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SMALL SCALE WASTE MANAGEMENT PROJECT

Wisconsin At-Grade Soil Absorption System: Siting, Design and Construction Manual

by

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PREFACE

The Wisconsin At-Grade Soil Absorption system is one of several soil absorption systems that can be used to treat and dispose of on-site wastewater through the soil. It is a relatively new system with the first system installed in 1982. Since that time a number of systems have been installed and it appears that this system has a lot of promise on sites that don't meet the criteria for in-ground soil absorption sytems but exceed the criteria for the Wisconsin Mound system.

This publication is an update and succeeds the publication entitled "WISCONSIN AT-GRADE SOIL ABSORPTION SYSTEM MANUAL SITING - DESIGN - CONSTRUCTION" which was dated May, 1989.

The at-grade system will continue to be evaluated. Additional information can be obtained through the SSWMP.

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THE WISCONSIN AT-GRADE SOIL ABSORPTION SYSTEM

SITING, DESIGN, AND CONSTRUCTION MANUAL

BY

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The Wisconsin at-grade soil absorption system accepts septic tank effluent and treats and disposes of it in an environmentally acceptable manner. It serves the same function as in-ground soil absorption trenches and mound systems. Figure 1 shows a schematic of the system, which consists of a septic tank and the soil absorption unit. When pressure distribution is used, a dose chamber is required. The existing soil surface is tilled, observation tubes and the aggregate are placed, the distribution network installed, the fabric covering laid on the aggregate and soil cover placed over the fabric and on the side slopes. The hydraulics and treatment concepts are very similar to the in-ground trench or bed and the mound system.

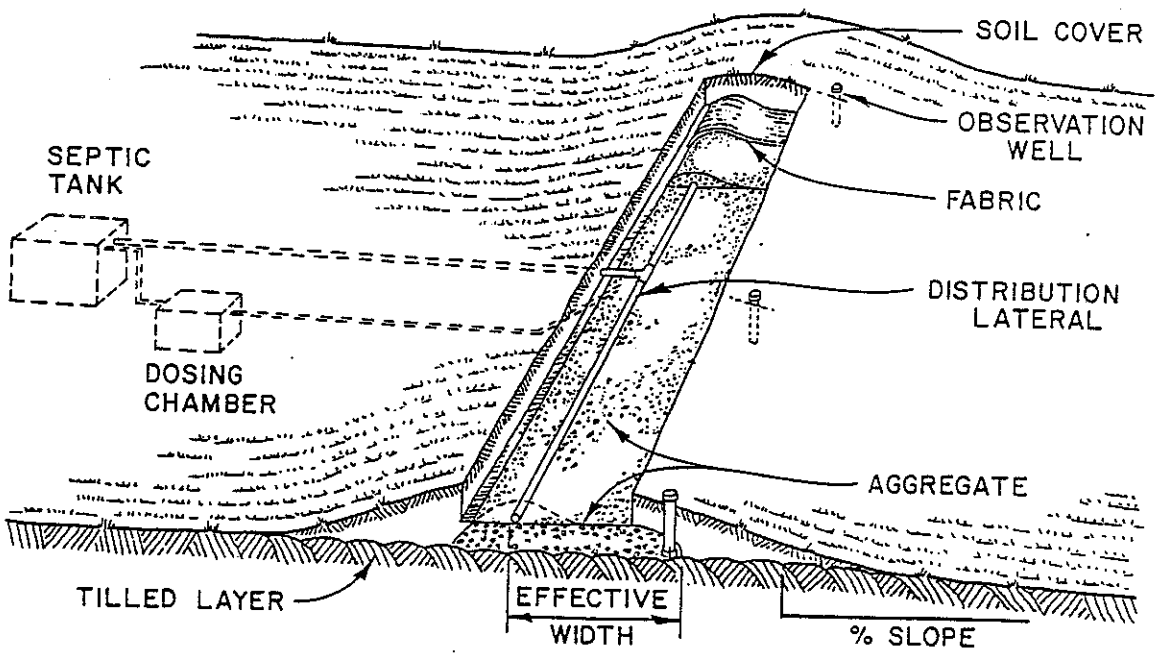

Fig. 1. Schematic of the At-grade Soil Absorption System

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Fig. 2 shows a cross section of 4 soil absorption systems; the in-ground trench or bed, the shallow in-ground trench or bed, the at-grade, and the mound. System selection is based on the soil site criteria established by local or state codes for soil absorption systems.

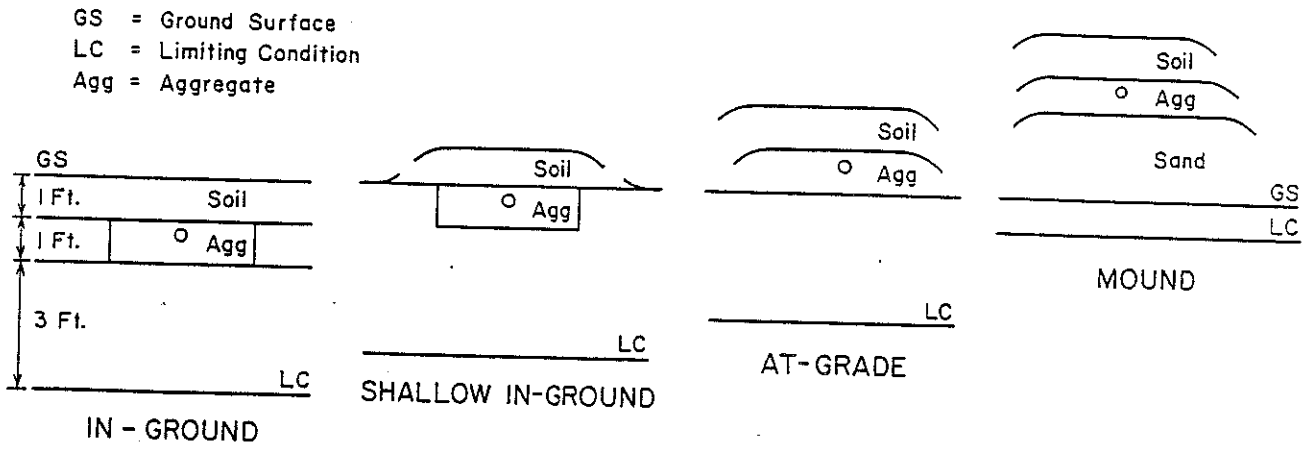


Fig. 2 Cross Section of 4 Soil Absorptions Units in Relation to Ground Surface and Limiting Conditions

The at-grade system has been evaluated in the field with 14 experimental systems which were from 1 to 5 years old and accepting domestic wastes from typical residences. All systems have been performing very well (Converse et al., 1988). As of Jan. 1990, there were over 250 units installed in Wisconsin.

SOIL AND SITE EVALUATION

Selection of the appropriate soil absorption system for a site should consider the following:

1. The landscape and topography for waterways and surface runoff. Avoid placing the system in areas where surface water accumulates or passes downslope.

2. Avoid concave slopes especially if the system will be large. Look for straight slopes, level sites, or convex slopes.

3. Avoid areas that have an excessive number of trees or rocks on the surface. Increase the size of the unit to compensate for the area of the tree stumps and rocks.

4. Evaluate several soil profiles in the area for the following:

   a. Depth to seasonal or permanent high water table for at least the depth dictated by code. It may range from 1 to 4 ft. For Wisconsin it is 3 ft beneath the proposed bottom of the system. For large systems evaluation to greater depths may be necessary.

b. Depth to bedrock for at least the required depth beneath the bottom of proposed system.

c. Texture, color, structure and consistence for at least the required depth beneath the bottom of the proposed system. Evaluate for soil banding, especially in sand textured soils. Evaluate the profile for layers that may restrict effluent flow.

d. Movement of effluent through the soil profile. Will it all move vertically downward? Will it all move horizontally away from its point of application? Will it move both vertically and horizontally and if so, can you estimate about how much will go in each direction? Figure 3 shows the effluent movement away from the at-grade unit for 4 different soil profile conditions.

e. Estimate the soil permeability based on the texture, structure and consistence. Do it for each layer of soil to the required depth beneath the proposed bottom of the system.

Horizontal and Vertical Separations:

Horizontal set backs from such features as wells and property lines are usually dictated by local codes and should be followed for all soil absorption systems. Most codes have required separation distances between the bottom of the aggregate and the high water table or bedrock. Table 1 gives the required distance of 3 ft for Wisconsin. Some codes may require only one foot of separation while some may require four feet of separation. The at-grade unit should follow the same separation distances as required for other soil absorption units.

Slopes:

Table 1 gives the slope limitation for at-grade systems. Limited experience is available for the steeper slopes. On the steeper slopes care must be taken to maintain safe construction practices as well as design.

Design Soil Loading Rate:

The design soil loading rate is based on the soil horizon that is in contact with the aggregate, which is the surface horizon for the at-grade system. Table 2 gives the recommended loading rates for various combinations of soil texture, structure, and consistence. These are estimates based on experience. Codes may dictate loading rates or area per bedroom based on the percolation rate. If percolation rates are required, then the rate should be determined for the most limiting horizon beneath the bottom of the system up to a distance of 3 ft (or code requirement) beneath the bottom of the system. Care should be used in sizing system absorption area based on percolation rates. If used, other criteria should also be used to make sure that the percolation rate is giving a reasonable absorption area. Table 3 gives sizing of absorption areas based on percolation rates.

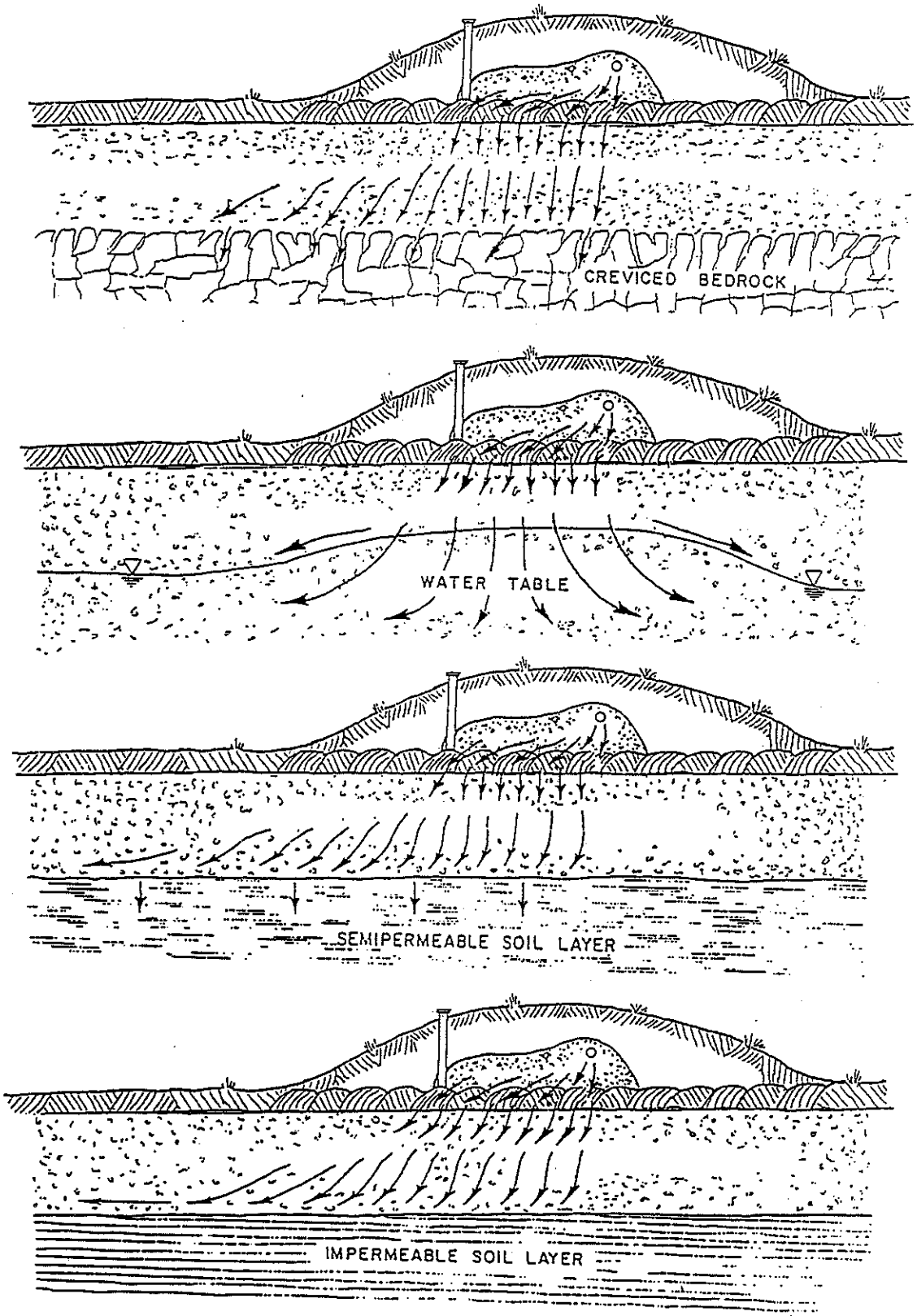


Fig. 3. Effluent Movement Away From the At-grade Unit Under Four Different Soil Profile Conditions

Table 1. Soil and Site Criteria for the Wisconsin At-Grade System Used in Wisconsin

Parameter	Limits
Depth from surface to high water[a]	> 3 ft
Depth from surface to bedrock	> 3 ft
Surface slope[b]	< 25 %
Permeability of soil (0-3 ft)	c
Flood plain	no

[a] May be seasonal which would be estimated by mottles. Wisconsin code sets 3 ft separation distance to limiting condition. Other codes may require other distances.

