MOUND FOR THE TREATMENT AND DISPOSAL OF SEPTIC TANK EFFLUENT"

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J.C. CONVERSE B.L. CARLILE

G.W. PETERSON

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J. C. Converse
Member ASAE

B. L. Carlile

G. W. Petersen

The mound system was developed to overcome soil and site conditions which limit the use of the conventional subsurface soil absorption systems due to slowly permeable soils, high ground water, or shallow soils. The system consists of a septic tank, a pumping or siphon chamber, and the mound (Fig. 1). In most cases, the septic tank is sized the same as for the conventional soil absorption system. A pump is used to elevate the effluent to the mound and to provide pressure for uniform distribution of effluent within the mound. In sites where the mound is down slope from the septic tank, a siphon could be used to provide the pressure for uniform distribution of effluent. The mound consists of the fill material, an absorption area, a cap and topsoil. The effluent is pumped into the aggregate absorption area where it is distributed through a series of perforated pipes. The cap, which is usually silt or clay, provides a barrier to infiltration, retains moisture for the vegetation, promotes runoff of precipitation and provides frost protection. The topsoil provides a good medium for vegetation.

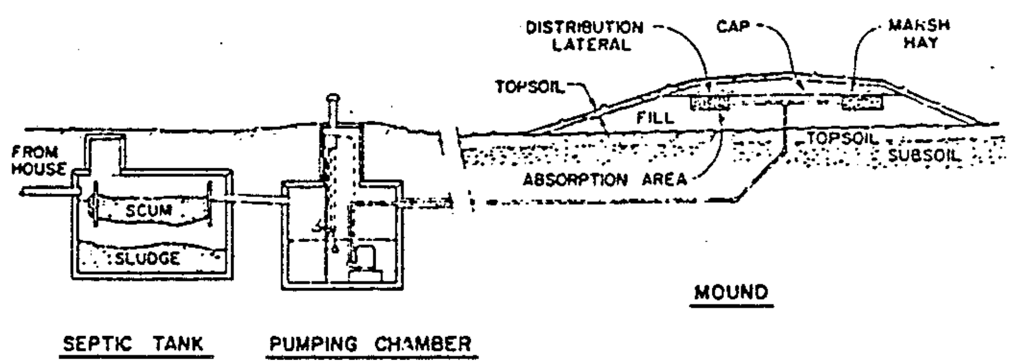

Fig. 1. A Cross-Section of a Septic Tank - Mound System for On-site Disposal

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J. C. Converse, Associate Professor, Agricultural Engineering Department, University of Wisconsin - Madison, B. L. Carlile, Associate Professor, Soil Science Department, North Carolina State University, Raleigh, G. W. Petersen, Professor, Agronomy Department, Pennsylvania State University, University Park, PA.

For permeable soils with high water table or with permeable shallow soil over porous or creviced bedrock, the main purpose of the mound is to provide adequate purification before the effluent reaches the high water table or creviced bedrock. Liquid disposal is usually not a problem because sufficient area is available to provide disposal. By elevating the absorption area above the natural soil and using a suitable fill material, there is sufficient fill and natural soil to provide adequate purification before the effluent reaches the groundwater or the creviced or porous bedrock.

Liquid disposal is the prime design consideration in slowly permeable soils. Purification will be achieved as the effluent moves through the mound and through the natural soil. First, fill material elevates the absorption area out of the wet slowly permeable soils and puts it into the drier, permeable fill. This allows the effluent to enter the more permeable natural topsoil over a larger area where it can move out laterally until absorbed by the less permeable subsoil. This requires sufficient basal area beneath the bed so the natural soil can absorb the effluent before it reaches the outer edges of the mound. If not, then seepage around the perimeter of the mound will occur. Secondly, the slimes that develop in the absorption area will not clog the fill material as readily or to the same degree as they would the less permeable soil. Thirdly, construction is eliminated in the wetter subsoil where smearing and compaction is unavoidable. Fourthly, the absorption area within the mound does not need to be as large as in a conventional system because of the more permeable fill material.

The NODAK system, first conceived in the late 1940's, was developed to overcome failure of the conventional soil absorption system on slowly permeable soils (Witz 1974). Recent adaptation and modification of this system for use on other soil and climatic conditions has resulted in different design and constuction practices (Converse et al. 1975 a b c, Wooding 1975, Hachmeier 1977). Other states have adapted these later designs, with or without modification, to fit their local topography and climatic conditions.

The authors' objective is to review the systems currently in use. Then, based on research and field experience, make recommendations on site limitations, design criteria and construction practices for a mound which should adequately purify and dispose of the household wastes. These recommendations will be for 1) slowly permeable soils with or without high water, 2) permeable soils with high water, and 3) shallow permeable soils with creviced or porous bedrock. However, continuing research and development may change the site limitation and design recommendations in this paper.

SOIL AND SITE REQUIREMENTS

Soil Morphology

Soil morphological features within the soil profile should be investigated before a mound system can be installed on a site. The features, indicated in Table 1, are those that relate to the infiltrative, percolative, and renovative ability of the soil, the depth to impermeable layer and high ground water.

The rates of infiltration and percolation are primarily controlled by soil texture and grade of structure--the more sandy and/or stronger the grade of structure, the greater the rate of infiltration and percolation. Soils with over 50% clay have slow infiltration and percolation rates if they have weak structure. For extremely well structured soils, percolation rates are higher and short circuiting of effluent between the structural

Table 1. Soil and Site Factors that Restrict Mound Construction

Soil groups	Restricting Factors					
	Depth to seasonal high water table	Depth to impermeable soil layer or rock strata	Depth to pervious bedrock	Depth to 50% by volume rock fragments	Percolation rate[b]	Slope
	meters (inches)				min/cm (min/in)	
Slowly permeable soils	> .5 (20)	> .5-1.5 (20-60)	> .5 (20)	> .5 (20)	24-48 (60-120)	< 6
Permeable soils with shallow pervious bedrock	-	-	> .5 (20)	> .5 (20)	1-11 (3-29) 12-24 (30-60)	< 12 < 6
Permeable soils with high water tables	> .5 (20)	> .5-1.5 (20-60)[a]	-	> .5 (20)	1-11 (3-29) 12-24 (30-60)	< 12 < 6

[a] see discussion in text

[b] percolation test depth at 0.5 m, 0.3 m and 0.5 m for slowly permeable, shallow soils and high water table soils, respectively

units may occur if flow approaches saturation. Because of the layered nature of clays, they are easily smeared and compacted by equipment, thus reducing the infiltration. Smearing is particularly critical when the soil is wet.

Percolation rates are being used to determine site suitability. Percolation tests are run at a depth of 0.5 - 0.6 m (20-24 in) from the natural soil surface in slowly permeable soils with a seasonal or perched water table. These soils will be suitable for a mound system if the percolation rates are 24 to 48 min/cm (60 - 120 min/in).

