WISCONSIN MOUND SOIL ABSORPTION SYSTEM

SITING, DESIGN AND CONSTRUCTION MANUAL

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PREFACE

The Wisconsin Mound system was developed in the early 1970's. In 1975 three manuals, known as Package 1, 2 and 3 were developed. In 1978 these three packages were consolidated into the "Design and Construction Manual for Wisconsin Mounds" for 1) slowly permeable soils, 2) shallow permeable soils over crevice bedrock, and 3) permeable soils with high water tables.

The soil and site criteria applicable for the Wisconsin mound was relatively conservative. Since the late 1970's mound research has continued with a number of articles written about it. These publications can be obtained through the Small Scale Waste Management Project, A publication list is available containing all the publications issued by the project.

This publication entitled "WISCONSIN MOUND SOIL ABSORPTION SYSTEM SITING, DESIGN AND CONSTRUCTION MANUAL" presents the latest concepts in siting, designing and constructing the Wisconsin mound system. The mound will continue to be researched and as needed revisions to this manual will be made.

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BY

James C. Converse   E. Jerry Tyler*

The Wisconsin mound wastewater soil absorption system was developed in the early 1970's to be used on sites with specific site characteristics where in-ground gravity flow trench or bed soil absorption system were restricted. The Wisconsin mound system has been widely accepted and incorporated in many state regulations. In 1980 the Wisconsin mound system was incorporated into the Wisconsin Administrative code (1980) as an alternative for sites that were not suitable for the in-ground trench or bed soil absorption system. It is one of several systems suitable for treating and disposing of the wastewater generated in residential and commercial units and is not suited for all sites.

The objectives are to treat and dispose of the wastewater via the subsurface in an environmentally acceptable manner and to protect the public health.

The concept of an elevated on-site system for sewage disposal was developed in the 1950's (Witz, 1974). In the 1970's significant modifications were made to overcome many system limitations (Converse et al., 1975 a, b, c,; Machmeier, 1977; Carlile et al, 1977).

Fig. 1 is a cross section of a Wisconsin mound system. It consists of a septic tank, a dosing chamber and the mound. As with other soil absorption systems,

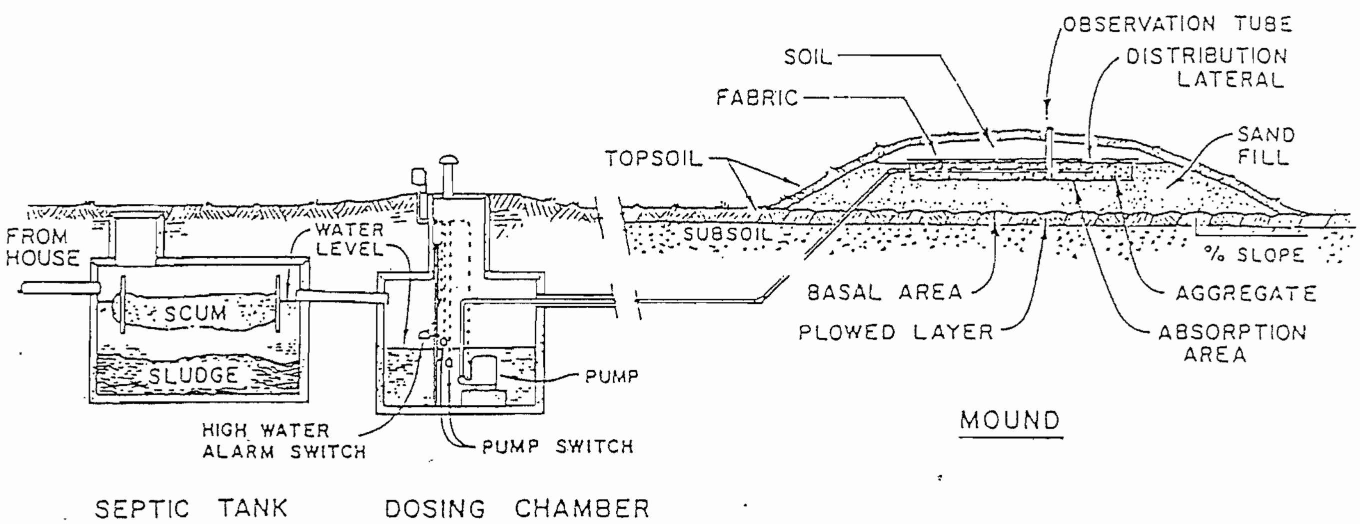

Fig. 1. Schematic of the Wisconsin Mound System.

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the septic tank removes most of the settleable solids and is a place for liquefaction of the more easily biodegradable solids. The dosing tank contains a pump or siphon which pressurizes a distribution network of small diameter pipe with small perforations and distributes the septic tank effluent uniformly along the length of the mound. The purpose of the mound is to accept septic tank effluent and along with the native soil treat and purify the wastewater to acceptable standards. The mound consists of a layer of suitable sand, aggregate, distribution system, and soil cover.

Originally the Wisconsin mound system was designed for individual homes with specific soil and site limitations and with wastewater flows of less than 750 gpd (Converse et al., 1975 a,b,c,; Converse, 1978). As the need for disposal of wastewater on sites where below grade systems were not appropriate and for disposal of greater wastewater volumes from small communities, clusters of homes, and commercial establishments increased, the demand for the Wisconsin mound system on these sites has increased. It is not unusual to see Wisconsin mound systems receiving wastewater flows in excess of 25,000 gpd. Evaluation of mounds on sites with more restrictions than currently allowed in most codes has resulted in utilizing mounds on more difficult sites. (Converse and Tyler, 1986a; 1986b). Based on the experience of siting, design and construction, concepts have been modified (Tyler and Converse, 1985; Converse and Tyler, 1987). The purpose of this manual is to consolidate these concepts and present the latest siting, design and construction criteria of the Wisconsin mound system.

SITING CRITERIA

A designer of on-site wastewater treatment and disposal systems must have a basic understanding of water movement into and through the soil especially on more difficult sites. This understanding is based on information collected during the site evaluation. The siting of the system and loading rates can be no better than the information used. Figure 2 shows a schematic of effluent movement within and away from mound systems under various soil profiles. Depending on the type of profile, the effluent moves away from the site vertically, horizontally or a combination of both. It should be noted that these concepts are true for all soil absorption systems. The sizing and configuration of all soil absorption systems, including the mound, is based on how the effluent moves away from the system and the rate at which it moves away from the system. Thus the designer must predict that movement and rate of movement or the design may be flawed and the system may fail. The prediction is made based on soil and site information obtained during site evaluation.

The siting and design concepts presented in this publication and elsewhere (Converse, et. al. 1989, and Tyler and Converse, 1986) results in soil absorption systems that are usually long and narrow. The more restrictive the site, the narrower and longer the soil absorption system. If these concepts are not followed, then the system may not perform as expected. It should be noted that these concepts will not apply to all soil and site situations, as soil absorptions systems are not compatible to all sites and should not be used on such sites.

Codes, regulating on-site subsurface disposal of wastewater, require a suitable depth of soil to treat the effluent before it reaches the limiting condition

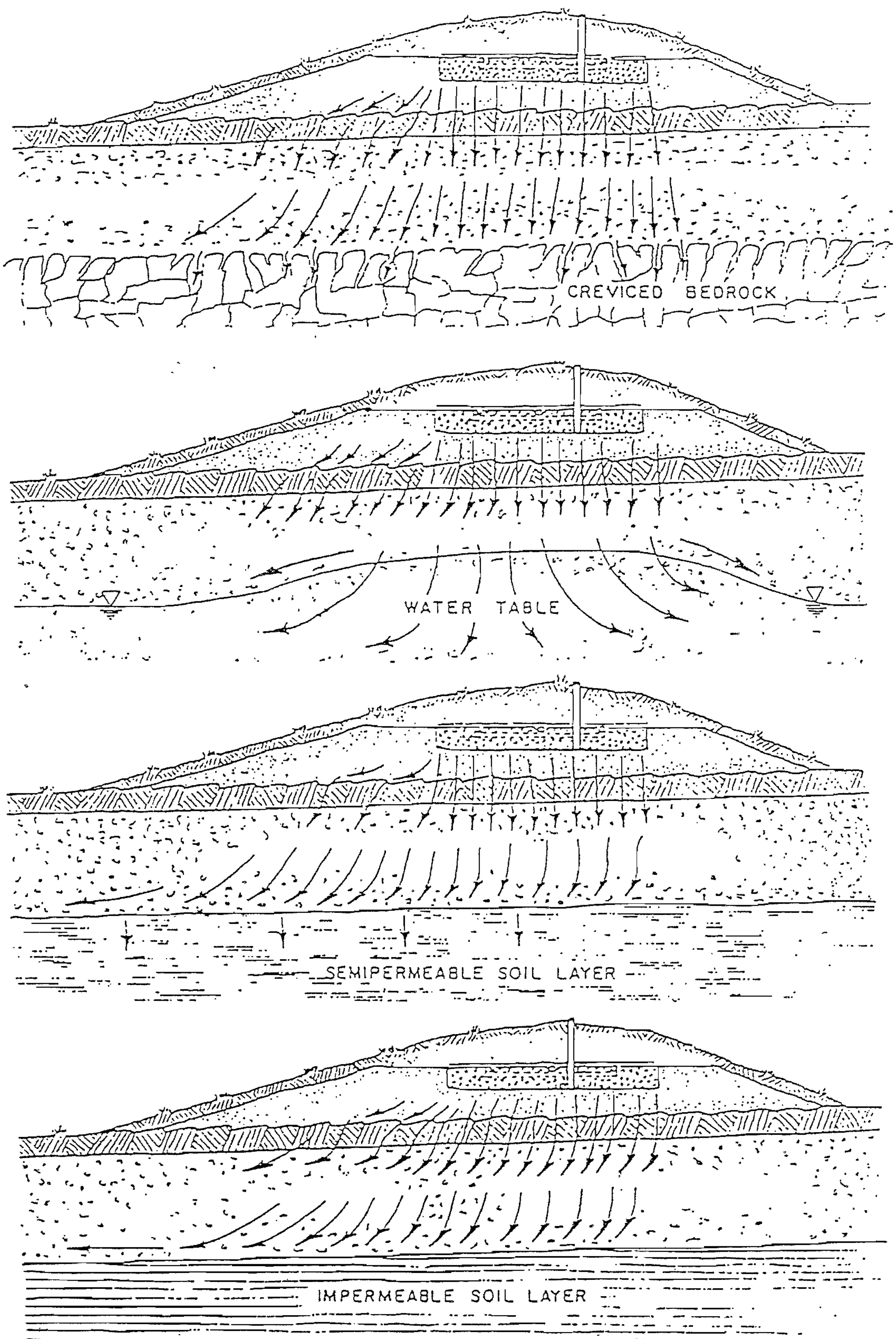


Fig. 2. Effluent Movement Within and Away from the Wisconsin Mound for Four Different Types of Soil Profiles.

such as bedrock or high water table or a slowly permeable soil layer. Figure 3 shows the relationship between the type of system that may be best suited and the location of the limiting condition beneath the ground surface, utilizing a 3 ft suitable soil separation distance. This suitable depth of unsaturated soil varies among codes but usually is between 1 to 4 ft. For the mound system this suitable depth consists of the distance from the ground surface to the limiting condition below ground surface plus the depth of sand between the ground surface and the infiltrative surface within the mound (normally the aggregate/sand interface or the exposed surface of chamber units). For the at-grade system, the suitable depth is from the ground surface to the limiting condition (Converse et al., 1989). For example, if the code required 2 ft of suitable soil and the site distance was greater than two feet but less than required for an in-ground system, an at-grade system would be better suited than a mound system for the site. However, if this distance was less, then a mound system may be most appropriate.

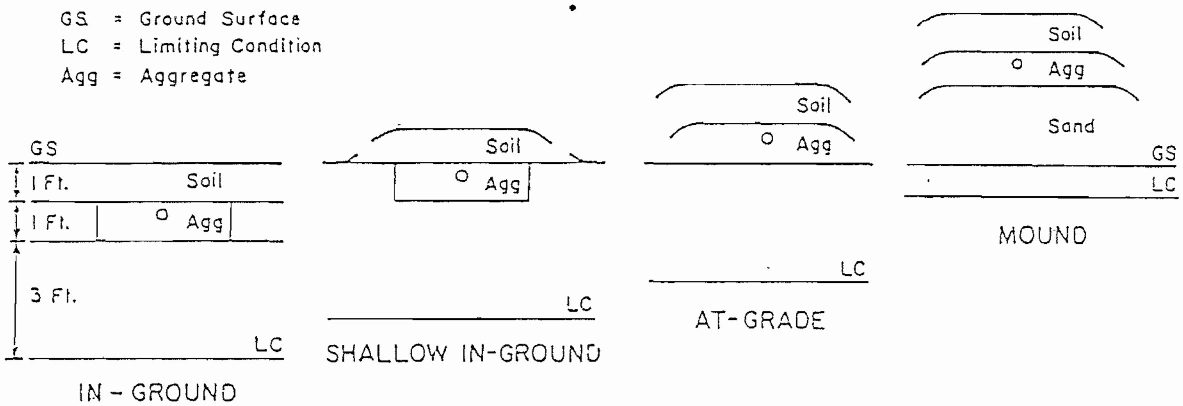


Fig. 3. Cross Section of Four Soil Absorption Units in Relation to Ground Surface and Limiting Conditions.

