SMALL SCALE WASTE MANAGEMENT PROJECT

The Wisconsin Mound System: Siting, Design, and Construction

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ABSTRACT

New concepts have been developed for the design of small and large Wisconsin mound systems. Mounds are designed using linear loading rate which is based on the vertical and horizontal soil acceptance rates. Depending upon the soil site conditions, wastewater will move away from the mound horizontally, vertically, or a combination of both. Mounds designed using this technique have performed well on very difficult sites with high water tables 10 in. (25 cm) below the surface, on soils with saturated vertical hydraulic conductivities rated moderately low, on slopes of 20-25%, over old systems, and on fill soils. The recommended mound fill is on the coarse side of medium to coarse Land. Construction planning is essential especially on larger mounds.

INTRODUCTION

The Wisconsin mound on-site wastewater disposal system was developed in the early 1970's to overcome the limitations of other designs for lands with difficult soil and site conditions. The Wisconsin mound has been used across the nation and the siting, design, construction and maintenance procedures have been incorporated into rules and regulations of many states. Originally mounds were designed for individual homes with moderate soil and site restrictions and with wastewater flows of less than 750 gal. (2850 L). As the need for disposal of wastewater on land with very severe landscape restrictions and for the disposal of greater wastewater volumes from small communities, clusters of homes, and commercial establishments in a safe and economical manner increased, the demand for mounds and large mound systems has increased. It is not unusual to see very large mounds or a number of mounds making up a system and serving wastewater flows in excess of 25,000 gpd (95,000 Lpd). With the increased need for the use of Wisconsin mounds for individual homes on severe sites and interest in larger systems, new design concepts have been defined based on wastewater flow in the soil (Tyler and Converse, 1985).

Recent research has provided new information that can be used to supplement current design procedures as presented by Converse (1978). The purpose of this paper is to discuss the most recent site criteria, design, construction and maintenance concepts of the Wisconsin mound.

MOUND SITING

Wisconsin mound design must be matched to the given soil and site as the soil is the ultimate receiver of the effluent. The designer must understand the hydraulic principles and treatment capabilities of the mound, the soil, and the site to successfully design for the transmission of the wastewater from the mound to the soil and have it continue safely away from the system. Figure 1 illustrates the hydraulic movement of wastewater for various types of soil conditions. For the site with creviced bedrock or very permeable soil, movement is primarily vertical, while for the soil with a very slowly permeable subsurface horizon, and for shallow water table sites, the movement is initially vertical followed by horizontal movement away from the system. The amount of wastewater that the soil will transmit away from the mound vertically is defined as the vertical acceptance rate (VAR) and the wastewater volume that the soil will move horizontally is defined as the horizontal acceptance rate (HAR). The sum of the vertical and horizontal acceptance rates is the linear acceptance rate (LAR) or the amount of wastewater that the system can accept per unit length (Fig. 2) (Tyler and Converse, 1985).

Wisconsin mounds are designed on the basis that all applied wastewater can be successfully transported away from the system and it no longer affects the subsequent wastewater additions and that it is treated and undetectable in the environment. Thus, in design, the vertical and horizontal acceptance rates and the treatment capacity can not be exceeded. All design parameters must be within the limits established by the site.

Site Criteria

Current site criteria for individual homes are very conservative (Converse, 1978; Wisc. Adm. Code, 1980). Recent research on the Wisconsin mound has shown that mounds can function effectively on more restrictive sites (Converse and Tyler, 1985). Table 1 gives current and recommended soil-site criteria for the Wisconsin mound for individual homes. Recommended site criteria are based on evaluation of over 40 Wisconsin experimental mounds serving two to five bedroom homes with design linear loading rates of 5 to 8 gpd/ft (60 - 100 Lpd/m) of mound length.

The vertical and horizontal wastewater acceptance rate for individual home systems is within the soil and site criteria in Table 1. For systems disposing of large volumes of wastewater, these limits may not be adequate and limits must be established for the specific site conditions and mound design based on principles outlined in this publication. The current criteria are presently being used by various states for larger mound systems. Further research is needed to determine the size limits for the criteria presented in Table 1.