Permeable soils with shallow creviced or porous bedrock should have the percolation test run at a depth of 0.3 - 0.4 m (12 to 16 in) from the natural soil surface to avoid a direct flow route of the water into the bedrock. These soils will be suitable for a mound system with percolation rates of 1 to 24 min/cm (3 - 60 min/in).

Permeable soils with a high water table should have the percolation test run at a depth of 0.5 - 0.6 m (20 - 24 in) from the natural soil surface. These soils will be suitable for mound systems with percolation rates between 1 to 24 min/cm (3 - 60 min/in).

The biological and chemical renovative ability of a soil is determined by the residence time of the effluent within the soil profile. This is reduced if the depth of soil is limited by various restricting factors such as water tables, impermeable soil layers, bedrock, and by an excessive volume of rock fragments.

For the purposes of siting mound systems, a water table includes both perched water tables and ground water tables as determined by direct observation or by the presence of soil mottling. Seasonally high ground water can sometimes be directly observed in unlined auger holes in early spring or late fall. However, occurrence of gray and red soil mottling phenomena can be used in all seasons to indicate periodic saturation with water. Lack of soil mottling does not always mean that seasonally perched water does not occur. Converse et al. (1975a) reports that some red clay soils, such as the Hibbing loam in northern Wisconsin, do not exhibit mottling but perched water is observed for extended periods of time. Perched or ground water tables should not be closer than 0.5 m (20 in) of the natural soil surface in order to provide adequate disposal and treatment.

Impermeable layers include impermeable rock strata and impermeable soil strata. These layers are so slowly permeable that they prevent or severely restrict the downward passage of sewage effluent. Some examples of impermeable soil strata are fragipans, claypans, and plinthite. The minimum distance criteria used for mounds ranges from 0.5 m (20 in) (Wooding 1975) to 1.5 m (5 ft) (Converse et al. 1975 a b c) from the soil surface to the impermeable layer. The minimum distance is dependent upon a number of factors such as climate, soil permeability and site slope. Sufficient lateral movement of the effluent is necessary to get the effluent away from the mound. If the minimum distance between the surface and impermeable layer is not sufficient, then surface seepage will occur. In northern climates frost penetration will reduce the effective area for lateral movement. Slowly permeable soils will require greater distances to the impermeable layer than will more permeable soils. Sloping sites will restrict lateral movement to one direction thus greater depth to the impermeable layer is required than on level sites. Therefore, local or regional conditions will dictate the minimum depth required. Further research and evaluation are required to establish the minimum distance for various site conditions.

Porous bedrock and rockiness also present problems for siting of mound systems as effluent renovation is probably minimal in most rock units. When the bedrock is creviced or porous the danger of contamination of the water table exists if the sewage effluent is not renovated when it enters the bedrock. This is a very serious problem in pervious carbonate rock units because of the typical pinnacling of these units which contain direct conducts (open solution channels) to the water table. Sites which are in rocky, very rocky, and extremely rocky phases should be examined in much greater detail to ensure that there are not areas of the proposed mound where the porous or creviced bedrock rises closer to the surface than 0.5 m (20 in).

Rock fragments can be considered as a dilutant in the soil medium as there is essentially no flow of effluent through the fragments. Also, very little renovation of sewage effluent occurs as it moves between the fragments. Therefore, even if bedrock (a lithic contact) is not present within a minimum distance from the soil surface, a high percentage of rock fragments in the soil will significantly decrease the renovating ability of that soil and could lead to short circuiting of inadequately treated sewage effluent to the water table. The amount of rock fragments that are considered to limit the use of a site for a mound system is thought to be approximately 50 to 70 % by volume. For instance, if a soil contains 50 % rock fragments by volume measurement in the upper 0.6 m (24 in) of the soil, and the disposal field is 5 m (16 ft) by 20 m (66 ft), then there is actually only 30 m^3 (1060 ft^3) of soil available for renovation of the sewage effluent rather than 60 m^3 (2120 ft^3) if the soil was free of rock fragments. In essence, having 50% rock fragments has reduced the volume of the renovating medium by one-half. Thus, larger basal areas beneath the mound may be required.

Siting

In addition to soil morphological considerations, various site requirements must be met before a mound system can be constructed. This includes landscape position as well as surface condition of the soil.

Mounds should not be constructed on flood plains, drainageways, depressions or areas of groundwater discharge (e.g. springs, aquifer discharge areas).

Slope considerations are very important in mound siting. The crested site is most desirable because the mound can be situated such that effluent can move laterally down both slopes. The level site allows effluent to move laterally in all directions. The sloping site is the least desirable, but most common, because all lateral movement is in one direction. On complex slope sites the mound should be located so the lateral flow isn't concentrated downslope in one area. Up slope runoff should be diverted around the mound.

Mounds in Wisconsin (Converse et al. 1975 a b c) are allowed on slopes up to 6% if the percolation rate is faster than 48 min/cm (120 min/in) and on slopes up to 12% if the percolation rate is faster than 12 min/cm (30 min/in). Pennsylvania (Wooding 1975) permits bed distribution mounds on sites with slopes of 8% or less while trench distribution is used at sites where the slope is 12% or less. Systems on steeper slopes, especially with slowly permeable soils may cause surface seepage.

The surface cover of a site must also be evaluated before it can be approved for a mound sytem. If the site has been cultivated, there is generally no problem unless a plow pan has developed. This pan can be broken up with a chisel plow. However, if the site is wooded or covered with large stones serious problems may arise. Trees should be cut as close to the soil surface as possible. Stumps should be left in place since extraction of these stumps will leave channels for effluent to move through. Small stones should be removed by hand. The extraction of stumps and large stones would necessitate the use of heavy equipment which would smear, compact and otherwise seriously disturb the infiltrative capacities of the site. Since plowing or some other type of mechanical disturbance of the site is frequently used, stumps and boulders may render the use of this equipment impractical and the site unsuitable for mound systems. However, in some cases hand spading could be substituted for plowing. Stones imbedded beneath the surface should be treated as a diluent and the depth of usable soil should be calculated accordingly.

The vegetative cover should be incorporated into the soil by plowing, chisel plowing or rototilling. Excess vegetation should be removed prior to surface preparation. Rototilling is satisfactory for unstructured soil such as sand, but should not be used on the heavier loams, silts, or clayey soils as it may destroy too much of the soil structure. Plowing or chisel plowing must be done perpendicular to the slope at a depth of 0.15 - 0.2 m (6-8 in). Moisture content must be low enough to prevent compaction and smearing of the plowed surface. The objective is to have a large surface area interface between the fill and natural soils so the effluent will infiltrate as rapidly as possible. Leaving the vegetative cover undisturbed results in an organic layer which hinders infiltration and allows the water to move laterally between the fill and soil interface.

Pennsylvania currently permits mound systems on fill material provided that the fill material has had at least four years to settle and the site meets the morphological cirteria discussed above.

