Errata and New Materials

The last entirely new edition of the Rainwater and Land Development manual was issued in November of 2006, but new materials have been added and changes and corrections made since that time to the manual text or figures. All of these have been included in subsequent printings and in files posted to the ODNR Rainwater and Land Development manual web page.

The following corrections or additions have been made since the first printing of the 2006 Rainwater and Land Development manual in November of 2006.

On **October 1, 2007**, the following pages were changed or corrected:
Table of Contents (both pages);
Chapter 1 pages 1, 2, 3, 4, 7, 8, 9, and 10;
Chapter 2 pages 1, 30, 33, 34, 36, 39, 40, 47, 48, 51, 60, 61, 72, Practice Note regarding Bioretention soils added;
Chapter 4 page 1;
Chapter 5 pages 1, 11, and 19;
Chapter 6 pages 6, 7, 8, 24, 25, 27, and 41;
Chapter 7 pages 1, 4 and 5.

On **November 29, 2007**, the following pages were changed or corrected:
Chapter 2 pages 44, and 76.

On **June 23, 2009**, the following pages were changed or corrected:
Chapter 2 pages 44 (equation rewritten but effectively unchanged);
Chapter 5 page 29 (practice numbering corrected);
Chapter 6 page 21 (practice numbering);
Chapter 7 pages 3, 7, 10, and 17 (practice numbering);
Appendix 6 pages 1-18 (new text-pg. 1, removed extra tables & a typo).

On **May 7, 2012**, the following pages were changed, corrected or added:
Table of Contents (both pages re: Perm Pavement and Appendixes 1, 4, 9, 10 and 11);
Chapter 2 (Page 1 table of contents changed, and pages 85-112 added);
Appendix 1 added;
Appendix 4 pages 2, 3, 4 and 5 updated;
Appendix 9 added;
Appendix 10 added;
Appendix 11 added.

On **August 30, 2012**, the following pages were changed, corrected or added:
Chapter 2 page 90 an overlapping figure and caption were corrected;
Chapter 2 pages 95, 96, and 98 properly formatted text (i.e. Italic and subscript);

If the printing date is known, then a set of new and updated pages can be obtained from the ODNR Rainwater and Land Development web page. See the errata tab, at this address: http://www.dnr.state.oh.us/soilandwater/water/rainwater/default/tabid/9186/Default.aspx. All new materials regarding the manual can be found at this site or by emailing or calling the Ohio Department of Resources, Division of Soil and Water Resources (614-265-6685 or dswc@dnr.state.oh.us).

This manual was updated on the following date ____________. Initials_________

Vertical Separation Distances - Give special consideration to the following situations:

- Infiltrating permeable pavement systems with recharge layers located over soils with ground water tables that reach within 2 feet of the subgrade infiltration bed.
- Infiltrating permeable pavement systems with recharge layers located over impermeable bedrock within 2 feet of the subgrade infiltration bed.

These situations are likely to result in mounding of stormwater to the level of the infiltration bed for extended periods, especially during the spring. These systems may still help meet watershed management goals - for example, baseflow maintenance and temperature moderation during summer low-flow periods. However, a more thorough mapping and modeling of surface and subsurface hydrology is necessary to prevent unintended consequences. The pavement system configuration and drainage system should be modified to achieve stormwater management goals while minimizing unintended consequences.

Soil surveys can be used as rough guidance during initial planning and site layout to identify areas where shallow water tables or shallow bedrock may be a concern. However, in areas where these concerns are known, a professional geotechnical engineer and/or professional soil scientist should be contracted to take core samples to a depth of 6 ft below the proposed subgrade depth and report: depth to bedrock, any layering of the subgrade representing significant changes in texture or structure, the particle size distribution of the subgrade soil, the particle size distribution of any deeper layers, and depth to water table (ideally the water table will be checked between late March to early May when the water table is highest).

Groundwater Concerns – Permeable pavement, as with any infiltrating practice, requires the designer to consider the potential for adversely impacting groundwater. Elevated pollution sources or areas with high risk of toxic spills should not be directed to permeable pavement without appropriate pretreatment.. Examples include maintenance yards where salt storage or distribution takes place, airport areas where deicing occurs, fueling stations and composting facilities.

Development sites that include both relatively clean runoff (e.g., rooftop runoff) and dirtier runoff (e.g., from a maintenance yard or material storage area) should consider separate stormwater management systems appropriate to the specific runoff source. In such a scenario, rooftop runoff or runoff from office parking could be safely directed to an infiltrating BMP without pretreatment, whereas runoff from a maintenance yard should be treated in a separate facility designed to minimize potential negative impacts to groundwater. Such areas should be separated with physical barriers (fence, curb, etc.) to minimize tracking of pollutants into “clean” runoff areas.

