Introduction to Small Flow Waste Treatment Systems

Course No: C02-028

Credit: 2 PDH

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An Introduction to Small Flow Waste Treatment Systems

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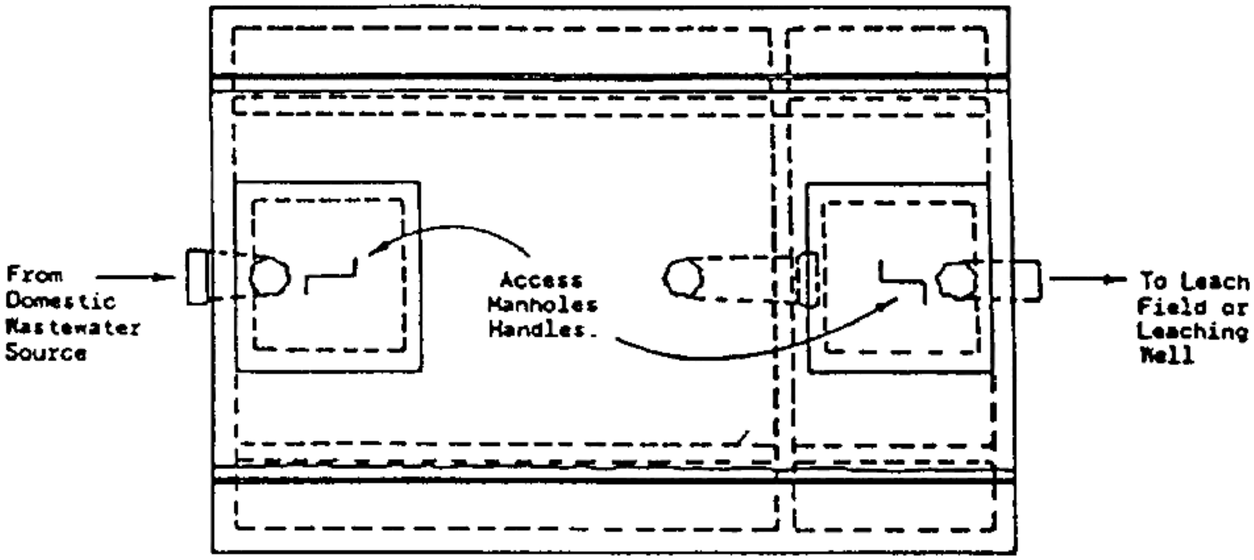
1. GENERAL CONSIDERATIONS

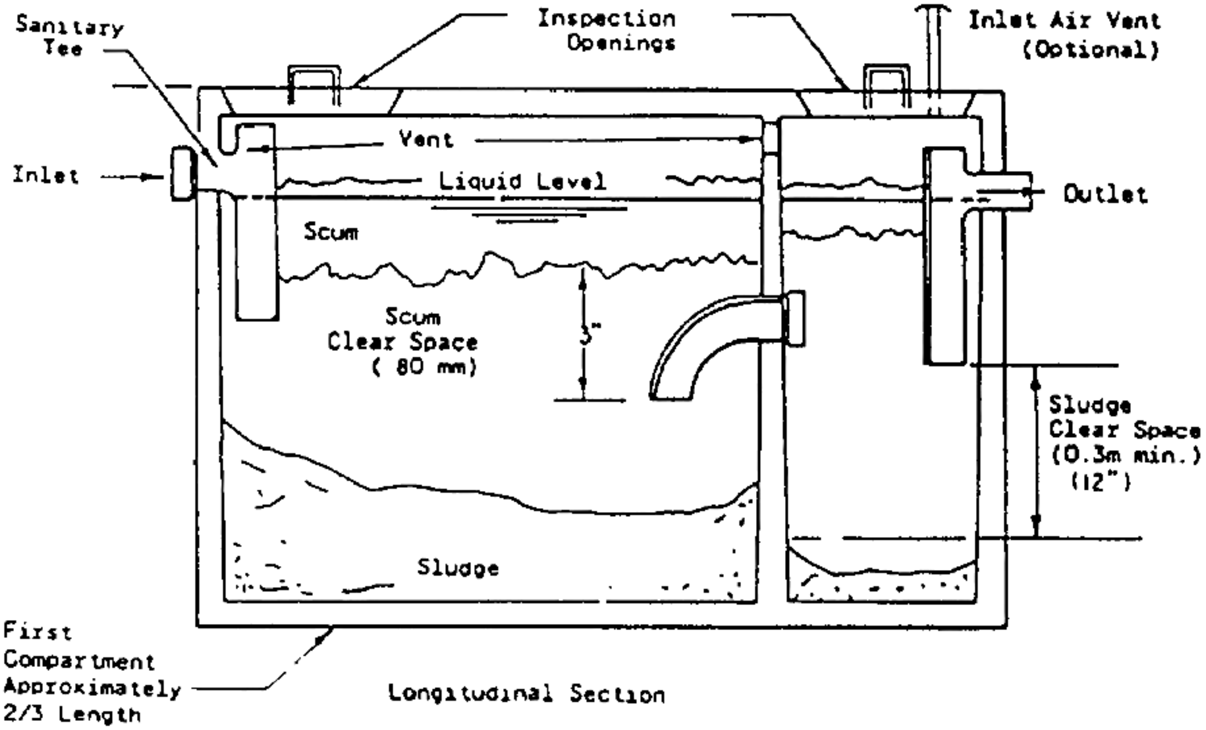
Treatment systems handling less than 1.0 million gallons per day are generally considered small treatment systems. For some packaged treatment systems, the principles of design are no different but the choice of equipment will usually differ from that used in large plants. This is usually due to the effect of economies of scale, whereby certain operations are economically feasible only on a large scale. In other cases, certain treatment systems such as septic tanks, Imhoff tanks, waterless toilets, mounding systems and composting toilets are only applicable to very small flows. Small packaged plants must make larger safety factor allowances for flow variation and temperature effects relative to total wastewater flows. Smaller package plants inherently have less operational flexibility; however, they are capable of performing effectively and efficiently. These small packaged plants may consist of trickling filter plants, rotating biological discs, physical-chemical plants, extended aeration activated sludge plants, and septic tanks. (Barnes and Wilson, 1976.) Design criteria for septic tanks, Imhoff tanks, waterless toilets, mounding systems, composting toilets, and filtration/reuse systems are given below.

2. SEPTIC TANKS

Septic tanks, with appropriate effluent disposal systems, are acceptable as a treatment system for isolated buildings or for single-unit residential buildings when permitted by regulatory authority and when alternative treatment is not practical. When soil and drainage characteristics are well documented for a particular site, septic tank treatment may be permanently feasible. Septic tanks perform settling and digestion functions and are effective in treating from 1 to 300 population equivalents of waste, but will be used only for 1 to 25 population equivalents, except when septic tanks are the most economical solution for larger populations within the above range. Minimum size will be at least 500-gallons capacity. In designing tanks, the length-to-width ratio should be between 2:1 and 3:1, and the liquid depth should be between 4 and 6 feet (fig 2-1). Detention time depends largely on the method of effluent disposal. When effluent is disposed of in subsurface absorption fields or leaching pits,



Plan



Longitudinal Section

Figure 2-1

Typical two-compartment septic tank

24 hours detention time based on average flows is required. The septic tank must be sized to provide the required detention (be low the operating liquid level) for the design daily flow plus an additional 25 percent capacity for sludge storage. If secondary treatment such as a subsurface sand filter or an oxidation pond is provided, this can be reduced to 18 hours. Open sand filter treatment can further reduce detention time to 10 to 12 hours. Absorption field and leaching well disposal should normally be limited to small facilities (less than 50 population equivalents). If the total population is over 50, then more than one entirely separate field or well would be acceptable. For 10 or more population equivalents, discharge of effluent will be through dosing tanks which periodically discharge effluent quantities near 80 percent of the absorption system capacity.

2.1 Subsurface absorption. Subsurface absorption can be used in conjunction with septic tank treatment when soil conditions permit. Percolation tests must be performed as required by the U.S. Public Health Service, and the groundwater table at the highest known or anticipated level must not reach any higher than 2 feet below the invert of the lowest distribution line. Absorption fields normally consist of open-joint or perforated distribution pipe laid in trenches 1 to 5 feet deep and 1 to 3 feet wide. The bottoms of the trenches are filled with a minimum of 6 inches of ¾ to 2½-inch rock or gravel (fig 2-2). The perforated distribution pipe is laid on top of this rock, and the open joints between pipe lengths are covered to prevent clogging. More rock is placed carefully over the pipe network, and then a semipermeable membrane is used over the rock layer to prevent fine-grained backfill from clogging the drainage zone. Distribution pipe may be spaced as close as 2 feet if the rock beneath is deep, the subsoil porous, and distance to bedrock greater than 4 feet. Generally, distribution pipelines are 3 to 6 feet apart laterally and are no longer than 100 feet. Consult EPA 625/1-80-012 for complete details and leach field special design information. Minimum depth of trench will be 18 inches, with 12 inches of backfill. Invert slopes will be 0.3 percent when dosing tanks are used and 0.5 percent when not used. Soil absorption systems will be 100 feet from water supply wells, 50 feet from streams, 10 feet from any dwelling or property lines. Soil testing is a mandatory prerequisite for and subsurface disposal of waste. Local and State regulations must be consulted for additional mandatory requirements.

