
- Walk around the lot and look for landscape changes that could interfere with or damage the mound system.
- Walk downslope of the mound to check for signs of surfacing sewage.
- Locate and open each inspection port to check for ponding.
- Activate the pump and check alarms.
- Open valve box at the end of each lateral to open and flush lines to remove debris that may clog holes in the small lateral pipes.
- After the lines are flushed, measure the squirt height for each line and compare it to the initial test to check for orifice plugging, broken pipe, or other problem. Record the results of this pressure test each time maintenance is conducted.

Mound System Summary

Mounds have a long history of use. When well designed, properly constructed, and adequately maintained they have a long service life. Mounds reliably provide high quality water to reach the natural soil surface under the mound. Mounds do not require a separate soil absorption system because the soil beneath the mound is the absorption field. Mounds are well suited to shallow soils and shallow or seasonally perched water tables. They are site specific so require a separate design for each site situation. The cost of engineered fill materials may make a mound more expensive than some other options. Because they have pumps, controls, and small diameter distribution pipes with orifices, they require more maintenance than traditional septic tank and lateral systems.

SAND FILTER SYSTEM

Sand filters have been used in wastewater treatment for many decades. The technology is used for single homes, clusters of homes, institutions, and small municipal systems. They have been used for discharging as well as non-discharging applications. Remember: In Kansas surface discharge from individual onsite systems is not permitted so a discharging system would only be an option for a cluster or a small community system that holds a NPDES permit.

Sand filters can be designed with several variations. All sand filters are designed and constructed to receive small, usually timed doses. This means that wastewater loading to the filter starts and stops at intervals. During the rest cycle wastewater seeps through the filter media while microbes provide the treatment and air is introduced before the next dose is applied.

Media is the material used in the bed of the filter. The media provides a degree of wastewater filtering or straining, but more importantly, provides a large surface area for the attachment of bacteria and other microorganisms that treat the wastewater. The media may range in size from sand to small pea gravel, depending on the design and operating conditions of the filter. The media must be within the size range specified in the design specifications to ensure that the filter will function properly. Other types of filters, similar to sand filters, utilize peat, foam, textile, or other material as media, and are discussed later in this chapter.

Sand filters may be designed and operated in either single-pass or recirculating mode. In a single-pass sand filter, the wastewater is applied to the top of the media and collected at the bottom for transfer to an absorption field. In a recirculating sand filter, the effluent from the media is split so part of it goes to the absorption field and the rest flows to the pump tank and is reapplied to the filter media. Typically 1/3 to 1/5 of the effluent from the sand filter is sent to the absorption field and the remainder is recycled to pass through the filter media again. In general, single-pass sand filters are larger in surface area and use coarse sand media rather than small gravel typical of recirculating filters. Although all are operated intermittently, the term intermittent sand filter is often used to refer to single-pass systems.

Dosing can be based on either time or level of water in the pump chamber. Time-dosing applies wastewater to the sand media for a fixed amount of time (or dose volume) at fixed time intervals (dose interval) when float switches allow pumping to be done. Time-dosing gives more even distribution of the wastewater throughout the day, but requires additional electronic controls. Even if time-dosing is used, the controls should be designed to override the timing and apply a dose if the level in the pump chamber rises too high, such as might occur when several loads of laundry are done in a short time period. Level-dosing applies wastewater whenever the water level in the pump or siphon chamber rises to a certain height and volume is not controlled.

Sand filters are usually used as the second step in wastewater treatment after solids in raw wastewater have been separated out in a septic tank. Effluent from a sand filter typically goes to a traditional soil absorption field. Over time, sand filters have proven themselves to be a reliable technology when properly designed, constructed, and maintained.

Sand Filter Components

Sand filters are constructed beds of sand or other suitable granular material, usually two to three feet deep. The filter material (called media) is typically contained in a liner made of plastic, concrete, or other impermeable material. Depending on the design, the sand filter may be situated above ground, partially above ground, or below ground, and the filter surface may be open or covered with soil. Septic tank effluent is applied to the filter surface in intermittent doses and receives treatment as it slowly trickles through the media. In most sand filters, the wastewater collects in an underdrain and flows by gravity or is pumped to an absorption field for final treatment and dispersal.

Sand filters are constructed and assembled on the site. Most materials are available locally, however, kits containing essentially all filter components, with the exception of the sand media, are also available. If the appropriate sand media cannot be obtained nearby, it must be shipped in, which will likely increase cost.

Suitable filter media can be purchased from aggregate companies or other suppliers. The media must be as clean and as uniform in size as possible to allow correct flow of wastewater. If the sand has too many small grains they will settle in the spaces between the larger grains, leaving inadequate space for the wastewater to flow. The media should be tested with a sieve analysis prior to use in the filter. The sieve analysis determines the amount of material that will pass through a mesh basket of a specific size.

Where appropriate sand media is not available or is too expensive, textile, foam, or peat media may be an alternative. A discussion of other media filters is included later in this chapter.

Sand Filter Operation

A few basic design, construction, and operating principles are common to every type of sand filter system. First, to prevent the sand filter from clogging, wastewater must be pre-treated in the septic tank to remove solids and scum. An effluent filter (or screen) is required in the septic tank as an additional step to ensure that no solids carry over to the filter media in times of heavy water use.

