AT-GRADE SYSTEMS FOR ON-SITE WASTEWATER TREATMENT AND DISPERSAL

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The Wisconsin at-grade soil absorption system was developed in the early 1980s for sites that were not suitable for in-ground trenches/bed and exceeded requirements for mounds. The "Wisconsin At-grade Soil Absorption System Siting, Design and Construction Manual, known as the at-grade manual, serves as the basic siting, design and construction manual for at-grade units (Converse et al. 1990). It has been accepted and used in a number of states. Due to its site limitations it is not as versatile as the mound or in-ground system. Fig. 1 shows a schematic of the at-grade unit. Care must be taken in making modifications to the at-grade unit so as to minimize failures. All three factors, siting, design and construction principles must be closely adhered to so as to minimize the risk of system failure. The on-site professional, i.e., the soil evaluator, designer, installer and inspector, must understand the principles of operation of the at-grade system before an attempt is made to site, design and install it. Operational and management must also be an integral part of the equation.

The purpose of this paper is to provide information on the siting, design and construction concepts of the at-grade. **The reader should obtain a copy of the 1990 At-Grade Manual[2] for a complete discussion on siting, design and construction.**

Figure 1 shows the components of the at-grade system. The system consists of a septic tank and the at-grade unit. A pump chamber is included if pressure dosing is required. If gravity flow is used, a distribution box should be placed in the up slope portion of the unit to provide at least 3 drop points along the length of the unit.

Fig. 2 shows the landscape location of the at-grade unit in relation in-ground trenches/beds and mound systems.

PRETREATMENT UNIT

The septic tank serves as the pretreatment unit for the at-grade unit. Converse (1999) discusses several options for septic tank/pump chamber combinations. If gravity flow is the option, then a single compartment or double compartment septic tank with an effluent filter is sufficient. If

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[2] The Wisconsin at-grade manual and related publications can be obtained from SSWMP, University of Wisconsin-Madison, 1525 Observatory Drive, Room 345. 608-265-6595. A publication list is available upon request at no cost. There is a small charge to cover copying and mailing. It can also be ordered over the web at hppt://www.wisc.edu/sswmp.

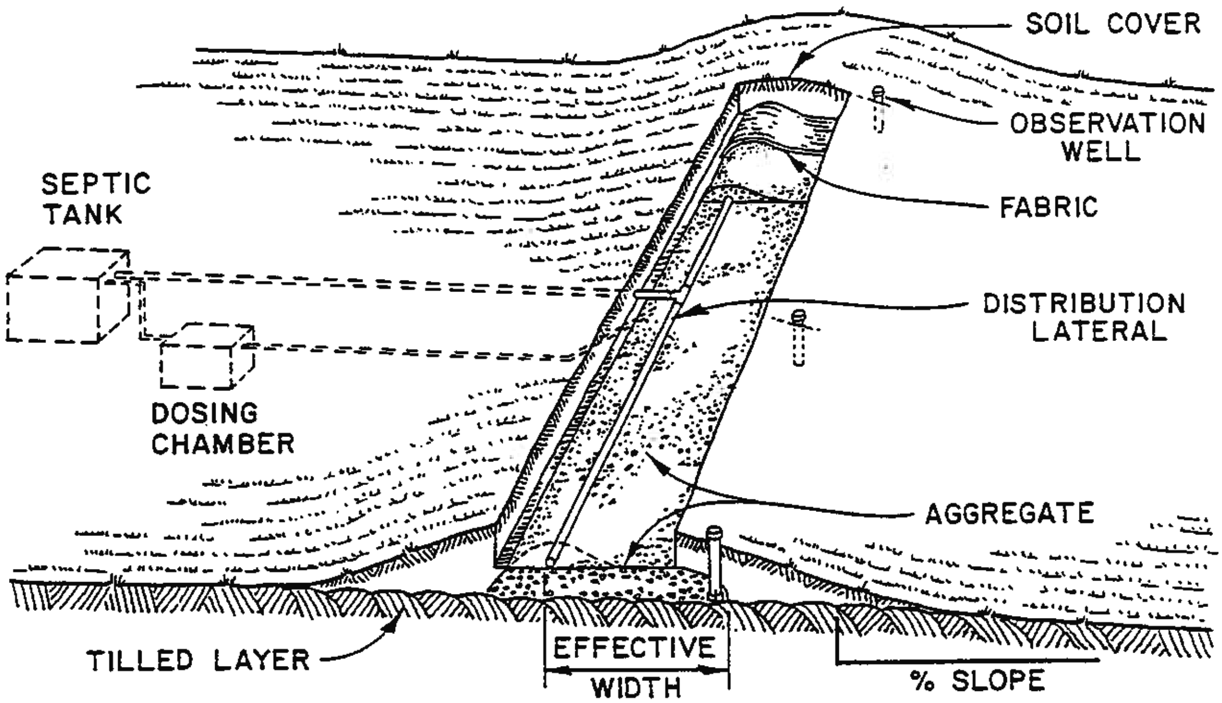

Fig. 1. Schematic of the at-grade soil absorption system. Note that both pressure distribution and gravity flow distribution are shown. In actual practice, only one will be installed (Converse et al. 1990).

