ONSITE WASTEWATER DISPOSAL

DISTRIBUTION NETWORKS FOR SUBSURFACE SOIL ABSORPTION SYSTEMS

Richard J. Otis, P.E.
Rural Systems Engineering
Madison, Wisconsin

I. Introduction

A. The manner in which wastewater is distributed over the infiltrative surface may be critical to the proper functioning and long term life of the soil absorption system. Localized overloading from poor distribution may result in inadequate treatment of the wastewater in rapidly permeable soils and accelerated clogging in all soils (Bouma, 1975; Robeck, et.al, 1964; McGauhey and Winneberger, 1964).

B. Many different types and designs of distribution networks have been tried in an effort to apply wastewater in an effective manner to all parts of the soil absorption system and to reduce the degree of clogging. Not all are satisfactory for all soil and site conditions because of the different patterns of loading of the infiltrative surface which result (Otis, et.al, 1978). Therefore, it is important first to decide what pattern of loading would be acceptable for the given site and then to select a network design which best provides that loading pattern.

II. Methods of Distribution

A. Gravity Flow

1. <u>Description</u>

The relative elevations between the pretreatment unit and the soil absorption system are such that the wastewater can enter the absorption system by gravity. This method is characterized by "trickle flow" because wastewater is discharged into the system as it is displaced from the pretreatment unit.

2. <u>Performance</u>

Distribution is very uneven, with localized overloading of the infiltrative surface. Clogging occurs in these areas first and then progresses through the system as the liquid seeks a more open surface. Ultimately, the entire bottom of the system may become clogged, resulting in continuous ponding of the infiltrative surface. This has the benefits of submerging the sidewalls, thereby increasing the area of infiltrative surface exposed to the flow, and increasing the hydraulic gradient across the clogging mat. However, these benefits may be offset by more severe clogging (Bendixen, et.al, 1950); Winneberger, et.al, 1960; Thomas, et.al, 1966; Univ. Wis., 1978), or by inadequate treatment before the clogging mat is formed in rapidly permeable soils (Univ, Wis, 1978).

B. Dosing

1. Description

The wastewater is collected after pretreatment for periodic discharge into the soil absorption system via a pump or siphon. In this manner, the absorption system receives wastewater in slugs between which no loading occurs.

2. Performance

The wastewater is distributed over a larger portion of the absorption system during each dose than is achieved with gravity flow. The "resting" period between doses allows the infiltrative surface to drain, exposing the clogging mat to air and drawing air into the soil below the mat (Hills and Krone, 1971). This promotes degradation of the clogging mat to maintain higher infiltration rates and to extend the life of the system (Univ. Wis., 1980). In sands or coarser textured materials, rapid infiltration rates can lead to bacterial and viral contamination of shallow groundwater. Therefore, in these soils, doses should be more frequent and smaller in volume. In finer textured soils where absorption is more of a concern than treatment, larger, less frequent doses are more suitable. See Table II. B-1 for recommended dosing frequencies.

TABLE II. B-1

Recommended Dosing Frequencies for Various Soil Textures (U.S. EPA, 1980)

Soil Texture	Dosing Frequency
Sand	4 doses/day
Sandy loam	1 dose/day
Loam	Frequency not critical[1]
Silt loam; silty clay loam	1 dose/day[1]
Clay	Frequency not critical[1]

[1] Long-term resting provided by alternating fields is desirable

C. Uniform Application

1. Description

Uniform application is similar to dosing except that the network used to distribute the wastewater is pressurized to control the application rate to all parts of the absorption system. By carefully designing the network, the entire infiltrative surface can be loaded uniformly and at a rate below the saturated hydraulic conductivity of the soil. Pumps or siphons are used for network pressurization.

2. Performance

The intent of uniform application is to load all parts of the absorption system equally while maintaining unsaturated conditions in the underlying soil for adequate treatment. Limited experience indicates that the method is successful (Univ. of Wis., 1978). Dosing frequencies presented in Table II. B-1 are also recommended for uniform application.

D. Selection of Distribution Method

The selection of the most appropriate method of distribution depends on whether absorption or treatment is the most critical concern. This is usually determined by the permeability of the soil and the geometry of the infiltrative surface. Under some conditions, the method of distribution is not critical, so selection is based on simplicity and cost.

Methods of distribution into trenches and beds on level sites or multiple trenches on sloping sites for various soil permeabilities are listed in order of their preference in Table II. D-1. For example, in very rapidly or rapidly permeable soils, ensuring adequate treatment is the primary concern. Therefore, uniform application should be employed. However, uniform application of wastewater into multiple trenches on sloping sites is more difficult and, for that reason, gravity distribution into serially loaded trenches may be more appropriate except in the very rapidly permeable soils. (Note that conventional trenches and beds are not recommended for rapidly permeable soils.). In the moderately permeable soils, dosing seems to reduce the degree of soil clogging but uniform application is not necessary since the soil's fine texture will ensure adequate treatment. Therefore, for level sites, dosing is the preferred method followed by gravity. Uniform application is third only because the cost may be greater, not because it is less effective. On sloping sites, gravity methods using serial distribution are recommended because dosing and uniform application into multiple trenches on sloping sites is difficult. Of the latter two, uniform application can be designed more easily and is preferred over dosing. It should be noted that uniform application, unlike the other methods, is appropriate for all applications but design difficulties and cost cause one of the other two to be preferred.

TABLE II. D-1

RECOMMENDED METHODS OF EFFLUENT DISTRIBUTION FOR VARIOUS SYSTEM GEOMETRIES AND SOIL PERMEABILITIES[1] (OTIS, 1981)

Soil Permeability (Percolation Rate)	Trenches or Beds on Level Site	Multiple Trenches on Sloping Sites (>5%)
Very Rapid[2]	Uniform application[3]	Uniform application
<1 min/in (<0.04 cm/sec)	Dosing	Gravity
	Gravity	Dosing
Rapid	Uniform application	Gravity
1-10 min/in (4-0.4 cm/sec x 10^{-2})	Dosing	Uniform application
	Gravity	Dosing
Moderate	Dosing	Gravity
11-60 min/in (4-0.7 cm/sec x 10^{-3})	Gravity	Uniform application
	Uniform application[4]	Dosing
Slow	Not Critical	Not Critical
60 min/in (>0.7 x 10^{-3} cm/sec)	Uniform application[4]	

[1] Methods of application are listed in order of preference.

[2] Conventional soil absorption systems not recommended for these soils.

[3] Should be used exclusively in alternating field systems to ensure adequate treatment

[4] Preferred method for large flows.

III. Design

A. Introduction

1. Types of Distribution Network Design

Several different distribution network designs are used in subsurface soil absorption systems. Most use drainage tile or pipes but small diameter pressure pipe is becoming used more frequently.

Large diameter perforated pipe networks

This type of network is used in most conventional systems to permit gravity flow or dosing. In the past, short sections of 4-in. clay tile spaced 1/4 to 1/2 in. apart were used. Treated building paper was placed over the top of each open joint to keep the rock or soil from entering the pipe. This pipe has been replaced by 4-in. bituminous fiber and plastic (rigid or flexible), perforated pipe. One or two rows of holes 1/2 to 5/8 in. in diameter spaced 3 in. apart are common in this type of pipe. Uniform distribution along the length of the pipe is not provided (Converse, 1974).

Small diameter perforated pipe networks

This type of network is used primarily in pressurized networks to provide uniform application. The pipe diameter, hole diameter and hole spacing are determined by each design. A minimum pipe diameter of 1-in. and hole diameter of 1/4 in. is recommended.

Other distribution designs.

Several other types of designs have been developed, many of which do not use pipe. These are primarily proprietary in nature and are discussed separately below.

2. Selection of Distribution Network Design

The choice of which network to use depends on the type and geometry of the absorption system and the method of distribution desired. Table III. A-1 lists the most appropriate network designs in order of preference for different system configurations. The various network designs listed are described in the following sections.

B. Large Diameter Perforated Pipe Networks

1. Single Line

Description

Single line networks are used in trenches for gravity flow or dosing. A single line in the center of each trench is used.

TABLE III. A-1

DISTRIBUTION NETWORKS FOR VARIOUS SYSTEM DESIGNS AND APPLICATION METHODS[a] (U.S. EPA, 1980)

Method of Application	Single Trench	Multi-Trench (Fills, Drains) On Level Site	Multi-Trench (Drains) On Sloping Site	Beds (Fills, Drains)	Mounds
Gravity	Single line	Drop box Closed loop Distribution box	Drop box Relief line Distribution box[b]	Closed loop Distribution box	Not applicable
Dosing	Single line Pressure	Closed loop Pressure Distribution box	Distribution box	Closed loop Pressure Distribution box	Not applicable
Uniform Application	Pressure	Pressure	Pressure[c]	Pressure	Pressure

[a] Distribution networks are listed in order of preference.

[b] Use limited by degree of slope

[c] Because of the complexity of a pressure network on a sloping site, drop boxes or relief lines are suggested.

Design

The distribution line is 3 to 4 in. diameter perforated pipe laid level or on a gradient of 1 to 2 in. per 100 ft. within the porous media. If the pipe has one row of holes, the pipe is set such that the holes are at the invert. If the pipe has two rows of holes, the pipe is laid such that the line bisecting the acute angle between the holes intersects the pipe invert. Two rows of holes are thought to be superior because of the small unobstructed channel left between the holes in the bottom of the pipe. The end of the pipe terminates in an observation vent or is capped.

Limitations

Traditionally, distribution lines have been limited to 100 ft. in length because pipe breakage, root penetration or settling may disrupt the flow within the pipe. These fears are largely unfounded since most of the flow occurs in the gravel. However, if lines do exceed 100 ft. in length, the inlet from the pretreatment unit could be located near the center of the line rather than at one end.

2. Closed Loop

Description

Closed loop networks are used for gravity flow or dosing in trench or bed systems that have the entire infiltrative surface at one elevation. The pipe is identical to that used for single lines and is laid in a similar manner.

Design

More than one line is used and the ends of each are connected to one another with ell, tee or cross fittings, as shown in Figure III. B-1. In beds, the lines are laid parallel with 3 to 6 ft. spacings. A tee, cross or distribution box is used at the inlet to the network.

3. Distribution Box

Description

Distribution box networks are used for gravity flow or dosing in multi-trench or bed systems which have independent single lines. The single lines in the network extend from a common watertight compartment called the distribution box. The purpose of the box is to divide the flow entering the box equally between all laterals leaving the box. In multi-trench systems, outlets to individual lines can be plugged to allow periodic resting of selected trenches.

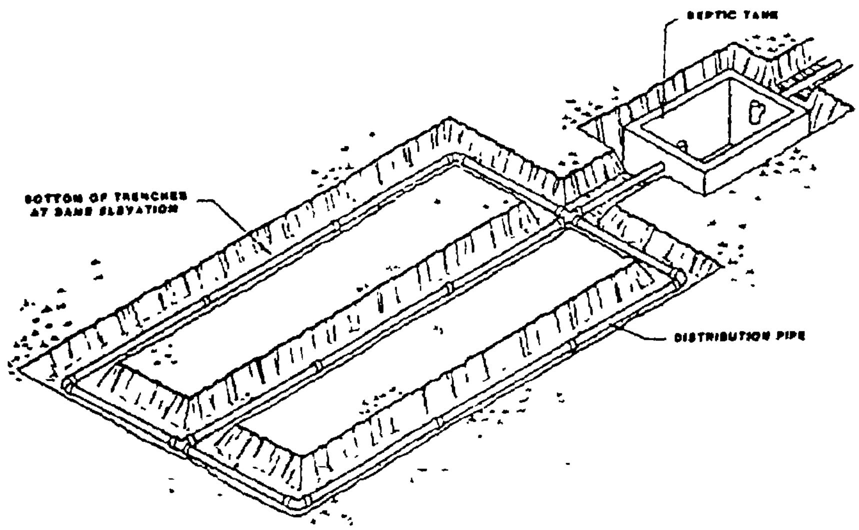


FIGURE III. B-1

Closed Loop Distribution Network

Design

The distribution box is normally purchased prefabricated. It is usually round or rectangular with a flat bottom and an above grade removable cover. It has a single inlet, and an outlet for each distribution line. The box must be set on a dry, frost-proof footing with the outlet inverts at the same elevation. The invert of the inlet should be at least 1 in. above the outlet inverts. If dosing is to be employed or the slope of the inlet pipe imparts a significant velocity to the influent, a baffle must be placed in front of the inlet.to absorb the influent energy and prevent short circuiting across the box. The slope of the lines leaving the box should be laid at the same gradient for at least 10 ft. beyond the box to ensure an even division of flow (See Figure III. B-2).