After the solids are removed in the septic tank, a pump equipped with an adjustable timing control doses the wastewater to the sand media in timed intervals. Applications are spaced intermittently to allow the sand media to drain between doses. This ensures that oxygen is introduced into the media between doses of wastewater. Oxygen is critical to the biological and chemical treatment processes taking place within the sand media.

Historically, sand filters were designed to flood the complete media surface with a thin layer of wastewater. Modern designs distribute wastewater evenly across the sand media surface. This is often accomplished by metering it evenly throughout a network of low-pressure distribution pipes. Figure VI-10 shows a plan view of a typical sand filter. As the wastewater percolates slowly through the filter media, natural physical, biological, and chemical processes occur which provide treatment. Most treatment occurs within the first 6 to 12 inches of the sand filter surface.

As wastewater percolates through the filter media suspended solids adhere to the sand grain surfaces through a process called adsorption where negatively charged grain surfaces attract positively charged waste particles. Larger suspended particles are also trapped in voids between grains.

Sand filters accomplish much of the treatment through natural biological processes. Like the soil in every yard, sand filters are home to a variety of organisms, many of which contribute to treatment by consuming organic matter in the wastewater. The sand media serves as a substrate with abundant pore space to transmit oxygen essential to the organisms. Bacteria are the most abundant organisms in the filters, and they decompose most of the waste. Other beneficial microbes found in the filter media include protozoa and worms, which also contribute to treatment. Most organic matter is broken down by microbes in the filter.

After the filter media has matured, usually within a few weeks, a microbial layer, called a biomat is formed at the boundary of the distribution network and the sand media. This thin dense layer is the most significant part of the sand filter. This layer contains a high concentration of microorganisms including bacteria and protozoa that consume the organic material in the wastewater. Protozoa feed on the bacteria and help prevent the biomat from becoming so thick that it clogs the sand media. This balance between the various life forms and the physical and chemical processes taking place in the sand filter results in extremely efficient, natural wastewater treatment. However these systems do have mechanical and electrical components that must have regular maintenance.