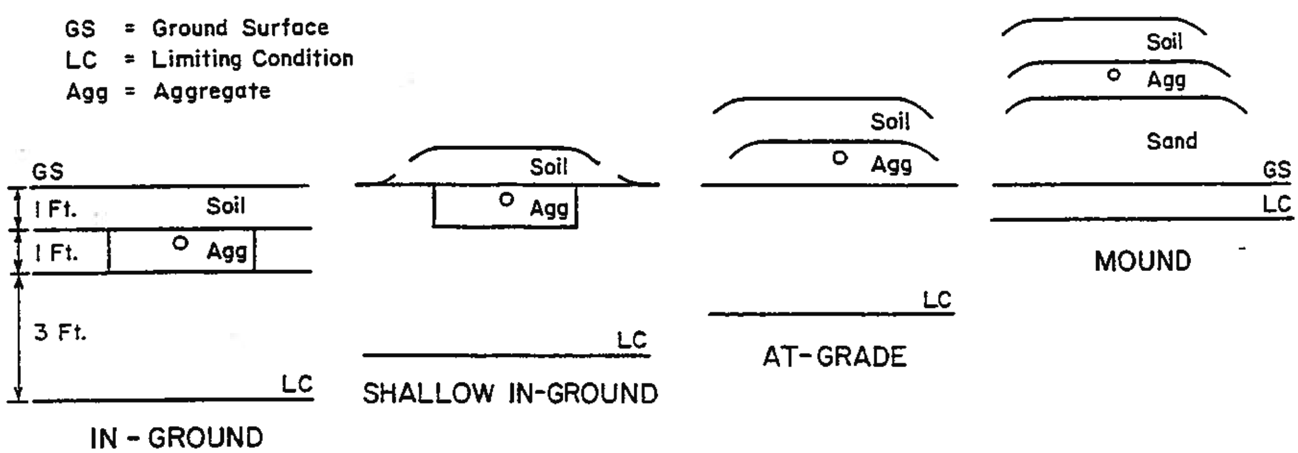

Fig. 2. Cross section of 4 soil absorption units shown in relation to ground surface and limiting conditions.

pressure distribution is the choice, then the following options may be considered.

1. A single compartment septic tank with effluent filter followed by a single compartment pump chamber.

2. A double compartment tank with the first compartment containing the effluent filter serving as the septic tank and the second compartment serving as the pump chamber.

3. A double compartment tank with both compartments serving as a septic tank with an effluent filter at the outlet of the second compartment, followed by a single compartment pump chamber. This may be the desired alternative as an "aerated baffle", known as the Nibbler Jr. (NCS, 1998) could be placed in the second compartment to reduce the organic matter if the at-grade unit ever fails due to breakout of effluent. The conversion would be minimal.

4. A single compartment tank with a pump vault within the septic tank. The effluent filter is incorporated in the pump vault that suspends from the outlet of the septic tank. An alternative is a double compartment tank with a hole in the center of the dividing wall to connect the two compartments together in the clear zone and the pump vault in the second compartment.

Demand dosing versus timed dosing for pressure distribution units.

Recent research on single pass sand filters shows that short frequent doses to the sand filter improves effluent quality (Darby et al., 1996). Short frequent doses require time dosing instead of demand dosing. Most at-grades are demand dosed where a large quantity of effluent is discharged into the mound. This large quantity of effluent moves through the sand rapidly (assuming no ponded condition), allowing insufficient time for the biota to totally treat the effluent. This forces fecals and pathogens further into the soil profile. Short frequent doses allows the effluent to be retained in the sand/soil for longer periods. Converse et al. (1991) showed some fecals found deep in the soil profile beneath at-grades. It may have been due to large infrequent doses. **Designers must consider using smaller doses when using demand dosing and they may want to consider timed dosing in distributing the effluent to the at-grade.** Timed dosing requires that surge capacity be incorporated into the septic tank and/or pump chamber to store the peak flows until it is dosed into the mound. Timed dosing also requires control panels which have become very user friendly. Converse (1999) discusses the various options in more detail including pump vaults, effluent filters and time/demand dosing.