Limitations

The use of distribution box networks should be restricted to level or gently sloping sites where the system can be installed so that the ground surface elevation above the lowest trench is above the box outlets inverts elevation (Machmeier, 1981). This recommendation is made because it is difficult to maintain the outlet inverts at the same elevation which is necessary for equal division of flow (Bendixen and Coulter, 1958). Carelessness in placement or backfilling, uneven settling or frost heaving will cause the misalignment. If the box were to settle unevenly so that the lowest trench is overloaded, the trench will pond and the flow will back up into the box where it can enter another trench (See Figure III. B-2). However, if the ground elevation

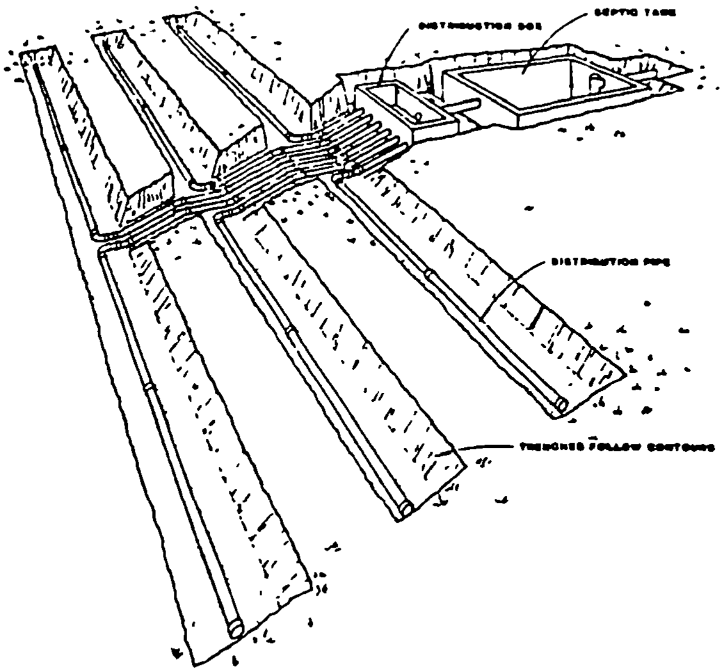
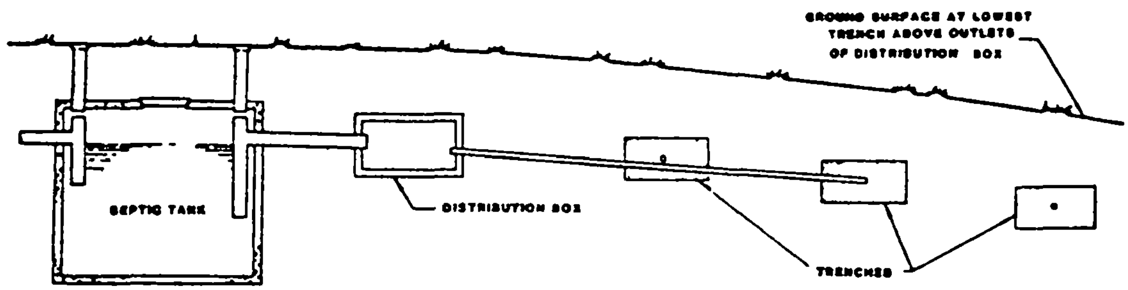


FIGURE III. B-2
Multi-Trench System on a Sloping Site Using a Distribution Box (Otis, et.al, 1978)



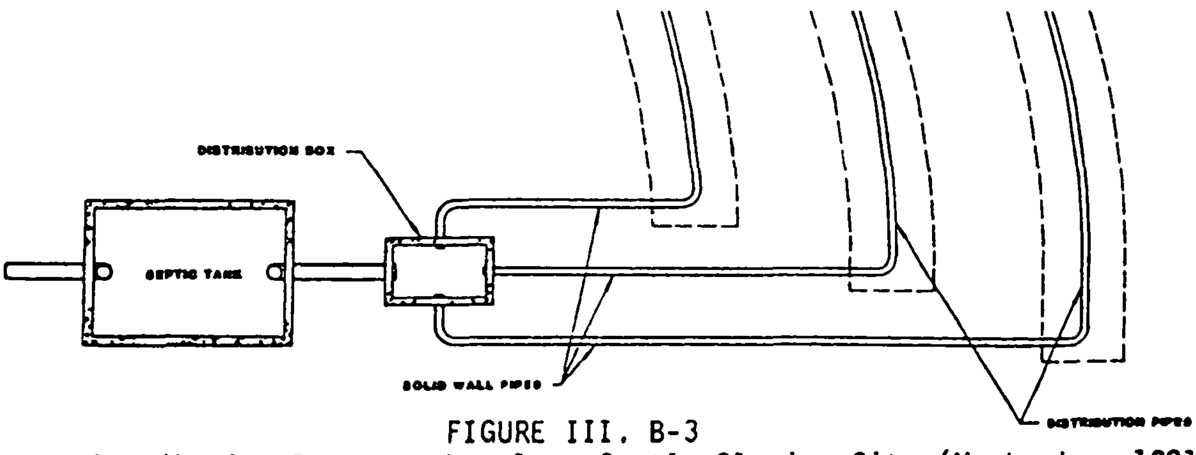


FIGURE III. B-3
Use of a Distribution Box on a Level or Gently Sloping Site (Machmeier, 1981)

over the trench is lower than the box outlets, the wastewater will seep onto the ground surface and the remainder of the system may never receive wastewater. On steeply sloping sites, drop boxes or relief lines should be used unless the distribution box is set carefully and its levelness maintained.

4. Drop Box

Description

Drop box networks are gravity flow networks used to serially load multi-trench systems. Each trench has its own drop box which accepts wastewater from the drop box upstream from it. The box discharges the liquid into the distribution line of the trench until the trench is filled to capacity. At that point, the drop box overflows into the next drop box downstream from it. This network is usually used on sloping sites since each drop box must be at a lower elevation than the one upstream from it, but they may be used on level sites as well by lowering each successive trench.

Design

A drop box, usually purchased prefabricated, is a circular box with a watertight bottom and a removable cover. It has an inlet, one or two outlets for the distribution lines and an overflow. The distribution line outlets are located at or near the bottom of the box. The invert of the overflow is located at the same elevation as the crown of the outlet or 2 in. above it to flood the trench to the top of the gravel. The inlet invert may be at the same elevation as the overflow invert or a few inches above. See Figure III. B-4.

Drop boxes may be located anywhere along the trench length. An elevation difference of 1 to 2 in. between successive drop boxes is all that is needed. Solid wall pipe is used between each drop box.

Limitations

The only limitation of this system is that it can be used only where gravity flow is appropriate. It is superior to all other gravity flow networks because of its characteristics of operation. Each trench is successively loaded to its full capacity. Thus, only the portion of the system required to absorb the wastewater is used. During periods of high flow or when evapotranspiration is low, more trenches are used. When flows are low or evapotranspiration is high, the lower trenches will drain dry and automatically go into a resting phase during which the infiltrative surface is rejuvenated. The upper trenches may also be rested by plugging the outlets to the distribution lines and forcing the liquid into the lower trenches. Another advantage is that additional trenches can be added easily to the existing system, if necessary.

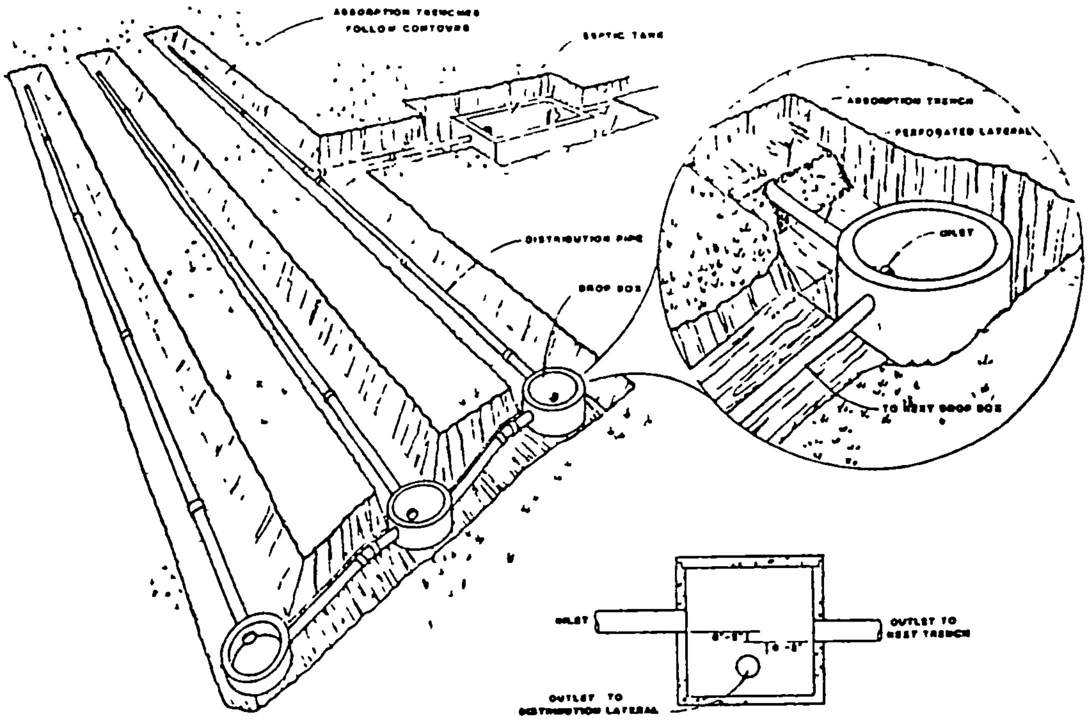


FIGURE III. B-4
Drop Box Network

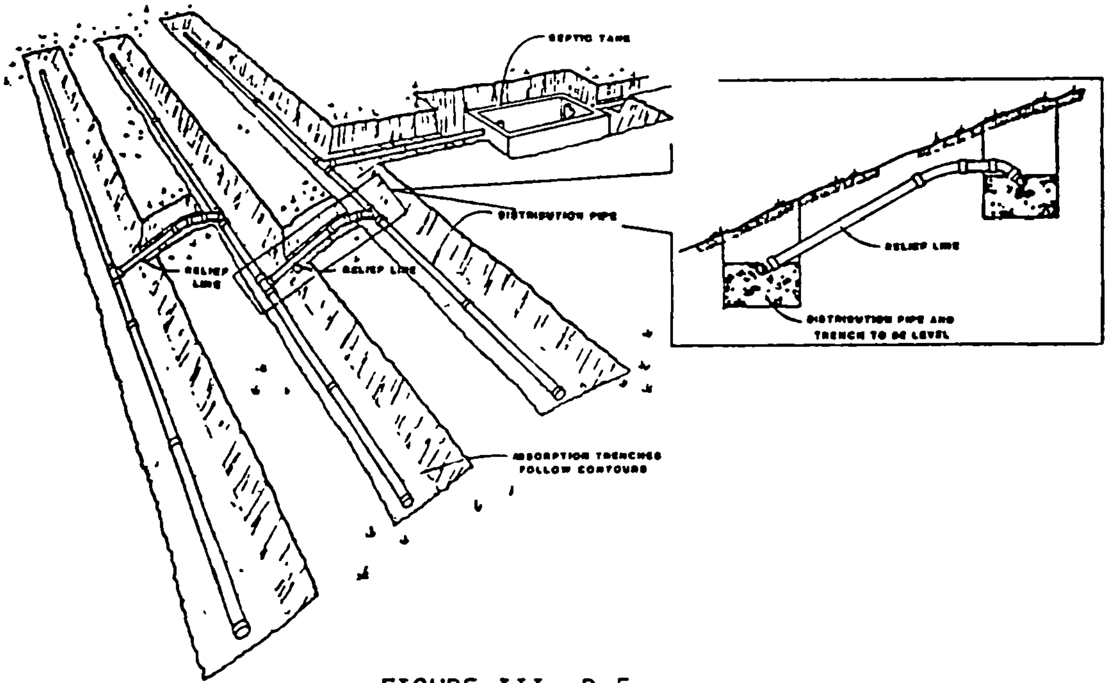


FIGURE III. B-5
Relief Line Network

5. Relief Line

- Description

Relief line networks may be used in place of drop box networks in multi-trench systems using gravity flow. Relief lines, used in place of drop boxes, are simple overflow lines interconnecting trenches such that one trench is filled before the wastewater overflows into the next trench.

- Design

A relief line is a solid wall pipe. The elevation of the invert of the overflow section is set above the crown of the distribution line as shown in Figure III. B-5. Relief lines between successive trenches should be staggered or separated by 5 to 10 ft. to prevent short curcuiting.

- Limitations

Relief lines have the same limitations as drop box networks but fewer of its advantages. There is less flexibility in operation because individual trenches cannot be closed off. Adding trenches to an existing system is also more difficult. Construction costs are less than drop box networks, however.

C. Small Diameter Pipe Networks (Pressure Distribution)

1. Description

Small diameter pipe networks are used primarily in pressure distribution networks. These networks are used to apply wastewater uniformly over the entire infiltrative surface during each dose. The network is designed to discharge equal volumes of wastewater from each perforation in the network. This is done by maintaining a uniform pressure within all parts of the network. A pump or siphon is used to pressurize the network.

2. Design

Pressure distribution networks usually consist of a solid pipe manifold which supplies wastewater to a number of perforated laterals. To maintain uniform pressure throughout the network, the headlosses incurred delivering the liquid to each perforation must be kept to a minimum by properly sizing the manifold and lateral diameters in relation to the size and number of perforations. This can be a long and tedious process. To simplify the design, a method using graphs and tables has been developed (Otis, 1981). If this method is used, a maximum difference in discharge rates, between perforations throughout the network will be 15 percent. The design procedure is outlined below:

Step 1: Layout a network

For any absorption field, more than one configuration of manifolds and laterals may provide uniform coverage of the infiltrative surface. The manifold may be located at one end, in the center, or off-center of the laterals as the situation demands. Central manifolds minimize lateral size because lateral sizing is based in part upon the length of lateral between the supply and distal ends. Central manifold inlets from the pressurization unit minimize manifold sizing for the same reason. For very long, narrow absorption areas, multiple manifolds may be used as long as the pressures at each manifold inlet are equal. To minimize leakage from the perforations nearest the manifold at the start of each dose, the laterals can be mounted above the manifold using tee-to-tee construction as shown in Figure III, C-1. In this manner, the manifold will fill before discharging into the laterals. However, provisions must be made for draining the manifold in localities where freezing is a concern. Where pumps are used for pressurization, the manifold may be drained back into the dosing chamber. This is impractical with large volume manifolds and impossible if siphons are used. In such instances, the manifold should be insulated and provisions made for manual draining if the system is left idle for any extended period of time.

