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_________

Title: Rainwater and Land Development: Ohio's Standards for Stormwater Management, Land Development and Urban Stream Protection

Date: December 2006

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Abstract: Stream systems, including their corridors, and wetland resources are vital environmental features and are extremely sensitive to urbanization. The intent of this book is to allow development to occur while minimizing the impact on water resources, especially streams.

This book defines Ohio's standards and specifications for stormwater practices implemented during land development. It is an update of the previous Rainwater and Land Development book completed in January 1996. The target audience is that group of professionals involved in the design and implementation of development projects.

This book aims to integrate water resource protection into development site planning in order to maintain or improve stream integrity. Early chapters discuss practices and strategies for protecting streams and wetlands, treating stormwater pollutants, rehabilitating streams and establishing permanent runoff controls. The latter portion of the book includes chapters regarding construction-phase practices, including standards and specifications for sediment control, temporary runoff control, soil stabilization and control of pollutants other than sediment. Appendixes offer further information regarding stormwater design examples, permits, helpful contacts, and soils.

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CONTENTS

We want to acknowledge all of the people who deserve credit for helping prepare this significant improvement to Ohio's *Rainwater and Land Development* manual – they were many.

Initially there were the ODNR Division of Soil and Water Conservation's traditional conservation partners: Ohio's soil and water conservation districts, the Ohio Environmental Protection Agency, the USDA Natural Resources Conservation Service and The Ohio State University Extension. Ultimately, many other individuals, representing the development and consulting industry, and local government became involved. They contributed suggestions, photos and content for this manual. Some helped by participating on a Rainwater and Land Development committee or subcommittee, by writing material or perhaps by reviewing drafts as they were developed. All who have contributed their time and efforts have our sincere thanks for their contributions. And we hope all will remain involved in our work to make further improvements in the future. Finally, from within the ODNR, we thank John Mathews for his leadership.

Samuel W. Speck, Director
Ohio Department of Natural Resources

David Hanselmann, Chief
Division of Soil and Water Conservation

CHAPTER 2

Post Construction Stormwater Management Practices

Post-construction stormwater management practices treat runoff from a development site *after* construction is complete. Their objectives range from capturing and treating pollutants in runoff to managing the increased frequency, volume and energy of stormwater runoff so that water resources are not degraded.

Historically, stormwater ponds were used to reduce downstream flooding. Today post-construction stormwater ponds add pollution control and stream protection as important design elements. Apply the structural practices found in this chapter to reduce pollutants, meet state and local permits and reduce downstream erosive effects of runoff. While all structural practices require maintenance, those provided here emphasize lower maintenance and generally self-sustaining processes. Other structural practices are available for use; yet all should be examined for their effectiveness, maintenance requirements and ability to function if maintenance is delayed.

Treatment occurs primarily through the processes of settling, adsorption, and biological uptake, while detention is utilized to curb the impact of increased runoff. Where soils are appropriate, infiltration provides substantial hydrologic benefits.

Structural practices treat runoff, but more is needed to effectively prevent and minimize impacts. Therefore additional management practices are strongly encouraged. Practices such as stream setbacks or reduction of impervious areas influence the layout and design of a development site so that important hydrologic areas are maintained and runoff is limited. Many of the management practices provided have more exhaustive reference sources given that should be consulted as they are applied. Note that while each of the management practices is beneficial, some community zoning or building standards may limit your ability to use a particular practice.

MANAGEMENT PRACTICES

STRUCTURAL PRACTICES

Page updated 5-4-12

Design Criteria

Diversion – Storm water runoff should be directed to the infiltration trench via dispersed sheet flow wherever possible. A grass filter strip of at least 25 feet must precede the infiltration trench in these situations. Where runoff is directed to the infiltration trench as concentrated flow (via a swale, storm sewer or other discrete conveyance), the infiltration trench must be designed "off-line" such that flows in excess of the Water Quality Volume (WQv) are diverted around the infiltration trench.

In addition, a diversion that allows the trench to be bypassed when the pretreatment system becomes clogged or otherwise fails should be included in the design. This can be accomplished by providing a drain valve.

Soil Hydraulic Conductivity – Soil infiltration rates within the trench must be between 0.52 and 2.4 inches per hour. The soil should have no greater than 20 percent clay content and less than 40 percent silt/clay content.

The list of soils in Ohio that meet the required infiltration rates and are potentially suitable for the installation of infiltration trenches can be found in Appendix E. However, do not use this or county soil surveys to determine final suitability. Site-specific soil tests should be performed to confirm that the hydraulic conductivity falls within the required range. A certified Soil Scientist or other trained professional shall perform one test hole per 5000 feet, with a minimum of two borings within the planned facility location. This evaluation shall include an evaluation of the normal and seasonal high groundwater levels.

Pretreatment – The potential for failure of infiltration practices due to clogging by sediments is high. Failure will result if sediment is not trapped before runoff enters the trench. Thus, it is imperative that the facility design includes a durable, maintainable pretreatment system for removing sediment from stormwater before the trench. This can be accomplished by installing a plunge pool. Where infiltration trenches are used to treat rooftop runoff with drainage areas of 1 acre or less, pretreatment can be accomplished by providing an underground trap with a permanent pool between the downspout and the infiltration trench (Fig 2.7.1). The trap must be accessible, but sealed tightly so that it does not become a breeding ground for mosquitoes.

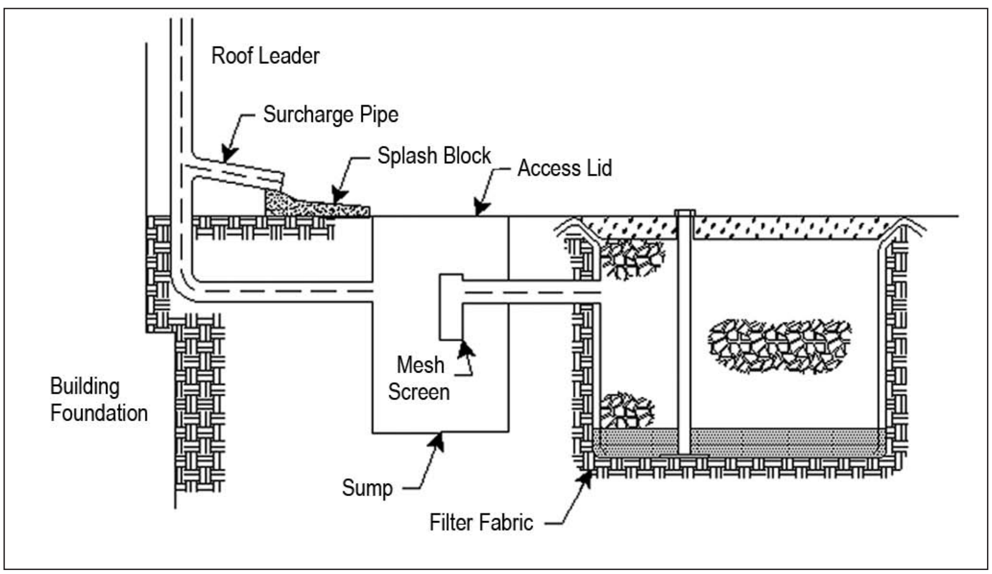

Figure 2.7.1 **Underground pretreatment facility and infiltration trench for treating rooftop runoff.**

Sizing the Pretreatment Facility – The size of the pretreatment facility is based on the infiltration rate of the soil in which the infiltration trench is built. For soils with infiltration rates of 2.0 inches per hour or less, the pretreatment facility shall be sized to contain 25% of the WQv. For infiltration rates greater than 2.0 inches per hour, the pretreatment facility shall be sized to contain 50% of the WQv.

Exit Velocity from Pretreatment Facility – The velocity of runoff as it exits from the pretreatment device must be non-erosive.

Drain Time Requirements – The practice is to be designed to infiltrate the Water Quality Volume (WQv, see page 30 of this chapt.) through the bottom floor of the structure in 24 to 48 hours. Drain times in excess of 72 hours should be avoided to prevent mosquito-breeding habitat from forming. Flows in excess of the WQv are to be diverted around the trench.

Dimensions – The dimensions of the storage reservoir (infiltration trench) are made by fitting the length, width and depth into a configuration, which satisfies drain time and storage volume requirements. The trench dimensions shall be sized by accepted engineering methods such as those outlined below:

1. Determine Initial Storage Depth – The bottom of the infiltration trench must be deeper than 2 feet to avoid freezing and shallow enough to leave at least 3 feet between the seasonal high-water table or bedrock and the trench bottom. Soil morphology also must be considered in determining the dimensions of the storage reservoir to utilize the optimum horizons or strata. The presence of a thin, slowly permeable soil horizon may require a trench depth which completely penetrates it to more permeable underlying material. Long trenches may need to be curved parallel to the topographic contour in order to keep the trench bottom elevation within the optimum depth in the soil profile.

2. Determine Area of Trench Bottom – The bottom of the trench is to be completely flat so as to allow runoff to infiltrate through the entire surface.

$$A_{min} = \frac{WQ_v}{Porosity*(E*T)}$$

Where:
A_{min} = Minimum area of the bottom of the trench (ft^2);
WQ_v = Water Quality Volume (ft^3); (Trench volume less stone volume).
E = Exfiltration Rate (ft/hr); (Soil infiltration rate at trench bottom)
T = Drain Time (hr) (Must be 24 to 48 hrs per Ohio EPA requirements)

The excavated volume of the trench is the WQ_v divided by porosity or the void space of the stone.

Determine Length and Width – A long, narrow trench is less affected by water table mounding. If depth to seasonal high-water table or bedrock is within 5 feet of the trench bottom, it is advisable to design the trench as long and narrow as possible. Otherwise, the configuration of the trench is not restricted and is only limited by site design constraints.

Stone – The infiltration trench is filled with clean, washed aggregate. Stone with a diameter of between 1 and 3 inches should be used.

Geotextile – The sides and top of the trench must be lined with a non-woven geotextile to restrict the amount of sediment entering the structure. The top layer of the geotextile should be covered by 6-to-12 inches of smaller sized gravel (0.75-inch diameter). This top layer

Underdrains shall be a perforated pipe capable of withstanding the expected load above it and exceeding the drainage capacity of the planting soil layer. The following requirements apply to underdrains:

- The underdrain system shall be placed at a minimum 0.5 % slope.
- Underdrain pipes shall be a minimum 4-in. diameter perforated pipe.
- Underdrains are placed within a layer of # 57 washed gravel, having a minimum of 3-in. of gravel above and 3-in. below the pipe.
- Underdrains shall be placed depending upon the purpose of the gravel layer:
  - o The underdrain is typically placed in the middle of the gravel layer in order to provide bedding material.
  - o To promote infiltration into in-situ soils or to create an anaerobic zone for denitrification, the underdrain is placed near the top of a gravel bed. Gravel depth is determined by water storage needed to infiltrate the entire water quality volume into the soil or the volume of water targeted for anaerobic treatment.
- Underdrain pipes shall end with a cap, or an elbow with a vertical pipe providing observation and/or cleanout at the elevated end of the pipe. Observation/cleanout pipes shall consist of a minimum 4 inch diameter vertical non-perforated PVC pipe extending to the surface of the practice and sealed with a removable watertight cap.
- Underdrains shall drain to an existing drainage system or other suitable stable outlet having positive drainage.

7. *Overflow and Routing* - Bioretention facilities shall have a non-erodible means of discharging flow exceeding the capacity of the practice. Commonly this will be an overflow pipe or drop inlet set at the maximum ponding elevation. Off-line facilities collect runoff and then are bypassed by major storm plows. Consideration for tailwater from the receiving system shall be made.

8. *Planting Materials* – Species planted in bioretention practices should be adapted to the region, pollution tolerant, and able to survive the variable moisture conditions. Most plants should be facultative (found equally in wetland or upland conditions) though some species found in either environment may be acceptable. Native and non-invasive plants shall be used.

   Select plants, which in a mature condition will be appropriate to the depth of soil and the underdrain system. For examples, trees may be selected if the planting soil can accommodate the root ball of the selected trees. Trees and large shrubs will require staking to prevent being dislodged by wind. A qualified landscape architect, botanist, or native plant dealer will be helpful to design a planting plan.

Design Checklist

1. Compute water quality volume (WQV). _____ WQV = C * P * A / 12, where:

WQv= water quality volume in acre-feet

C = runoff coefficient (Use formula below or coefficient from Ohio EPA NPDES permit)

P = 0.75 inch precipitation depth

A = area draining into the BMP in acres _____

Planned Site Imperviousness (i) _____ (Eg. For 80% imperviousness use 0.8)

$C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04$

C = _____

2. Compute critical storm detention requirements. Substitute local requirement if they differ from the critical storm method.

Design Storm	Peak Discharge Rate (cfs)	24-hour Runoff Volume (show units)		Percent Increase	Design Discharge (cfs)
		Pre-Development	Post- Development		
1-year					
2-year					
5-year					
10-year					
25-year					
50-year					
100-year					

3. Determine whether bioretention is an appropriate stormwater practice for the area.

- Limited drainage area (<2 acres perhaps even less than 1 acre)
- Outlet for an underdrain and or soils of sufficient hydraulic conductivity to fully drain the practice or a suitable outlet for an underdrain system in a period of 40 to 72 hours.
- Sites with sufficient fall between inflow point to outflow (generally 5 feet). Shallower facilities are expected to reduce the effectiveness of treatment.
- Additional stormwater detention needs do not make bioretention unfeasible
- No continuous groundwater flow or seasonal high groundwater table above the practice bottom. Or perimeter drains are sufficient to lower seasonal high groundwater table.
- Low potential for groundwater pollution (high pollution loads, high groundwater table or extremely permeable soils)
- Can meet setback requirements found in Table 2.10.1

4. Additional local conditions or criteria affecting design:

2.11 Permeable Pavement

Figure 2.11.1 Pervious Concrete at Indian Run Park in Dublin, Ohio.

Description

Permeable pavement systems consist of a permeable pavement surface layer and one or more underlying aggregate layers designed to temporarily store stormwater. Most permeable pavement systems are designed to infiltrate stormwater into the underlying soil, reducing the volume of runoff leaving the site. Where the underlying soil will not permit full infiltration of runoff, outlets and/or underdrains are used to remove excess runoff and discharge it to an appropriate outlet[1].

Research has shown that permeable pavement can be a very effective component of a stormwater management system, mitigating many of the water quality and quantity impacts associated with runoff from impervious pavements. Permeable pavements reduce suspended solids, metals and petroleum hydrocarbons in runoff, and significantly reduce runoff volumes and peak flow rates.

Permeable pavements perform water quality functions by filtering suspended solids and hosting microbial organisms known to biodegrade pollutants. Depending upon the construction of the pavement, soil infiltration, transpiration (vegetated open celled grids), and increased soil adsorption may all contribute to reducing offsite runoff and associated adverse impacts. Additionally permeable pavements provide some moderating of water temperatures compared to conventional pavements.

1 Note: Permeable pavements and their drainage strucures must be considered as part of the larger site and stormwater system when meeting local peak discharge requirements.

There are a variety of permeable pavement surfaces available in the commercial marketplace, including pervious concrete, porous asphalt, permeable interlocking concrete pavers, clay pavers, concrete grid pavers, and plastic grid pavers. While the design specifics vary for each product, permeable pavements have the same general structural components detailed in this practice.

There are several examples of permeable pavement installations that are still functioning well after 15 or 20 years (see e.g., Adams, 2003). If designed, constructed, and maintained according to the following guidelines, permeable pavements should have life spans comparable to traditional impervious pavements.

Condition where practice applies and settings to avoid

Permeable pavement can be used in most settings where traditional pavements are used. It is especially well suited to parking lots, sidewalks, playgrounds and plazas. Permeable pavement can be used in driveways if the homeowner is aware of the stormwater management function and subsequent maintenance requirements of the pavement.

Areas of Heavy Traffic - Permeable pavement typically is not specified for areas that experience high traffic loads or high vehicle weight traffic such as busy roadways or travel lanes in heavily used parking lots. However, permeable pavement is suited for parking lanes on roadways and in parking lots. When it is necessary to use traditional pavement for traffic lanes, runoff can be directed as sheet flow to permeable pavement areas.

Areas of Potential Groundwater Contamination – Permeable pavements should not be used in heavy industrial developments, areas with chemical storage, fueling stations or areas with significant risk of spills that might contaminate groundwater. Permeable pavements should not be used for sites located over contaminated soils without placing an impermeable liner between the pavement structure and soils.

Other Sites to Avoid

Unstable slope areas – permeable pavement should not be used in slip prone areas where concentrated infiltration may exacerbate slope instability

Steep slopes - areas with slopes steeper than 10 percent present design challenges that are difficult to overcome

Sediment sources - sites with sources of sediment (from vehicles, bare soils, spoil piles, sand storage, etc.) should be separated from permeable pavements with filter strips or other sediment removal practices.

Anticipated Performance

Permeable pavements are projected to perform well in reducing the annual load of suspended solids, metals and hydrocarbons in runoff, and significantly reduce runoff volumes and peak flow rates. Permeable pavements filter solids in the pavement layer and may completely remove them in the matrix of the sub-pavement layers depending upon the nature of the subgrade and designed drainage of the system. Though this varies with design; filtering, detention, adsorption processes all contribute to some degree in reducing pollutants in contributed flows and offsite runoff. Permeable pavements also buffer water temperatures. Increased infiltration into the subgrade soils contributes to the highest removal of pollutants from site runoff, although some pollutants such as soluble nutrients, chlorides or sodium raise concern for groundwater pollution.

Table 2.11.1 Anticipated performance of permeable pavements.