This manual does not provide methods and procedures for describing and interpreting soil and site conditions used to determine suitability and design parameters for a Wisconsin mound. A soil scientist or other qualified soil evaluator should be employed to provide site descriptions and interpretations. It is best if the soil evaluator works with the designer and installers to insure proper use of the site.

Table 1 gives soil and site criteria for the Wisconsin mound based on research and field experience. When the mound was originally developed in the 1970's the criteria are conservative as there was very little experience with mound systems. Since that time considerable research has been conducted on more difficult sites (Converse and Tyler, 1985, 1987). Care must be taken when using these criteria as they are for the most difficult sites utilizing on-site systems. Design configuration, loading rates and construction are very critical for the successful functioning of the system.

Depth to High Water Table:

High ground water table, including seasonally perched water table, should be greater than about 10" beneath the ground surface. High water table is determined by direct observation, interpretation of soil mottling or other criteria. Since it is impossible to detect soil mottles in black surface

Table 1. Recommended Soil and Site Criteria for the Wisconsin Mound System. Based on Research and Field Experience (Converse and Tyler, 1985, 1987)

Parameter	Value
Depth to High Water Table (Permanent or Seasonal	10 in.
Depth to Crevice Bedrock	2 ft.
Depth to Non-crevice Bedrock	1 ft
Permeability of Top 10 in.	Moderately Low
Site Slope	25 %
Filled Site	Yes[a]
Over Old System	Yes[b]
Flood Plains	No

[a]Suitable according to soil criteria (texture, structure, consistence).
[b]The area and back fill must be treated as fill as it is a disturbed site.

horizons, it is difficult to determine the exact location of seasonal saturation during wet periods. At some sites, during wet periods, saturation may occur at the sand/soil interface at the toe of the mound as the effluent is restricted from moving away from the mound. This effluent is usually extremely low in fecal bacteria but has high nitrates and chlorides (Converse and Tyler, 1985; 1987). Under these saturated conditions there is the possibility of leakage of this water from the toe of the mound for a few days during seasonal saturation of the soil.

Depth to Bedrock:

Bedrock should be classified as crevice, non-crevice semi-permeable or non-crevice impermeable. Two feet of natural soil depth is suggested for the crevice bedrock as it is assumed that very little treatment takes place in the crevice bedrock. The natural soil aids in the treatment of the effluent and the extra foot of natural soil acts as a factor of safety as the first water table that the effluent will contact may be permanent and potable. Potable water is usually separated from seasonal water table, therefore shallower depths are required for the non-crevice bedrock as the potential for ground water contamination is much less. In the non-crevice very slowly permeable or impermeable bedrock, the effluent flow will be horizontal and in the semi-permeable sandstones the flow will be both vertical and horizontal.

Soil Permeability:

Most codes have used the percolation test to size the soil absorption system. The percolation test is empirically related to the loading rate and it has been shown that the percolation test is very variable. Loading rates should be based on soil texture, structure and consistence with the percolation test, if required, to confirm morphological interpretations. This approach requires more detailed site evaluation and will be used for mound design and siting. Table 2 gives the design soil loading rates based on morphological interpretations.

Slope:

Mounds can be placed on sites with slopes upwards of 25%. Systems on steep slopes with slowly permeable soils should be narrow to reduce the possibility of toe seepage. Slope limitation is primarily for construction safety. It is very difficult to operate equipment on such steep slopes and installers should be warned about the construction hazards.

Filled Sites:

Fill is defined as the soil placed on a site to raise the elevation of the site. Typically it is placed on top of the natural soil and may consist of soil with textures ranging from sand to clay or a mixture of textures. During placement soil structured is destroyed and the soil is usually compacted. Under these circumstances the permeability of the soil is reduced and variable. Thus, if a system is to be placed on the site, sufficient time must pass to allow the soil structure to develop and compaction to be reduced via worm and/or freeze/thaw activity. A more intensive soil evaluation must be done because of the variability encountered in filled sites over naturally occurring sites. Many more observation locations are generally needed for filled sites compared to non-filled sites.

Over Old Systems:

Mounds have been successfully placed over failing in-ground soil absorption units. The soil above the system has been disturbed and must be treated as a filled site when evaluating the soil for loading rate. A more detailed evaluation of the effluent movement must be done especially if a mound is placed over a large in-ground system.

Flood Plain:

It is not recommended to install any soil absorption system in a flood plain, drainage ways or depressions unless flood protection is provided.

Horizontal Separation Distances:

The same separation distances, between the mound and the respective site features, that apply for in-ground systems should apply for the Wisconsin mounds. On sloping sites the upslope and end distances should be measured from the upslope edge or ends of the aggregate to the respective features and the downslope distance should be measured from the downslope toe of the mound to the respective features. As with all wastewater infiltration systems on sloping sites that have primarily horizontal flow from the mound, a greater downslope horizontal separation distance may be appropriate to avoid weeping into a ditch or basement that may be located downslope.

Sites with Trees and Large Boulders:

Generally, sites with large trees, numerous smaller trees or large boulders are less desirable for mound systems because of the difficulty in preparing the site. If a more desirable site is not available, the trees must be cut at ground level. The stumps should not be removed. If the tree stumps and/or

Table 2. Estimated Wastewater Design Basal Loading Rates for the Surface Horizon Based on Soil Morphological Conditions For Wisconsin Mound Systems.

	Soil Condition of Horizon at Sand/Soil Interface	If Yes The Loading Rate In gpd/ft^2 Is:
	(Instructions: Read questions in sequence. When the conditions of your soil match the question, use that loading rate and do not go further).	
A.	Is the horizon gravelly coarse sand or coarser?................	0.0
B.	Is consistence stronger than firm or hard, or any cemented class?..	0.0
C.	Is texture sandy clay, clay or silty clay of high clay content and structure massive or weak, or silt loam and structure massive?...	0.0
D.	Is texture sandy clay loam, clay loam or silty clay loam and structure massive?..	0.0
E.	Is texture sandy clay, clay or silty clay of low clay content and structure moderate or strong?......................	0.2
F.	Is texture sandy clay loam, clay loam or silty clay loam and structure weak?..	0.2
G.	Is texture sandy clay loam, clay loam or silty clay loam and structure moderate or strong?............................	0.4
H.	Is texture sandy loam, loam, or silt loam and structure weak?...	0.4
I.	Is texture sandy loam, loam or silt loam, and structure moderate or strong?..	0.6
J.	Is texture fine sand, very fine sand, loamy fine sand, or loamy very fine sand?......................................	0.6
K.	Is texture coarse sand with single grain structure?............	0.8

boulders occupy a significant amount of the surface area, the size of the mound should be increased to provide sufficient soil to accept the effluent. The site evaluator should provide location and size information about trees and boulders.

MOUND DESIGN CONCEPTS

As with all soil absorption systems, a mound wastewater infiltration system must be sized and configured to match the soil and site conditions and the volume and quality of wastewater applied to it. Thus it is imperative that the designer has sufficient information about the quality and quantity of effluent, soil and site features and understands the mound operating principles and movement of effluent away from the system. The designer, in cooperation with the soil scientist or site evaluator, must accurately estimate the design soil loading rate (Table 2) and determine the direction of flow away from the system (Fig. 2) before the mound can be properly designed.

The design consists of estimating the 1) sand fill loading rate, 2) soil (basal) loading rate and 3) linear loading rate for the site. Once these three design rates are determined, the mound can be sized for the site. Figs. 4 and 5 show a cross section and plan view of the mound on sloping and level sites, respectively, and shows dimensions that must be determined.

<u>Sand Fill Loading Rate</u>:

The design sand loading rate for the absorption area (aggregate/sand interface in Figs. 4 and 5) is dependent upon the quality of effluent applied and the type and quality of fill material placed beneath the aggregate. The loading rate in this manual assumes a sand that meets the guidelines and a typical domestic septic tank effluent quality. If commercial septic tank effluent is used, such as from restaurants, the loading rates should be reduced as the strength of the effluent may be much greater thus accelerating and intensifying the clogging of the aggregate/sand interface (Seigrest et al., 1985). If higher quality effluent is used, such as that from sand filters or aeration units, higher design loading rates may be justified. Limited experience with these wastewaters makes it difficult to predict long term loading rates.

The purpose of the sand fill, along with the native soil, is to treat the effluent to an acceptable level. A very coarse sand will not provide adequate treatment and a very fine sand can not be loaded at acceptable levels without severe clogging, thus resulting in mound failure. Thus a sand must be selected that provides satisfactory treatment and allows for a reasonable loading rate.

During the initial development of the mound, medium sand (USDA classification) was considered suitable for mound fill but it was soon shown that premature failure resulted for sand fill that was on the fine side of medium or was a fine sand. Bank run sand, which was classified as medium sand, was also found unsuitable, in most cases, as it was usually poorly sorted and contained a lot of fines. Currently the recommendation is to use a coarse sand with a minimum amount of fines which appears to give acceptable treatment at an acceptable loading rate. It is also important to provide a specification that provides acceptable treatment and is available at a reasonable cost. Standard classifications such as USDA are not suitable as they are very broad. For example a coarse sand may or may not be acceptable while a medium sand may be as it depends upon a combination of various sand fractions.

Fig 6 can be used as a guide for selecting a suitable mound sand fill. Based on a sieve analysis of the total sample, the sand fill specification should fit between the ranges given in Fig. 6. In addition the sand fill must not have

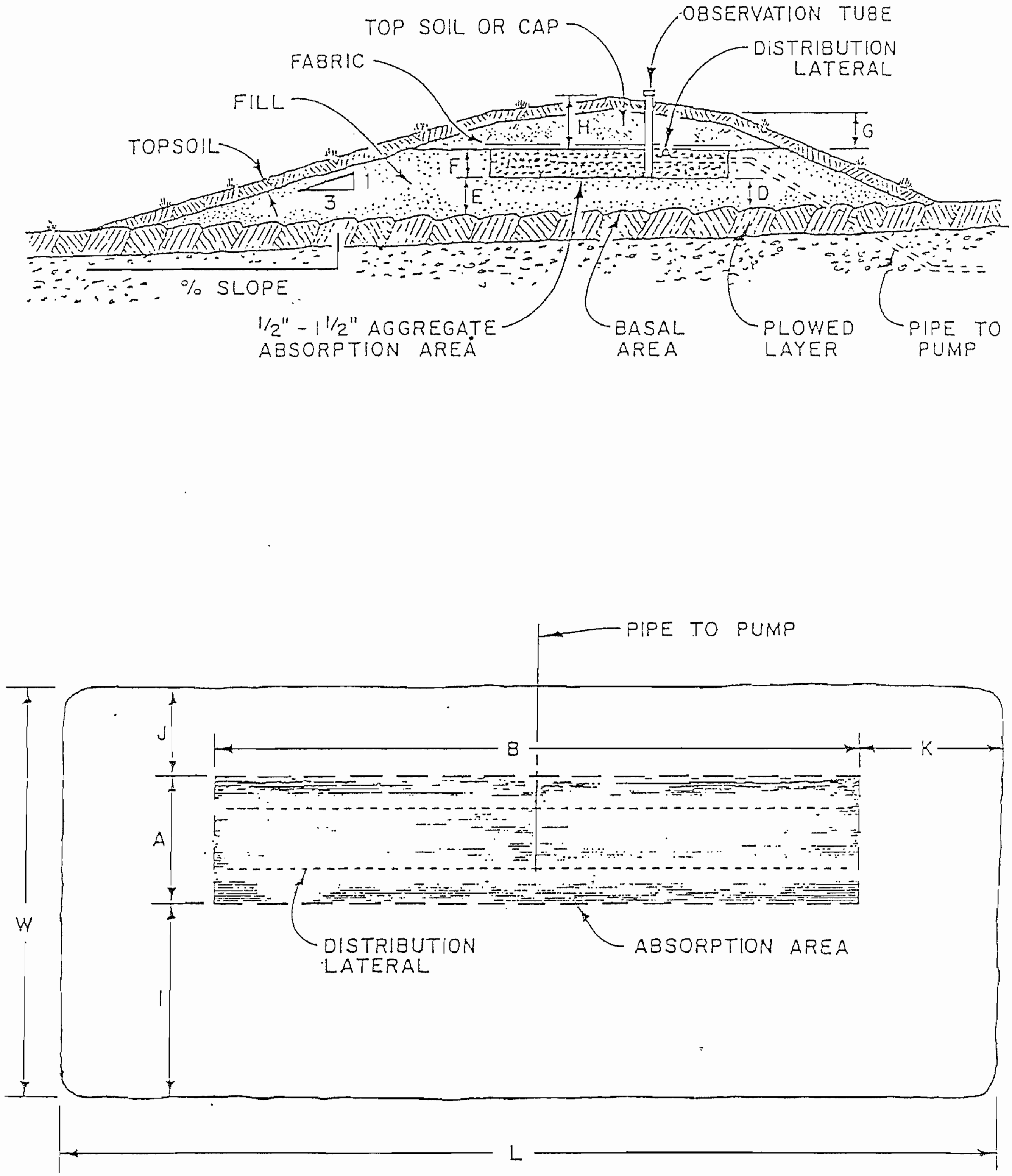


Fig. 4. Cross Section and Plan View of a Mound System on a Sloping Site.