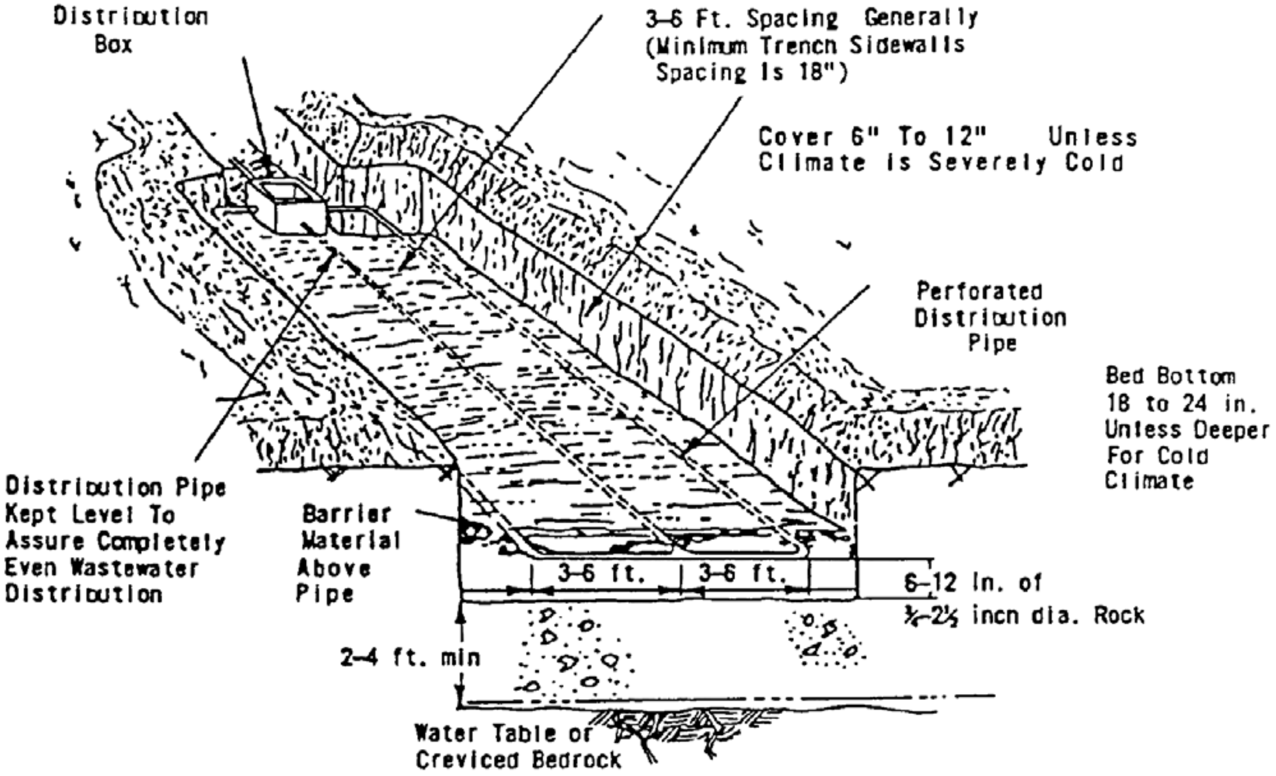


Figure 2-2

Sub-surface absorption system

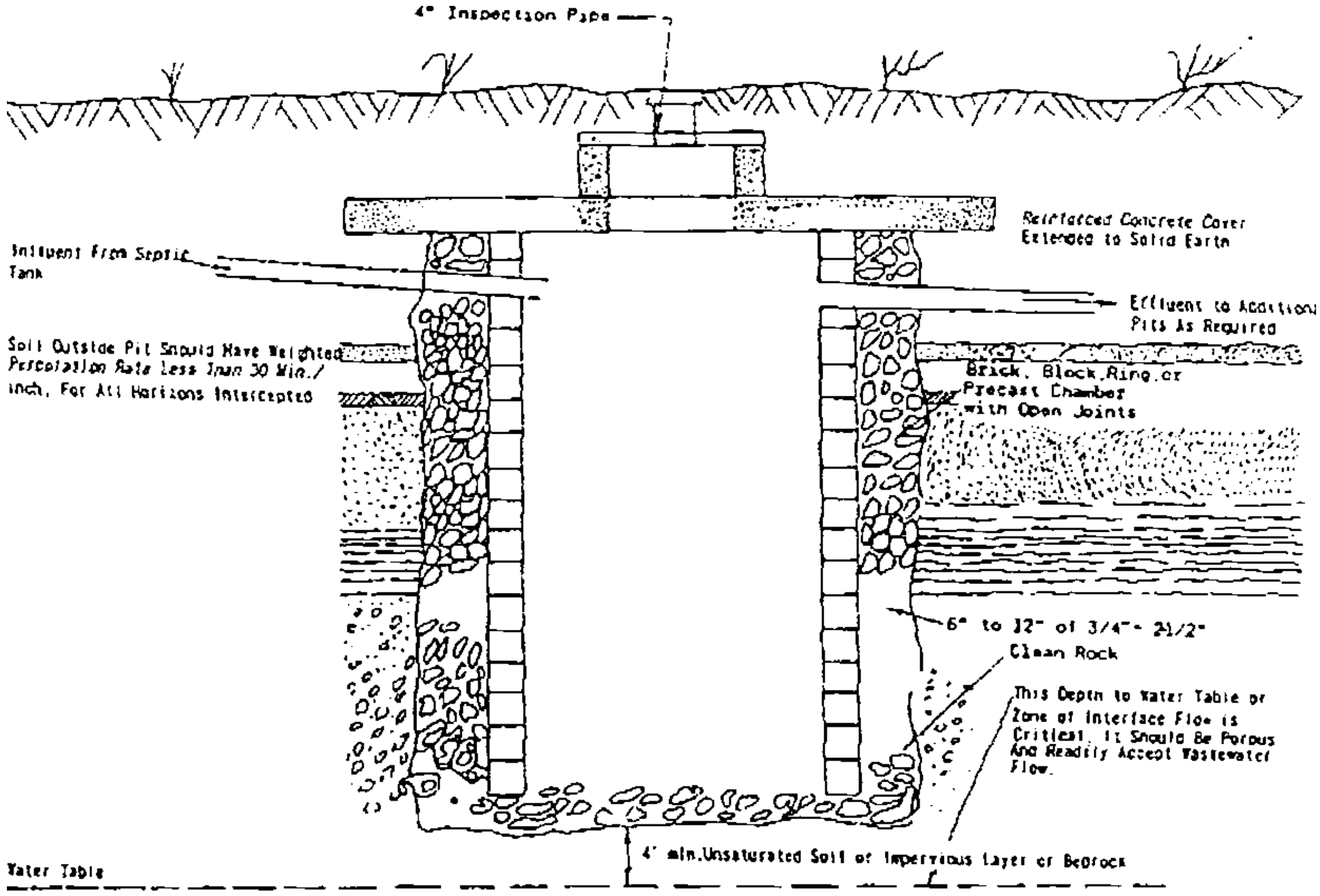


Figure 2-3

Seepage pit cross-section

2.2 Leaching wells. Leaching wells can be used for septic tank effluent disposal where subsoil is porous. Although absorption beds are generally preferred, site characteristics and cost considerations may encourage the use of a leaching well. Wells are constructed with masonry blocks or stone with lateral openings, and gravel outside to prevent sand from entering the well. If more than one well is required, they should be spaced at intervals with at least twice the diameter of a well as distance between well hole sides. Percolation area is that area on the side and bottom of the hole for the leaching well. The bottom of a leaching well should be 4 feet above seasonal high water. See figure 2-3 and EPA Manual No.625/1-80-012.

2.3 Subsurface sand filters. Septic tank effluent can also be applied to subsurface sand filters. Subsurface explorations are always necessary. Clogging and installation costs are significant disadvantages. Where recirculatory sand filters on used dose rate may range between 3-5 gallons per day per square foot, Consult EPA Manual No.625/1-80-012, Harris et al., 1977, and Ronaye et al., 1982, for appropriate procedures for site evaluation and design parameters.