Category	Subcategory	Full WQv Infiltration	Partial Infiltration	No Infiltration
Runoff Water Quality	Suspended Solids*	>90%	80-90%	80%
	Phosphorus*	Medium	Medium	Medium
	Nitrogen/Nitrates*	Low	Low	Low
	Heavy Metals	High	High	High
	Bacteria	Not clear at this time. Other practices using media filtration do treat bacteria. Using a sand layer may enhance this.		
	Thermal	Permeable pavements with a reservoir storing the WQv or most of that volume are expected to provide good thermal attenuation, but this will vary based on the particular design (i.e. material, the storage volume, outlet configuration etc.)		
	Oil and Grease	High	High	High
	Poly Aromatic Hydrocarbon	Comparable to conventional pavements, reduced compared to asphalts sealed with coal-tar based coatings.		
	Chlorides & Sodium**	Not controlled.		
Runoff Volume Reduction		85-90%	%WQv-captured * 85%	
Recharge		High	Medium	Not at all.
Runoff Time of Concentration		Improved lag time, but varies with design.		
Peak Flow Attenuation		Significant peak flow attenuation, but varies with design.		

* There would be an expected improvement with the addition of sand layers and/or vegetative systems.
** May be a significant groundwater concern depending upon winter application practices.

Planning Considerations

Preliminary Site Evaluation - The overall site should be evaluated for potential permeable pavement/infiltration areas early in the design process, as effective permeable pavement design requires consideration of soils, grading, outlets, groundwater, and other site infrastructure.

Size of Project – Small projects such as walkways, or driveways with limited traffic may not have associated requirements for treating or storing stormwater. Therefore small scale projects may not need the depth of stone reservoir described in this practice. There are still numerous benefits to applying permeable pavements even with less stone subbase than this practice describes. For small scale practices where local or state regulations do not require treating the water quality volume, manufacturer recommendations should be consulted.

Soils - Permeable pavements may be used on any soil type, although soil conditions determine whether an underdrain is needed. Less permeable soils (most Hydrologic Soil Group C or D soils, some HSG B soils) usually require an underdrain, whereas soils with higher permeability (HSG A, and some HSG B soils) often do not. Estimates of soil permeability are available based on soil type, but designers should verify underlying soil permeability rates before proceeding with site and stormwater system design (see discussion below). Special measures may be needed when permeable pavement will overlay high shrink-swell soils in order to limit moisture or to stabilize these soils.

Subgrade Compaction - One of the major benefits of permeable pavement is runoff volume reduction from infiltration into underlying soils. Subgrade compaction severely limits the infiltration capacity of the underlying soil. For permeable pavement systems with an infiltration component, the subgrade should not be compacted according to traditional pavements. Structural integrity of permeable pavements is ensured through several mechanisms other than subgrade compaction (see discussion below). If the structural design of the pavement section requires subgrade compaction to achieve the required design strength or to minimize the possibility of pavement failure, then soil permeability should be measured based on the required subgrade design.

Separation Distances - Permeable pavements should not be located or used where their installation would: create a significant risk for basement seepage or flooding; interfere with public or private wells, septic or sewage disposal systems; or cause problematic groundwater issues. These issues should be evaluated and potential problems avoided by the designer.

Horizontal Separation Distances

- separation from buildings - permeable pavement systems should be installed at least 10' away from up-gradient building foundations and 100' from down-gradient foundations, unless an acceptable barrier is provided or the building foundation can adequately handle additional water;
- sanitary sewers - care should be taken to minimize infiltration of runoff into sanitary sewers and building laterals;
- septic systems - permeable pavement should be installed no closer than 100' from a septic system or leach bed; when this or any infiltration BMP is located up-gradient, appropriate perimeter drainage should be used to prevent flows from reaching the septic system;
- drinking water wells - permeable pavement should not be located within 25' of a private drinking water well or within the sanitary isolation radius of a public drinking water supply well. (The isolation radius ranges from 50 to 300 feet, and is based on the well's average daily pumpage; see the chart below.) If it is necessary to pave within the sanitary isolation radius, use of an impermeable bottom liner and an underdrain discharging beyond the isolation radius is recommended, especially if the pavement will support motorized vehicles.

Feature protected by setback	Setback Distance (feet)	
Building Foundations or basements	At least 10' downgradient or 100' upgradient of foundations	
Septic Systems	At least 100' separation	
Private Well	At least 25' (See OAC 3701-28-10)	
Public Well	50 – 300 ft minimum depending upon Average Daily Water Demand (based upon sanitary isolation distance found in OAC 3745-9-04)	
	Average Daily Pumpage (Q) (gal/day)	Sanitary Isolation Radius (feet)
	0-2500	50
	2501-10,000	Square root of Q
	10,001 – 50,000	50 + Q/200
	Over 50,000	300
Source Water Protection Area	See Ohio EPA Source Water Protection Area. Each area may have its own specific requirements.	

Table 2.11.2 Horizontal separation distances.

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.

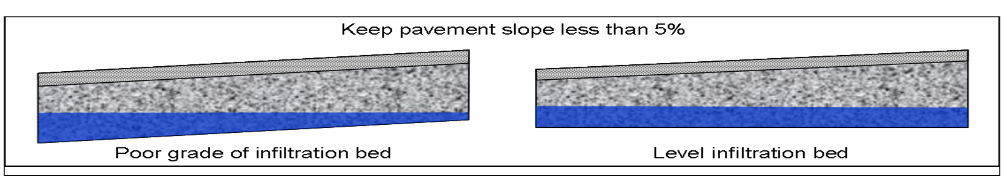

Figure 2.1.2 Level infiltration beds and limited pavement slope maximizes stormwater treatment and storage.

Figure 2.11.3 Terrace sloping areas to limit the pavement slope (photo credit: Brandon Andreson).

Runoff from External Areas - Drainage from traffic lanes or other impervious surfaces (e.g., sidewalks) can be directed to permeable pavement surface as sheet flow. The impervious area contributing runoff should be less than twice the area of permeable pavement receiving the runoff. Roof drains and leaders may connect directly to the subbase reservoir, but should be provided a means of trapping sediment prior to the subbase reservoir. Runoff from permeable areas (lawns or landscaping) or other sediment sources should not be directed onto permeable pavement.

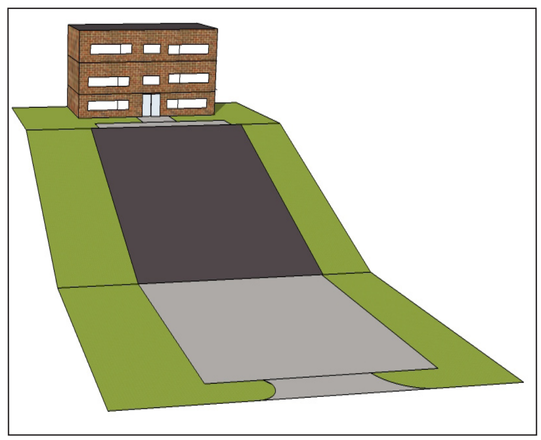

Figure 2.11.4 Calculate "run-on" from impervious areas, making sure it does not exceed twice the pervious pavement (infiltration bed) area.

Sites to Use or Consider Use of an Impermeable Liner

A impermeable liner should be used for permeable pavement systems for sites:

- all sites over contaminated (or potentially contaminated) soils
- sites with high pollution potential source areas
- sites with slip prone soils
- sites in source water protection areas

A impermeable liner may be considered for permeable pavement systems for sites with:

- subgrade soil infiltration rates less than 0.02 in/hr
- depth to bedrock or seasonal high water table less than 2 ft below subgrade infiltration bed
- karst geology

If the site requires a liner, the designer should consider whether a different BMP (e.g., bioretention, constructed wetland, wet swale) may be more appropriate.

Stormwater Detention - Sub-pavement infiltration beds are typically sized to manage the water quality volume and to convey stormwater without allowing ponding into the pavement itself. These sub-pavement aggregate "reservoirs" also may be designed to mitigate the peak discharge of less-frequent, more intense storms (such as the critical storm or 100-yr event). Discharge control typically is provided by an outlet control structure. The specific design of these structures may vary, depending on factors such as rate and storage requirements.

Construction Sequencing - The permeable pavement system is most susceptible to failure during construction, and therefore it is important that the construction be undertaken in such a way as to prevent:

• Compaction of underlying soil

• Clogging the subgrade soil or geotextile with sediment and fines

• Tracking of sediment onto pavement

• Drainage of sediment laden waters onto permeable surface or into aggregate base

Permeable pavement will be prone to failure if it is not protected from sources of sediment. Sediment on the subgrade infiltration bed will greatly reduce the infiltration capacity of the final practice. For this reason, it is ideal that nearby areas or areas contributing runoff are completely stabilized prior to construction of the permeable pavement system. Additional means of controlling sediment may be necessary if all disturbed areas can not be stabilized completely before permeable pavement construction. Leaving nearby disturbed area below grade can be helpful to prevent sediment from running onto the permeable pavement area. More effective sediment barriers and controls may be needed.

Quick succession from excavation to placement of materials during dry weather is ideal for protecting the practice's long term functioning. Planned pavement areas that will be exposed for a period of time while other site construction occurs may be excavated within twelve (12) inches, but no closer than six (6) inches, of the final subgrade elevation. Following construction and site stabilization, sediment should be removed and final grades established only when materials can be placed in a timely manner.

Maintenance - Permeable pavements have different maintenance requirements than traditional pavements, discussed in some detail below. The use of permeable pavement must be carefully considered in all areas where the pavement potentially could be seal coated or paved over due to lack of awareness by a new owner, such as individual home driveways. In those situations, a system that is not easily altered by the property owner may be more appropriate. Educational signage at permeable pavement installations may promote its prolonged use. Maintenance is critical to the long-term performance of permeable pavement, especially those activities that prevent clogging of the surface pavement and subsequent clogging of the subsurface layers by accumulated sediments and organic matter. The most important activities to protect the long term function of permeable pavement include periodic vacuum sweeping to remove accumulated sediments and organic materials, monitoring of the drainage functions of the pavement and maintenance/cleanup of landscaped areas contiguous to the parking area (CSN, 2010).

Cost Considerations - The primary added cost of a permeable pavement/infiltration system lies in the underlying aggregate bed, which is generally deeper than a conventional pavement subbase. However, this additional cost may be offset by a significant reduction in the number of inlets and pipes. Permeable pavement systems may eliminate or reduce the need (and associated costs, space, etc.) for surface detention basins. When all these factors are considered, permeable pavement with infiltration is increasingly competitive with traditional pavement for the pavement and associated stormwater management costs.

Types of Permeable Pavement

Porous Asphalt - Porous asphalt is very similar to conventional bituminous asphalt except the fines have been removed to maintain interconnected void space. Research has led to improvements in porous asphalt through the use of additives and higher-grade binders. Porous asphalt is similar in appearance to standard asphalt and is suitable for use in any climate where standard asphalt is appropriate. Guidance specific to the design, installation and maintenance of porous asphalt is available from the National Asphalt Pavement Association (NAPA, 2008), the University of New Hampshire Stormwater Center (UNHSC, 2009) and Flexible Pavements of Ohio.

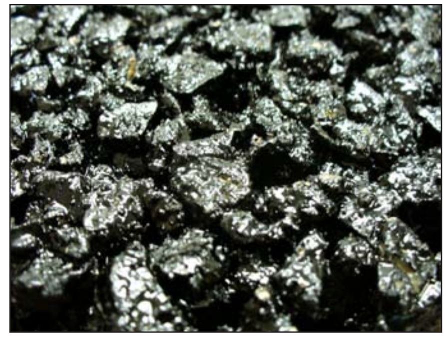

Figure 2.11.5 Porous Asphalt

Pervious Concrete - Pervious concrete is produced by reducing the fines in the mix to maintain interconnected void space for drainage. Pervious concrete has a coarser appearance than its conventional counterpart but may be colored similar to traditional decorative concrete. In northern climates such as Ohio, pervious concrete should always be underlain by a stone subbase designed for proper drainage and stormwater management, and should generally not be placed directly on a soil subbase. Special care must be taken during the placement of the pervious concrete to avoid overworking the surface and creating an impervious pavement. Guidance on the design, installation and maintenance of pervious concrete is available from the Ohio Ready Mix Concrete Association (ORMCA, 2009). ORMCA also offers installer training and certification for pervious concrete.

Figure 2.11.6 Pervious Concrete

Block or Brick Pavement - A number of concrete or clay paver products are available, providing either a traditional brick pavement look or more complex designs and configurations. Block or brick pavements maintain drainage through gaps between the pavers filled with small, uniformly-graded gravel. The pavers are bedded on a stone or sand layer that provides uniform support and drainage. Pavers are especially well suited for plazas, patios, small parking areas, parking stalls in larger lots, and streets.

Permeable interlocking concrete pavement (PICP) are one commonly used product that consist of 3 1/8" thick concrete units or pavers with various shapes, patterns, and colors. The size and complexity of the project determines whether PICP may be placed by machine or by hand. Guidance for design, installation and maintenance of concrete pavers is available from the manufacturer and the Interlocking Concrete Pavement Institute (ICPI, 1995).

Figure 2.11.7 Permeable Interlocking Concrete Pavement

Reinforced Turf and Gravel Filled Grids - Grid-type permeable pavements consist of open-celled concrete or plastic structural units filled with small, uniformly-graded gravel or turf that allows infiltration through the pavement surface. The structural units are underlain by a stone and/or sand drainage system for stormwater management. Reinforced turf applications are excellent for fire access roads, overflow parking, occasional use parking (such as at religious facilities and athletic facilities). Reinforced turf is also an excellent application to reduce the required standard pavement width of paths and driveways that must occasionally provide for emergency vehicle access.

Figure 2.11.8 Vegetatated Grid System utilitized for fire access.

Figure 2.11.9 Vegetated Grid System with established turf grass.

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

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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.

Drawdown Calculation - Ideally, the water quality volume will be drained within 48 hours in preparation for the next runoff event. The approach to determine drawdown characteristics is different depending on whether the permeable pavement is an infiltrating or non-infiltrating system.

The entire area under both permeable (e.g., parking lanes or pull-in parking) and conventional pavement (e.g., traffic lanes) may be used as infiltration or storage area as long as the WQv/sub-base gravel layer is fully interconnected and the soil infiltration capacity is adequate throughout the area. A minimum of 33% of the infiltration bed should be covered with permeable pavement.

For non-infiltrating systems, the drawdown calculation should follow the procedure used for surface detention basins with the depth and head adjusted for the porosity of the aggregate. For WQv detention under permeable pavement, a 24 hour drawdown time is recommended, with no more than ½ of the water quality volume draining from the facility in the first 8 hours. The drawdown control device should have a minimum orifice diameter of 1".

For infiltrating systems, the WQv should be infiltrated into the subgrade soil within 48 hours. The design infiltration rate of the subgrade soil will be based on field measurements at the appropriate depth, and be verified during construction (see section on measurement and verification of subgrade infiltration rate). The infiltration rate shall be based on the final, after-compaction subgrade properties, if compaction is required[4].

There are a number of factors - including soil compaction, surface smearing, aggregate “masking”, sedimentation, and air entrapment - that typically mean the actual infiltration rate under real-world, post-construction conditions will be substantially lower than the measured infiltration rate. To increase the likelihood of achieving design performance over the long-term, it is recommended that an infiltration rate equal to one-half the measured infiltration rate of the subgrade be used for the design:

$$f_{design} = 0.5*f_{measured}$$

Where: f_{design} = design subgrade infiltraion rate (L/T)

$f_{measured}$ = field measured subgrade infiltration rate (L/T)

The following table presents estimates of design infiltration rate that can be used for initial planning considerations until field measurements can be collected[5].

Soil Texture of Subgrade Soil	Clay Content (%)	Clay + Silt Content (%)	Preliminary f_{design} (in/hr)	Soil Texture of Subgrade Soil	Clay Content (%)	Clay + Silt Content (%)	Preliminary f_{design} (in/hr)
Sand	< 8	< 15	3.0	Sandy Clay Loam	20 - 35	<55	0.05
Loamy Sand	< 15	< 30	2.0	Clay Loam	27 - 40	54 - 80	0.02
Sandy Loam	< 20	< 60	0.9	Silty Clay Loam	27 - 40	>80	0.02
Loam[5]	7 - 27	48 - 80	0.2	Silty Clay	40 - 60	>80	0.02
Silt Loam[5]	< 27	48 - 100	0.1	Sandy Clay	35 -55	<55	<0.01
Silt[5]	<12	80 - 92	0.1	Clay	> 40	>55	<0.01

Table 2.11.4 Estimated infiltration rate based on soil texture.

4 If the subgrade will be compacted to meet structural design requirements of the pavement section, the design infiltration rate of the subgrade soil shall be based on measurement of the infiltration rate of the subgrade soil subjected to the compaction requirements.

5 For silt, silt loam and loam subgrade textures, check for the presence of a fragipan, which can severely limit permeability.

For infiltrating systems, the drawdown calculation shall be determined using the following equation. The infiltration area A_{inf} shall be the bottom area of the infiltration bed.

$$T_d = WQv / (f)(A_{inf})(\varphi_{aggregate})$$

Where

T_d = drawdown time (T)
WQv = water quality volume (L^3)
f = infiltration rate of subgrade soil (L/T)
A_{inf} = area of infiltration bed (L^2)
$\varphi_{aggregate}$ = porosity of aggregate base

WQv Sample Problem

A site in Columbus proposes to install 1 acre of permeable pavement that will also receive sheet flow from 2 acres of traditional asphalt. The subgrade infiltration area is equal to the area of the permeable pavement. The measured subsurface infiltration rate (fmeasured) of the native soil is 0.5 in/hr. The aggregate base is composed of No. 57 aggregate. Calculate the WQv, the depth of the WQv, the porosity adjusted WQv depth, and the time necessary for the WQv to drain into the native soil.