[b] Limited experience on 25% slope. Recent systems, not reported by Converse et al. (1988), have been placed on 25-30% slopes.

[c] The standard percolation test was not performed on the sites during the experimental phase (Converse et al., 1988). The estimated percolation rates for the surface horizon are between 0 and 60 mpi with the majority of the sites having rates of 30 mpi or faster.

DESIGN PRINCIPLES

System Configuration:

The system configuration must meet the soil site criteria and also fit on the site. As with other soil absorption systems, they should be designed long and narrow (Tyler and Converse, 1985; Converse and Tyler, 1986). Necessary design configuration may not fit on some sites thus requiring other alternatives. Prior to the design, the soil evaluator/designer must use the soil profile description to 1) estimate the effluent acceptance rate of the soil and 2) determine the flow path of the effluent as it moves through the soil profile and away from the system. For example, if there is a restrictive layer such as soil banding, hardpan, platy structure or high water table, the flow may be primarily horizontal and thus the design must be long and narrow (Fig. 3). If the platy structure is in the surface horizon or just below it, tilling will reorient the structure and should allow for vertical flow. If there is no restrictive layer, then the flow will be vertical and the effective width of the system may be greater. Unfortunately, it is very difficult to determine the exact effective width that the system should be. A system that is too wide may leak at the downslope toe or either toe on level sites. Other factors such as gas transfer and exchange beneath the absorption area (aggregate/soil interface) are also affected by the width of the system (Tyler et al., 1986). If there isn't sufficient length along the contour, but there is sufficient distance along the slope, configuration 3 and 4 in Fig. 4 may be appropriate for the site but only for at-grades using a pressure distribution network.

Effective Absorption Area:

The effective absorption area is that which is available to accept effluent. The effective length of the absorption area is the actual length of the aggregate along the contour. The effective width on sloping sites is the distance from the distribution pipe to the toe of the aggregate and on level

Table 3. Sizing of the Effective Area Based on Percolation Rates*

Soil Class (mpi)	Sizing (sq. ft / bedroom)
Class 1 (0 - 10)	165
Class 2 (10 - 30)	250
Class 3 (30 - 45)	300
Class 4 (45 -60)	330

*Taken from Wisc. Adm. Code (1985) on sizing using trench bottom area. The recommended approach to sizing is to use Table 2.

conditions but "good estimates" are suggested based on experience and judgement by the authors. If the flow away from the system is primarily vertical (Fig 4a), then the linear loading rate can be high but the recommended rate is below 10 gpd/linear ft otherwise the absorption area becomes excessively wide, especially on the slower permeable soils such as the silt loams to silty clay loams. However, if the more permeable soils are shallow and flow is primarily horizontal (Fig. 3d) then the linear loading rate should be constrained to 3-4 gpd/linear ft. This approach will normally result in systems that are narrow and therefore long.

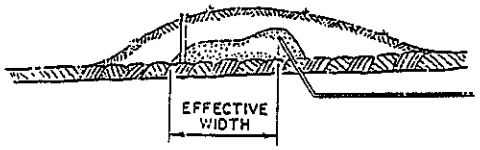
Total Length and Width:

Once the effective length and width of aggregate/soil contact area are determined, it is necessary to add about 5 ft on each side and end of the aggregate to tie the system into the existing soil surface with the cover soil. Greater widths are satisfactory if additional landscaping is desired. However, use of heavy machinery on the downslope toe should be avoided especially if there is any horizontal movement of effluent caused by a slowly permeable horizon or high water table.

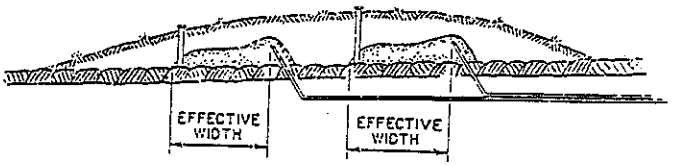
Distribution Network:

The at-grade system can be designed for either gravity or pressure distribution. The pressure distribution network requires a dose chamber while the gravity network does not as long as the pretreatment tank outlet is at a higher elevation than the distribution network. Because of the limited experience with gravity units, pressure distribution networks are being installed in all gravity units with the manifold being stubbed just outside the unit. If gravity distribution should not function properly, or if continued research shows they do not provide a reasonable length of service, the unit can be converted to pressure distribution easily. At this time pressure distribution is preferred and recommended for at-grade systems.

Gravity Distribution: Figure 5 shows the typical distribution pattern for both pressure and gravity flow. Typically in gravity flow, the effluent leaves the distribution pipe at one or two locations, moves vertically down

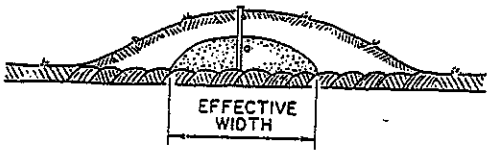


A



B

CROSS SECTIONS ON SLOPING SITES



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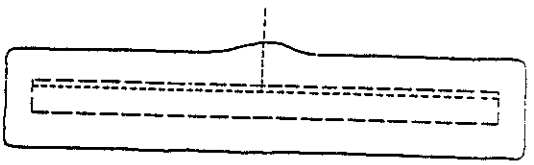
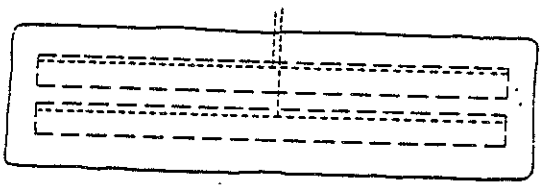
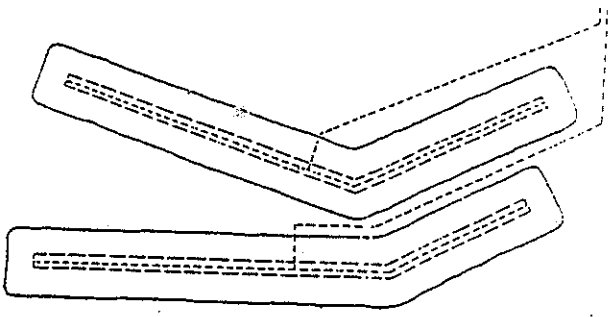
CROSS SECTION ON LEVEL SITE



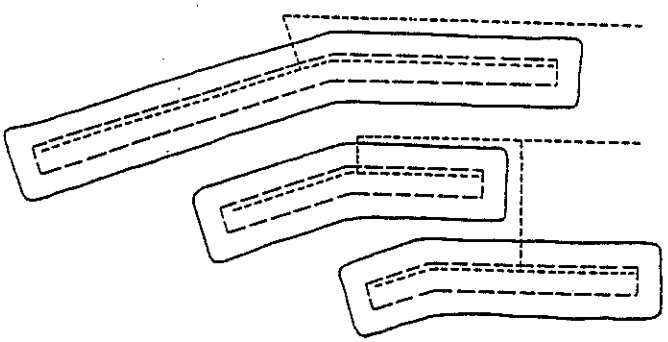
Configuration 1 with cross section A



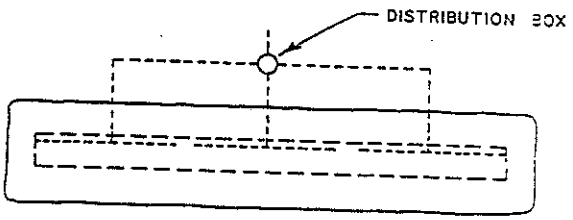
Configuration 2 with cross section B



Configuration 3 with cross section A

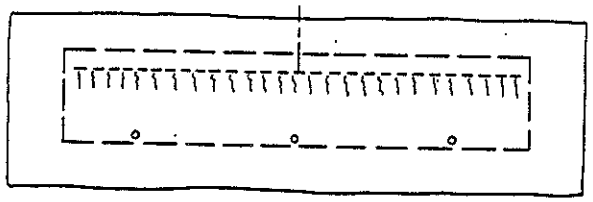


Configuration 4 with cross section A

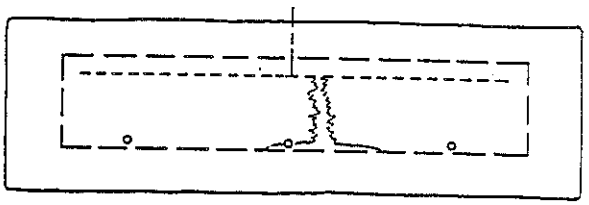


Configuration 5 with cross section A

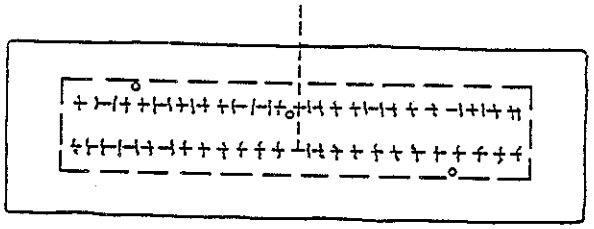
Fig. 4. Typical Configurations of At-Grade Units That Have Been Installed



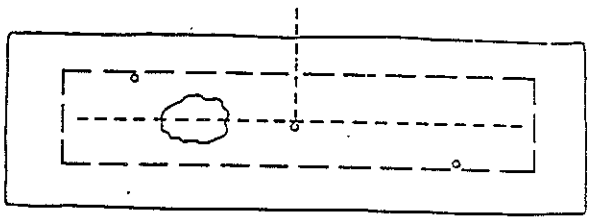
Pressure Distribution Using a Single Line on Sloping Site



Gravity Distribution Using a Single Line on Sloping Site



Pressure Distribution Using 2 lines On a Level Site



Gravity Distribution Using a Single Line on a Level Site

Fig. 5. Typical Distribution Patterns for Pressure and Gravity Distribution Networks

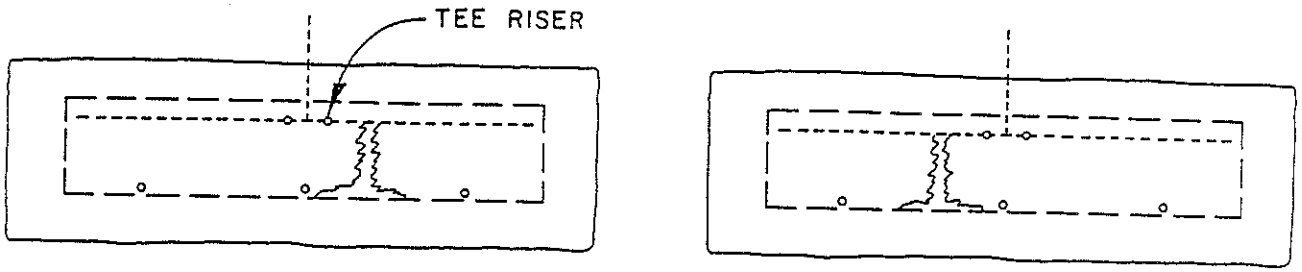
through the aggregate and then moves horizontally along the soil/aggregate interface until it infiltrates into the soil (Converse, 1974). As the clogging mat develops, the effluent will move further down the slope until it infiltrates. Eventually it will reach the toe of the aggregate and then it will move horizontally along the toe until it infiltrates. This phenomenon is called creeping clogging. Ponding will occur along the toe of the aggregate and may be observed in the observation tubes if the tubes are located downslope of where the effluent left the distribution pipe. If not, ponding will eventually appear in the observation tubes as the ponded effluent creeps along the toe of the aggregate. As noted in Fig 5, a large part of the effective infiltration area may not be used with gravity distribution on sloping sites.