2.4 Percolation tests. In the absence of groundwater or subsoil information, subsurface explorations are necessary. This investigation may be carried out with shovel, posthole digger, or solid auger with an extension handle. In some cases the examination of road cuts or foundation excavations will give useful information. If subsurface investigation appears suitable, percolation tests should be made at typical points where the disposal field is to be located. Percolation tests determine the acceptability of the site and serve as the basis of design for the liquid absorption.

2.4.1 Six or more tests will be made in separate test holes uniformly spaced over the proposed absorption field site.

2.4.2 Dig or bore a hole with horizontal dimensions of 4 to 12 inches and vertical sides to the depth of the proposed trench.

2.4.3 Carefully scratch the bottom and sides of the excavation with a knife blade or sharppointed instrument to remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate. Add 2 inches of coarse sand or fine gravel to the bottom of the hole. In some types of soils the sidewalls of the test holes tend to cave in or slough off and settle to the bottom of the hole. It is most likely to occur when the soil is dry or when overnight soaking is required. The caving can be prevented and more accurate results obtained by placing in the test hole a wire cylinder surrounded by a minimum 1-inch layer of gravel of the same size that is to be used in the tile field.

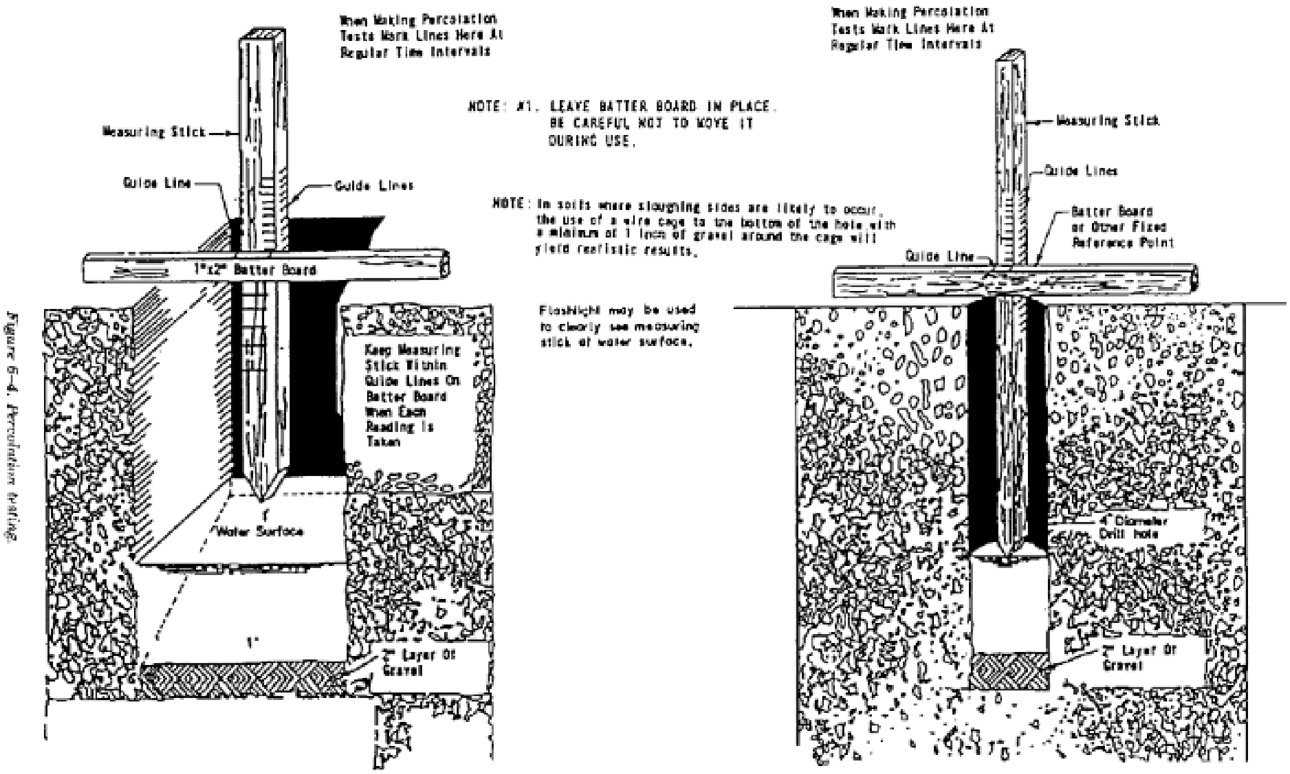
2.4.4 Carefully fill the hole with clear water to a minimum depth of 12 inches above the gravel or sand. Keep water in the hole at least 4 hours and preferably overnight. In most soils it will be necessary to augment the water as time progresses. Determine the percolation rate 24 hours after water was first added to the hole. In sandy soils containing little clay, this prefilling procedure is not essential and the test may be made after water from one filling of the hole has completely seeped away.

2.4.5 The percolation-rate measurement is determined by one of the following methods:

2.4.5.1 If water remains in the test hole overnight, adjust the water depth to approximately 6 inches above the gravel. From a reference batter board as shown in Figure 2-4, measure the drop in water level over a 30-minute period. This drop is used to calculate the percolation rate.

2.4.5.2 If no water remains in the hole the next day, add clean water to bring the depth to approximately 6 inches over gravel. From the batter board, measure the drop water level at approximately 30-minute intervals for 4 hours, refilling to 6 inches over the gravel as necessary. The drop in water level that occurs during the final 30-minute period is used to calculate the percolation rate.

2.4.5.3 In sandy soils (or other soils in which the first 6 inches of water seeps away in less than 30 minutes after the overnight period), the time interval between measurements will be taken as 10 minutes and the test run for 1 hour. The drop in water level that occurs during the final 10 minutes is used to calculate the percolation rate. Figure 2-5 will be used to determine the absorption area requirements from percolation rate measurements. Tile fields are not usually economical when drop is less than 1 inch in 30 minutes.



NOTE: #1. LEAVE BATTER BOARD IN PLACE. BE CAREFUL NOT TO MOVE IT DURING USE.

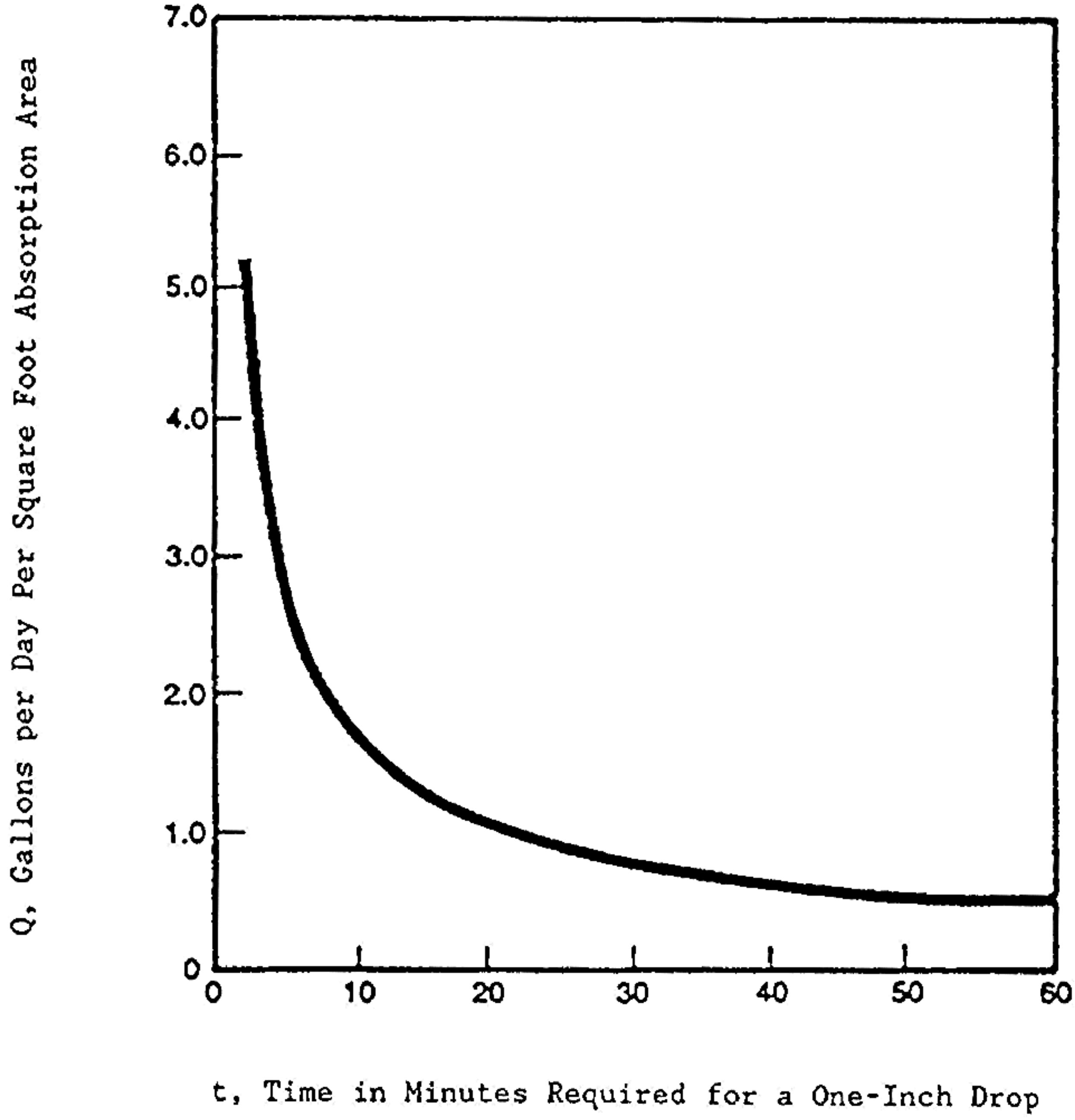
NOTE: In soils where sloughing sides are likely to occur, the use of a wire cage to the bottom of the hole with a minimum of 1 inch of gravel around the cage will yield realistic results.

