Appendix D.13

Method for Designing Infiltration Structures

Introduction

The following procedures shall be used for designing infiltration trenches (I-1) and basins (I-2) to meet the water quality (WQ_v), the channel protection (Cp_v), and the overbank flood protection (Qp) volume requirements. These methods are based on the 1984 Maryland Standards and Specifications for Infiltration Practices (MDE, 1984) and Modelling Infiltration Practices Using TR-20 (MDE, 1983).

The use of infiltration practices depends on careful site investigation. The feasibility conditions listed in Chapter 3.3 and in Appendix D.1 are to be investigated and are equally important in ensuring the proper function of an infiltration practice. Should a site investigation reveal that any one of the feasibility tests is not adequate, the implementation of infiltration practices should not be pursued. Alternate feasibility criteria may be permitted only in those conditions where the local jurisdictions can justify and ensure proper application.

D.13.1 Soil Textures

The hydrologic design methods presented in this appendix are based on the utilization of two hydrologic soil properties, the effective water capacity (C_w) and the minimum infiltration rate (*f*) of the specific soil textural groups, as shown in Table D.13.1. The effective water capacity of a soil is the fraction of the void spaces available for water storage, measured in inches per inch. The minimum infiltration rate is the final rate that water passes through the soil profile during saturated conditions, measured in terms of inches per hour. The hydrologic soil properties are obtained by identifying the soil textures by a gradation test for each change in soil profile. The soil textures presented in Table D.13.1 correspond to the soil textures of the U.S. Department of Agriculture (USDA) Textural Triangle presented in Figure D.13.1.

The data presented in Table D.13.1 are based on the analysis of over 5,000 soil samples by the USDA under carefully controlled procedures. The use of the soil properties established in Table D.13.1 for design and review procedures will offer two advantages. First, it provides for consistency of results in the design procedures. Second, it eliminates the need for the laborious and costly process of conducting field and laboratory infiltration and permeability tests.

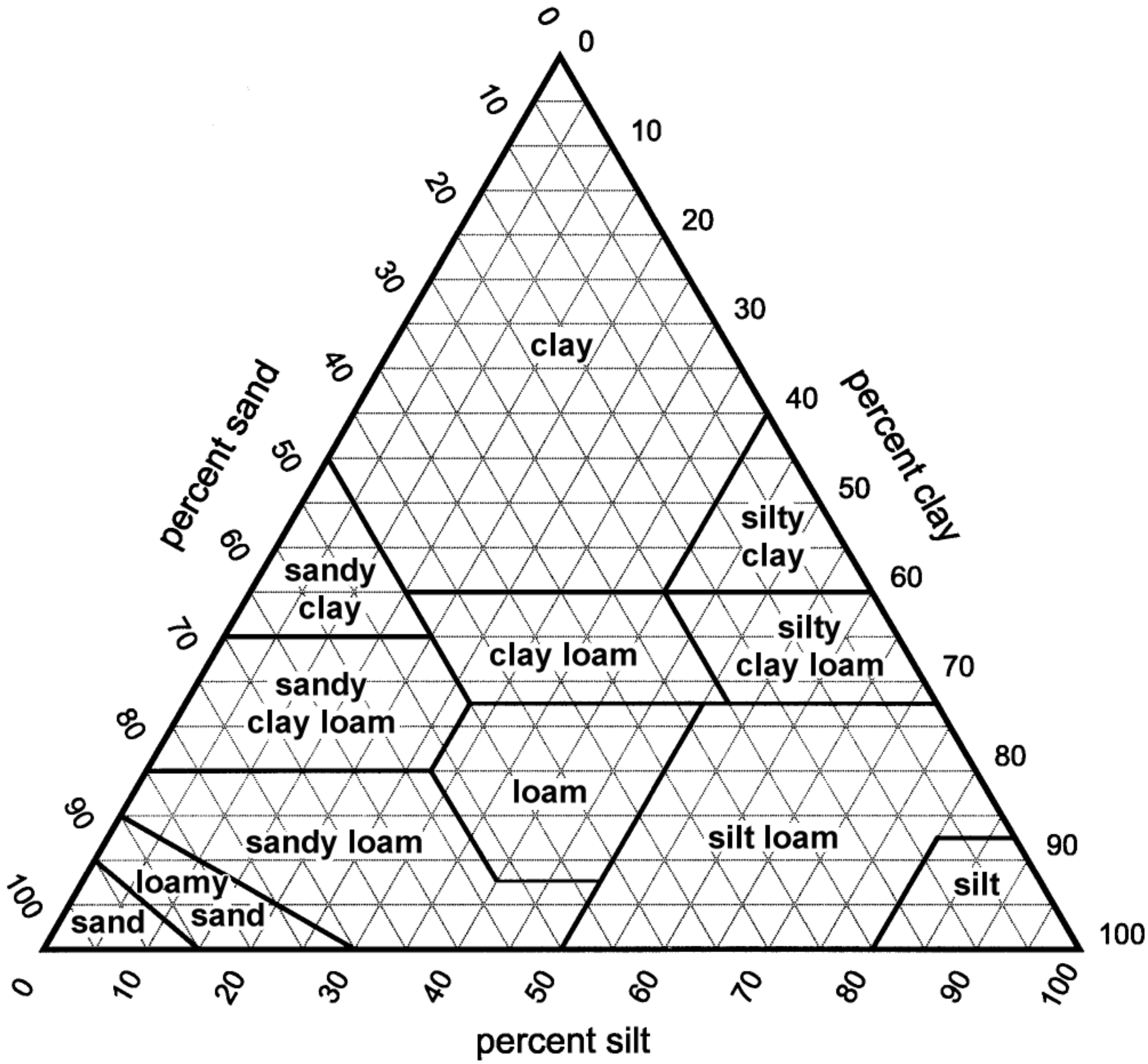
Table D.13.1 Hydrologic Soil Properties Classified by Soil Texture*

