CHAPTER 5: OTHER INFILTRATION DEVICES

The following infiltration practices may be implemented for very small drainage areas, such as a single residence, a parking lot, or a commercial building. As with retention basins, infiltration capacity and runoff volume are the two primary components in the design. These practices can be implemented in the "upland " areas to reduce stormwater runoff quantity and improve quality, by removing stormwater from the surface water regime and putting it into the sub-surface or groundwater regime.

INFILTRATION TRENCHES AND DRY WELLS

These two devices are very similar in that they consist of a hole in the ground that is filled with coarse aggregate, and then covered with a pervious layer of soil. The purpose of these methods, is to direct the runoff to the infiltration area, where it will "soak into" the ground.

The dry well is used primarily to retain runoff from residential and commercial rooftops (Fig. 5.1). Infiltration trenches are used to capture runoff from streets and parking lots (Fig. 5.2).

Two primary criteria for determining if a particular site is suitable for an infiltration trench or dry well, is the same as they are for retention basins.

1. **Seasonal high groundwater and bedrock are at least 4 feet below the bottom of the trench/dry well.**

2. **Infiltration capacity of the soil is at least 0.52 inches/hour, 4×10^{-4} cm/sec** (U.S. Soil Conservation Service soil classification group A or B).

If either of these two criteria is not met, an infiltration method should not be used at the site.

There are various in-depth methods that have been developed to determine the size of an infiltration trench (reference 41). However, instead of going into a detailed analysis, the following estimate is provided.

As a minimum, provide storage volume equal to 0.5 inches of runoff per acre of impervious surface.

EXAMPLE 5.1: An infiltration trench is to capture 0.5 inches of runoff from a 1 acre parking lot, determine the trench dimensions.

1. The volume of runoff from the 1-acre parking lot is determined by:

   1 acre x 43560 sq. ft./acres x 0.5 inch x 1 ft./12 inch = **1815 cubic feet**

2. The storage volume available in the trench does not include the aggregate backfill. The volume of the trench can be estimated by:

$$V_{tr} = V_{ro} / 0.4 \qquad (10)$$

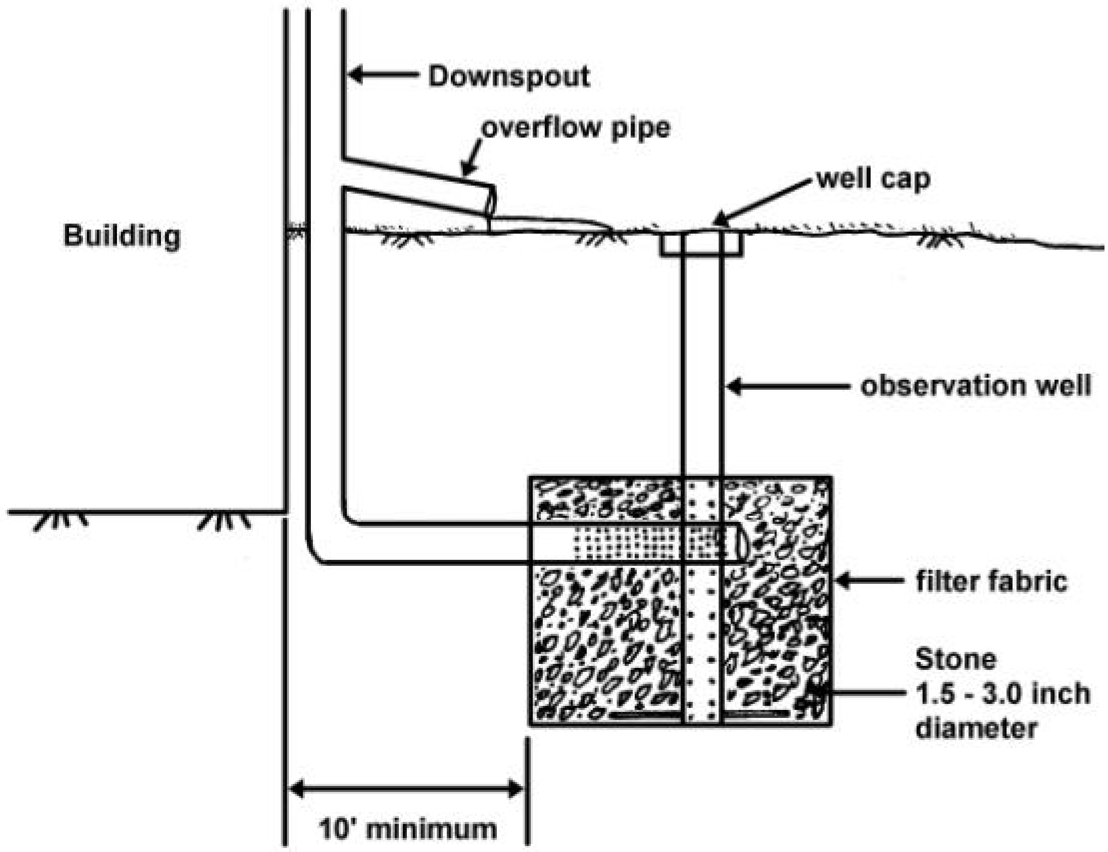


Figure 5.1 - Typical Drywell

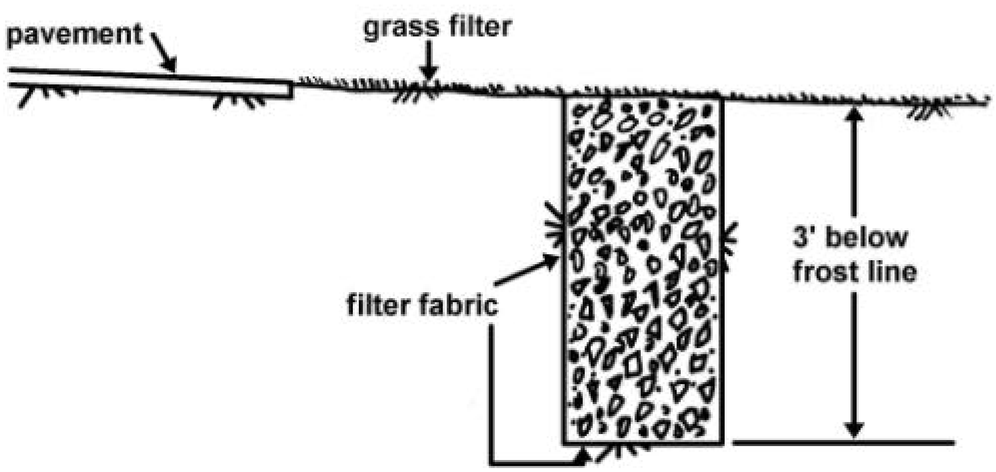


Figure 5.2 - Infiltration Trench

(adopted from reference 38)

where: **V_{tr}** - total volume of trench
V_{ro} - total volume of runoff
0.4 - is the effective porosity, to account for the volume occupied by the aggregate

The total volume of the trench would be estimated using equation (10):

V_{tr} = 1815 cubic feet / 0.4 = **4540 cubic feet**

3. If the trench is 6 feet wide and 4 feet deep, the required length of the trench should be:

$$L_{tr} = V_{tr} \;/\; w \times d \qquad (11)$$

where: **L_{tr}** - length of trench
V_{tr} - volume of trench
w - width of trench
d - depth of trench

L_{tr} = 4540 cu.ft. / (4 ft. x 6 ft.) = **190 ft**

Following are some guidelines for designing infiltration trenches:

1. Infiltration rate of the soil should exceed .52 inches per hour.
2. The bottom of the trench should be at least four feet above the seasonal high groundwater.
3. The trench should be backfilled with washed aggregate, 1-1/2 to 3 inch in diameter. If fine material is used, the voids in the aggregate will be reduced, which will reduce the storage capacity in the trench. Better pollutant removal can be achieved using a trench configuration that is broad and shallow, as opposed to being narrow and deep.)
4. Clogging of infiltration trenches by sediment is a primary mode of failure. Thus, **it is essential that either the sediment be controlled before it is picked up by runoff, or it is captured before it reaches the trench.** There should be a vegetative filter strip at least 20 feet wide between the runoff source and the trench.
5. Filter fabric (non-woven is recommended) must surround the backfill material. Without the filter fabric, the trench will become clogged with sediment, and it will be necessary to dig up the entire the trench. Filter fabric will make maintenance somewhat easier.
6. To accommodate flows that exceed the capacity of the infiltration trench, provide a non-erosive channel leading to a watercourse.
7. For infiltration trenches to work during freezing weather, it is suggested that the bottom of the trench be placed about 3 feet below the frost line. (Thus, in Michigan, such trenches would have to be extremely deep to be effective.)
8. Install an observation well in the trench to determine if the trench is functioning.
9. The bottom of the trenches should have a flat bottom (0% slope).