Disturbed sites such as mine spoils, landfills, slag and bottom or fly ash piles pose special problems and should be evaluated closely to determine if effluent will move through these materials and what type of purification occurs within these materials.

Soil Grouping

Soils with similar characteristics can be grouped to facilitate decisions regarding site suitability for mound systems. Thus, soils in the same group would require the same type of mound design. All the soil series mapped in Pennsylvania by the Soil Conservation Service have been placed into 15 groups according to water table, shallowness, probable percolation rate, flooding potential, and special pollution hazards (Wooding 1975). Soils have been mapped in Wisconsin according to permeabilities (Baker 1977), expressed as hydraulic conductivity values that were determined by the crust test (Bouma and Denning 1972). Soil groups can be extremely valuable in evaluating potential land used at a regional level. While soil groups are a distinct aid in determining a site's potential for use of mound systems, individual on-site investigations are necessary when siting a mound system.

MOUND DESIGN

The mound design is based upon the expected daily wastewater volume and natural soil and fill material characteristics. It must be sized such that it will accept the daily wastewater volume without surface seepage and groundwater pollution. It must also be designed to prevent the encroachment of high groundwater tables into the mound. The design procedure includes five steps which are: 1) design of the absorption area within the mound, 2) dimensioning of the mound, 3) basal area requirements (natural soil - fill interface), 4) design of the distribution network, and, 5) design of the pumping system. Each of these steps will be described and will be followed by a design example.

Absorption System Within Mound

Fill Material: The fill material beneath the absorption area (at the aggregate - fill interface, Fig. 1, 2, 3) within the mound will determine the size of the absorption area for a given loading rate. Medium textured sands, sandy loams, soil mixtures, bottom ash, strip mine spoil and slags have been used or are being tested. The more permeable the fill material, the smaller the absorption area within the mound and the less purification that results. Thus a balance must exist between purification and absorption area size.

In some states the fill material is graded. For example, in North Carolina a 0.10- 0. 15 cm (4-6 in) layer of coarse sand is placed under the aggregate to act as a coarse filter to reduce the clogging potential of the effluent. The sand layer is graded into the main body of the filter material consisting of a mixture of coarse sand and sandy loam topsoil to yield a textural material of 88 to 93 % sand and 7 to 12 % finer grained material. The filter material interfacing with the natural soil should be a similar textural material and integrated with the top few inches of the soil surface (Carlile et al. 1977).

In Pennsylvania the fill material must be graded to meet certain specifications for clay content of 5 - 15% depending on the structure of the soil (Wooding 1975).

In Wisconsin the fill material should preferably be a medium textured sand. The sand does not have to be washed and some fines are desirable but significant amounts of silt and clay are not recommended (Converse et al. 1975 a b c).

As with any soil absorption system, crusting of the infiltrative area will occur and thus reduce the infiltrative capacity of the system. The recommended loading rate for medium textured sand and the sand mixture of North Carolina with crusting is 5 cm/day (1.23 gal/ft^2/day) (Bouma 1975, Carlile et al. 1977) and the recommended loading rate for sandy loams is 2.4 cm/day (.6 gal/ft^2/day) (Bouma 1975, Wooding 1975). With adequate depth of fill these loading rates should give unsaturated flow which provides adequate purification as it moves through the fill (McCoy and Ziebell 1975). Bottom ash as a fill material is currently being evaluated for loading rates and purification (Zaltzman 1977).

System Configuration: The absorption area within the mound can be a bed or trenches (Fig. 2 & 3). The site condition will dictate to some extent what type should be used. For permeable shallow soils over creviced or porous bedrock, either configuration is satisfactory. For soils with high water tables, narrow trenches or rectangular beds are necessary to avoid encroachment of the high-water table into the mound (Bouma et al. 1975). For the permeable soils, the bed can be up to 3.3 m (10 ft) wide without significant elevation of the groundwater. For the slowly permeable soils, two or three parallel narrow trenches, 0.9 - 1.2 m (3 - 4 ft) wide, should be used with sufficient spacing between each trench for the natural soil to absorb the effluent before it reaches the down slope trench.

Since disposal is the critical criteria and a large natural soil area is required, the narrow trenches need to be placed perpendicular to the site slope to avoid concentrating the effluent into a small area which would occur if a square bed was used. If the effluent is concentrated into too small an area, it will not infiltrate into the natural soil by the time it reaches the edge of the mound, thus causing surface seepage.

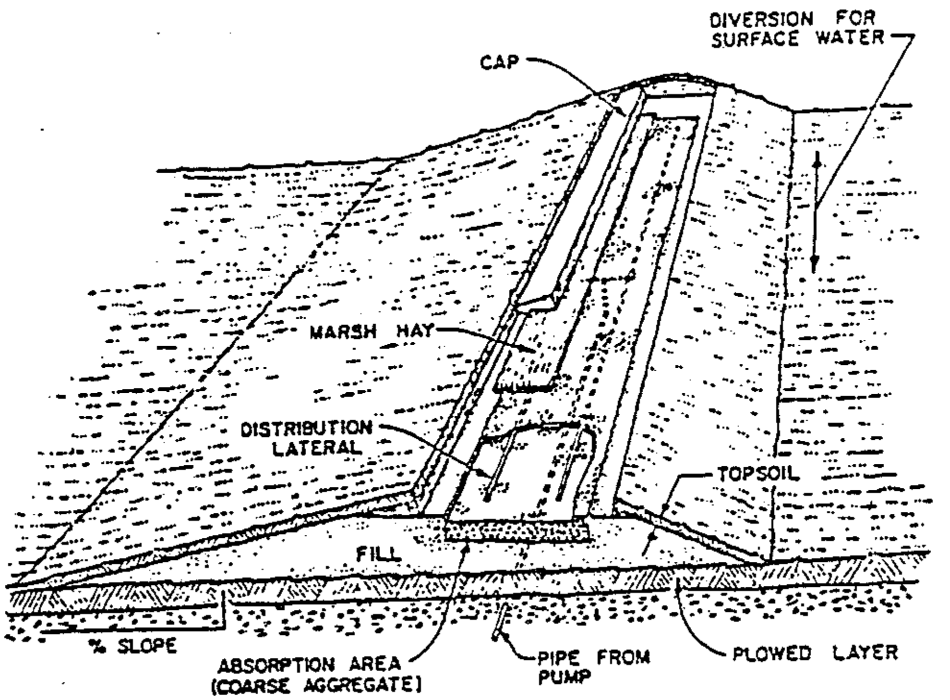

Fig. 2. A Mound System Utilizing a Bed as the Absorption Area.