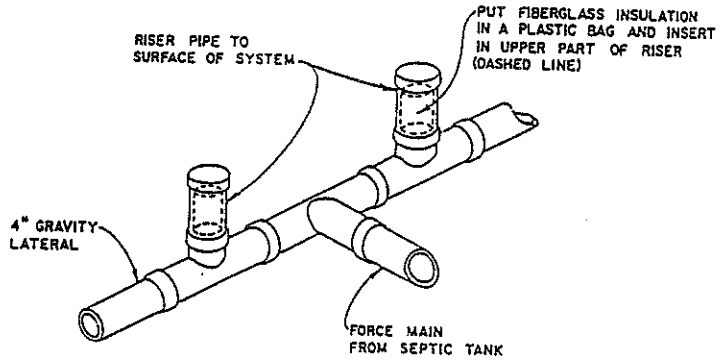
On level sites, the effluent will spread out over the whole area just as it does in in-ground trenches or beds. Thus on some sites it may be appropriate to make the bottom of the absorption area level provided an acceptable separation distance between the bottom of the aggregate and the bedrock or high water table is maintained (Table 1). The system is then approaching a shallow in-ground system (Fig. 2) for which there is limited experience. Care must be taken not to reduce the infiltration rates in the soil due to construction practices. The effective infiltrative area must be quite level or the effluent will not flow to high areas until lower areas are excessively ponded. Sites that appear to be level may actually have a slight slope. In that case up to one half the absorption area may be ineffective if the system is designed as a level site.

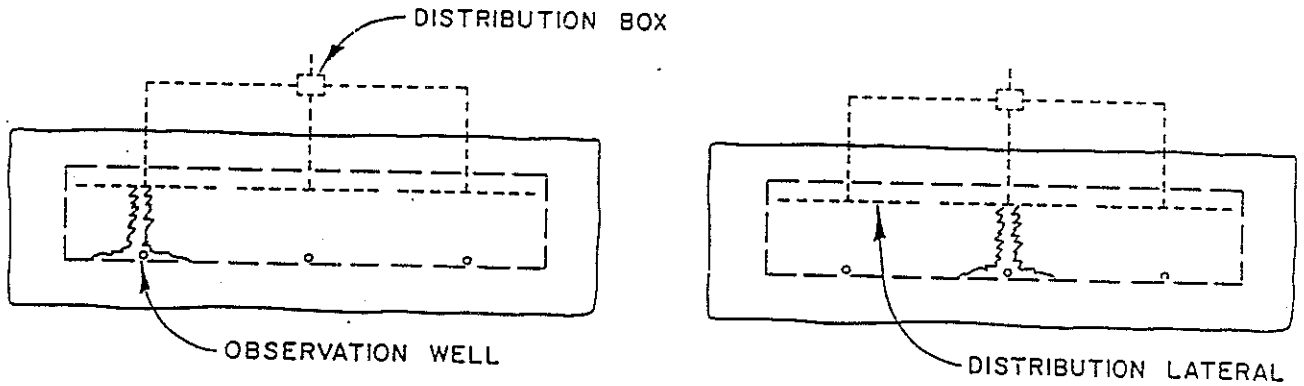
If gravity flow is used, it must be restricted to the single absorption area configuration (Fig 4, configuration 1 and 5) as the effluent will enter one or the other absorption area unless provisions are made so the flow can be directed to either trench through a distribution box or drop box arrangement. In which case, all of the flow will be directed to one area until it is switched to the other area.

As the effluent ponds at the toe of the aggregate, seepage to the surface may occur resulting in raw effluent on the surface which must be avoided. This seepage will continue to occur until corrective action is taken. Corrective action includes converting the system to pressure distribution by connecting the pressure distribution network to a dose chamber (Fig 1) or by providing some means of diverting the flow from area to area in the system. This can be done by providing a distribution box up slope of the at-grade unit (Fig 4, configuration 5) or providing diverting tees and risers where the pipe from the septic tank connects to the perforated distribution pipe (Fig 6). Figure 6 also shows the distribution of effluent as it is distributed to different parts of the system. The disadvantage of this approach, is that someone has to divert the flow occasionally. When done it will allow part of the system to rest.

Pressure Distribution: Pressure distribution is the recommended method of distribution of the septic tank effluent in the at-grade unit. Fig. 5 shows how the effluent is spread along the contour. The effluent leaves the lateral through the small diameter hole and moves vertically downward through the aggregate where it infiltrates into the soil. As it comes in contact with the soil, it will move laterally away (downslope on sloping sites and laterally in all directions on level sites) and infiltrates into the soil.







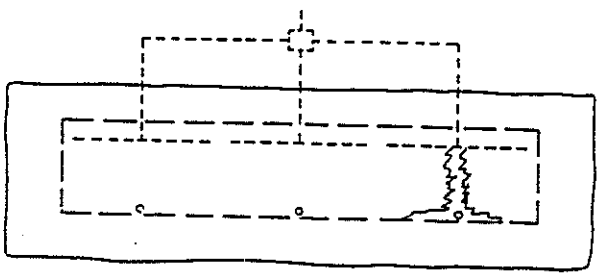


Fig. 6. Typical Distribution Patterns for Gravity Using Tees and Distribution Boxes

This approach should minimize the severe progressive clogging that typically occurs in gravity systems, but a clogging mat can occur in pressure systems.

The pressure distribution network configuration will vary depending upon the size and dimensions of the absorption area. For level sites with narrow absorption areas, a single lateral in the center along the length of the absorption area will suffice (Fig. 5). For wider absorption areas, it may be appropriate to use parallel laterals, fed by a manifold, and spaced equal distance apart so that the distance from the edge of the aggregate to the lateral is one half the distance of the spacing between the laterals and using a center manifold especially on longer units (Fig. 5).

On sloping sites for all systems, the distribution network consists of a single perforated pipe on the upslope edge of the aggregate with a center feed preferred (Fig. 5). For wider absorption areas on sloping sites, some contractors have installed parallel laterals with one lateral near the upslope edge and a parallel lateral midway down the slope. This approach has some validity in that it spreads the effluent over a wider area. If this approach is used and the slope is minimal, it is best to install the pipes level by placing more aggregate beneath the lower laterals. Designing pressure distribution networks for sloping sites is risky and provisions such as valves to equalize the flow to each lateral are recommended. Otis (1981) describes a procedure for designing a system for a sloping site.

The design of the pressure distribution network consists of 1) selecting the perforation diameter and spacing, 2) sizing the lateral length and diameter 3) selecting the number of laterals, 4) calculating the flow rate and dose volume, 6) sizing the force main, 6) sizing the pump based on head and flow rate, and 7) sizing the dose chamber. The design steps along with a design example are given in the appendix.

Observation Tubes:

Capped observation tubes, extending from the aggregate/soil interface to or above final grade, are placed in the absorption area provide easy access for observing ponding in the aggregate. Seepage at the toe of the unit, the result of excessive ponding, is the most probable cause of failure. On sloping sites the observation tubes must be placed just upslope of the downslope edge of the aggregate with the downslope edge of the tube at the edge of the aggregate. These observation tubes, consisting of 4 in. dia. PVC pipe with slots in the lower portion of the tube, must be stabilized so that they don't pull out when removing the cap. Fig. 7 shows three examples of stabilizing the observation tubes. The tubes can be cut off at final grade and recessed slightly to avoid being damaged by lawn mowers. Screw-type or slip caps are commonly used for the cover.

Cover:

After the aggregate, distribution pipe and observation tubes have been installed, a geotextile synthetic fabric is placed on the aggregate. Hay, straw or other material is not to be used in place of the fabric. Approximately one foot of soil cover is placed on the fabric and extended and tapered to a distance of at least five feet beyond the aggregate edge. The surface is seeded to vegetation to reduce erosion.

Table 2. Estimated Wastewater Design Soil Loading Rates for the Surface Horizon Based on Soil Morphological Conditions for Wisconsin At-grade Systems

Soil Condition of Horizon in Contact with Aggregate (Instructions: Read questions in sequence. When the conditions of your soil match the question, use that loading rate and do not go further).	If Yes The Loading Rate In gpd/ft^2 Is:
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

sites it is the width of the aggregate (Figs. 1, 4 and 8).

Depending on the soil texture and other characteristics, the required absorption area can be determined using Table 2. The width is based on the linear loading rate acceptable to the site. The linear loading rate, which is defined as the loading rate per linear foot of system (gallons per day per linear foot along the contour (gpd/lf)), can be greater for deep permeable soils than for a shallow zone of permeable soil over a less permeable soil. Unfortunately it is difficult to estimate the linear loading rate for many soil

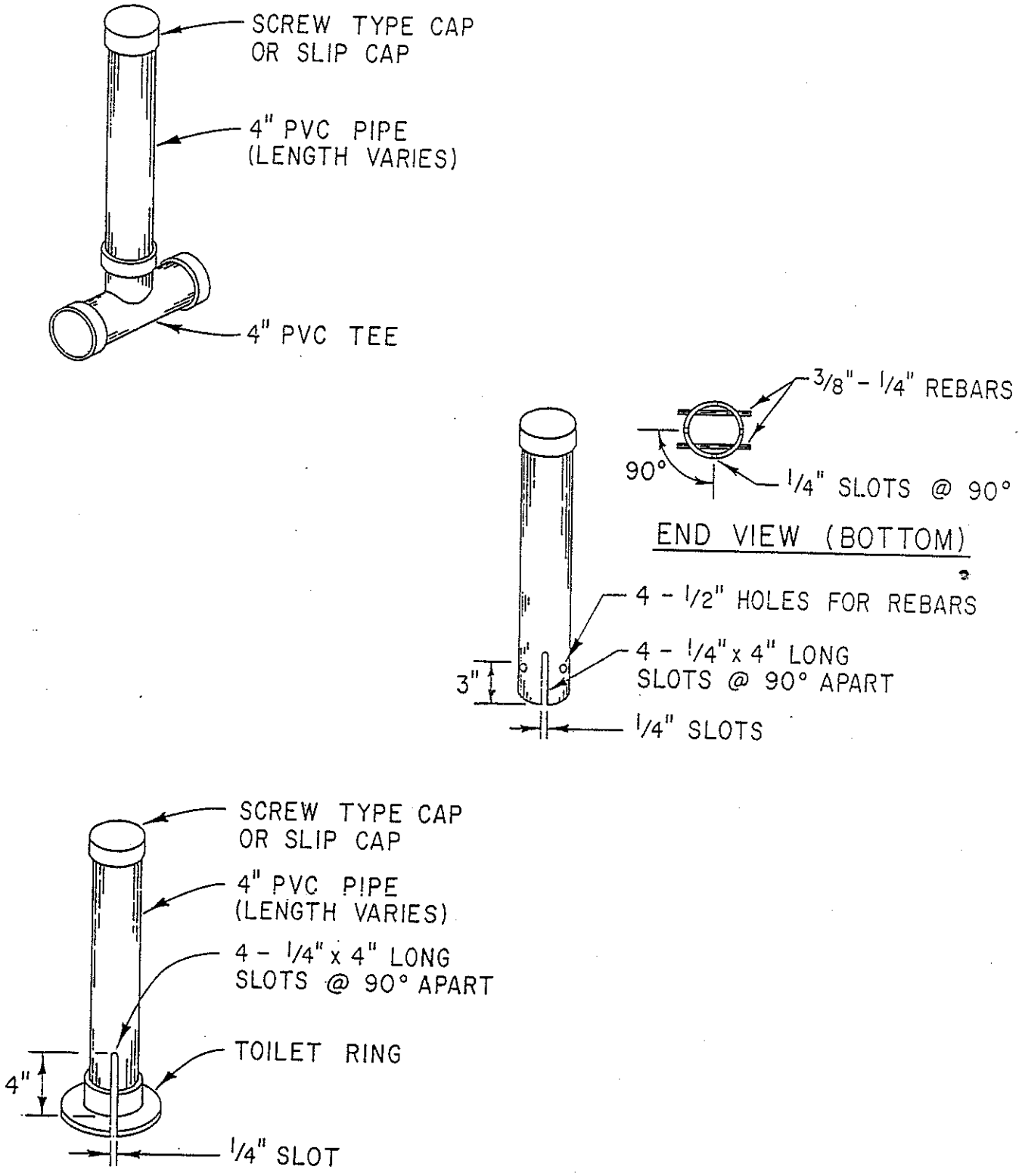


Fig. 7. Three Methods of Stabilizing Observation Tubes

DESIGN AND CONSTRUCTION EXAMPLE

Design:

When working with on-site wastewater treatment systems, the evaluator/designer must evaluate the soil site conditions and then select the best system for the site that meets the owner's needs and causes the least impact on the environment. When evaluating the site the following should be done (Refer to previous section on soil and site criteria for more detail):

1. Evaluate the landscape for surface water movement. Measure elevations and distances on the site so that slope, contours and available areas can be determined.

2. Describe several soil profiles where the system will be located. Determine the limiting conditions such as bedrock, high water table, and soil permeability.

The designer uses the information to design a system that will fit the site. Not all sites meet the criteria for on-site soil absorption systems and an alternative to soil absorption may be necessary.

