Native Soil Assessment for Small Infiltration-Based Stormwater Control Measures

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December 2013

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Purpose

The primary purpose of this guidance document is to provide a field soil assessment methodology that can be used to:

1. Assess the suitability of a project site for small infiltration-based stormwater control measures (SCMs), including which areas of a project site, if any, are most suited for infiltration SCMs, and
2. Obtain field data that can be used for SCM sizing and design including options for determining permeability (Ksat).

Introduction

Emerging regulatory requirements for post-construction stormwater control emphasize the use of low impact development including infiltration-based stormwater SCMs. Many characteristics of a project site may influence compliance feasibility with stormwater control requirements including those related to soil and geotechnical considerations. Stormwater control performance criteria often include a design storm event and the designer must have sufficient knowledge of the native soils to correctly locate and size the LID SCMs. Many design practitioners rely on the use of existing soil classifications and values found in "look-up" tables or maps (i.e. USDA SCS maps, county-wide maps, descriptive charts, etc.), which are often are too generalized to apply with confidence to a specific site. However, field analysis methods that provide native soil information and data relevant to infiltration-based SCMs are evolving and consequently, there is confusion as to the types of field testing that will support good site assessment and SCM design. Adding to the complexity are the myriad of methods to use field data to determine certain soil parameters of interest such as saturated hydraulic conductivity (Ksat). These methods often require use of empirical equations, correction factors, statistical methods, and/or modeling, which may significantly affect the accuracy of use for SCM sizing and design.

This guidance provides simple and cost-effective field investigation methodologies to support location and sizing for small-scale infiltration-based SCMs. Small-scale SCMs are generally those for which the sidewall of the SCM provides a significant component of infiltration relative to the bottom of the SCM. Large-scale SCMs (i.e. those for which the sidewall infiltration is minimal compared to infiltration through the bottom of the SCM) are not addressed in this guidance. Additionally, methodologies that are appropriate for both shallow (e.g., bioretention) and deep (e.g., infiltration trench) small-scale SCM types are provided. In preparing this guidance, it was assumed that the more commonly utilized infiltration-based SCMs to comply with post-construction stormwater control requirements will be shallow systems as they are typically less expensive to install, easier and less expensive to maintain, and the degree to which they are functioning (or not functioning) is readily apparent. Deep SCMs are presumed to typically be used when local geologic or geotechnical knowledge indicates that a deeper stratum may more readily allow infiltration than shallow strata, or other project or site constraints indicate that deep SCMs may be a better solution. Guidance is also provided when more robust or expanded soil analysis may be warranted.

The development of the methodology included review of existing methodologies, consultation with state and national soil experts; and, expertise and experience of the authors. The final product is a methodology based on credible, accepted soil analysis methods; is relatively inexpensive; yields sufficient data for the need; and, is appropriate for small-scale LID SCMs.

Throughout this document, consideration and discussion of the application of these guidelines among the jurisdiction, the design professional and the geotechnical engineer is encouraged. This guidance is a starting point and, coupled with existing site information and geotechnical expertise, will support optimal SCM siting and design. In many cases, information such as specific SCM type, elevation, depth or location may not be known and will have to be assumed or estimated by the geotechnical engineer and/or design professional. Modifications to the methodology should be based on sound engineering and geologic judgment to accommodate the unique characteristics of each project as they relate to each unique site.

Use of Terminology in this Document

The challenge of understanding the various soil testing methods is compounded by the improper use of terms especially when discussing the realm of stormwater management. Historically, the primary driver to obtain information related to soil and water was focused on agriculture or design of septic and leachfield systems, and the terminology, methods, and reporting often served these particular data needs. A succinct terminology distinction is provided in the "Manual for Soil Investigation in Pennsylvania" (Pennsylvania Association of Professional Soil Scientists, Version 2.0 (2010) :

"Much confusion has arisen by the utilization of the terms infiltration, permeability, saturated hydraulic conductivity and percolation…let us define these terms. Infiltration refers to the entry of water into soil at a water-soil interface. Percolation refers to the downward movement of water through soil and rock. Permeability is synonymous with saturated hydraulic conductivity and is abbreviated as K or Ksat…Permeability is defined as a quantitative measure of a saturated soil's ability to transmit water when subjected to a hydraulic gradient."