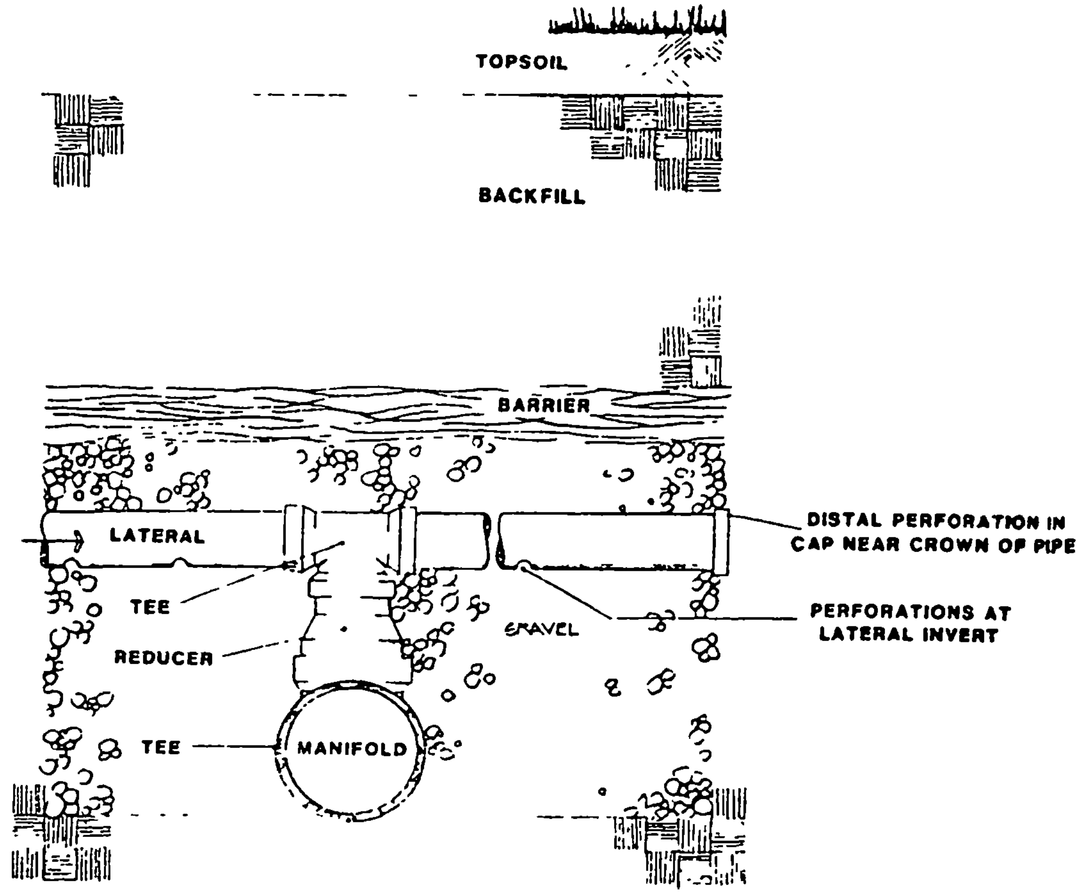


FIGURE III. C-1: Tee-to-Tee Lateral/Manifold Construction (Otis, 1981)

Step 2: Select perforation size and spacing

Uniform distribution can be approached best by providing as many uniformly spaced perforations as practically possible. Perforation diameters of 1/4-in to 5/8-in are common. Smaller diameter perforations permit more perforations per unit length of lateral to provide more uniform coverage, but holes smaller than 1/4-in in diameter are more likely to clog. Larger spacings between perforations permit longer laterals, but spacings too great result in localized overloading of the soil's infiltrative surface. Maximum spacings of 10 ft are suggested here, but spacings lesss than 5 to 6 ft are more desirable.

In bed systems, lateral spacings equal to the perforation spacings are recommended. Perforations between any two laterals should be staggered so that they lie on the vertices of equilateral triangles. This arrangement will provide the most uniform distribution of liquid.

Since the laterals drain between doses, air must be vented from the laterals at the beginning of each dosing cycle. To facilitate venting, the perforation at the distal end of each lateral should be drilled horizontally in the end cap near the crown of the pipe (See Figure III. C-1).

Step 3: Determine lateral pipe diameter

Use Figures III. C-2 through III. C-8 to determine the appropriate lateral diameter for the selected perforation diameter, perforation spacing and lateral length. These figures were developed for plastic pipe using the Hazen-Williams equation for closed conduit flow (Hazen-Williams Coefficient of C_h = 150), allowing no more than a 10 percent head loss from the supply end to the distal end of the pipe (Otis, 1981).

Step 4: Calculate the lateral discharge rate

The lateral discharge rate is equal to the perforation discharge rate times the number of perforations in the lateral The perforation discharge can be obtained from Table III. C-1 or calculated using the orifice equation:

$$q = 11.79\ d^2 h_d^{\frac{1}{2}}$$

where q is the perforation discharge rate in gpm, d the perforation diameter in inches, and h_d the distal in-line pressure in ft. (An orifice coefficent of 0.6 for sharp-edged orifices is used.)

The distal in-line pressure, h_d, is important in the design of the network. At low pressures it is not significant in the network pipe sizing for level sites, but a sufficiently high in-line pressure should be selected to minimize the effects of

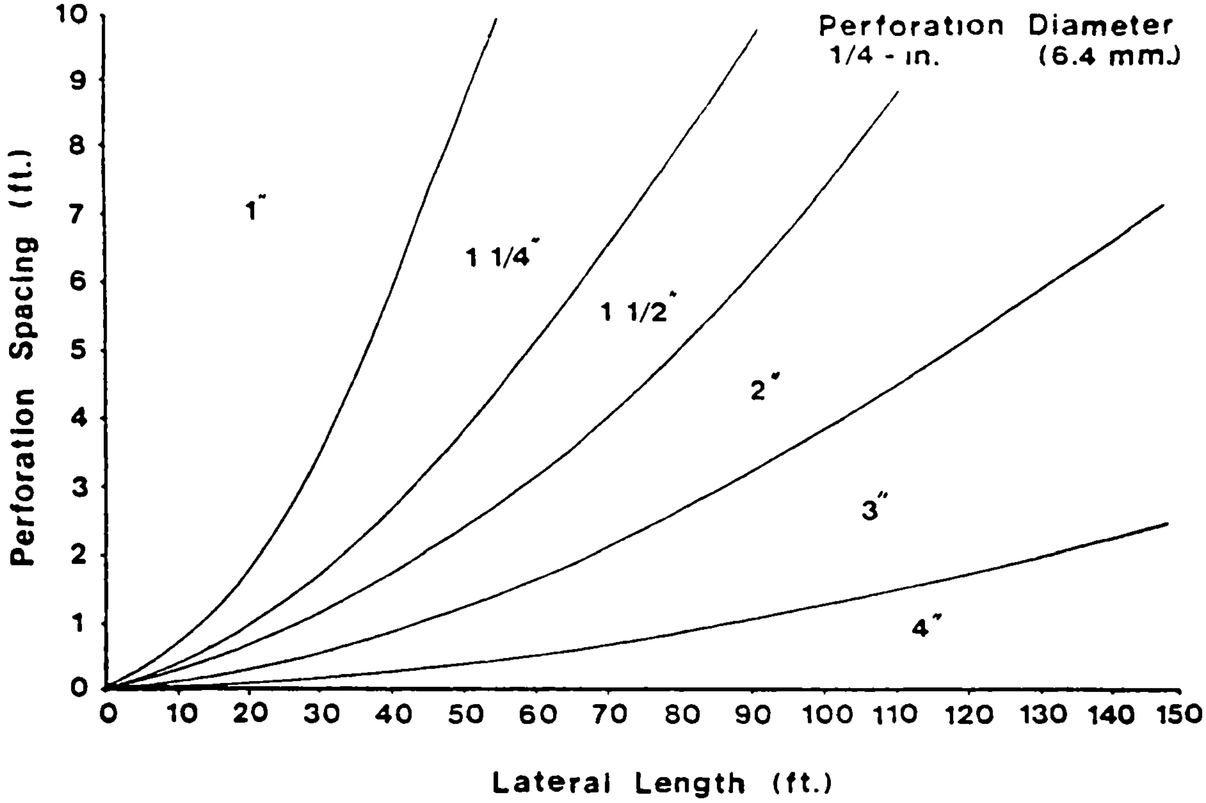


FIGURE III. C-2

Minimum Lateral Diameter for Plastic Pipe (C_h = 150) Versus Perforation Spacing and Lateral Length for 1/4 in. Diameter Perforations (Otis, 1981)

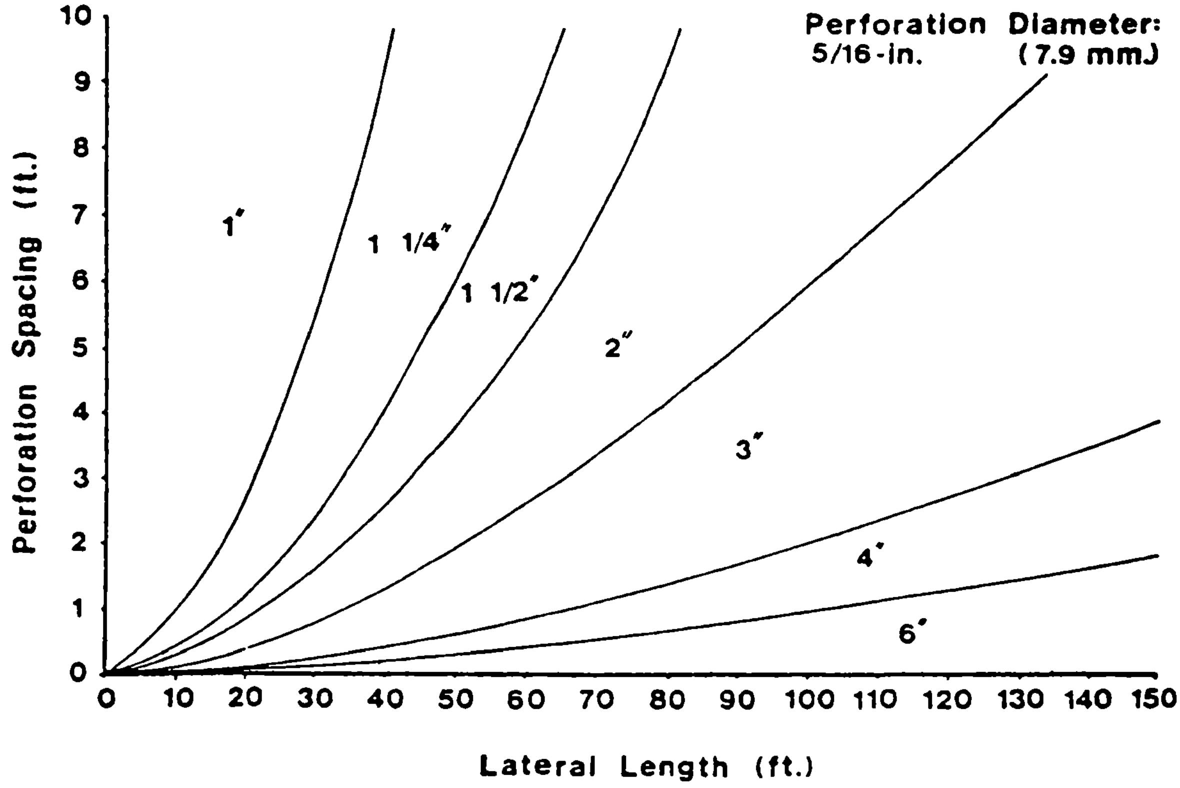


FIGURE III. C-3

Minimum Lateral Diameter for Plastic Pipe (C_h = 150) Versus Perforation Spacing and Lateral Length for 5/16 in. Diameter Perforations (Otis, 1981)

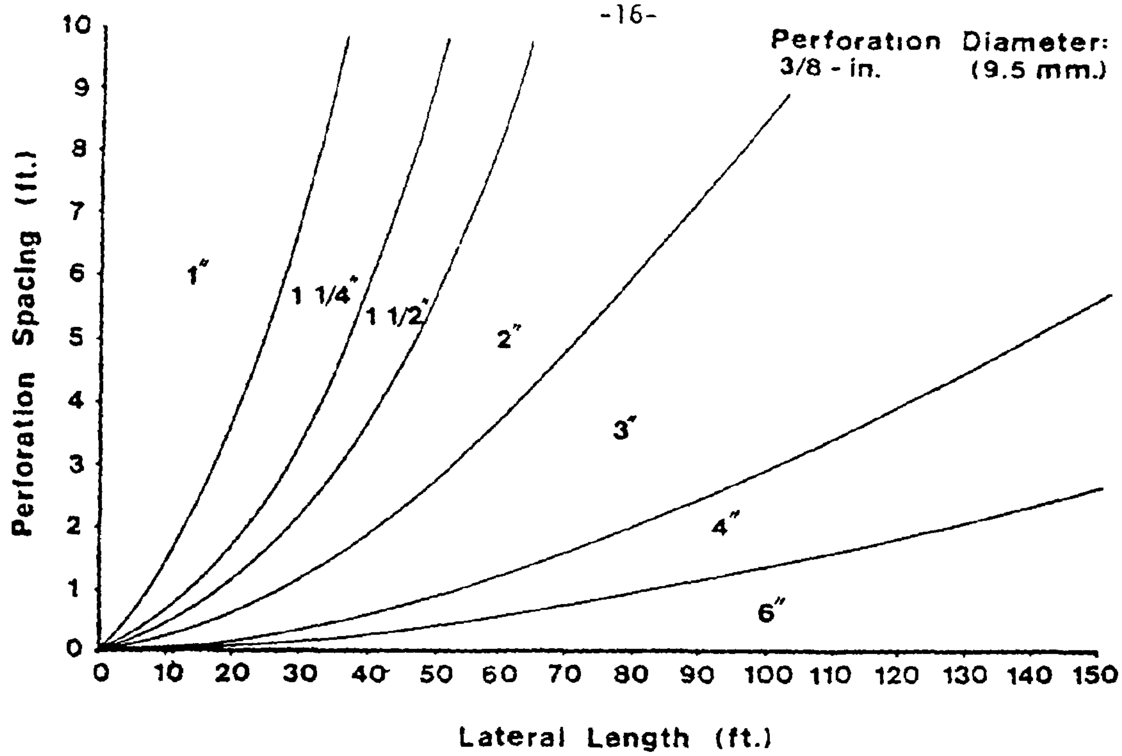


FIGURE III. C-4

Minimum Lateral Diameter for Plastic Pipe (C_h = 150) Versus Perforation Spacing and Lateral Length for 3/8 in. Diameter Perforations (Otis, 1981)