Calculate the WQv:

WQv = C*P*A
i = 100% impervious = 1.0
C = 0.89
P = 0.75 inches
A = 3 acres
WQv = (0.89)(0.75 in)(3 ac) = 2.0 ac-in = 0.17 ac-ft = 7300 ft^3

Calculate the WQv "depth":

$D_{WQv} = WQv/A_{inf}$ = 2.0 ac-in/1.0 ac = 2.0 inches

Calculate the porosity adjusted WQv depth:

$\varphi_{aggregate} = 0.35$
$D_{agg\text{-}WQv} = WQv /(A_{inf})(\varphi_{aggregate}) = D_{WQv} /(\varphi_{aggregate})$ = 2.0 in/0.35 = 5.7 inches

Calculate the WQv drain time:

$f_{design} = 0.5\ f_{measured}$ = 0.5 (0.5 in/hr) = 0.25 in/hr
$T_d = WQv / (A_{inf})(f_{design})$ = 2.0 ac-in/(1.0 ac * 0.25 in/hr) = 8 hr
T_d = 8 hr < 48 hr

Water Quantity (incl. Peak Discharge) Credits - The peak rate of runoff from a site is radically altered by development. The hardening of pervious areas, and the improved hydraulic efficiency of the drainage network contribute to increased flow peaks, as well as extended periods of higher discharge. Permeable pavements considerably reduce flow peaks, when compared with traditional pavements, through several mechanisms including subgrade infiltration (also called exfiltration), temporary storage and increased flow path resistance.

Permeable pavement can be encouraged by appropriately crediting the storm-water management benefits provided. The ways that permeable pavement potentially can receive credit include:

- infiltration or extended detention of the WQv (described above)
- stormwater utility credit or fee reduction
- critical storm adjustment
- peak discharge attenuation

The ways that permeable pavement may be used to fulfill the WQv requirement are discussed in the previous section. The other three quantity "credits" are discussed here.

Stormwater Utility Credit - [Note: All credits are at the discretion of the local stormwater management authority.] All contributing drainage area for which the permeable pavement system fully infiltrates the WQv should receive full credit for runoff volume reduction and water quality purposes, and partial to full credit for peak flow reduction. Permeable pavement systems with partial or no infiltration should be considered for a partial credit because of the combination of water quality benefits, runoff volume reduction, and flow peak reduction.

Critical Storm Adjustment - The State of Ohio does not regulate stormwater discharges for large, infrequent rainfall events (e.g., 1-year to 100-year events). However, controlling discharge for these events is an important consideration toward protecting public safety and minimizing damage to property and infrastructure. Many Ohio communities have peak discharge or "flood control" regulations aimed at reducing the impacts of large events. Many of those communities have adopted the Critical Storm criteria for peak discharge control (ODNR, 1980). The following recommendations are designed to encourage consideration of permeable pavement while still protecting the public interest.

For permeable pavement systems, the CN for Critical Storm determination should be based on the abstraction potential, which is a function of infiltration capacity of the underlying soil and the elevation at which underdrains are placed above subgrade. Until more definitive research is developed by NRCS or another research entity, it is recommended that the Critical Storm CN for the permeable pavement system be based on TR-55 guidance (USDA, 1986) for "newly graded areas" or "open space in poor condition" based on the hydrologic soil group (HSG) of the in-situ soil and the measured subgrade infiltration rate upon completion of excavation of the underground reservoir.

Soil HSG (in/hr)	Measured Infiltration Rate	CN
A	> 1.0	68
B	> 0.2	79
C	> 0.05	86
D	> 0.02	89

Table 2.11.5 Recommended Critical Storm CN for A_{inf} for No Underdrains or Underdrains Placed D_{agg}-WQv or Higher above Subgrade.

Soil HSG (in/hr)	CN
A	77
B	86
C	91
D	94

Table 2.11.6 Recommended Critical Storm CN for A_{inf} for Underdrains Placed Directly on Subgrade.

Modeling Stormwater Detention and Peak Discharge Attenuation - The aggregate subbase "reservoir" can be used as a detention basin to temporarily store stormwater. Outfitted with an appropriate outlet, the aggregate reservoir may be able to meet local peak discharge requirements for the area that drains to the permeable pavement system. Otherwise, the aggregate reservoir and outlet become part of the overall drainage network that needs to be properly "routed" to determine inflow to an end-of-pipe facility.

The following guidelines will help ensure the permeable pavement system achieves long-term structural and stormwater management goals:

- Peak discharge requirements are set by local regulations. All stormwater systems that incorporate permeable pavement require review and approval from the local stormwater authority. Preliminary approach, plans and calculations should be discussed as early as possible with the plan reviewer to facilitate communication and avoid delays in review and approval.
- The available storage volume is equal to area*depth*effective porosity of the aggregate layer(s).
- though porosities for washed, uniformly-graded aggregate may approach 0.4, some percentage of the voids will be unavailable for storage because of previous wetting and entrapped air resulting in a lower usable or effective porosity; for consideration of intense design events such as a NRCS type II distribution, use of a conservative effective porosity of 0.35 for clean, uniformly-graded aggregate is merited.
- the porosity of the pavement course typically will be substantially lower than the aggregate base; when needed for calculations/routing, porosities for the pavement should be taken from guidance provided by the specific industry association.
- For infiltrating systems, the modeler should assign a steady discharge (often termed exfiltration rate) equal to the final (or minimum) infiltration rate.
- The aggregate reservoir should be designed to prevent the (routed) 10-yr, 24-hr design event from rising to the elevation of the bottom of the pavement course.
- The site design should include a secondary, surface drainage network that will pass the 100-yr, 24 hr event without damage to property assuming failure of the permeable pavement system. The model should show flow paths and elevations for the 100-yr, 24-hr design event with the permeable pavement treated as impervious.

Subgrade Infiltration Capacity - The hydrologic performance of infiltrating permeable pavement systems requires special attention to the subgrade soil (i.e., soil at the bottom of the aggregate reservoir) and the infiltration bed surface throughout planning, design and construction. The following guidelines will help ensure the permeable pavement system achieves long-term stormwater management goals:

- The bottom surface area of the infiltration bed should not be less than the surface area of the permeable pavement. The designer should consider increasing the infiltration bed surface area by extending the infiltration bed under adjacent traditional pavement. Such an expansion of the infiltration bed may be necessary to achieve the required drawdown time for the WQv.
- The bottom surface area of the infiltration bed should be at least 33% of the sum of the area of the permeable pavement surface plus all contributing impervious surfaces (parking lot, roads, driveways, sidewalks, roofs, etc.), that is $A_{inf} > 0.33*(A_{perm\text{-}pave} + A_{impervious})$.

- The bottom of the infiltration bed should be level or nearly level. Sloping bed bottoms will lead to poor distribution and reduced infiltration.
- For infiltrating systems, the subgrade should not be compacted as it would be for traditional pavements. If the structural design of the pavement section requires subgrade compaction to achieve a required design strength, then subgrade infiltration should be measured based on the required subgrade design.
- The design infiltration rate of the subgrade soil should be based on field measurements at the appropriate depth and verified during construction (see section on measurement and verification of subgrade infiltration rate).

Design Criteria - Pavement Structure Design

Structural Design – The designer shall refer to the appropriate industry association or manufacturer's specifications for structural design of the permeable pavement system.

Table 2.11.7 Reference appropriate specifications for structural design.

Pavement Type	Guidance	Website
Porous Asphalt	Porous Asphalt Pavements for Stormwater Management: Design, Construction and Maintenance Guide. Info Series 131, Revised November, 2008. National Asphalt Pavement Association, Lanham, MD.	www.asphaltpavement.org www.flexiblepavements.org
Pervious Concrete	Specifier's guide for Pervious Concrete Pavement with Detention. Revised October, 2009. Ohio Ready Mixed Concrete Association, Columbus, OH.	http://www.ohioconcrete.org
Concrete Pavers	Structural Design of Interlocking Concrete Pavement for Roads and Parking Lots. ICPI Tech Spec Number 8. Interlocking Concrete Pavement Institute, Washington, DC.	http://www.icpi.org
Grid Pavements	Concrete Grid Pavements. ICPI Tech Spec Number 8. Interlocking Concrete Pavement Institute, Washington, DC.	http://www.icpi.org
Vegetated Grid Pavements	See various manufacturer specifications	

Infiltrating Systems:

Pavement & bedding material - see industry association guidance.

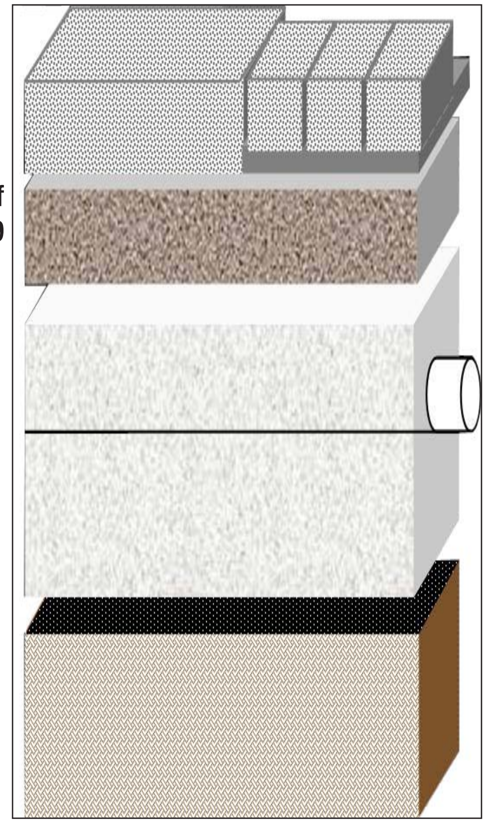
Filter or Stabilizing (choker) course - minimum 2” of AASHTO #57 if larger aggregate is used for reservoir course or AASHTO #7, #8 or #9 if the reservoir course uses #57 and the paving material requires it for stability. Use open graded crushed stone for maximum stability.

Underdrains - 4”-6” dia. PVC placed at top of recharge layer.

Recharge course - sized to infiltrate the WQv from the contributing drainage area (minimum 3” depth). Typically AASHTO #57 or larger clean, uniformly-graded coarse crushed aggregate.

Permeable geotextile fabric or sand layer equivalent

Subgrade - uncompacted subgrade



Closed Systems:

Pavement & bedding material - see industry association guidance.

Filter or Stabilizing (choker) course - minimum 2” of AASHTO #57 if larger aggregate is used for reservoir course or AASHTO #7, #8 or #9 if the reservoir course uses #57 and the paving material requires it for stability. Use open graded crushed stone for maximum stability.

Reservoir course - clean, uniformly-graded coarse crushed aggregate, typically #57, #4, #3 or #2.

Underdrains - 4”-6” dia. PVC placed placed on subgrade.

Impermeable liner (if necessary)

Compacted subgrade graded with positive slope toward the outlet

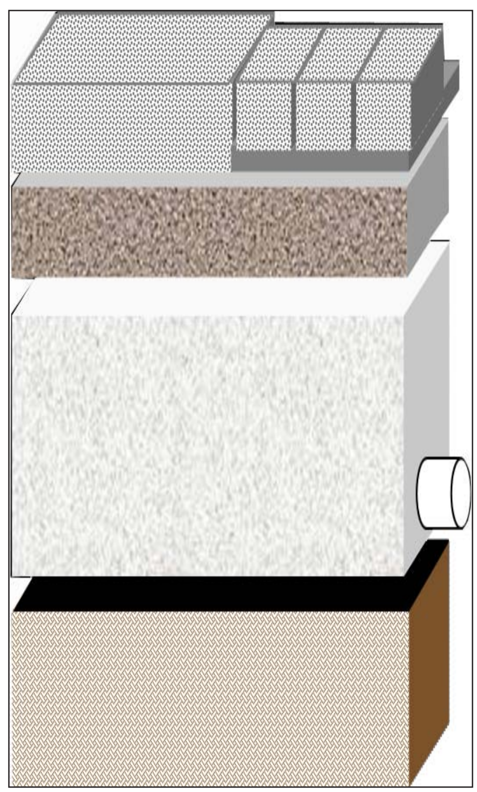


Figure 2.11.10 Types of materials used in infiltrating and closed permeable pavement systems.

Subgrade Preparation - The subgrade shall be designed to carry the desired traffic load. Check the appropriate industry association or manufacturer's specifications for compaction requirements. Design infiltration rates must be adjusted to account for intended and unintended subgrade compaction.

Subgrade Soil/Aggregate Base Interface - For open (infiltrating) systems on fine-textured soils a geotextile should be placed between the native soil and the aggregate base[6]. The geotextile limits the migration of fines, limits the settling of aggregate into the underlying soil, and helps to distribute surface loads.

For infiltrating systems, given the soil characteristics of the native soil, alternative materials such as a layer of clean sand may be placed in lieu of a geotextile on top of the native soil layer to provide adequate separation between the native soil and aggregate base in an open system (UNHSC. 2009).

For closed systems, an impermeable liner shall be placed between the native soil and the aggregate base using standard measures to prevent puncture of the geomembrane (e.g., smooth subgrade, sand bedding, geotextile). Prevent lateral flow by bringing the impermeable liner to the surface or by securing the liner to a cut-off or perimeter wall making sure that the outlet pipe and any other penetrations of the liner are adequately sealed. An impermeable liner should be used for permeable pavement systems for:

- all sites over contaminated (or potentially contaminated) soils
- sites with high pollution potential source areas
- sites with slip prone or shrink swell soils
- sites in source water protection areas

A closed system may also be used to prevent saturation of the underlying soil for structural reasons; consult a geotechnical engineering or pavement design engineer to determine whether a closed system is required based on soil conditions.

Perimeter Barrier: Some paving materials will be prone to lateral movement unless secured against a perimeter barrier. This may be a cut stone or concrete barrier or a manufactured edge restraint. Concrete barriers at the surface grade or as a raised curb can also serve as a way to secure the impermeable liner in non-infiltrating systems to prevent lateral flow between cells in a sloping situation. Where open graded subbase material will be placed against conventional road base material or soils, some type of barrier may be needed to prevent migration of fines into the permeable pavement subbase and movement of water into the conventional road base.

Aggregate Bed - The underlying aggregate bed is typically 8-36 inches deep and is a function of structural requirements, stormwater storage requirements, frost depth considerations, site grading, and anticipated loading. Several sizes of aggregate may be required for pavement bedding, stabilizing courses, or stormwater storage. It is critical the aggregate be uniformly graded, clean washed, and contain a significant void content. Pavements subject to movement will need fractured or crushed stone to mazimize stability of the base. A range of aggregate sizes has been used successfully in permeable pavement projects. Choice of aggregate(s) will depend on structural requirements, local availability, and cost. Check the appropriate industry association or manufacturer's specifications for specific aggregate requirements.

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6 UNHSC, 2009. UNHSC Design Specifications for Porous Asphalt Pavement and Infiltration Beds. Revised October, 2009. University of New Hampshire Stormwater Center, Durham, NH. http://www.unh.edu/erg/cstev/pubs_specs_info.htm.

Underdrains and observation well - Most permeable pavement systems should be designed with an underdrain system to efficiently drain the system during larger events. To avoid damage to the pavement layer, water within the subsurface stone storage bed should only rise to the level of the pavement surface in extremely rare events based on the risk tolerance of the engineer, owner or MS4 (we recommend a minimum of the 10-yr, 24-hr event). Underdrains should be installed with positive drainage and capped at dead ends of drains. For permeable pavement areas of at least 10,000 square feet, at least one observation/cleanout standpipe should be installed near the center of the pavement and shall consist of rigid 4 to 6 inch non-perforated PVC pipe. This should be capped flush with or just below the top of pavement elevation and fitted with a screw or flange type cover. Portions of the underdrain system within 1 foot of the outlet structure should be solid and not perforated.

Figure 2.11.11 Commonly used stone for stabilizing and reservoir layers (not to scale).

Additional Manufacturer or Industry Recommendations: There may be industry or manufacturer specific recommendations or requirements that will be unique to the particular paving material. These should be followed without undermining the water quality functioning of this practice. For instance, some porous asphalt guidance recommends the use of additional drainage such as catch basins with surface inlets or perimeter aggregate drains that can capture surface runoff and direct the storm water to the reservoir course. Designers must consider how sediments will be kept out of the aggregate base in this particular instance.

Construction

Any non-traditional stormwater practice presents challenges during the construction phase that require extra attention to plan detail (both for the design engineer and the contractor) and benefit from construction oversight by the design engineer or others with intimate knowledge of system design and function. Infiltrating permeable pavement systems increase complexity by striving to maintain infiltration capacity while ensuring structural integrity. For these systems, the design engineer should provide additional detail or requirements that protect or assure design infiltration capacity, and this capacity should be confirmed with field measurements during construction.

Acceptable Conditions for Initiating Construction - Construction of the permeable pavement shall begin only after all the contributing drainage area has been stabilized with vegetation and the planned cover or suitable sediment barriers placed in order to prevent contamination with sediments. Do not construct the permeable pavement practice in heavy rain or snow. Check industry guidance for suitable temperatures for construction. Construction of any infiltration BMP should be completed during a window of dry weather - excess compaction or smearing of the subgrade will ensure failure of the stormwater functions of the practice and threaten non-compliance with local or state requirements.

Erosion, Sediment and Runoff Controls - Keeping sediment out of this practice is critical. Rigorous installation and maintenance of erosion, sediment and runoff control measures should be provided to divert runoff and to prevent sediment deposition on the pavement surface, the subgrade or within the stone bed. A non-woven geotextile may be folded over the edge of the pavement to reduce the likelihood of sediment deposition. Any construction materials that are contaminated by sediments must be removed and replaced with clean materials (CSN, 2010). Surface sediment should be removed as soon as possible using a vacuum sweeper.