GRASSED (VEGETATED) SWALE

The most common practice of drainage is through the use of curb and gutter, or "drain enclosures," which allow the water to be carried away quickly, solving the drainage problem. However, as has been pointed out earlier, getting the water away quickly simply moves the problem to a downstream property owner or community and may not actually solve the problem. In addition, conveying runoff through drain enclosures has virtually no positive impact on water quality.

A grassed swale, to many, would be referred to as a "ditch." Ditches are something that property owners and drainage engineers have been trying to eliminate for years. However, in the past few years, it has been realized that there are water quality benefits to using swales in lieu of pipes or gutters. Grassed swales allow pollutants to be filtered out by the grasses while also allowing infiltration into the ground. As a result, pollutant loading can be reduced significantly through the use of grassed swales.

Various studies throughout the United States and Canada indicate significant reduction in runoff rates and pollutant loadings when grassed swales are used as opposed to pipes or gutters. However, the biggest obstacle to overcome when proposing a grassed swale is the general public's perception that grassed swales are "drainage problems," and "eye-sores."

The swale may require periodic maintenance to remove trapped sediments. The primary concern with swale maintenance is keeping good cover of grass, which may require periodic reseeding or sodding. Property owners adjacent to the swale should be educated in the function of the swale, as their actions may impact negatively on the swale's performance by keeping the grass too short or applying fertilizers and herbicides.

Figure 5.3 provides a sketch of a grassed swale, which has incorporated swale blocks. It would be desirable to configure the check dam in a "V" shape, to try to minimize the erosion at the ends of the check dam. The purpose of the swale block is to provide a "mini" in -line retention basin. The storage capacity behind the swale blocks is designed equal to the volume of runoff that is desired to be retained.

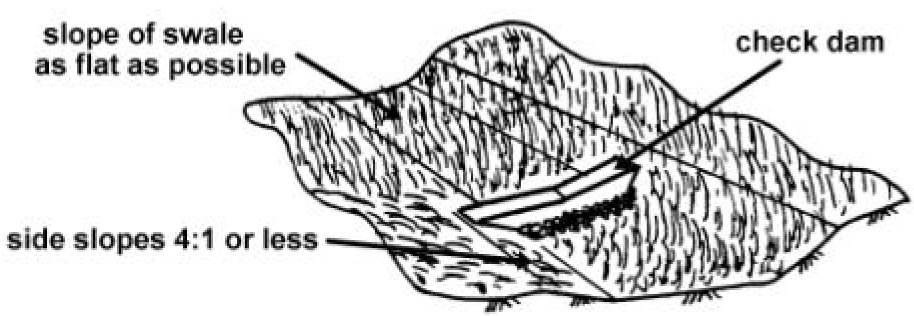
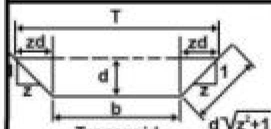
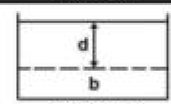
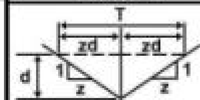
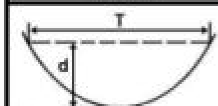
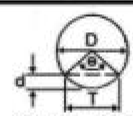
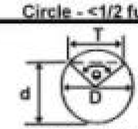


Figure 5.3 - Grassed Swale with Check Dam

Figure 5.4 provides a listing of area, wetted perimeter, and hydraulic radius for various swale shapes. Figure 5.5 provides an approximate method for computing the volume of storage behind swale blocks.