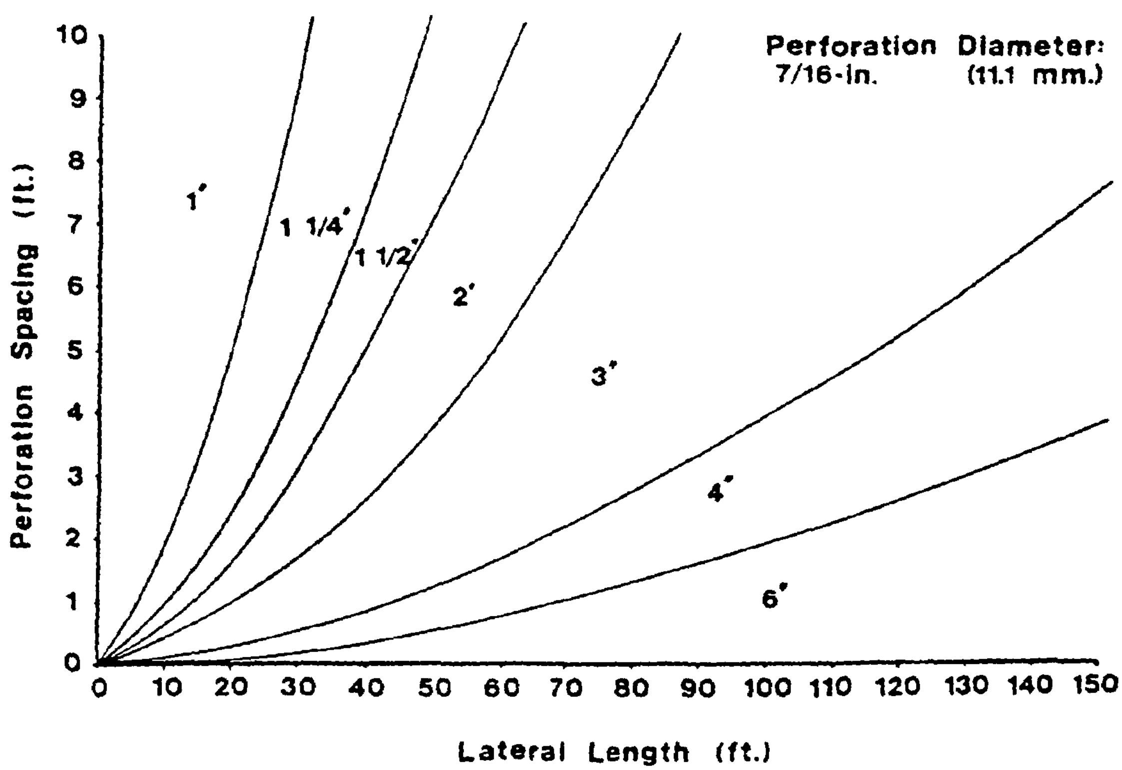


FIGURE III. C-5

Minimum Lateral Diameter for Plastic Pipe (C_h = 150) Versus Perforation Spacing and Lateral Length for 7/16 in. Diameter Perforations (Otis, 1981)

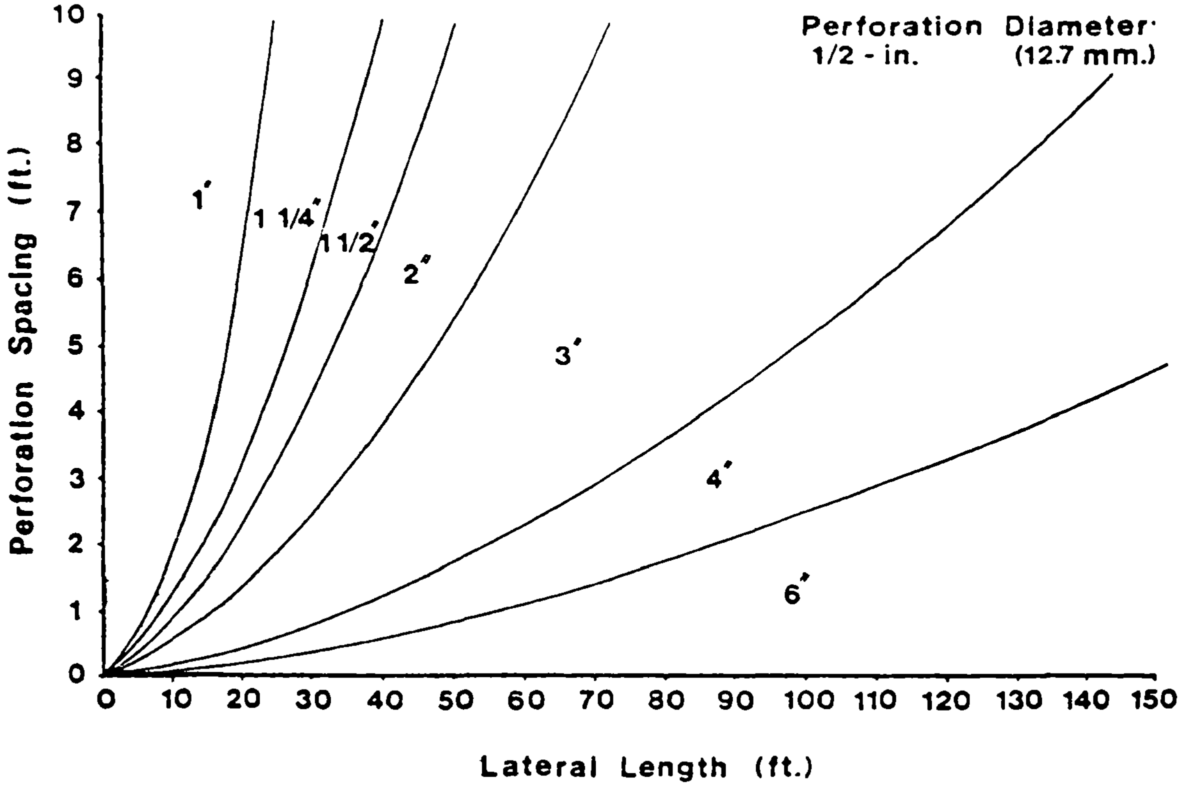


FIGURE III. C-6

Minimum Lateral Diameter for Plastic Pipe (C_h = 150) Versus Perforation Spacing and Lateral Length for 1/2 in. Diameter Perforations (Otis, 1981)

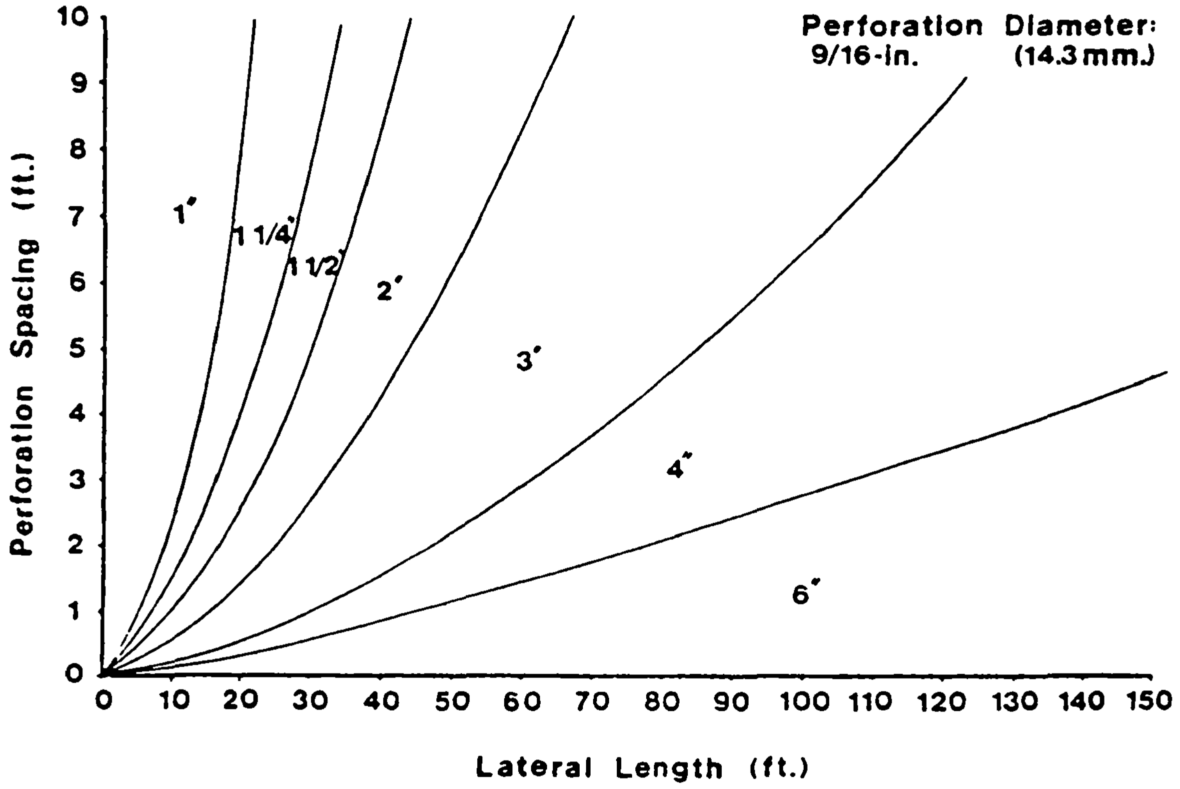


FIGURE III. C-7

Minimum Lateral Diameter for Plastic Pipe (C_h = 150) Versus Perforation Spacing and Lateral Length for 9/16 in. Diameter Perforations (Otis, 1981)

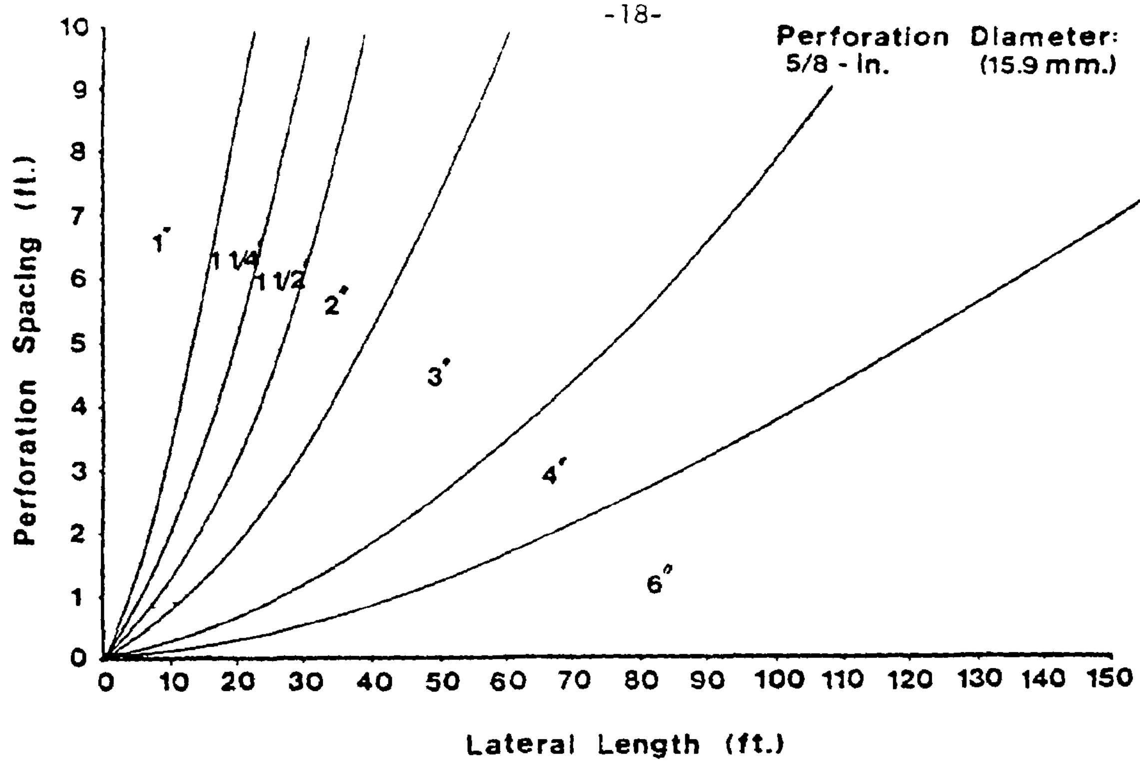


FIGURE III. C-8

Minimum Lateral Diameter for Plastic Pipe (C_h = 150) Versus Perforation Spacing and Lateral Length for 5/8 in. Diameter Perforations (Otis, 1981)

TABLE III. C-1

Perforation Discharge Rates 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

variations in the elevation of perforations that will occur in construction of the system. An elevation difference of ±10 percent between perforation elevations will result in a 10 percent difference in discharge rates between the highest and lowest perforation. A minimum in-line pressure of 2.5 ft permits a ±3 construction tolerance. However, h_d should not be excessive because it affects the perforation discharge rate resulting in increased junction losses and pump or siphon capacity.