Flashlight may be used to clearly see measuring stick at water surface.

Figure 6-4. Percolation testing.

Figure 2-4

Percolation testing



Formula: $Q = \frac{5}{\sqrt{t}}$

Figure 2-5

Absorption area requirements

3. WATERLESS TOILETS

3.1 Humus "composting" toilets. The U.S. Forest Service (Fay and Walke, 1975) and several manufacturers have developed several types of humus toilets. (Hartenstein and Mitchell, 1978.) All are watertight and depend upon microbiological decomposition for their reduction in volume and their destruction of pathogens. The patented "Clivus Multrum" is the forerunner of the modern composting toilet. The Clivus Multrum essentially involves only a toilet seat and a large sloped container with floor tilted at 33 degrees. This allows excreta to aerate and to gradually move to the base of the chute toward an access hatch. Excess moisture evaporates through a 6 inch roof vent. The system depends upon the user depositing peat moss or soil into the chute periodically. Kitchen waste, toilet paper, shredded paper or other biodegradable waste should also be added regularly. After about three years, and once each year thereafter, a small amount of “humus-like” compost may be removed from the access port and used as fertilizer. These units are very efficient, inexpensive, simple and easy to install. Their only shortcoming is space, for they require a slope or must be installed on the second floor. They should be seriously considered in mountainous terrain or when buildings are built on slopes. Smaller box-like units have been designed and installed in Scandinavia and England but these require an electric heater.

3.2 Incineration toilets. Incineration toilets are available from several manufacturers. They are self-contained. After each use, when the lid is closed the waste is incinerated, using gas or electricity. Maintenance costs for new elements and ash removal are high. Such toilets are energy intensive and cannot be recommended except for isolated sites or for emergency installations. They are, however, safe, easy to install and, if constructed and maintained properly, are acceptable to personnel.

3.3 Chemical toilets. Chemical toilets are usually manufactured of fiberglass and are inexpensive to install and maintain. The chemicals used have a high pH and have been known to cause minor burns. A fragrance is usually added to mask odors because no biological degradation occurs between cleanings. After cleaning, pumper trucks usually transport the treated wastes to a sewage treatment plant. Chemical units are less desirable than humus units because they require not only greater energy costs, but constant maintenance and hauling to a treatment plant. Another chemical treatment method is to use mineral oil as the transfer liquid. These units are common on cargo vessels, and at national parks, rest areas and gas stations and do have some advantage over other chemical toilets. Wastes are pumped to a central holding tank, do undergo considerable degradation during storage, and are more aesthetically acceptable. Their maintenance requires highly trained personnel. Ozonation units have been produced by several firms which couple anaerobic and aerobic treatment and ozone saturation. However, such units installed in California have proven to be expensive.

3.4 Aerated pit latrines. Units of small size assigned to the field or to relatively remote locations may utilize aerated pit latrines. These latrines are improved versions of the “privy.” The pit may be excavated, using a backhoe or hand labor. Usually the pit walls are supported by 2x4 lumber and lagging. The privy structure is best designed to allow easy transport to a new location. It may be uncoupled from the pit wall supports and carried to another location when the pit is filled with waste to within two feet of the ground surface. With the structure removed, the remaining pit is buried with topsoil and seeded to grass. Some modern designs utilize passive solar panels to produce a rising current of warm air which passes out of a screened vent pipe. Screened openings are provided at the base of the privy structure to allow cool air to move laterally across the top of the pit, up and then out of the vent. Latrines can be operated as composting toilets if leaves, wood chips and pine straw are added to the excreta. If well designed and responsibly maintained, the aerated pit latrine will not harbor vectors nor will odors accumulate. For further details, see Wagner and Lanoix, 1958.

4. FILTRATION/REUSE SYSTEMS

In order to meet stricter standards, improved intermittent sand filters have been developed to treat wastes from Imhoff tanks or septic tanks. The system developed included a recirculation tank and an open sand filter (Figure 4-1). A clock mechanism and pump assure a recirculation rate which results in fresh liquid being dosed onto the surface of the sand filter. Solids are partially washed onto the sand and kept odor-free. Float controls provide override of timer clocks should flows increase to near overflow levels before the clock sets pumps into action.