Mound Fill Quality

The mound fill sand used for construction is to disperse the wastewater as it infiltrates into the original soil and offer treatment before reaching the soil. Generally, the finer the sand the better the treatment and the slower the wastewater acceptance. Mound fill sand quality must be a compromise between treatment and dispersement.

CREVICED BEDROCK

WATER TABLE
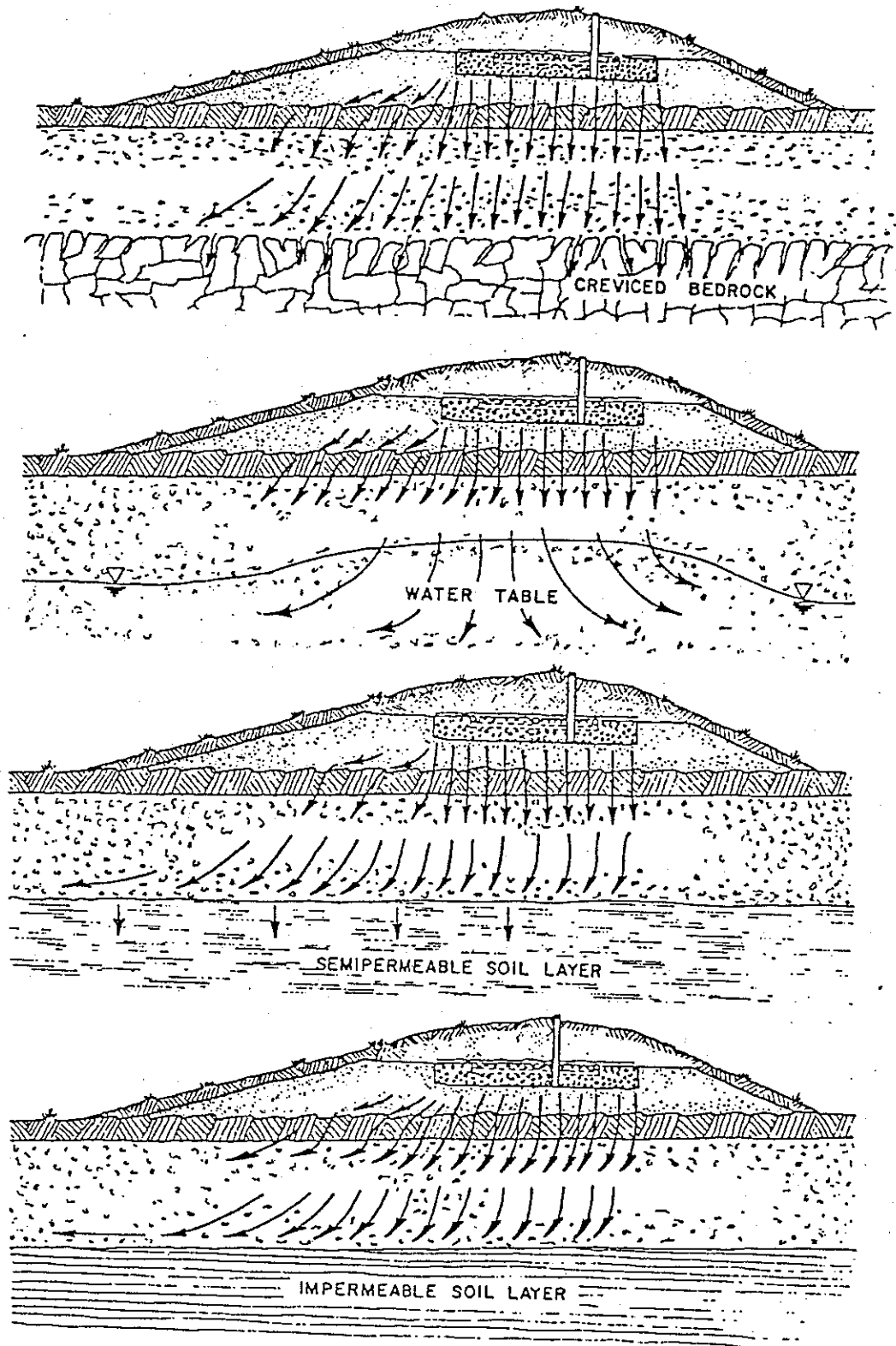
SEMIPERMEABLE SOIL LAYER

IMPERMEABLE SOIL LAYER

Fig. 1   Schematics Showing Effluent Movement Within and
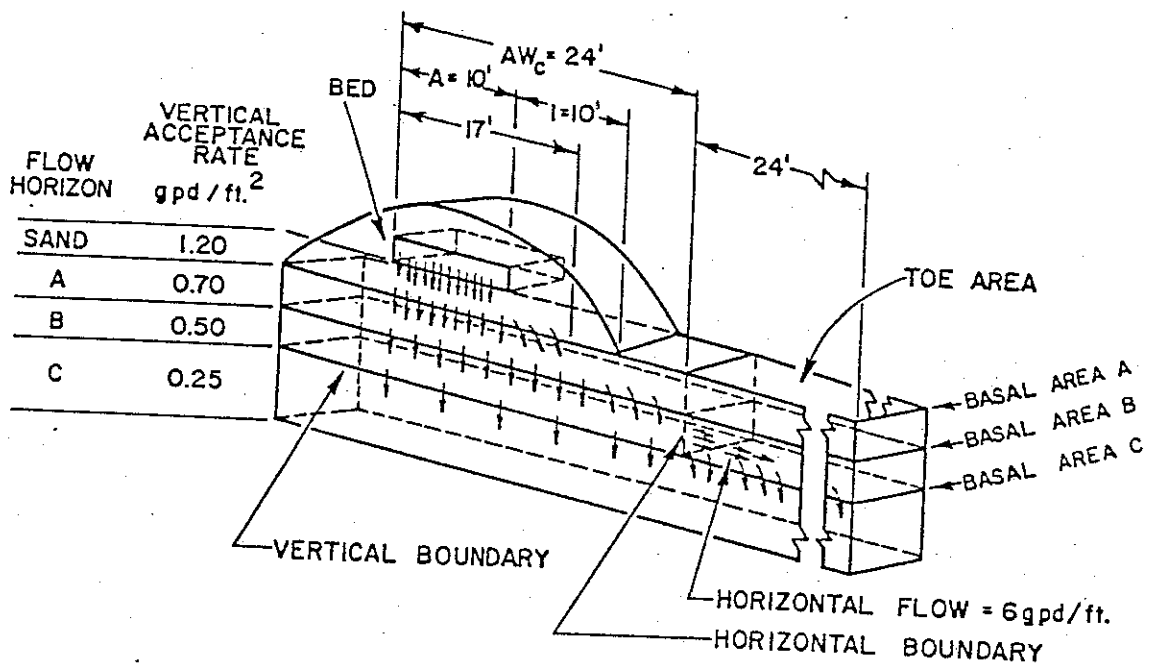Away from the Mound for Various Soil Profiles

Fig. 2 A One Foot (30 cm) Thick Cross Section Showing the Design Parameters for the Design Example. Each Arrow Represents One Gallon (3.8 L) of Effluent

Table 1. Current and Recommended Soil and Site Criteria for the Wisconsin Mound System for Individual Homes (After Converse and Tyler, 1985)

Parameter	Current[a]	Recommended[b]
Depth to High water table	24 in.	10 in.
Depth to Bedrock	24 in.	24 in.[c]
Vertical Saturated Hydraulic Conductivity[d]	Moderate	Moderately Low
Slope	12%	20 – 25%[ef]
Fill Soil	No	Yes[g]
Over old systems	No	Yes
Flood Plains	No	No

(a) Assumes linear loading rates are < 12 gal/ft.
(b) Generally the more restrictive the site the lower the linear loading rate.
(c) No research has been done to determine if the current recommendation can be changed.
(d) Hydraulic Conductivity based on SCS guidelines (Soil Survey Staff, 1981).
(e) Caution must be used during construction for safety of operator.
(f) Limited research data used to make this recommendation.
(g) The backfill over old systems must be treated as fill soil.