Texture Class	Effective Water Capacity (C_w) (inch per inch)	Minimum Infiltration Rate (f) (inches per hour)	Hydrologic Soil Grouping
Sand	**0.35**	**8.27**	**A**
Loamy Sand	**0.31**	**2.41**	**A**
Sandy Loam	**0.25**	**1.02**	**A**
Loam	**0.19**	**0.52**	**B**
Silt Loam	**0.17**	**0.27**	**B**
Sandy Clay Loam	**0.14**	**0.17**	**C**
Clay Loam	**0.14**	**0.09**	**D**
Silty Clay Loam	**0.11**	**0.06**	**D**
Sandy Clay	**0.09**	**0.05**	**D**
Silty Clay	**0.09**	**0.04**	**D**
Clay	**0.08**	**0.02**	**D**

* Source: Rawls, Brakensiek and Saxton, 1982

Based on the soil textural classes and the corresponding minimum infiltration rates, a restriction is established to eliminate unsuitable soil conditions. Soil textures with minimum infiltration rates less than 0.52 inches per hour are not suitable for usage of infiltration practices. These include soils that have a 30 percent clay content, making these soils susceptible to frost heaving and structurally unstable, in addition to having a poor capacity to percolate runoff. Soil textures that are recommended for infiltration systems include those soils with infiltration rates of 0.52 inches per hour or greater, which include loam, sandy loam, loamy sand, and sand.

Figure D.13.1 USDA Soils Textural Triangle



D.13.2 Hydrologic Design Methods

D.13.2.1 General Design Situations

There are two general types of situations where infiltration practices may be used. First , one may be interested in the dimensions of an infiltration device that is required to provide storage of the WQ_v, and/or the Cp_v or Q_p. Second, site conditions may dictate the layout and capacity of infiltration measures and one might be interested in determining the level of control provided by such a layout. In the latter case, control may not be sufficient and additional control, possibly using other acceptable Best Management Practices (BMPs), may be required. It is important to emphasize that the same principles of design apply to both cases.

Design methodologies are presented for two infiltration practices: infiltration trenches (I-1) and infiltration basins (I-2). The design procedures are based on either intercepting the WQ_v from the area contributing runoff or using the truncated hydrograph method for control of the runoff from an area for either Cp_v or Q_p. The design equations may be defined for either case of stormwater quality or quantity control because the volume of water (V_w) stored in the individual infiltration practice may be determined from the methods described in Chapter 2 (for WQ_v) and in Appendix D.13.3 for Cp_v and/or Q_p.