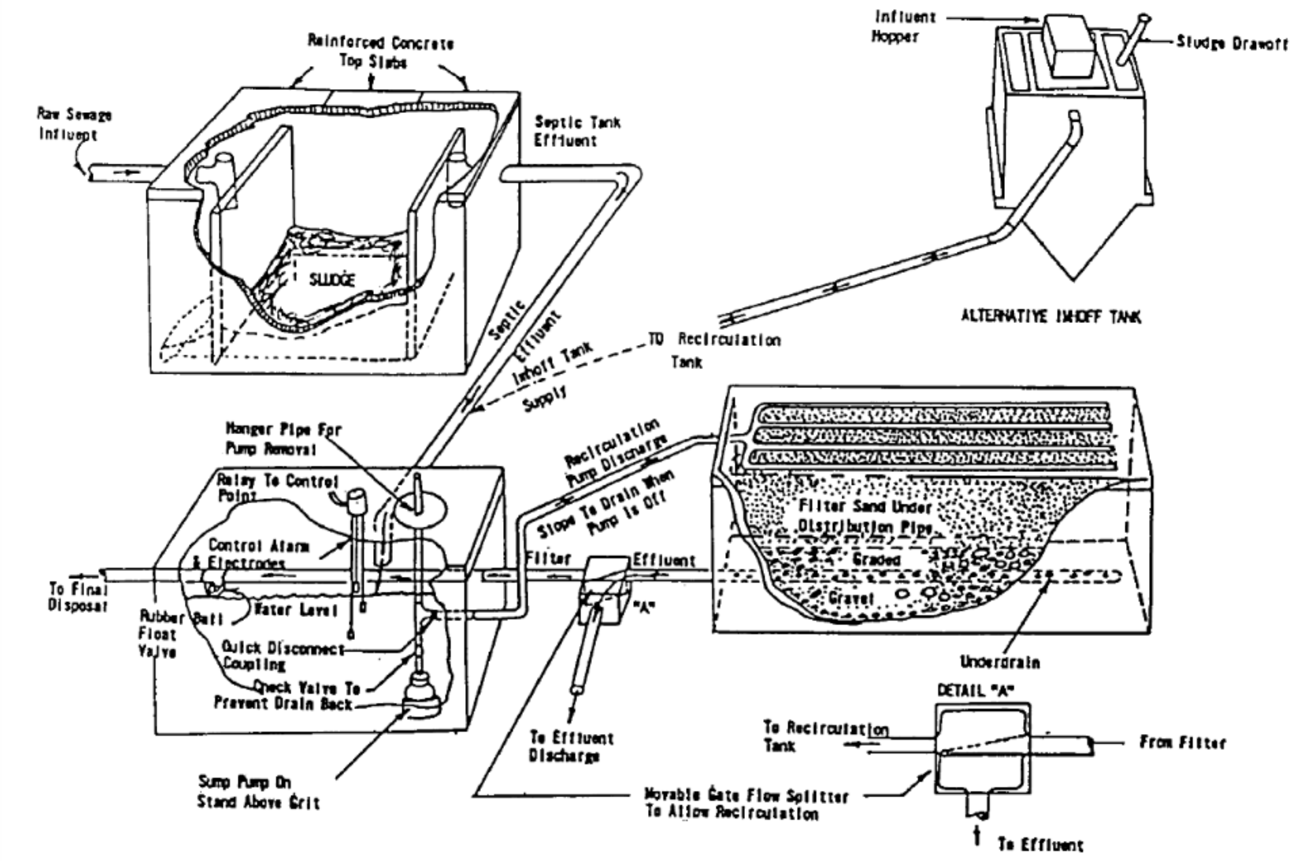


Figure 4-1

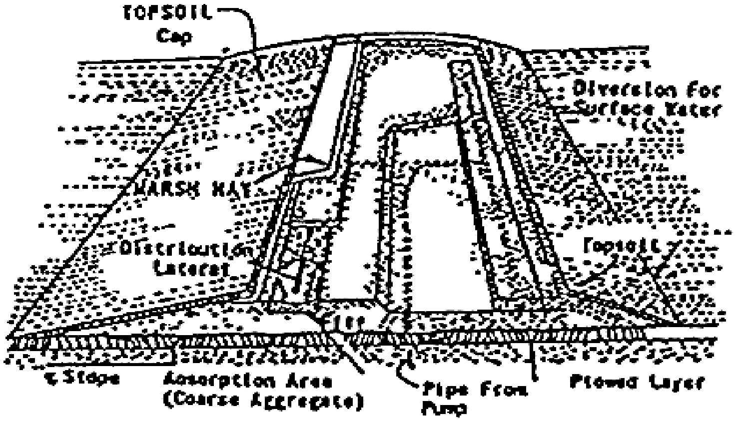
Filtration and reuse systems

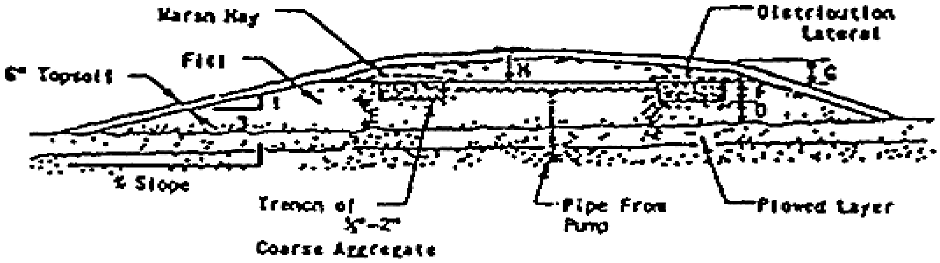
Dosing is through troughs rather than through central pipe and splash block. Sand size is coarse, 0.0118 to 0.059 inch for the top 2 feet of filter, to allow a dose rate of 5 gallons per day per square foot. The recirculation tank receives some underdrainings from the filter and mixes this with the septic waste. The recirculation tank should be between ¼ and ½ the size of the Imhoff or septic tank. A simple movable gate directs flow from the drain either to the recirculation tank, or to chlorination or other further treatment and ultimate discharge. A tee turned upside-down and a rubber ball suspended in a stainless steel basket under the open end of the tee will also provide adequate flow control. Recirculation is kept between 3:1 to 5:1. Pumps are set to dose every 2 to 3 hours and to empty the recirculation tank. The recirculation pumps are sized so that 4 to 5 times the amount of raw sewage is pumped each day. Duplicate, alternative pumps are required. Sand and gravel are placed carefully so as not to crush the plastic or tile pipe underdrains. Usually two separate sand filters are built so that filters can be raked each week and allowed to completely aerate. Prior to winter operation, the top 2 inches of sand on the filters is replaced. Since these filters are placed on the surface, they must be surrounded by a fence and landscaped. Effluent will be of good quality, with biochemical oxygen demand values ranging between 1 to 4 milligrams per liter. In the winter, ammonia may range 40 to 50 milligrams per liter. Pathogens are practically completely removed.

5. MOUND SYSTEMS

Installations may be sited upon low-lying plains, reclaimed swamps, or poorly drained areas. Ordinarily a septic tank and leach field would be used for small flows, but soil conditions or high clay content, high water table, shallow depth to bedrock and slow percolation make ordinary soil disposal techniques unfeasible. The septic tank-mound system may then have application.

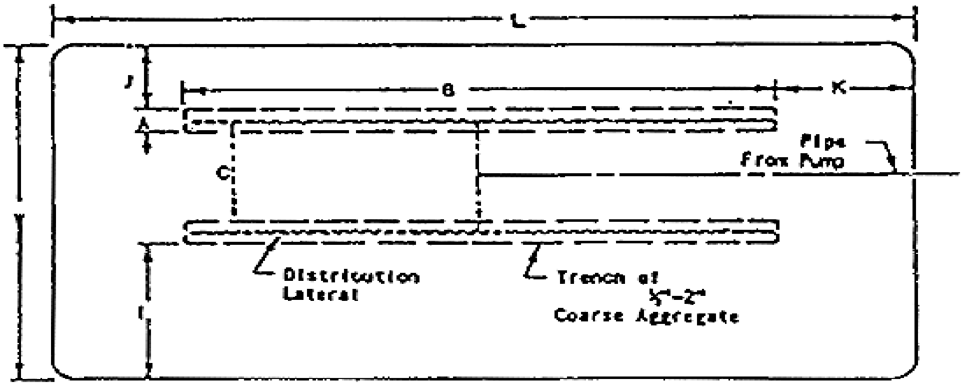
5.1 Description. A typical mound system is shown in Figure 5-1. A siphon may replace the pump if the mound is located downslope. The mound itself consists of fill material, an absorption area, a distribution system, a cap and a covering of topsoil. Effluent is dosed into the absorption area through the distributor piping. The fill material provides the major zone of purification before the cleansed effluent passes into the buried topsoil of the original soil line. The cap is of fill, deep enough to protect the piping; it should be sloped and contain sufficient silt and clay as to encourage runoff of rainfall. The topsoil above is seeded with grasses to prevent erosion and encourage some evapotranspiration. In pervious soils above shallow bedrock, the mound must be deep enough to provide absorption of pollutants before they can infiltrate bedrock and enter groundwater.





A detailed cross-section of a mound using trenches for the absorption area. Normally used on slowly permeable soil sites.

D or E = Fill depth (1 ft. minimum if water table is 2 ft. beneath soil surface)
F = Trench or bed depth (minimum 9in. 6in below pipe)
G = Frost protection cap, runoff promoter.
H = Cap apex, minimum 1.5 ft.
L = Length



A = Bed or trench width
B = Bed or trench length.
C = Spacing between trenches.
K = End slope length.
I = Downslope.
J =Upslope

A Detailed plan view of a monud using trenches for the absorption area. This system recommended for slowly permeable soils with high water tables.