In the arena of stormwater management "infiltration" seems to be the common term used to describe the rate at which stormwater is absorbed by and moves through the soil. In soil science, these processes are more often described as infiltration into the soil with subsequent percolation through the soil layer. In this document, the authors use "infiltration" to describe both infiltration and percolation processes. "Permeability" provides stormwater practitioners with an understanding of how rapidly a soil will transmit stormwater through the saturated soil profile under a specific hydraulic gradient. "Ksat" is used throughout this guidance as the abbreviation for the coefficient of permeability.

Also note that the term "boring" is used for the purpose of observing the soil profile. However, except as indicated otherwise, an "excavation" may be substituted for the same purpose. Similarly, the term "drill" is the term used as the means of creating the boring. Except as otherwise indicated, it is meant to be synonymous with "excavating" or "digging" of an excavation. The two methods are meant to be interchangeable.

The methodologies are guidelines only for the means of assessing the infiltration rates. Aspects related to permits, disposal of soil cuttings and samples, backfill, compaction, site restoration, etc. are not addressed. It is incumbent on the user to follow all laws, regulations, policies, and procedures, and sound engineering judgment in decommissioning the borings.

THESE METHODS DO NOT ADDRESS HEALTH OR SAFETY ASPECTS ASSOCIATED WITH THEIR USE. HEALTH AND SAFETY OF PERSONNEL CONDUCTING THE METHODOLOGIES AND OF PEDESTRIANS, PASSERS-BY, SITE OWNERS OR TENANTS, ETC. SHOULD BE CONSIDERED. IT IS THE RESPONSIBILITY OF THE USER TO COMPLY WITH ALL APPLICABLE HEALTH AND SAFETY LAWS, REGULATIONS, POLICIES AND PROCEDURES, AND TO ENSURE THAT THE METHODOLOGIES ARE USED SAFELY.

Native Soil Assessment for Small Scale Infiltration-Based Stormwater Control Measures

Step 1: Initial Site Assessment

Initial Site Assessment is encouraged early in the design of post-construction SCMs. Infiltration SCMs may be required to comply with post-construction stormwater control requirements. Various characteristics of a site, including soil and geotechnical constraints, may limit or preclude the use of infiltration SCMs. Early in the project planning phase, the Project Applicant should identify all site characteristics that may influence (both positively and negatively), the ability of the site to infiltrate stormwater. The list below relates to soil and geotechnical feasibility only and the Project Applicant is encouraged to review the full list of possible infeasibility constraints as provided by the municipality.

The Initial Site Assessment should identify features that may influence infiltration potential and/or location of infiltration based SCMs such as:

- Slope / topography of parcel and surrounding area
- Protected vegetation or habitat (endangered species, heritage oaks, etc.)
- Springs, seeps
- Bedrock outcrops
- Soil types from USDA Soil Charts, local geologic and geotechnical knowledge, etc.
- Nearby drinking water wells
- Existing soil or groundwater contamination
- Geotechnical or geologic constraints that may impact public safety or property
- Other constraints that would render areas unavailable for infiltration-based SCMs

Step 2: Interpretation of Initial Site Assessment

If the Initial Site Assessment indicates that there is sufficient documentation of characteristics that *entirely preclude* the use of shallow or deep infiltration based SCMs go to **Step 2A**. Examples of such characteristics might be unstable slopes throughout the site; high groundwater, shallow impervious bedrock throughout the site, etc. Note: poor soils do not necessarily preclude the use of infiltration based SCMs, but may limit the amount of, or areas usable for, infiltration.

If the Initial Site Assessment indicates that site characteristics do not preclude the use of infiltration based SCMs, go to **Step 2B**.

Step 2A: Omit use of infiltration-based SCMs. Infiltration analysis complete.

When site conditions entirely preclude the use of infiltration-based SCMs, the Project Applicant will need to contact the municipal representative responsible for the project to determine any required documentation of the infiltration infeasibility and the adjusted post-construction requirements for the project.