Clearing and Excavation - Clear and excavate the area for pavement and base courses in a manner that maintains the infiltrative capacity to the greatest extent possible (Brown, 2010). First insure plans detail staging of work in order to maintain the infiltrative capacity of the subgrade soils. Compaction of the subgrade soils will be increased by working in wet conditions, allowing construction equipment to work or travel across the area and by smearing the final soil surfaces during excavation. Final grade of the bed should be level for infiltrating systems, while closed or lined systems should have positive drainage to the outlet. To protect and maintain subgrade infiltrative capacity (adapted from Brown, 2010):

- Do not all allow excavation in wet conditions or if wet weather is forecasted for the construction period or before the area can be filled. Excavate in dry soil moisture conditions and avoiding excavating immediately after storms without a sufficient drying period.
- Do not allow equipment or haul routes to cross the planned pavement area, especially once excavation has begun.
- Station and operate excavating equipment from outside the planned pavement area or from unexcavated portions of the area using an excavation staging plan (see figure 2.11.12).
- Leaving 6 to 12 inches of undisturbed soil above the sub grade elevation if geotextile and base material placement will be delayed.

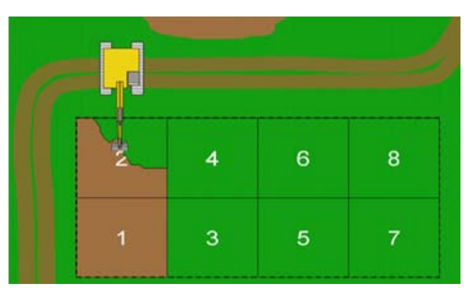

Figure 2.11.11 Stage excavation so that it can be done without compacting the subgrade.

- Dig the final 9-12 inches by using the teeth of the excavator bucket to loosen soil so as not to smear the sub grade soil surface. Avoid grading the bottom (subgrade) surface of the practice with construction equipment. Final grading or smoothing of the bottom should be done by hand or suitable tracked equipment with low ground pressure.
- Avoid allowing water to pond in bottom of cuts.
- Areas that have been allowed to trap sediment must have sediment removed and be relatively dry before final excavation down to the subgrade elevation. Any accumulation of sediments on the finished subgrade should be removed with light equipment and the subgrade surface lightly scarified with hand tools. *Very important note: limit breaking natural soil structure (especially for clayey-silty soils) or risk adversely impacting the infiltrative capacity of the subgrade.
- Finally, before placing geotextile and base aggregate, the final subgrade infiltration rate must be measured for infiltrating systems and reported to the local stormwater authority.

Place geotextile or planned filter material on the uncompacted subgrade and place geotextile up and over the sides of the excavated area. Place geotextiles so that there is a minimum of 16 inches of overlap between subsequent rolls of fabric (see manufacturers recommendation) and a minimum of four feet of material beyond the sides of the excavation. Secure geotextile so that it will not move or wrinkle as aggregate is placed. Some designers may use an alternative filter material such as sand and/or pea gravel between the base aggregate (reservoir layer) and the subgrade soils instead of geotextile (see e.g., UNHSC, 2009). Non-infiltrating designs may compact the subgrade and replace the geotextile with a suitable impermeable lining. Excess fabric (beyond the excavation) should not be trimmed until there is no possibility of sediment entering the pavement area.

Place reservoir course of aggregate and underdrain system. For infiltrating systems, plans will dictate the depth of aggregate to be placed beneath the underdrain system, although this generally exceeds 3 inches. Dead ends of pipe underdrains shall be closed with a suitable cap placed over the end and held firmly in place. For permeable pavement areas of at least 10,000 square feet, at least one observation/cleanout standpipe shall be installed near the center of the pavement and shall consist of rigid 4 to 6 inch non-perforated pvc pipe. This should be capped flush with or below the top of pavement elevation and fitted with a screw or flange type cover. Portions of the underdrain system within 1 foot of the outlet structure should be solid and not perforated.

Spread 4-12 inch lifts of the washed stone aggregate comprising the reservoir layer. Place and spread lifts of stone without driving on the subgrade and being careful not to damage drainpipes, connections or observation wells. Place at least 4 inches of additional aggregate above the underdrain. The aggregate layer should be lightly compacted, although industry references vary on the degree and number of passes with a roller. The Interlocking Concrete Pavement Institute (ICPI, 2007; LID,) specifies making 2 passes with a roller in vibratory mode and at least 2 passes in static mode until there is no movement of the stone, while the National Asphalt Pavement Association recommends compacting each lift with a light roller or vibratory plate compactor. Do not crush the aggregate with the roller.

Install filter/stabilization layer (and bedding layer if used). This course transitions from a larger aggregate size of the subbase to a size that will fill large voids and provide a smooth surface for the pavement layer. Its use depends upon the size of the aggregate course below. For pervious concrete and porous asphalt, AASHTO No. 57 may be used for the reservoir layer and in the layer transitioning to pavement. For interlocking pavers, a smaller size aggregate will be used as a filter layer and also as a bedding layer. These layers should be spread, leveled and compacted to their designed thicknesses.

Install paving materials. Install the planned paving materials in accordance with manufacturer or industry specifications for the particular type of pavement, whether pervious concrete, porous asphalt (Hansen, 2008; Jackson, 2007), interlocking pavers or grid pavers.

Maintenance

Permeable pavements require maintenance to provide stormwater benefits over a long time period. Because permeable pavements convey water through the pavement and also effectively trap fine materials, the majority of maintenance efforts will be to keep the system permeable (unclogged) and to manage pollutants such as salts that might effect groundwater. Therefore regular inspection will evaluate whether the surface and the bed of the pavement are functioning as intended. In other words, water should continue to move through the pavement, not pond into the pavement layer, and drain from the reservoir layer in sufficient time. Maintenance of the pavement will remove fine materials as they collect in the surface and prevent winter deicing materials from being overused or clogging the system.

Effective management includes educating the property owner, landscapers, maintenance staff, snow removal personnel and general users. In this regard, an operation and maintenance plan, signage, maintenance agreements, and contracts will serve as important points of reference for these audiences. Each document should reflect the appropriate actions to take and those to avoid for the appropriate audience. For example, landscaping personnel that work adjacent to the pavement area should be required to keep landscaping materials, such as soil, mulch or plants off the pavement and to use adequate sediment control and/or stabilization for bare areas. Snow removal, pavement repair and similar contracts should include notes regarding appropriate and inappropriate actions regarding the permeable pavement area. Because permeable pavements will be maintained and managed differently than traditional pavements, signage at permeable pavement installations is recommended. This will promote its prolonged use and prevent conventional pavement management from damaging the system. An example of this includes preventing seal coating of porous asphalt or allowing snow to be stockpiled on a permeable pavement.

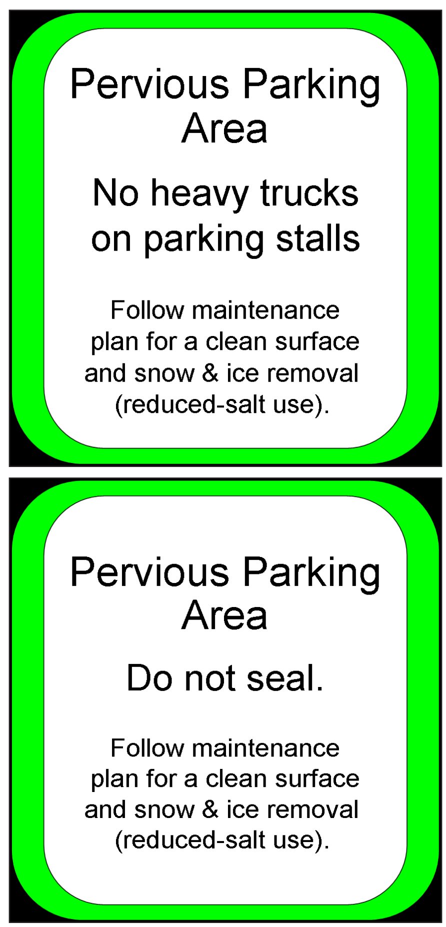

Figure 2.11.13 Examples of signage that might be used to protect permeable pavements.

An operation and maintenance plan should be prepared by the designer and provided to the owner and the stormwater authority as well as the property manager and maintenance personnel. An operation and maintenance plan for permeable pavement should detail specific actions that must be performed and their timing and/or frequency. It also describes potential damaging actions and measures to take to prevent damage to the permeable pavement. The operation and maintenance plan should also provide detailed information regarding the observation well and the depth or elevations of the underdrain system and outlet, so that the water levels under the pavement can be monitored and compared to the designed function of the system. The operation and maintenance plan should provide the normal drain time (hours) of the pavement as tested following construction (ASTM 1701).

Three main strategies dominate permeable pavement operation and maintenance:

Prevent clogging of the pavement and regularly remove accumulated fines. Vacuum sweeping is necessary to remove grit, leaves and other debris collecting at the pavement surface. This should be done two to four times a year. Times that especially will have an accumulation of material include after winter snow melt and after leaf drop in the fall. Vacuums used on paver systems with bedding material should be able to remove sediments and organic matter without removing the bedding aggregate. If bedding aggregate is removed, it should be replaced. Preventing clogging also involves managing adjacent vegetated and landscaped areas. These area should be maintained in healthy vegetation. Soil, mulch and other landscaping materials should never be stored or stockpiled directly on the pavement. Construction equipment should not be driven over or stored on the pavement.

Snow and Ice Removal. Sand or cinders is not recommended for use on permeable pavements with some exceptions[7]. Instead winter maintenance should focus on timely snow plowing and judicious use of deicing materials. Deicing materials present a problem in any pavement system due to their solubility and history of building up to levels that are toxic to plant and animal life. In permeable pavements, high salt use has an increased potential of reaching groundwater sources, but case studies of permeable pavements have shown a reduced need for deicing material to be applied to permeable pavements due to the effects of a warmer subbase. The operation and maintenance plan should provide guidelines for reduced salt use responsive to the actual ice on the pavement rather than typical rates applied on conventional pavements in the Midwest. Snow should not be stockpiled on the pavement. The operation and maintenance plan should show where snow will be pushed or stockpiled during plowing. The operation and maintenance plan should detail the blade depth that plow operators should use, because in some instances, such as grid pavements, snow plow operators may need to raise the blade slightly to avoid dislodging the surface. In every case, care should be taken with snow plowing to keep from gouging the pavement or dislodging aggregate or pavers.

Repair permeable pavements appropriately. Areas may be repaired using the same treatment as the original permeable pavement application or, in the case of porous asphalt or pervious concrete, small areas (not the lowest area on a sloping section) can be replaced with standard (impermeable) pavement. In that case the stone bed of the entire pavement will continue to provide storage and infiltration as designed. In no case should seal coats or new impermeable pavement layers be applied, as is typical in traditional asphalt pavements.

Inspection Items. The following are suggested items for inspection and are adapted from CSN, 2010:

- Using the observation well, observe the rate of drawdown in the practice. Measure the water level in the observation well following a storm event exceeding one half inch of rainfall. This should be done immediately after the storm, recording the precipitation amount, the time of the measurement and the water level in the well. Observe and record the water level after 24, 48 and 72 hours. Actual expected performance will depend on

7 No salt use is recommended during the first season on pervious concrete and some sand may be utilized being careful not to clog the pavement. Stockpiling snow on pervious concrete is not consider by industry representatives to be a problem.

the soils and the intended performance of the design. If the subgrade soils were hydrologic soil group D, there may still be water standing in the reservoir layer after 48 or 72 hours. There should not be standing water above the elevation of the underdrain, and this would indicate problems with the outlet or underdrain system being clogged. Assess potential clogging of the subgrade soils and geotextile by comparing the actual drawdown rate to the intended or design performance of the reservoir layer.

- Observe the pavement surface during and after rain for evidence of ponding, deposited sediments, leaves or debris. Address any signs of clogging or accumulated fine material by performing vacuum maintenance.
- Inspect the structural integrity of the pavement surface for damage such as missing infill material or broken pavers, spalling, rutting, or slumping of the surface. Any adversely affected areas should be repaired as soon as possible.
- Check contributing impervious areas and their associated pretreatment or runoff control structures for sediment buildup and structural damage. Remove sediment as needed.
- Inspect adjacent and contributing drainage area for sources of sediment or areas that may need better stabilization with erosion control.

Typical Maintenance Activities	Anticipated Schedule
Avoid sealing with construction sediments	During construction & long-term
Water vegetated grid pavement areas and adjacent vegetated areas to ensure good growth	As necessary during first growing season
Avoid sealing or repaving with non-porous materials	Long-term
Clean pavement to ensure pavement is free of debris and sediments	As needed (at least twice a year)
Check to see that pavement dewaters during large storms and does not pond into surface (check observation well for appropriate water levels)	After large storms
Inspect upland and adjacent vegetated areas. Seed & straw bare areas.	As needed
Inspect pavement surface for structural integrity and areas in need of repair. Repair as needed.	Annually

Table 2.11.8: Typical maintenance activities for permeable pavement (adapted from WMI, 1997)

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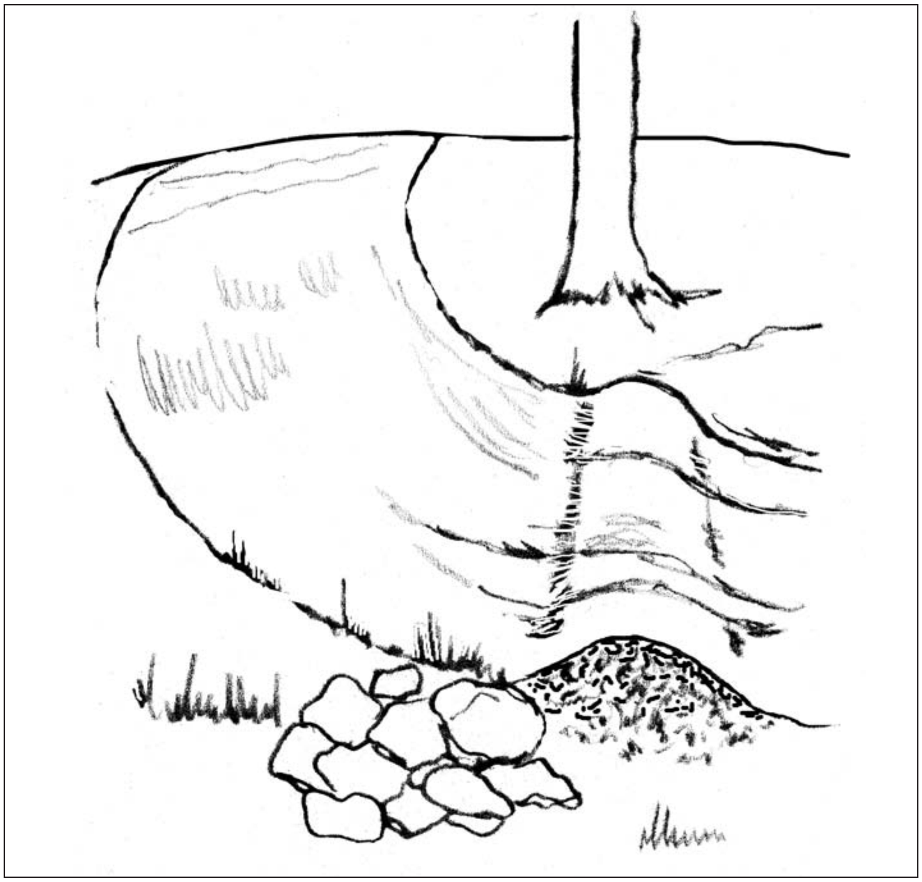
5.6 Water Bar



Description

A water bar is a diversion constructed across the slope of an access road or utility right-of-way. Water bars are used to reduce concentrated runoff on unpaved road surfaces, thus reducing water accumulation and erosion gullies from occurring. Water bars divert runoff to road side swales, vegetated areas or settling ponds.

Conditions Where Practice Applies

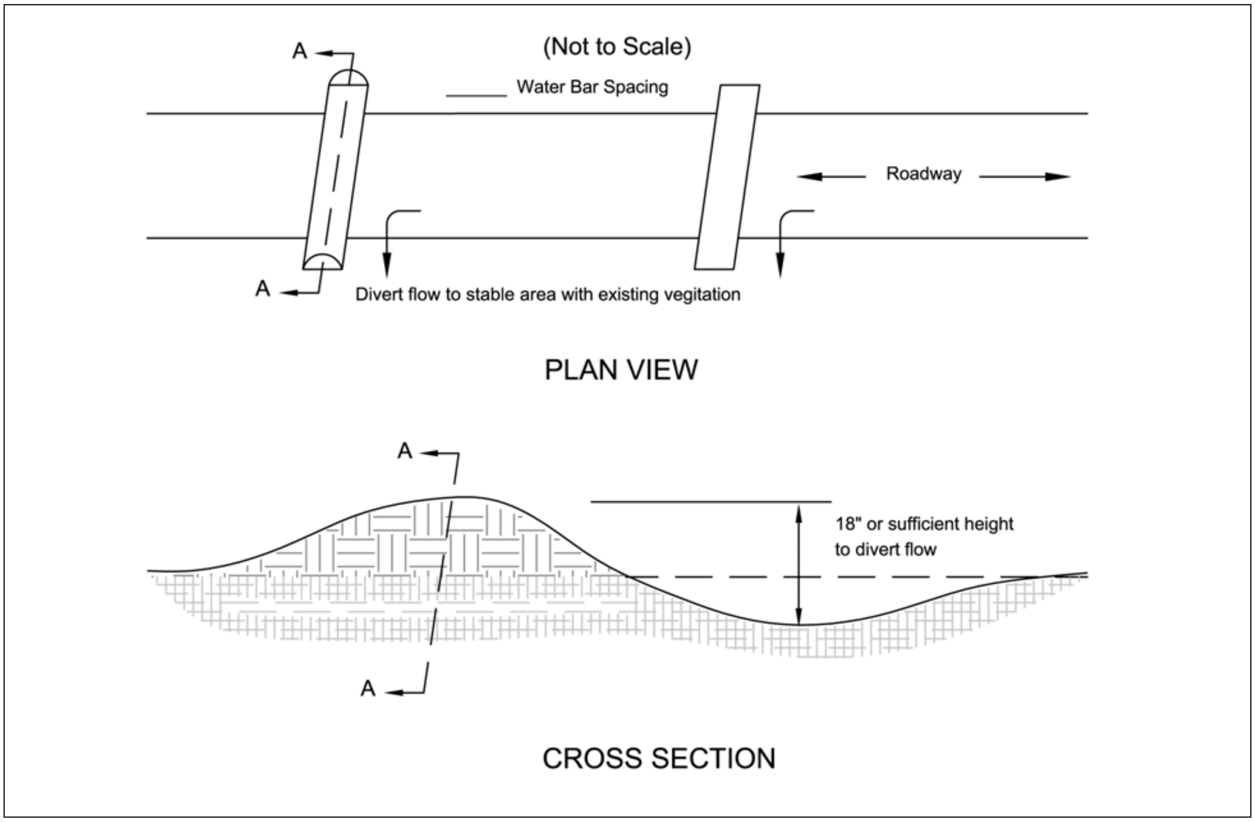
Water bars are used at construction site ingress/egress points, on long sloping access roads, on temporary construction roads, or at utility right-of-ways which do not have a stable surface or where runoff would otherwise collect and cause erosion.