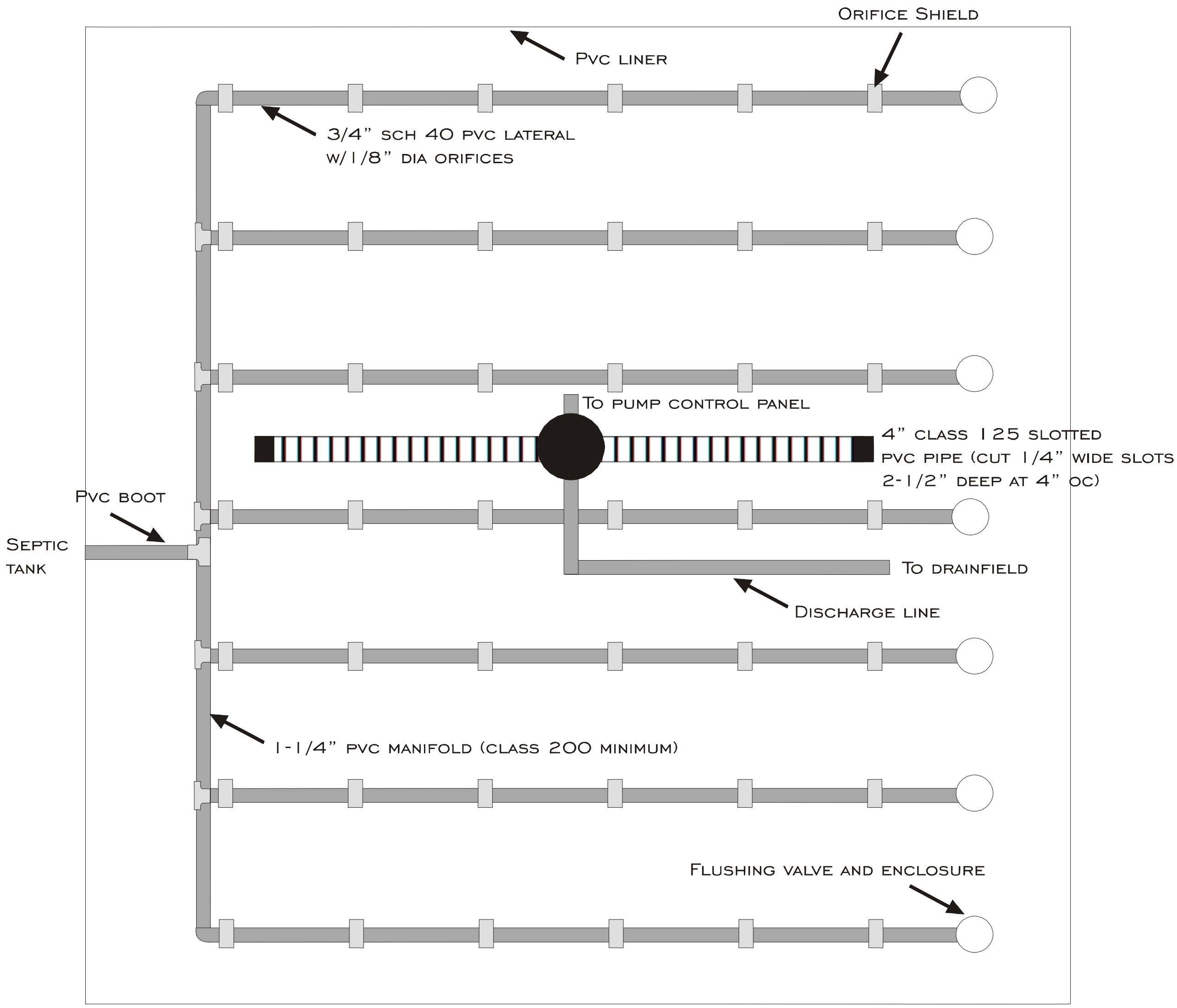


Figure VI-10. Plan View of Sand Filter Laterals and Drain

Single-Pass Sand Filter

Single-pass sand filters are constructed onsite and usually require an excavation about 3 to 4 feet deep. Single-pass (or intermittent) sand filter media has an effective size of 0.25 to 0.75mm. Before construction, a thorough site evaluation is needed to ensure the media bed will be level. The media bed must also be located to prevent inflow of surface water runoff. Generally, the entire media bed is contained in an impermeable membrane liner. A graded layer of washed gravel such as pea gravel is placed around underdrain pipes at the bottom of the media bed. The filter media is then placed on top of the layer of pea gravel. As with all sand filters, the depth of the media depends on the size of the grains and other factors, but normally ranges from 24-36 inches. Another layer of pea gravel is placed on top of the media bed, surrounding the network of distribution pipes. Geotextile fabric is then placed on top of the entire bed and covered with loam topsoil. A section view of a typical single-pass sand filter is shown in Figure VI-11.

Most single-pass sand filters are dosed frequently using a timer. After the wastewater percolates through the bed, it collects in the underdrains. From here it either flows or is pumped to a soil absorption field for final treatment. The hydraulic loading rate for single-pass sand filters is typically 1.2-1.5 gallons per day, per square foot. This is a relatively low rate compared with other sand filters, which helps to ensure the filter does not become overloaded or clogged. Due to this low hydraulic loading rate, single-pass sand filters usually require more surface area to treat the same amount of wastewater than recirculating sand filters. However, with efficient landscaping techniques, the space used for single-pass sand filters can be available for other aesthetic uses.

Recirculating Sand Filter

In a recirculating sand filter, wastewater flows by gravity from the septic tank to a dose tank, which is equipped with a pump, floats, and controls. Wastewater is then pumped to the filter media when it reaches a certain level in the tank or in timed doses. After the wastewater trickles through the media, it is collected in the underdrains. A flow splitter, either in the filter or dose tank, then directs a portion of this treated wastewater back to the dose or recirculation tank where it mixes with septic tank effluent and is returned to the filter media. The remaining filter media effluent bypasses the recirculation or dose tank and goes directly to the soil absorption field.

The recirculated sand filter effluent has a ratio of 3:1 to 5:1 when compared to effluent discharged to the soil absorption field. Weirs, moveable gates, and other devices are often used to direct part of the sand filter return flow to the recirculation tank and the remaining flow goes to the absorption field. A common way to divide flow is to use a tee in the return line from the sand filter underdrain that extends into the recirculation tank with the straight part going to the soil absorption field. A rubber ball in a screened cage rises with the water in the tank and plugs the tee when the tank reaches a certain level. When this happens, the remaining sand filter effluent is diverted to the soil absorption field.

Regardless of how flow is divided, the filter effluent and septic tank effluent are mixed in the recirculation tank so the wastewater applied to the sand filter is less concentrated than septic tank effluent. The wastewater also contains more oxygen than septic tank effluent, which helps eliminate odors.