Step 2B: Conduct Shallow Quick Infiltration Testing

If the Initial Site Assessment indicates that use of **shallow infiltration-based SCMs** (e.g. vegetated swales, bioswales, bioretention facilities, shallow infiltration basins, etc.) may be feasible, a "Shallow Quick Infiltration Test" may provide information to refine shallow SCM siting within the project and associated sizing calculations. See **Attachment 1** for Shallow Quick Infiltration Test methodology.

If Initial Site Assessment indicates that use of **deep infiltration based SCMs** (e.g. seepage pits, deep infiltration basins, etc.) may be feasible, a "Deep Quick Infiltration Test" may provide additional information to support determination of whether shallow and/or deep infiltration-based SCMs should be utilized. See **Attachment 2** for Deep Quick Infiltration Test methodology.

Step 2C: Interpretation of Quick Infiltration Test Results

The soil profiles encountered and the results of the "quick" testing (shallow or deep) should be evaluated as to which areas or strata tested appear to have the better infiltration potential. Factors considered should include the presence of bedrock, clay soil, subsurface water, and other factors that may inhibit infiltration; as well as sandy and gravelly soils, and other factors that would enhance infiltration potential. Infiltration rates should be evaluated and SCM design should focus on placing the SCMs in the better locations and/or strata.

After evaluating the soil profiles and infiltration test results, the engineer may judge that no further data are needed and the soil infiltration assessment is complete. For example, if the initial data indicate poor to very poor draining soils throughout the site, no additional data are necessary as the risk of undersizing the SCM is low since the designer will typically use a conservative soil infiltration value to size the SCM based on the site information.

However, the engineer may judge that more soil data may be necessary or would facilitate a better design. For example, confirming results from the initial test may be particularly important where the initial data indicate moderate to good infiltration rates. In such a case, further testing might indicate that the good infiltration is limited in extent and that the site overall has poor draining soils. Without confirmation of the infiltration rates, the designer may size the facility based on the initial test data only to undersize the

SCM as the native soils actually allow less infiltration than originally determined. Gathering more data could consist of conducting additional quick tests in areas not previously tested, or conducting extended infiltration tests in areas previously tested by quick means.

See **Attachment 3** for “Extended Infiltration Testing” methodology.

ATTACHMENT 1
Shallow Quick Infiltration Testing Methodology

1. For small sites with limited areas for infiltration-based SCMs, drill 1 profile boring and 2 infiltration test borings in each potential SCM area.

2. For acreage and unconstrained sites:
   - Up to 5 acres: drill 1 profile boring and 2 infiltration test borings per acre of potentially usable area for SCMs.
   - Over 5 acres: drill 1 profile boring per geologic unit that may be usable for SCMs, with 2 to 4 infiltration test borings associated with each profile boring.

3. Profile borings should be 6" to 12" diameter and should extend 5' to 10' below the invert known or assumed elevation of the planned SCM. The boring cuttings should be observed and the soils in the borings sampled as necessary to allow accurate logging. Where excavations are utilized to determine the profile, they should be no wider than necessary to facilitate logging of the strata with the same level of detail as for borings.

4. All soil strata should be identified on the logs as to USCS classification, consistency, presence of moisture or free water, color, impermeable and permeable zones, and any other characteristics that may be pertinent to infiltration potential. All logs should include the boring identification, date of drilling, auger type and diameter, sampling methods, and surface elevation (known or assumed).

5. Infiltration test borings should also be 6" to 12" diameter. They should be of depths such that the zone tested will range from about the elevation of SCM invert, to about 2' below the elevation of the invert.

6. Infiltration test excavations should be dug by any means to approximately the elevation of the *top* of the planned SCM. From the elevation of the top of the planned SCM to 2' below the elevation of the *invert* of the SCM, a hand auger or hand shovel should be used to excavate the actual test zone. Preferably, the test zone should be 6" to 12" in diameter; if conditions mandate a larger diameter, it should be as close to 12" as is practicable.

7. A perforated pipe, of a diameter that will facilitate the taking of the test measurements should be placed in each test boring or in the test zone of each test excavation.

8. The annulus between each perforated pipe and the boring sidewall should be filled with fine gravel.

ATTACHMENT 1
Shallow Quick Infiltration Testing Methodology (cont.)