Section	Area a	Wetted Perimeter p	Hydraulic Radius r	Top Width T
 Trapezoid	$bd + zd^2$	$b + 2d\sqrt{z^2+1}$	$\frac{bd + zd^2}{b + 2d\sqrt{z^2+1}}$	$b + 2zd$
 Rectangle	bd	$b + 2d$	$\frac{bd}{b + 2d}$	b
 Triangle	zd^2	$2d\sqrt{z^2+1}$	$\frac{zd}{2\sqrt{z^2+1}}$	$2zd$
 Parabola	$\frac{2}{3}dT$	$T + \frac{8d^2}{3T}$ [1]	$\frac{2dT^2}{3T^2 + 8d^2}$ [1]	$\frac{3a}{2d}$
 Circle - <1/2 full [2]	$\frac{D^2}{8}\left(\frac{\pi\theta}{180} - \sin\theta\right)$	$\frac{\pi D\theta}{360}$	$\frac{45D}{\pi\theta}\left(\frac{\pi\theta}{180} - \sin\theta\right)$	$D\sin\frac{\theta}{2}$ or $2\sqrt{d(D-d)}$
 Circle ->1/2 full [3]	$\frac{D^2}{8}\left(2\pi - \frac{\pi\theta}{180} + \sin\theta\right)$	$\frac{\pi D(360 - \theta)}{360}$	$\frac{45D}{\pi(360-\theta)}\left(2\pi - \frac{\pi\theta}{180} + \sin\theta\right)$	$D\sin\frac{\theta}{2}$ or $2\sqrt{d(D-d)}$

[1] Satisfactory approximation for the interval $0 < \frac{d}{T} \leq 0.25$
When $\frac{d}{T} \geq 0.25$, use $p = \frac{1}{2}\sqrt{16d^2 + T^2} + \frac{T^2}{8d}\sinh^{-1}\frac{4d}{T}$

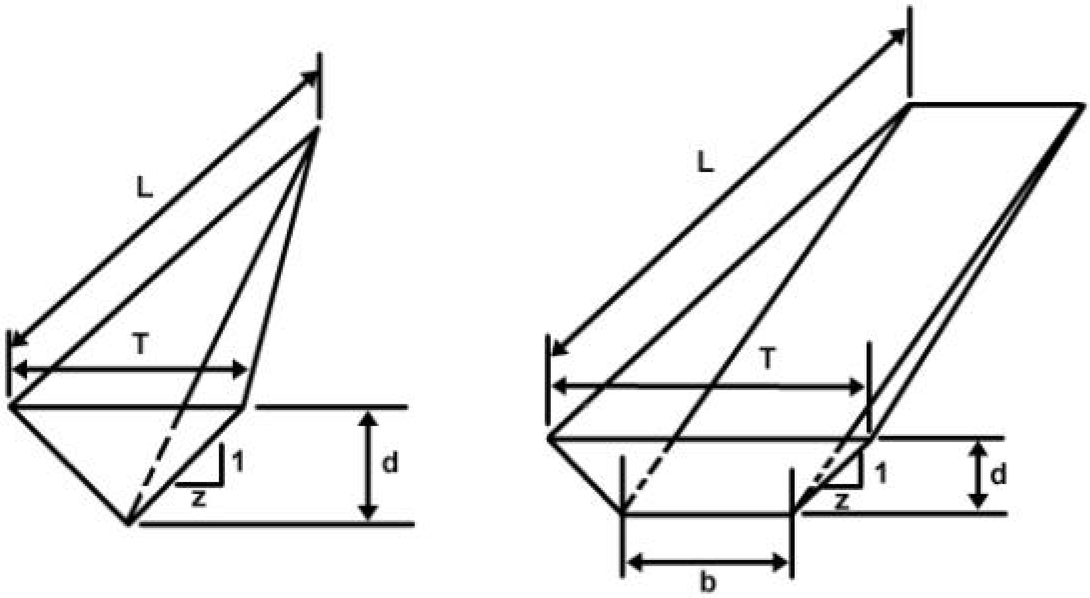
[2] $\theta = 4\sin^{-1}\sqrt{d/D}$
[3] $\theta = 4\cos^{-1}\sqrt{d/D}$
} Insert θ in degrees in above equations

REFERENCE

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H.H. Bennett, Chief
ENGINEERING STANDARDS UNIT