D.13.2.2 Design of Infiltration Trenches (I-1)

The design of an infiltration trench is based on the textural class of the soils underlying the trench such that a feasible design is possible. The design of an infiltration trench is also based on the maximum allowable depth of the trench (d_{max}). The maximum allowable depth should meet the following criteria:

$$d_{\max} = \frac{fT_s}{n}$$

Where f is the final infiltration rate of the trench area in inches per hour, T_s is the maximum allowable storage time in hours, and n is the porosity (V_v/V_t) of the stone reservoir.

An infiltration trench is sized to accept the design volume that enters the trench (V_w) plus the volume of rain that falls on the surface of the trench (PA_t) minus the exfiltration volume (fTA_t) out of the bottom of the trench. Based on the SCS hydrograph analysis, the effective filling time for most infiltration trenches (T) will generally be less than two hours. The volume of water that must be stored in the trench (V) is defined as:

$$V = V_w + PA_t - fTA_t \quad \text{(Equation D - 13.1)}$$

where P is the design rainfall event (ft), and A_t is the trench surface area (ft^2). For most design storm events, the volume of water due to rainfall on the surface area of the trench (PA_t) is small when compared to the design volume (V_w) of the trench and may be ignored with little loss in accuracy to the final design.

The volume of rainfall and runoff entering the trench can be defined in terms of trench geometry. The gross volume of the trench (V_t) is equal to the ratio of the volume of water that must be stored (V) to the porosity (n) of the stone reservoir in the trench; V_t is also equal to the product of the depth (d_t) and the surface area (A_t):

$$V_t = V/n = d_t A_t n \quad \text{(Equation D - 13.2)}$$

Combining equations D.13.1 and D.13.2 yields the following relationship:

$$d_t A_t n = V_w - fTA_t \quad \text{(Equation D - 13.3)}$$

Because both dimensions of the trench are unknown, this equation may be rearranged to determine the area of the trench (A_t) if the value of d_t were set based on either the location of the water table or the maximum allowable depth of the trench (d_{max}):

$$A_t = \frac{V_w}{nd_t + fT}$$

Procedures for Infiltration Trench Design

1. Determine the volume of water for storage using the methods for WQ_v, Cp_v, or Q_p found in Chapter 2 and/or Appendix D.13.3.

2. Compute the maximum allowable trench depth (d_{max}) from the feasibility equation, $d_{\max} = fT_s/n$ Select the trench design depth (d_t) based on the depth that is the required depth above the seasonal groundwater table, or a depth less than or equal to d_{max}, whichever results in the smaller depth.

3. Compute the trench surface area (A_t) for the particular soil type using Equation D.13.3.

In the event that the sidewalls of the trench must be sloped for stability during construction, the surface dimensions of the trench should be based on the following equation:

$$A_t = (L - Zd_t)(W - Zd_t)$$

where L and W are the top length and width, and Z:1 is the trench side slope ratio. The design procedure would begin by selecting a top width (W) that is greater than $2 \times Zd_t$ for a specified slope (Z). The side slope ratio value will depend on the soil type and the depth of the trench. The top length (L) may then be determined as:

$$L = Zd_t + \frac{A_t}{W - Zd_t}$$

D.13.2.3 Design of Infiltration Basins (I-2)

The design of an infiltration basin is based on the same soil textural properties and maximum allowable depth as the infiltration trench such that a feasible design is possible. However, because the infiltration basin uses an open area or shallow depression for storage, the maximum allowable depth (d_{max}) should meet the following criteria:

$$d_{\max} = f \times T_p$$

where f is the final infiltration rate of the trench area in inches per hour and T_p is the maximum allowable ponding time in hours.

An infiltration basin is sized to accept the design volume that enters the basin (V_w) plus the volume of rain that falls on the surface of the basin (PA_b) minus the exfiltration volume (fTA_b) out of the bottom of the basin. Based on the SCS hydrograph analysis, the effective filling time for most infiltration basins will generally be less than two hours therefore <u>use $T = 2$ hours</u>. The volume of water that must be stored in the trench (V) is defined as

$$V = V_w + PA_b - fTA_b \quad \text{(Equation D - 13.4)}$$

where P is the design rainfall event (ft), and A_b is the basin surface area (ft^2). For most design storm events, the volume of water due to rainfall on the surface area of the basin (PA_b) is small when compared to the design volume (V_w) of the basin and may be ignored with little loss in accuracy to the final design.