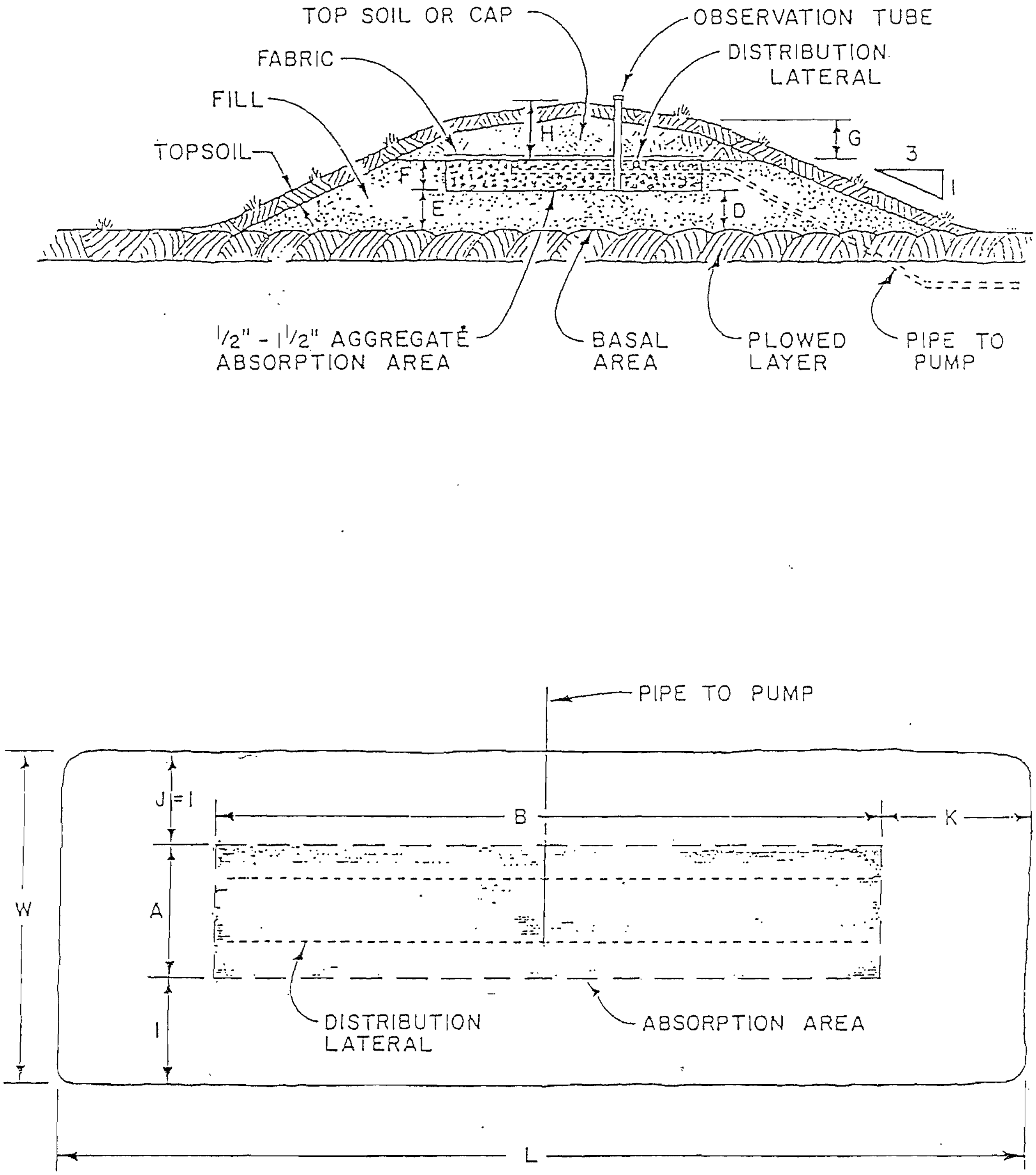


Fig. 5. Cross Section and Plan View of a Mound on a Level Site.

more than 20% (by wt) material that is greater than 2 mm in diameter which can include stone, cobbles and gravel. Also there must not be more than 5% silt and clay (<.053 mm) in the fill. This guideline is based on experience and judgement. According to USDA classification this is a coarse sand, however many other sands could be defined as coarse sand according USDA and not meet this guideline for mound sand fill. C-33 specification (ASTM, 1984) for fine aggregate does fit within this guideline but the coarser (>2 mm) and finer (<.053) fractions must be evaluated to make sure they meet the limits. A sand with an effective diameter (D_{10}) of 0.15 to 0.3 and a uniformity coefficient (D_{60}/D_{10}) between 4 and 6 fit within this guideline provided the coarser (>2 mm) and finer (<.053) fractions meet the guideline.

<u>The recommended design loading rate for a sand fill that meets this guideline (Fig. 6) is 1.0 gpd/ft^2 if the effluent is a typical domestic septic tank effluent</u>. This assumes that there is a factor of safety provided. It assumes, for design purposes, that a home generates 75 gpcd with two people per bedroom or 150 gallons per bedroom per day. Based on a number of studies, the average quantity of effluent generated per day is about 45 gpcd (Witt et al. 1974). Converse and Tyler, 1987, found, based on water meter reading in the home, that the wastewater generated in the home averaged 47% of design with a range of 29 to 82%. If water meter readings are used for design purposes, the design sand loading rate should be reduced accordingly. Systems loaded to design without appropriate factor of safety will fail due to overloading. Similar procedures should be followed for commercial establishments including lower loading rates due to the higher strength effluent as discussed above.

<u>Basal Loading Rates</u>:

The basal area (sand/soil interface in Figs. 4 and 5) is the area enclosed by the B(A+I) for sloping sites (Fig. 4) and B(A+I+J) for level sites where J equals I for level sites (Fig. 5). It is sized according to the long term infiltration rate (assuming a clogging mat forms) for the soil at the sand/soil interface (Table 2). This interface receives relatively clean effluent since the wastewater has already passed through sand and normally a clogging mat does not develop at this interface, thus over sizing the basal area. Additional over sizing usually results because the distance required to maintain a 3:1 mound side slope is greater than that required for the infiltration basal width except for maybe the very slowly permeable soils or the very steep sites.

<u>Linear Loading Rate</u>:

The linear loading rate is defined as the amount of effluent (gallons) applied per day per linear foot of the system (gpd/lf). The design linear loading rate is a function of effluent movement rate away from the system and the direction of movement away from the system (horizontal, vertical or combination, Fig. 2). If the movement is primarily vertical (Fig 2a), then the linear loading rate is not as critical as if the flow is primarily horizontal (Fig. 2d). Other factors such as gas transfer from beneath the absorption area suggests that the absorption area width be relatively small (Tyler et al, 1986). It is difficult to estimate the linear loading rate for a variety of soil and flow conditions but based on the authors' experience "good estimates" can be given. If the flow away from the system is primarily vertical (Fig. 2a), then the linear loading rate can be high but should be in the range of 8 to 10 gpd/lf otherwise the absorption area is excessively wide, especially for the slower

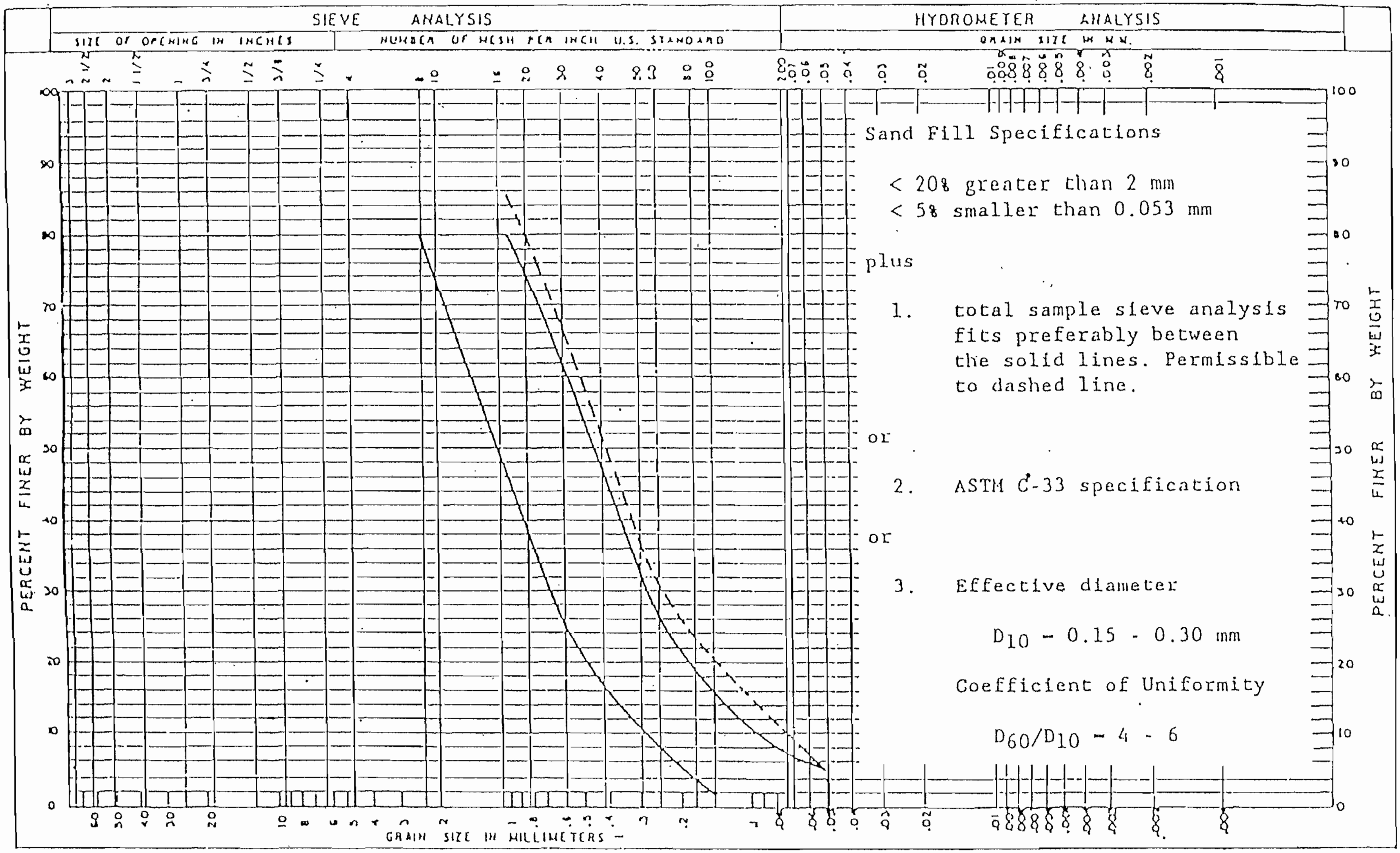


Fig. 6. A guideline for the selection of the sand fill for Wisconsin mounds. The total sample sieve analysis contains 20% or less material larger than 2.0 mm and contains 5% or less material finer than 0.053 mm plus one of three additional specifications listed in figure. The fraction greater than 2 mm can have stones, and cobbles

permeable soils such as silt loams. However, if the flow is shallow and primarily horizontal (Fig. 2d) then the linear loading rate should be in the range of 3 - 4 gpd/lf. This approach will result in long and narrow systems.

