A-2. Soils

Chapter Contents

Importance of Soil Composition in SCMs

The soil composition of many stormwater SCMs also is vital to their relative success or failure in achieving their intended purpose. Soil composition can vary according to the design objectives (e.g., nutrient removal), as well as in situ topsoil composition. Properly designed soil media aids in infiltration and natural detention as well as plant health.

Soil Media

Soils are highly complex systems that provide essential environmental benefits including biofiltration of pollutants, nutrients for plant growth, and the storage and slow release of storm flows. The ability of soil to effectively store and slowly release water is dependent on its properties—texture, structure, organic matter content, and biota—as well as depth. Plant roots, macro fauna, and microbes tunnel, excavate, penetrate, and physically and chemically bond soil particles to form stable aggregates that enhance soil structure and porosity. Soil properties are the principal factor controlling the fate of water in the hydrologic system. Water loss, utilization, contamination, and purification are all affected by the soil (Brady and Weil, 2007).

Organic matter is a critical ingredient in the function of a soil. Mixed into the soil, organic matter absorbs water, physically separates clay and silt particles, and reduces erosion. Microbes and vegetation depend on the replenishment of organic matter to retain and slowly release nutrients for growth. Construction activity removes the upper layers of soil, compacts exposed sub-soils low in organic matter, and alters the site's hydrologic characteristics by converting the predominantly subsurface flow regime of the pre-disturbance site to primarily overland flow.

Soil permeability is an important design factor in stormwater SCMs. It is necessary to know the infiltration rate of in-situ soils for infiltration devices and permeable pavement. It is also advantageous and sometimes necessary to have low permeability in-situ soil for systems where permanent ponded water is required (e.g. stormwater wetlands and wet ponds). In some SCM systems (e.g. sand filters, bioretention, etc.), high permeability media is required within the SCM, but since relatively small quantities are typically required, suitable soils can be imported to a site if necessary.

The organic content of soils can be an important factor in SCM selection and design for two reasons. First, SCM vegetation thrives best with the proper soil organic content. Organic content requirements for the soil in planted areas can range from 2-10% (Oregon State University Forest Nursery Manual, 1984), but it is a very site and plant specific value, based on an analysis of the topsoil. The organic content of soils can affect pollutant removal rates in SCMs that pass stormwater through soil media. High organic content has been shown to increase removal rates of nutrients, some metals, and some organic compounds.

The possibility of contaminated soils should also be considered in SCM design and placement. SCM's that rely on infiltration or treatment through in-situ soils should not be located in areas of contaminated soils or they should be removed prior to installation of the SCM.

Another important aspect of soils is their typically high erosivity. Soils need to be quickly stabilized with vegetative cover or they will suffer from wind and water erosion (sometimes severely). Vegetative cover must be properly maintained over the life of the SCM to prevent bare spots from occurring and the subsequent erosion of the exposed soils. Sometimes additional measures (e.g. rock linings, geosynthetics, etc.) must be taken to protect soils from erosion in certain circumstances (i.e., steep slopes, excessive SCM outlet velocities, etc.).

Agronomic soil testing is an important step for design and planting of many SCMs. Having the soil tested will provide site specific information and recommendations for fertilizer application to help achieve good vegetation growth and survival. Soil testing is also required for engineered media used in bioretention cells to determine whether the P-index is in the allowable range. The North Carolina Department of Agriculture & Consumer Services, Agronomic Services Division provides soil testing services: http://www.ncagr.gov/agronomi/sthome.htm

In-situ Soil Testing

Determining the infiltration rate of the in-situ soil subgrade and the elevation of the seasonal high water table (SHWT) are the most important steps of the hydrogeologic design process. The soil infiltration rate determines many important design aspects of various SCMs (the type of permeable pavement design (infiltration or detention), infiltration basin surface area, etc.).

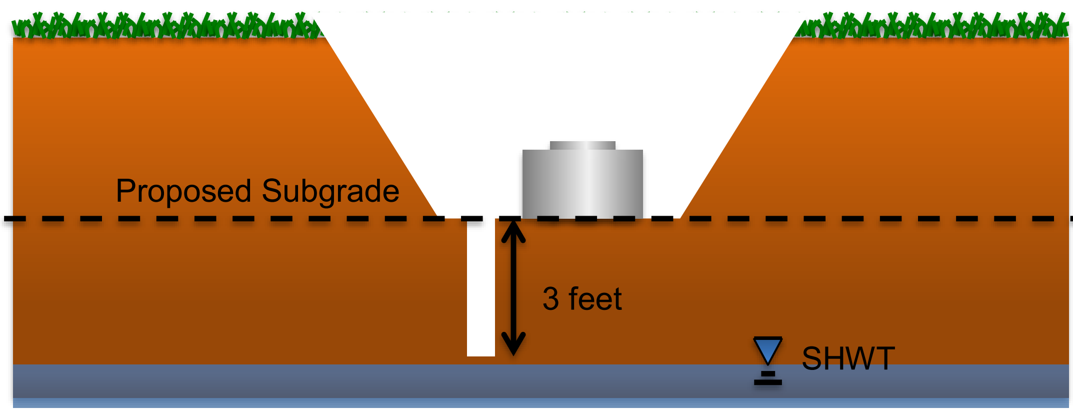
All soil test pits, soil borings, soil permeability tests and associated documentation shall be conducted under the direct supervision of an appropriately licensed North Carolina design professional. During all subsurface investigations and soil test procedures, adequate measures shall be taken to ensure personnel safety and prohibit unauthorized access to the excavations at all times. Entering a soil pit excavated below the water table can be extremely dangerous and should be avoided. Soil pits beneath the water table typically indicate that the site is unsuitable for permeable pavement or infiltration devices. Therefore, no further soil study may be needed.