Figure 5-1

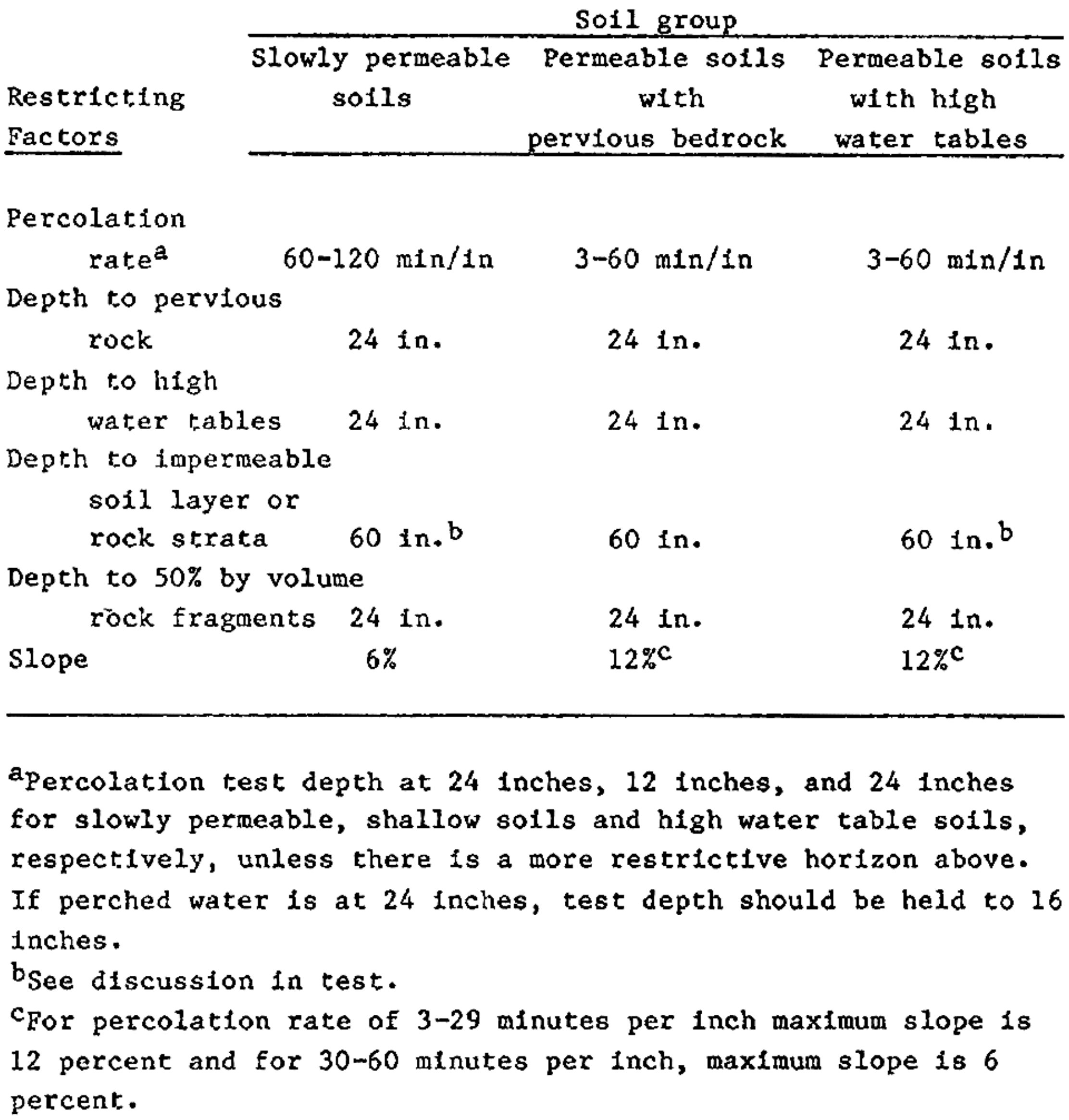
Mound system - trenches

5.2 Site considerations. Table 5-1 summarizes soil and site factors that restrict mound systems. In using Table 5-1, percolation tests are usually run at 20-24 inches from the natural surface. As shown for slowly permeable soil, if the percolation rate is less than 60 minutes per inch, the soil is permeable so that the slope of the site may be cautiously increased to keep effluents in the upper soil horizons. If the percolation rate is greater than 120 minutes per inch, then the soil is so impermeable as to disallow use of a standard mound system. Soil characteristics, water table depth and amount of large fragments dramatically influence mound design. In Figure 5-1, a mound system using two trenches is illustrated; while in Figure 5-2, the bed absorption system is shown. For further information on design criteria and installation, see EPA Manual No. 625/1-80-012.

5.3 Depth to pervious rock. A minimum of 24 inches of unsaturated natural Soil is required beneath the mound. This natural soil provides additional purification capacity and serves as a buffer in protecting the groundwater from contamination. It also reduces the amount of fill material needed for the mound, serving as a part of the unsaturated soil needed for purification.

5.4 Depth to high water table. High groundwater, including perched water tables, should be a minimum of 2 inches beneath the soil surface to provide adequate disposal and purification. High water tables can be determined by direct observation or by soil mottling. Occurrence of grey and red soil mottling phenomena can be used to indicate periodic saturation with water. However lack of mottling does not always mean that seasonally perched water does not occur. Looking at mottling is meaningful but direct observation is preferable if there is any doubt.

5.5 Depth to impermeable soil layer or rock strata. The depth to impermeable soil or rock strata can vary over a range (see Fig 5-1 and Fig 5-2). The optimum distance will vary for a given site. Sufficient area must be available so that the effluent can move away from the mound. Otherwise, effluent will build up in the mound and cause seepage out the toe of the



Restricting Factors	Soil group Slowly permeable soils	 Permeable soils with pervious bedrock	 Permeable soils with high water tables
Percolation rate[a]	60-120 min/in	3-60 min/in	3-60 min/in
Depth to pervious rock	24 in.	24 in.	24 in.
Depth to high water tables	24 in.	24 in.	24 in.
Depth to impermeable soil layer or rock strata	60 in.[b]	60 in.	60 in.[b]
Depth to 50% by volume rock fragments	24 in.	24 in.	24 in.
Slope	6%	12%[c]	12%[c]

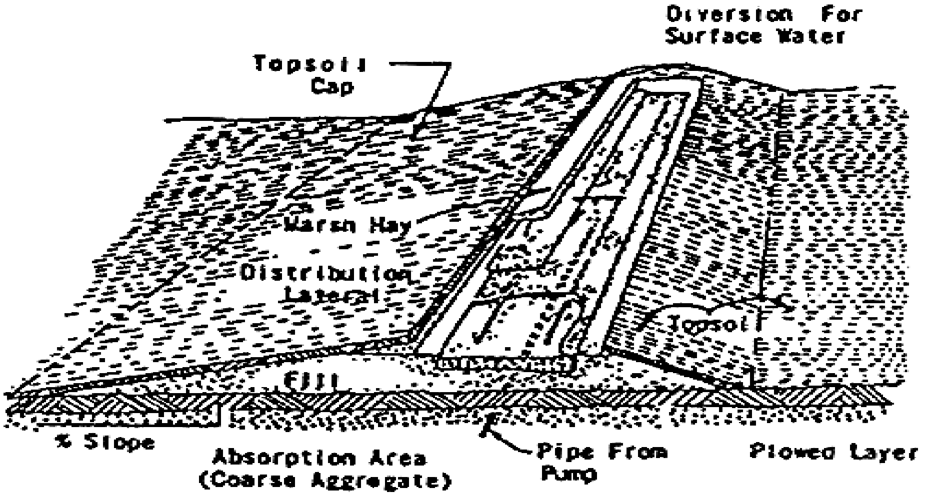
[a] Percolation test depth at 24 inches, 12 inches, and 24 inches for slowly permeable, shallow soils and high water table soils, respectively, unless there is a more restrictive horizon above. If perched water is at 24 inches, test depth should be held to 16 inches.

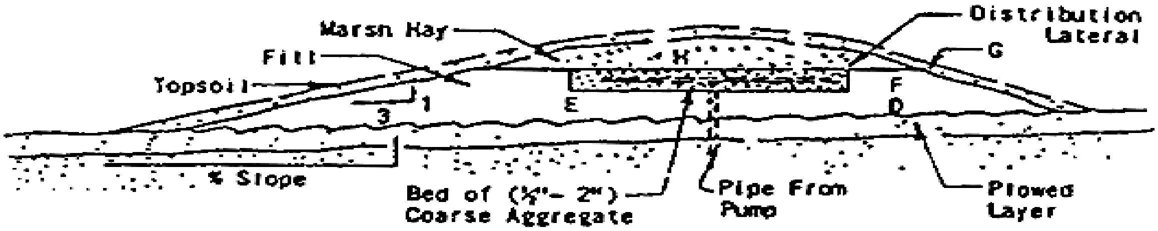
[b] See discussion in test.

[c] For percolation rate of 3-29 minutes per inch maximum slope is 12 percent and for 30-60 minutes per inch, maximum slope is 6 percent.

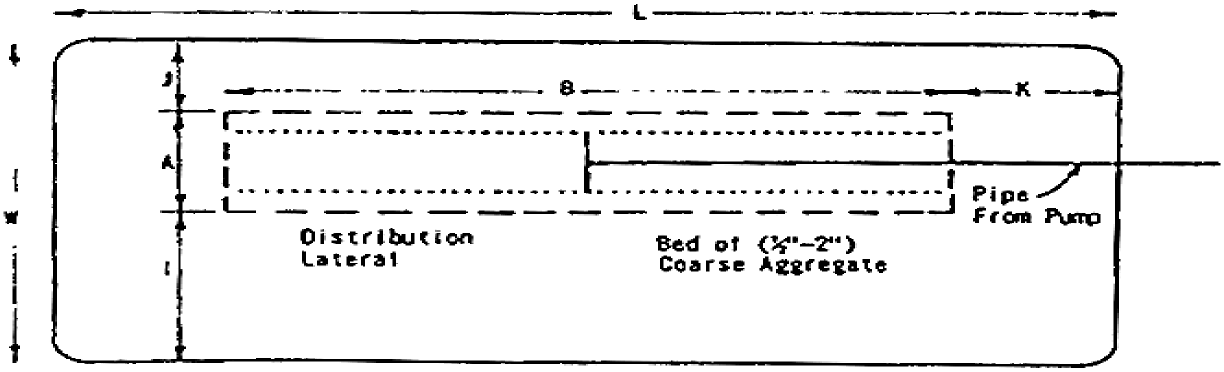
Table 5-1

Soil and site factors that restrict mound systems





A detailed cross-section of a mound using a bed for the absorption area. Normally used on shallow permeable soils with creviced bedrock or permeable soils with high water tables.