Step 5: Calculate manifold diameter

If the manifold diameter is to be uniform throughout its length, Table III. C-2 can be used. Based on the manifold location and the lateral size and spacing, the manifold diameter can be read from the table. The diameter obtained is that necessary to maintain no more than a 5 percent headloss from the manifold inlet to distal end.

To reduce pipe costs in larger systems, the manifold may be telescoped in size, decreasing in diameter as the flow decreases along its length. Using the following equation, F_i values are calculated for each lateral segment:

$$F_i = 9.8 \times 10^{-4} Q_i^{1.85}$$

where Q_i is the flow in the ith manifold segment in gpm. The F_i values represent empirical friction factors for each manifold segment, derived from the Hazen-Williams equation. See Otis (1981) for the derivation. The manifold diameter, D_M, then can be computed using:

$$D_M = \left[\frac{\sum_{i=1}^{M} L_i F_i}{f h_d} \right]^{0.21}$$

pressure head 2'

where M is the number of manifold segments, L_i is the length of the ith segment (lateral spacing) in ft, f is the fraction of the total headloss desired in that manifold segment or series of manifold segments, and h_d is the distal pressure in the lateral in ft. To maintain less that a 10 percent headloss, f must be less than or equal to (0.1/number of manifold segments) x number of manifold segments in the section under design.

Step 6: Determine the dose volume

In systems where the laterals are long in comparison to the manifold, dosing volumes should be made large in relation to the pipe volume to reduce the significance of the leakage. Five to ten times the network pipe volume is suggested. However, this volume should not be larger than the required dose volume calculated by dividing the average daily flow by the desired

TABLE III. C-2.

Maximum Manifold Length (ft) for Various Manifold Diameters Given the Lateral Discharge Rate and Lateral Spacing (Otis, 1981

Lateral Discharge Rate (gpm): End Manifold	Central Manifold	Manifold Diameter = 1 1/4" Lateral Spacing (ft) 2	4	6	8	10	Manifold Diameter = 1 1/2" Lateral Spacing (ft) 2	4	6	8	10	Manifold Diameter = 2" Lateral Spacing (ft) 2	4	6	8	10
		ft														
10	5	4	8	6	8	10	10	8	12	16	20	12	16	24	24	30
20	10	4	4	6			4	4	6	8	10	6	8	12	16	20
30	15	2					2	4	6			4	8	6	8	10
40	20											4	4	6	8	10
50	25											2	4	6	8	
60	30											2	4			
70	35											2	4			
80	40											2				
90	45											2				
100	50											2				
110	55															
120	60															
130	65															
140	70															
150	75															
160	80															
170	85															
180	90															
190	95															
200	100															

Lateral Discharge Rate (gpm): End Manifold	Central Manifold	Manifold Diameter = 3" Lateral Spacing (ft) 2	4	6	8	10	Manifold Diameter = 4" Lateral Spacing (ft) 2	4	6	8	10	Manifold Diameter = 6" Lateral Spacing (ft) 2	4	6	8	10
		ft														
10	5	26	40	48	56	70	42	64	84	96	110	84	136	174	208	240
20	10	16	24	30	32	40	26	40	54	64	70	54	84	108	128	150
30	15	12	16	24	24	30	20	28	36	48	50	42	64	84	96	110
40	20	10	12	18	16	20	16	24	30	32	40	34	52	66	80	90
50	25	8	12	12	16	20	14	20	24	32	40	30	44	60	72	80
60	30	6	8	12	16	20	12	16	24	24	30	26	40	48	64	70
70	35	6	8	12	8	10	10	16	18	24	30	24	36	48	56	60
80	40	6	8	6	8	10	10	12	18	16	20	22	32	42	48	60
90	45	4	8	6	8	10	8	12	18	16	20	20	28	42	48	50
100	50	4	4	6	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	6	8	10	12	16	18	24	30
200	100	2	4				4	4	6	8	10	10	16	18	24	30

dosing frequency (See Table II. B-1). The nomograph in Figure III. C-9 can be used to calculate the pipe volume. If the crown of the manifold lies below the lateral inverts, the manifold pipe volume does not need to be included. If this is not the case, the nomograph also can be used to determine the manifold volume. If the minimum dose based on pipe volume is larger than the required dose based on dosing frequency, a different network may have to be designed to reduce the pipe volume.

Step 7: Determine minimum pump or siphon discharge rate

This is calculated by summing the perforation or lateral discharge rates.

Step 8: Calculate the total friction losses

The total friction losses are the sum of the losses in the delivery pipe and the network losses. The friction loss in the delivery pipe between the dosing chamber and the network inlet is determined by using the minimum discharge rate computed in Step 7. This can be calculated using the Hazen-Williams equation:

$$\text{Friction loss} = L_d \left[\frac{3.55\ Q_M}{C_h D_d^{2.63}} \right]^{1.85}$$

where L_d is the length, in ft, of the delivery pipe from the dosing dosing chamber to the network inlet, D_d is the pipe diameter in inches, Q_M the discharge rate in gpm and C_h is the Hazen-Williams friction factor equal to 150 if the pipe is plastic. The total network losses are equal to 1.31 times the distal pressure selected for the network, h_d. (See Otis, 1981).

Step 9: Select the pressurization unit.

Pump selection is based on the pumping head and discharge rate required for the network. The static lift or the difference in elevation between the low water level in the dosing chamber and the lateral inverts must be added to the friction losses computed in Step 8 to obtain the total pumping head. Using the head-discharge curves supplied by the manufacturer, a pump able to efficiently discharge the minimum rate or greater from Step 7 at the total pumping head is selected.

Siphons are selected based on the manufacturer's stated average discharge rate. This rate must be equal to or greater than the minimum discharge rate of the network. To function properly, the siphon discharge invert must be elevated above

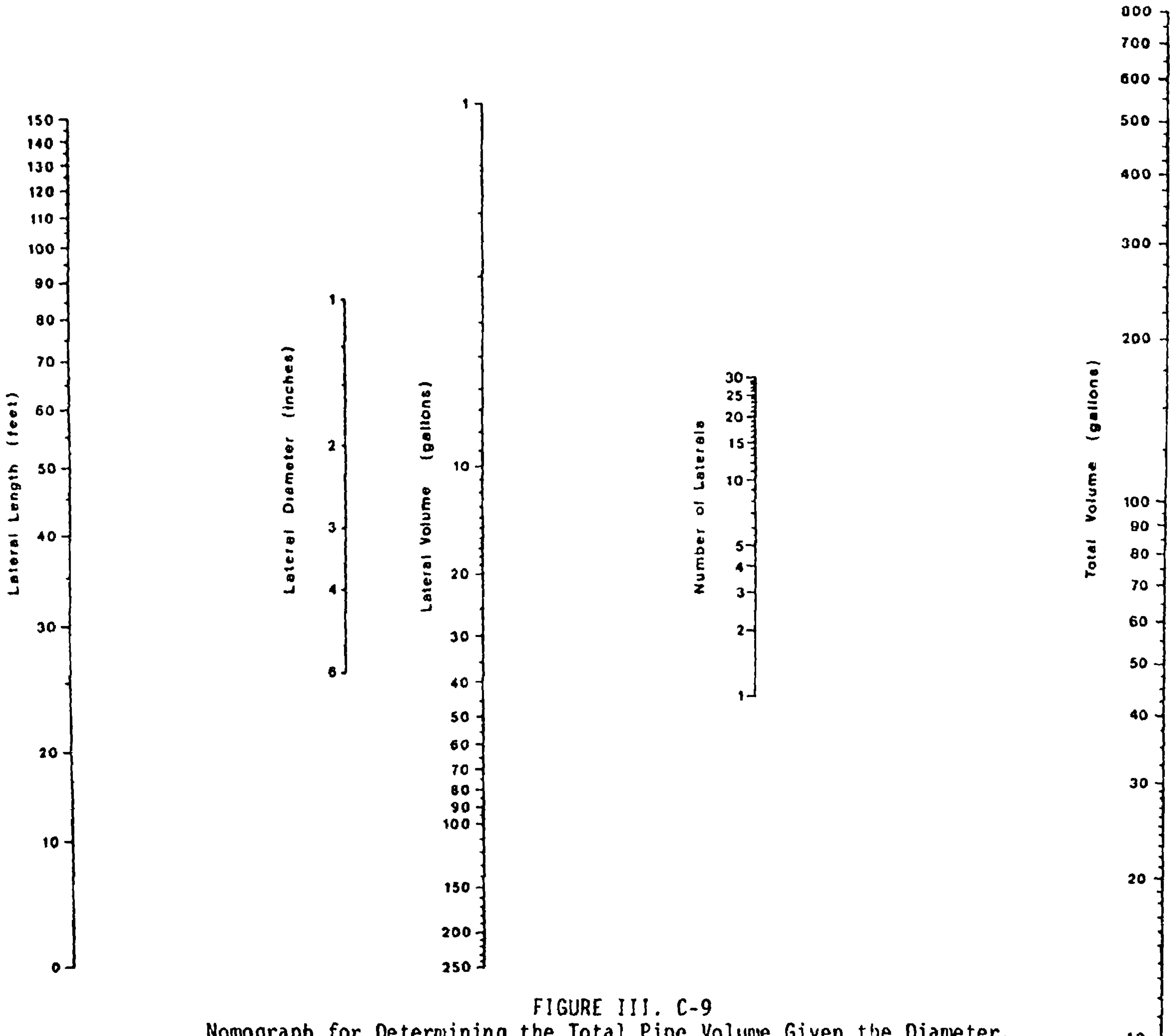


FIGURE III. C-9
Nomograph for Determining the Total Pipe Volume Given the Diameter, Length and Number of Laterals (Manifolds) (Otis, 1981)

the lateral inverts a distance equal to or greater than the friction losses estimated in Step 8. The delivery pipe from the siphon should be one nominal size larger than the siphon to facilitate air venting unless the slope of the delivery line from the siphon is great enough that the pipe does not fill until the network is pressurized.

Step 10: Size of the dosing chamber

The dosing chamber is a crucial component of the network design. It must discharge the appropriate volume at the required rate with each dose. Also, appurtances must be selected carefully to insure proper and reliable operation.

The volume of the chamber is determined by the dosing volume computed in Step 6. A reserve capacity above the active dosing volume equal to one day's average flow should be provided if single pumps are used. This will provide one day or more for repairs with normal water fixture use in case of pump failure. A reserve volume is not needed if siphons are used because overflows by-passing the siphon are provided.

Necessary appurtances include level controls and high water alarm switches for pump systems, and suitable access to the pressurization unit for servicing. A typical pumping chamber is shown in Figure III. C-10. Switch selection and installation are extremely important because the most frequent cause of pump failure is a switch malfunction. The switches should be sealed from the corrosive atmosphere in the chamber and all electrical contacts and relays must be mounted outside the chamber. Provisions should be made to prevent gases in the chamber from following the electrical conduits into the control box. The high water alarm switch should be located 2-3 in (5-8-cm) above the pump activation level. This switch must be on a separate circuit from the pump level controls. Access for maintenance is best provided by a manway located over the pump or siphon.

Siphons or siphon breakers must be used in networks where the low water level in the dosing chamber is above the lateral inverts. If a pump without a siphon breaker is used in such an instance, a natural siphoning of liquid out the chamber will occur. A simple siphon break can be merely a small hole drilled in the discharge line at the highest point in the dosing chamber.

3. Example: Design a pressure distribution network for a mound system to be constructed for a 3-bedroom home. The absorption area within the mound is to be 6 ft x 65 ft. The distribution laterals will be approximately 8 ft above the pump elevation. The distance from the pump to the mound is about 75 ft.