Generally treatment is good through medium sand (as defined by the USDA-SCS, Soil Survey Staff, 1981) when small doses of effluent are applied. With very large dose volumes treatment is reduced. There is limited data concerning the treatment of wastewater by mounds with coarser sands. However, it would appear that adequate treatment can be achieved if dose volumes are correct and the soil conditions are adequate to assure final polishing.

A recent survey by the authors would suggest that ponding in the gravel bed is occurring in some mounds even though actual loading rates for mound wastewater disposal systems is approximately half of the design (Converse and Tyler, 1985). There appears to be a correlation between the sand grain size distribution and ponding. Fine sand fill mounds generally are ponded while the coarser sands have not ponded. The alternatives to avoid the problem of ponding include reducing the design loading rate of the mound or using coarser fill sand.

Currently Wisconsin code requires a fill material with less than 50% by weight passing a 0.25 mm sieve (Wisc. Adm. Code, 1980). This material, if it meets the code requirements, can be a bank run material or a manufactured sand. In some situations, the sand type has been misjudged, thus resulting in a fine sand or a sand on the fine side of medium. The USDA-SCS classification of sands is very broad, thus giving a wide size range. More recently some installers have been using a manufactured sand which is on the coarse side of medium or a coarse sand according to USDA-SCS standards. Indiana uses a State Highway specification which is very similar to the ASTM-C33 classification (Jones, 1985). Idaho is recommending a sand fill classified according to ASTM-C33 standard (Shook, 1985). Even though the manufactured sand may be more expensive, it gives a uniform material and removes the judgement factor required when bank run sands are used.

Based on the current research information, fine sands, as defined by USDA-SCS, should never be used in mounds and indications are that a coarse sand or a sand on the coarse side of medium is most likely the best material if a loading rate of a 1.2 gpd/ft^2 (5 cm/d) is used. Caution should be taken not to have dose volumes that are large, as treatment is compromised. Loading rates less than 1.2 gpd/ft^2 (5 cm/d) are recommended for mounds which receive restaurant or other commerical wastewater (Siegrist et al., 1985) and for larger mounds with wide beds. Less information is available for large mounds with loadings less than design. Some large mounds with problems have been overloaded (Thomas, 1985).

Mound Performance on Severe Sites

On sites with very shallow seasonal water tables and a very slowly permeable subsurface soil horizon, water has been found at the toe of mounds for a few days during very wet seasons for individual household systems. It is very difficult to determine if this water is surface water or mound leakage since fecal bacteria counts were used as indicators of wastewater contamination and were very low (Converse and Tyler, 1985). In most cases when water is on the surface at the downslope edge or toe of the mound, the sand fill within the toe of the mound is saturated several centimeters deep.

DESIGN PRINCIPLES

A mound must not only fit the site, but the loading must not exceed the landscape treatment and disposal capability or any of the soil acceptance rates. For large systems it may be advantageous to have a number of narrow systems rather than one very large mound to maintain tolerable loadings to specific landscape elements. For example, a mound system designed for 16,000 gpd (60,800 Lpd) for a trailer court consists of 900 ft. (275 m) of mound bed that is 15 ft. (4.6 m) wide to give a design linear loading rate of 18 gpd/ft (232 Lpd/m). The mound bed was divided into 6 separate mounds so that the system would fit on the nearly square parcel of land available (Tyler and Converse, 1985). Currently a 26,000 gpd (98,800 Lpd) mound system is under construction for a trailer court which consists of 9 narrow mounds of various lengths instead of one or two large mounds. Thus, a series of narrow mounds constitute a system and the same hydraulic flow principles used for small mounds can be used. Similar principles should apply to in-ground systems. Therefore all systems should be designed on the basis of linear loading rate.