Soil test pits shall be dug to the expected subgrade elevation (see Figure 1 below). Placement of the test pits shall be such that it provides adequate characterization of the infiltration area. The total number of required soil profile pits shall be placed equidistant from each other to provide adequate characterization of the infiltration area. The recommended number of soil test pits for SCMs utilizing infiltration are as follows:

Table 1: Recommended number of soil test pits (Source: NCSU-BAE)

Area of Infiltration System	Number of Soil Test Pits
< 2,000 sf	1 soil test pit
2,000 – 20,000 sf	2 soil test pits
> 20,000 sf	1 soil test pit per 10,000 sf

Figure 1: Schematic of a soil test pit (Source: NCSU-BAE)



One of the most widely accepted methods for in-situ soil infiltration testing is ASTM D 3385 *Standard Test Method for Infiltration Rate in Field Soils Using Double-Ring Infiltrometer*. A double-ring infiltrometer consists of two concentric metal rings driven into the soil and filled with water. The outer ring helps prevent divergent flow within the soil. The drop in water level or volume within the inner ring is used to calculate an infiltration rate. The infiltration rate is the depth of water per surface area over time. The diameter of the inner ring should be approximately 50% to 70% of the diameter of the outer ring, with a minimum inner ring size of 4 in. Double-ring infiltrometer testing equipment designed specifically for that purpose may be purchased. Other constant head permeability tests, such as the Constant Head Permeameter, that utilize in-situ conditions and accompanied by an independent published source reference can be used for establishing the permeability rates.

Where soil or groundwater properties vary significantly between soil explorations, additional soil profile pits should be conducted as necessary to resolve such differences and accurately characterize the subsurface conditions below the permeable pavement. The designer shall use the median infiltration rate determined from the in-situ soil testing for design purposes.

In addition to an in-situ soil infiltration rate test, a soil boring shall be conducted within each test pit. The boring shall extend to a depth of three feet below the subgrade elevation or to the water table, whichever occurs first. The borings shall be performed and reported in accordance with ASTM D 1452 *Practice for Soil Investigation and Sampling Auger Borings* and ASTM D 1586 *Test Method for Penetration Test and Split-Barrel Sampling of Soils.* Soil permeability tests shall be conducted on the most hydraulically restrictive horizon or substratum below the subgrade. If the permeability of the most restrictive soil horizon varies greatly from the results of the in-situ infiltration test, then the licensed professional shall consider decreasing the design soil infiltration rate accordingly.

Separation from Seasonal High Water Table (SHWT)

To function properly, some SCMs require a minimum separation of two feet from the bottom of the SCM down to the SHWT elevation. However, the minimum separation may be reduced to no less than 1 foot if the applicant provides a hydrogeologic evaluation that demonstrates that the water table will subside to its pre-storm elevation within five days or less. In order to support allowing less than 2 feet of separation, the following should be provided:

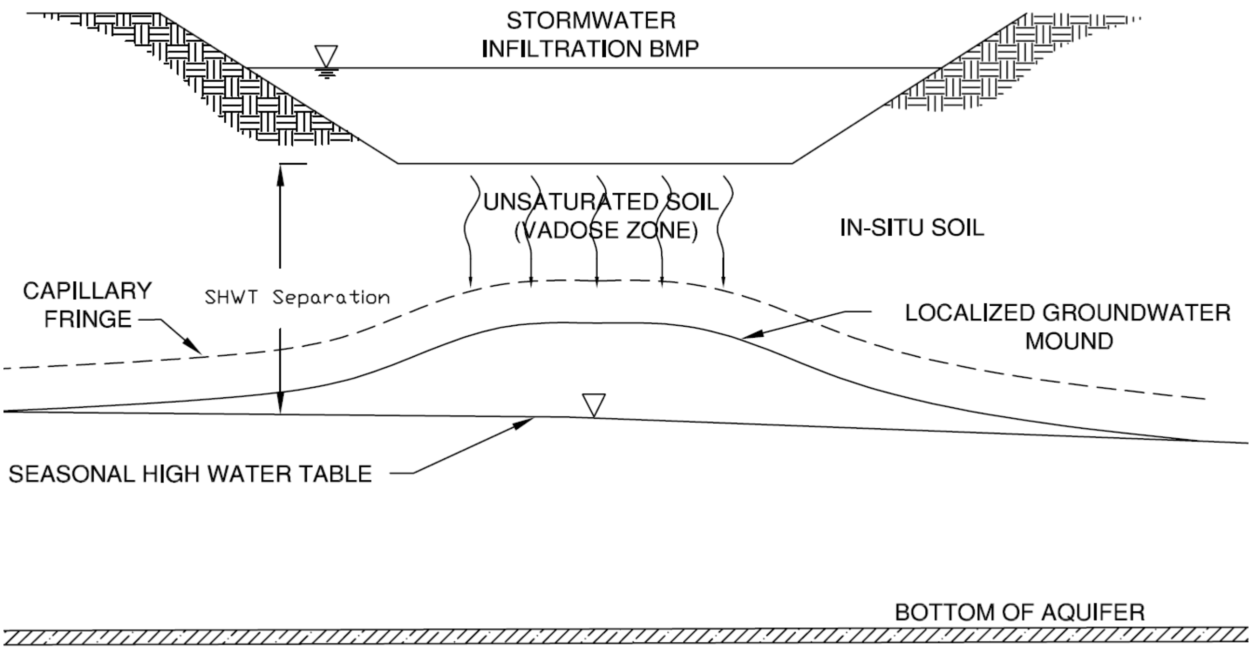
A hydrogeologic evaluation prepared by a licensed professional. This evaluation shall be based on borings for which the numbers, locations, and depths are sufficient to define the components of the hydrogeologic evaluation. In addition to borings, other techniques may be used to investigate the subsurface conditions at the site. These techniques may include geophysical well logs, surface geophysical surveys, and tracer studies. This evaluation shall be presented in a report that includes the following components:

1. A description of the regional and local geology and hydrogeology;
2. A description, based on field observations of the site, of the site topographic setting, streams, springs and other groundwater discharge features, drainage features, existing and abandoned wells, rocky outcrops, and other features that may affect the movement of the contaminant plume and treated wastewater;
3. Changes in lithology (rock type) underlying the site;
4. Estimated depth to confining layers;
5. The hydraulic conductivity and transmissivity of the affected aquifer(s);
6. Depth to the seasonal high water table;
7. A discussion of the relationship between the affected aquifers of the site to local and regional geologic and hydrogeologic features;
8. A discussion of the groundwater flow regime of the site prior to operation of the proposed facility and post operation of the proposed facility focusing on the relationship of the system to groundwater receptors, groundwater discharge features, and groundwater flow media; and
9. A mounding analysis under the proposed infiltration basin to predict the level of the SHWT five days after the occurrence of the water quality design storm. Any mounding that occurs after the design storm must subside in a period of five days or less.

A capillary fringe above the SHWT can reduce the depth of unsaturated soil zone to less than two feet. Typically, a licensed professional will observe redoxomorphic features of the soil as a surrogate for the location of the seasonal high water table. Often, this information dictates whether a SCM will be designed to infiltrate stormwater in an infiltration basin or to retain it in a wet detention pond. The capillary fringe often extends six inches above the redoxomorphic features in the soil. The capillary fringe lies just above the water table, where water can be drawn upward by capillary forces. In other words, if the SHWT is found 2 feet below the bottom of a proposed infiltration SCM, the capillary fringe may reduce the available unsaturated soil depth to 1.5 feet.

Local water table mounding effects can prevent infiltration from occurring in time for the next storm. The time for water to move through the unsaturated zone is governed by two parameters: (1) the thickness, and (2) the vertical hydraulic conductivity of the unsaturated zone. In the soil beneath an infiltration basin, the water table will eventually rise under the unsaturated zone, which is caused not only by vertical percolation of infiltrating water, but also the lateral movement from the temporary ground water mound caused by the basin. Coastal aquifers often do not have a strong gradient to flow laterally through the aquifer, resulting in a limited ability for a groundwater mound to dissipate. If there is not an adequate a gradient for a local, temporary mound to dissipate into the surrounding water table, then an infiltration basin above the mound may not draw down in less than five days even if the soil under the infiltration basin is pure sand with a very high unsaturated hydraulic conductivity. Figure 1 provides a snapshot of groundwater interaction with an infiltration SCM during a drainage event. Mounding can occur locally, which reduces the drainage gradient of water in the SCM.

Figure 2: Groundwater Mounding



No evidence or precedent exists to suggest a smaller water table requirement will meet infiltration basin function. The complex nature of water table/infiltration basin interactions makes hard-and-fast rules difficult to apply in all situations. Currently, the 2 feet separation dictates site design options for designers and developers. Compared to other states, North Carolina's separation requirement is rather small—other states and localities require two to five feet of separation. Given the lack of precedent for a smaller separation across the board, it is suggested that the 2 feet separation be maintained.