SITING CRITERIA

A designer must have a basic understanding of wastewater movement into and through the soil especially on more difficult sites. Typically the sites are not as difficult for at-grades as they are for mounds as there is a greater distance from the ground surface to the limiting condition such as bedrock or saturation. If the code separation distance is less than 3 ft, then the difficulty becomes greater. However, there may be other characteristics such as soil banding that may be a factor in selecting at-grades over in-ground trench/bed units. Fig. 3 shows a schematic of effluent movement away from the at-grade under various soil profiles. Depending on the type of profile, the effluent moves away from the unit vertically, horizontally or a combination of both. These concepts are true for all on-site systems. Fig. 3a, (top figure) shows the movement primarily vertical where the soil is very permeable or crevice bedrock is present that allows for vertical movement. Fig. 3b shows a high seasonal or permanent water table. When the effluent reaches the saturated condition, it is forced horizontally as all the soil pores are full of water. Fig. 3c shows a semi-permeable condition beneath the surface. As the effluent reaches the semi-permeable area, it forces some of the effluent to move horizontally with some of it moving vertically until it reaches a point where it all moves vertically. Fig. 3d shows an impermeable layer beneath the surface. As the effluent reaches the impermeable area, it forces the effluent to move horizontally. Undoubtably, there will be some leaks in the restrictive layer with effluent moving downward. These conditions affect how the at-grade is configured. The designer must predict the direction and rate of movement or the design may be flawed resulting in treated effluent breaking out on the ground surface. The prediction is based on soil and site information obtained during site evaluation and experience.

The sizing and configuration of all soil absorption units , including at-grades, is based on how the effluent moves away from the unit and the rate at which it moves away.

Soil and Site Limitations:

Table 1 gives the soil and site criteria for Wisconsin at-grade systems used in Wisconsin. These distances may vary depending on code requirements in other areas. The separation distance for all soil based units receiving septic tank effluent is 3 ft. If the requirement were 4 ft than 4 ft would be used in Table 1.

Soil Loading Rates:

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). Evaluation of the soil profile to a depth of 3 ft must be done. If a restrictive horizon is encountered, the tendency is to use the loading rate for the more restrictive horizon which results in an enlarged aggregate area. At the same time the linear loading rate must be appropriately selected otherwise toe leakage may occur. **The configuration of the at-grade must fit the soil profile with the soil loading rate and the linear loading rate matching the soil profile.**