Dimensioning the Mound:

Figs. 4 and 5 show the cross section and plan view of the mound for sloping and level sites: The dimensions are based on the site conditions and loading rates which are site specific.

Absorption Area Width (A): The width of the absorption area is a function of the linear loading rate and the design loading rate of the sand fill selected.

Absorption Area Length (B): The length of the absorption area is a function of the design loading rate (gpd) and the width of the absorption area (A).

Basal Length and Width: For sloping and level sites the basal width is (I + A) and (I + J + A), respectively, and the basal length is (B). The width is determined by the linear loading rate and the infiltration rate for the surface soil horizon (sand/soil interface).

Slope Width (I) and (J): For sloping sites the downslope width (I) is a function of the basal width (A + I) and the absorption area width (A). Upslope width (J) is a function of the 3:1 recommended side slope and is dependent upon the depth of the mound and the slope of the site. A typical dimension is 8 to 10 ft. but can be greater or less depending on the des'.re mound side slope and the slope of the site. For level sites the slope widths (J) and (I) are equal and are a function of the required basal width or the minimum recommended mound side slopes, whichever is greater.

Slope Length (K): The slope length (K) is a function of the mound depth and the desired mound end slope. The recommended end slope is 3:1 but can be greater. Steeper mound side slopes are not recommended as they can become a safety hazard if the mound is to be mowed. Typical dimensions are 10 - 15 ft.

Depth (D): This depth is a function of the suitable soil separation depth required by code and the depth of the limiting condition from the soil surface. If the required separation distance from the absorption surface to the limiting condition, such as bedrock or high water table, is 3 ft and the limiting condition is 1 ft beneath the ground surface, than (D) must be a minimum of 2 ft.

Depth (E): This depth is a function of the surface slope and width of the absorption area (A) as the absorption area must be level.

Depth (F): This depth is at least 9 in. with a minimum of 6 in. of aggregate beneath the distribution pipes, approximately 2 in. for the distribution pipe and 1 in. of aggregate over the pipe.

Depth G) and (H): The recommended depth for (G) and (H) is 12 in. and 18 in., respectively, for the colder climates areas and 6 in. and 12 in. for the warmer climates. The (H) depth must be greater than the (G) depth to promote runoff on the top of the mound.

Mound Cover:

The purpose of the soil cover is to provide a medium for a vegetative cover and protection. Any soil material that will support a suitable vegetative cover is satisfactory. This material may range from a sandy loam to a clay loam. A sand does not support a suitable vegetative cover. A heavier textured soil will promote more precipitation runoff than a lighter texture soil and will also hold more moisture during dry periods thus reducing the drying out of the vegetative cover on the top and sides.

Effluent Distribution Network:

The mound system is designed with a pressure distribution network to distribute the effluent along the length of the mound. Gravity distribution will not distribute it uniformly but drops it in one or two locations (Converse, 1974, Machmeier and Anderson, 1988). Otis, 1981, gives design criteria and examples for pressure distribution. A design procedure and example are included in the appendix of this publication.

Observation Tubes:

It is essential for all soil absorption systems to have observation tubes extending from the infiltrative surface (aggregate/sand interface) to or above the ground surface for the purposes of observing the performance of the infiltrative surface. The wells provide an easy access to the infiltrative surface to see if ponding is occurring. Tubes should be placed at 1/6, 1/2 and 5/6 points along the length of the absorption area. All observation tubes must be securely anchored. Fig. 7 illustrates three methods of anchoring the observation tubes. Slip or screw caps can be used. If brought to the surface, they should be recessed slightly as lawn mowers may destroy the caps. If brought above ground surface, schedule 40 PVC pipe is recommended.

DESIGN EXAMPLE

Evaluate the following soil profile for a soil absorption system and if appropriate design a soil absorption system for the site.
Site Criteria

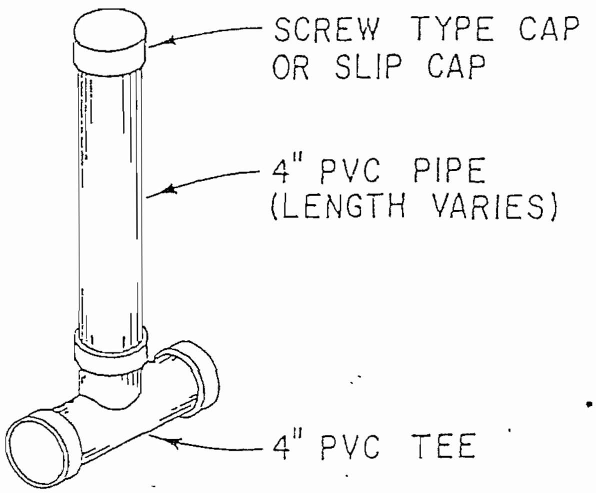
1. Soil Profile - Summary of 3 soil pit evaluations.

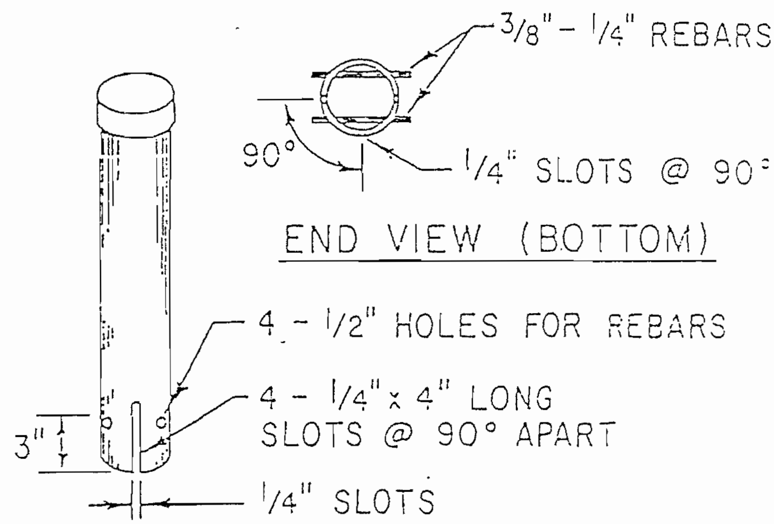
   0 - 6 in. sil; 10YR6/4&2/1; strong, moderate, angular blocky structure; friable consistence.

   6 - 11 in. sil; 10YR5/3; moderate, fine platy structure; firm consistence.

   11 - 20 in. sicl; 10YR6/3; moderate, fine, subangular blocky structure; firm consistence; few, medium, distinct mottles starting at 11".

   20 - 36 in. sic; 10YR5/3; massive structure; very firm consistence; many, medium, prominent mottles.





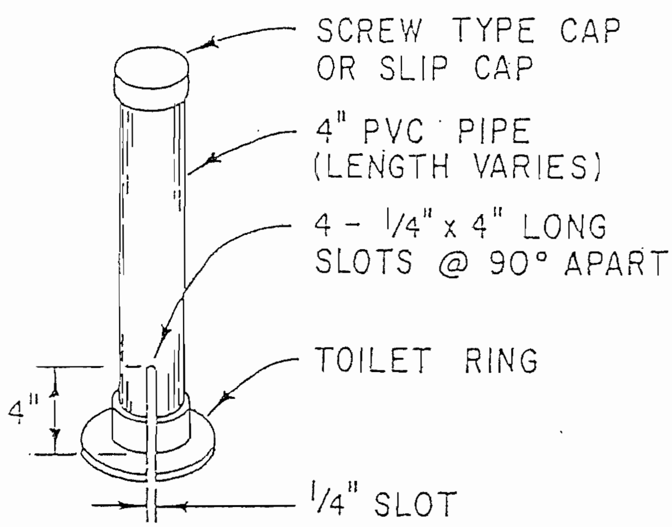


Fig. 7. Three Methods for Stabilizing Observation Tubes.

2. Slope 15%

3. The area available consists of 180 ft long along the contour and 50 ft along the slope. There are a 3 medium sized trees in the area.

4. The establishment generates about 300 gallons of wastewater of domestic septic tank effluent quality per day based on meter readings.

Step 1. Evaluate the Quantity and Quality of Wastewater Generated.

For all on-site systems a careful evaluation must be done on the quantity of wastewater generated. As indicated earlier, most code values have a built in safety factor and includes peak flows. Thus these values can be used directly in the design calculations. However, it is appropriate for the designer to assess if the establishment is typical for the code values assigned to it. If metered values are used, it is recommended to double the average daily flow rate for design purposes. However, the average flow rate should be based on a realistic period of time and not be, for example, an average of six months of very low daily flow rates and 6 months of very high flow rates. If that is the case, than the high flow rates should be used for design.

The quality of the wastewater must also be assessed. If it is typical domestic septic tank effluent, these sizing criteria may be used. However, if it is commercial septic tank effluent, lower soil loading rates are recommended (Siegrist, et al., 1985).

Design Loading Rate = 600 gpd.

Step 2. Evaluate the Soil Profile and Site Description for Design Linear Loading Rate and Soil Loading Rate.

For this example and convenience the one soil profile description is representative of the site. A minimum of 3 evaluations must be done on the site. More may be required depending on the variability of the soil. The soil evaluator must do as many borings as required to assure that the evaluation is representative of the site. In evaluating this soil profile the following comments can be made:

- The silt loam (A) horizon (0 - 6 in.) is relatively permeable because of its texture, structure and consistence. The effluent flow through this horizon should be primarily vertical.

  The silt loam (E) horizon (6 - 11 in.) has a platy structure and strong consistence. The consistence will slow the flow up and the platy structure will impede vertical flow and cause the flow to r horizontally. However, if this layer is tilled, the platy struc. will be rearranged and the flow will be primarily vertical. <u>Thus tillage must be done at least 12 in. on this site to rearrange the platy structure</u>.

The silty clay loam (B) horizon (11 - 20 in.) is slowly permeable because of the texture and firm consistence. The flow will be a combination of vertical and horizontal in the upper portions and primarily horizontal flow in the lower portion of the horizon due to the nature of the next lower horizon. During wet weather the (B) horizon may be saturated with flow moving horizontally.

The silty clay (C) horizon (20 -36 in.) will accept some vertical flow as the effluent moves downslope horizontally in the upper horizons. The flow through this profile will be similar to the profile shown in Fig. 2c.

Based on experience a properly designed mound system should function on this site. It meets the minimum site recommendations found in table 1.

Linear Loading Rate:

Based on this soil profile and discussion under the Linear Loading Rate section, the linear loading rate must be in the range of 3 - 4 gpd/lf.

Linear Loading Rate = 4 gpd/lf.

Soil (Basal) Loading Rate:

A soil loading rate for the soil horizon in contact with the sand (basal area) is selected based on the surface horizon (A). Use table 2 to determine the design soil loading rate which, for silt loam soil with moderate structure, is found under item (I), provided the platy structure is tilled.

Soil (Basal) Loading Rate = 0.6 gpd/ft^2

Step 3. Select the Sand Fill Loading Rate.

The section entitled "Sand Fill Loading Rate" and Fig. 6 give guidelines for selecting a suitable sand fill quality for the Wisconsin mound system. Other fills may be used but caution should be used as performance data is very limited with other fills.

Design Sand Loading Rate = 1.0 gpd/ft^2

Step 4. Determine the Absorption Area Width (A).

A = Linear Loading Rate / Sand Loading Rate

= 4 gpd/lf / 1.0 gpd/ft^2

= 4 ft

Step 5. Determine the Absorption Area Length (B).

B = Design Flow Rate/Linear Loading Rate

= 600 gpd/4gpd/lf

= 150 ft

Step 6. Determine the Basal Width (A + I).

The basal area required to absorb the effluent into the natural soil is based on the soil at the sand/soil interface and not on the lower horizons in the profile. An assessment of the lower horizons was done in step 2 when the linear loading rate was estimated. As discussed in Step 2, the soil (basal) loading rate is 0.6 gpd/ft^2.

A+I = Linear Loading rate / Soil Loading Rate

= 4 gpd/ft / 0.6 gpd/ft^2

= 6.7 ft

Since A = 4 ft

I = 6.7' - 4' = 2.7 ft (will be larger due to mound side slope)

Step 7. Determine Mound Fill Depth (D).

Assuming the code requires 3 ft of suitable soil and soil profile indicates 11 in. of suitable soil then:

D = 36" - 11" = 25 in.

Step 8. Determine Mound Fill Depth (E).

For a 15% slope with the bottom of the absorption area level then:

E = D + 0.15(A)

= 25" + 0.15(48")

= 32 in.