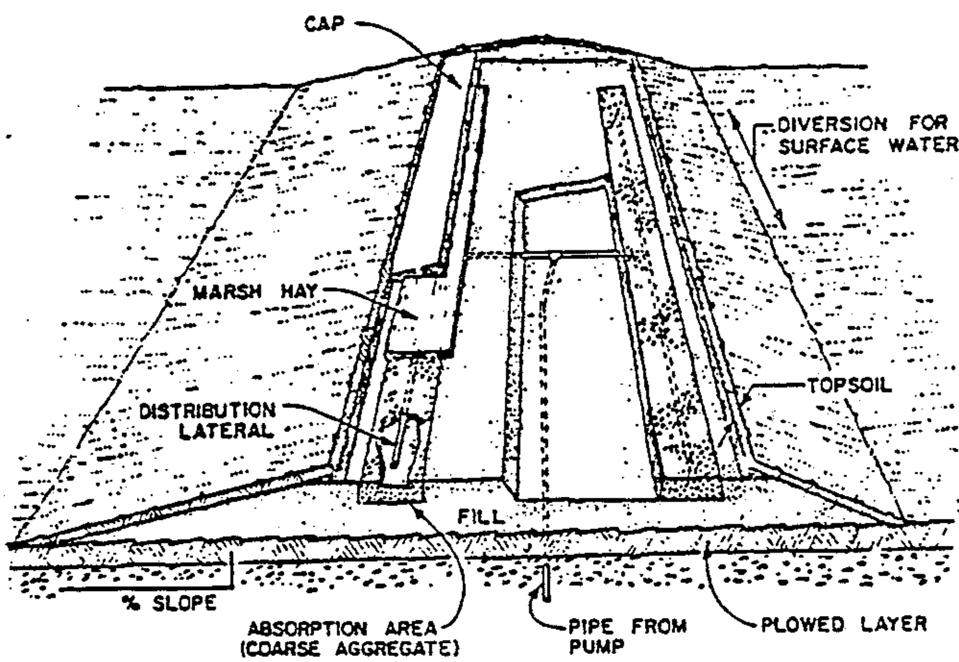

Fig. 3. A Mound System Utilizing A Trench as the Absorption Area. This System is Recommended for Slowly Permeable Soils with High Water Tables.

The bottom of the course aggregate within the bed and trenches must be level and at the same elevation so one area of the bed or one trench is not overloaded.

Mound Dimensions

Mound Depth: The depth of the mound will consist of the depth of fill material the depth of trench or bed, and the depth of cap and topsoil (Fig. 4). The depth of fill will be dependent upon its purification potential. An unsaturated flow depth of .9 - 1.2 m (3 - 4 ft) of sand and sandy loam and natural soil is sufficient for purification (McCoy and Ziebell 1975, Tyler et al. 1978). Other types of fill materials may require greater depth of fill.

For slowly permeable and permeable soils with a high water table at a minimum of 0.5 m (20 in) from the surface, a minimum of 0.4 m (16 in) of fill is required between the natural soil surface and the bottom of the trench to provide the minimum 0.9 m (3 ft) of soil. For water tables greater than 0.6 m (2 ft) a minimum of 0.3 m (1 ft) of fill is required which allows for smaller sizing of the trench or bed absorption area since the sizing is done on the more permeable fill material. For permeable soils on creviced or porous bedrock, it is recommended that a minimum of 0.6 m (2 ft) of fill be used with a minimum natural soil depth of 0.5 m (20 in) because once the effluent enters the bedrock very little purification will occur. The extra depth of fill over the creviced or porous bedrock is recommended because the effluent may flow directly into a potentially potable aquifier.

The trench or bed depth should be 0.15 - 0.3 m (6 - 12 in). A minimum of 0.10 - 0.15 m (4 - 6 in) of aggregate should be placed beneath the distribution pipe with 2.5 - 5 cm (1 - 2 in) of aggregate above the pipe. This should allow for several days storage of effluent within the aggregate. The aggregate should be clean stone or rock fragments 1.2 - 5 cm (1/2 - 2 in) size which will not deteriorate as effluent flows through. Bottom ash is currently being investigated as a substitute aggregate.

The cap and top soil should be thick enough to provide sufficient depth to promote runoff of precipitation and provide frost protection. The depth at the center should be 0.4 to 0.6 m (1.5 - 2 ft) depending on the width of the mound. The outer edge of the trench or bed should have at least 0.3 m (1 ft) of soil above the aggregate. In milder climates, shallower depths may be sufficient for runoff as frost penetration may not be a problem. Approximately 0.15 m (6 in) of good quality topsoil should be placed over the entire mound to promote good vegetative growth. Little or no vegetation on the mound will result in erosion of the mound surface and could result in failure of the system. Thus the mound depth will range from approximately 0.9 m (3.0 ft) up to 1.5 m (5 ft) deep.

Mound Length and Width: The side slope on the mound should be no steeper than 3:1 to maintain good stability and ease of maintenance of the vegetative cover (Fig. 4). The mound length, which runs perpendicular to the site slope, consists of the trench or bed length and the necessary slope lengths (Fig. 5).

The mound width, which parallels the slope, consists of the bed width or trench widths, the space between trenches and the upslope and down slope width (Fig. 5). Some slope width adjustments are required on sloping sites in order to maintain the desired side slopes. The most critical dimensions of the mound are 1) the depth of the fill beneath the trench or bed, 2) the bed or trench length and width, 3) spacing between trenches and, 4) the down slope distance between the trench or bed edge and the

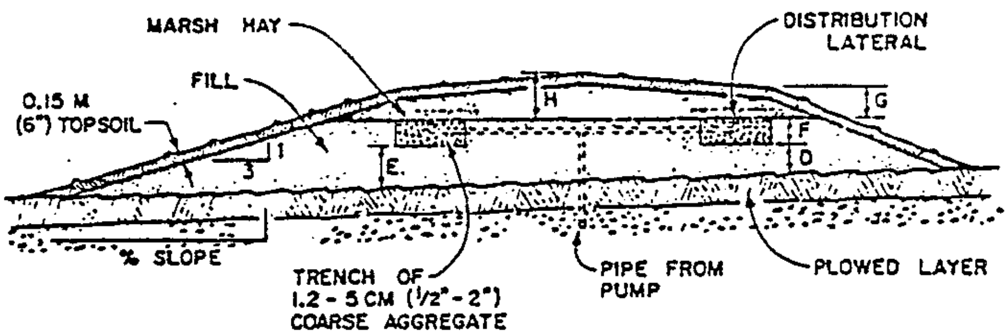

Fig. 4. A Detailed Cross-Section of a Mound Using Trenches for the Absorption Area.