Assume for the example the following site factors:

1. Soil profile is:

   0 - 12 in. sil; 10YR 6/4&2/1; moderate, medium, subangular blocky structure; friable consistence.
   12 - 24 in. sicl; 5YR 3/1; moderate, fine, subangular blocky structure; firm consistence.
   24 - 36 in. sic; 10YR 5/3; strong, medium, platy to massive structure; very firm consistence; many, medium, prominent mottles at 3 ft.

2. Slope is 20%.

3. Distance available along the contour is 175 ft and along the slope it is 30 ft.

4. Design for a 3 bedroom house.

Based on the above information, it appears that an at-grade system is suited for this site because estimated high water is at 36 in., the surface soil horizon is permeable, and code setback requirements are assumed to be satisfied.

Steps:

1. Determine the design flow rate (DFR).

   Since this is a 3 bedroom house, use 150 gallons per bedroom or a design flow rate of 450 gpd.

2. Estimate the soil loading rate (SLR) for the site.

   Use table 2 for selecting the appropriate soil loading rate (SLR) that matches the soil conditions. It is based on the soil horizon that is in contact with the aggregate. Since this is a silt loam with good structure and friable consistence, use a

   $$SLR = 0.6 \text{ gpd/ft}^2$$

   Note: In table 2 there is no mention of platy structure which will have a tendency do impede vertical flow. If the platy structure is in the surface horizon or slightly below and it can be tilled, the reorientation should allow the flow to move vertically through the horizon.

3. Estimate the linear loading rate (LLR) for the site.

   Evaluate the soil profile to estimate a linear loading rate. Since this profile consists of a permeable soil over a slowly permeable soil with massive structure, the flow will be primarily horizontal with some vertical flow (see Fig. 3c). Also, since the slope is fairly steep, a narrow system is appropriate. Based on experience and the discussion in the Design Principles section, an appropriate linear loading rate is:

   $$LLR = 4.0 \text{ gpd/lf}$$

4. Determine the effective absorption width (A) of the unit.

   Since the estimated linear loading rate is 4 gpd/ft and the soil loading rate is 0.6 gpd/ft^2 then:

   $$A = LLR \; / \; SLR$$

   $$= 4 \text{ gpd/ft} \; / \; 0.6 \text{ gpd/ft}^2$$

   $$= 6.7 \text{ ft}$$

   This is the effective width of the aggregate. If this was on a non-sloping site, then the total aggregate width would be 6.7 ft. Since this is on a sloping site, the total aggregate width will be about 8.0 - 9.0 ft as approximately 1.5 to 2 ft of aggregate must be placed upslope of the distribution pipe to support the distribution network and satisfy the angle of repose of the aggregate (Fig. 1 and 8).

5. Determine the absorption length (B) of the unit.

   The length of the absorption area (B) is dependent on the design flow rate (DFR) and the linear loading rate (LLR) then:

B = DFR / LLR

= 450 gpd / 4 gpd/lf

= 112 ft

Thus the effective absorption area is 112 ft by 6.7 ft or 750 ft^2.

6. Determine the configuration of the system that best fits the site.

Once the effective width and length of the absorption area are determined, the designer must determine how it will best fit on the site. On some sites it may be necessary to divide the absorption area into several units if there isn't sufficient length along the contour. Fig. 4 show various configurations that have been used. The most common is the single unit that is placed on the contour. On some sites it may be necessary to build several parallel units using alternating pumps to dose each unit or design a pressure distribution system for a sloping site.

7. Determine the overall length (L) and width (W) of the unit.

It is necessary to tie the aggregate into the surrounding soil surface by placing soil about 5 ft wide around the perimeter of the aggregate (Fig. 1 and 8). Greater widths for landscaping purposes are satisfactory.

L = absorption length (B) + soil cover end lengths

= 112 ft + 5 ft + 5 ft

= 122 ft

W = absorption width (A) + upslope width of aggregate (C) + soil cover side widths

= 6.7 ft + 2 ft + 5 ft + 5 ft

= 19 ft

8. Determine the height of the unit.

Design for a minimum of 6 in. of aggregate beneath the distribution pipe and about 2 in. above the pipe. As shown in Fig. 8a, the aggregate will taper off at the edges. Place synthetic fabric over the aggregate and approximately 1 ft of soil cover over the fabric. Thus the height of the unit above the original grade will be approximately 2 ft at the distribution lateral and tapering to the edges.

9. Design a distribution system for the unit.

Since the absorption area is relatively narrow and on a slope, a

single distribution line along the length is satisfactory. It would be located 6.7 ft upslope of the aggregate toe. If the site was level, the distribution pipe would be located in the center of the aggregate. The distribution can either be gravity or pressure but pressure distribution is recommended.

Gravity: If gravity is used, provisions should be made so the flow can be diverted to at least 2 locations within the unit either using two vertical risers near the center inlet tee or use a distribution box as shown in Fig. 6. The gravity laterals consist of 4" perforated PVC drain pipe preferably with a center inlet. One distribution lateral along the length of the absorption area for gravity is sufficient regardless of the width of the absorption area. A pressure distribution line should be installed next to the gravity distribution line because gravity distribution in these systems has not been proven with time. If several absorption areas are installed (Fig. 4, configuration 2, 3 or 4) gravity distribution is not recommended.

Pressure: Design the pressure network as per procedure outlined in the appendix. Normally the network consists of a single lateral along the length of the absorption area. On wider absorption areas, some have installed several parallel laterals. (Fig. 5) but only on relatively low slopes. Care must be taken to get equal distribution in the laterals if they are not at the same elevation.

Construction:

As with all soil absorption systems, proper construction is very important. The following steps should be followed when constructing the at-grade unit. There are variations to this approach, but the principles should be followed closely.

Steps:

1. Lay out the system with the length following the contour.

2. Cut all grass, brush and trees just above ground surface and remove. Do not remove tree stumps. In wooded areas rake off dead vegetation if over an inch thick. Avoid heavy vehicle traffic on the site.

3. Check for proper soil moisture prior to construction. For single grain soil, such as sand, the moisture content is not as critical as for structured soil. The soil is too wet to till if it takes on a wire form when rolled between the hands.

4. Till the area following the contour to a depth of 6 to 8 in. The tilled area should be at least the total length and width of the system. A mold board plow, chisel plow, or chisel teeth mounted on a backhoe bucket are satisfactory for tillage. The normal teeth on a backhoe are not satisfactory and must not be used. Chisel teeth, mounted on a backhoe, is the preferred method as it is easier to till around boulders and tree stumps. It also allows for deeper tilling to break up platy structure. A rototiller may be used (but not recommended) for single grain soils, such as sand, but not for

structured soils. Care must be taken not to compact and smear the soil during the tillage operation. Driving on the tilled area can rut and compact the soil and is not recommended.

5. Install the inlet pipe from the pretreatment unit or dose chamber from the upslope side either prior to plowing or after plowing. If it enters from the downslope edge or if the site is level, place the pipe prior to tilling with minimum disturbance of the downslope edge of the system. Bring the force main in at right angles to the absorption area and connect to the upslope end (preferably) of the manifold and not the center of the manifold if a manifold is used.
Do not bring the force main in from the end of the absorption area to the center of the system as this would destroy the soil structure beneath the absorption area. If required to come in from the end, use either an end feed or bring the force main in on the upslope side of the absorption area.

   Avoid traffic on the tilled area especially beneath the aggregate area and downslope. If compaction or ruts occur in the upslope or downslope area during construction, retill the compacted or rutted area. Minimize the subsoil disturbance beneath and downslope of the absorption area.

6. Place the three observation tubes at 1/6, 1/2, and 5/6 of the absorption length and exactly at the toe of the aggregate. The tubes must be constructed and placed so that ponded effluent at the downslope edge of the aggregate may be observed in the tubes. Stabilize the observation tubes (Fig. 7).

7. Place the aggregate in the designated area of the tilled area to a depth of 6 in. Work from the upslope edge of the system.

8. Place the distribution network level along the length of the unit and connect it to the inlet pipe from the pretreatment unit or dose chamber. Place 2 in. of aggregate on top of the network.

9. Place non-biodegradable geotextile synthetic fabric (not building paper, burlap, hay or straw) over the aggregate. Extend it only to the edge of the aggregate.

10. Place approximately 12 in. of soil over the fabric and taper it to a distance of at least 5 ft in all directions from the aggregate. Finish grading round the system to divert surface water away. Seed and mulch the exposed areas immediately after construction to control erosion.

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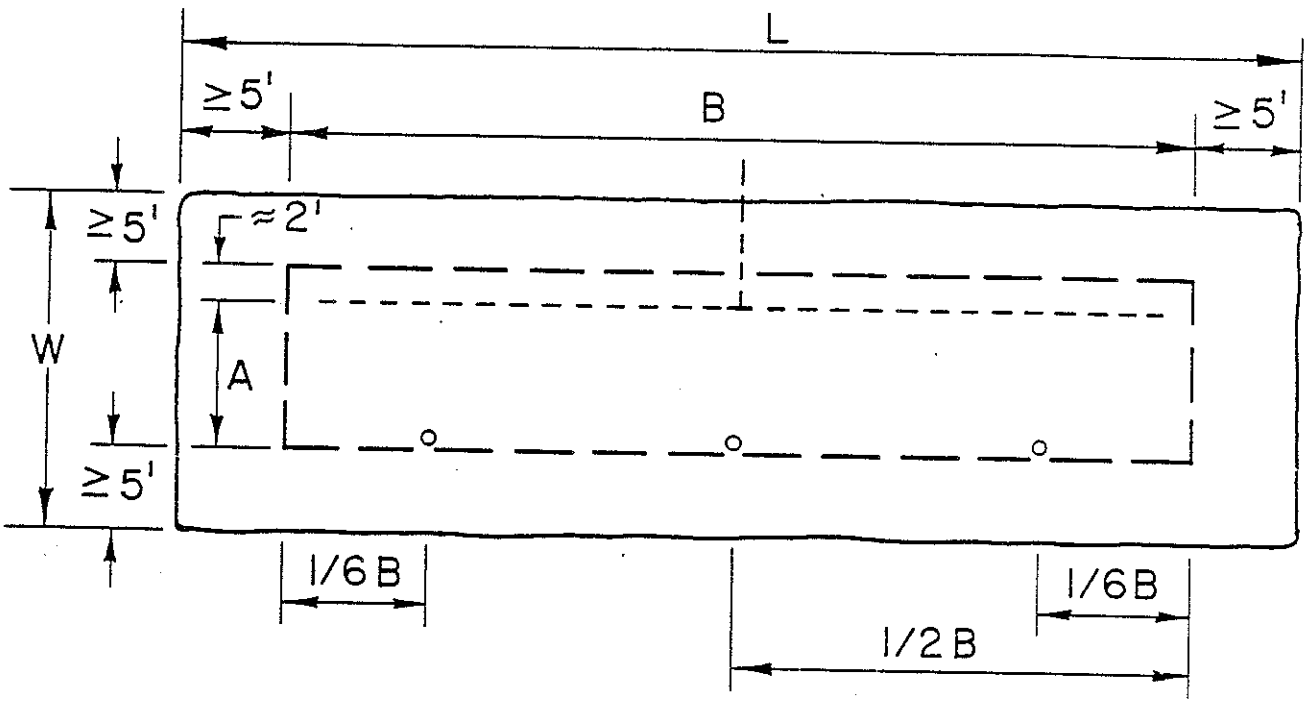