9. A suitable elevation datum should be established from which each measurement can be taken. The elevation of the datum relative to the elevation of the top of the SCM should be noted.

10. Using a hose equipped with a water meter that is sufficiently accurate at the flow anticipated, a graduated water tank, or other suitable means of measuring water volume, add water to the approximate elevation of *top* of the planned SCM and maintain the head for 30 minutes.

11. At the end of the 30-minute period, shut off water and record volume of water that entered the test boring.

12. As the water level falls, measure from the datum to the water level at suitable intervals. Measurements should be to the degree of precision practicable (usually 1/8-inch or 0.01 foot) for a period of 2 hours. Depending upon the rate of fall, intervals between measurements may need to be from 1 minute to 30 minutes. Intervals should be as uniform as is practicable, however, as the water level falls and the head is reduced, the infiltration rate may decrease and the measurement intervals may need to be incrementally lengthened.

13. If a test boring runs dry within 2-hour measurement period, refill the boring and continue measuring the falling head to end of original 2-hour period. If it runs dry again, refill and continue measurements to the end of the original 2-hour period. If it runs dry a third time, do not refill, the testing of that boring is complete.

14. If the fall recorded in any test boring is less than 6” in 2 hours, continue taking measurements for an additional 2 hours (4 hours total).

15. See **Attachment 4** for a discussion of how to report the test results; see **Attachment 5** for suggestions regarding calculation of K_{SAT} from the infiltration test rates.

ATTACHMENT 2
Deep Quick Infiltration Testing Methodology

1. For small sites with limited areas for infiltration-based SCMs, drill 2 profile / test borings in each potential deep SCM area.

2. For acreage and unconstrained sites:
   - Up to 5 acres: drill 3 profile / test borings per acre potentially usable for SCMs.
   - Over 5 acres: drill 4 profile / test borings per geologic unit that may be usable for SCMs.

3. Profile / test borings should be 6” to 12” diameter. They should extend 5’ to 10’ below the known or assumed bottom elevation of the planned SCM. The boring cuttings should be observed and the soils in the borings sampled as necessary to allow accurate logging. Use of excavations for deep testing is probably not practical.

4. All soil strata should be identified on the logs as to USCS classification, consistency, presence of moisture or free water, color, permeable and impermeable zones, and any other characteristics that may be pertinent to infiltration potential. All logs should include the boring identification, date of drilling, auger type and diameter, sampling methods, and surface elevation (known or assumed).

5. A perforated pipe, of a diameter that will facilitate the taking of test measurements should be placed in each profile / test boring.

6. The annulus between each perforated pipe and the boring sidewall should be filled with fine gravel.

7. A suitable elevation datum should be established from which each measurement can be taken. The elevation of the datum relative to the elevation of the top of the SCM should be noted.

8. Using a garden hose equipped with a water meter, a graduated water tank, or other suitable means of measuring water volume, add water to approximate elevation of *top* of the planned SCM and maintain the head for 30 minutes.

9. At the end of the 30-minute period, shut off water and record volume of water that entered the test boring.

ATTACHMENT 2
Deep Quick Infiltration Testing Methodology (cont.)

10. As the water level falls, measure from the datum to the water level at suitable intervals. Measurements should be to the degree of precision practicable (usually 1/8-inch or 0.01 foot) for a period of 2 hours. Depending upon the rate of fall, intervals between measurements may need to be from 1 minute to 30 minutes. Intervals should be as uniform as is practicable, however, as the water level falls and the head is reduced, the infiltration rate may decrease and the reading intervals may need to be incrementally lengthened.

11. If a test boring runs dry within the 2-hour measurement period, refill the boring and continue measuring the falling head to end of original 2-hour period. If it runs dry again, refill and continue measurements to the end of the original 2-hour period. If it runs dry a third time, do not refill, the testing of that boring is complete.

12. If the fall recorded in any test boring is less than 6” in 2 hours, discontinue testing as deep infiltration is not practical.

13. See **Attachment 4** for a discussion of how to report the test results; see **Attachment 5** for suggestions regarding calculation of K_{SAT} from the infiltration test rates.

