APPENDIX C – SITE EVALUATION AND SOIL TESTING PROTOCOL FOR STORMWATER INFILTRATION

Site Evaluation and Soil Testing Protocol for Stormwater Infiltration

C1.0 INTRODUCTION

C1.1 Purpose of the Protocol

The purpose of this protocol is to describe evaluation and field testing procedures to:

- Determine if stormwater infiltration best management practices (BMPs) are well suited to a site, and at what locations; and
- Obtain the required data for stormwater infiltration BMP design.

C1.2 When to Conduct Testing

Designers are encouraged to conduct site evaluation and soil testing early in the development planning and design process so that information gained can be incorporated into the design. Chapters 2 and 3 of this guide describe planning and design principles, processes and practices to better integrate stormwater management into the development planning process. It is recommended that site evaluation and soil testing be conducted following the development of a preliminary plan for the proposed development. The designer should possess an understanding of potential BMP types and locations prior to soil testing. On-site tests may be carried out in advance to identify potential BMP types and locations.

C1.3 Who Should Conduct Testing

Qualified professionals, who can substantiate by qualifications or experience their ability to carry out the evaluation, should conduct the soil testing. A professional, experienced in observing and evaluating soil conditions is necessary to ascertain conditions that might affect BMP performance that cannot be thoroughly assessed with testing procedures.

C2.0 SOIL INFILTRATION TESTING: A MULTI-STEP PROCESS

Soil infiltration testing is a four-step process to obtain the necessary information for stormwater management planning and design. The four steps include:

1. Background Evaluation
    - Based on available published and site specific data;
    - Includes consideration of proposed development plan;
    - Used to identify potential BMP types, locations and soil test locations;
    - Done prior to field work; and
    - On-site soil tests may be done to identify/screen potential BMP locations.

2. Test Pit or Soil Boring Observations
    - Includes multiple testing locations;
    - Provides an understanding of sub-surface conditions; and

- Identifies limiting conditions (e.g., aquitard, bedrock or water table elevations).

3. Infiltration Testing
   - Must be conducted on-site;
   - Various testing methods are available; and
   - Different testing methods for screening versus verification purposes.

4. Design Considerations
   - Determination of a suitable infiltration rate for design calculations; and
   - Consideration of desired BMP drawdown period.

C2.1 Step 1. Background Evaluation

Prior to performing testing and developing a detailed site plan, existing site conditions should be inventoried and mapped including, but not limited to:

- Surficial geology and underlying stratigraphy;
- Watercourses (perennial and intermittent), water bodies, wetlands and floodplains;
- Small headwater drainage features;
- Topography, slope, and drainage patterns;
- Existing land cover and land use;
- Natural heritage conservation areas; and
- Other man-made features or conditions that may impact design such as existing nearby structures (buildings, infrastructure, etc.).

A sketch plan or preliminary layout plan for the proposed development should be evaluated, including:

- The preliminary grading plan and areas of cut and fill;
- The location and water surface elevation of all existing, and location of proposed water supply sources and wells;
- The location of all existing and proposed on-site wastewater (septic) systems;
- The location of other features of note such as utility rights-of-way, water and sewer lines, etc.;
- Existing data from borehole, well and geophysical testing; and
- Proposed location of development features (buildings, roads, utilities, etc.).

In Step 1, the designer should determine the potential location of infiltration BMPs. The approximate location of these BMPs should be noted on the proposed development plan and should serve as the basis for the location and number of soil tests to be performed on-site.

Important: If the proposed development is located on areas that may otherwise be suitable for stormwater infiltration BMPs, or if the proposed grading plan is such that potential BMP locations are eliminated, the designer is strongly encouraged to revisit the proposed layout and grading plan and adjust the development plan as necessary.

Development of areas suitable for infiltration BMPs does not preclude the use of subsurface infiltration BMPs for runoff volume reduction and groundwater recharge benefits (e.g., soakaways, infiltration trenches and chambers, perforated pipe systems).

C2.2 Step 2. Test Pit or Soil Boring Observations

Test pits or soil borings provide information regarding the soil horizons and overall soil conditions both horizontally and vertically in that portion of the site. Multiple observations can be made across a site at a relatively low cost and in a short time period. The use of test pits is preferable to soil borings as visual observation is narrowly limited in a soil boring and the soil horizons cannot be observed *in-situ*, but must be observed from the extracted borings.