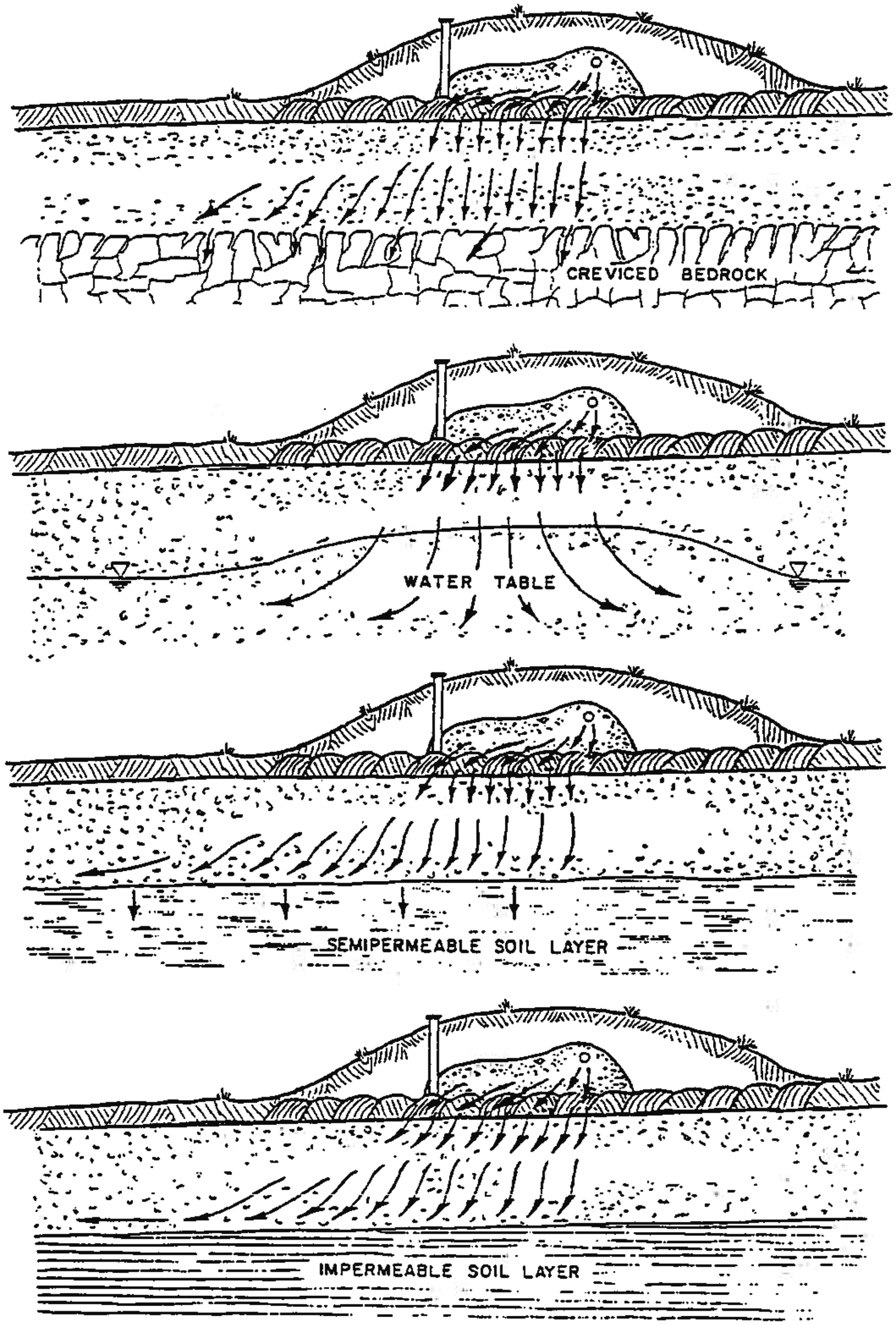

Fig. 3. Effluent movement away from the at-grade units under four different soil profile conditions (Converse et al. 1990).

Table 1. Soil and site criteria for the Wisconsin at-grade system used in Wisconsin (Converse et al. 1990).

Parameter	Limits
Depth from surface to high water[a]	3 ft
Depth from surface to bedrock	3 ft
Surface slope[b]	<25%
Soil permeability	c
Flood Plain	No

[a] Seasonal saturation is estimated by mottles.

[b] Slopes limited due to construction. Some systems have been placed on steeper slopes. Slopes > 15% must incorporate pressure distribution.

[c] The soil permeability is estimated using soil texture, structure and consistence. Soil permeability limits for at-grades will be similar to in-ground trenches/beds.

DESIGN PRINCIPLES

System Configuration:

The system configuration must meet the soil site criteria and fit on the site. As with all soil absorption units, they should be long and narrow (Tyler and Converse, 1985; Converse and Tyler, 1986). 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. If there is a restrictive layer such as soil banding, hard pan, platy structure or high water table, the flow may be primarily horizontal and thus the design long and narrow. If there is no restrictive layer, then the flow will be vertical and the effective width of the system may be greater. It is difficult to determine the exact effective width of the system. A system that is too wide may leak at the down slope toe or either toe on level sites. Other factors such as gas transfer and exchange beneath the absorption area 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 length along the slope, then it may be possible to stack them up the slope sufficiently apart so the up slope unit does not impact the down slope unit (Converse et al. 1990). Fig. 4 shows a cross section and plan view of an at-grade unit on a sloping site.

Effective Absorption Area:

The effective absorption area is that which is available to accept effluent (Fig. 4). The effective length is the actual length of the aggregate along the contour. The effective width on sloping sites is the width from the distribution pipe to the toe of the aggregate and on level sites it is the

Table 2. Estimated wastewater design soil loading rates for the surface horizon based on soil morphological conditions for Wisconsin at-grade systems (Converse et al., 1990).

Soil condition in contact with the 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