Planning Considerations

If the contributing area is disturbed, this practice should be associated with sediment traps that will receive and treat the runoff.

The outlet of each water bar must be resistant to erosion. For small contributing areas, spreading the flow into a undisturbed vegetated area may be sufficient. For larger areas or higher velocities flow may need rock outlet protection to prevent gully erosion.

Specifications
for
Water Bar



1. The minimum water bar dimensions shall be:

   Top width of berm/dike – 2 feet minimum.

   Height/depth – 18 inches unless otherwise noted on plans.

   Side Slopes – Sufficiently flat to accommodate the expected traffic.

2. The spacing between water bars shall be as noted:

   Table 5.6.1 Water Bar Spacing

Road Grade (%)	Distance (Ft.)
1	400
2	250
5	135
10	80
15	60
20	45

3. The field location shall be adjusted as needed to provide a stabilized safe outlet.

4. The diverted runoff shall be directed onto an undisturbed vegetative area, to a settling trap or basin or trap if contributing area is stable.

5. Diversions/dikes shall be compacted by traversing with equipment during construction.

6. The water bars shall be angled slightly downslope across the centerline of the travel lane.

6.2 Sediment Trap

Description

A sediment trap is a temporary settling pond formed by construction of an embankment and/or excavated basin and having a simple outlet structure that is typically stabilized with geotextile and rip-rap. Sediment traps are constructed to detain sediment-laden runoff from small, disturbed areas for a sufficient period of time to allow the majority of the sediment to settle out. They are established early in the construction process using natural drainage patterns and favorable topography where possible to minimize grading.

Conditions Where Practice Applies

Sediment traps are used:

1. At the outlets of diversions, channels, slope drains, or other runoff conveyances that discharge sediment–laden water.
2. Below disturbed areas where the total contributing drainage area is **5 acres or less**. If the contributing drainage area is greater than 5 acres, the use of a Sediment Basin is recommended.
3. Where access can be maintained for removal and proper disposal of sediment.
4. In drainage swales or areas, where sediment control is needed upstream of a drainage pattern leading to a storm drain inlet.
5. Where the required life of the structure will be 18 months or less.

6. Where failure of the structure will not result in loss of life; or cause damage to buildings, roads, utilities, or other properties.

Note: Sediment traps, that have the entire capacity achieved through excavation, may have larger drainage areas without compromising the stability of the sediment trap.

Planning Considerations

Timing – Sediment traps shall be constructed as a first step in any land-disturbing activity, and shall be made functional before upslope land disturbance takes place. Sediment traps are temporary measures with a typical design life of 6 months to 18 months. One or more traps are often built early in the construction process to capture sediment, prior to construction of a larger structure (e.g., sediment basin or modified detention basin) is constructed. Sediment traps are to be functional during the entire construction process, both before and after new drainage systems are constructed.

Location – Sediment traps usually are placed near the edges of construction sites so to be out of the way of major construction activities.

Diverting Runoff – Temporary diversions at the perimeter of sites are used to direct runoff to sediment traps (see Temporary Diversion Specifications).

Storm-Sewer Diversions – Storm drains may be temporarily redirected through sediment traps during construction. After construction, the temporary pipes are removed and runoff is allowed to flow through the permanent storm drain as originally intended.

Utilities – Give special consideration to sediment trap location and possible interference with construction of proposed drainage ways, utilities and storm drains.

Trapping Efficiency – Improved sediment trapping efficiencies can be achieved by including both a “wet” storage volume and a drawdown or “dry” storage volume that enhances settling and prevents excessive sediment losses during large storm events. In order to maintain effectiveness, sediment must be periodically removed from the trap to maintain the required design volume. Frequent inspection and appropriate maintenance should be provided until the construction site is permanently protected against erosion.

Design Criteria

Capacity - The minimum total design volume for the sediment trap shall consist of two components, the dewatering zone and the sediment storage zone. These zones are shown schematically in Figure 6.2.1. The volume of the dewatering zone shall be calculated for the entire drainage area by the method shown below. The drainage area includes the entire area contributing runoff to the sediment basin, offsite as well as on. The sediment storage volume may be in the form of a permanent pool or wet storage to provide a stable-settling medium, while the dewatered volume shall be in the form of a draw down or dry storage of at least 67 cubic yards per acre which will provide extended settling time during less frequent, larger storm events.

a) Dewatering Zone Volume –

The volume of the dewatering zone shall be a minimum of 1800 cubic feet per acre of drainage (67 yd3/acre) or the minimum stated in the current NPDES construction general permit. The total volume of the dewatering zone shall be measured from the base of the stone outlet structure to the crest of the stone outlet structure.

7.1 Minimized Phased Disturbance

Description

Phased disturbance limits the total amount of grading at any one time and sequences operations so that at least half the site is either left as undisturbed vegetation or re-stabilized prior to additional grading operations. This approach actively monitors and manages exposed areas, so that erosion is minimized and sediment controls can be more effective in protecting aquatic resources and downstream landowners.

Condition Where Practice Applies

This practice can be applied anywhere development occurs and is well suited to protect critical areas on and off site, such as wetlands, streams, ponds and highly erodible areas subject to high erosion rates. The practice is applicable where natural vegetation can act as a soil stabilizer during development and perhaps as a water quality feature after construction.

Planning Considerations

Two planning principles should be applied for phased disturbance. First, developments should be fit around the natural site conditions (e.g. topography, drainage, vegetation and setting) and thus involve less grading and fewer offsite impacts than conventional development patterns. Practically this means retaining undisturbed green space around water resources and on critical areas like steep slopes.

The second planning principle is focused on managing active construction, so that at least 50% of the land area is maintained in vegetation. By anticipating the timing and extent each grading and construction operation, along with erosion and sediment controls, exposed ground does not sit idle. This management principle is applied by developing phases of a project that can be brought to completion quicker than the entire parcel; and by utilizing an effective construction sequence to assist project managers to anticipate the next step towards stabilization and completion.

Ideally with phasing and effective sequencing, a parcel is divided between vegetated inactive areas and active areas where work is continuous from clearing operations, through grading, drainage and construction until final re-stabilization with vegetation. A realistic construction sequence is an essential planning tool for this practice with the goal that only areas under active construction have exposed soils.

Construction Operation	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
PHASE 1: Roadway, Storm & Utilities	←	—	—	—	—	—	→												
Install construction site entrance	•																		
Fence natural & tree protection area	•																		
Install SW/sed basin, diversion and silt F.		•																	
Seed SW/Sed basin areas		•																	
Clear ROW		•																	
Grading, install storm, San. and utilties		•	•																
Place inlet protection on storm sewers			•																
Grade road swales and stabilize			•	•															
Road construction				•	•														
Seed/mulch graded areas					•	•													
PHASE 1: Home Construction					←	—	—	—	—	→									
Clear home sites					•	•	•												
Install silt fence & filter berms					•														
Basement excavation & rough grading					•	•	•	•											
Temporary seeding on lots						•	•	•	•										
Final yard grading								•	•	•									
Permanent seed and mulch								•	•	•									
PHASE 2: Roadway, Storm & Utilities								←	—	—	→								
Install sediment trap, silt F. and filter B.								•											
Seed sediment trap								•											
Grading, install storm, San. and utilties									•	•									
Place inlet protection on storm inlets										•									
Erosion control matting on swales										•									
Road construction											•								
Winterization- Seed/mulch graded areas										•	•								
PHASE 2: Home Construction												←	—	—	—	—	—	—	→
Clear home sites												•	•						
Install filter berms													•						
Basement excavation														•	•				
Temporary seeding on lots															•	•	•		
Final yard grading																	•	•	
Permanent seeding and mulching																		•	•
Remove temp riser, clean out SW pond																			•
Adapt SW pond outlet for permanent configuration																			•

Figure 7.1.1 Sample Sequence of Construction Operations

7.2 Clearing and Grubbing

Description

Clearing and grubbing is the removal of trees, brush and other unwanted material in order to develop land for other uses or provide access for site work. Clearing generally describes the cutting and removal of above ground material while grubbing is the removal of roots, stumps, and other unwanted material below existing grade.

Clearing and grubbing includes the proper disposal of materials and the implementation of best management practices in order to minimize exposure of soil to erosion and causing downstream sedimentation.

Condition Where Practice Applies

This practice may be applied anywhere existing trees and other material must be removed for development to occur. The potential for erosion and sedimentation increases as: the vegetation removed; area disturbed or watercourses encountered increases.

Planning Considerations

Site assessment, selection and marking

Sites should be assessed to determine areas to be left undisturbed as well as trees or vegetated areas to be saved (see tree preservation area). These areas need to be clearly marked on plans and in the field. Land clearing activities should not begin until the site assessment and the field marking is concluded.

Timing and Phasing

Large-scale sites should be cleared in phases, with initiation of each phase delayed until actual construction is scheduled for that area of the site.

Erosion, sediment and stream instability potential

Clearing in some areas should be avoided or delayed due to the potential for destabilization. Cleared sites on heavy soils and steep slopes are subject to excessive erosion and may require additional practices to keep the soil in place. Land clearing during dry or frozen times will decrease compaction and potential water quality problems from runoff.

Stream corridors should be left in tact unless and until plans have been made to immediately restore stable conditions. These areas are subject to rapid erosion once vegetation is removed and soon become a source of sediment downstream. Alternatively naturally vegetated stream corridors help protect water resources from pollution generated during grubbing and grading operations.

Design Criteria

Timber Salvage – Develop plans specifying the kind and location of timber to be salvaged, the location of haul roads and skid trails, location and width of natural buffer zones around water bodies, and the location and methods of stream crossings. The method of disposing of all material that will not be salvaged should also be specified. Plans should also include the best management practices that will be used to protect the cleared area from erosion.

Identify and protect healthy trees following specifications in the **Tree and Natural Area Preservation** practice. Where possible, preserve a natural buffer/filter strip adjacent to all water bodies. Avoid clearing to the water bodies' edge.

1. Where it is necessary to clear to the water's edge, appropriate sediment control should be used and seeding and other stabilization should be initiated within 2 days of work becoming idle.
2. Phase work so that only part of the site is being cleared at any given time. This will reduce the amount of time soil is exposed to erosive forces. Follow examples in the **Phased Disturbance** practice.
3. Install earth diversions to intercept and divert runoff to stable outlets and appropriate sediment ponds.
4. All debris should be kept out of surface water resources. If possible, leave mulch or vegetation on the ground to decrease runoff and potential runoff. See the "Disposal Options" section, below.
5. Exposed areas not planning for immediate earthwork should be temporarily seeded to prevent further erosion at the site. See the **Temporary Seeding** practice. Additional stabilization or sediment control practices may be necessary to keep soil on the site.

Grubbing – Grubbing removes roots and stumps by digging or pushing over with earth moving equipment. Grubbing should be carefully monitored near lakes and streams to protect the water's edge. Removing root systems near the banks of streams and lakes make cause the area to become unstable and erode. If possible, avoid grubbing at all near the water's edge.

Tree Removal –

1. Where trees and stumps are removed in separate operations, trees may be used for commercial purposes such as lumber, firewood, or mulch.

2. Trees and stumps may be removed in one operation. This method leaves materials that can be useful in stream restoration and stabilization (e.g rootwads, vanes). may be used as a rootwads for streambank restoration work. Be certain that sufficient trunk is left for effective anchoring in the bank. Tops of trees should be removed and chipped for mulch.
3. Operating heavy equipment too close to trees will result in damage or loss due to soil disruption, compaction and trunk damage. It is recommended that all heavy equipment operations be limited to outside the drip line of all trees to be preserved. The drip line is the area from the trunk of the tree outward to a point at which there is no longer any overhanging vegetation.
4. In forested wetlands, shallow–rooted species are protected by each other from potential wind damage. Whenever trees are removed from a forested wetland, the possibility of blow downs or windthrow increases. Shallow rooted species are also protected by edge trees, which shield the prevailing wind side of the woodlot. It is helpful to leave as many edge trees as possible on the prevailing wind side of the cleared area.

Disposal Options –

Where possible, all stumps, roots, logs, brush, limbs, tops and other debris resulting from the clearing or thinning operation should be disposed of by processing through a chipping machine. The chips can then be utilized as mulch (see Mulching practice), as part of a site stabilization or final landscaping plan. Organic material may also be disposed of at an approved composting facility.

Note that treetops, stumps and field stone which are cleared and piled/windrowed in suitable areas can improve habitat for wildlife such as rabbits, raccoons, snakes, salamanders, toads and frogs.

Maintenance

Land clearing itself requires no maintenance except maintenance of the equipment used in the land clearing operation. Tree protection that utilizes fencing and signage should be maintained throughout the clearing stages. It is also important to maintain all other temporary and permanent practices that are used in conjunction with the land clearing to prevent soil erosion and sedimentation.

Common Problems / Concerns

Clearing of areas planned for preservation may occur and desirable species may be damaged, therefore preservation areas should be well marked.

During construction, naturally vegetated banks of stream and lakes may become destabilized. Clearly mark areas where natural vegetation must be maintained, and immediately implement stabilization plans of denuded areas.

As large areas are disturbed, site erosion potential drastically increases until cover is re-established. Establish temporary seedings as soon as clearing/grubbing and grading activities stop or become idle.

7.3 Tree and Natural Area Reservation

Description

Tree and natural area preservation insures that important vegetated areas existing on-site prior to development will survive the construction process. Tree protection areas prevent the losses and damages to trees that are common as a result of construction. This practice is useful to protect individual trees, and areas of forest or natural vegetation in stream corridors, or open space.

Conditions Where Practice Applies

This practice is applicable to any tree, forested or naturally vegetated area planned for long-term survival and subject to construction impacts. Existing trees provide valuable benefits during and after construction including: reduced erosion, reduced runoff rates and volume, reduced cooling costs, sound and visual barriers and higher property values.

Planning Considerations

Preservation of important natural areas must begin before the location of buildings, roads and utilities is determined. Early site planning should include delineating forested areas and significant trees and creating an inventory of the existing trees on-site. These should influence the placement of roads, buildings, and parking areas in the same manner as topography, streams and wetlands.

Tree Stand Delineation – Useful information for the delineation may include:
- Stands of trees to be preserved
- Individual trees of significance due to age, size, history, or aesthetic value

7.4 Construction Entrance

Description

A construction entrance is a stabilized pad of stone underlain with a geotextile and is used to reduce the amount of mud tracked off-site with construction traffic. Located at points of ingress/egress, the practice is used to reduce the amount of mud tracked off-site with construction traffic.

Conditions Where Practice Applies

A construction entrance is applicable where:

- Construction traffic leaves active construction areas and enters public roadways or areas unchecked by effective sediment controls;
- Areas where frequent vehicle and equipment access is expected and likely to contribute sediment to runoff, such as at the entrance to individual building lots.

Planning Considerations

Construction entrances address areas that contribute significant amounts of mud to runoff by providing a stable area for traffic. Although they allow some mud to be removed from construction vehicle tires before they enter a public roads, they should not be the only practice relied upon to manage off-site tracking. Since most mud is flung from tires as they reach higher speeds, restricting traffic to stabilized construction roads, entrances and away from muddy areas is necessary.

If a construction entrance is not sufficient to remove the majority of mud from wheels or there is an especially sensitive traffic situation on adjacent roads, wheel wash areas may be necessary. This requires an extended width pad to avoid conflicts with traffic, a supply of wash water and sufficient drainage to assure runoff is captured in a sediment pond or trap.

Proper installation of a construction entrance requires a geotextile and proper drainage to insure construction site runoff does not leave the site. The use of geotextile under the stone helps to prevent potholes from developing and will save the amount of stone needed during the life of the practice. Proper drainage may include culverts to direct water under the roadway or water bars to direct muddy water off the roadway toward sediment traps or ponds.

Design Criteria

The area of the entrance must be cleared of all vegetation, roots, and other objectionable material. Geotextile will then be placed the full width and length of the entrance.

Stone shall be placed to a depth of at least 6 inches. Roads subject to heavy duty loads should be increased to a minimum of 10 inches. Surface water shall be conveyed under the entrance, through culverts, or diverted via a water bars or mountable berms (minimum 5:1 slopes) so as to convey sediment laden runoff to sediment control practices or to allow clean water to pass by the entrance.