Step 1: Network layout

A central manifold network with 4 laterals, 2 on either side of the manifold is selected. The laterals are to be 32 ft long

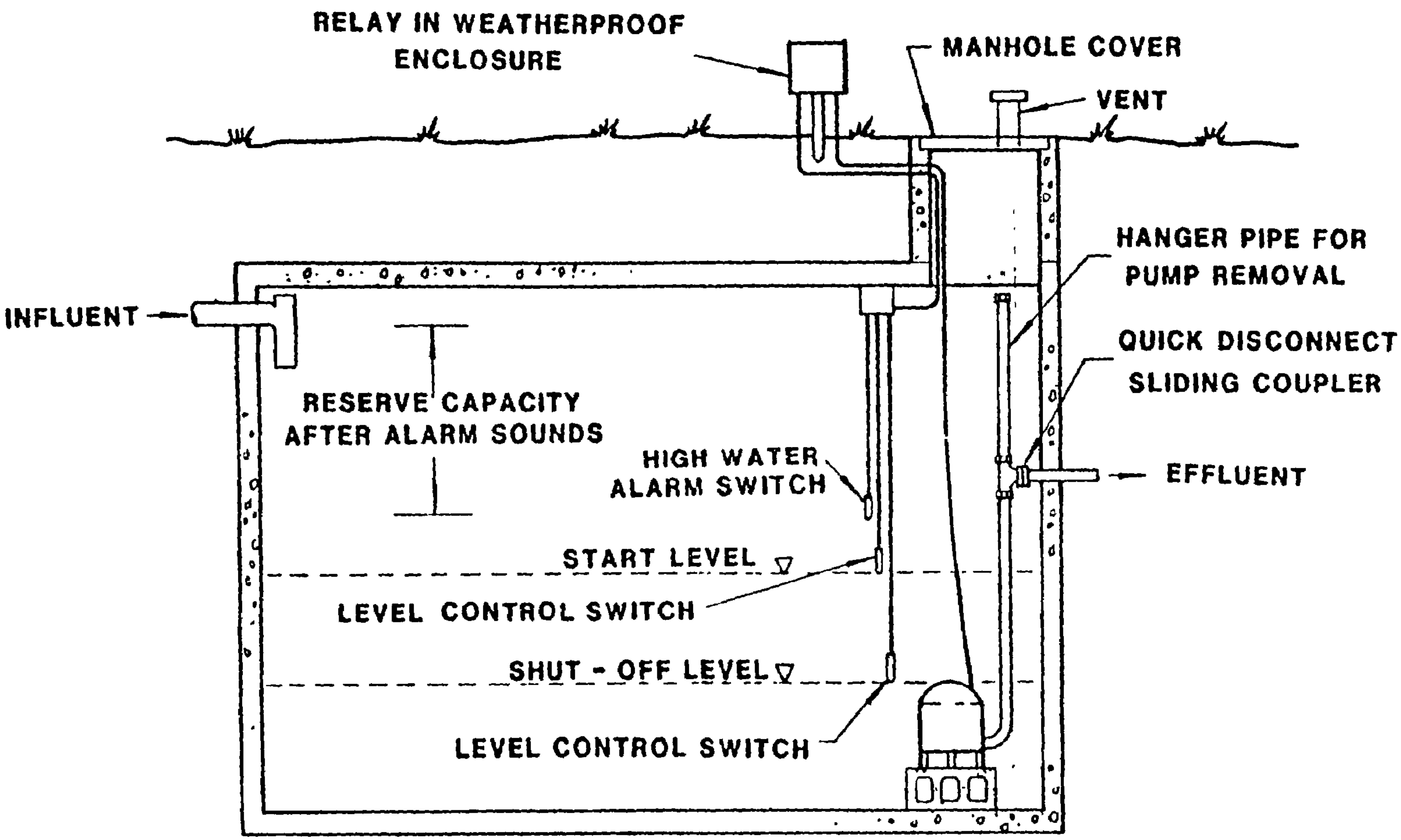


FIGURE III. C-10

TYPICAL PUMPING CHAMBER FOR DOSING SOIL ABSORPTION SYSTEMS (U.S. EPA, 1980) and spaced 3 ft apart.

Step 2: Perforation size and spacing

One-quarter inch perforations spaced 30 in apart are selected.

Step 3: Lateral pipe diameter

From Figure III. C-2 a lateral diameter of 1 1/4-in is required.

Step 4: Lateral discharge rate

Using 2.5 ft distal in-line pressure, 1/4-in perforations will discharge 1.17 gpm (Table III. C-1).

$$\text{No. perforations/lateral} = \frac{\text{32 ft lateral}}{\text{2.5 ft spacing}} = \text{13 perforations}$$

Lateral discharge rate = 1.17 gpm/perforation x 13 perforations/lateral
= 15 gpm/lateral

Step 5: Manifold diameter

The manifold length is the distance between the first and last lateral in the network. In this case it is 3 ft. Table III. C-2 indicates that a central manifold network discharging 15 gpm into laterals spaced 3 ft apart can use a 1 1/2-in manifold with a maximum length of 3 ft or a 2-in manifold with a maximum length of 6 ft. The 1 1/2-in manifold is sufficient.

Step 6: Dose volume

A mound should be dosed 2 to 4 times daily. However, the minimum dose volume should be 5 to 10 times the network pipe volume.

$$\text{Required dose volume} = \frac{\text{150 gpd/bdrm x 3 bdrm}}{\text{4 doses/day}} = \text{115 gal/dose}$$

Minimum dose volume = 10 x total pipe volume

In this case, the manifold will be located below the lateral inverts so only the lateral volume need be considered. However, to prevent freezing, the manifold and delivery line are to be drained back to the dosing chamber. Therefore, the dose volume must be increased by the volume of water which will drain back. The nomograph in Figure III. C-9 can be used to determine these volumes quickly. To determine the lateral volume, place a straight edge at 32 ft on the "Lateral Length" scale and connect it with the 1 1/4-in mark on the "Lateral Diameter" scale. The straightedge crosses the "Lateral Volume" scale at about 2 gal/lateral. Rotate the straightedge at about this point on the "Lateral Volume" scale and align it with 4 on the "Number of Laterals" scale. Where it crosses the "Total Volume" scale, read the total lateral volume. In this case, it is less than 10 gal and off the scale, so multiply 2 gal/lateral times 4 laterals to obtain the total volume.

Total lateral volume = 2 gal/lateral x 4 laterals = 8 gal

Minimum dose volume = 10 x 8 gal = 80 gal => Use 115 gal/dose

Using the same procedure, the manifold and delivery line volume can be determined. A 3-in delivery line, 75 ft long, is to be used. The manifold is 1 1/2-in diameter, 3 ft long.

Manifold/delivery line volume = 1 gal + 27 gal = 28 gal

Therefore,

Total dose volume = 115 gal/dose + 28 gal = 145 gal/dose

Step 7: Pump capacity

Discharge rate = 4 laterals x 15 gpm/lateral = 60 gpm

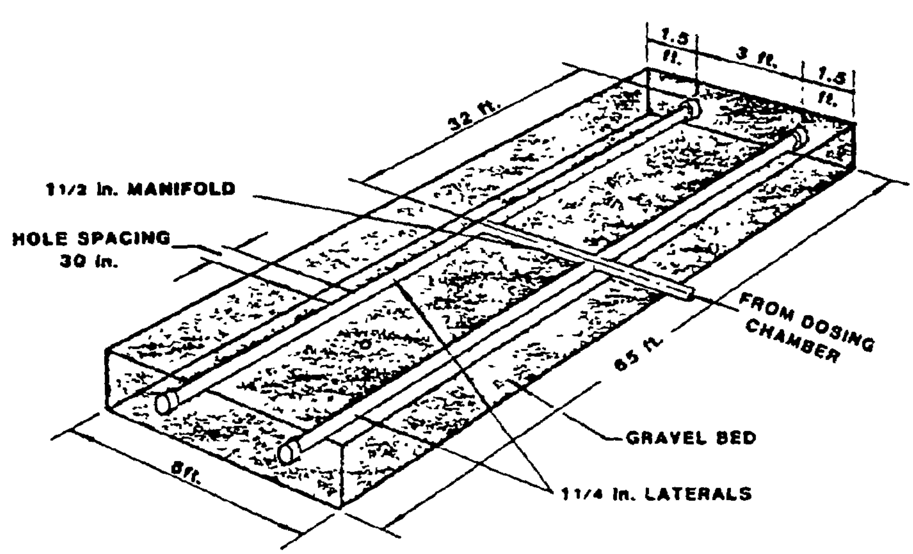


FIGURE III. C-11

Pressure Distribution Network for Design Example

Step 8: Total friction losses

Network losses = 1.31 x distal in-line pressure

= 1.31 x 2.5 ft = 3.3 ft

Delivery losses (3-in delivery pipe)

$$= L_d \left[\frac{3.55\ Q_M}{C_h D_d^{2.63}} \right]^{1.85}$$

$$= 75\ \text{ft} \left[\frac{3.55 \times 60\ \text{gpm}}{150 \times (3\ \text{m})^{2.63}} \right]^{1.85} = 0.7\ \text{ft}$$

Step 9: Pump selection

Total pumping head = Network losses + Delivery losses + Static lift

= 3.3 ft + 0.7 ft + 8 ft = 12 ft

Therefore, a pump capable of pumping 60 gpm against a head of 12 ft is selected.

Step 10: Dosing chamber volume

Chamber volume = Dose volume + Reserve

= 115 gal/dose + 200 to 400 gal reserve

= 325 to 500 gal

4. Limitations

Pressure distribution networks have the advantages over other networks of providing dosing in addition to more uniform application, permitting irregular field configurations, providing equal division of flow between multiple trenches and simultaneous application of effluent over large absorption areas. However, they are not well suited to sloping sites. The static heads between laterals installed at different elevations will vary thereby affecting the perforation discharge rates. If this is not properly compensated for, unequal distribution between the various infiltrative surfaces will result.

If the infiltrative surfaces are restricted to only two different elevations of equal loading, two separate distribution networks can be used with each network receiving alternate doses through the use of alternating pumps, valves or siphons. Each network is designed separately. This arrangement provides the best assurance of an equal division of flow. If the infiltrative surface areas are not equal or or more than two levels are necessary, a single network can be designed by taking into account the differences in the total heads within each lateral.

D. Other Distribution Designs

Several other distribution designs are used occasionally. Most of these are proprietary in nature. Little performance data is available.

1. Inverted Network

Inverted networks are similar to conventional gravity flow systems except that the perforated pipe is laid with the holes at or near the crown of the pipe. This arrangement is designed to provide more uniform distribution of wastewater over a large area, and to prolong the life of the field by collecting any settleable solids passing out of the septic tank in the bottom of the pipe. Water-tight sumps are located at both ends of each inverted line to facilitate periodic removal of the accumulated solids. Limited testing indicates distribution is not improved substantially over conventional gravity flow networks (Converse, 1974).

2. Case System

The Case System is a network of specially treated concrete blocks mortared together to form a sealed conduit. The block conduit is set in a trench and backfilled eliminating the need for distribution pipe and porous media. The septic tank effluent flows through the block and diffuses through the porous block walls and into the soil.

3. Gravel-less System

Similar to the Case System, large diameter drainage pipe 10-in to 12-in in diameter enclosed in drainage fabric is buried without porous media. The volume in the pipe acts as the storage volume while the liquid seeps out into the soil.

4. Leaching Chambers

This method employs open bottom chambers, in place of perforated pipe and gravel for distribution and storage of the wastewater. The chambers interlock to form an underground cavern over the soils' infiltrative surface. The wastewater is discharged into the cavern through a central weir, trough or splash plate and allowed to flow over the infiltrative surface in any direction. Access holes in the roof of the chamber allow visual inspection of the soil surface and maintenance as necessary.

IV. Construction

A. Materials

Three to 4-in diameter pipe or tile is typically used for nonpressurized networks. Either perforated pipe or 1 ft lengths of suitable drain tile may be used. The perforated pipe commonly has one or more rows of 3/8 to 3/4 in diameter holes. Hole spacing is not critical. Table IV. A-1 can be used as a guide for acceptable materials for nonpressurized networks.

Plastic pipe is used for pressure distribution networks because of the ease of drilling and assembly. Either PVC Schedule 40 (ASTM D 2663) or ABS (ASTM 2661) pipe may be used.

B. Large Diameter Perforated Pipe Placement

To insure a free flow of wastewater, the distribution pipe should be laid level or on a grade of 1-in to 2-in per 100 ft. To maintain a level or uniform slope, several construction techniques can be employed. In each case a tripod level or transit is used to obtain the proper grade elevations. Hand levels are not adequate.

The rock is placed in the excavation to the elevation of the pipe invert. The rock must be leveled by hand to establish the proper grade. Once the pipe is laid, more rock is carefully placed over the top of the pipe. Care must also be taken when flexible corrugated plastic pipe is used, because the pipe tends to "float" up as rock is placed over the top of the pipe. One method is to employ special holders which can be removed once all the rock is in place.

C. Small Diameter Perforated Networks

Pressure distribution networks are usually fabricated at the construction site. This may include drilling holes in distribution laterals. The holes must be drilled on a straight line along the length of the pipe. This can be accomplished best by using 1-in by 1-in angle iron as a straight-edge to mark the pipe. The holes are then drilled at the proper spacing. Care must be used to drill the holes perpendicular to the pipe and not at an angle. All burrs left around the holes inside the pipe should be removed. This can be done by sliding a smaller diameter pipe or rod down the pipe to knock the burrs off.

Solvent weld joints are used to assemble the network. The laterals are attached to the manifold such that the perforations lie at the bottom of the pipe. The rock is placed in the absorption area first, to the elevation of the distribution laterals. The rock should be leveled by hand, maintaining the same elevation throughout the system, before laying the pipe. After the pipe is laid, additional rock is placed over the pipe.

TABLE IV. A-1

PIPE MATERIALS FOR NONPRESSURIZED DISTRIBUTION NETWORKS (U.S. EPA, 1980)

Type of Material	Specification	Class
Clay Drain Tile	ASTM C-4	Standard Drain Tile
Clay Pipe		
Standard and Extra-Strength Perforated	ASTM C-211	Standard
Bituminized Fiber Pipe		
Homogeneous Perforated	ASTM D-2312	
Laminated-Wall Perforated	ASTM D-2313	
Concrete Pipe		
Perforated Concrete	ASTM C-44 (Type 1 or Type 2)	ASTM C-14[a]
Plastic		
Acrylonitrile-Butadiene-Styrene (ABS)	ASTM D-2751[b]	
Polyvinyl Chloride (PVC)	ASTM D-2729[b] D-3033[b] D-3034[b]	
Styrene-Rubber Plastic (SR)	ASTM D-2852[b] D-3298[b]	
Polyethylene (PE)		
o Straight Wall	ASTM D-1248[b]	
o Corrugated (Flexible)	ASTM F-405-76[b]	

[a] Must be of quality to withstand sulfuric acid.

[b] These specifications are material specifications only. They do not give the location or shape of perforations.