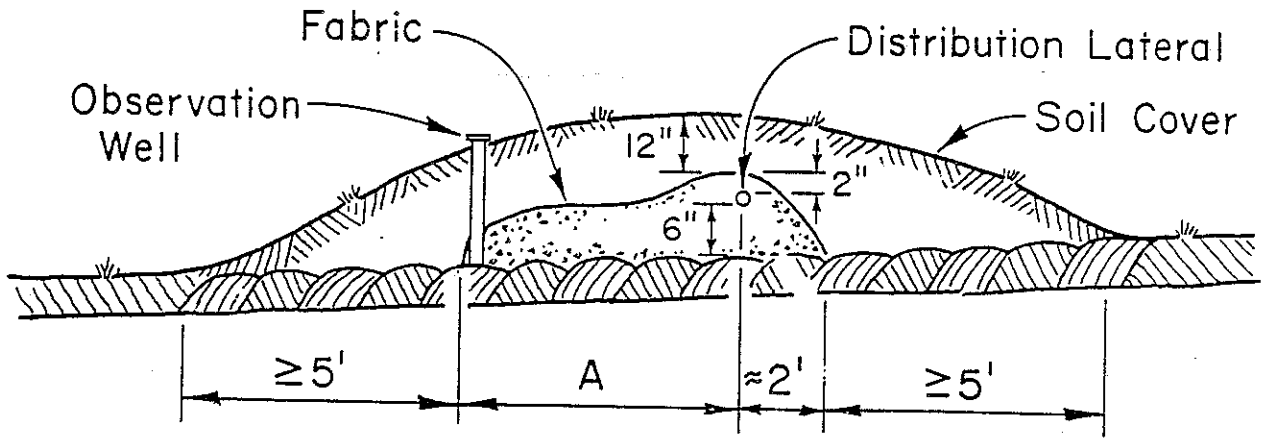
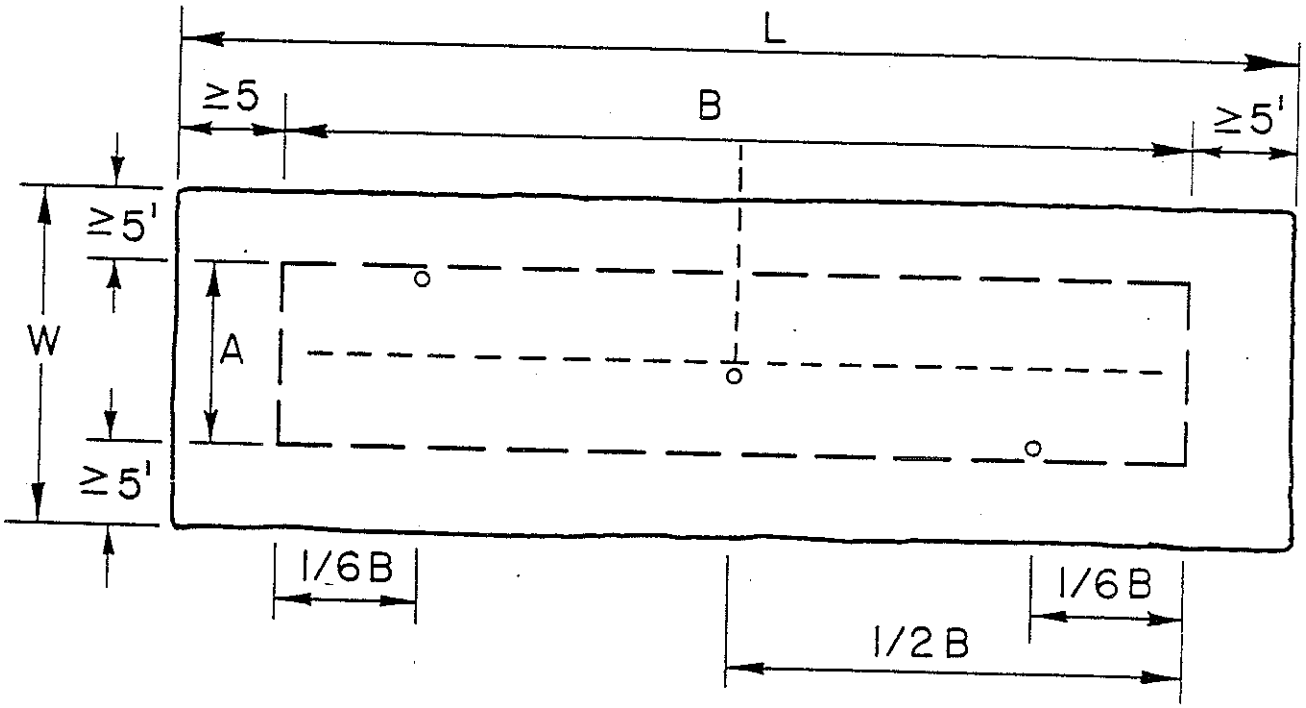


Fig. 8a. Plan View and Cross Section of Wisconsin At-grade Unit with a Single Absorption Area on a Sloping Site



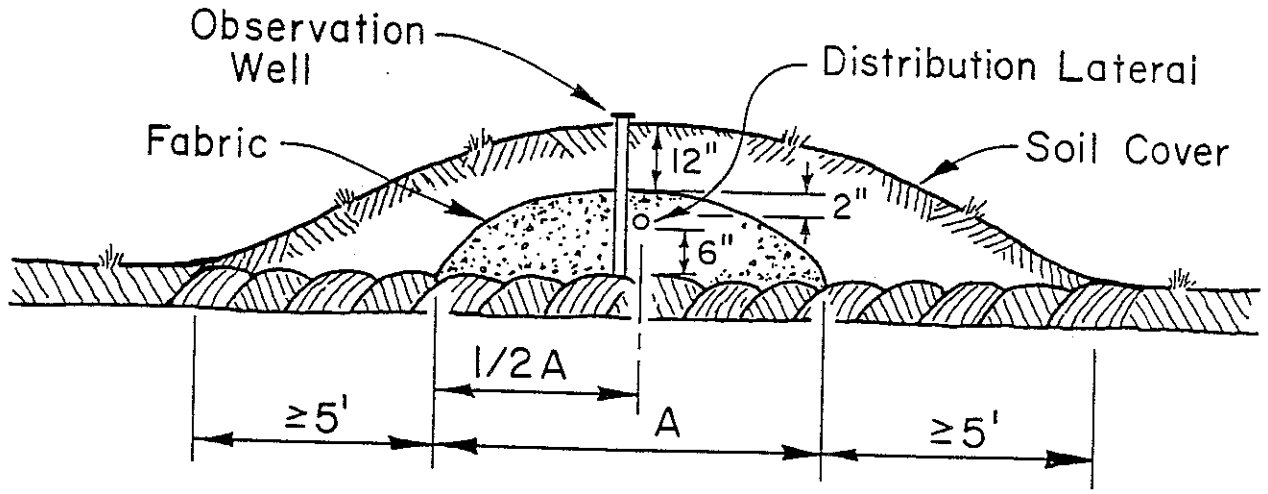
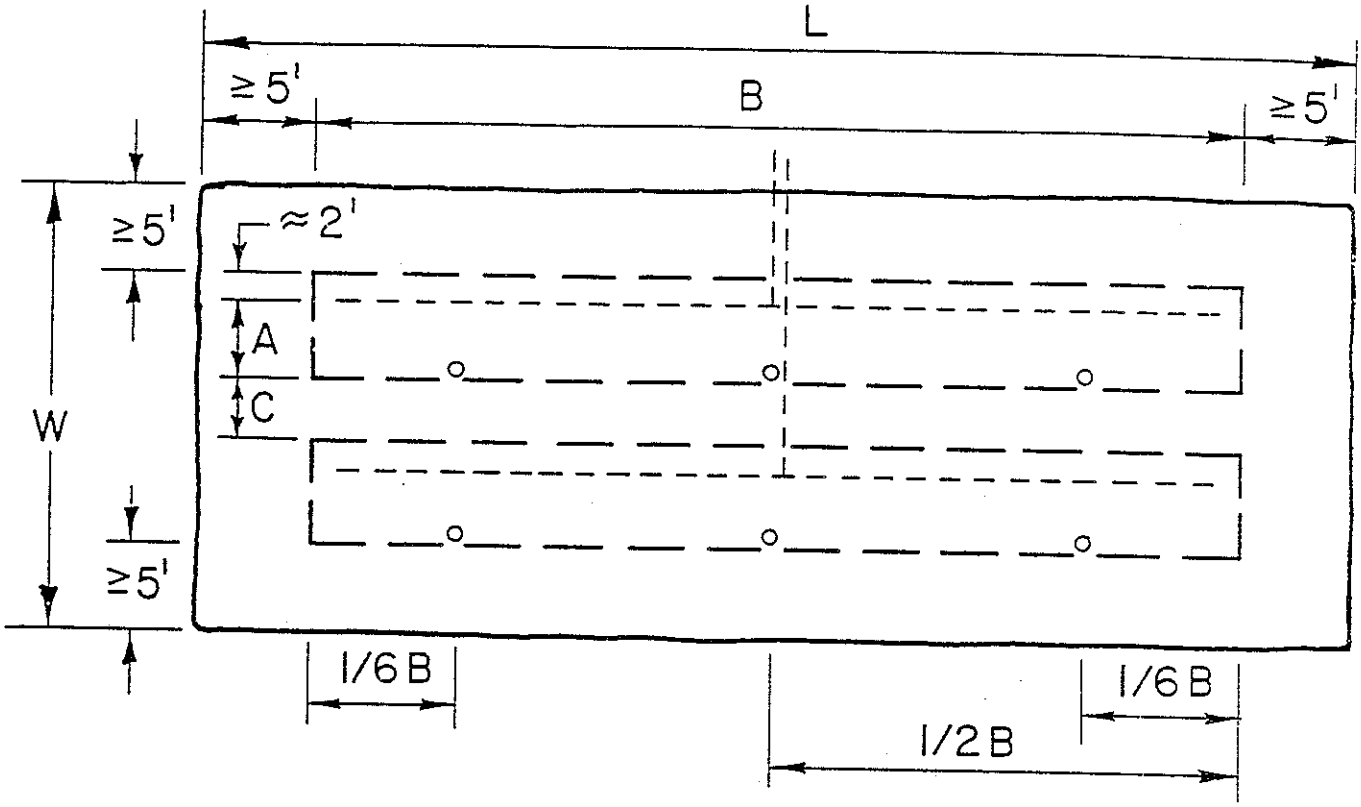


Fig. 8b. Plan View and Cross Section of a Wisconsin At-grade Unit with an Single Soil Absorption Area on a Level Site



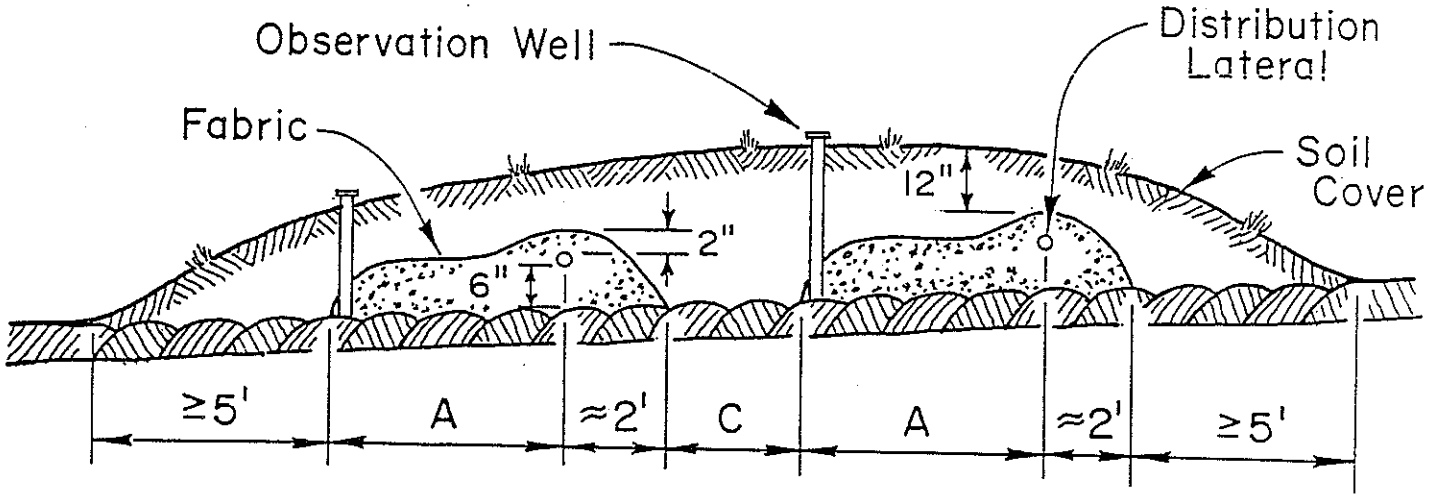
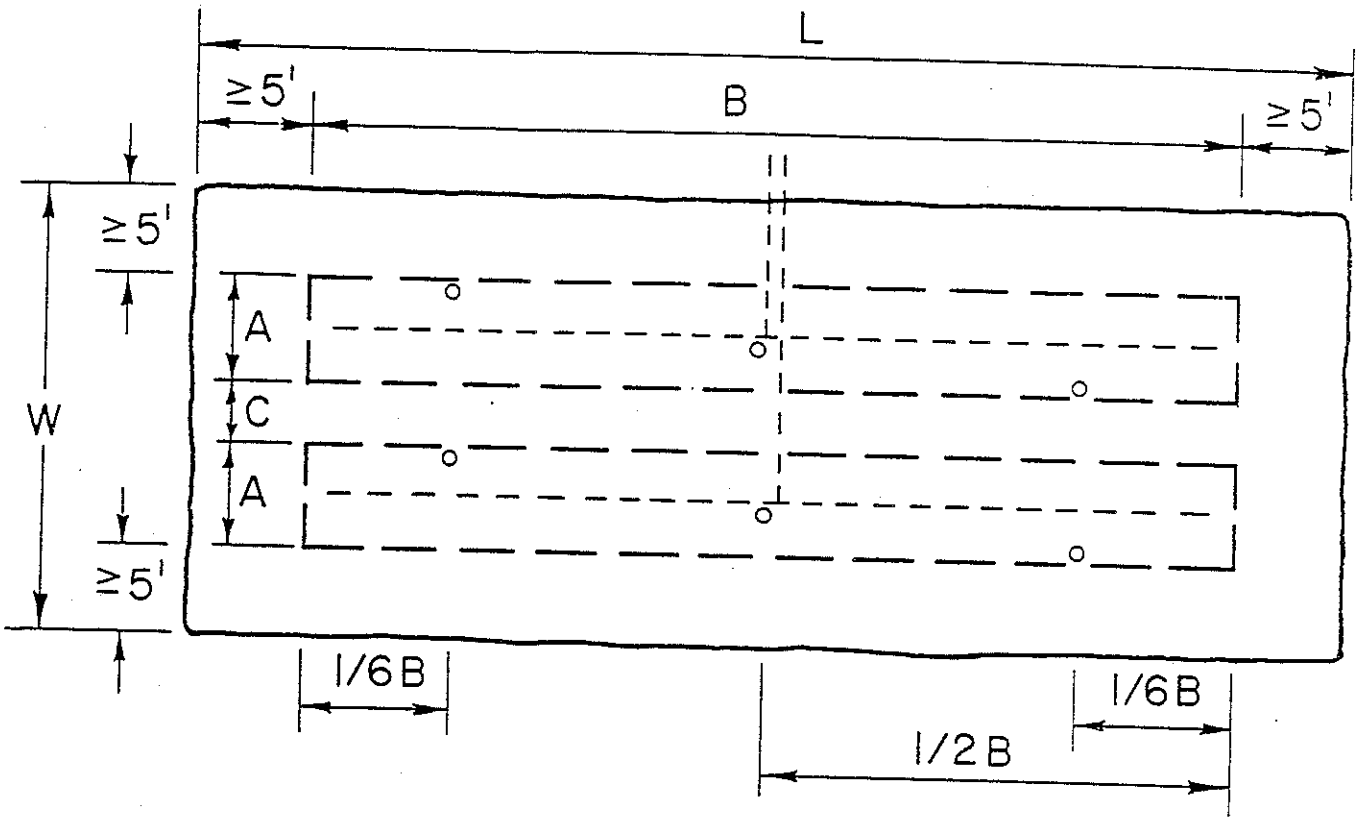