STANDARD DWG. NO.
ES - 33
SHEET 1 OF 1
DATE: 6-6-50
REVISED: 8-6-99

Figure 5.4 - Hydraulic Elements of Channel Sections



Triangular-Shaped Swale

Top width (T) = 2zd

Volume = $\frac{d^2 zL}{6}$

Trapezoidal-Shaped Swale

Top width (T) = b + 2zd

Volume = $(d^2\, zL)/3 + (dbL)/2$

Figure 5.5 - Estimated Volume of Storage Behind Swale Blocks

Example 5.2: Given: One-acre parcel that is 80% impervious. Design swale block spacing to retain 0.5 inch of runoff per acre of impervious surface from the parcel within the swale. The swale has a 4 -foot bottom width, and a side slope of 4:1(h:v), and a bottom sl ope of 0.005 feet/feet (.5%). In addition, the swale should be designed to carry the 2 -year flow which is estimated to be 30 cfs at this location. The roughness coefficient is taken to be 0.07.

Design the swale, and the swale block spacing.

1. **Estimate volume of runoff** from the parcel that is to be stored within the swale behind the swale block:

   Volume = 1 Acre x 43560 sq.ft/acre x 0.8 imp x 0.5/12 ft runoff = 1452 cubic feet

2. **Estimate volume available** behind the swale block, assuming a trapezoidal shape:

$$\text{Volume} = (dzL)/3 + (dbL)/2 \quad \text{(see Figure 5.5)} \qquad (12)$$

where:
- b - bottom width
- d - depth
- z - side slopes (h:1v)
- L - length between swale blocks

Using equation (12), and assuming a depth of 1.5 feet, the length of the swale is estimated to be:

$$1452 = [(1.5)^2\, 4(L)]/3 + [(1.5)4L]/2$$
$$1452 = 3L + 3L$$
$$L = 242 \text{ feet}$$

(The required length could be reduced to 156 feet if the depth were increased to 2 feet.)

3. **Estimate channel depth** to carry the 30 cfs design flow using Manning's equation:

$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2} \qquad (13)$$

where: **A** - area (for trapezoid) - $(bd + zd^2)$ (ft.^{2})
R - hydraulic radius - (see figure 5.4) (ft.)
n – Manning's roughness coefficient
S - slope (feet/feet)

Note: When computing the area and hydraulic radius, b (width) is the channel "bottom" width at the top of the swale block and d(depth) is the distance between the water surface and the top of the swale block. From figure 5.5, the channel width at the top of the swale block in this example is equal to:

$$T = b + 2zd = 4 + 2(4)(1.5) = 16 \text{ ft.}$$

Using equation (13):

$$30\text{cfs} = \frac{1.486}{0.07} A R^{2/3} (.005)^{1/2}$$

Thus: $ar^{2/3} = 20$

d	a*	p**	r	$ar^{2/3}$
0.1 1.1	20.0 22.4	24.3 25.1	0.82 0.90	17.6 20.8

The area (a) can be computed using:

$$* \; a = bd + zd^2 = 16d + 4d^2 \qquad \text{(from figure 5.4)}$$

By trial and error it is possible to determine the depth needed to obtain $AR^{2/3} = 20$. By assuming a depth, the wetted perimeter (p) can be computed using:

$$** \; p = b + 2d\sqrt{z^2 + 1} = 16 + 2d\sqrt{17} = 16 + 8.25d$$

For an assumed depth of 1.1 feet, the computed $AR^{2/3}$ is very close to the $AR^{2/3}$ value that is required. It would be advisable to include a freeboard elevation try to account for any uncertainties. Figure 5.6 shows the swale configuration. Note that the depth (d) is the distance above the swale blocks. The area below the top of the swale blocks is storage area, and does not convey floodwaters.

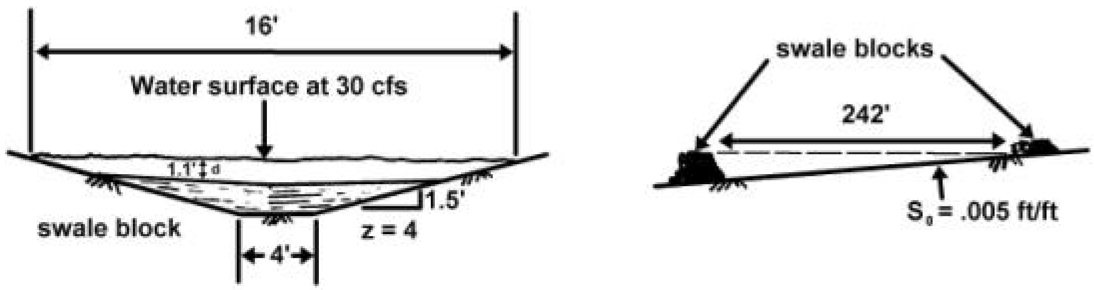


Figure 5.6 - Swale Configuration For Example

Following are some guidelines for grassed swales:

1. The side slopes should be 4:1 (h:v) or flatter.
2. Underlying soil should have a permeability that is .5 inches/hour or greater (an A or B type soil).
3. Dense vegetation that is water tolerant and resistant to erosion should be planted.
4. Slope should be less than 2% (2 feet per 100 feet). Slopes that exceed 2% should include check dams to limit the velocity and potential erosion.
5. Velocities should be less than 5 feet per second.
6. Set the top of the swale at least .5 feet above the design flow water surface elevation.

GRASS FILTER STRIPS

The use of grass filter strips can be quite effective in removing particulate pollutants from overland flow. Some of the uses include directing runoff from parking lots or rooftops across a filter strip before discharging into a drainage course, or infiltration basin. The object of a filter strip is for the grass to act as an obstruction to flow and result in the particulates settling out. For a filter strip to work, it is necessary for the depth of flow to be less than the grass height.

Research has been done relating to the effectiveness of filter strips. Such research (references 6 & 31) indicated that the effectiveness of the filter strip is a function of several variables, such as rainfall intensity, total rainfall, slope of the filter strip, depth of flow on the filter strip, length of contributing area, particle size, and filter-strip length.

In addition to these variables, there are unknowns, such as spacing of the plants and sediment accumulation. Instead of trying to include design charts for all of the possible variables, it is suggested that a filter strip width of about 20 feet at a slope of about 1% be used where possible. This criteria would capture more than 90% of particles that are 10µ (10 micron) or larger for most conditions. (Note: As a reminder, fine sand is about 40µ to 100µ, silt is about 10µ, and clay is about a 1µ-size particle.)

In many instances, more than 90% of particles that are less than 10µ will be captured by a 10-foot filter strip. To capture particles that are 1µ, filter strip widths in excess of 400 feet may be required. Research has indicated that filter strip widths to capture 1µ particles would have to be up to 100 times longer than required for 10µ particles.

Filter strips are typically used in conjunction with other stormwater-management practices to reduce the sediment being introduced into the drainage system. Because the filter strips are very effective at capturing particulates, there will be considerable amount of maintenance that will be required to keep the filter strips functioning. The grass should be cut only when absolutely necessary to ensure that the filtering capacity of the strip is maintained. In addition, it will be necessary to frequently vacuum near the point at which the flow will enter the filter strip. Without adequate maintenance, the effectiveness of the filter strip will be greatly reduced, and there is a possibility that the sediments will be picked up by future runoff events.

At times it may be necessary to incorporate the sediments into the soil by plowing up the grass strip and replanting the area, preferably with sod.

Following are some guidelines that may be used for the construction of filter strips:

1. It is suggested that, at a minimum, the filter strip be about 20 feet wide with a slope of about 1%. This width and slope does contain a factor of safety. Thus, if site conditions require some modifications to the filter strip, the modifications can be done, and the strip can still achieve significant sediment reduction.
2. Grasses that are used in the filter strip should be resistant to water inundation and salt. Grasses such as perennial rye grass, tall fescue, and creeping red fescue have shown a resistance to salt and can grow in a Michigan climate. It would be advisable to plant a mixture of grasses to minimize the possibility of a disease or fungus killing the ground cover composed of a single species.
3. Care should be taken in the final grading so that flow is not channelized on the filter strip. The runoff from the contributing area should be as wide as possible to allow the flow to spread out, which will facilitate the deposit of particles.
4. Filter strips are most applicable for small watershed areas, typically less than 5 acres.
5. Soils most suitable for filter strips include types A, B, and C. D soils may be used, but they are less desirable.
6. If the contributing area has a high output of sediment, the filter strip may require an excessive amount of maintenance to keep it functioning. Thus, to keep the filter strip effective, erosion-control techniques may have to be incorporated into the contributing area to reduce the sediment runoff.