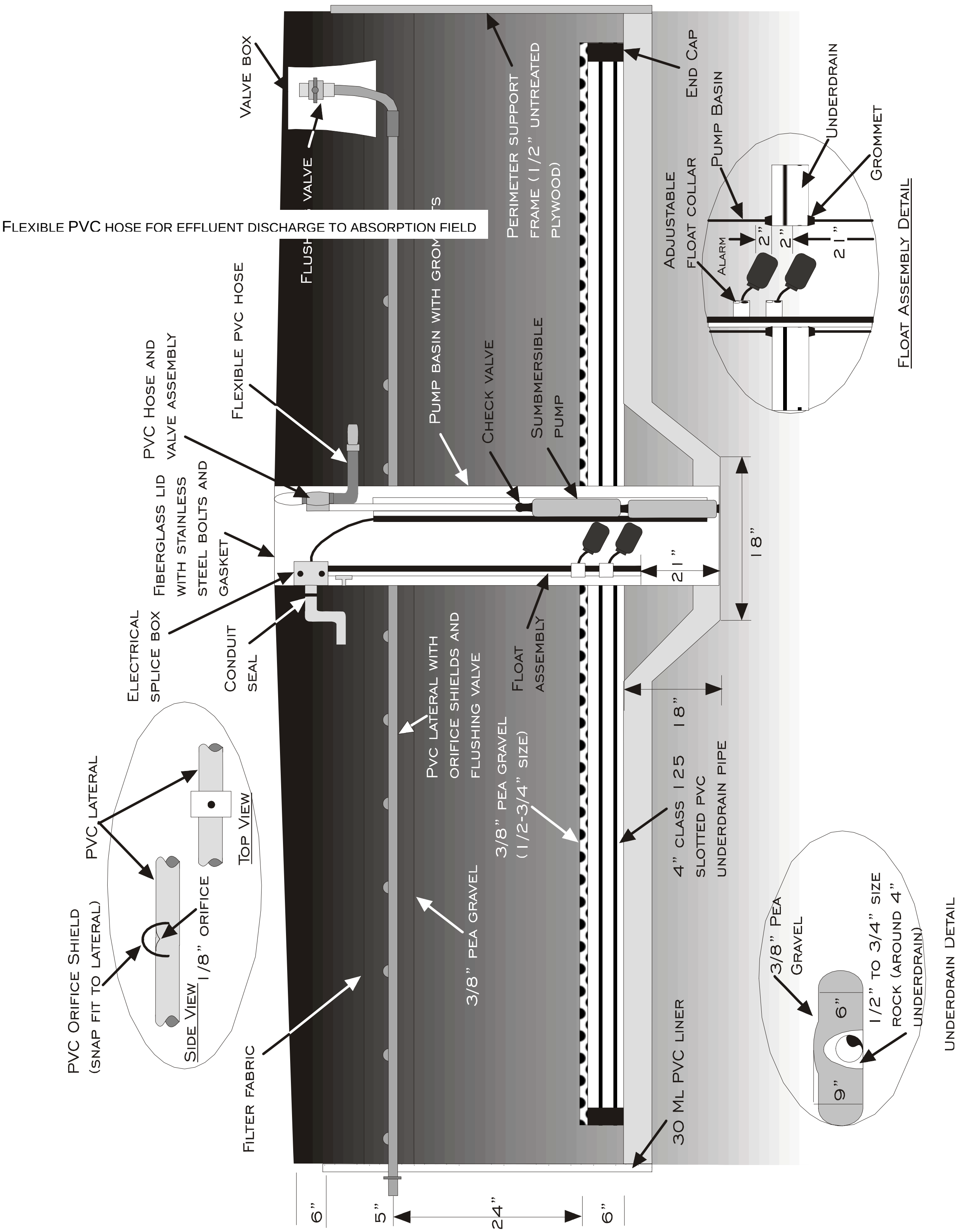


Figure VI-11. Section View of Typical Single-Pass Sand Filter Showing Components

The recirculating sand filter media has an effective size of 0.8-3.0 mm, which is coarser than media used in single-pass sand filters and, therefore, less prone to clogging. Hydraulic loading rates typically are 3-5 gallons per day per square foot, which means that less area is needed to treat the same amount of wastewater than with single-pass sand filter designs. Recirculating filters require more energy and routine maintenance than single-pass sand filters. Unlike the single-pass sand filter that is covered with soil, recirculating sand filters are typically covered with small stones or a loose-fitting cover, which maximizes oxygen transfer and minimizes disturbance.

Disadvantages of recirculating sand filters are that they are more sensitive to cold temperatures and more prone to freezing than the single-pass filter that is regularly dosed with warmer septic tank effluent and protected by a soil cover. Sometimes this problem can be remedied by adjusting the dosing frequency and recirculation ratio or by providing the sand filter bed with an insulating cover.

Recirculating sand filters are more commonly used for treating wastewater from small communities, residential developments, recreational areas, shopping centers, or institutions.. They can be used for sources generating up to 120,000 gallons of wastewater per day. They are usually constructed with two or more beds that can be operated in parallel or in series, which allows parts of the filter media to be rested while others are working. Some recirculating sand filters have removable covers that insulate from extreme cold weather, reduce odors, and minimize maintenance. Because odors are generated when septic tank effluent is dosed to the filter surface, the sand filter should be sited downwind from residences and businesses.

Sand Filter Media

The composition, size, uniformity, and depth of the media affect sand filter performance. In some areas where sand is not available locally, other materials, such as crushed glass, anthracite, garnet, mineral tailings, or bottom ash, may be used for filter media. Characteristics of the media's composition, such as its solubility, acidity, and hardness, must be considered in the filter design.

The size and uniformity of the filter media also affects the performance of the sand filter. Grains should be relatively uniform in size to prevent clogging. The media should be neither too coarse nor too fine. Coarse media may allow wastewater to pass though the filter too fast and not receive adequate treatment. Fine media may slow passage too much, is prone to clogging, and can prevent good oxygen transfer to parts of the filter.

"Effective size" and "uniformity coefficient" are measurements used to express these characteristics. Effective sizes for sand filter media range from 0.25-3.0 mm in diameter. Both types of sand filters have specific media size range requirements. A uniformity coefficient of four or less is recommended for all filter media. Figure VI-12 shows example sand filter media sieve analysis of a coarse media for recirculating filter and fine media for a single-pass filter. It is extremely important that the media be washed to be free of fines. A qualified person, perhaps an engineer, should inspect the media for cleanliness before it is used as filter media.