Fig. 8c. Plan View and Cross Section of a Wisconsin At-grade Unit with Two Absorption Areas With in a Single Unit on a Sloping Site



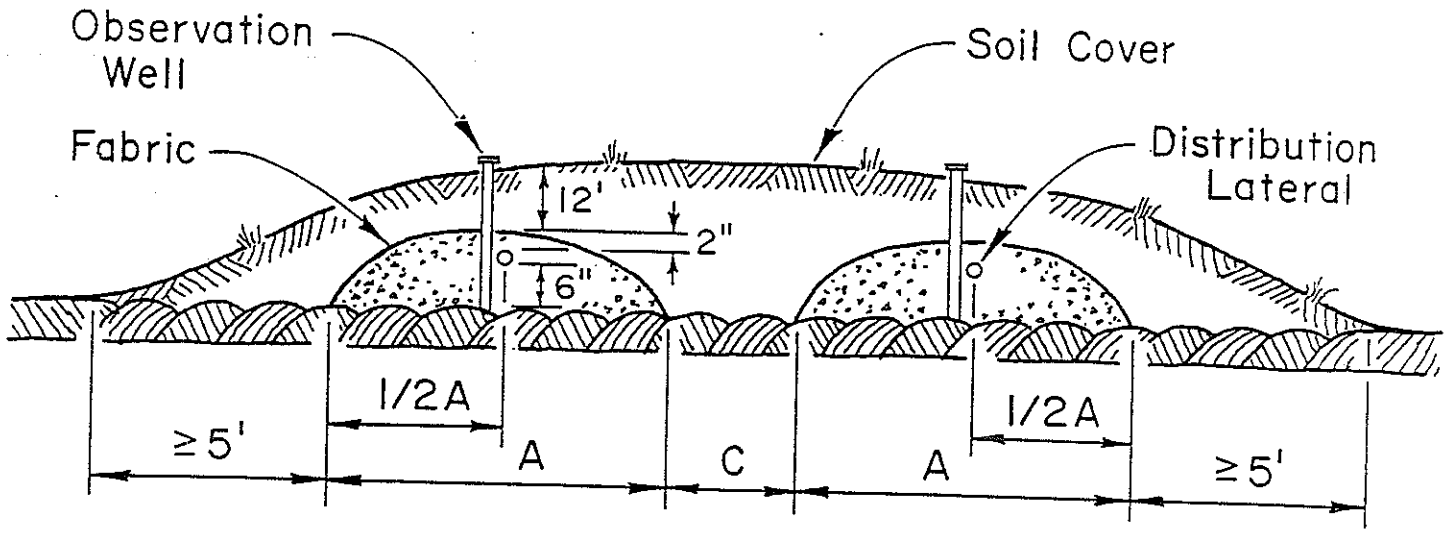


Fig. 8d. Plan View and Cross Section of a Wisconsin At-grade Unit with Two Absorption Areas Within a Single Unit on a Level Site

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 holes 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. Design of the Distribution Network.

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. Typical perforation diameters are 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.**

   Use $n = (p/x) + 0.5$ for center feed/center manifold or $n = (p/x) + 1$ for end feed/end manifold where n = number of perforations, p = lateral length in feet and x = perforation spacing in feet. If not a whole number round off to nearest whole number.

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 absorptions 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. Design of the force main, pressurization unit, dose chamber and controls.

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 and the total length of the force main and the diameter selected. The elevation or lift is the elevation difference between the pump shutoff 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 manufactures 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-9) 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 conncections must be outside the dose chamber.

DESIGN EXAMPLE

Design a pressure distribution network for the at-grade system described in the main text of this publication. The absorption area is 112 ft long and 8 ft wide with an effective width of 6.7 ft. 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 and 8a).

2. Determine the lateral length.

Using a center feed, the lateral length is:

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

$$= (112 \text{ ft} / 2) - 0.5 \text{ ft}$$

$$= 55.5 \text{ ft}$$

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 2.5 ft and lateral length of 55.5 ft, the lateral diameter is 2" (Schedule 40 PVC).

5. **Determine the number of perforations per lateral.**

   Using 2.5 ft spacing in 55.5 ft yields 23 perforations per lateral. ($n = (p/x) + 0.5$; $n = (55.5/2.5) + 0.5 = 22.7$ or 23)

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 = 23 perforations x 1.17 gpm/perforation

   = 26.9 gpm/ lateral

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

   Since this is a narrow absorption area (6.7 ft effective width), a single distribution pipe located 6.7 ft upslope of aggregate toe is sufficient to distribute the effluent. One could use two parallel distribution pipes with the second one spaced 3.3 ft upslope of the aggregate toe. However, this would double the required flow rate. One distribution pipe with center feed will be used.

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, assume there were 2 parallel lines (4 laterals) spaced 5 ft apart with a center manifold with each lateral having a discharge rate of 26.9 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 5 ft lateral spacing for 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 26.9 gpm/lat.

   = 53.8 gpm or 54 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 - g which are located below the following table. Orifice is synonymous to perforation.

Total Flow	Orifice Flow	Elevation Difference	Force	Orifice Main	Total
Flow Rate (gpm)			Head (ft)		
20	0.43	9.0	0.18	0.34	9.5
40	0.86	9.0	0.59	1.36	11.0
60	1.29	9.0	1.22	3.06	13.3
80	1.72	9.0	2.07	5.46	16.5
100	2.15	9.0	3.14	8.51	19.7

Procedure:

a. Select 5 flow rates above and below the network discharge rate which is 53 gpm in this example.

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 46 orifices, the orifice flow rate is 0.43 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. orifice diameter, 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 54 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 operate a a lower pump efficiency as the intersection is near the end of the pump curve. Pump B is the preferred pump.

4. Determine dose volume.

Fig. A-7 gives a total pipe volume of 18 gallons for the two 2" dia. by 55.5 ft laterals. Use a dose volume of 5 to 10 times the lateral pipe volume which is 90 to 180 gallons per dose.

(Using a straight edge, place it on the left column at 65.5 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 18 gal).

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 carry over of solids. Screens and filters may be installed to minimize solids carried to the distribution network. Seeds of all shapes and sizes along with towelettes 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. A PORTABLE AIR SUPPLY IS ESSENTIAL.

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

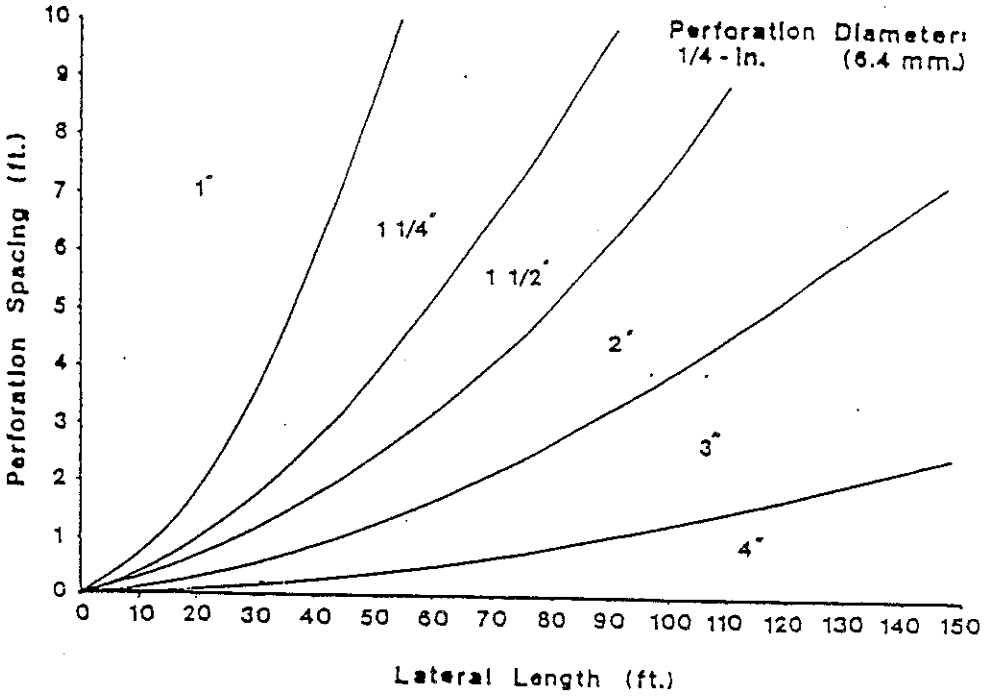


Fig. A-1 Minimum Lateral diameter for Plastic Pipe (C=150) Versus Perforation Spacing and Lateral Length for 1/4" Diameter Perforation (Otis, 1981).

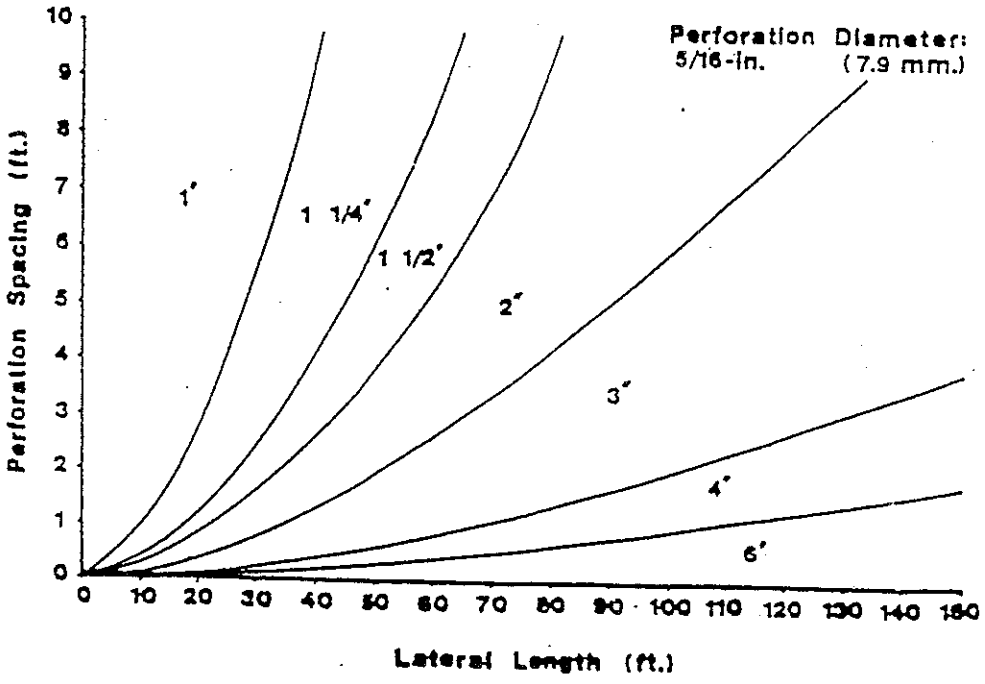


Fig. A-2. Minimum Lateral Diameter for Plastic Pipe (C=150) Versus Perforation Spacing and Lateral Length for 5/16" Diameter Perforations (Otis, 1981)