Karst Terrain - Active karst regions are found in parts of Ohio (Hull, 1999; ODNR, 1999), and complicate development and stormwater system design. The use of permeable pavement or other infiltration BMPs in karst regions may promote the formation of sinkholes. In karst regions, a detailed geotechnical survey should be conducted to the satisfaction of the local approval authority. Permeable pavement designs in karst should exceed the minimum vertical separations recommended above and consider the use of an impermeable bottom liner and an underdrain. Additionally they should not receive runoff from other (external) impervious areas.

Freeze-Thaw - Water entrapped in the pavement during freezing and thawing cycles will result in cracking, scaling and/or deterioration of the pavement (NRMCA, 2004). Therefore, the pavement structure and drainage system should be designed to ensure free drainage of the pavement surface and to prevent ponding into the pavement structure. Permeable pavements may be more resistant to freezing and may thaw faster than conventional impermeable pavement due to the water content and ground temperature in the underlying soil and the ability to infiltrate meltwater (Backstrom, 2000).

Frost Heave - Frost heave occurs when underground water accumulates in ice formations or ice "lenses", expanding and pushing the pavement structure upward resulting in uneven pavement (Leming et al., 2007) . Unlike their traditional counterparts, permeable pavements are specifically designed to introduce water below the pavement surface. Therefore, the pavement structure and drainage system should be appropriate for the subgrade soils (Leming et al., 2007; UNH, 2009).

One recommendation is to increase pavement or aggregate base thickness to accommodate the extra load carried by the surface course during spring thaw (Leming et al., 2007) and is reflected in some guidance for portland cement pavement surfaces (see ORMCA, 2009).

Frost heave is a serious concern for finer textured soils. Sands and coarser aggregates are much less susceptible to frost heave. One straightforward approach to minimize frost heave is to provide a base aggregate course thickness to minimize the formation of ice in the underlying subgrade. The University of New Hampshire Stormwater Center (UNH, 2009) recommends that the thickness of the permeable pavement structure (i.e., pavement plus sub-base thickness) be a minimum of 0.65 x design frost depth for the location. Local maximum frost penetration depth oftentimes can be provided by the local building authority. In the absence of locally available information, the following table can be used.

Located North of Latitude	Max. Frost Depth (inches)	Min. Recommended Thickness (0.65 x Max Frost Depth in inches)
38.3	24	16
38.7	26	17
39.0	28	18
39.3	30	20
39.7	32	21
40.0	34	22
40.3	36	24
40.7	38	25
41.0	40	26
41.3	42	27
41.7	44	29
42.0	46	30

Table 2.11.3 Frost depth and minimum recommended pavement system (pavement + sub-base) thickness by latitude (interpolated from Fig. 13 in Floyd, 1978; http://www.ngs.noaa.gov/PUBS_LIB/GeodeticBMs/#figure13)

Grading – The bottom of the infiltration bed should be level or nearly level. Sloping bed bottoms will lead to poor distribution and reduced infiltration. It is recommended permeable pavement surface slopes be less than 5% to optimize the ponding depth under the pavement surface. Where topography doesn't permit a single level infiltration bed, multiple infiltration beds may be benched or terraced to obtain the necessary infiltration area and to promote more uniform infiltration.

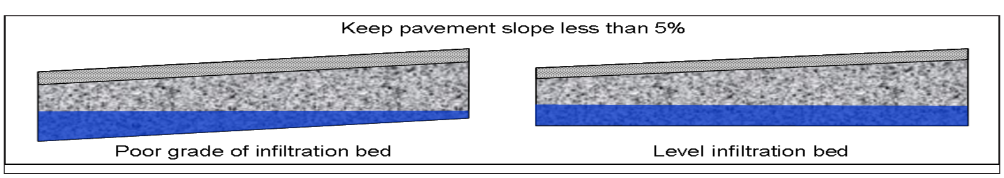

Figure 2.1.2 Level infiltration beds and limited pavement slope maximizes stormwater treatment and storage.

Design Criteria - General/Introduction

Permeable pavements typically will be designed to address two types of design criteria:

- Minimum specifications should be met to ensure the long-term structural performance appropriate to the specific use of the pavement (pavement type, location, type of traffic, traffic load, etc.). The pavement should meet all design, construction and maintenance requirements of the local approval authority.
- Secondly, permeable pavement typically will be part of the stormwater management infrastructure of the development site. Therefore, meeting specific design criteria should allow the permeable pavement system to receive credit toward meeting water quality treatment performance requirements of the NPDES Construction General Permit (OEPA, 2008) and/or receive appropriate credit toward meeting local peak discharge requirements.

Design Criteria - Stormwater Requirements

The Ohio DNR and Ohio EPA mandate is to ensure post-construction stormwater performance over the long-term. This means the permeable pavement system must show equivalent WQ performance to the structural BMPs listed in Table 2 of the NPDES Construction General Permit (Ohio EPA, 2008), or be part of a larger stormwater system that collectively meets those requirements. Permeable pavement can be used to meet the WQv requirement for either new development or re-development.