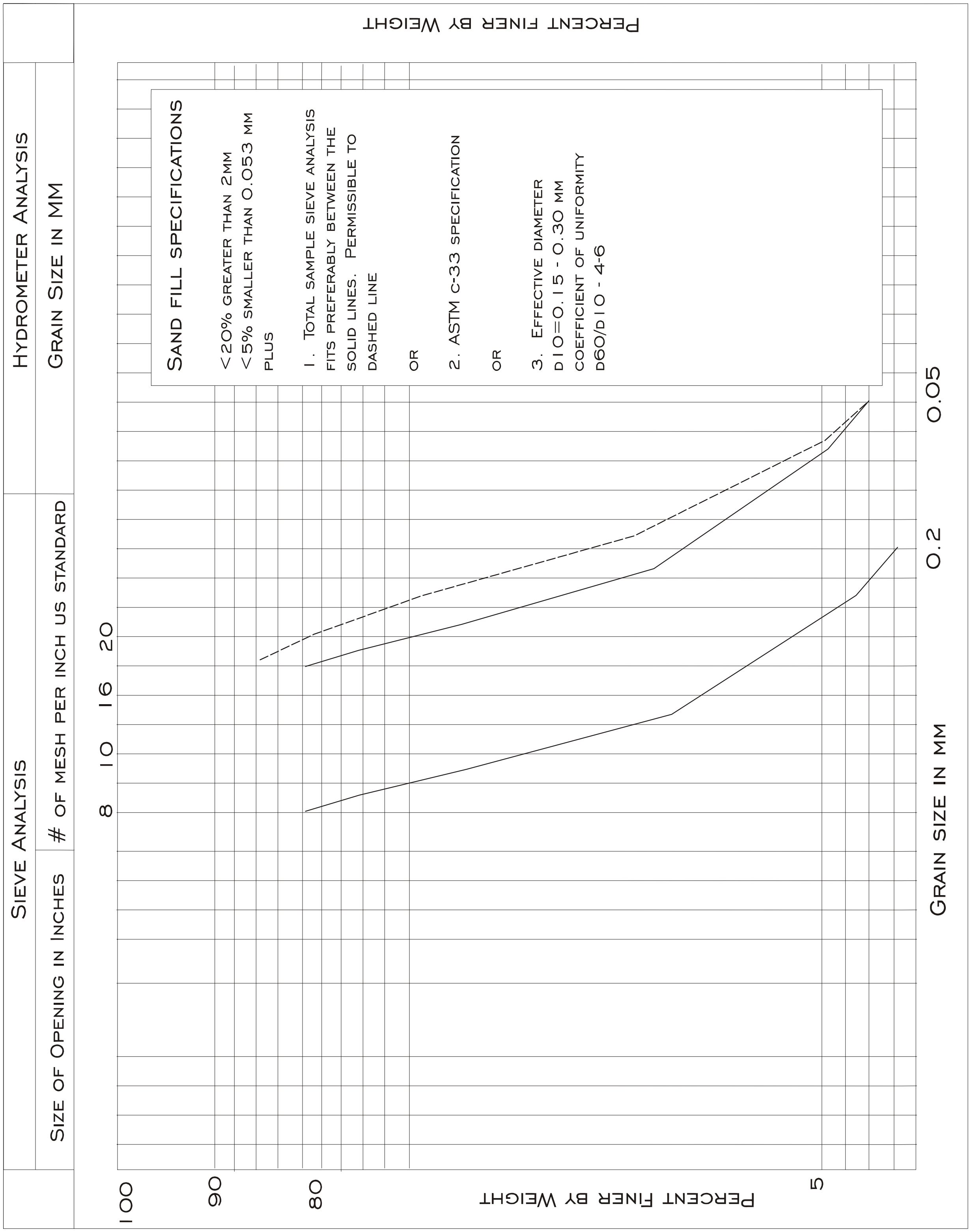


Figure VI-12. Examples of Sand Filter Sieve Analysis

Sand Filter Loading

The organic loading rate depends on the strength of the wastewater. Know the concentration of wastewater before designing the system. Wastewater containing high levels of organic material can reduce the filter's effectiveness over time and increase the need for maintenance.

Hydraulic loading, or the amount of wastewater distributed over the media surface, must be uniform to ensure consistent treatment. Uneven distribution may cause one part of the media bed to be overloaded and wastewater may be flushed through the media without receiving adequate treatment. Wastewater dosed too frequently causes similar problems. Doses should be spaced to allow the media adequate time to drain and re-aerate.