A detailed plan view of a mound using a bed for the absorption area.

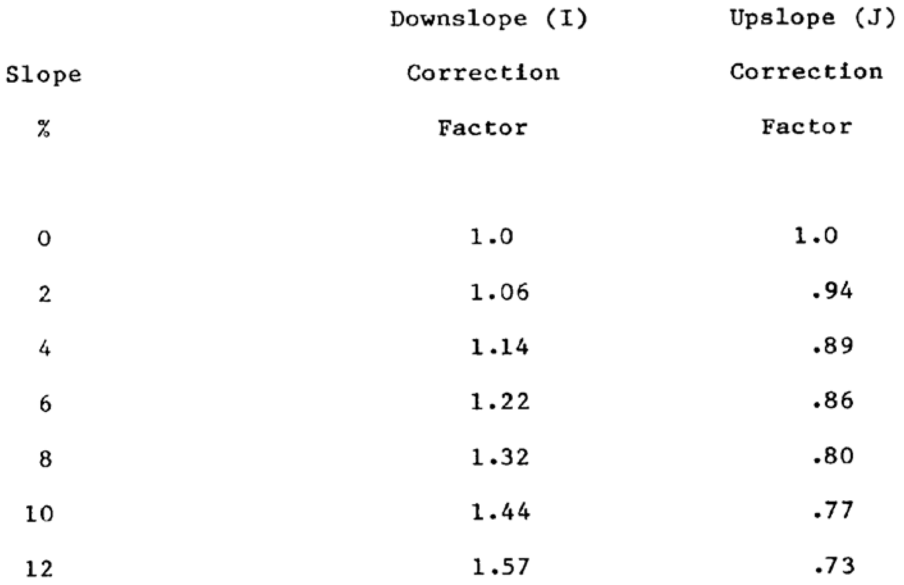
Figure 5 – 2

Mound system - beds

mound. Climatic factors, soil permeability, slope, and system configuration affect this distance. Slowly permeable soils require more area to remove the effluent from the mound than do permeable soils. Frost penetration reduces the effective area for lateral movement; thus, in warmer climates, depth requirements are not as great as for colder climates. Level sites require shallower depths than do sloping sites, as more area is available for effluent dispersal since the effluent can move in several directions. Less depth is required for long narrow mounds than is required for more square systems because the square system concentrates the liquid into a smaller area.

5.6 Depth to 50 percent volume rock fragments. Rock fragments do not assist in purification and disposal of effluents. They cause the effluent to be concentrated between the fragments. This may lead to saturated flow and, thus, poorer purification. If the soil contains 50 percent rock fragments by volume in the upper 24 inches of soil, then there is only half the soil available for purification and disposal of the effluent. Depths greater than 24 inches must be used if the soil beneath the mound contains more than 50 percent by volume of rock fragments. This is especially true for permeable soils over creviced bedrock and in areas where the high water table may intersect a potable water supply.

5.7 Slopes. Site selection is very important. The crested site is the most desirable because the mound can be situated such that the effluent can move laterally down both slopes. The level site allows lateral flow in all directions but may present problems in that the water table may rise higher beneath the mound in slowly permeable soils. The most common is the sloping site where all the liquid moves in one direction, away from the mound. However, proper design can overcome this limitation, especially in the less permeable soils. The mound should be placed upslope and not at the base of the slope. On a site where there is a complex slope, the mound should be situated such that the liquid is not concentrated in one area of the downslope. Upslope runoff should be diverted around the mound. Mounds require more stringent slope specifications than conventional systems because of their reliance on lateral movement of effluent through the upper soil horizons. Lateral movement becomes more important as soil permeability becomes less. Thus, on more slowly permeable soils, the maximum allowable slopes are less. For the more permeable soils (3-29 minutes per inch), slopes up to 12 percent should function without surface seepage because lateral movement is not so great. For tighter soils (30-120 minutes per inch), slopes should not exceed 6 percent. For sloping sites, the downslope distance (I) must be lengthened and the upslope distance (J) shortened. Table 5-2 may be used for this calculation.



Slope %	Downslope (I) Correction Factor	Upslope (J) Correction Factor
0	1.0	1.0
2	1.06	.94
4	1.14	.89
6	1.22	.86
8	1.32	.80
10	1.44	.77
12	1.57	.73

Table 5-2

Correction factors for mounds on sloping sites

5.8 Special siting considerations. Construction of mound systems as well as conventional systems is not recommended in flood plains, drainage ways, or depressions. Generally, sites with large trees, numerous smaller trees, or large boulders are unsuitable for the mound system because of difficulty in preparing the surface and the reduced infiltration area beneath the mound. As with rock fragments: tree roots, stumps and boulders occupy space, thus reducing the amount of soil for proper purification. if no other site is available, then it is recommended to cut the trees off at ground level, leaving the stumps. A larger mound area may be necessary if too many stumps are involved for sufficient soil to be made available to accept the effluent. Separating distances should be considered between the toe of the fill and the respective features such as a building, well, slope or stream. When the mound or fill is located upslope from a building or other features on soils with slow percolation rates or slowly permeable subsoil layers, the separating distances should be increased.

5.9 Basal area calculation. The natural soil-fill area interface is the basal area. The effluent is accepted from the overlying mound fill through this area into the subsoil beneath. While, for level sites, the basal area equals the mound area; for sloping sites, only the basal area downslope from the bed or trenches may be considered effective. It includes the area enclosed by B x (A+C+I) for a trench system (Fig 5-1), or B x (A+I) for a bed system (Fig 5-2). The percolation rate for the natural soil will determine how much area is required. For percolation rates applicable for mound systems, the design loading rates are:

Table 5-3

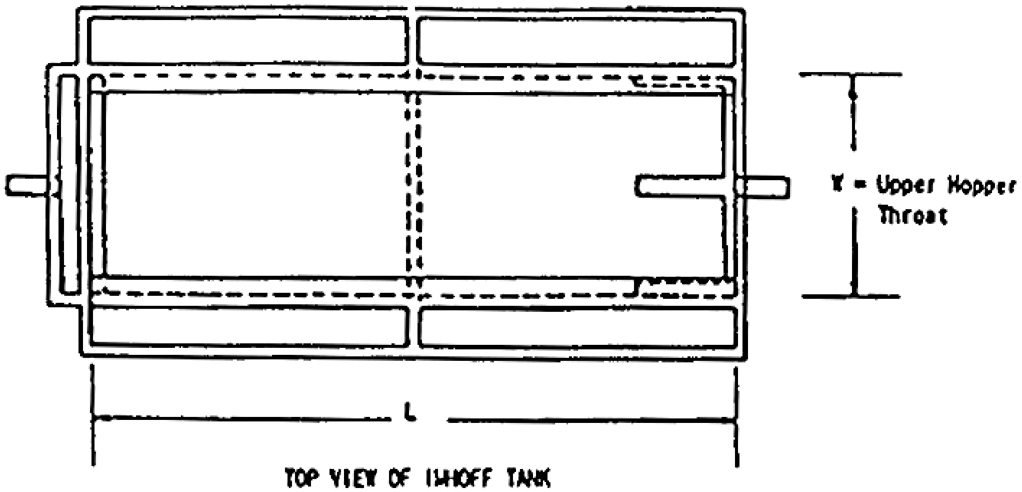
Percolation Rates and Corresponding Design Loading Rates	
Percolation Rate (minutes/inch)	Design Loading Rate (gallons/SF/day)
3 – 29	1.2
30 – 60	0.74
60 – 120	0.24