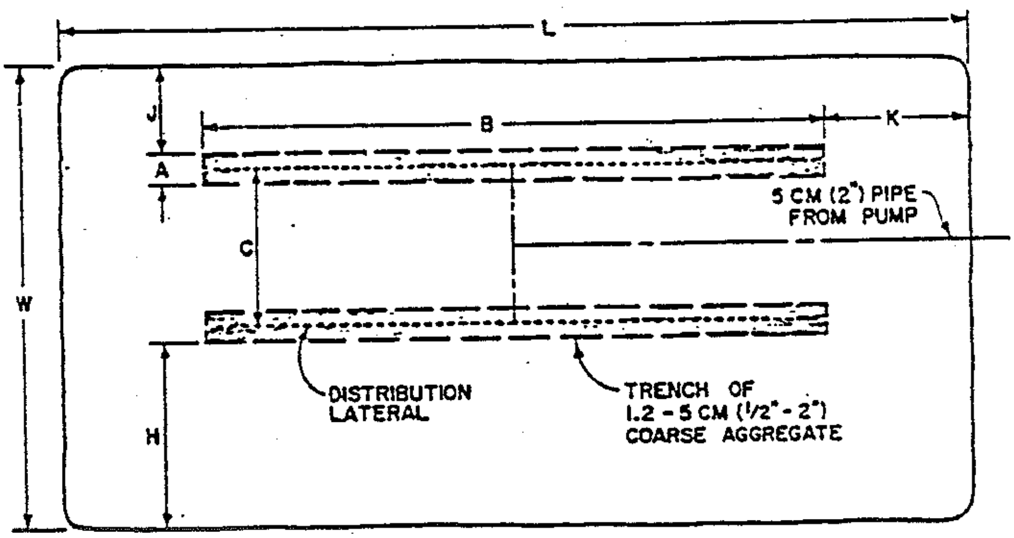

Fig. 5. A Detailed Plan View of a Mound Using Trenches for the Absorption Area.

toe or edge of the mound. The other dimensions can be approximate.

Basal Area

The basal area is the natural soil area beneath the mound. Its purpose is to assist in purification, to absorb the effluent and transmit it to the subsoil beneath the mound or transmit it laterally to the subsoil outside the mound perimeter without causing surface seepage. In less permeable subsoils, a large portion of the effluent moves laterally to the subsoil outside of the mound.

The size of the basal area is determined by the natural soil infiltrative capacity. For percolation rates of 1 - 12 min/cm (3 - 30 min/in), 12 - 25 min/cm (30 - 60 min/in) and 25 - 48 cm/in (60 - 120 min/in), the design loading rates are 5, 3, and 1 cm/day (1.23, .74, and .24 gal/ft^2/day) respectively (Converse et al. 1975 a b c, Bouma 1975). For sloping sites the active basal area is determined using the area beneath the trenches (bed), between the trenches and down slope from the trenches (bed). It does not include the basal area upslope of the trenches (bed) nor at the ends of the trench (bed) because the effluent will primarily move down slope.

One design calls for removing the vegetation from the site, then encompassing mound with a berm to reduce seepage. This berm is constructed using less permeable soil and compacting it (Wooding 1975). In some cases the berm is keyed into the soil a depth of 0.3-0.46 m (1-1.5 ft) (Shaffer 1977). Compaction of the natural soil or keying in a less permeable soil material will reduce the lateral flow of effluent out of the mound system thus causing a bathtub effect. The area down slope of the mound should not be compacted or driven on during construction.

Distribution Network

The conventional method of effluent distribution is the 10 cm (4 in) diameter perforated pipe. This pipe has two rows of holes with each hole about 1.6 cm (5/8 in) diameter spaced 7.6 cm (3 in) apart. Uniform distribution over the bed or trench area by gravity or dosing does not occur because of the large number of holes (Converse 1974, Otis et al. 1978). As the effluent is pumped in or flows in by gravity, it is concentrated within one small area of the bed or trench. This results in saturated flow thru the fill material, thus poor purification.

In mound systems, the effluent must be uniformly distributed for several reasons. In the permeable soils over creviced or porous bedrock, the effluent must be spread out over the entire bed to provide unsaturated flow thru the fill. Secondly, in the more slowly permeable soils, it is necessary to distribute the effluent along the total length of the trenches or bed. If it is concentrated in one area, the effluent moves rapidly through the fill and moves laterally down slope at the fill-natural soil interface. This area becomes overloaded thus resulting in surface seepage with the remaining portion of the mound unused.

The only way to obtain uniform distribution is to use a pressure system consisting of a manifold with small diameter laterals and holes (Converse 1974, Converse et al. 1975, Otis et al, 1974 and 1978). Figure 6 shows a typical effluent distribution system for a trench system. Machmeier (1975) developed a computer program to predict lateral lengths for various size diameter laterals and hole size such that the distribution didn't vary more than 10% along the length of the lateral (Table 2). For 0.76 m (30 in) spacing with a 0.64 cm (1/4 in) hole, and pipe diameter of 2.5 cm (1 in), maximum lateral length was found to be 7.6 cm (25 ft). Converse (1974) through field testing, concluded that lateral lengths up to 7.6

Table 2. Allowable Lateral Lengths in Meters (Feet) for Three Pipe Diameters, Three Perforation Sizes, and Two Perforation Spacings (Machmeier 1975)

Perforation Spacing m (in)	Perforation Diameter cm (in)	Pipe Diameter 2.5 cm (1 in)	3.2 cm (1-1/4 in)	3.8 cm (1-1/2 in)
0.76 (30)	0.48 (3/16)	10.4 (34)	15.6 (52)	21.3 (70)
	0.56 (7/32)	9.1 (30)	13.7 (45)	17.4 (57)
	0.64 (1/4)	7.6 (25)	11.6 (38)	15.2 (50)
0.90 (36)	0.48 (3/16)	11.0 (36)	18.3 (60)	22.9 (75)
	0.56 (7/32)	10.1 (33)	15.5 (51)	19.2 (63)
	0.64 (1/4)	8.2 (27)	12.8 (42)	16.5 (54)

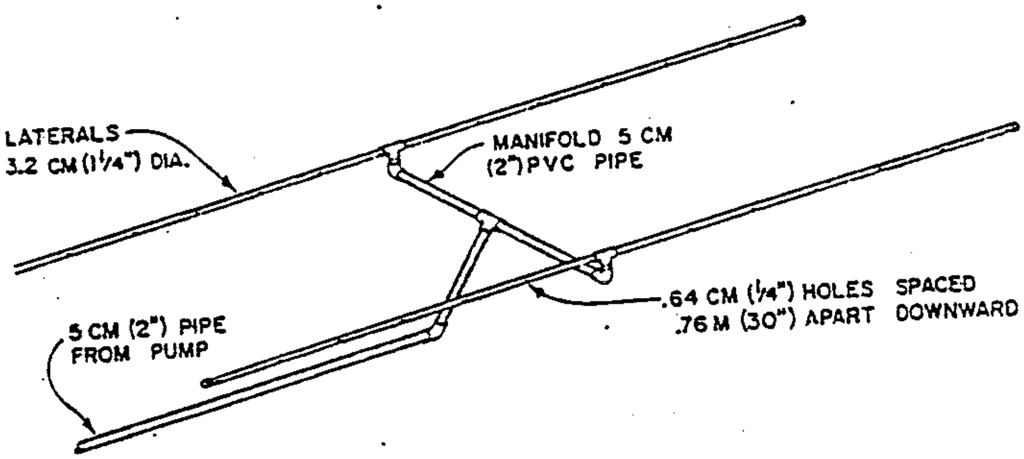

Fig. 6. Distribution System for Mound with Bed or Trench Absorption Area. Dimensions are for the Design Example. Other Dimensions are Given in Table 2.

m (25 ft) gave good distribution. Otis et al. (1978) outlines design procedures for determining lateral lengths and hole size and spacing.