Sand Filter Treatment Efficiency

Biochemical oxygen demand (BOD) and Total Suspended Solids (TSS) are common indicators used by regulatory agencies to assess wastewater treatment and the impact of discharge on the environment. BOD is a measure of the amount of oxygen microorganisms need to consume and break down organic matter, and is typically measured for 5 days. TSS is a measure of the amount of particulates suspended in the wastewater. Single-pass sand filters are capable of reducing five-day BOD and TSS in wastewater to 5 and 17 mg/L or less, respectively (see Table VI-2). Sand filters also remove many pathogens, such as viruses and harmful bacteria. One disadvantage of sand filters is that they are not very effective at removing phosphorus from wastewater. Single-pass filters oxidize nitrogen but are not considered effective nitrogen removers. Recirculating filters oxidize the nitrogen and return the effluent to the anaerobic dose tank resulting in some denitrification.

Sand Filter Operation and Maintenance

Most operation and maintenance requirements for single-pass and recirculating sand filter beds are relatively simple. Maintenance for some system components includes periodic inspection and service by a trained service provider. For example electrical components, such as alarms, pumps, floats, and timers, need to be checked and serviced according to manufacturer's recommendations. Measurement of the septic tank sludge and scum depths should be done after the first year of installation and approximately every three years thereafter to determine when the septic tank needs pumping. Pipes, valves, and other system components need to be checked regularly, and screens and filters need to be cleaned.

Pumps used for onsite systems are often designed to last 10-25 years. In corrosive environments they deteriorate and are subject to wear. Electrical components deteriorate with age and use, so they will need to be replaced. As with all mechanical devices, regular maintenance of the system extends the useful life.

A key maintenance issue for a single-pass sand filter is to flush the distribution lines. It is important to clean accumulated solids out of the lines and keep the distribution orifices (holes) clear so that the effluent is spread uniformly over the sand media. Failure to perform line flushing will eventually cause non-uniform loading and clogging at the sand media surface (biomat) in areas of overload. Each distribution line typically has a cleanout assembly at the end for flushing. It is recommended that the distribution lines be flushed at least annually.

Sand filter performance is quite consistent over time. Operation and maintenance requirements are moderate;more than traditional septic tank lateral systems but less than many other enhanced treatment systems. In addition, overall treatment costs often compare favorably with other alternative systems.

Eventually, in some filters the biomat may become clogged. When this happens removing the top layer of sand or raking the surface to disrupt the biomat are options. However, in buried filters this is not a feasible option so temporarily removing the filter from service until the biomat breaks down is a possible option.

PEAT, TEXTILE, FOAM, AND OTHER MEDIA FILTERS

Under certain conditions, other types of media filters may be used in place of sand filters. These filters may be suitable for locations where sand media is not available or when onsite construction of a sand filter is not possible or practical. These filters are similar in function and design to a sand filter. However, a prepackaged media bed unit is typically used in place of a site built sand filter. The media used in the prepackaged unit may be a natural material such as peat, or a synthetic material such as textile. Other types use synthetic foam or some type of fixed film material such as small plastic balls as media. One disadvantage of the peat system is that the peat must be replenished and replaced over time. Replacement intervals are estimated to be seven to eight years.

Advances being made in alternative media filter design are occurring too rapidly to justify a detailed discussion of all these systems. The designer is advised to consult the latest manufacturers' information, research, or review articles. The basic operational principles for media filters remain similar or the same as sand filters. Septic tank effluent is intermittently dosed to the filter and treated effluent is discharged to a soil absorption system.

The textile filter operates in much the same way as a peat filter. The textile filter comes in a prepackaged module which is brought to the site and connected in series or parallel with other modules. The textile filter provides a large surface area for the development of a microbial population to assist in higher treatment efficiency. In addition, the textile media retains high porosity which helps maintain aerobic conditions. Some textile filters may contain a small ventilation fan to aid in keeping air available so the media remains aerobic. The textile filters may be constructed as single pass or recirculating similar to sand filter designs. A higher level of treatment is achieved if the system is recirculating. Textile filters also require routine maintenance. The filter media may be cleaned and reused if clogging occurs.

ROCK-PLANT FILTER (VEGETATED SUBMERGED BED)

A natural wetland's ability to cleanse and treat contaminated water has been recognized for a long time. However, the use of small constructed wetlands (rock-plant filters) for treatment of wastewater from small sources – homes, businesses, and similar sources – is relatively new. The term "rock-plant filter" has been selected because, even though these systems use wetland plants and share some of the same natural processes as a natural wetland, they are man-made systems. In recent years the term "vegetated submerged-bed" has been adopted in the onsite industry. Most rock-plant filters in the United States are located in the southeastern part of the country, but they are also used in Scandinavia and Canada. The first rock-plant filters in Kansas were installed in 1993. Changes in design specifications for use in Kansas have been based on monitoring of these systems. A publicly accessible system installed in 1995 is located at the Corps of Engineers swimming beach at the gathering pond below Milford Lake.

A rock-plant filter consists of a traditional septic tank, a lined treatment cell, and a soil absorption field. The lining of the treatment cell must be impermeable to prevent the loss of wastewater from the cell or allow the inflow of water during a wet season. Typically a heavy plastic membrane or well-compacted clay is used. The absorption cell or field transfers the pre-treated wastewater to the soil. Several options can be used for the absorption field including: an unlined wetland using plants that can tolerate both wet and dry conditions, traditional rock and pipe or chamber laterals, or other soil absorption.