ATTACHMENT 3

Extended Test Methodology

The following "extended" methodology is intended to provide more comprehensive soil/geotechnical information where the results from the Initial Site Assessment and/or Quick methodology, as well as other site and design considerations warrant a more thorough soil analysis to facilitate better SCM design.

1. Extended test methodology for *deep* SCMs is too complex an issue to be adequately addressed in these guidelines. Test locations, depths, methods, etc. should be discussed among the jurisdiction, the design professional and the geotechnical engineer and a consensus reached as to the appropriate means of securing the data required for design of the deep SCMs on the specific site.

2. For *shallow* extended testing, locations, depths, continuity of subsurface conditions, etc. should be discussed among the jurisdiction, the design professional and the geotechnical engineer. Consideration should be given to drilling and testing at least twice as many test borings as recommended under Quick Testing.

3. Extended shallow test methodology should be essentially the same as Steps 3 through 14 under Quick Testing, except for the following:
   a. Consideration should be given to presoaking the test borings for up to 24 hours prior to commencing testing.
   b. Measurements for extended testing should continue for 4 hours or more, regardless of infiltration rates.
   c. The 30-minute constant head period may be excluded if adequate constant head data were obtained during Quick Testing.

4. See **Attachment 4** for a discussion of how to report the test results.

ATTACHMENT 4
Reporting of Test Results

1. Reporting of test results, whether quick or extended, shallow or deep, should contain essentially the same information.

2. For each test boring, tabulate the test data showing:
    a. Test identification
    b. Date drilled
    c. Date tested
    d. Test boring diameter
    e. Perforated pipe diameter
    f. Test boring depth
    g. Strata present in the test zone
    h. Elevation of top of SCM (known or assumed)
    i. Elevation of invert of SCM (known or assumed)
    j. Test duration
    k. Volume introduced between commencement of filling and the end of the 30-minute constant head period, typically in units of cubic feet
    l. Head during initial 30-minute period
    m. Time of the first falling head measurement and depth to the water surface
    n. Time of each subsequent measurement and depth to the water surface
    o. Intervals between measurements
    p. Incremental drop between measurements
    q. Infiltration rate between measurements, typically in units of inches per hour

3. Provide a map showing the approximate locations of all profile and test borings, as well as property lines, landmarks, planned improvements and SCM locations (if known), and other pertinent features that will help the user better understand the boring and testing program.

4. Provide log of each profile boring

5. Provide report summarizing data and discussing the potential for use of infiltration based SCMs on the site or area(s) tested.

ATTACHMENT 5

Suggestions Regarding Calculation of K_{SAT} from Infiltration Test Results from this Guidance Document

There are many field methodologies and associated calculations for determining Ksat. Most of these methodologies are complex, expensive and/or do not result in data that truly represent the site conditions. The methodologies provided in this guidance document attempts to approximate saturated soil conditions in the field, without the complexity of field Ksat determination methods, to obtain infiltration rate data that can be used for SCM sizing and design. However, if the designer is not satisfied with this approximation, calculation of a Ksat value for SCM sizing and design, using field derived infiltration data is a challenge but can be accomplished. One method that may be useful is provided in Appendix VII of the Orange County Technical Guidance Document (DAMP Exhibit 7.III) that allows calculation of a "design" K value (KDESIGN). (http://ocwatersheds.com/documents/wqmp/tgd/).

On page VII-29 of that appendix, an equation for calculation of the "tested infiltration rate" (It) in units of inches/hour is presented. The tested infiltration rate is then divided by a factor of safety of 2.0 to determine the "measured infiltration rate" (KM). Per this document, KM is utilized to determine if infiltration is simply infeasible. Pages VII – V-35 then present a means by which two additional factors of safety (SA and SB) may be derived. SA is a factor that is weighted for specific levels of confidence in the data; SB relates to operational or construction factors. Lastly, KDESIGN is calculated by multiplying KM by SA and SB.

It is suggested that the SCM designer discuss the project with the geotechnical engineer to get a sense of how well the field derived data may approximate the Ksat condition to better estimate sizing factors. Use of this or any other methodology is left to the discretion of the design engineer.