Step 9. Determine Mound Depths (F), (G), and (H).

F = 9 in. (6 in. of aggregate, 2 in. for pipe, and 1 in. aggregate)

G = 12 in. (6 in. in warmer climates)

H = 18 in. (12 in. in warmer climates)

Step 10. Determine the Upslope Width (J).

Using the recommended mound side slope of 3:1 then:

$J = 3(D + F + G)$

$J = 3(25" + 9" + 12")$

$= 11.5$ ft.

(Actual width will be less because of the site slope)

Step 11. Determine the End Slope Length (K).

Using the recommended mound end slope of 3:1 then:

$K = 3((D+E)/2 + F + H)$

$= 3((25" + 33")/2 + 9" + 18")$

$= 14$ ft.

Step 12. Determine the Downslope Width (I).

Using the recommended mound side slope of 3:1 then:

$I = 3(E + F + G)$

$= 3(32" + 9" + 12")$

$= 13$ ft

(Actual width may be greater because of the site slope)

Note this value is greater than (I) in Step 6 and is the recommended width to use.

Step 13. Overall Length and Width (L + W).

$L = B + 2K$

$= 150' + 2(14')$

$= 178$ ft.

$W = A + I + J$

$= 4 + 13 + 12$

$= 29$ ft

If this site was level, than I = J. For soil profiles allowing more vertical flow, the linear loading rate could approach 10 gpd/lf and the mound would be shorter and wider.

Step 14. Design a Pressure Distribution Network.

A pressure distribution network system, including the distribution piping, dosing chamber and pump or siphons, must be designed. A design example is given in the appendix.

MOUND PERFORMANCE

The first Wisconsin mound system of the current design was installed in 1973. In Wisconsin alone there are over 12,000 mound systems. Many other states have adopted the technology. Proper siting of all soil absorption systems, including the mound, is essential otherwise the system may not function as planned.

In Wisconsin the mound system has a success rate of over 95% (Converse and Tyler, 1986). This success rate is due in part to a very strong educational program relating to siting, design and construction.

A mound can fail either at the 1) aggregate/sand interface due to a clogging mat or 2) at the sand/soil interface due to the inability of the soil to accept the effluent. Converse and Tyler (1989) discuss the mechanisms that may cause failure and methods to rectify the problems.

MOUND CONSTRUCTION

A construction plan for any on-site system is essential. A clear understanding between the site evaluator, designer, contractor and inspector is critical if a successful system is installed. It is important that the contractor and inspector understand the principles of operation of the mound system before construction commences otherwise the system may not function as intended. It is also important to anticipate and plan for the weather. It is best to be able to complete the mound before it rains on it. The tilled area and the absorption area must be protected from rain by placing sand on the tilled area and aggregate on the absorption area prior to rain. The following points are essential.

1. The mound must be placed on the contour. Measure the average ground elevation (prior to tillage) along the upslope edge of the absorption area which will be used to determine the elevation of the absorption area.

2. Grass, shrubs and trees must be cut close to the ground surface and removed from the site. In wooded areas with excessive litter, it is recommended to rake the majority of it from the site.

3. Locate the entrance of the force main into the mound. It is recommended to bring it into the center on the upslope side. If it must be brought in from the downslope side, especially on sites with horizontal flow, it should be brought in perpendicular to the side of the mound with minimal disturbance to the downslope area.

3. At the proper moisture level, the mound site must be tilled. The proper moisture level to a depth of 7 to 8 in. must be such that the

soil will crumble and not take on a wire form when rolled between the palms. The purpose is to roughen up the surface and incorporate most of the vegetation. This can be done with a mold board plow, chisel plow or chisel teeth mounded on a tool bar attached to the bucket of a backhoe. <u>The backhoe bucket teeth are not satisfactory and must not be used.</u> Rototillers are prohibited on structured soils but can be used on unstructured soils such as sands. However, they are not recommended. Tilling along the contour is required. Protect the tilled area from rain by placing a layer of sand on it.

If a platy structure is present in the upper horizons, it is necessary to till it. Normally the chisel teeth mounded on a backhoe bucket is preferred as it can be used to till around stumps and till deeper than the other methods. Stumps are not to be removed but tilled around. If there is an excessive number of stumps or boulders, than the basal area should be enlarged or another site found.

4. Once the site is tilled a layer of sand should be place before it rains on the tilled area. Placement of the sand should be such as not to rut up or compact the tilled area. All work should be done from the upslope side so as not to compact the downslope area especially if the effluent flow is horizontal away from the system.

   Sand should be placed with a backhoe or moved around the site with a track type tractor. Wheeled tractors will rut up the site.

5. Place the proper depth of sand then form the absorption area with the area bottom being level. Protect this infiltrative area from rain by placing the aggregate prior to rain.

6. Place a suitable aggregate to the desired depth in the area provided. The aggregate must be clean and sound and will not deteriorate. Limestone is not recommended.

7. Place the pressure distribution pipe and connect it to the force main and cover with 1 in. of aggregate.

8. Cover the aggregate with a geotextile synthetic fabric.

9. Place a minimum of 6 inches of suitable soil cover on the sides of the mound and to the prescribed depth on the top of the mound.

10. Final grade the mound and area with light weight equipment so surface water moves away from the mound and does not accumulate on the upslope side of the mound.

11. Seed and mulch the entire exposed area to avoid erosion. Landscape it with shrubs and plants so that it fits into the surrounding area. The top of the mound may be somewhat dry during the summer months and the downslope toe may be somewhat moist during the wet seasons (Schutt, 1981).

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APPENDIX

PRESSURE DISTRIBUTION NETWORK DESIGN

Septic tank effluent or other pretreated effluent can be distributed in the soil absorption unit either by trickle, dosing, or uniform distribution. Trickle flow, known as gravity flow, through the 4" perforated pipe does not distribute the effluent uniformly but concentrates it in several areas of the absorption unit. Dosing is defined as pumping or siphoning a large quantity of effluent into the 4" perforated pipe for distribution within the soil absorption area. It does not give uniform distribution but does spread the effluent over a larger area than does gravity flow. Uniform distribution, known also as pressure distribution, distributes the effluent somewhat uniformly throughout the absorption area. This is accomplished by pressurizing relatively small diameter pipes containing small diameter perforations spaced uniformly throughout the network and matching a pump or siphon to the network.

This material has been extracted and modified from a paper entitled "Design of Pressure Distribution Networks for Septic Tank - Soil Absorption Systems" by Otis, 1981.

The orifice equation and the Hazen-Williams friction relationships were used to size the network. A sharp-edged orifice coefficient of 0.6 and a Hazen-Williams friction factor of 150 for plastic pipe was used.

DESIGN PROCEDURE

The design procedure is divided into two sections. The first part consists of sizing the distribution network which distributes the effluent in the aggregate and consists of the laterals, perforations and manifold. The second part consists of sizing the force main, pressurization unit and dose chamber and selecting the controls.

A. <u>Design of the Distribution Network</u>.

Steps:

1. Configuration of the network.

   The configuration and size of the soil absorption system must meet the soil site criteria. Once that is established, the distribution network can be designed.

2. Determine the length of the laterals.

   Laterals are defined as the length from the manifold to the end of the lateral. For a center manifold it is approximately one half the length of the absorption area. For end manifolds it is approximately the length of the absorption area.

3. Determine the perforation spacing and size.

   The size of perforations, spacing of perforations and thus the number of perforations must be matched with the flow rate to the network. For small systems, typical perforation spacing is 30 to 36" while in larger systems spacing may be from 5 to 7 ft. Lateral spacing is somewhat arbitrary but generally equal to the perforation spacing. It is recommended to place the perforations in an equilateral triangle among the adjacent laterals. A typical perforation diameter is 1/4" but other sizes are used.

4. Determine the lateral pipe diameter.

   Based on the selected perforation size and spacing, use Figures A-1 thru A-6 to select the lateral diameter.

5. Determine the number of perforations per lateral.

   Select the perforation spacing and divide the spacing length into the lateral length to give the number of perforations per lateral.

6. Determine the lateral discharge rate.

   Based on the distal pressure selected, Table A-1 gives the perforation discharge rate. Typical distal pressure is 2.5 ft. Multiply the number of perforations per lateral by the discharge rate to yield the lateral flow rate.

7. Determine the number of laterals and the spacing between the laterals.

   For absorption areas less than 5 ft wide, one distribution pipe along the length of the absorption area is sufficient. For absorption areas 5 to 10 ft wide, two parallel distribution pipes may be appropriate. For absorption areas wider than 10 ft wide, two to three parallel distribution pipes may be appropriate. A balance must exist between the perforation size, spacing and number and pump size. Absorption areas wider than 10 - 15 ft are not recommended.

8. Calculate the manifold size.

   Use Table A-2 to determine the diameter of the manifold for both end and center manifolds. Manifold length is the distance between the outside laterals. For two parallel laterals, it is the distance between the laterals. For a single distribution pipe with end or center feed, there is no manifold.

9. Determine the network discharge rate.

   This value is used to size the pump or siphon. Take the lateral discharge rate and multiply it by the number of laterals or take the perforation discharge rate and multiply it by the number of perforations.

B. <u>Design of the Force Main, Pressurization Unit, Dose Chamber and Controls</u>.

Steps:

1. Develop a system performance curve.

   The effluent pumps that are typically used for pressurizing distribution networks are centrifugal pumps. The flow rate is a function of the total head that the pump works against. As the head becomes larger, the flow rate decreases but the flow rate determines the network pressure and thus the relative uniformity of discharge throughout the distribution network. The best way to select the pump is to evaluate the system performance curve and the pump performance.

   The total head, that the pump must work against, is the 1) network losses, 2) friction losses in the force main, and 3) elevation lift. The network loss is assumed equal to the distal pressure selected, which is 2.5 ft in most cases. This assumes that the manifold and laterals were sized according to the above procedure. The friction loss in the force main is determined using Table A-3, the total length of the force main and the diameter selected. The elevation or lift is the elevation difference between the pump shut-off level and the invert of the laterals.

2. Determine the force main diameter.

   A force main size must be determined in step 1, part B.

3. Select the pressurization unit.

   Pumps

   Using pump performance curves, select the pump that best matches the required flow rate at the operating head. Plot the pump performance curve on the system curve. Then determine if the pump will produce the flow rate at the required head. Do not undersize the pump. It can be oversized but will add to the expense of the system. Effluent pumps have been designed for septic tank effluent and must be used. Clear water sump pumps will not last very long.

   Siphons

   Care must be taken in sizing siphons. The head that the network operates against has to be developed in the force main. If the discharge rate out the perforations is greater than the siphon flow rate, the distal pressure in the network will not be sufficient. Some manufacturers recommend that the force main be one size larger than the siphon diameter to allow the air in the force main to escape. However this will reduce the distal pressure in the network which may be below the design distal pressure. Falkowski and Converse, 1988, discuss siphon performance and design.

4. Determine the dose volume required.

   The lateral pipe volume determines the minimum dose volume. The recommended dose volume is 5 to 10 times the pipe volume. Use Fig A-7 to estimate the pipe volume and then multiply it by the appropriate value to determine the dose volume.

5. Size the dose chamber.

   The dose chamber (Fig. A-1) must be large enough to provide:

   a. the dose volume.
   b. the average daily volume if a single pump is used.
   c. the dead space resulting from placement of the pump on a concrete block.
   d. a few inches of head space.

6. Select controls and alarm.

   Select quality controls and alarm. Mercury control floats are superior to all other type of switches. All electrical connections must be outside the dose chamber.

DESIGN EXAMPLE

Design a pressure distribution network for the mound system described in the main text of this publication. The absorption area is 150 ft long and 4 ft wide. The force main is 150 ft long and the elevation lift is 9 ft.

A. Design of the Distribution Network.

Steps:

1. Configuration of the network.

   This is a narrow absorption unit on a sloping site (Fig 4).

2. Determine the lateral length.

   Using a center feed, the lateral length is:

   $$\text{Lateral length} = (\text{Absorption length (B)} / 2) - 0.5 \text{ ft}$$

   $$= (150 \text{ ft} / 2) - 0.5 \text{ ft}$$

   $$= 74.5 \text{ ft}$$

3. Determine the perforation spacing and size.

   Select 1/4 in. dia. Perforations with a 3 ft spacing.

4. Determine the lateral diameter.

   Using Fig A-1 with a perforation spacing of 3 ft and lateral length of 74.5 ft, the lateral diameter is 2" (Schedule 40 PVC).

5. Determine the number of perforations per lateral.

   Using 3 ft spacing in 74.5 ft yields 24.8 or 25 perforations per lateral.