As with other enhanced treatment systems, rock-plant filters provide a substantially higher level of pretreated wastewater than traditional septic tanks. Plant roots serve as a structure for bacterial attachment and consume some wastewater nutrients. A significant amount of treatment by bacterial action in the rock bed continues even when the plants are dormant, resulting in little variation in effluent quality throughout the year.

Of the different types of enhanced treatment systems (such as sand filters and ATUs), the rock-plant filter is the only option that does not require electricity for operation. On sites where elevations and slope allow for gravity flow through the treatment and absorptions cells the operational expense is minimal. This system does require homeowner (or service provider) awareness and maintenance to monitor system performance and check that the plants are in good health. Specifically any activity that results in large doses of chemicals like bleach, pesticides, antibiotics, lye, etc. will damage or kill both plants and beneficial microbes.

K-State Research and Extension publication, *Rock-Plant Filter Design and Construction for Home Wastewater Systems*, MF-2340 describes current ideas about designing and installing rock-plant filters for use in Kansas. The companion publication *Rock-Plant Filter Operation, Maintenance, and Repair*, MF-2337 presents information about how to service and care for these filters for good, long term performance. This type of care is needed to assure that the treatment component will function as designed and intended.

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PROTOCOL
INSPECTION OF NEW OR EVALUATION OF EXISTING ENHANCED TREATMENT UNITS

GOAL: Ensure the integrity of the enhanced treatment component to adequately treat wastewater, protect waters of the state from contamination, and dispose of human waste in a sanitary manner for the protection of public health.

POLICY: Inspection of a new or evaluation of existing enhanced treatment unit will be completed at the request of the landowner, contractor, lending agency, or other concerned party. The inspection of a new enhanced treatment unit shall occur before the unit is put into operation. The inspection shall address at least the evaluation points listed below. An assessment summarizing the inspection or evaluation shall be provided to all individuals who have legal interest in the outcome of the evaluation. A file of all original letters, data, supporting evidence and documents shall be maintained by the permitting agency.

PROCEDURE:

A. If the enhanced treatment unit is manufactured, refer to the manufacturer's guidelines and instructions for specific standards applicable to the unit being inspected or evaluated.

B. All new enhanced treatment units should meet the design and construction guidelines from one or more of the following sources: the Environmental Health Handbook; K-State Research and Extension publications; publications of National Small Flows Clearing House, EPA, established equipment manufacturer, National Onsite Wastewater Recycling Association (NOWRA), or other credible source. Record which guidelines the unit meets.

   1. The electrical supply shall be served by a separate circuit that is only connected to the enhanced treatment unit component and related equipment.

   2. All electrical connections outside of buildings are made in a water tight enclosure or sealed in moisture proof materials. Existing electrical and mechanical components must show no evidence of corrosion, especially at connections. Any corroded parts or materials shall be replaced with new parts or materials.

   3. All wiring outside of buildings shall be in water-tight exterior conduit. Any conduit that penetrates a container which will have a moist or corrosive atmosphere (such as pump tank or septic tank) shall be sealed by caulk, a trap containing mineral oil, or other method. This prevents corrosive gasses from the container exiting through the conduit to the control panel or other location, and causing corrosion.

   4. The control panel should be easily accessible with tamper resistant closures. The control panel components should be clearly labeled and should include instructions about the purpose and adjustments of the various components.

   5. All systems with a liquid pump should have a high water level alarm. The float should be lifted to activate the alarm, verifying that the alarm sounds and can easily be heard inside the house.

6. For all liquid pumps, lift the float that activates the pump to be sure it operates as designed and installed. While the pump is operating, check that water is reaching only the intended delivery point. Verify that there are no leaks in the delivery line. Lush vegetation near the septic tank, pump tank, or along the pipeline route may be evidence of a leak. If timers are used in the control panel, check that they are set in accordance with the instructions (a copy should be in the control panel).
7. Check for evidence of past malfunction or problems including: high water level in pump tank, wet conditions on ground surface, or lush vegetation in unexpected locations such as around pump tank or pressure lines to the field.
8. For existing systems, check water use records or obtain a statement signed by owner that there are no water leaks into drains (provide dye tablets to the owner or occupant to check for leaking toilets). This will prevent system overload from excess water.
9. Determine if there has been any change in activity such as a bedroom addition, home business, or home food production or preservation that would increase flows or change wastewater "strength".
10. Look carefully for evidence of damage or openings where extraneous water may enter the system (down spout, sump pump, surface runoff, etc.)
11. Look for water treatment components that may add excessive volumes of wastewater exceeding the system design. This equipment could include automatic flushing filters, a whole-house reverse osmosis system, or similar types of equipment.

Appendix A. Mound Design Computation Sheet (Domestic Wastewater Only)

Step 1. Site and Soil Evaluation.

1. Site slope is ________ percent, or percent /100 = ________ (decimal).
2. The available area is ___________ feet length; ___________ feet width.
3. Depth to limiting soil condition is __________ inches.

Step 2. Determine Wastewater Flow Rate.

The **Wastewater Flow Rate** is __________ gpd (_____ bedrooms x 150 gpd).