Full infiltration of WQv - Permeable pavement, without prior OEPA approval, may be used to meet the WQv requirements of the Construction General Permit (CGP) as long as the practices designed to fully infiltrate the WQv and follows the design, construction and maintenance protocols outlined in this section.

No infiltration - If the site is not suitable for deep infiltration (e.g., lined system or compacted subgrade), permeable pavement may be considered for WQv on a case-by-case basis with prior approval from OEPA and the local MS4. This scenario will require an appropriately designed outlet control to release runoff over a 24 hour period; however, no additional sediment storage volume (=0.2*WQv) is required. The volume of runoff detained shall drain over 24 hours, releasing no more than one half the volume in the first eight hours. Monitoring of system function/performance may be required.

Partial infiltration of WQv - If the site is capable of partially infiltrating the WQv, the volume infiltrated may be subtracted from the WQv when determining detention requirements. As for the no infiltration scenario, an appropriately designed outlet will be needed to release runoff over 24 hours, releasing no more than one half the volume in the first eight hours.. This scenario requires prior approval from OEPA and the local MS4.

Redevelopment Projects - For redevelopment projects, the area of permeable pavement receives a 1:1 credit toward the 20% reduction in impervious area requirement of the CGP. All areas draining to the permeable pavement receive credit toward the impervious area reduction as long as the storage layer is designed to hold and either infiltrate (within 48 hours) or release (with a drain time of 24 hours, releasing no more than half the WQv in the first 8 hours) the water quality volume AND the permeable pavement system meets all other requirements outlined in this guidance.

Inspection and Maintenance - Permeable pavement must be inspected and cleaned regularly to maintain the hydrologic performance of the pavement system. Therefore, Ohio EPA will consider permeable pavement as meeting the requirements of the CGP only if the property owner has a maintenance agreement approved by the local MS4 that includes the minimum practices outlined under the section titled “Maintenance” below.

Water Quality Calculations -

Calculate the **total water quality volume** (WQv) using the following equation:

$$WQv\ (ac\text{-}ft) = C*P*A \qquad \text{(Equation 1)}$$

Where: C = volumetric runoff coefficient

P = 0.75” rainfall

A = drainage area (acres)

For the permeable pavement surface, C = 0.89.

For other contributing drainage area, determine C according to guidance in the NPDES Construction General Permit (Ohio EPA, 2008). Either look up the C value in Table 1 of the CGP, or use the following equation:

$$C = 0.858i^3 – 0.78i^2 + 0.774i + 0.04 \qquad \text{(Equation 2)}$$

Where: i = watershed imperviousness ratio, the percent imperviousness divided by 100

If the additional contributing drainage area is entirely impervious surfaces (traditional pavements and/or roofs), i = 1 and C = 0.89.

No additional storage is required for sediment accumulation.

Converting Storage Volume to Storage Depth - The sub-pavement volume available for temporary storage of stormwater will typically be filled with aggregate (washed, uniformly-graded stone or gravel). The volume occupied by the aggregate itself is unavailable for water storage. The remaining volume of voids is available for storage of water:

$$V_T = V_S + V_V \qquad \text{(Equation 3)}$$

Where: V_T = Total Volume

V_S = Solids Volume

V_V = Voids Volume

A more common way to communicate about the volume available for water storage is the aggregate porosity, φ, the ratio of void-space volume to the total volume:

$$\varphi_{aggregate} = V_V / V_T$$

Aggregate porosity can range from 0.30 to 0.40 (Ferguson, 2005). However, some percentage of the voids will be unavailable for additional stormwater storage because of previous wetting and entrapped air resulting in a lower usable or effective porosity. We recommend using an aggregate porosity of $\varphi_{aggregate}$ = 0.35 in the following calculations[2,3].

The aggregate thickness required to meet the WQv objective can be calculated:

$$D_{agg\text{-}WQv} = WQv/(A_{reservoir} * \varphi_{aggregate})$$

Where: $D_{agg\text{-}WQv}$ = required aggregate thickness (L)

WQv = water quality volume (L^3)

$A_{reservoir}$ = basal area of aggregate reservoir (L^2)

$\varphi_{aggregate}$ = aggregate porosity

2 Note that the porosity of the pavement itself typically is substantially lower than the aggregate base; when needed for calculations, porosities for the pavement should be taken from guidance provided by the specific industry association.

3 A number of underground storage chambers have been developed and designed to provide both sturctural support for pavements and temporary stormwater storage. Because the void space within the chambers approaches 100%, these chambers may provide a cost-effective alternative to a sub-pavement reservoir consisting entirely of aggregate. Guidance for both the chambers and the industry association for the desired pavement should be consulted to ensure sturctural performance.