6. Determine lateral discharge rate (LDR).

   Using a distal pressure of 2.5 psi, Table A-1 gives a discharge rate of 1.2 gpm for the 1/4" dia. perforation. Thus:

   LDR = No. perforations/lat. x discharge rate/perforation

   LDR = 25 perforations x 1.2 gpm/perforation

   = 30 gpm/lateral

7. Determine the number of laterals and the spacing between the laterals.

   Since this is a narrow absorption area (4.0 ft), a single distribution is sufficient to distribute the effluent.

8. Calculate manifold size.

   Since there is only a single distribution line along the length of the absorption unit with a center feed (2 laterals), there is no manifold in this system.

   However, assuming there were 2 parallel lines (4 laterals) spaced 5 ft apart with a center manifold with each lateral having a discharge rate of 26.4 gpm, Table A-2 gives a manifold diameter of 3". (Proceed down left column to 30 gpm/center manifold, then right to column 5. It shows for a 5 ft lateral spacing and 3" dia. manifold a maximum length of 10 ft which is greater than the 5 ft for this unit).

   As a rule of thumb for smaller systems, the diameter of the manifold can be the same as the force main.

9. Determine network discharge rate (NDR).

   NRD = No. of laterals x Lateral Discharge Rate

   = 2 laterals x 30 gpm/lat.

   = 60 gpm

B. Design of the Force Main, Pressurization Unit, Dose Chamber and Controls.

Steps:

1. Calculate the system performance curve.

Use the following table to develop a system performance curve. Follow procedures (a) through (g) which are listed below the table. Orifice is synonymous to perforation.

Total Flow	Orifice Flow	Elevation Difference	Force Main	Orifice	Total
Flow Rate (gpm)		Head (ft)			
20	0.40	9.0	0.18	0.29	9.5
40	0.80	9.0	0.59	1.17	10.8
60	1.20	9.0	1.22	2.65	12.9
80	1.60	9.0	2.07	4.71	15.8
100	2.00	9.0	3.14	7.36	19.5

Procedure:

a. Select 5 flow rates above and below the network discharge rate (60 gpm).

b. Calculate the orifice (perforation) flow rate for each of the flows. This is done by dividing the flow rate by the number of orifices in the network. For 20 gpm and 50 orifices, the orifice flow rate is 0.40 gpm.

c. The elevation head is the height that the effluent is lifted.

d. The force main head is the head loss in the force main for the given flow rate. Table A-3 gives the friction loss.

e. The orifice head is calculated by $H = (Q/(11.79*d^2))^2$. H is head in ft, Q is orifice flow rate in gpm, and d is orifice diameter in inches. For 1/4 in. diameter orifice, the equation is $H = (Q/0.737)^2$.

f. The total head is the sum of the elevation, force main and orifice heads.

g. Plot the flow rates vs. total head (Fig. A-8).

2. Determine the force main diameter.

A force main of 3 in. was selected in step 1 of Part B.

3. Select a pressurization unit.

   Plot the pump performance curves of several effluent pumps on the system performance curve (Fig. A-8). Select a pump that will provide at least 60 gpm (X on the curve). The system will operate at the intersection of the pump performance curve and the system curve. Select pump B or C as Pump A will not provide sufficient volume and pressure. Pump C may be oversized for the system and result in extra cost and operating at a lower pump efficiency.

4. Determine dose volume.

   Fig. A-7 gives a total pipe volume of 23 gallons for the two 2" dia. by 74.5 ft laterals. Use a dose volume of 5 to 10 times the lateral pipe volume which is 115 to 230 gallons per dose.

   (Using a straight edge, place it on the left column at 74.5 ft and also on the 2 in. dia. point of the 2nd column. Mark the point of intersection of the straight edge and column 3. On column 3 pivot to the 2 mark on column 4 and read the total volume on the right hand column which is 10 gal/lateral).

5. Size the dose chamber.

   Based on the dose volume, storage volume and room for a block beneath the pump and control space, a 750 to 1000 gallon chamber will be sufficient (Fig. A-9).

6. Select controls and alarm.

   Use mercury control floats and a quality alarm with a mercury control float.

CONSTRUCTION AND MAINTENANCE

Good common sense should prevail when constructing and maintaining these systems. Good quality components should be used. Water tight construction practices should be employed. All electrical controls must be outside the dose chamber as the interior environment is very humid and corrosive. Regular maintenance and pumping of the septic tank should be employed to minimize solids carry-over. Screens and filters may be installed to minimize solids carried to the distribution network. Seeds of all shapes and sizes along with toilettes have been found in the laterals. Proper baffle maintenance in the septic tank is essential. Surface runoff should be diverted away from the septic tank and dose chamber. Any settling after construction should be filled in so that the ground surface slopes away from the tanks and chambers. DO NOT ENTER THESE TANKS WITHOUT PROPER SAFETY EQUIPMENT INCLUDING A SELF CONTAINED BREATHING APPARATUS.

Table A-1 Perforation Discharge Rates in Gallons per Minute Versus Perforation Diameter and In-Line Pressure (Otis, 1981)

In-Line Pressure (ft)	Perforation Diameter (in)						
	1/4	5/16	3/8	7/16	1/2	9/16	5/8
	gpm						
1.0	0.74	1.15	1.66	2.26	2.95	3.73	4.60
1.5	0.90	1.41	2.03	2.76	3.61	4.57	5.64
2.0	1.04	1.63	2.34	3.19	4.17	5.27	6.51
2.5	1.17	1.82	2.62	3.57	4.66	5.90	7.28
3.0	1.28	1.99	2.87	3.91	5.10	6.46	7.97
3.5	1.38	2.15	3.10	4.22	5.51	6.98	8.61
4.0	1.47	2.30	3.31	4.51	5.89	7.46	9.21
4.5	1.56	2.44	3.52	4.79	6.25	7.91	9.77
5.0	1.65	2.57	3.71	5.04	6.59	8.34	10.29

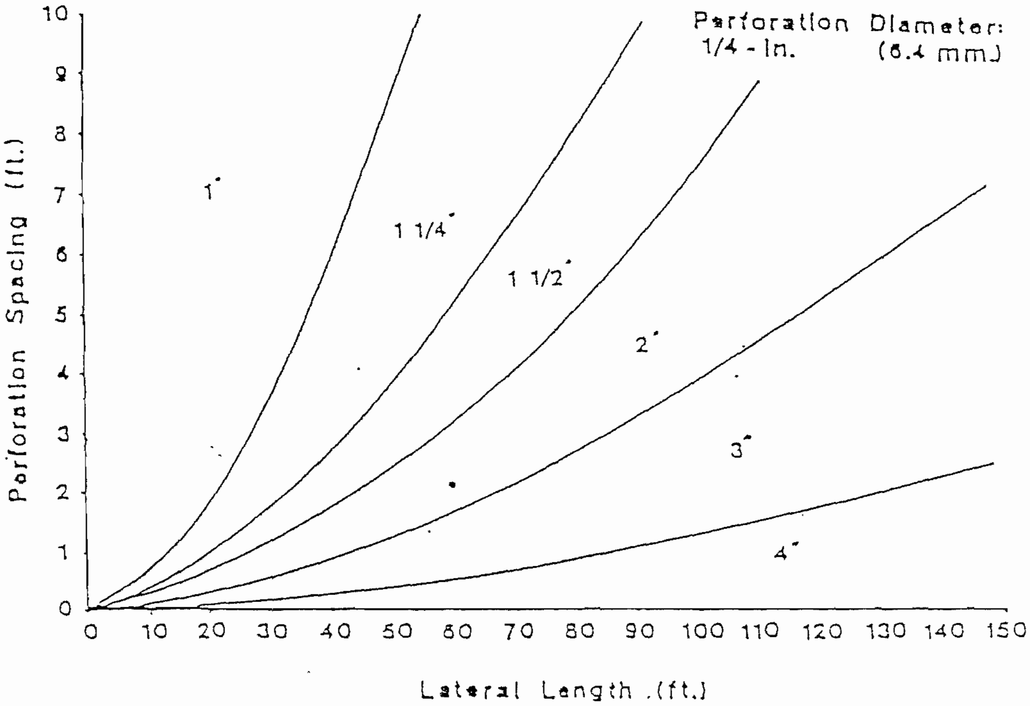

Fig. A-1. Minimum Lateral diameter for Plastic Pipe (C-150) Versus Perforation Spacing and Lateral Length for 1/4" Diameter Perforations (Otis, 1981)

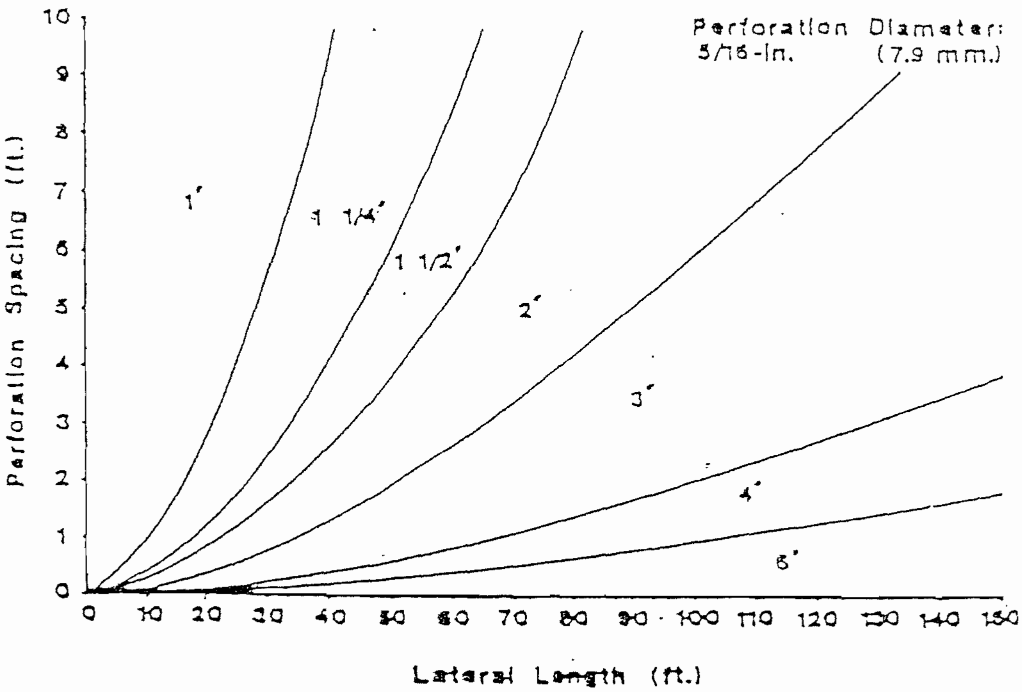

Fig. A-2. Minimum Lateral Diameter for Plastic Pipe (C-150) Versus Perforation Spacing and Lateral Length for 5/16" Diameter Perforations (Otis, 1981)

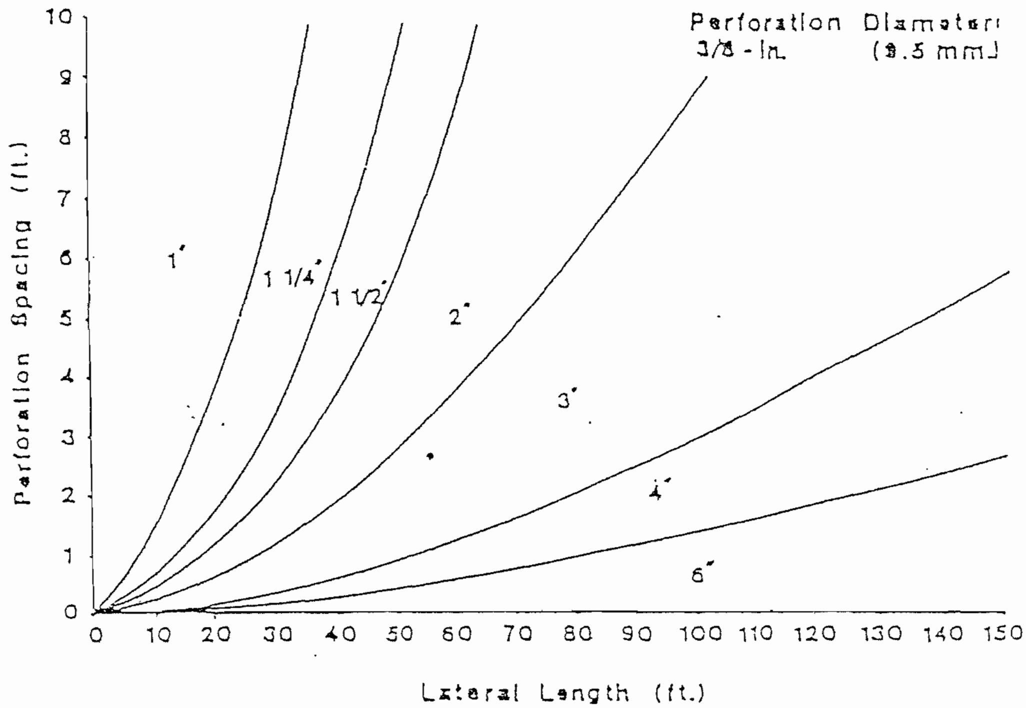

Fig. A-3. Minimum Lateral Diameter for Plastic Pipe (C=150) Versus Perforation Spacing and Lateral Length for 3/8" Diameter Perforations (Otis, 1981)