Step 3. Select the Linear Loading Rate (from Table VI-5)**: Linear Loading Rate** _____ gpd/lf.

Impermeable layer or water table, 3 to 4 gpd/lf; Semi-permeable layer, 5 to 6 gpd/lf; Permeable or cracked rock layer, 8 to 10 gpd/lf.

Step 4. Select the Sand Fill Loading Rate. Sand Fill Loading Rate is 1 gpd/ft^2.

As long as the recommended sand fill specifications is followed.

Step 5. Determine the Distribution Area Width.

Distribution Area Width = Linear Loading Rate / Sand Fill Loading Rate.

Distribution Area Width is ___________ feet, or ___________ inches.

Step 6. Determine the Distribution Area Length.

Distribution Area Length = Wastewater Flow Rate / Linear Loading Rate

Distribution Area Length is ___________ feet.

Step 7. Select the Basal Area Loading Rate (from Table VI-5).

The basal loading rate is based on the surface soil layer but may be reduced because of the underlying soil profile conditions. The **Basal Loading Rate** is ___________ gpd/ft^2.

Step 8. Determine the Minimum Basal Width.

Minimum Basal Width = Linear Loading Rate / Basal Area Loading Rate.

Basal Width is _________ feet.

Step 9. Determine Upslope Sand Fill Depth.

Upslope Sand Fill Depth = (48 inches) - (Depth to limiting soil condition).

Upslope Sand Fill Depth is __________ inches.

Step 10. Determine Downslope Sand Fill Depth.

Downslope Sand Fill Depth = (Upslope Sand Fill Depth) + (Site Slope as a decimal) x (Distribution Width in inches). **Downslope Sand Fill Depth** is ___________ inches.

Step 11. Select the Distribution Area, Distribution Cap, and Mound Cover Depths.

Distribution Area (Aggregate) Depth is 9 inches.

Mound Cover Depth = 6 inches.

Distribution Cap Depth is __________ inches. Distribution cap depth range is 8-12 inches. The wider the Distribution area the deeper the cap should be to ensure good drainage of runoff.

Step 12. Determine the Upslope Fill Width.

Upslope Width = (Side Slope Ratio) x (Upslope Sand Fill Depth + Aggregate Depth + Mound Cover Depth) x (Upslope width correction factor) from table below.

Upslope Width is __________ inches, or __________ feet.

Step 13. Determine the Downslope Fill Width.

Downslope Width = (Side Slope Ratio) x (Downslope Sand Fill Depth + Aggregate Depth + Mound Cover Depth) x (Downslope width correction factor) from table below.

Downslope Width is __________ inches, or __________ feet. The Downslope Width plus the Absorption Area Width must equal or exceed the Basal Area Width.

Step 14. Determine the End Slope Length.

End Slope Length = (Side Slope Ratio) x [Average sand fill depth (Upslope Sand Fill + Downslope Sand Fill) / 2] + Aggregate Depth + Mound Cover Depth).

End Slope Length is __________ inches, or __________ feet.

Step 15. Overall Mound Length and Width.

Overall Length = (Distribution Area Length, feet) + (2 x End Slope Length, feet).

Overall Length is __________ feet.

Overall Width = (Distribution Area Width, ft) + (Upslope Width, ft) + (Downslope Width, feet).

Overall Width is ___________ feet.

Site Slope (percent)	**Upslope Width Correction Factors**					**Downslope Width Correction Factors**				
	Side Slope Ratios (run per unit of rise)					Side Slope Ratios (run per unit of rise)				
	3	4	5	6	7	3	4	5	6	7
0	1	1	1	1	1	1	1	1	1	1
1	0.971	0.962	0.952	0.943	0.935	1.031	1.042	1.053	1.064	1.075
2	0.943	0.926	0.909	0.893	0.877	1.064	1.087	1.111	1.136	1.163
3	0.917	0.893	0.870	0.847	0.826	1.099	1.136	1.176	1.220	1.266
4	0.893	0.862	0.833	0.806	0.781	1.136	1.190	1.250	1.316	1.389
5	0.870	0.833	0.800	0.769	0.741	1.176	1.250	1.333	1.429	1.538
6	0.847	0.806	0.769	0.735	0.704	1.220	1.316	1.429	1.563	1.724
7	0.826	0.781	0.741	0.704	0.671	1.266	1.389	1.538	1.724	1.961
8	0.806	0.758	0.714	0.676	0.641	1.316	1.471	1.667	1.923	2.273
9	0.787	0.735	0.690	0.649	0.613	1.370	1.563	1.818	2.174	2.703
10	0.769	0.714	0.667	0.625	0.588	1.429	1.667	2.000	2.500	3.333
11	0.752	0.694	0.645	0.602	0.565	1.493	1.786	2.222	2.941	4.348
12	0.735	0.676	0.625	0.581	0.543	1.563	1.923	2.500	3.571	6.250
13	0.719	0.658	0.606	0.562	0.524	1.639	2.083	2.857	4.545	11.111
14	0.704	0.641	0.588	0.543	0.505	1.724	2.273	3.333	6.250	50.000
15	0.690	0.625	0.571	0.526	0.488	1.818	2.500	4.000	10.000	