Pumping System

The components of the pumping system that requires designing are the pumping chamber, the pump size, and the pump controls and alarm system. (Fig. 7).

Pumping Chamber: A sufficient quantity of effluent must be available at each dose to give as uniform distribution as possible. The quantity depends upon the frequency of dose and the pipe void space. Since small diameter pipe is recommended, the void space is quite small. The more frequent the dose, the less chance of obtaining saturated flow, thus, the better the purification. However, dosing too frequently could lead to faster crusting and poorer distribution of effluent. Dosing frequencies of four times daily and once daily is recommended for sand and sandy loams respectively, (Bouma 1975). Other fill materials may require other loading frequencies.

Maintaining a given dosing frequency is impossible due to family daily activity and variation of water use from family to family. This, coupled with the various sizes and shapes of tanks, makes it difficult for the installer to get the desired loading rate and frequency of dose. Therefore, liquid level control flexibility must be available so a given quantity per dose can be obtained.

It is more important to get the proper quantity per dose than a given dosing frequency. Therefore, it is recommended to set the level control of the pump so that it pumps into the mound the quantity obtained by dividing the design load by the number of doses recommended per day for the given fill. For a three bedroom home with a sand filled mound and a design loading rate of 1.7 m^3/day (450 gal/day), the dosing quantity is 0.43 m^3/dose (113 gal/dose) (1.7 m^3gal/day ÷ 4 doses/day). For a three bedroom home with a sandy loam filled mound, the dosing quantity is 1.7 m^3/dose (450 gal/day), using once a day dosing as recommended. The pumping chamber should be sized to hold an extra quantity of effluent in case of pump or control failure. Also, extra room is needed for controls, elevation of pump off the bottom and flow back after the pump shuts off. Therefore a pumping chamber of 2-3 m^3 (500-750 gal) is recommended.

Pump Size: Proper pump selection is necessary for proper operation of the pressure distribution system. A pump which does not supply sufficient capacity at a sufficient head will not give good effluent distribution (Converse et al. 1974). Pump selection is based on its performance curve. The total head is equal to: 1) the elevation difference between pump and lateral invert, 2) friction loss in pipe between pump and distal end of lateral, and 3) a recommended head at the distal end of lateral of 0.7 m (2 ft).

From field experience, Converse et al. (1975), based pump selection using 1.5 m (5 ft) of head at the inlet with minimum flow of 95 L/min (25 gpm) for systems for three bedrooms and 114 L/min (30 gpm) for four bedrooms. Machmeier (1976), using a computer analysis, recommends a minimum of 0.15 m (6 in) of head at the supply end of the lateral but small elevation differences along the length of the laterals will greatly affect distribution which should not be the case when higher pressure is used. Based on these field experiences and computer analysis a head of 0.6 m (2 ft) at the distal end of the lateral is recommended (Otis et al. 1978).

From Figure 8, the flow rate based on L/m² (gpm/ft²) of soil absorption area for a given head, perforation size and spacing can be determined. If the pump cannot supply the needed capacity then the pump performance curve will go to equilibrium with the distribution system demand curve by following the selected curve in Figure 8. Smaller pump capacities can be used if smaller perforations are used in the pipe. Perforations as small as .32 cm (1/8 in) have been used successfully.

Pump and Alarm Control: The control system for the pumping chamber consists of a control for operating the pump and an alarm system to detect when the system is malfunctioning.

Since water use quantities vary and size and shape of pumping chambers vary, it is essential to have a pump control system that can be adjusted to meet the recommended loading rate into the mound. Some of the types of controls in use or being tried are mechanical floats, diaphram pressure switches, mercury magnetic switches, and the mercury level controls.

The mechanical float switch is used primarily in "clean" water sumps. It does not allow for adjusting the quantity of water to be pumped. The diaphram pressure switches require a vent to the atmosphere. These cannot be adjusted for different on-off levels but different on-off levels can be purchased. These units have created service problems due to leaks in the diaphrams, sewage solids and greases caking on the switch and condensation collecting in the vent tubes. Mercury magnetic switches are activated by a float which raises a magnet in contact with the switch case. Limited water level height adjustment can be done. The most reliable and service free is the mercury level control which is incased in a polyethylene casing. Two switches are required and are suspended from above the pump. This unit gives the greatest flexibility in adjusting water level but is the most costly. Currently being developed is the mercury built-in differential switch which eliminates the need for two switches but limits the flexibility in adjusting water level.

The high water alarm system consists of a switch in the chamber and a jewel light with or without an audio alarm in the home which is readily visible. The alarm system should be on a separate circuit from the pump control. The switch in the chamber may be a diaphram pressure switch, a mercury magnetic switch or a mercury level control switch.

Siphons: Siphon systems can be designed where sufficient elevation exists between the mound and the siphon chamber. This will eliminate the need for a pump. However, the siphon must be designed to deliver the same head and flow rates at the distribution system as a pump system. The distribution system consisting of manifold and laterals must be designed so that they drain after each siphon.

DESIGN EXAMPLE

Design a mound system for a site with the following site conditions for a three bedroom house. Bedrock, impermeable layer, and high volume rock fragments were not encountered in site evaluation.

Slope	6%
Percolation rate	43 min/cm (110 min/in)
Ground water	50 cm (20 in)
Design Loading	1.7 m³/day, (450 gal/day) (based on 150 gal/bedroom)

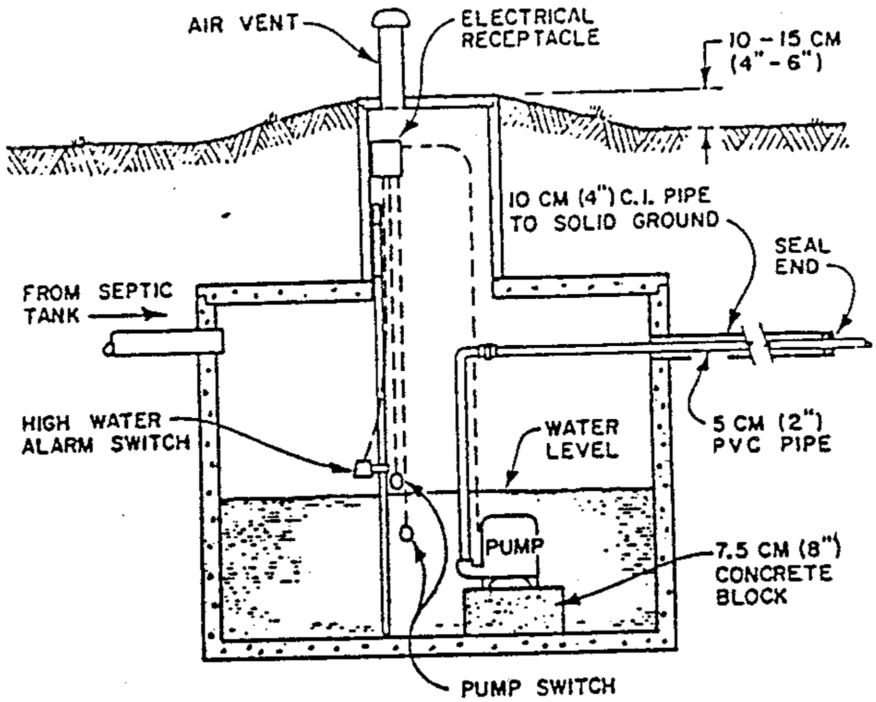

Fig. 7. A Detailed Cross-Section View of Pumping Chamber.