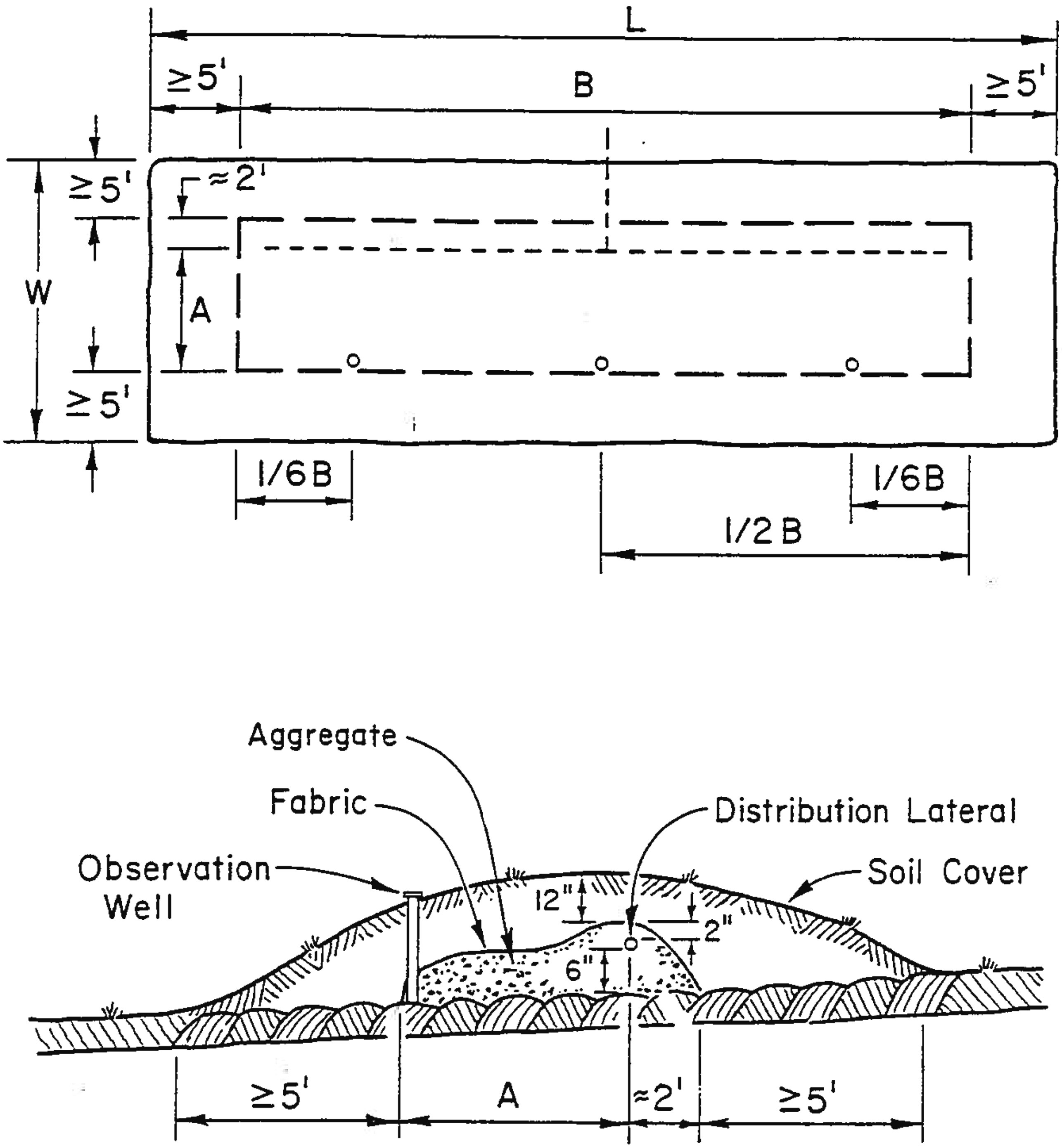

Fig. 4. Cross section and plan view of an at-grade unit on a sloping site (Converse et al, 1990)

width of the aggregate area. Table 2 is used to determine the area of the effective aggregate area and the linear loading rate determines the length and width of the effective area.

Linear Loading Rate:

The linear loading rate is defined as the amount of effluent (gallons) applied per day per linear foot of the system along the natural contour (gpd/lf). The design linear loading rate is a function of effluent movement rate away from the system and the direction of movement away from the system (horizontal, vertical or combination, Fig. 3). If the movement is primarily vertical (Fig. 3a), then the linear loading rate is not critical. If the movement is primarily horizontal (Fig. 3d), the linear loading rate is extremely important. Figure 5 illustrates the effect of linear loading rate on the configuration selected. Other factors such as gas transfer beneath the absorption area suggest that the absorption area width be relatively small (Tyler et al., 1986).