D. Distribution Boxes

If used, distribution boxes should be installed level and placed in an area where the soil is stable and remains reasonably dry. To protect the box from frost heaving, a 6-in layer of 1/2 to 2-1/2 in rock should be placed below and around the sides of the box. Solid wall pipe should be used to connect the box with the distribution laterals. Separate connections should be made for each lateral. To insure a more equal division of flow, the slope of each connecting pipe should be identical for at least 5 to 10 ft beyond the box.

E. Dosing Chambers

Monolithic concrete, fiberglas or plastic tanks should be used as dosing chambers. Steel is not recommended because of the corrosive nature of the waste. The tank must be watertight to avoid groundwater infiltration. Waterproofing consists of adequately sealing all joints with asphalt or other suitable material. Coating the outside of the tank prevents groundwater from seeping into the tank. Asphalt coating the inside and outside of steel tanks helps retard corrosion. Application of 4-mil plastic to the wet asphalt coating protects the coating when back filling. At high water table sites, flotation collars should be used so the chamber does not float out of position due to hydrostatic pressures on a near-empty tank. This is not normally a problem for concrete tanks, but for the lighter-weight materials, such as steel or fiberglas, it could present a problem. The manhole riser pipe should be a minimum of 24-in in diameter and should extend 6-in above ground level to keep surface water from entering the chamber. A cast iron pipe sleeve or other suitable device can be slipped over the plastic pipe extending from the tank to unexcavated soil to provide protection from breakage due to backfilling or settling.

V. Operation and Maintenance

A. Routine

Routine maintenance is required in alternating field systems and in systems employing dosing, uniform application or distribution boxes.

1. Alternating Fields

On a regular schedule, usually annually, an operating field is taken out of service to "rest" and a "rested" field is put into service. The switch should be done in later spring or early summer when the soil temperatures are warm so that a good biological mat can develop quickly to ensure adequate treatment.

2. <u>Systems Employing Dosing or Uniform Application</u>

Systems employing pumps for dosing should be inspected monthly for proper switch and pump operation. On and off switches as well as the high water alarm switch should be tested. Periodically, the pump discharge rate should be checked by timing the period it takes the pump to empty the chamber. If the time has increased significantly, the pump should be removed and inspected for wear, clogging or impellor damage. The distribution network should also be checked for obstructions.

Siphons should be observed semi-annually for proper operation. The bell and any bell vents should be flushed each year.

3. <u>Distribution Boxes</u>

Systems employing distribution boxes should be inspected semi-annually. The levelness of the box should be checked in the fall after the first heavy frost and again in the spring after the frost has left the ground. In areas with no frost, annual inspections should be sufficient. The box should be leveled, if necessary.

B. Other

Improper maintenance of the pretreatment unit may result in plugging of the distribution network. Rodding of the pipe may be necessary. Pressure distribution networks can be flushed, if necessary, by cutting the ends of the laterals and activating the pump or siphon.

VI. Questions

1. What factors influence the selection of a distribution method?

2. Under what conditions should drop boxes not be used? Pressure distribution?

3. What special considerations should be taken in the placement and operation of siphons?

4. How could dosing be employed on sloping sites? Would other methods be more satisfactory?

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VIII. Problems

A. Statements

1. Pressure Distribution: Level Site

A multi-trench system is to be constructed on a level site in a sandy loam soil. It is to receive an average flow of 250 gpd. The system is to consist of 5 trenches, each 3 ft x 40 ft and spaced 9 ft on center.

Design a pressure distribution network for this system. The dosing chamber is to be located 50 ft from the first lateral.

2. Pressure Distribution: Large Bed

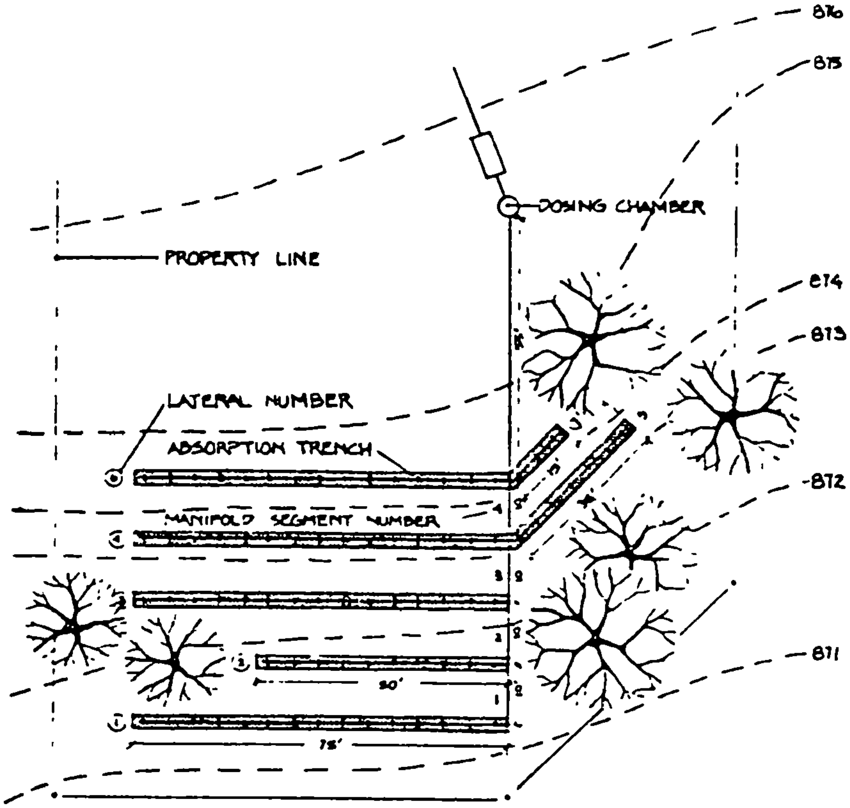
A subsurface soil absorption system is to be used for wastewater disposal in a small community. Three beds, each designed for 15,000 gpd, are to be used. The beds will be 100 ft x 130 ft.

Design a pressure distribution network for one of the beds. The dosing chamber will be located 200 ft from the network inlet. If siphons are used for pressurization, what should be their elevation in relation to the lateral inverts?

3. Pressure Distribution: Sloping Site

A multi-trench system is to be constructed on a sloping site. It will serve a 4-bedroom home with a present average flow of 200 gpd. Five trenches will be used as shown in the figure below. Because of large trees, the trenches will be of unequal lengths as shown. The elevations of the distribution lateral inverts will be as follows:

Lateral No.	Invert Elevation
1	873.0 ft
2	873.5 ft
3	874.0 ft
5 & 6	874.5 ft
6 & 7	875.5 ft



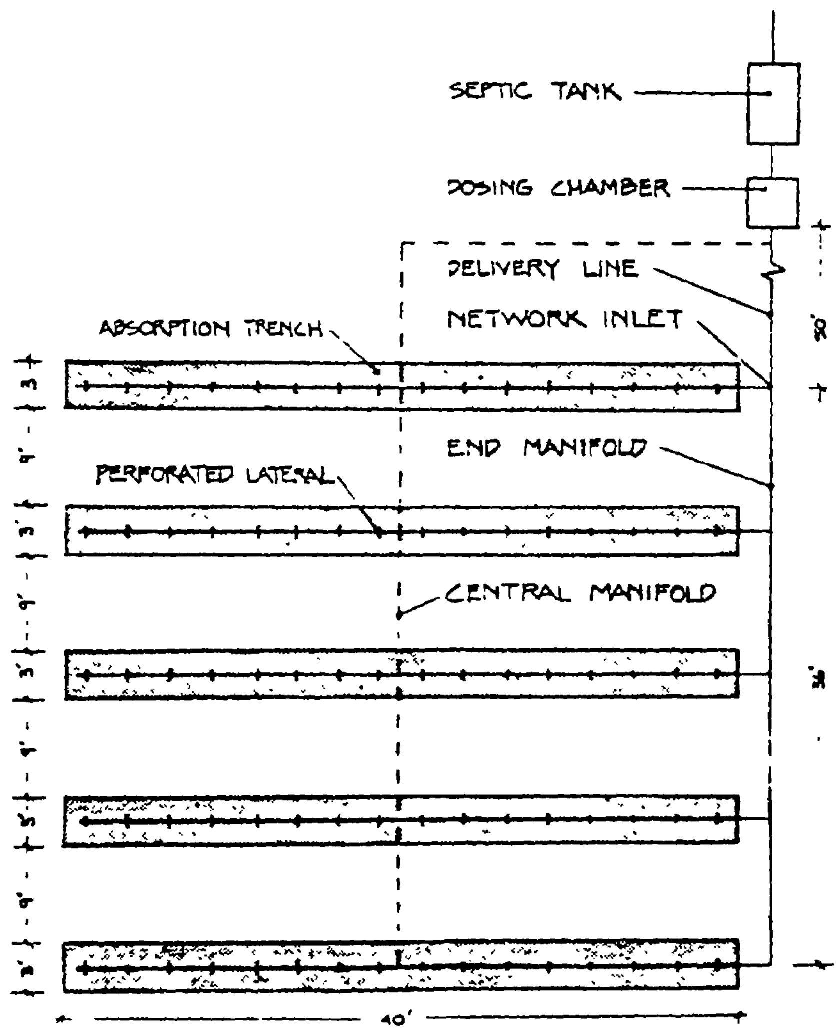
Network Layout for a Trench System on a Sloping Site (Problem 3)

B. Solutions

1. Pressure Distribution: Level Site

Step 1: Layout network

Two layouts would be suitable for this system. The distribution laterals can be fed either by an end or a central manifold. With an end manifold, 5 laterals are required, while a central manifold requires 10 laterals. An end manifold will be used in this example.



End and Central Manifold Configurations for a Trench System on a Level Site (Problem 1)

Step 2: Select perforation size and spacing

Perforations 1/4-in in diameter spaced 2.5 ft will be used. (Other combinations may be just as suitable).

Step 3: Select lateral diameter

To provide the most uniform effluent application over the trench bottom, the first and last perforations in the lateral will be located one-half the perforation spacing from either end of the trench. Therefore,

Lateral Length = 40 ft - (1/2 x 2.5) = 38.75 ft

From Figure III. C-2 (for 1/4-in diameter perforations), the minimum lateral diameter for a 38.75 ft lateral with a 2.5 ft perforation spacing is 1 1/2-in.

Step 4: Calculate the lateral discharge rate

A minimum in-line pressure of 2.5 ft is desired. From Table III. C-1, a 1/4-in perforation will discharge 1.16 gpm at this pressure.

$$\text{No. of Perforations/Lateral} = \frac{40}{2.5} = 16 \text{ perforations}$$

Lateral Discharge Rate = 16 x 1.16 gpm = 17.5 gpm

Step 5: Calculate the manifold size

The manifold diameter is to be uniform along its length to simplify construction.

Manifold Length = 4 ft x 9 ft = 36 ft

From Table III. C-2, an end manifold with lateral discharge rates of 17.5 gpm and lateral spacings of 9 ft can have a maximum length of 20 ft for a 2-in diameter or 43 ft for a 3-in diameter. Therefore, a 3-in diameter is necessary.

Step 6: Determine dose volume

The crown of the manifold is to be located below the lateral inverts and the manifold drained back into the dosing chamber at the end of each dose. Therefore, the minimum dose volume is based on lateral pipe volume only. Using the nomograph in Figure III. C-9, a straightedge is placed at 38.75 ft on the Lateral Length scale and at 1 1/2-in on the Lateral Diameter scale. The straightedge crosses the Lateral Volume scale at about 3.5 gal. Maintaining this point on the Lateral Volume scale, the straightedge is rotated to align with 5 on the Number of Laterals scale. The straightedge crosses the Total Pipe Volume scale at 17.5 gals. A minimum dose volume of 5 to 10 times the total pipe volume or 90 to 175 gal should be used.

The required dosing frequency taken from Table II. B-1 is 1 dose/day for sandy loam. Therefore,

$$\text{Required Dosing Volume} = \frac{250 \text{ gpd}}{1 \text{ dose/day}} = 250 \text{ gal/dose}$$

The minimum dose is less than the required dosing volume so the network is satisfactory. Since the manifold will drain back to the dosing chamber, the dose volume must be increased in volume equal to that in the manifold and delivery line. If a 50 ft 3-in diameter delivery line is used, the volume increase is equal to 50 ft + 36 ft or 86 ft of 3-in pipe. Using the nomograph in Figure III. C-9, this volume is determined to be approximately 32 gals. Therefore,

$$\text{Dosing Volume} = 250 \text{ gal} + 32 \text{ gal} = 282 \text{ gal}$$

Step 7: Calculate the minimum discharge rate

Minimum Discharge Rate = 5 laterals x 17.5 gpm/lateral

Step 8: Calculate total friction losses

$$\text{Network losses} = 1.31 \times \text{distal in-line pressure}$$

$$= 1.31 \times 2.5 \text{ ft} = 3.28 \text{ ft}$$

$$\text{Delivery losses} = L_d \left[\frac{3.55\ Q_M}{C_h D_d^{2.63}}\right]^{1.85}$$

$$= 50 \text{ ft} \left[\frac{3.55 \times 87.5 \text{ gpm}}{150 \times (3\text{-in})^{2.63}}\right]^{1.85} = 0.9 \text{ ft}$$

$$\text{Total losses} = \text{Network losses} + \text{Delivery losses}$$

$$= 3.28 \text{ ft} + 0.9 \text{ ft} = 4.2 \text{ ft}$$

Step 9: Select pressurization unit

In this instance, a pump is to be used.

Total Pumping Head = Static Head + Friction Losses

If the low water level in the dosing tank is 5 ft below the lateral inverts, the total pumping head is:

5 ft + 4.2 ft (friction losses from Step 8) or 9 ft

Using head-discharge curves provided by manufacturers, a pump able to discharge at least 80 gpm against 9 ft of head is selected.