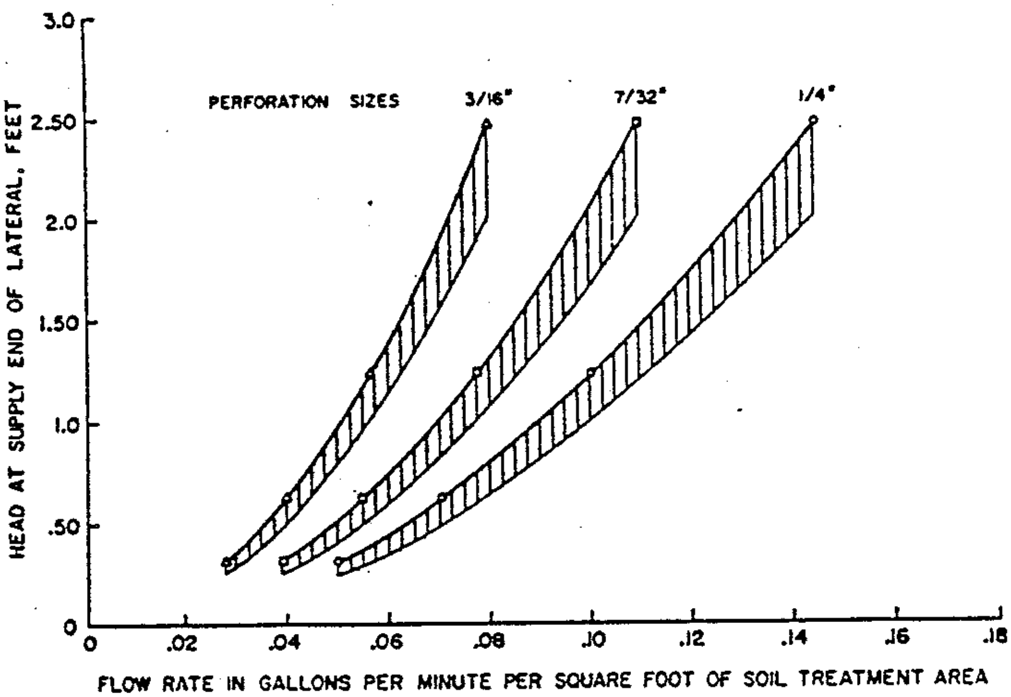

Fig. 8. Flow Rate vs Head for Perforations Spacing of 0.76 m (2.5 ft) and Lateral Spacing of 0.9 m (3.0 ft). The Lower Curve for Each Perforation Represents the Head at the Distal End (Machmeier 1975).

Step 1: Absorption area in mound

Select a fill material that will have adequate hydraulic conductivity and purification which is within a reasonable cost. For this example, a medium textured sand will be used that has an infiltration rate of 5 cm/day (1.23 gal/ft^2/day).

Since this is a slowly permeable site with high ground water, the absorption area must be a trench system which will spread the liquid out along the slope and also minimize the encroachment of the ground water into the mound.

Absorption area required = 1.7 m^3/day ÷ .05 m/day = 34 m^2 (364 ft^2)

Assume a trench width of 0.9 m (3 ft) then:

Trench length = 34 m^2 ÷ 0.9 m = 37.8 m (124 ft)

This is too long for a 1 trench system, therefore 2 or 3 parallel, trenches of equal length should be constructed so that the liquid will not concentrate in a small area. (More than 3 parallel trenches may concentrate the liquid into a small area and also result in higher mounds on sloping sites.)

For a two trench system:

Trench length = 37.8 m ÷ 2 = 18.9 m (62 ft.)

Trench spacing is determined by the design loading rate of the natural soil which for a soil of 110 min/in. percolation rate is 1 cm/day (.24 ft^2/day). Since one-half of the effluent is distributed in each trench then:

Trench spacing = 0.85 m^3 ÷ (0.01 m/day) (18.9 m)
= 4.5 m (15 ft) on center

Step 2: Mound Dimensions

(For this design example, the letter notations are found in Fig. 4 and 5).

Mound depth = fill depth at center + trench depth (F) + top (H)

Fill depth at center = min. depth (D) at upper edge of upslope trench plus slope adjustment on 6% slope.
= 0.41 m + 0.06 m (2.7 m) = 0.57 m (1.9 ft) at center

Trench depth (F) = 0.23 m (.75 ft)

Cap and top soil (H) = 0.45 m (1.5 ft) minimum which include 0.30 m cap and 0.15 m of top soil

Mound depth = 0.57 + 0.23 + 0.45 = 1.25 m (4.1 ft)

Mound length = trench length (B) + 2 end slope lengths (K) of 3:1 slope
= 18.9 m + 2 (1.25) (3)
= 18.9 m + 7.5 m = 26.4 m (87 ft)

Mound width = trench width (A) + spacing between trench centers (C) + upslope width (J) + downslope width (H)

trench widths (A) = 0.9 m
distance between centers (C) = 4.5 m
upslope depth (D+F+G) = 0.94 m depth (at upper edge of upslope trench)
upslope width (J) = .9 x 3 - slope correction
= 2.70 m - 0.3 m (estimate)
= 2.4 m
downslope depth (E+F+G) = 1.26 m
where E = D + slope adjustment
= 0.41 m + 5.4 (0.06)
= 0.73 m
downslope width (H) = 1.3 x 3 + slope correction
= 3.9 + 1.8 (estimate)
= 5.7 m (19 ft)
mound width = .9 + 4.5 + 2.4 + 5.7
= 13.5 m (44 ft)

Therefore, mound is 1.3 m high by 26.4 m long by 13.5 m wide.