Design Loading Rates

Selecting the proper design wastewater volumes and system loading rate is a difficult task. Many state codes have a built-in factor of safety for the flow rate. For example, Wisconsin (Wisc. Adm. Code, 1980) calculates flows based on 150 gal. (570 L) per bedroom per day which is equivalent to 75 gpcd (285 Lpcd) with two people per bedroom, while the average water usage is 45 gpcd (170 Lpcd) (Witt et al., 1974). For community or cluster systems this factor of safety may be larger than necessary. For large systems with more than five homes, Wisconsin uses a design flow of 45 gpcd (170 Lpcd) assuming four people per home multiplied by a 1.5 factor of safety. Thus for ten three-bedroom homes, the design flow is 2,700 gpd (10,300 Lpd) versus 4,500 gpd (17,100 Lpd) using the criteria for one to five homes. This is a 40% reduction in the size of the system.

In Wisconsin for systems over 8,000 gpd (30,400 Lpd), three absorption areas are required with two areas in use at any one time. For example, a system with code loading of 10,000 gpd (38,000 Lpd) and soil loading rate of 1 gpd/ft^2 (4 cm/d) requires 10,000 ft^2 (930 m^2) of bed area. Since this is a large system, there will be three 5,000 ft^2 (465 m^2) areas with two absorption areas in operation and one resting. Thus there is the 1.5 factor of safety in the sizing plus the factor of safety of code loading versus actual water usage. The latter factor of safety will vary depending on the water habits of the establishment.

If systems fail after reducing the factor of safety on the basis that the actual wastewater volume is less than normally estimated, then no advantage has been gained. It is possible that the soil of larger systems should be loaded at lower rates for satisfactory performance. Extreme caution should be taken to alter design flow numbers resulting in smaller systems unless it can be justified on the established landscape loading limits.

Design acceptance rates for mounds and soil absorption systems depend on the nature of the mound fill and the soil and site conditions. Establishing the rates is also based on the type of flow expected in that area of the system. Table 2 lists some vertical unsaturated and horizontal saturated hydraulic conductivities.

After determining the flow types as outlined in the section on mound princi-
ples and establishing the soil characteristic values similiar to those found
in Table 2, but for regional soils of your interest, then these design proce-
dures can be used. It is recognized that establishing these numbers is very
difficult and variations at one site are great. Extreme care must be taken
when selecting these numbers.

Design Steps

To fit a mound to a given site, a series of design steps must be followed to
make sure all conditions are met. Converse (1978), USEPA (1980), Converse et
al. (1977) give design procedures for mounds. These design procedures are
based on small individual home systems for non-severe sites. For large sys-
tems or severe sites, more advanced design concepts are needed. Tyler and
Converse (1985) present these recent design concepts for large systems and
give two case studies.

Table 2. Relationship of Soil and Mound Fill Texture to
Vertical Unsaturated and Horizontal Saturated
Hydraulic Conductivity. These Values Assume that
the Soil does not have Platty, or Massive Struc-
ture, Appreciable Amounts of Swelling Clays,
Compacted or High Bulk Density

Texture[c]	Vertical Unsaturated Hydraulic Conductivity[a]		Horizontal Saturated Hydraulic Conductivity[b]	
	gpd/ft^2	cm/d	gpd/ft^2	cm/d
Mound Fill Sand[d]	1.2	5.0	250	1000
Coarse Sand[d]	1.2	5.0	250	1000
Medium Sand[d]	0.8	3.3	150	625
Loams Silt Loam Fine Sand	0.7	2.9	60	250
Dense Silt Loams Silty Clay Loams	0.5	2.0	10	40
Clay Loams Clays	0.25	1.0	1	4

(a) Vertical unsaturated hydraulic conductivity assumes
    that unsaturated flow is desirable for treatment and/
    or clogging presence has induced unsaturated flow.
(b) Horizontal saturated hydraulic conductivity is higher
    than the vertical hydraulic conductivity and much
    higher than the unsaturated vertical hydraulic con-
    ductivity. Note the difference between saturated
    and unsaturated hydraulic conductivity for a given
    texture is greater for coarser materials.
(c) Definition by USDS-SCS except for mound fill, which
    is defined in the Mound Fill section of this text.
(d) Assumes pressure distribution to maximize treatment
    capability.

In evaluating a site and designing a system, the following steps must be followed:

1. Evaluate the site to identify predicted wastewater flow zones in the soil.

2. Establish the horizontal and vertical boundaries of the system and determine the boundary acceptance rate (vertical and horizontal) based on a one foot cross section with the one foot dimension parallel to the contour (Fig. 2). These acceptance rates are determined during the soil/site evaluation.