The stabilized construction entrance shall meet the specifications that follow.

Maintenance

The entrance shall be maintained in a condition that will prevent tracking or flow of mud onto public rights-of-way. This may require periodic top dressing with additional stone or the washing and reworking of existing stone as conditions demand and repair and/or cleanout of any structures used to trap sediment. All materials spilled, dropped, washed, or tracked from vehicles onto roadways or into storm drains must be removed immediately. The use of water trucks to remove materials dropped, washed, or tracked onto roadways will not be permitted under any circumstances.

Common Problems / Concerns

Mud is allowed to accumulate and is tracked on to public right-of-ways. The entrance and associated construction roads may need dressing with additional stone.

Soft depression areas develop in entrance area. Stone may not have been underlain with geotextile or insufficient stone base has been provided.

Appendix 1: Post-Construction Stormwater Design Examples

This appendix uses three hypothetical development sites in order to demonstrate the design of post-construction stormwater practices presented earlier in specifications.

Each practice example utilizes the existing and the proposed developed site and hydrologic characteristics to determine the sizing and configuration of each practice. The base requirements are presumed to be Ohio EPA's Construction General Permit post-construction requirements (detention of the water quality volume) and the detention of the critical storm (see the Critical Storm Method) from the development in order to prevent increases in downstream flooding and streambank erosion.

Each practice use the following steps to proceed through the design:

Step 1 - Calculate Water Quality Volume (WQv)
Step 2 - Compute Peak Discharge Requirements
Step 3 - Identify Other Local Development Criteria/Requirements
Step 4 - Determine if the Site and Soils Are Appropriate for the Practice
Step 5 - Determine Practice Location and Preliminary Geometry to Meet Requirements
Step 6 - Check Design to Ensure All Requirements Are Met

CONTENTS

Section A: Dry Extended Detention Basin

This design example illustrates the design of a dry extended detention stormwater basin that provides water quality treatment and peak discharge control within a highly impervious commercial development.

The layout of the North Country Automotive development is shown in Figure 1.A.1. The development site totals 7.7 acres draining to a single point on the north property line with no off-site watershed area. The site impervious area at completion of construction is estimated to be 5.3 acres. The example assumes that the local community has adopted the Critical Storm Method criteria to control peak discharges[1]. The pre-developed and post-developed site flow paths are shown in Figure 1.A.2. (limited to those used for calculations).

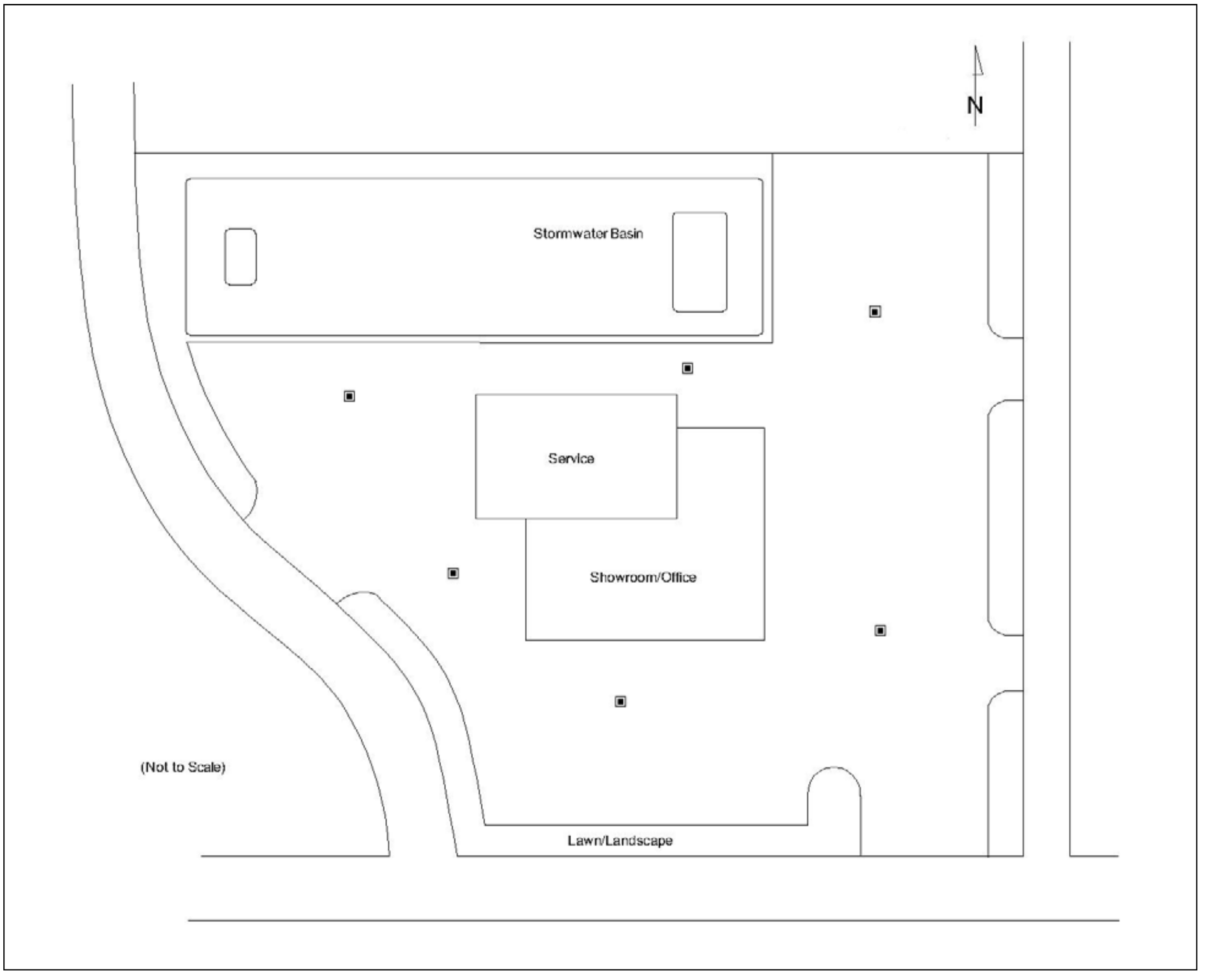


Figure 1.A.1. North Country Automotive Site Plan.

[1] The Critical Storm Method is a set of criteria for controlling the peak discharge of stormwater from large storm events (1 - 100 yr recurrence interval) recommended by ODNR-DSWC since 1980. See Goettemoeller, R.L., D.P. Hanselmann, and J.H. Bassett. 1980. Ohio Stormwater Control Guidebook. Ohio Department of Natural Resources, Division of Soil and Water Districts, p47.

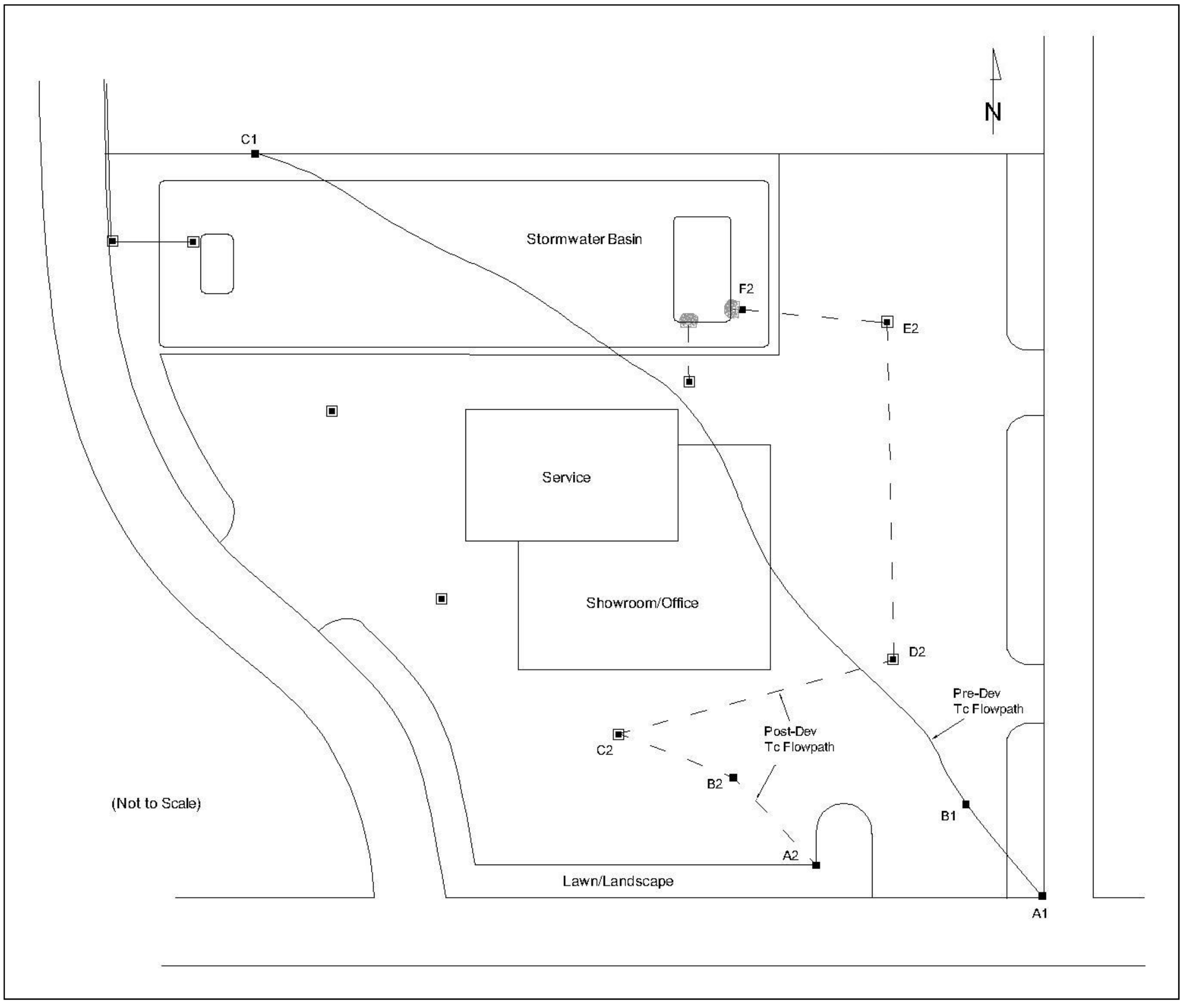


Figure 1.A.2. North Country Automotive Site Plan with pre-developed and post-developed flow paths.

<u>Site Data</u>
Total Drainage Area (A) = 7.7 ac
Estimated Impervious Area = 5.3 ac
Soil Types
  Existing: 100% HSG-C
  Proposed: 100% HSG-D

<u>Summary Hydrologic Data</u>
WQv = 0.26 ac-ft

	Pre	Post
CN =	70	96
Tc =	33.3 min	3.5 min

Calculation of Preliminary Stormwater Storage Volumes and Peak Discharges

Step 1 - Calculate Water Quality Volume (WQv)

The water quality volume (WQv) is a post-construction stormwater control requirement in Ohio (NPDES Storm Water Construction General Permit; OEPA, 2008). The WQv is determined according to the following equation:

$$WQv = C*P*A \qquad \text{Equation 1.A.1}$$

where:

C = runoff coefficient

P = 0.75 inch precipitation depth

A = drainage area

For open water, C = 1. At this site, the surface area of the detention basin at full WQv is estimated to be 0.4 acres.

For the remainder of the site, the runoff coefficient can either be selected from Table 1 of the NPDES Storm Water Permit, or calculated using the following equation:

$$C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04 \qquad \text{Equation 1.A.2}$$

where i is the fraction of post-construction impervious surface.
For this site, total impervious area = 5.3 acres from a drainage area of 7.3 acres (i.e., total site drainage area - surface area of detention basin at full WQv).

$$i = 5.3/7.3 = 0.73 \qquad \text{Equation 1.A.3}$$

$$C = 0.858(0.73)^3 - 0.78(0.73)^2 + 0.774(0.73) + 0.04 = 0.52 \qquad \text{Equation 1.A.4}$$

Therefore, the WQv is:

$$WQv = [1.0*0.75 \text{ in}*0.4 \text{ ac} + 0.52*0.75 \text{ in}*7.3 \text{ ac}]*(1 \text{ ft}/12 \text{ in}) \qquad \text{Equation 1.A.5}$$

= <u>0.26 ac-ft</u>

= 11,400 ft^3

Peak Discharge Summary
Project: North Country Automotive

	Cover Description	Soil Name	Hydrologic Group	Drainage Y/N	CN	Area (acres)
Existing Condition	Woods (good condition)	Ellsworth	C		70	7.7
	Existing Conditions				**70**	**7.7**
	Cover Description	**Soil Name**	**Hydrologic Group**		**CN**	**Area (acres)**
Proposed Condition	Impervious Area				98	5.3
	Open space (good condition)	Ellsworth	D		80	0.8
	Detention Basin				98	1.6
	Proposed Conditions				**96**	**7.7**

Table 1.A.1. Curve Number (CN) for existing (pre-developed) and proposed (post-developed) condition.

	Segment	Flow Type	Surface Cover	Mannings n	Length ft	Slope %	Veloctiy ft/s	Tt min
Existing Condition	A_1 to B_1	Overland - sheet	Woods - Light Underbrush	0.40	100	3		21.0
	B_1 to C_1	Overland - shallow conc	Woods - Light Underbrush	0.10	700	3.5	0.95	12.3
	Total	**Existing**			**800**			**33.3**
	Segment	**Flow Type**	**Surface Cover**	**Mannings n**	**Length ft**	**Slope %**	**Veloctiy ft/s**	**Tt min**
Proposed Condition	A_2 to B_2	Overland - sheet	Pavement	0.011	100	2.0		1.4
	B_2 to C_2	Overland - shallow conc	Pavement	0.025	100	2.0	2.9	0.6
	C_2 to D_2	Pipe - storm drain (12”)	Pipe	0.013	250	2.0	6.4	0.6
	D_2 to E_2	Pipe - storm drain (15”)	Pipe	0.013	300	2.0	7.4	0.7
	E_2 to F_2	Pipe - storm drain (18”)	Pipe	0.013	150	4.0	11.9	0.2
	Total	**Proposed**			**900**			**3.5**

Table 1.A..2. Time of Concentration (Tc) for existing ((pre-developed) and proposed (post-developed) condition.

RI years	P in	Q_{pre} in	Q_{post} in	Percent Increase Q	q_{pre} cfs	q_{post} cfs
1	2.00	0.24	1.57	554	0.86	21.3
2	2.40	0.41	1.96	378	1.8	26.1
5	2.98	0.70	2.53	261	3.7	33.1
10	3.47	0.99	3.02	205	5.5	39.0
25	4.17	1.44	3.71	158	8.5	47.3
50	4.76	1.86	4.29	131	11.2	54.3
100	5.38	2.32	4.91	112	14.1	61.6

Table 1.A.3. Summary runoff depth (Q) and peak discharge (q) for existing (pre-developed) and proposed (post-developed) conditions with critical storm (bold type).

Step 2 - Compute Peak Discharge Requirements

> Note: Peak discharge control is typically regulated through local entities (e.g. stormwater district, municipal, township or county governments). The state of Ohio recommends use of the Critical Storm Method[1] for peak discharge control, but the requirements will vary by community. Check local stormwater regulations to determine which peak discharge control method you must use.

This example uses the NRCS Curve Number Methodology to perform hydrologic calculations. TR-20, HEC-HMS or other software that uses NRCS procedures should provide similar results.

Tables 1-1 and 1-2 summarize the inputs necessary to determine the curve number (CN) and time of concentration (Tc) for the existing (pre-development) and proposed (post-development) conditions. Table 1-3 summarizes the existing and proposed runoff depths and peak discharges for the 1-year, 24-hr through 100-year, 24-hr rainfall events.

The *critical storm* is determined from the percent increase in runoff volume from the 1-year, 24-hr storm for the proposed (post-developed) conditions when compared to the existing (pre-developed) conditions (Goettemoeller et al., 1980):

$$Percent\ Increase = \frac{Q_{post} - Q_{pre}}{Q_{pre}} x\,100 \qquad \text{Equation 1.A.6}$$

From Table 1-3, the percent increase in the 1-year, 24-hr runoff for the proposed development is:

$$Percent\ Increase = \frac{1.57 - 0.24}{0.24} x\ \ 100 = 554\% \qquad \text{Equation 1.A.7}$$

For an increase greater than 500%, the *critical storm* for peak discharge control is the 100-year, 24-hr event - i.e., the 100-year, 24-hr post-developed peak discharge must be less than the existing (pre-developed) 1-year, 24-hr peak discharge. These values are shown in bold type in Table 1.A.3.

Step 3 - Identify Other Local Development Criteria/Requirements

Commercial development in this community is subject to a 5% minimum landscaped area requirement - the proposed design meets this requirement. No additional setback or stormwater requirements were identified.

Step 4 - Determine if the Development Site and Soils Are Appropriate for the Use of a Dry Extended Detention Basin

The site drainage area is 7.7 acres, all of which is mapped as Ellsworth silt loam soil in the county soil survey. Ellsworth silt loam soils are suitable for creation of an extended detention basin with a wet forebay and permanent micropool. The subsoil is silty clay loam derived from glacial till and has slow permeability. Because the soil has slow permeability, there may be extended periods when the basin cannot be mowed. This subsoil is suitable material for construction of the embankment for the stormwater basin.

[1] The Critical Storm Method is a set of criteria for controlling the peak discharge of stormwater from large storm events (1 - 100 yr recurrence interval) recommended by ODNR-DSWC since 1980. See Goettemoeller, R.L., D.P. Hanselmann, and J.H. Bassett. 1980. Ohio Stormwater Control Guidebook. Ohio Department of Natural Resources, Division of Soil and Water Districts, p47.