Step 3: Basal Area

On sloping sites the basal area is that area under and downslope of the trenches (B x (A+C+H)). On level sites it is the total area under the mound except for the end areas (B x W). The design loading rate of soil with a percolation rate of 43 min/cm (110 min/in) is 1 cm/day (.24 ft^2/day)

Basal area required = daily flow ÷ infiltrative cap of soil
= 1.7 m^3/day ÷ 0.01 m/day = 170 m^2

Basal area available = trench length (B) x (trench width (A) + spacing (C) + downslope length (H))
= 18.9 x (.9 + 4.5 + 5.7) = 210 m^2

Therefore, sufficient area is available. If it were not, then the down slope width would be increased until sufficient area is available.

Step 4: Distribution Network

The system consists of a manifold and laterals. T to T construction is used so the manifold fills before the laterals receive effluent. Using a perforation diameter of .64 cm (1/4 in), lateral lengths of 9.1 m (30 ft), and 0.76 m (2.5 ft) perforation spacing, Table 2 shows that a 3.2 cm (1-1/4 in) diameter pipe is required. The distribution system requires a manifold of 5 cm (2 in) diameter PVC pipe which is 4.6 m (15 ft) long. Hole location is shown by Figure 6. Laterals on one side of manifold have one more hole than laterals on other side. These holes are located about 5 cm (2 in) from manifold.

Step 5: Pumping System

Based on a design flow of 1.7 m^3/day (450 gal/day), and a dosing frequency of four times a day, the volume per dose is .43 m^3/dose (115 gal/dose). Storage for an additional day's supply is desirable if failure occurs. Additional space for placing a pump above the floor, and space for flow back is required. Therefore a pump chamber capacity of 2.8 m^3 (750 gallons) should be adequate.

Figure 8 is used to size the pump. Using a lateral spacing of 0.9 m (3 ft) and perforation spacing of 0.76 m (2.5 ft) with 0.64 cm (1/4 in) diameter holes and a distal end head of 0.61 m (2 ft) a flow rate of 5.9 L/m^2 (0.145 gpm/ft^2) of absorption area is required. For a 34 m^2 (364 ft^2) absorption area, a pump capacity of 200 L/min (52 gpm) is required. Assuming an elevation difference of 3.1 m (10 ft) between pump and lateral invert, a friction loss from pump to distal end of laterals of 2.4 m (8.0 ft), and a 0.6 m (2 ft) head at the distal end of lateral, the total head is 6.1 m (20 ft). Therefore, a pump needs to deliver a minimum of 200 L/min (52 gpm) at a given head of 6.1 m (20 ft). Otis et al. (1978) outlines a more detailed procedure for determining head loss.

MOUND CONSTRUCTION TECHNIQUES

Site Preparation

A site which meets the criteria established in Table 1, should be selected and staked. The next step is to determine where the pipe from the pumping chamber will connect to the distribution system in the fill material. The discharge pipe from the pump to the mound area should then be installed prior to soil surface preparation for the mound to avoid compaction of the prepared area. The pipe from the pump can be laid below the frost line or it can be laid on a uniform slope back to the pumping chamber so that it drains after each pumping. The trench to the mound area should be carefully backfilled and compacted to prevent back seepage of effluent along the pipe.

Proper soil moisture content is extremely important on the less permeable sites containing heavy textured soils. If the soil is too wet, smearing and compaction will result, thus lowering the infiltration capacity of the soil. Proper moisture content can be determined on a sample of soil obtained at the bottom of the plow layer, by rolling it between the hands. If it rolls into a ribbon, the site is too wet to prepare. If it crumbles as it is rolled, soil preparation can proceed.

Trees should be cut at ground level and excess vegetation removed prior to plowing. The site should be moldboard plowed, chisel plowed or rototilled. It should be done perpendicular to the slope. Rototilling must be avoided on the heavier soils because it tends to break up the surface structure. Once preparation has been done, placement of the fill should proceed immediately. Precautions must be taken to avoid vehicular traffic directly on the prepared surface.

Placement of Fill Material

The fill material is placed around the edge of the plowed area, being careful to keep the wheels of the front-end loader or dump truck off the plowed area. Excess vehicular traffic should be avoided down slope of the mound. The material can then be moved into place by using a small crawler tractor with a blade or a small self-propelled rototiller with a blade. Always keep a 0.15 m (6 in) layer of sand beneath the crawler tracks to prevent compaction of the natural soil.

The filter material is then placed and leveled to the maximum height required. The absorption area is formed on the fill and is leveled to the proper elevation. If a mixture of sand and topsoil is used, as in construction of the Sewage Renovation Levee system in North Carolina, then these materials are laid down in 5-7.5 cm (2-3 in) layers of each and mixed by use of a power rototiller (Carlile et al. 1977).

Distribution of Effluent

After leveling the bottom of the bed or trenches at the proper elevation, 10-15 cm (4-6 in) of coarse aggregate of 1.2 - 5.0 cm (1/2-2 in) size is placed in the bed or trench. The distribution system, as shown in Figure 6, is then placed and connected to the pipe from the pumping chamber. The laterals are laid fairly level with the manifold sloping slightly toward the inlet pipe. Additional aggregate is added to completely cover the pipe. The 10 cm (4 in) conventional perforated pipe or modification of it, are not recommended because of their poor distribution characteristics (Otis et al. 1978) which may lead to early failure of the system.

Final Mound Cap

Some material such as straw, marsh hay, untreated building paper, or fibrous nylon fabric is placed over the aggregate to prevent soil infiltration into the aggregate. In colder climates a cap of heavy soil material is added to provide frost protection and promote runoff (Fig. 2, 3, 4). The depth of cap ranges from 0.15 m (6 in) on the outer edges of the absorption area to 0.30 m (1 ft) in the center of the mound. Then a soil cover of silt loam to sandy loam top soil is placed to a depth of at least 0.15 m (6 in) over the entire mound. In milder climates if the cap is not used, the top soil should be crowned in the center to allow precipitation to readily drain off the surface.

The mound is now ready to be landscaped. A grass cover should be established over the top of the mound area and should be the best lawn grasses adaptable to the area. Shrubs should not be planted on top of the mound but may be placed around the side slopes of the mound. These shrubs should be somewhat moisture tolerant since the toe area of the mound may be quite moist during various times of the year.

Maintenance

The mound system normally requires little maintenance if properly constructed and dosed. In colder climates, care should be taken to ensure that the supply lines all drain back to the pumping chamber after each dose to prevent freezing or are below the frost line. As in any system, solids must be kept out of the supply line to prevent clogging at the fill-aggregate interface as well as the perforations of the supply line. This is best done by pumping the septic tank every three years to prevent solids carryover into the pumping chamber. If the system does become clogged, some restoration procedures are possible. If the perforated lines have solids accumulated in them, these can be flushed by removing the end caps and pumping clean water from the pump chamber. This can be facilitated by putting turn-ups at the end of each lateral and bringing it to the mound surface with a cap. Where the absorption bed is clogged at the sand-gravel interface, some restoration can be accomplished by resting the system for several weeks. This is best accomplished during the dryer summer months. Studies are now underway to look at chemical restoration of some systems through use of strong oxidizing chemicals which destroy the clogging material (Harkin and Jawson 1976).

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