3. Determine the vertical wastewater application width based on boundary vertical and horizontal acceptance rates.

4. Determine the linear loading rate based on vertical and horizontal acceptance rates.

5. Determine the basal width of each horizon beneath the mound based on the vertical acceptance rate of the horizon and the linear loading rate.

6. Determine the mound bed width based on the linear loading rate and infiltration rate into the sand fill.

7. Determine the bed length based on the design flow rate and linear loading rate.

8. Complete the rest of the design based on procedures by Converse (1978)

Design Example

Design a mound for a site with a code design flow rate of 2,000 gpd (7600 Lpd). When using a code design flow rate, a factor of safety is assumed. However, a closer look at the water habits of the establishment is warranted. Figure 2 shows a schematic for the design example.

1. Evaluate the site.

The soil horizons consist of a 12 in. (30 cm) loam A horizon, 12 in. (30 cm) of silt loam B horizon and at least 36 in. (90 cm) of slowly permeable clay C horizon. Vertical acceptance rates are assumed to be 0.70 (2.9), 0.5 (2.1), and 0.25 gpd/ft^2 (1.0 cm/d) for the loam, silt loam and clay horizons, respectively, assuming a clogging layer which will likely not develop because of the sand layer above (Table 2). A vertical acceptance rate of 0.5 gpd/ft^2 in the B horizon, instead of the 0.7 gpd/ft^2 as shown in Table 2, is used because the silt loam structure is slightly platy, which would impede vertical flow, but not horizontal flow. The table values assume an unsaturated flow regime and a unit hydraulic gradient. Slope is 10% (Fig. 2). Mottling is evident at 16 in. (40 cm) below the ground surface.

2. Boundary conditions:

    a. Vertical boundary location is at the C horizon with a vertical acceptance rate (VAR) of 0.25 gpd/ft^2 (1 cm/d).

    b. The horizontal boundary is located on the landscape and serves as the referece point for the mound location. This boundary will be at the toe of the mound or downslope of the mound toe. From Table 2 the horizontal saturated hydraulic conductivity is estimated at 60 gpd/ft^2 (250 cm/d). Using the following:

$$HAR = KAdH/dx$$

where:

$$K = \text{horizontal hydraulic conductivity}$$
$$= 60 \text{ gpd/ft}^2 \text{ (Table 2)}$$
$$A = \text{area of horizontal flow (1 ft by 1 ft)}$$
$$= 1 \text{ ft}^2$$
$$dH/dx = \text{hydraulic gradient (slope)}$$
$$= 0.1$$
$$HAR = (60)(1)(.1)$$
$$= 6.0 \text{ gpd/ft}$$

The horizontal acceptance rate (HAR) is 6.0 gpd/ft. Since horizontal flow is anticipated, the area downslope must be evaluated for a restriction; if one is found, then the horizontal boundary is located at that restrictive point (Tyler and Converse, 1985).

3. Determine the vertical wastewater application width.

The horizontal and vertical loading rates (HLR and VLR) can be the horizontal and vertical acceptance rate (HAR and VAR). The loading rate must not exceed the acceptance rate, but for design they can be equal. Assuming no horizontal flow in the A horizon so the surface soil at the mound toe does not get too wet, the basal loading for the A horizon can not exceed the basal loading for the B horizon. The application width is the vertical flow in the C horizon upslope of the horizontal boundary. Therefore:

$$AW_C = HAR \div (VAR_B - VAR_C)$$

where:

$$AW_C = \text{application width at the C horizon}$$
$$HAR = \text{horizontal acceptance rate in the B horizon}$$
$$VAR_B = \text{vertical acceptance rate into the B horizon}$$
$$VAR_C = \text{vertical acceptance rate into the C horizon}$$
$$AW_C = 6.0 \text{ gpd/ft} \div (0.5 - 0.25)\text{gpd/ft}^2$$
$$AW_C = 24 \text{ ft}$$