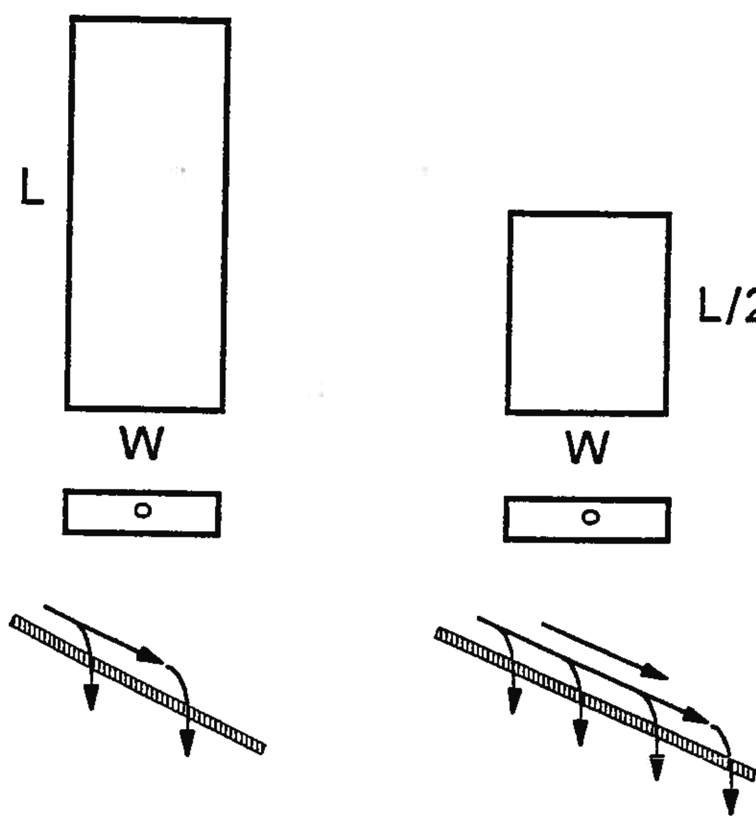

Fig. 5. The effect of linear loading rate based on system configuration on a sloping site. The sand or soil loading rates (gpd/ft^2) are the same but the linear loading rate for the right figure is twice that of the left figure. The soil may not be able to move the effluent away from the system fast enough resulting in back up and breakout at the mound toe.

It is somewhat difficult to estimate the linear loading rate for a variety of soil and flow conditions but based on the authors' experience "good estimates" can be given. If the flow is primarily vertical (Fig. 3a), then the linear loading rate can be high but should be limited to a range of 8-10 gpd/lf otherwise the absorption area is excessively wide, especially if the soil absorption unit is in the slower permeable soils such as silt loams. If the flow is primarily horizontal because of a shallow restrictive layer or limiting condition such as seasonal saturation or bedrock (Fig. 3d) then the linear loading rate should be approximately 3 gpd/lf, resulting in long and narrow systems. Converse (1998) gives a more detailed explanation and provides two examples of estimating linear loading rate.

Total Length and Width:

It is necessary to add about 5 ft to each end and sides to tie the system to the existing soil surface with the soil cover. These widths can be greater than this. Thus, the total length is sum of the aggregate length plus 10 ft and the width is the effective width, the aggregate up slope of the distribution lateral plus 10 ft (Fig. 4).

Distribution Network:

The at-grade unit can be designed for either gravity or pressure distribution. Pressure distribution requires a pump tank with added costs but it does spread the effluent along the length of the unit and utilizes the total effective area of the aggregate. **Pressure distribution is the preferred and recommended method of distribution.** Fig. 6 shows the typical distribution pattern for pressure and gravity utilizing a distribution box up slope. Gravity distribution should be used in conjunction with a distribution box so the flow can be directed to at least 3 drop points along the length of the unit. Converse et al. (1990) show distribution patterns for level sites and provides a detailed discussion relative to pressure and gravity distribution.

Observation Tubes:

Observation tubes, extending from the aggregate/soil interface to or above final grade, are placed in the absorption area to provide easy access for observing ponding in the aggregate. On sloping sites the tubes are placed at the 1/4 and 3/4 points along the contour at the toe of the aggregate. The tube must be perforated along the bottom 6" of the side wall and secured using a toilet flange, tee or reinforcing rods (Converse et al., 1990).

Cover:

A geotextile synthetic fabric is placed on the aggregate. Approximately 8 - 12" of soil cover is placed over the aggregate extending at least 5 ft beyond the edge of the aggregate. The cover should support vegetation. Erosion protection must be implemented before a vegetative cover is established.