Step 5 - Determine Pond Location and Develop Preliminary Geometry to Meet WQv and Peak Discharge Requirements

The proposed location of the stormwater basin (see Figure 1.A.2) reflects the best combination of characteristics (landscape position, access to outlet, minimized earth moving, appropriate soils, etc.) for siting the basin. Existing ground elevation at the proposed pond outlet is 935 MSL. An existing 24" storm sewer runs along the west edge of the property, with an invert elevation of 928 MSL at the proposed discharge point. [For more information on siting and planning an extended detention basin, see section 2.6.]

The basin will be designed to include a permanent micropool and wet forebay, an extended detention volume to protect water quality and stream channel stability, and storage necessary to control the peak discharge rate.

The NPDES Storm Water Permit (OEPA, 2008) specifies a dry extended detention basin include a water quality volume (WQv) with a drawdown time of 48 hours. The permit also requires an additional sediment storage volume equal to 20% of the WQv which, for a dry extended detention basin, should consist of a permanent micropool and forebay each sized at 10% of the WQv.

$$V_{micropool} \text{ and } V_{forebay} \geq 0.1*WQv = 0.1*0.26 \text{ ac-ft} = 0.026 \text{ ac-ft} = 1140 \text{ ft}^3 \qquad \text{Equation 1.A.8}$$

A plan view of the basin layout (Figure 1.A.3) reflects the following:

- extended detention water quality volume (WQv)
- a wet forebay with a minimum volume of 0.1*WQv and 3' depth
- permanent micropool with a minimum volume of 0.1*WQv and 4' depth
- a flow length to flow width ratio of 4:1, exceeding the 3:1 requirement
- positive slope (~0.8%) toward the outlet to facilitate surface drainage [Note: this is not enough slope to prevent extended periods of soil wetness.]
- 4:1 side slopes for safety and ease of maintenance
- an emergency spillway constructed in native soil (i.e., not in the constructed embankment)

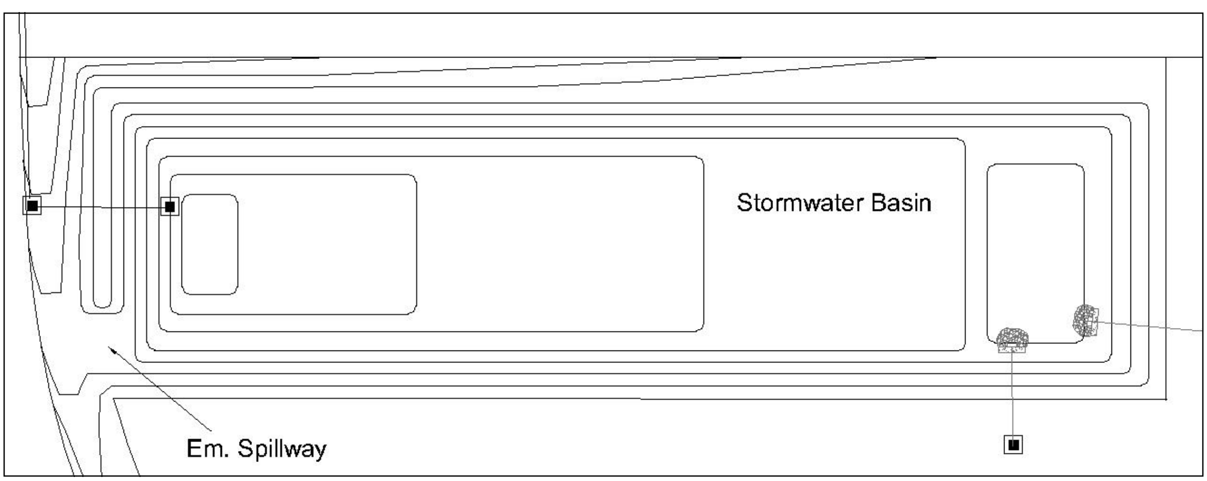


Figure 1.A.3. Plan View of the Basin Layout.

Set elevations for pond structures

- The pond bottom is set at elevation 930.0 and the riser invert is set at 929
- A manhole will be installed in the sewer main with a barrel invert (outfall) elevation at 928 ft

Establish permanent micropool and WQv water surface elevations

A stage-area-storage table (Table 1.A.4) reflects the geometry of the stormwater basin (Figure 1.A.3) designed to meet permanent micropool, forebay, extended detention (WQv) and peak discharge control requirements.

- The permanent micropool volume of 0.05 ac-ft (surface elevation 934.0) exceeds 0.1*WQv
- The extended detention water quality volume WQv of 0.26 ac-ft above the permanent micropool has a top elevation of approximately 935.5

Elevation MSL (ft)	Surface Area (acre)	Average Area (acre)	Incremental Depth (ft)	Incremental Volume (ac-ft)	Cumulative Volume (ac-ft)	Vol above Perm Pool (ac-ft)
930.0	0.004	-	-	-	-	-
934.0	0.02	0.01	4.0	0.05	0.05	-
934.5	0.10	0.06	0.5	0.03	0.08	0.03
935.0	0.22	0.16	0.5	0.08	0.16	0.11
935.5	0.40	0.31	0.5	0.15	0.31	0.26
936.0	0.52	0.39	0.5	0.20	0.48	0.43
937.0	1.05	0.76	1.0	0.76	1.24	1.19
938.0	1.25	1.15	1.0	1.15	2.39	2.34
939.0	1.36	1.30	1.0	1.30	3.69	3.64
940.0	1.47	1.41	1.0	1.41	5.10	5.05
941.0	1.58	1.53	1.0	1.53	6.63	6.58

Table 1.A.4. Stage-Area-Storage Information for Dry Extended Detention Basin.

Determine orifice size for 48-hour drawdown of WQv

The controlling parameters are WQv = 0.26 ac-ft, depth of WQv = 1.5 ft, and minimum drain time, T_d = 48 hours. Note that "the outlet structure for the post-construction BMP must not discharge more than the first half of the WQv in less than one-third of the drain time" (p22, NPDES Storm Water Construction General Permit; OEPA, 2008).

The average discharge rate for the WQv is:

$$Q_{avg} = \frac{WQv}{T_d} = \frac{(0.26\ ac \cdot ft)\left(\frac{43560\ ft^2}{1\ ac}\right)}{(48\ hr)\left(3600\ \frac{s}{hr}\right)} = 0.065\ cfs$$ Equation 1.A.9

The discharge equation for an orifice is:

$$Q = ca\sqrt{2gh}$$ Equation 1.A.10

By rearranging, we can estimate needed orifice area, as:

$$a = \frac{Q}{c\sqrt{2gh}}$$ Equation 1.A.11

Using an orifice coefficient of c = 0.6, and average head, h = d/2 = (1.5 ft)/2 = 0.75 ft, the required orifice size is:

$$a = \frac{0.065\ \frac{ft^3}{s}}{0.6\sqrt{2(32.2\ \frac{ft}{s^2})(0.75\ ft)}} = 0.0156\ ft^2$$ Equation 1.A.12

resulting in an estimated orifice diameter of:

$$d = \left(\frac{4a}{3.14}\right)^{0.5} = \left[\frac{4(0.0156\ ft^2)}{3.14}\right]^{0.5} = 0.141\ ft \times \frac{12\ in}{1\ ft} = 1.7\ in$$ Equation 1.A.13

This estimate is a good starting point for selecting the WQv orifice size, because it will always meet the two drawdown requirements: (1) the specified minimum drain time, T_d; and (2) the outlet must not discharge more than the first half of the WQv (or EDv) in less than one-third of the drain time. A larger or smaller orifice should be considered if it will help meet other environmental, cost, or maintenance goals, but must be tested for the two drawdown criteria.

Choosing the largest orifice size meeting the criteria lowers the likelihood of a clogged orifice and slightly lessens the storage volume required to meet the peak discharge requirement. In this situation, a 1.7" diameter orifice was the largest orifice that met the above two drawdown requirements (see Figure 1.A.4) and, thus, will be used as the extended detention (WQv) outlet.

Determine storage and outlet configuration to meet peak discharge requirements

As noted under Step 2, this dry detention basin is designed to meet the Critical Storm Method (CSM) for peak discharge control as well as the WQv requirement. Additional storage volume must be added that, with appropriate outlet design, will allow the basin to meet the following requirement:

- The peak rate of discharge from the post-construction 100-year, 24-hour event (the critical storm) must be released at the existing (pre-development) 1-year, 24-hour discharge rate

Proprietary stormwater modeling software was used to try a combination of stage-storage and outlet configurations until the critical storm requirement was satisfied while considering the following:

- use best practices outlined in Section 2.6 of the Rainwater and Land Development manual
- minimize cut/fill and grading

The resulting detention basin geometry is presented in Figure 1.A.3 and Table 1.A.4. The resulting outlet configuration is shown in Figure 1.A.5.

The outlet structure consists of a 3 ft by 3 ft concrete catch basin (e.g., ODOT No. 2-3) with invert at 929 MSL and 2.5'x2.5' iron grate at 938.1 MSL. The following comprise the outlets:

- 1.7" diameter extended detention water quality volume (WQv) orifice (invert 934.0 MSL) drilled into 6" PVC pipe using a non-clogging design
- 4.2" diameter orifice (invert 935.5 MSL) that controls release of the critical storm (100-year, 24-hour)
- 2.5'x2.5' iron grate (invert 938.1 MSL) for emergency overflow and maintenance access

The catch basin will be connected - using a 12" diameter conduit - to the 2' diameter storm sewer at the road along the west property boundary. A tailwater analysis was performed using the modeling software and the storm sewer's design elevation (invert at 928 MSL; 25-yr full pipe flow at 930 MSL) and assumed elevation for the 100-yr event (935 MSL).

In addition, this design includes an emergency spillway excavated into native soil with the following characteristics:

- Invert (crest) elevation of 938.5 MSL
- Level section length of 25 ft, weir length (i.e., crest width) of 25 ft
- Spillway crest perpendicular to flow
- With all other outlets blocked and starting from the permanent pool elevation of 934.0 MSL, will safely convey the 100-yr, 24-hr event with at least 1 ft freeboard below top of embankment

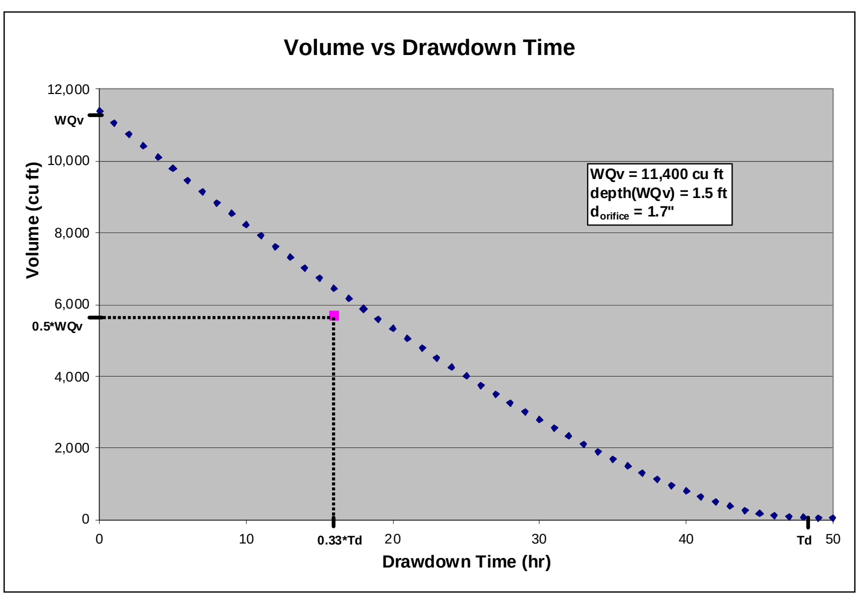


Figure 1.A.4. Dry Extended Detention Basin - Drawdown from Full WQv.

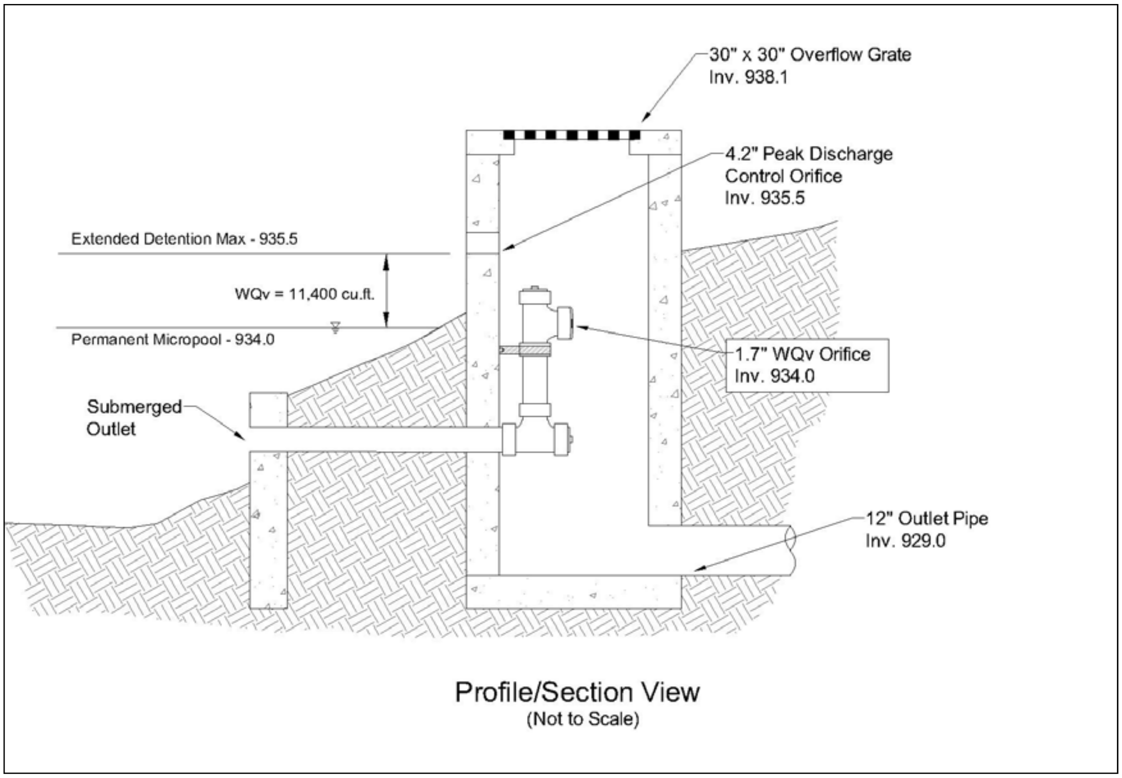


Figure 1.A.5. Outlet Configuration for Dry Extended Detention Basin (not to scale).

Step 6 - Check Design to Ensure All Requirements Are Met

From full WQv, check that WQv meets minimum 48 hour drain time, and discharges no more than 1/2 the water quality volume, 0.5*WQv (5050 ft^3), in the first 1/3 of the drain time, 0.33*T_d (16 hr). This requirement is met and illustrated in Figure 1.A.4.

Check peak discharge for all events (see Table 1.A.5).

RI years	P in	$q_{post\text{-}in}$ cfs	Allowed $q_{post\text{-}out}$ cfs	Estimated $q_{post\text{-}out}$ cfs
1	2.00	21.3	0.86	0.48
2	2.40	26.1	0.86	0.55
5	2.98	33.1	0.86	0.63
10	3.47	39.0	0.86	0.68
25	4.17	47.3	0.86	0.75
50	4.76	54.3	0.86	0.80
100	5.38	61.6	0.86	0.85

Table 1.A.5. Critical Storm Method Peak Discharge Check.

Section B: Wet Extended Detention Basin

This design example illustrates the design of a wet extended detention stormwater basin that provides water quality treatment and peak discharge control within a condominium development. This residential development will consist of 74 units of "active senior" living units and a well-equipped clubhouse for recreation, exercise and social functions. The layout of the development is shown in figure 1.B.1.

The development site consists of 24.2 acres having 10.2 acres of impervious area. An additional 8.5 acres of off-site area drains to the development site. The pre-developed site soils and flow paths are shown in Figure 1.B.2, while the post-developed flow paths (limited to that used for calculations) are shown in figure 1.B.3.