Test pit excavations or soil borings should extend to a depth of between 2.5 to 5 metres below ground surface or until bedrock or fully saturated conditions are encountered. It is important that the tests provide information related to conditions at least 1.5 metres below the proposed bottom elevation of the infiltration BMP. Test pit trenches should be benched at 1 metre depth intervals for access and infiltration testing. A test pit should never be accessed if soil conditions are unsuitable for safe entry, or if site constraints preclude entry or exit. Where excavation of a test pit to the required depth would create an undesirable or unsafe condition, two soil borings may be conducted instead.

At each test location, the following conditions should be noted and described:

- Soil horizons (upper and lower boundary);
- Soil texture and colour for each horizon;
- Color patterns (mottling) and observed depth;
- Depth to water table (if encountered);
- Depth to bedrock (if encountered);
- Observations of pores or roots (size, depth);
- Estimated type and percent coarse fragments;
- Hardpan or other limiting layers; and
- Strike and dip of soil horizons.

At the designer's discretion, soil samples may be collected at various horizons for additional analyses (e.g., grain size analysis).

The number of test pits or soil borings varies depending on site conditions and the proposed development plan. General guidelines are as follows:

- For infiltration BMPs with footprint surface areas from 50 to 900 square metres, a minimum of two test pits or one test pit and two soil borings are required at, or within 10 metres of the proposed location to determine the suitability and distribution of soil types present;
- For infiltration BMPs with footprint surface areas greater than 900 square metres, a minimum of one test should be conducted for each 450 square metres of

footprint surface area. Tests should be conducted equidistant from each other to provide adequate characterization of the area;

- For linear infiltration BMPs a minimum of one test should be conducted within each soil mapping unit present along the proposed BMP location. Soil borings should be conducted every 50 metres and a test pit should be conducted every 450 metres; and
- For sites with multiple infiltration BMPs, each with footprint surface areas less than 50 square metres, a minimum of one test pit is required and one soil boring per infiltration BMP location is recommended.

The recommendations above are guidelines. Additional tests should be conducted if local conditions indicate significant variability in soil type, geology, water table levels, bedrock or topography. Similarly, uniform site conditions may indicate that fewer tests are required.

C2.3 Step 3. Infiltration Testing

A variety of field tests exist for estimating the infiltration rate of the native soil that include the use of permeameter or infiltrometer devices, percolation tests and empirical relationships between grain size distribution and hydraulic conductivity. At least one test should be conducted at the proposed bottom elevation of the infiltration BMP, plus additional tests at every other soil horizon encountered within 1.5 metres below the proposed bottom elevation. A minimum of two tests per test pit are recommended. More tests are warranted if results from the first two tests are substantially different. The geometric mean value should be used to determine the average infiltration rate for each soil horizon following multiple tests.

Based on field observations, infiltration testing results and the desired drawdown period (typically 48 hours), the designer may elect to modify the proposed bottom elevation of a BMP (see Step 4). Therefore, personnel conducting infiltration tests should be prepared to adjust test locations and depths depending upon observed conditions.

Infiltration testing methods discussed in this protocol include:

- Guelph permeameter test;
- Double-ring infiltrometer test;
- Borehole permeameter test; and
- Percolation test.

There are differences between these methods. Guelph permeameter and double-ring infiltrometer tests estimate the vertical movement of water through the bottom of the test area. The outer ring helps to reduce the lateral movement of water in the soil. Borehole permeameter and percolation tests allow water movement through both the bottom and sides of the test area. For this reason, the measured rate of water level drop in these types of tests must be adjusted to represent the discharge that is occurring on both the bottom and sides of the test hole.

For initial screening of a site for potential BMP types and locations, percolation tests and grain size analyses of samples from soil borings are suitable methods for estimating the infiltration rate of the native soil. Tests should not be conducted in the rain or within 24 hours of significant rainfall events (>15 millimetres depth), or when the temperature is below freezing. The preferred testing period is during April and May. This is the period when infiltration is likely to be diminished by saturated conditions. Percolation tests conducted between June 1 and December 31 should be done following a 24 hour pre-soaking period to simulate field saturated conditions. Pre-soaking is not required for permeameter or infiltrometer test methods.

To verify native soil infiltration rates for design purposes, it is strongly recommended that infiltration tests be carried out with a permeameter or infiltrometer to determine the field saturated hydraulic conductivity (K_{fs}), rather than percolation tests or grain-size analyses. Alternatively, other permeability test procedures that yield a saturated hydraulic conductivity rate can be used, such as formulas developed by Elrick and Reynolds[1], or others for computation of hydraulic conductivity and saturated hydraulic conductivity.