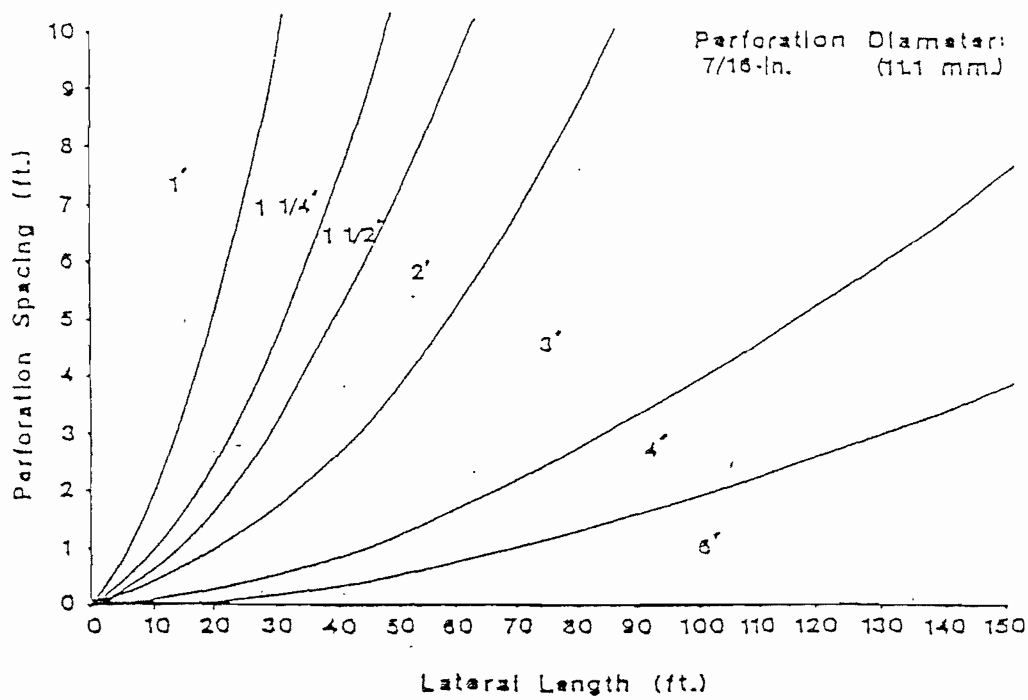

Fig. A-4. Minimum Lateral Diameter for Plastic Pipe (C=150) Versus Perforation Spacing and Lateral Length for 7/16" Diameter Perforations (Otis, 1981)

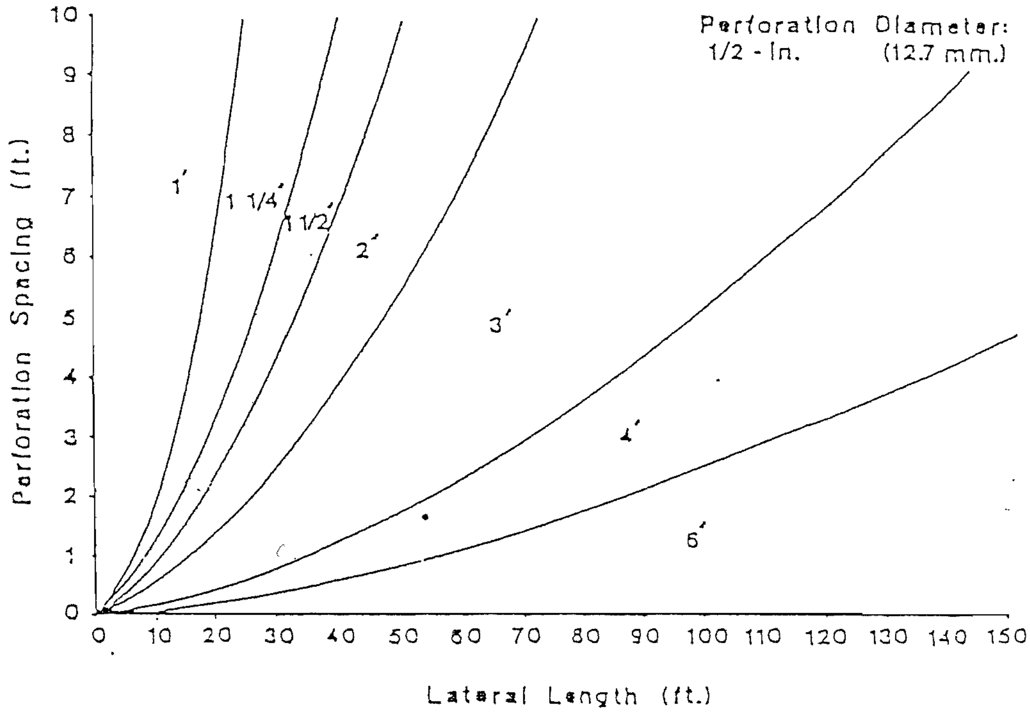

Fig. A-5. Minimum Lateral Diameter for Plastic Pipe (C-150) Versus Perforation Spacing and Lateral Length for 1/2" Diameter Perforation (Otis, 1981)

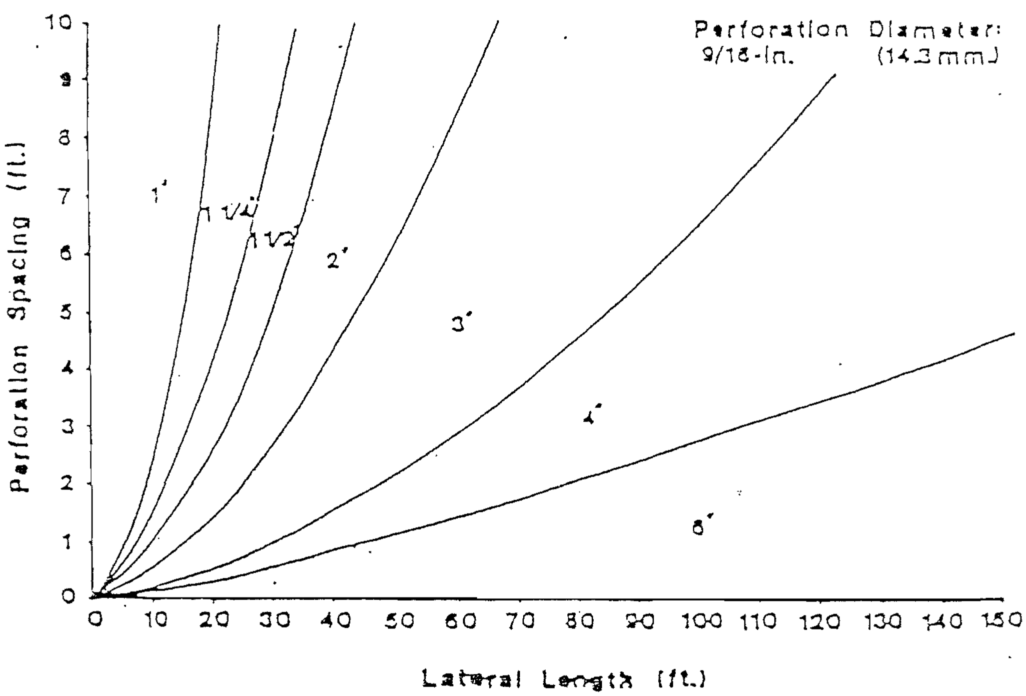

Fig. A-6. Minimum Lateral Diameter for Plastic Pipe (C-150) Versus Perforation Spacing and Lateral Length for 9/16" diameter Perforations (Otis, 1981)

Table A-2. Maximum Manifold Length (ft) for Various Manifold Diameters Given the Lateral Discharge Rate and Lateral Spacing (Otis, 1981)

Lateral Discharge Rate (gpm)		Manifold Diameter = 1 1/4"					Manifold Diameter = 1 1/2"					Manifold Diameter = 2"					Manifold Diameter = 3"					Manifold Diameter = 4"					Manifold Diameter = 6"				
		Lateral Spacing (ft)					Lateral Spacing (ft)					Lateral Spacing (ft)					Lateral Spacing (ft)					Lateral Spacing (ft)					Lateral Spacing (ft)				
End Manifold	Central Manifold	2	4	6	8	10	2	4	6	8	10	2	4	6	8	10	2	4	6	8	10	2	4	6	8	10	2	4	6	8	10
10	5	4	4	6	8	10	10	8	12	16	20	12	16	24	24	30	26	40	48	56	70	42	64	84	96	110	82	136	174	208	210
20	10	4	4	6			4	4	6	8	10	6	8	12	16	20	16	24	30	32	40	26	40	54	64	70	54	84	108	128	150
30	15	2					2	4	6			4	8	6	8	10	12	16	24	24	30	20	28	36	48	50	42	64	84	96	110
40	20											4	4	6	8	10	10	12	18	16	20	16	24	30	32	40	34	52	66	80	90
50	25											2	4	6	8		8	12	12	16	20	14	20	24	32	40	30	44	60	72	80
60	30											2	4				6	8	12	16	20	12	16	24	24	30	26	40	48	64	70
70	35											2	4				4	8	12	8	10	10	16	18	24	30	24	36	48	56	60
80	40											2					6	8	6	8	10	10	12	18	16	20	22	32	42	48	60
90	45											2					4	8	6	8	10	8	12	18	16	20	20	28	42	48	50
100	50											2					4	4	4	8	10	8	12	12	16	20	18	28	36	40	50
110	55																4	4	6	8	10	8	12	12	16	20	16	24	36	40	40
120	60																4	4	6	8	10	6	8	12	16	10	16	24	30	32	40
130	65																4	4	6	8	10	6	8	12	16	10	14	24	30	32	40
140	70																2	4	6	8		6	8	12	8	10	14	20	24	32	40
150	75																2	4	6			6	8	12	8	10	14	20	24	32	30
160	80																2	4	6			6	8	6	8	10	12	20	24	32	30
170	85																2	4	6			4	8	6	8	10	12	20	24	24	30
180	90																2	4				4	8	6	8	10	12	16	24	24	30
190	95																2	4				4	8	4	8	10	12	16	18	24	30
200	100																2	4				4	4	6	8	10	10	16	18	24	30