4. Determine linear loading rate (LLR)
$$LLR = VAR_C(AW_C) + HAR$$
$$LLR = (.25 \text{ gpd/ft}^2)(24 \text{ ft}) + 6 \text{ gpd/ft}$$
$$LLR = 12 \text{ gpd/ft}$$

5. Determine the basal widths for each horizon.

$$\text{Basal Width of Horizon A} = I = LLR \div VAR_A$$
$$= 12 \text{ gpd/ft} \div 0.7 \text{ gpd/ft}^2$$
$$= 17 \text{ ft}$$

The toe of the mound will end 7 ft upslope of the horizontal boundary. The toe should be extended several feet downslope to insure a factor of safety. For this example I = 10 ft as it gives a 3:1 side slope on the downslope area of the mound (Fig. 2) (Converse, 1978).

$$\text{Basal Width of Horizon B} = LLR \div VAR_B$$
$$= 12 \text{ gpd/ft} \div 0.5 \text{ gpd/ft}^2$$
$$= 24 \text{ ft}$$

$$\text{Basal Width of Horizon C} = LLR \div VAR_C$$
$$= 12 \text{ gpd/ft} \div 0.25 \text{ gpd/ft}^2$$
$$= 48 \text{ ft}$$

Since the application width (AW_C) is 24 ft. and the HAR_B is 6 gpd/ft in the B horizon, the waste water will move horizontally in the B horizon for an additional 24 ft down slope beyond the horizontal boundary at which point all the effluent will be moving vertically downward. Thus the area downslope must be unused for additional water absorption and unrestricted by driveways, ditches, foundations, etc., as in essence this is where the horizontal boundary should be if no further horizontal flow is permitted.

6. Determine the bed width (A)
   A = LLR ÷ infiltration rate of the sand fill.
   A = 12 gpd/ft ÷ 1.2 gpd/ft^2
   A = 10 ft

7. Determine bed length (B)
   B = Daily Design Flow ÷ LLR
   B = 2,000 gpd ÷ 12 gpd/ft^2
   B = 167 ft

Thus the mound will have a bed area which is 167 ft. long by 10 ft. wide. If the parcel is less than 190 ft. (58 m) wide along the contour, which is the length of the mound needed for a 167 ft. (51 m) bed, then the mound can be divided into segments. For example, the mound may be divided into two segments, each with a bed length of 84 ft. (26 m). The spacing between the beds, if parallel and one downslope of the other, is at least 24 ft. (7.5 m) from the toe of the upslope mound to the upslope edge of the downslope mound. Additional space may be needed for equipment to manuever during construction. Placing the two mound segments on different slopes may be advantageous.

8. Determine the remaining dimensions of the mound as shown by Converse (1978).

Performance During Stress Conditions

During periods of wet weather when the water table approaches its highest point more effluent will move horizontally away from the system with some horizontal flow in the A horizon. It is possible that some leakage at the toe may occur under extreme wet conditions. Research data indicates that the leakage quality is good (Converse and Tyler, 1985). However, leakage should be minimal as the design flow rate is greater than the actual flow rate. During these periods, the water usage to the mound should be reduced to relieve stress on the mound and minimize leakage.

CONSTRUCTION PLANNING

A construction plan for mound systems especially for large mounds or multiple mound systems is critical. A clear understanding between the site evaluator, designer, contractor, and inspector is needed. The following questions must be answered prior to construction.

1. Is the mound following the contour?

2. What should be done with the excess vegetation in the proposed mound area?

3. At what moisture state can the soil be tilled?

4. What is the best procedure for plowing or roughing up the surface?

5. How deep should the tillage occur?

6. How can the sand be placed on the plowed area with minimum traffic on the mound?

7. Is there sufficient distance between mounds without impinging on the area downslope of the upslope mound during construction of the down-slope mound or does construction need to be done from the ends?

8. What quality of sand is to be used? Does it meet specifications?

9. What is the best approach to place the gravel in the bed without compacting and silting the sand?

10. How can the plowed surface and the exposed sand surface be protected from the rains? Rains falling on these surfaces may cause silting and reduce vertical flow.

11. Most importantly, do the contractor and his employees understand the principles of operation and construct accordingly so as not to violate these principles?

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