Many *in-situ* methods have been developed for determining field saturated hydraulic conductivity within the unsaturated (vadose) zone of the soil. Detailed testing methods and standards that are available but not discussed in detail in this protocol include (but are not limited to):

- Constant head well permeameter method (i.e., Guelph Permeameter method)[2, 3];
- Constant head double-ring infiltrometer method[3, 4];
- Constant head pressure (single-ring) infiltrometer method[5];

A complete guide for comparing standard methods is presented in ASTM International Designation D5126-90 (2004)[6]. Further detailed discussion on standard methods can also be found in Amoozegar and Warrick (1986)[5].

[1] Elrick, D.E. and Reynolds, W.D. 1992. Infiltration from constant head well permeameters and infiltrometers. In, G.C. Topp, W.D. Reynolds and R.E. Green (Eds.). Advances in measurement of soil physical properties: Bringing theory into practice. Special Publication 30. Soil Society of America. Madison, WI.

[2] Reynolds, W.D., Elrick, D.E. 1986. A method for simultaneous *in-situ* measurement in the vadose zone of field-saturated hydraulic conductivity, sorptivity and the conductivity-pressure head relationship. *Ground Water Monitoring Review*. No. 9. pp. 184-193.

[3] Reynolds, W.D. 1993. Saturated Hydraulic Conductivity: Field Measurement. In, M.R. Carter (ed.). Soil Sampling and Methods of Analysis. Chapter 56. Canadian Society of Soil Science. Lewis Publishers. Ann Arbor, MA.

[4] ASTM International. 2003. Designation D 3385-03, Standard Test Method for Infiltration Rate of Soils in Field Using a Double-Ring Infiltrometer. West Conshohocken, PA.

[5] Amoozegar, A. and Warrick, A.W. 1986. Hydraulic conductivity of saturated soils: field methods. In, A. Klute (ed.) Methods of Soil Analysis. 2nd edition. No. 9 Agronomy. American Society of Agronomy, Madison, WI.

[6] ASTM International. 2004. Designation D5126-90 (2004), Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone. West Conshohocken, PA.

For the purpose of designing the infiltration BMP, hydraulic conductivity values (typically in centimetres per second) generated from permeameter or infiltrometer tests must be converted into infiltration rates (typically in millimetres per hour). **It is critical to note that hydraulic conductivity and infiltration rate are two different concepts and that conversion from one parameter to another cannot be done through unit conversion**. Particularly for fine grained soils, there is no consistent relationship due to the many factors involved. Table C1 and Figure C1 describes approximate relationships between hydraulic conductivity, percolation time and infiltration rate. Measured hydraulic conductivity values can be converted to infiltration rates using the approximate relationship described in Figure C1.

Table C1: Approximate relationships between hydraulic conductivity, percolation time and infiltration rate

Hydraulic Conductivity, K_{fs} (centimetres/second)	Percolation Time, T (minutes/centimetre)	Infiltration Rate, 1/T (millimetres/hour)
0.1	2	300
0.01	4	150
0.001	8	75
0.0001	12	50
0.00001	20	30
0.000001	50	12

Source: Ontario Ministry of Municipal Affairs and Housing (OMMAH). 1997. Supplementary Guidelines to the Ontario Building Code 1997. SG-6 Percolation Time and Soil Descriptions. Toronto, Ontario.