Pressure distribution using a single line on a sloping site

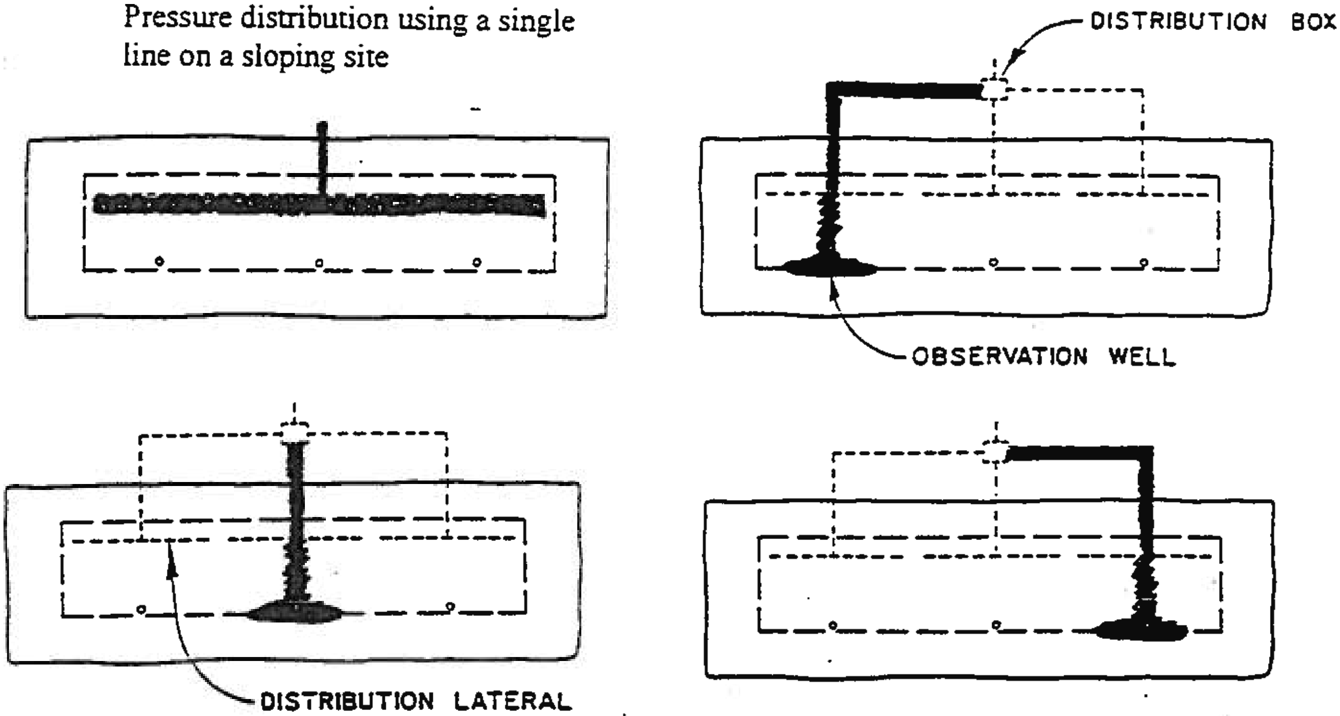

Fig. 6. Typical distribution patterns for pressure distribution (top left) and gravity flow with a distribution box with 3 drop points on sloping sites. Distribution box should sit in the upslope edge of at-grade (Converse et. al., 1990).

DESIGN EXAMPLE

Design an on-site system based on the following soil profile description (modified from Converse et al., 1990).

Site Criteria

1. Soil profile is- Summary of 3 soil pit evaluations.

0 - 12"	Sil; 10YR 6/4&2/1; moderate, medium, subangular blocky structure; friable consistence.
12 - 36"	Sicl; 5YR 3/1; moderate, fine subangular blocky structure; firm consistence
36+"	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 170 ft and along the slope it is 30 ft.

4. Design is for a 3 bedroom house.

It appears that an at-grade system is suited for this site because the estimated saturation is at 36", the surface horizon is permeable and code setback requirements are assumed to be satisfied.

Step

1. **Determine the design flow rate (DFR).**

   Since this is a 3 bedroom home, use 150 gpd/bedroom.

   DFR = 3 br x 150 gpd/br
   = 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 gpd/ft^2

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

   Evaluate the soil profile to estimate the linear loading rate.

   The silt loam surface (A) horizon (0-12") is relatively permeable because of the texture, structure and consistence. The effluent flow will be vertically down through the aggregate, horizontally along the soil surface and vertically into the soil.

   The silty clay loam (E) horizon (12 - 36") has a moderate structure and firm consistence. Table 2 indicates that it can be loaded at 0.4 gpd/ft^2 which is less than the 0.6 gpd/ft^2 for the upper horizon. The consistence is firm which means the flow will be slightly restricted compared to friable. Thus, as the effluent moves downward through the (A) horizon, it will be slowed up because of the texture, structure and consistence change and be forced to move horizontally as effluent moves vertically.

   The silty clay loam (C) horizon (36+") has a strong medium platy to massive structure with very firm consistence. As the effluent from the (E) horizon approaches this horizon, the vertical flow of the effluent is considerably slowed. Effluent moves more slowly through silty clay. The massive nature of the soil slows up flow and the very firm consistence also slows up the flow. The platy structure directs the flow horizontally. Thus most of the flow will be going in the horizontal direction with some vertical movement. Fig. 3c depicts this site. There is approximately 30 - 36" of suitable soil for the effluent to move horizontally away from this site. Thus a linear loading rate of 5 or 6 would be appropriate for this site.