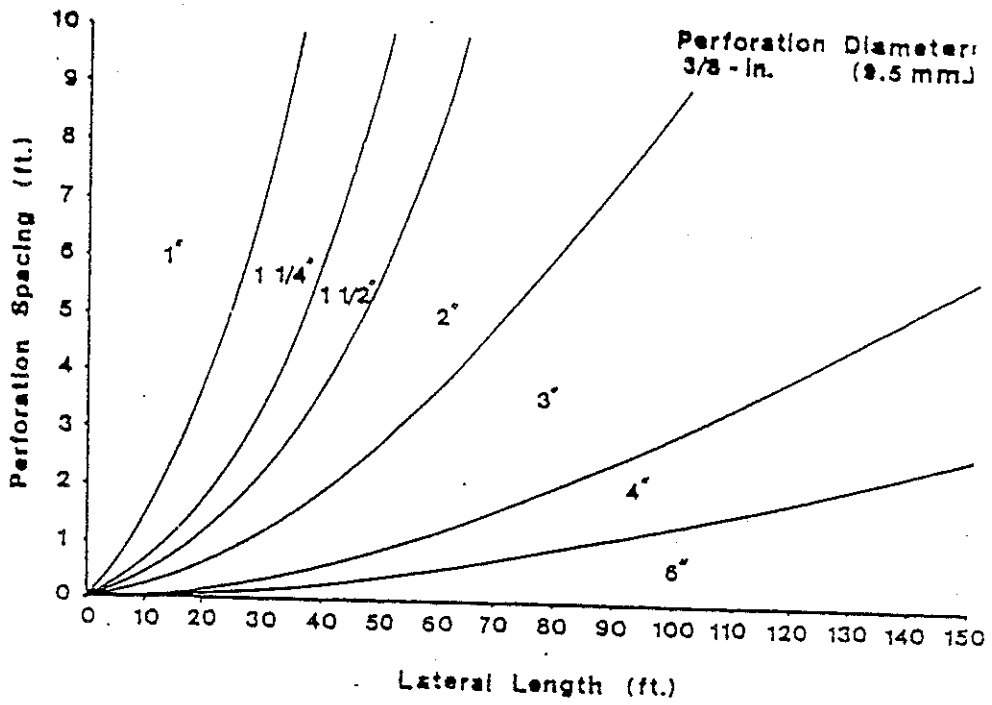


Fig. A-3 Minimum Lateral Diameter for Plastic Pipe (C=150) Versus Perforation Spacing and Lateral Length for 3/8" Diameter Perforations (Otis, 1981)

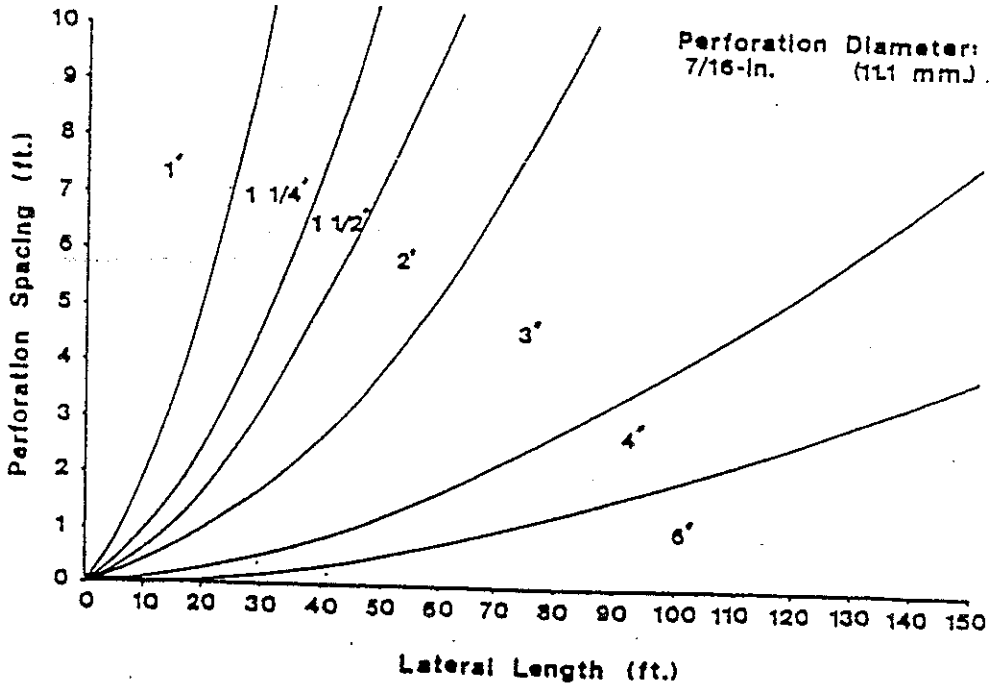


Fig. A-4 Minimum Lateral Diameter for Plastic Pipe (C=150) Versus Perforation Spacing and Lateral Length for 7/16" Diameter Perforations (Otis, 1981)

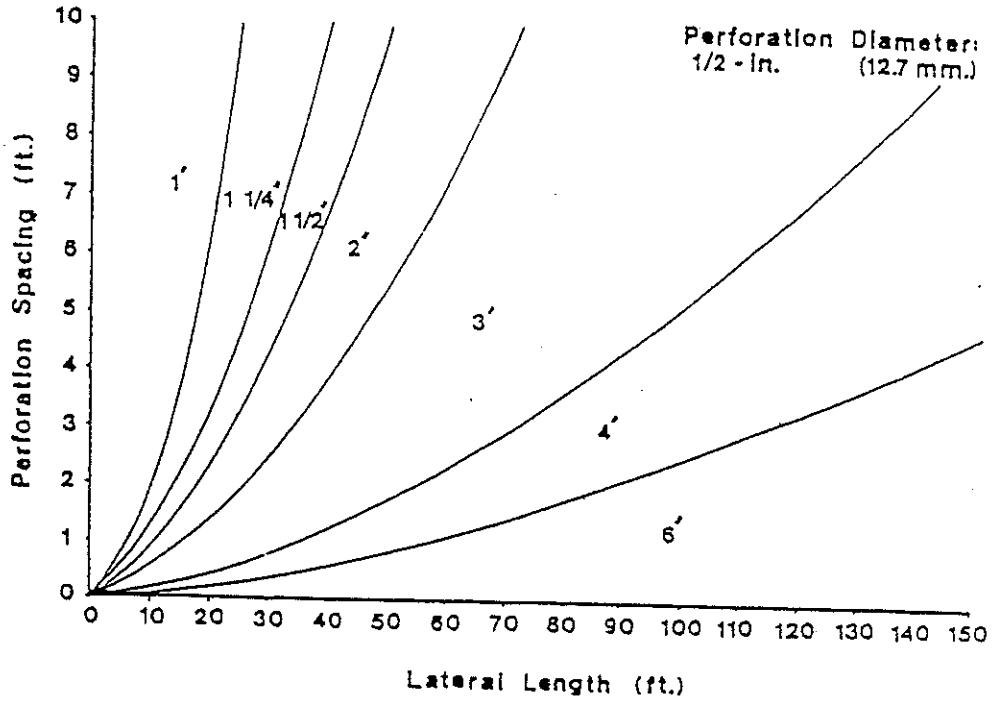


Fig. A-5. Minimum Lateral Diameter for Plastic Pipe (C=150) Versus Perforation Spacing and Lateral Length for 1/2" Diameter Perforation (Otis, 1981)

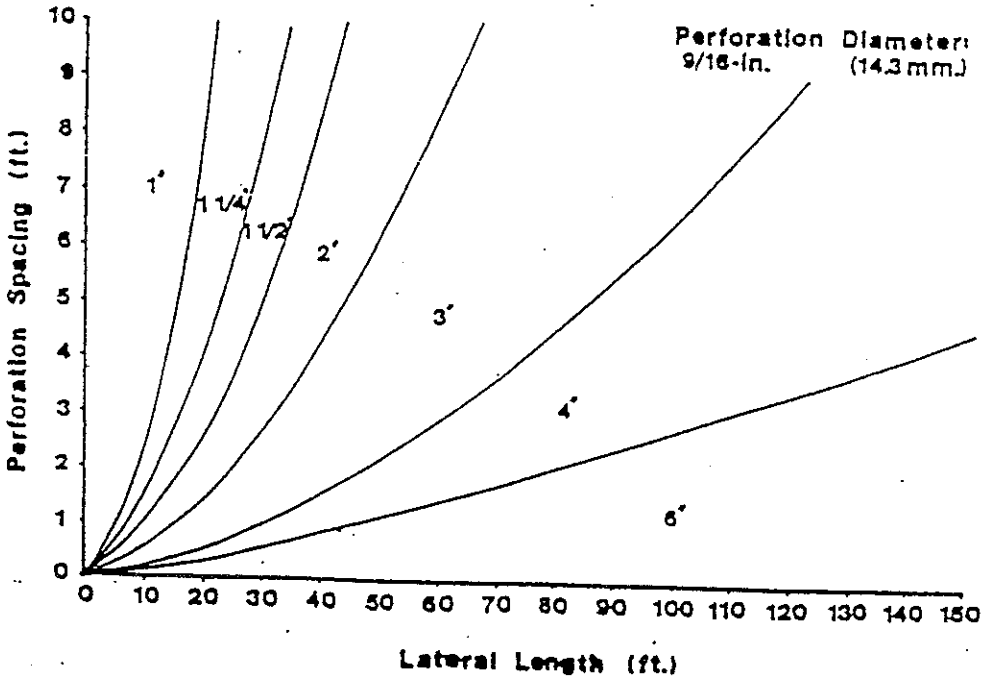
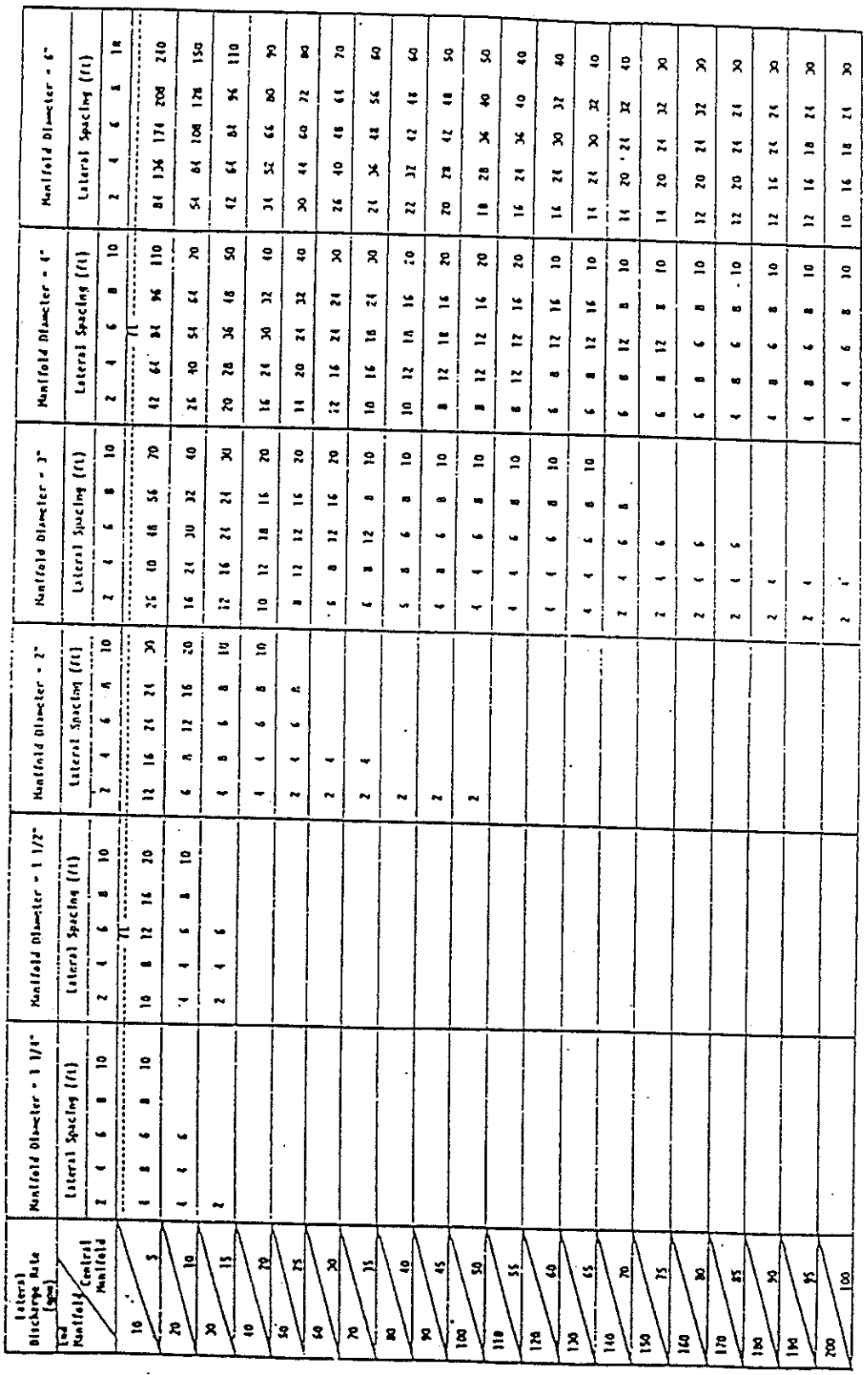