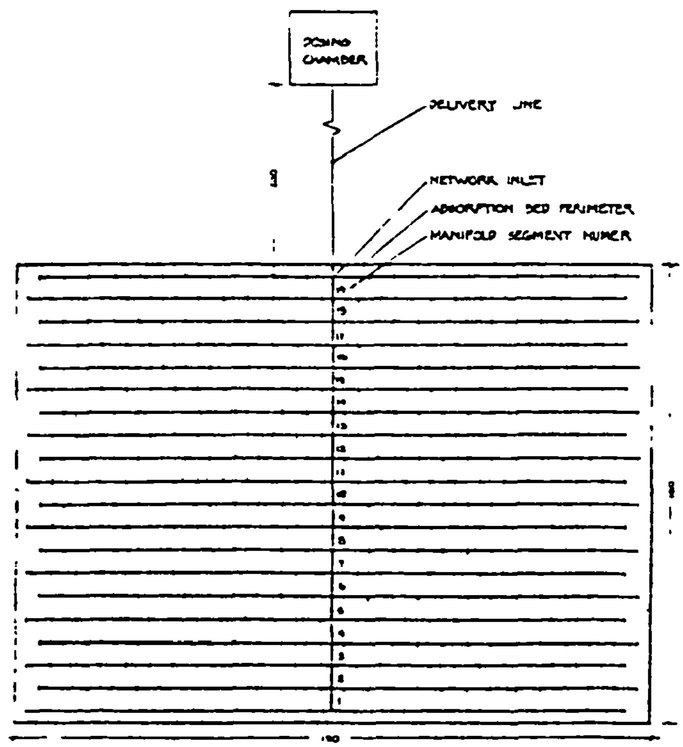
Step 10: Size the dosing chamber

Since only one pump is to be used, a reserve volume equal to one day's average flow is necessary in case of pump failure. Therefore, a volume of 280 gal (dose volume) + 250 gal (average daily flow) or 530 gal must be provided between the pump off switch and the dosing chamber inlet invert. (The high water alarm switch is located just above the pump on switch.)

2. <u>Pressure Distribution: Large Bed</u>

Step 1: Layout network

A central manifold configuration is selected as shown below.



Network Layout for Large Bed System (Problem 2)

Step 2: Select perforation size and spacing

Perforations are to be 3/8-in diameter spaced 5 ft apart. The perforations are to be staggered between laterals to provide more uniform distribution (See figure).

Step 3: Select lateral diameter

From Table III. C-4: 2-in laterals required

Step 4: Calculate the lateral discharge rate

A minimum in-line pressure of 2 ft is used. From Table III. C-1:

Perforation Discharge Rate = 2.34 gpm

$$\text{Perforations/lateral} = \frac{65}{5} = 13$$

Lateral Discharge Rate = 13 x 2.34 gpm = 30 gpm/lateral

Step 5: Calculate Manifold size

This network is too large to determine the manifold size from Table III. C-2. Therefore, the F_i values are calculated.

$$\text{Number of Manifold Segments} = \frac{100}{5\text{ ft}} - 1 = 19 \text{ segments}$$

Results of Calculations to Determine Manifold Segment Diameters

Segment No.	Q_i (gpm)	F_i	ΣF_i	D_m (in)	Segment No.	Q_i (gpm)	F_i	ΣF_i	D_m (in)
1	60[a]	1 91	1.91		11	660	161.2	704.99	
2	120	6.88	8.79	4.98[b]	12	720	189.4	894.39	9.02
3	180	11.57	23.36		13	780	224.9	1119.29	
4	240	24.81	48.17	6.15	14	840	251.9	1371.19	9.55
5	300	37.49	85 66		15	900	286.1	1657.29	
6	360	52.53	138.19	7.05	16	960	322.4	1979 59	10.04
7	420	69.86	208.05		17	1020	360.9	2340.59	
8	480	89 44	297 49	7.80	18	1080	401.1	2741.59	10.48
9	540	111.2	408.19		19	1140	443.2	3184.89	10.70
10	600	135.1	543.79	8.44	Inlet	1200	-	-	-

[a] 2 laterals x 30 gpm/lateral

[b] From manifold diameter equation (Step 5)

Allowing 0.1 h_d loss of head in the manifold, the necessary manifold diameter can be calculated.

$$D_M = \left[\frac{L \sum_{i=1}^{M} F_i}{0.1\ h_d}\right]^{0.21} = \left[\frac{5\ \text{ft} \times 3184.89}{0.1 \times 2\ \text{ft}}\right]^{0.21} = 10.7\text{-in or } 12\text{-in}$$

By this method, a 12-in manifold would be required.

A uniform sized manifold is not necessary. To save expense and to provide more uniform distribution by reducing the difference between lateral entrance losses, the manifold should be telescoped to smaller diameters downstream. The same method as above may be used to determine the proper diameters for each segment if the allowable headloss in the manifold is assumed to be linear along its length. Making this assumption, each segment may account for $(0.1 \div 19)h_d$ of the manifold function loss. Calculated diameters of the even numbered segments appear in the table. For example, the diameter for segment 2 is:

$$D_2 = \left[\frac{5\ \text{ft} \times 8.79}{2 \times \frac{0.1}{19} \times 2\ \text{ft}}\right]^{0.21} = 4.98\text{-in or } 6\text{-in}$$

From the table, the nominal manifold diameters are selected:

Manifold segments:		
	1-3	6-in
	4-8	8-in
	9-16	10-in
	16-19	12-in

Step 6: Determine dose volume

The crown of the manifold is to be located below the lateral elevation. A manual drain valve will be installed on the manifold to drain the manifold when the network is out of service. From Figure III. C-9:

Minimum Dose Volume = 10.5 gal/lateral x 40 laterals x (5 to 10)

= 2100 to 4200 gal/dose

From Table II. B-1:

$$\text{Required Dose Volume} = \frac{15{,}000\ \text{gpd}}{4\ \text{dose/day}} = 3750\ \text{gal}$$

This is satisfactory.

Step 7: Calculate the minimum discharge rate

Minimum Discharge Rate = 30 gpm/lateral x 40 laterals

= 1200 gpm

Step 8: Calculate total friction losses

Network Losses = 1.31 h_d = 1.31 x 2 ft = 2.62 ft

$$\text{Delivery Losses (200 ft of 12-in)} = 200 \text{ ft} \times \left[\frac{3.55 \times 1200 \text{ gpm}}{150 \times (12\text{-in})^{263}}\right]^{185}$$

$$= 0.55 \text{ ft}$$

Step 9: Select pressurization unit

A 12-in siphon with a manufacturer's average discharge rating of 1200 gpm is selected. The discharge invert must be elevated a minimum of 3.2 ft above the lateral inverts.

Step 10: Size the dosing chamber

A dosing volume of 3750 gal is to be used. The siphon has a 30-in draw. No reserve volume is necessary since the sipon has an overflow.

3. <u>Pressure Distribution: Sloping Site</u>

Step 1: Layout network

A layout as shown in the figure is to conform to the trench layout.

Step 2: Select the perforation size and spacing

Because the static heads in the laterals in each trench will vary, either the perforation diameter or the perforation spacing must be changed to maintain uniform application of effluent to each of the infiltrative surfaces. It is most practical to change the spacing, since the perforation diameters normally can only change by nominal drill bit sizes.

A perforation diameter of 1/4-in is selected with a maximum spacing of 5 ft. Since the lateral at the lowest elevation will have the highest perforation discharge rate due to the greater static head, the maximum spacing is to be used in this lateral.

To determine the spacing for the remaining laterals, it is necessary to compute the fraction of the dosage rate that is directed into each lateral to provide uniform distribution. Knowing this and the in-line pressure, the perforation discharge rates can be determined for each lateral and thence, the perforation spacing.

To calculate the lateral discharge rates, the discharge rate of the lowest lateral must be calculated first based on the perforation diameter and spacing selected. To do this, a minimum in-line pressure in the uppermost lateral must be selected. Then the minimum in-line pressure in the lowermost lateral is equal to the minimum in-line pressure in the uppermost lateral plus the elevation difference between the two laterals less the upstream manifold losses. Therefore, in Lateral 1:

$$\text{Minimum In-line Pressure} = 2.5 + (875.5 - 873.5) - (\frac{4}{4} \times 0.1) \times (2.5) = 4.75 \text{ ft}$$

From the perforation discharge equation:

$$\text{Perforation Discharge Rate} = 11.79\ (1/4\text{-in})^2\ (4.75\text{ ft})^{1/2} = 1.60 \text{ gpm}$$

$$\text{Lateral Discharge Rate} = \frac{75\text{ ft}}{5\text{ ft}} \times 1.6 \text{ gpm} = 24 \text{ gpm}$$

Knowing that the ratio of the lateral discharge rates to the total trench loading in each trench must be equal to maintain uniform distribution, the remaining lateral discharge rates, in-line pressures and perforation discharge rates can be calculated (See accompanying table). The perforation spacing is determined by first dividing the lateral discharge rate by the perforation discharge rate to obtain the number of perforations per lateral and then dividing this into the trench length. The accompanying table presents the results of these calculations.

Step 3: Select lateral diameter

Figure III. C-2 is used to select the later diameter. The diameters obtained appear in the table. To reduce the number of different pipe diameters, larger nominal diameters ultimately may be chosen. For instance, laterals 1 through 4 could be 1 1/2-in pipe.

Step 4: Calculate the lateral discharge rate

This was done in Step 2. See the table.

Step 5: Calculate manifold size

The manifold is to be a uniform diameter throughout.

Manifold length = 4 segments x 10 ft = 40 ft

Since the lateral discharge rates vary, F_i must be computed for each segment.

$$F_i = 9.8 \times 10^{-4} Q_i^{1.85}$$

Manifold Segment	Q_i	F_i
1	24 gpm	0.35
2	40 gpm	0.90
3	64 gpm	2.15
4	99 gpm	4.82
	Total	8.22

$$D_M = \left[\frac{\sum_{i=1}^{M} L_i \; F_i}{f \; h_d} \right]^{0.21} = \left[\frac{10 \text{ ft} \times 8.22}{0.1 \times 2.5 \text{ ft}} \right]^{0.21}$$

= 3.38 in => 4-in

- Step 6: Determine dose volume

Since the manifold must fill entirely before the upper laterals are filled, the lateral and manifold pipe volume must be included in the calculation of the minimum dose volume. Figure III. C-9 is used to make this calculation.

Lateral Volume:	275 ft of 1 1/2-in	=	26 gal
	75 ft of 2-in	=	12
	50 ft of 1-in	=	2
Manifold Volume:	40 ft of 4-in	=	26
			66 gal

Five to 10 times the pipe volume gives a minimum dose volume of 330 to 660 gal/dose equal to about 1 dose per day. If a 330 gal dose is used, at average daily flow 1 dose will occur every 1 1/2 days. This is satisfactory.

Determination of Lateral Diameters on a Sloping Site (Problem 3)

Lateral No	Trench Length (ft)	Trench Width (ft)	Loading Rate, (gpd/ft^2)	Trench Loading (gpd)	% Total Loading	In-Line Pressure (ft)	Perforation Diameter (in)	Perforation Discharge Rate (gpm)	Lateral Discharge Rate (gpm)	No. Perforations	Perforation Spacing (ft)	Lateral Length (ft)	Lateral Diameter (in)
1	75	3	0.5	112.5[a]	18 8[b]	4 75	1/4	1 69	24	15	5 0	72.5	1 1/2
2	50	3	0.5	75.0	12.5	4.31	1/4	1 53	16[c]	10[d]	5.0[e]	47 5[f]	1 1/4
3	75	3	0.5	112.5	18.8	3.88	1/4	1 45	24	17	4.4	72.8	1 1/2
4	75	3	0.5	112 5	18 8	3.44	1/4	1.37	24	18	4.2	72.9	1 1/4
5	35	3	0.5	52.5	8.8	3 44	1/4	1 37	11	8	4.4	32.8	1
6	75	3	0.5	112 5	18.8	2.50	1/4	1.17	24	21	3.5	73.3	2
7	15	3	0.5	22.5	3.8	2.50	1/4	1.17	5	4	3.8	13.1	1
Total	400	-	-	600	100 3	-	-	-	128	-	-	-	

[a] 75 ft x 3 ft x 0.5 gpd/ft^2 = 112.5 gpd

[b] (112/5 ÷ 600) x 100 = 18.8%

[c] (24 ÷ 18 8) x 12 5 = 16 gpm

[d] 16 ÷ 1 53 = 10 perforations

[e] 50 ÷ 10 = 5 ft

[f] 50 - (5 ÷ 2) = 47.5 ft

Step 7: Calculate the minimum discharge rate

This is the sum of the lateral discharge rates equal to 128 gpm from the table.

Step 8: Calculate total friction losses

Network losses = 1.31 x 2.5 ft = 3.3 ft

$$\text{Delivery losses} = L_d \left[\frac{3.55\ Q_M}{C_h\ D_d^{2.63}} \right]^{1.85}$$

$$= 20\ \text{ft} \left[\frac{3.55 \times 128\ \text{gpm}}{150 \times 4\text{-in}^{2.63}} \right]^{1.85} = 0.2\ \text{ft}$$

Total losses = Network losses + Delivery losses

= 3.3 ft + 0.2 ft = 3.5 ft

Step 9: Select pressurization unit

In this case, a siphon can be used. It would be selected on the basis of the average rated discharge. The discharge invert would be set at a minimum of 3.5 ft above the uppermost lateral invert.

Step 10: Size the dosing chamber

The draw of the siphon and size of the dose selected, 330 gal, is sufficient to size the dosing chamber.