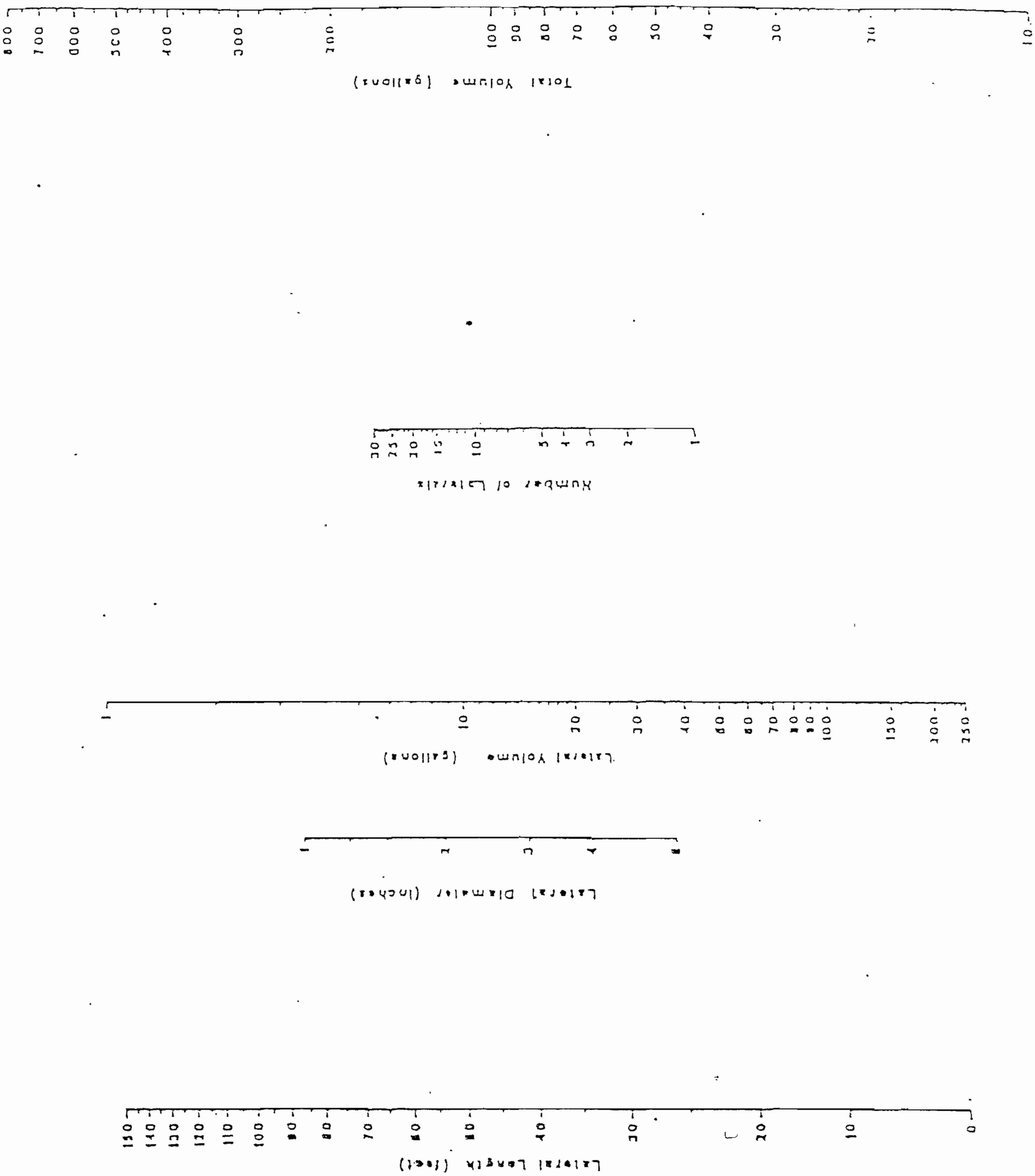

Fig. A-7 Nomograph for Determining the Total Pipe Volume Given the Diameter, Length and Number of Laterals (Otis, 1981).

Table A-3. Friction Losses in Schedule 40 PVC Plastic Pipe (C-150) Versus Flow Rate and Pipe Diameter (Otis, 1981)

Flow gpm	1	1 1/4	1 1/2	2	3	4	6	8	10	12	Flow gpm
	Pipe Diameter (in.) ft/100 ft										
1	0.10										1
2	0.35	0.12									2
3	0.75	0.25	0.10								3
4	1.28	0.43	0.13								4
5	1.93	0.65	0.27	0.07							5
6	2.70	0.91	0.38	0.09							6
7	3.59	1.21	0.50	0.12							7
8	4.60	1.55	0.64	0.16							8
9	5.72	1.93	0.80	0.20							9
10	6.95	2.35	0.97	0.24							10
11		2.80	1.15	0.28							11
12		3.29	1.35	0.33							12
13		3.31	1.57	0.39							13
14		4.37	1.80	0.44	0.06						14
15		4.97	2.05	0.50	0.07						15
16		5.60	2.31	0.57	0.08						16
17		6.27	2.58	0.64	0.09						17
18		6.96	2.87	0.71	0.10						18
19			3.17	0.78	0.11						19
20			3.49	0.86	0.12						20
25			5.27	1.30	0.18						25
30				1.32	0.25	0.06					30
35				2.42	0.34	0.08					35
40				3.10	0.43	0.11					40
45				3.35	0.54	0.13					45
50				4.68	0.65	0.16					50
60					0.91	0.23					60
70					1.21	0.30					70
80					1.55	0.38					80
90					1.93	0.46	0.07				90
100					2.35	0.58	0.08				100
125					3.55	0.88	0.12				125
150					4.97	1.23	0.17				150
175						1.63	0.23	0.06			175
200						2.09	0.29	0.07			200
250						3.16	0.44	0.11			250
300						4.42	0.61	0.15			300
350							0.82	0.20	0.07		350
400							1.05	0.26	0.09		400
450							1.30	0.32	0.11		450
500							1.58	0.39	0.13		500
600							2.72	0.55	0.18	0.08	600
700							2.95	0.73	0.25	0.10	700
800							3.77	0.93	0.31	0.13	800
900							4.69	1.16	0.39	0.16	900
1000								1.41	0.47	0.20	1000

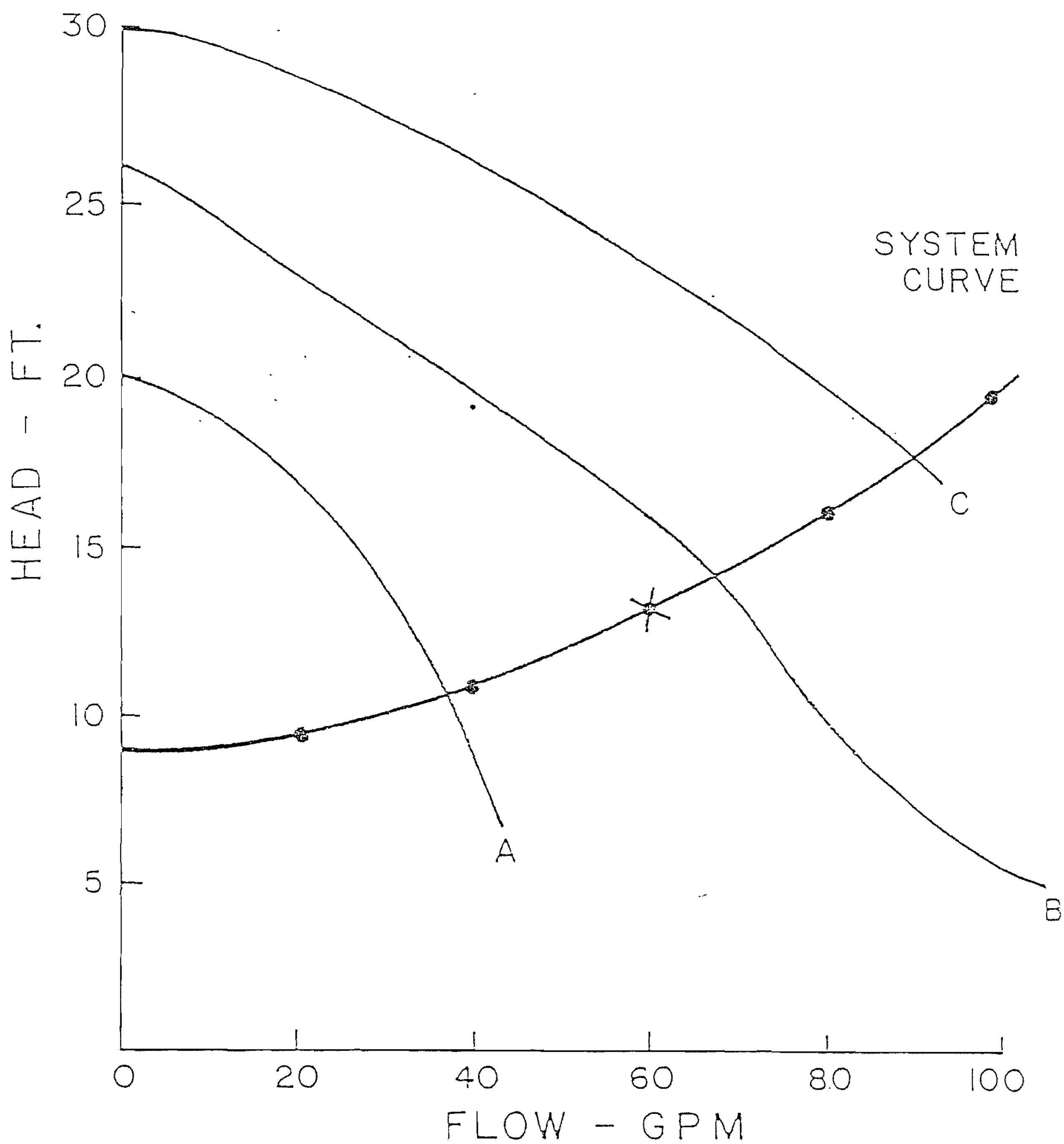

Fig. A-8 System Performance Curve and Several Pump Performance Curves for the Example Problem. For this example, the pump must provide a flow of at least 60 gpm (represented by X on the system performance curve. Pump A, represented by performance curve A, will not provide it. Pump C exceeds the requirement considerably and the curves intersect near the end of the pump curve. Pump B is the correct pump to select as it is just slightly above the desired point (X) and it is toward the middle of the pump curve.

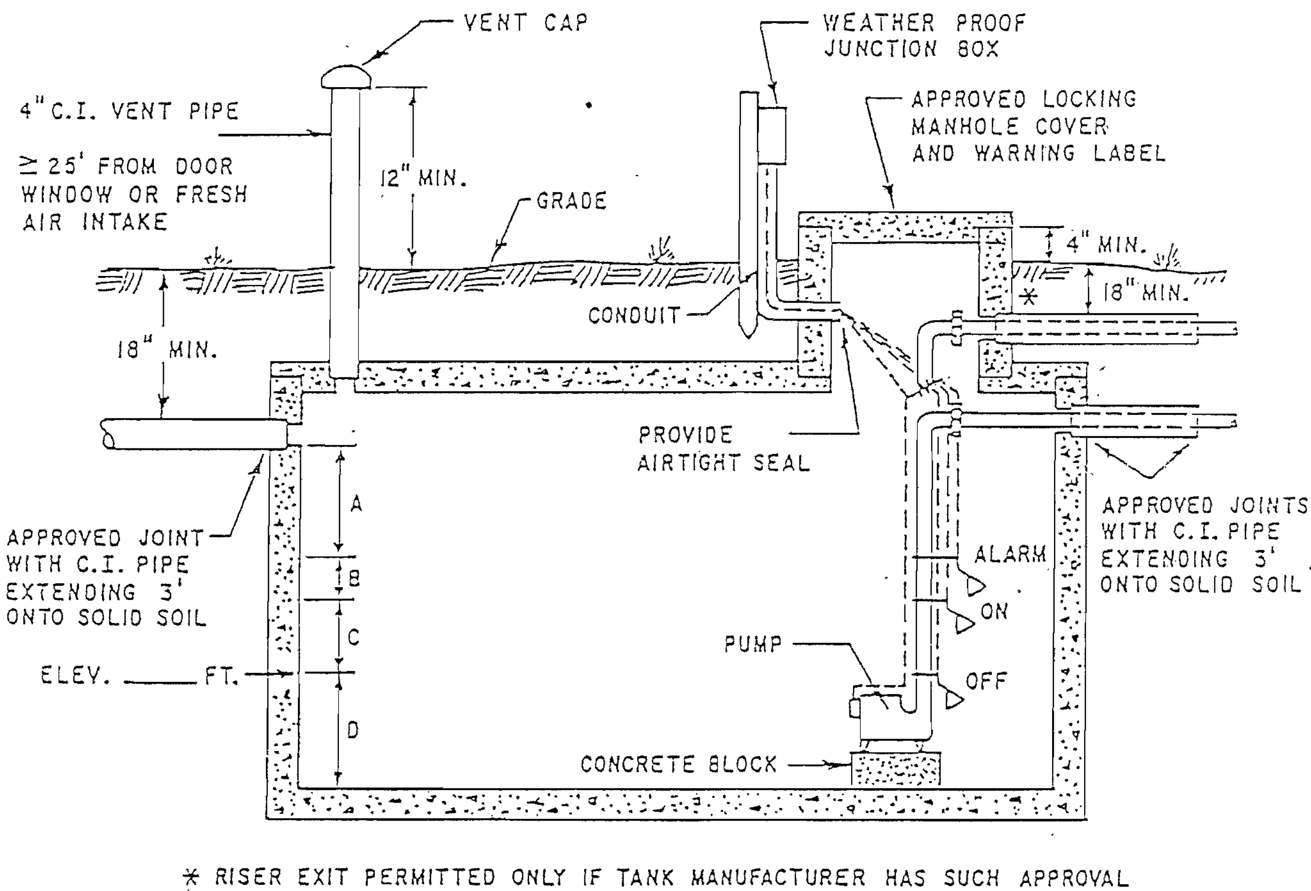

Fig. A-9. Cross Section of a Dose Chamber with a Pump and Control Unit as Required in Wisconsin (Wisc. Adm. Code, 1985)