6. IMHOFF TANKS

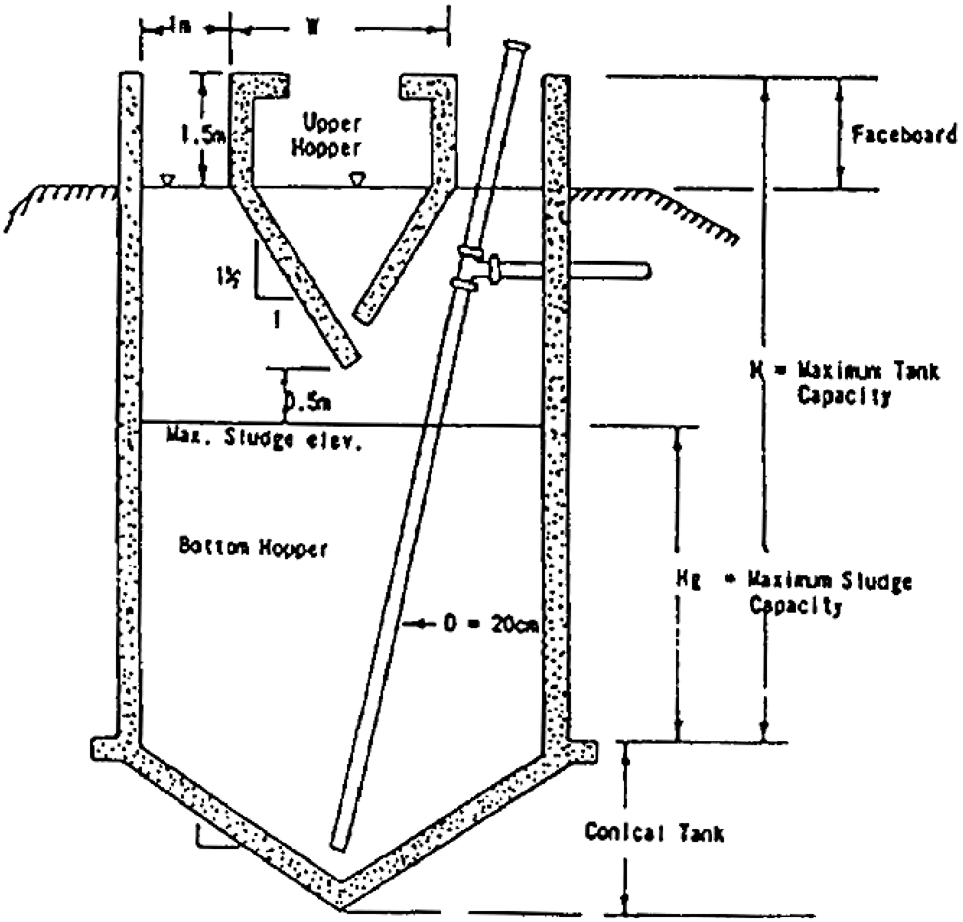
Perhaps the main weak point of a septic tank involves the attempt to combine sedimentation and decomposition of accumulated sludge in the same tank. Rather than use a heated digester, another system was devised now known as the "Imhoff tank," In these tanks, sedimentation is separated from digestion. Solids that settle in the upper portion of the tank pass through a slot into a bottom hopper. Here, the sludge digests and, once stabilized, may be periodically removed from the bottom of the vee-shaped or conical tank for subsequent further treatment. Gases produced by the decomposition of the sludge are vented along the sides of the lower compartment and are not allowed up to the sedimentation chamber. De-sludging is carried out about 4 times each year at a moisture content of 93 percent. A typical design is shown in figure 6-1.

6.1 Operational considerations. Operating problems include the following: foaming, scum formation, and offensive odors. A high "freeboard" unit will insure that foam and scum are retained. Their accumulation will allow the development of a homogeneous layer from which a light sludge may be periodically removed when the units are serviced either by hand or through auxiliary pipes and valves. As sludge depth increases, scum accumulation decreases. A deep sludge layer also results in a more dense sludge. This simple system is well suited for small plants because no mechanical equipment is required. Usually, scum is removed daily if the freeboard is inadequate. if the tank has more than one compartment, sludge must be resettled by reversing flow (usually at night) for a short time and allowing "readjustment." Imhoff tanks may be heated and have mechanical augers to remove densified sludge. Manufacturers produce single and multiple-chambered units as well as very steep-sided, round tanks.

6.2 Design criteria. Overflow rates should not exceed 600 gallons per square foot at the average flow rate, with detention of no less than 3 hours. See figure 6-2 for details of a two-compartment Imhoff tank.



TOP VIEW OF IMHOFF TANK



END VIEW

Figure 6-1

Typical Imhoff Tank

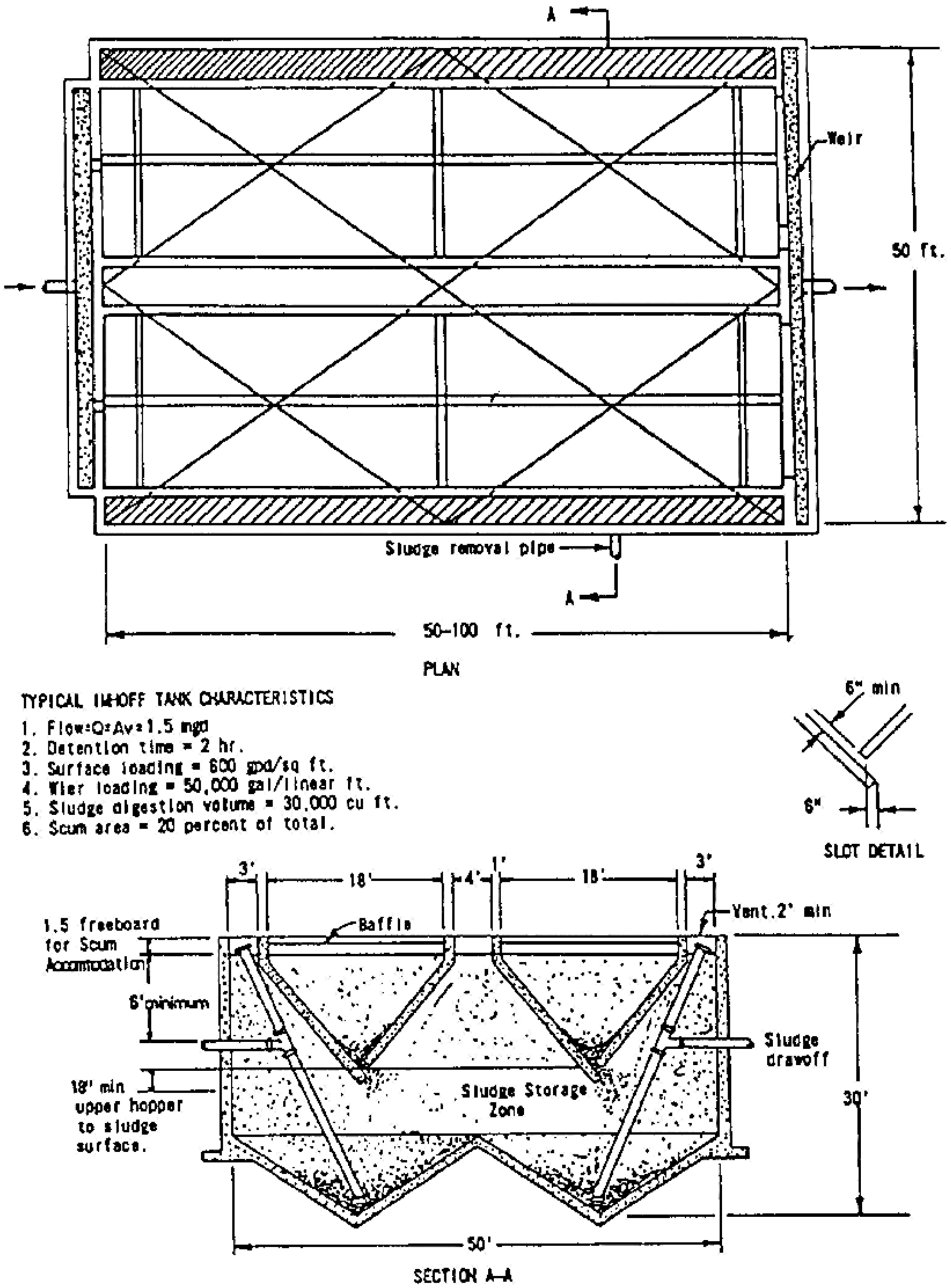


Figure 6-2

Two-compartment Imhoff Tank

7. PACKAGE TREATMENT PLANTS

Complete package treatment plants can be obtained from various manufacturers. The systems are usually based on biological treatment such as extended aeration, contact stabilization, and activated biological filters. These systems are capable of handling population equivalents of 10 to more than 1,000, but generally should be considered only for flows of 0.1 million gallons per day or less. Some prefabricated plants may be relocated, depending on size and original construction. Most of these units are factory fabricated and shipped as complete units, ready for connections to piping and power. Small physico-chemical units have been developed as “add on" units to existing facilities to provide additional treatment efficiency. Physico-chemical systems also have the flexibility to operate in an “on-off" mode which is not possible with biological systems. However, they are often costly to operate, require skilled attention, and produce large amounts of sludge.