Fig. A-6. Minimum Lateral Diameter for Plastic Pipe (C=150) Versus Perforation Spacing and Lateral Length for 9/16" diameter Perforations (Otis, 1981)

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



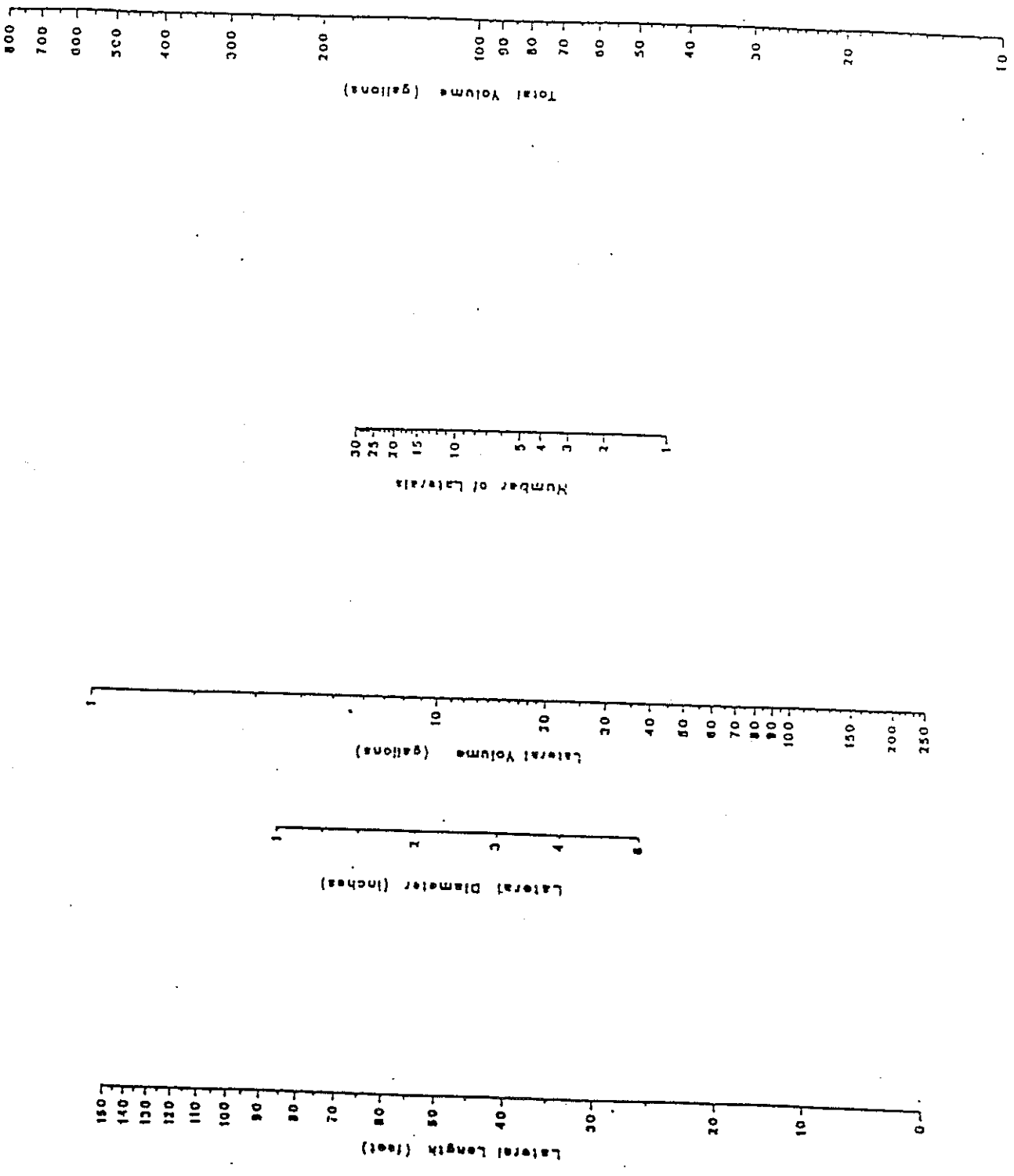


Fig. A-7. Nomograph for Determining the Total Pipe Volume Given the Diameter, Length and Number of Laterals (Otis, 1981).

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

Flow gpm	Pipe Diameter (in.) 1	1 1/4	1 1/2	2	3	4	6	8	10	12	Flow gpm
	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

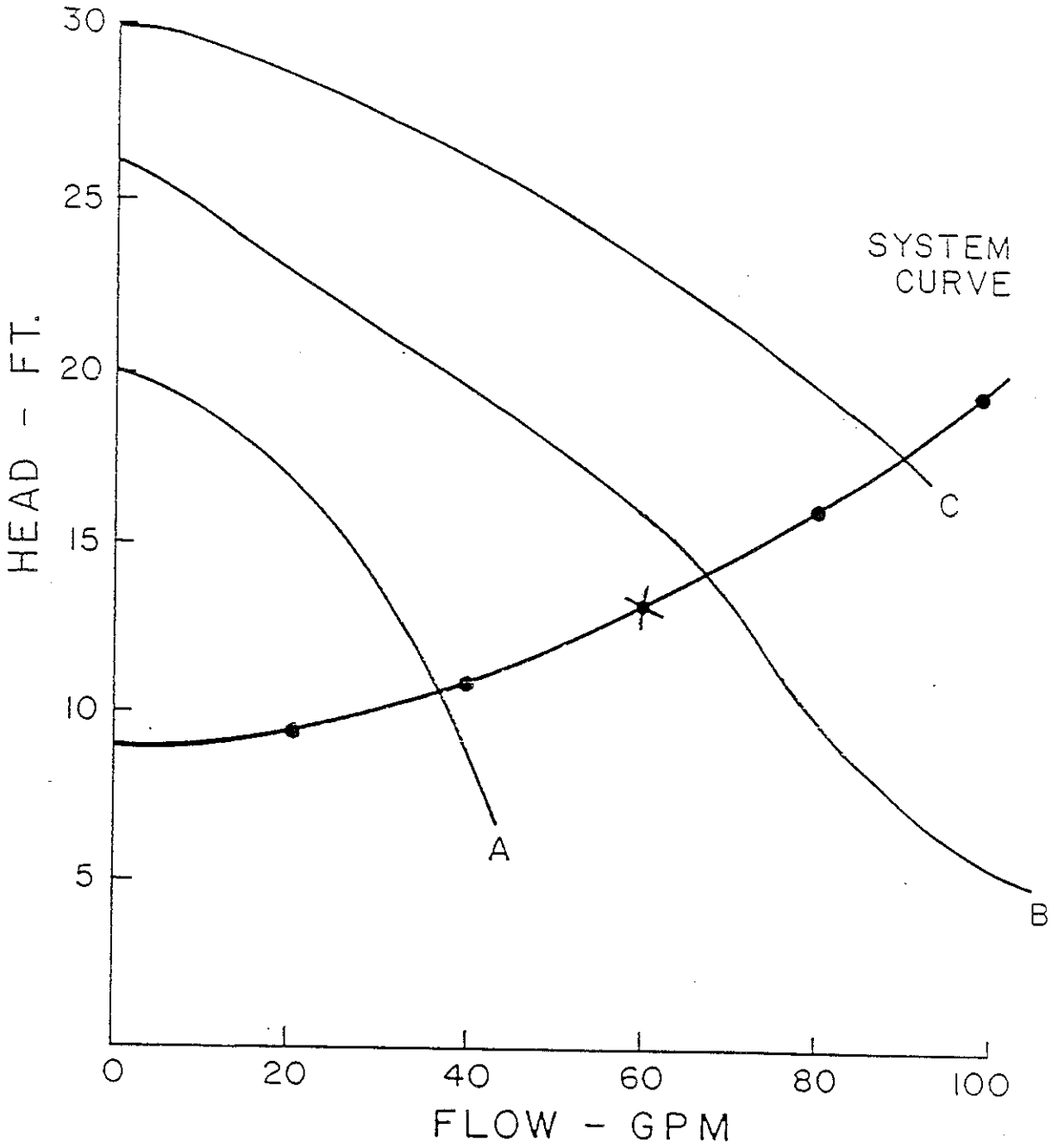


Fig. A-8 System Performance Curve and Several Pump Performance Curves for the Example Problem. For this example, the pump must provide a flow of at least 60 gpm (represented by X on the system performance curve. Pump A, represented by performance curve A, will not provide it. Pump C exceeds the requirement 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.

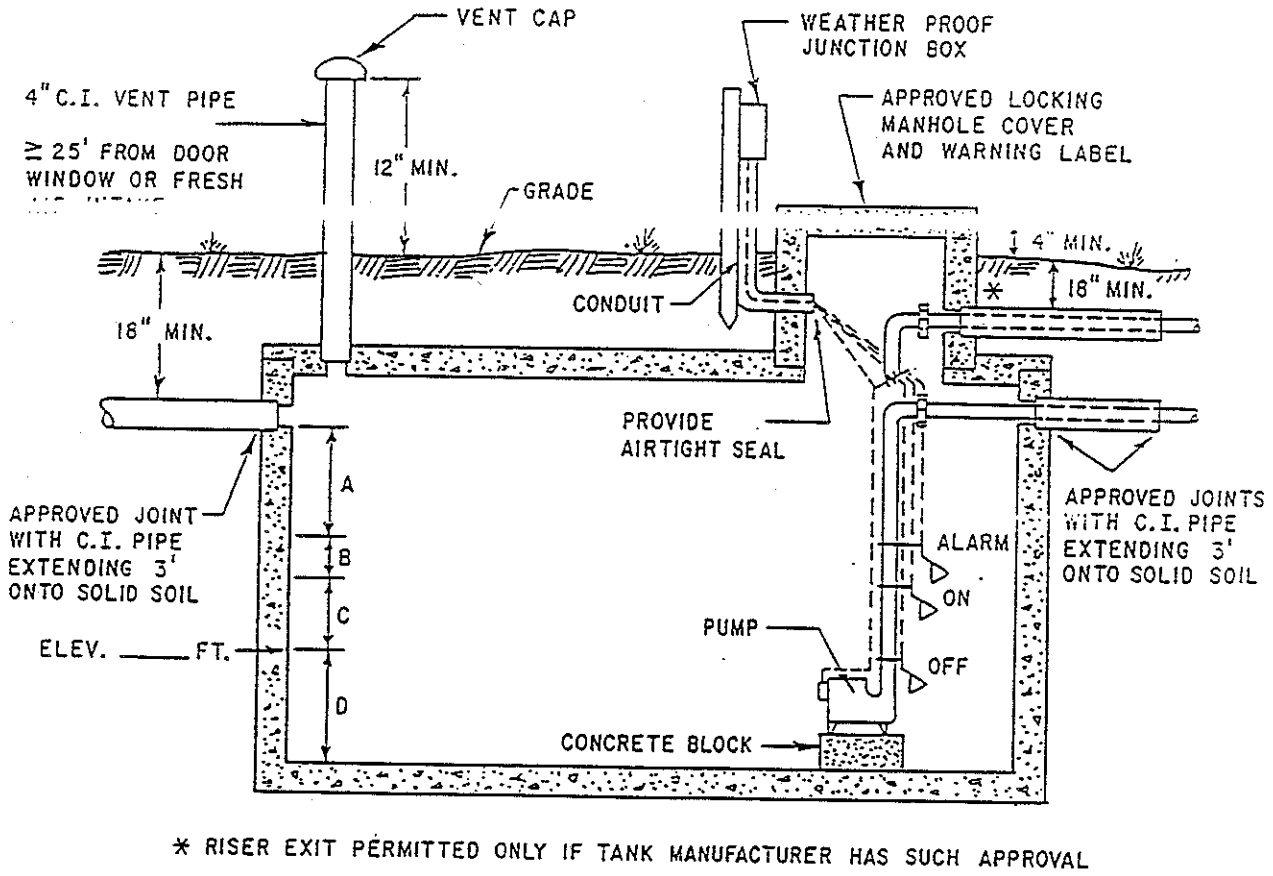


Fig. A-9. Cross Section of a Dose Chamber with a Pump and Control Unit as Required in Wisconsin (Wisc. Adm. Code, 1985)