Linear Loading Rate = 5 gpd/lf.

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

A = LLR / SLR

= 5 gpd/ft / 0.6 gpd/ft^2
= 8.33 ft

5. Determine the effective absorption length (B) for the unit.

B = DFR / LLR

= 450 gpd / 5 gpd/ft
= 90 ft

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. In this case there is 170 ft along the contour so this unit can be placed on the contour. A linear loading rate of 4.0 would give an an effective absorption length of 113 ft which would also fit on the site.

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

Add a minimum of 5 ft of soil on both ends and sides.

L = B + 2 end slopes

= 90 ft + 2(5) = 100 ft

W = A + up slope width of aggregate (C) + soil cover side widths
= 8.33' + 2' (estimated) + 2 x 5'
= 20.3' or 21 ft

To add an additional factor of safety, B could be easily increase since length along the contour is available.

8. Determine the height of the unit.

Use a minimum of 6" of aggregate beneath the distribution pipe, and about 2" above the pipe and 8-12" of soil over the aggregate. Place geotextile fabric over the aggregate. The height will be

H = 6" + 2" + 2" + 10"
= ~ 20"

9. Design a distribution network for the site.

A pressure distribution network design includes the distribution piping, dosing chamber and pump. A design example is available through Converse et al.(1990). The following points should be considered. Otis (1981) provides a design procedure.

- Since the absorption area is relatively narrow and on a slope, a single distribution line along the length is satisfactory. It would be located 8.3 ft up slope of the aggregate toe. Another approach would be to use two lines with center feed with one line located at 4.1 ft up slope and one line located 8.3 ft up slope of the down slope toe. If a single line is used place the orifices about 12" apart since the width is about 8 ft. On the two line network, stagger the orifices with 2 ft spacing.

- Consider using 3/16" holes instead of 1/4" holes with an effluent filter on the line. Data is available for 3/16" hole spacing but not in Converse et al. (1990).

- Timed dosing to the at-grade which requires surge capacity in the septic tank/pump chamber. However, most at-grades will continue to be demand dosed. In both cases the dose volume should be much less than previously recommended with not more than 5 times the void volume of the laterals. For example if the void volume of the laterals within the distribution network was 7 gallons, the dose volume would be 35 gpdose net. The total dose would be 35 gal. plus the flow back of the force main and manifold.

- **Provide easy access to flush the laterals such as turn-ups at end of laterals.**

CONSTRUCTION

Proper construction is very important. The following steps should be followed when constructing the at-grade units (Converse et al., 1990). There are variations to this approach but the principles should be followed.

Steps

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

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

3. Check for proper soil moisture prior to construction. For single grain soil, 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. Determine where the force main from the pump chamber enters the at-grade unit. It will either be an end feed or an center feed. For long units, center feed is preferred. For center feed the force main can enter from the up slope center or the down slope center. If it be brought in from the down slope side, especially on slowly permeable soils where the effluent flow may be horizontal, it should be brought in perpendicular to the side of the unit with minimal disturbance to the down slope area. All vehicular traffic must be kept in a very narrow corridor. Minimal damage is done if the soil is dry. Soil should be packed around the pipe and anti-seep collars should be installed to minimize effluent and water following the pipe. Entering from the down slope center should be the last choice on sites that are slowly permeable with shallow seasonal saturation. Placement of the pipe can be done after tilling but extreme care must be taken not to disturb the tilled area.

5. Till the area following the contour to a depth of 6 - 8". 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. Chisel teeth mounded on a backhoe is the preferred method and 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, on single grain soils, such as sand. The backhoe bucket has been used but not recommended. It requires flipping the soil and much slower than chisel plowing.

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

6. Place observation tubes at the 1/6, ½ and 5/6 points along the toe of the aggregate area.. The tubes must be placed so that ponded effluent at the down slope edge of the aggregate may be observed in the tubes. Stabilize the tubes.

7. Place the aggregate in the designated area of the tilled area to a 6 in. depth. **Work from the up slope side and avoid compaction along the down slope side especially if the effluent moves horizontally away from the unit.**

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

9. Place geotextile synthetic fabric over the aggregate. Extend it only to the edge of the aggregate.

10. Place 8-12" of soil over the fabric and taper it to a distance of at least 5 ft in all directions from the aggregate. Finish grading around the system to divert surface water away. Seed and mulch the exposed areas immediately after construction to control erosion.

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