The volume of rainfall and runoff entering the basin can be defined in terms of basin geometry. The geometry of a basin will generally be in the shape of an excavated trapezoid with specified side slopes. The volume of a trapezoidal shaped basin may be approximated by:

$$V = \frac{(A_t + A_b)d_b}{2} \quad \text{(Equation D-13.5)}$$

where A_t is the top surface area of the basin (ft^2), A_b is the bottom surface area of the basin (ft^2), and d_b is the basin depth (ft). By setting Equations D.13.4 and D.13.5 equal the following equation may be used to define the bottom area (A_b):

$$A_b = \frac{2V_w - A_t d_b}{(d_b - 2P + 2fT)} \quad \text{(Equation D-13.6)}$$

If a rectilinear shape is used, the bottom length and width of the basin may be defined in terms of the top length and width as:

$$L_b = L_t - 2Zd_b$$

$$W_b = W_t - 2Zd_b$$

where Z is a specified side slope ratio (Z:1). By substituting the above relationships for L_b and W_b, into Equation D.13.6, the following equation is derived for the basin top length:

$$L_t = \frac{V_w + Zd_b(W_t - 2Zd_b)}{W_t(d_b - P) - Zd_b^2} \quad \text{(Equation D-13.7)}$$

Procedures for Infiltration Basin Design

1. Determine the volume of water for storage using the methods for WQ_v, Cp_v, or Q_p found in Chapter 2 and/or Appendix D.13.3.

2. Compute the maximum allowable basin depth (d_{max}) from the feasibility equation, $d_{max} = fT_p$. Select the basin design depth (d_b) based on the depth that is the required depth above the seasonal groundwater table, or a depth less than or equal to d_{max}, whichever results in the smaller depth.

3. Compute the basin surface area dimensions for the particular soil type using Equation D.13.6.

Note: If a rectilinear shape is used, the basin top length (*L_t*) and width (*W_t*) must be greater than *$2Zd_b$* for a feasible solution. If *L_t* and *W_t* are not greater than *$2Zd_b$* the bottom dimensions would be less than or equal to zero. In this case, the basin depth (*d_b*) shall be reduced for a feasible solution.

D.13.3 The Truncated Hydrograph Method for Stormwater Quantity Management

Most stormwater polices require that the peak discharge from the post-developed hydrograph for a selected return period(s) not exceed the peak discharge from the pre-developed hydrograph after development for stream channel erosion control and/or flood control purposes. In previous stormwater quantity management infiltration design methods, the difference between the pre-development and post-development runoff volumes was stored in the proposed infiltration structure. In most cases, this volume of runoff occurs prior to the actual hydrograph peak (see Figure D.13.2) and therefore actual peak discharge control is not provided. Therefore, when considering infiltration practices for peak discharge or stormwater quantity control, the truncated hydrograph method should be used to determine the necessary infiltration storage volumes.

The pre-development and post-development peak discharges can be computed using standard SCS methodology (TR-55 Tabular or TR-20). The time (T_2) at which the allowable discharge occurs on the receding limb of the post-development hydrography, as shown in Figure D.13.1 is determined from the SCS methods. The volume of runoff under the post-development hydrograph and to the left of the allowable discharge at T_2 is the design storage volume (V).

The computed infiltration storage volume, V, may be adjusted to account for the volume of water which exfiltrates from the infiltration structure during the period of time required to fill the structure. The exfiltration volume (V_e) is the product of the minimum soil infiltration rate (ft/hr), the filling time (hrs), and the surface area of the infiltration practice. The filling time (T_f) of the infiltration practice may be determined directly from the post-development hydrograph as shown in Figure D.13.1. T_f is the difference between T_2, where the allowable discharge occurs on the recession limb and the time T_1 where the discharge value on the rising of the hydrograph is equal to the minimum infiltration discharge. The minimum discharge is equal to the minimum soil infiltration rate (ft/sec) times the surface area (ft^2) of the infiltration practice.

Figure D.13.2 Truncated Hydrograph Method