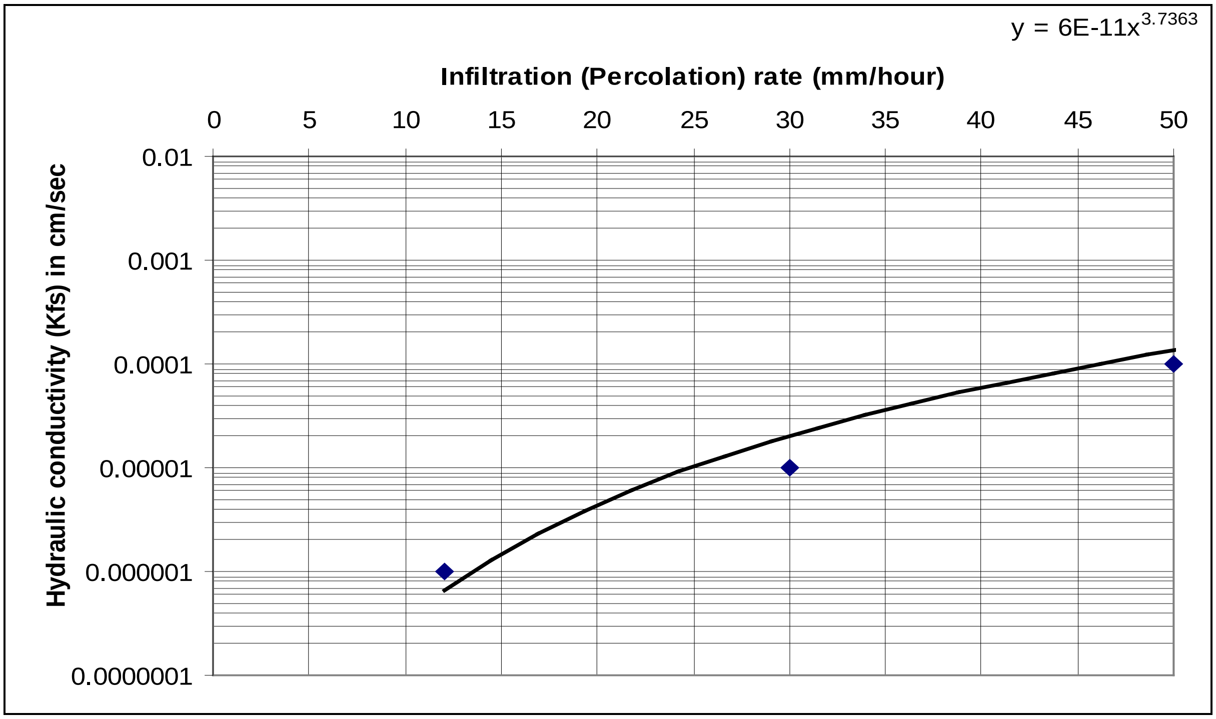
Following testing, the test pits should be refilled with the original soil and the surface replaced with the original topsoil.

The results and locations of all test pits, soil borings and infiltration tests should be included in documents submitted to commenting and approval agencies in support of the development proposal.

C2.4 Step 4. Design Considerations

The infiltration rate used to design an infiltration BMP must incorporate a safety correction factor that compensates for potential reductions in soil permeability due to compaction or smearing during construction, gradual accumulation of fine sediments over the lifespan of the BMP and uncertainty in measured values when less permeable soil horizons exist within 1.5 metres below the proposed bottom elevation of the BMP.

Figure C1: Approximate relationship between infiltration rate and hydraulic conductivity



Source: Ontario Ministry of Municipal Affairs and Housing (OMMAH). 1997. Supplementary Guidelines to the Ontario Building Code 1997. SG-6 Percolation Time and Soil Descriptions. Toronto, Ontario.

The measured infiltration rate (in millimetres per hour) at the proposed bottom elevation of the BMP must be divided by a safety correction factor selected from Table C2 to calculate the design infiltration rate. To select a safety correction factor from Table C2, calculate the ratio of the mean (geometric) measured infiltration rate at the proposed bottom elevation of the BMP to the rate in the least permeable soil horizon within 1.5 metres below the bottom of the BMP. Based on this ratio, a safety correction factor is selected from Table C2. For example, where the mean infiltration rate measured at the proposed bottom elevation of the BMP is 30 mm/h, and the mean infiltration rate measured in an underlying soil horizon within 1.5 metres of the bottom is 12 mm/h, the ratio would be 2.5, the safety correction factor would be 3.5, and the design infiltration rate would be 8.6 mm/h. Where the soil horizon is continuous within 1.5 metres below the proposed bottom of the BMP, the mean infiltration rate measured at the bottom elevation of the BMP should be divided by a safety correction factor of 2.5 to calculate the design infiltration rate.

Table C2: Safety correction factors for calculating design infiltration rates

Ratio of Mean Measured Infiltration Rates[1]	Safety Correction Factor[2]
≤ 1	2.5
1.1 to 4.0	3.5
4.1 to 8.0	4.5
8.1 to 16.0	6.5
16.1 or greater	8.5

Source: Wisconsin Department of Natural Resources. 2004. Conservation Practice Standards. Site Evaluation for Stormwater Infiltration (1002). Madison, WI.

Notes:

1. Ratio is determined by dividing the geometric mean measured infiltration rate at the proposed bottom elevation of the BMP by the geometric mean measured infiltration rate of the least permeable soil horizon within 1.5 metres below the proposed bottom elevation of the BMP.
2. The design infiltration rate is calculated by dividing the geometric mean measured infiltration rate at the proposed bottom elevation of the BMP by the safety correction factor.

The design infiltration rate should be used to determine the maximum depth of the water storage component of the BMP, based on the desired drawdown period (typically 48 hours to fully drain the BMP; see Chapter 4 for guidance regarding the design of specific infiltration BMP types). Based on the calculated design infiltration rate, assumptions regarding the bottom elevation of the BMP may need to be reconsidered and further infiltration testing may be warranted.