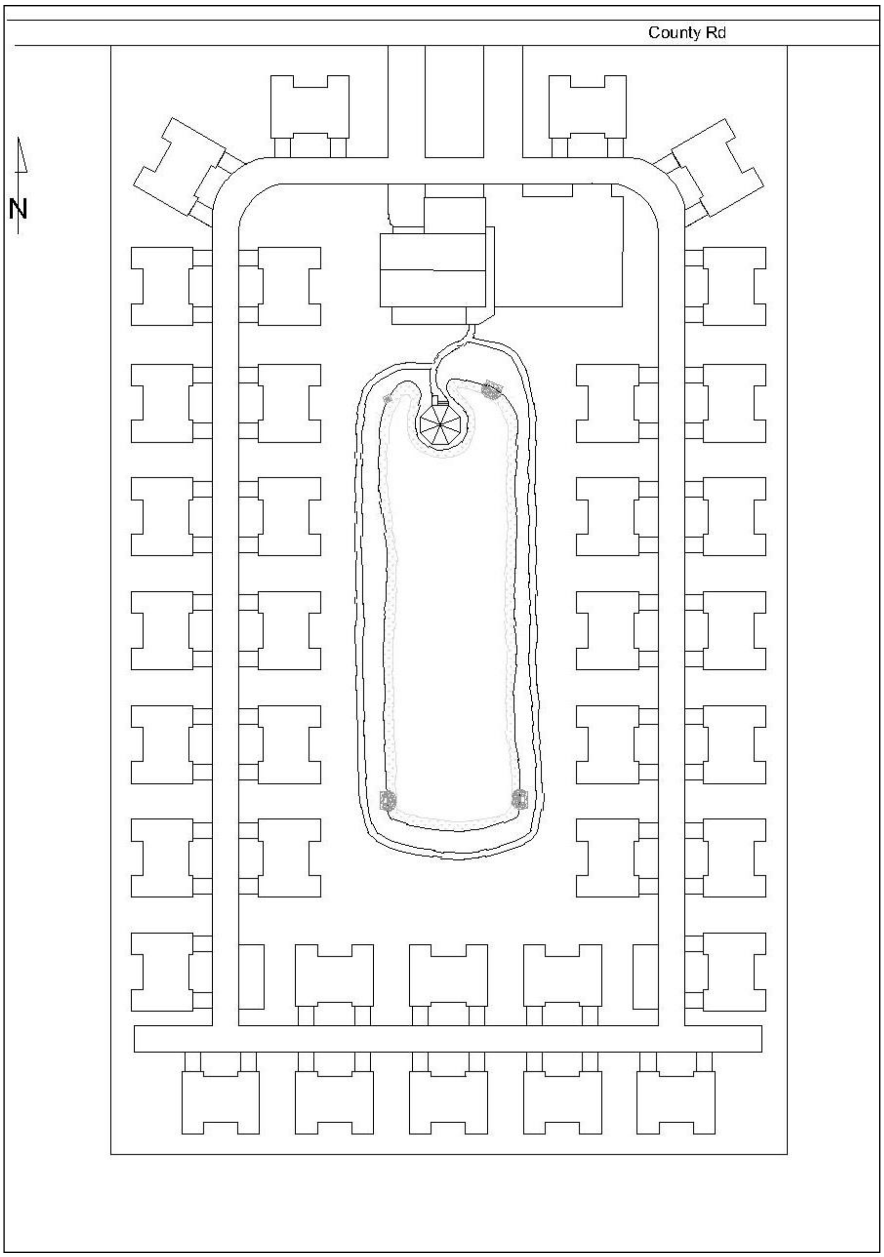


Figure 1.B.1. Autumn Knoll Subdivision Site Plan.

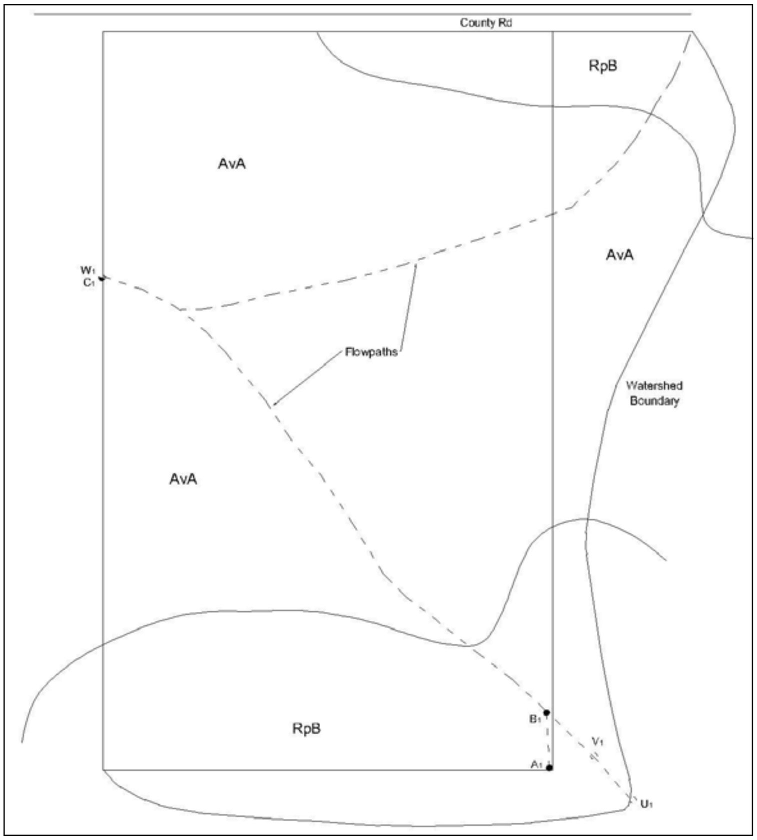


Figure 1.B.2. Pre-Development On-site and Off-site Soils and Drainage.

<u>Development Site Data</u>
Total On-Site Drainage Area (A) = 24.2 ac
Estimated Impervious Area = 10.2 ac
Soil Types
Existing: 25% HSG-C, 75% HSG-D
Proposed: 100% HSG-D

<u>Drainage from Off-site</u>
Off-site Drainage Area (A) = 8.5 ac
Estimated Impervious Area = 0 ac
Soil Types: 60% HSG-C, 40% HSG-D

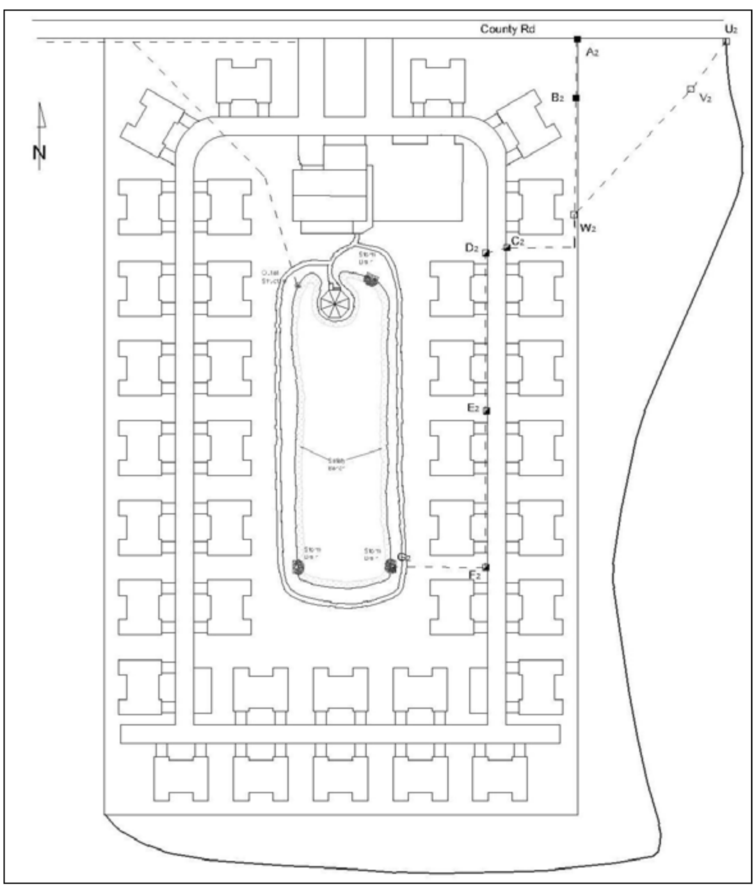


Figure 1.B.3. Post-Development On-site and Off-site Drainage.

<u>Summary Hydrologic Data</u>
WQv = 0.53 ac-ft
EDv = 0.40 ac-ft

	Pre	Post
CN(site) =	84	89
Tc(site) =	66 min	27 min
CN(offsite) =	83	83
Tc(offsite) =	71 min	30 min

Calculation of Preliminary Stormwater Storage Volumes and Peak Discharges

Step 1 - Calculate Water Quality Volume (WQv)

The water quality volume (WQv) is a post-construction stormwater control requirement in Ohio (NPDES Storm Water Construction General Permit; OEPA, 2008). The WQv is determined according to the following equation:

$$WQv = C*P*A \qquad \text{Equation 1.B.1}$$

where:

C = runoff coefficient

P = 0.75 inch precipitation depth

A = drainage area

For open water, C = 1. At this site, the surface area of the detention basin at full extended detention volume is estimated to be 1.5 acres.

For the remainder of the site, the runoff coefficient can either be selected from Table 1 of the NPDES Storm Water Permit, or calculated using the following equation:

$$C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04 \qquad \text{Equation 1.B.2}$$

where i is the fraction of post-construction impervious surface.

For this site, total impervious area = 10.2 acres from a drainage area of 22.7 acres (i.e., total site drainage area - surface area of detention basin).

$$i = 10.2/22.7 = 0.45 \qquad \text{Equation 1.B.3}$$

$$C = 0.858(0.45)^3 - 0.78(0.45)^2 + 0.774(0.45) + 0.04 = 0.31 \qquad \text{Equation 1.B.4}$$

Therefore, the WQv is:

$$WQv = [1.0*0.75\text{ in}*1.5\text{ ac} + 0.31*0.75\text{ in}*22.7\text{ ac}]*(1\text{ ft}/12\text{ in}) \qquad \text{Equation 1.B.5}$$

= <u>0.53 ac-ft</u>

= 23,200 ft^3

Step 2 - Compute Peak Discharge Requirements

Note: Peak discharge control is typically regulated through local entities (e.g. stormwater district, municipal, township or county governments). The state of Ohio recommends use of the Critical Storm Method[1] for peak discharge control, but the requirements will vary by community. Check local stormwater regulations to determine which peak discharge control method you must use.

This example uses the NRCS Curve Number Methodology to perform hydrologic calculations. TR-20, HEC-HMS or other software that uses NRCS procedures should provide similar results.

Tables 1.B.1 and 1.B.2 (a and b) summarize the inputs necessary to determine the curve number (CN) and time of concentration (Tc) for the existing (pre-development) and proposed (post-development) conditions. Table 1.B.3 summarizes the existing and proposed runoff depths and peak discharges for the 1-year, 24-hr through 100-year, 24-hr rainfall events.

The *critical storm* is determined from the percent increase in runoff volume generated from the development site for the 1-year, 24-hr storm, comparing proposed (post-developed) conditions to the existing (pre-developed) conditions (Goettemoeller et al., 1980):

$$Percent\ \ Increase = \frac{Q_{post} - Q_{pre}}{Q_{pre}}\, x\, 100$$ Equation 1.B.6

Using data from Table 1.B.3, the percent increase in the 1-year, 24-hr runoff volume for the proposed development site is:

$$Percent\ \ \ Increase\ \ = \frac{1.38 - 1.05}{1.05}\, x\ \ 100\ = 31\,\%$$ Equation 1.B.7

For an increase greater than 20% but less than 50%, the *critical storm* for peak discharge control is the 5-year, 24-hr event - i.e., the stormwater detention facility must be designed such that the 5-year, 24-hr post-developed peak discharge does not exceed the existing (pre-developed) 1-year, 24-hr peak discharge. These values are shown in bold type in Table 1.B.3. In addition, the proposed peak discharge for the 10-year through 100-year events must not exceed the existing (pre-developed) discharge for like year events.

Step 3 - Identify Other Local Development Criteria/Requirements

The local subdivision regulations included lot size, lot width, road width and setback requirements that affected site layout. No additional stormwater requirements were identified.

Step 4 - Determine if the Development Site and Soils Are Appropriate for the Use of a Wet Extended Detention Basin

The site drainage area is 24.2 acres, all of which is mapped as Rossmoyne silt loam or Avonburg silt loam soil in the county soil survey[2]. The wet basin will be located in area mapped solely as Avonburg silt loam. Avonburg silt loam soils are suitable for creation of an extended detention basin with a permanent pool. The subsoil is clay loam derived from glacial till and has slow permeability. The constructed basin will lie predominantly below existing grade; a small amount of soil material will be used for construction of an embankment along the western and northern edges of the stormwater basin.

[1] The Critical Storm Method is a set of criteria for controlling the peak discharge of stormwater from large storm events (1 - 100 yr recurrence interval) recommended by ODNR-DSWC since 1980. See Goettemoeller, R.L., D.P. Hanselmann, and J.H. Bassett. 1980. Ohio Stormwater Control Guidebook. Ohio Department of Natural Resources, Division of Soil and Water Districts, p47.

[2] Note - Readily available county soil survey data provide excellent planning level information but typically are not accurate enough for engineering design. As part of site evaluation, a certified soil scientist should be contracted to perform an on-site soil investigation to provide an accurate representation of soil conditions and limitations at the development site.

Peak Discharge Summary
Project: Autumn Knoll Senior Living Residential Development

	Cover Description	Soil Name	Hydrologic Group	CN	Area (acres)
Existing Condition Site Only	Agriculture - Row Crop SR & CR	Rossmoyne	C	82	6.1
	Agriculture - Row Crop SR & CR	Avonburg	D	85	18.1
	Existing Conditions			**84**	**24.2**
	Cover Description	**Soil Name**	**Hydrologic Group**	**CN**	**Area (acres)**
Proposed Condition Site Only	Impervious Area			98	10.2
	Open space (good cond)	Rossmoyne/Avonburg	D	80	12.0
	Detention Basin			98	2.0
	Proposed Conditions			**89**	**24.2**
	Cover Description	**Soil Name**	**Hydrologic Group**	**CN**	**Area (acres)**
Off-site Condition	Agriculture - Row Crop SR & CR	Rossmoyne	C	82	5.1
	Agriculture - Row Crop SR & CR	Avonburg	D	85	3.4
	Existing Conditions			**83**	**8.5**

Table 1-B-1. Curve Number for existing and proposed conditions, as well as off-site area.

	Segment	Flow Type	Surface Cover	Mannings n	Length ft	Slope %	Veloctiy ft/s	Tt min
Existing Condition Site Only	A_1 to B_1	Overland - sheet	Cultivated Residue Cover >20%	0.17	100	1.2		14.0
	B_1 to C_1	Overland - shallow conc	Cultivated - Minimum Tillage	0.101	1130	0.5	0.4	52.3
	Total	**Existing**			**1230**			**66.3**
	Segment	**Flow Type**	**Surface Cover**	**Mannings n**	**Length ft**	**Slope %**	**Veloctiy ft/s**	**Tt min**
Proposed Condition Site Only	A_2 to B_2	Overland - sheet	Dense Grass	0.24	100	1.0		19.9
	B_2 to C_2	Overland - shallow conc	Grass Swale	0.050	380	1.0	1.6	3.9
	C_2 to D_2	Pipe - storm drain (18”)	Pipe	0.013	40	0.6	3.3	0.2
	D_2 to E_2	Pipe - storm drain (18”)	Pipe	0.013	260	0.3	3.3	1.3
	E_2 to F_2	Pipe - storm drain (24”)	Pipe	0.013	260	0.2	3.9	1.1
	F_2 to G_2	Pipe - storm drain (30”)	Pipe	0.013	170	0.3	4.6	0.7
	Total	**Proposed**			**910**			**27.0**

Table 1-B-2a. Time of Concentration (Tc) for existing and proposed conditions, as well as drainage from the off-site area.

Peak Discharge Summary (cont'd)
Project: Autumn Knoll Senior Living Residential Development

	Segment	Flow Type	Surface Cover	Mannings n	Length ft	Slope %	Velociiy ft/s	Tt min
Existing Condition Off-site Condition	U_1 to V_1	Overland - sheet	Cultivated Residue Cover >20%	0.17	100	1.5		12.8
	V_1 to W_1	Overland - shallow conc	Cultivated - Minimum Tillage	0.101	1250	0.5	0.4	57.9
	Total	**Existing**			**1350**			**70.7**
Proposed Condition Off-site Condition	**Segment**	**Flow Type**	**Surface Cover**	**Mannings n**	**Length ft**	**Slope %**	**Velociiy ft/s**	**Tt min**
	U_2 to V_2	Overland - sheet	Cultivated Residue Cover >20%	0.17	100	1.5		12.8
	V_2 to W_2	Overland - shallow conc	Cultivated - Minimum tillage	0.101	300	0.7	0.4	11.9
	W_2 to C_2	Overland - shallow conc	Grass Swale	0.050	180	1.0	1.6	1.9
	C_2 to D_2	Pipe - storm drain (18")	Pipe	0.013	40	0.3	3.3	0.2
	D_2 to E_2	Pipe - storm drain (18")	Pipe	0.013	260	0.3	3.3	1.3
	E_2 to F_2	Pipe - storm drain (24")	Pipe	0.013	260	0.3	3.9	1.1
	F_2 to G_2	Pipe - storm drain (30")	Pipe	0.013	170	0.3	4.6	0.6
	Total	**Proposed**			**1310**			**29.8**

Table 1-B-2b. Time of Concentration (Tc) for existing and proposed condition for off-site drainage only.

RI years	P in	Q_{pre} in	Q_{post} in	$Q_{off\text{-}site}$ in	Q_{pre} Ac-ft	Q_{post} Ac-ft	q_{pre} cfs	q_{post} cfs
1	2.42	1.05	1.38	1.00	2.8	3.5	16.1	38.1
2	2.90	1.43	1.81	1.37	3.9	4.6	22.4	50.4
5	3.56	1.99	2.41	1.91	5.4	6.2	31.4	67.7
10	4.07	2.43	2.89	2.35	6.6	7.5	38.6	81.3
25	4.77	3.06	3.55	2.97	8.3	9.3	48.6	100.0
50	5.32	3.56	4.08	3.47	9.6	10.7	56.6	114.7
100	5.89	4.09	4.63	3.99	11.1	12.2	65.0	130.0

Table 1-B-3. Summary runoff depth or volume (Q) and peak discharge (q) for existing (pre-developed) and proposed (post-developed) conditions with critical storm (bold type).

Step 5 - Determine Pond Location and Develop Preliminary Geometry to Meet WQv and Peak Discharge Requirements

The proposed location of the stormwater basin (see Figure 1.B.1) reflects several goals for this development project (including appropriate soils). In particular, the wet basin is considered the centerpiece of this development, with "waterfront condos" selling for a premium. The basin will also be over-excavated to provide fill material to raise the elevation of the condo structures. Existing ground elevation at the proposed pond outlet is 829 MSL. As part of this development, a storm sewer will be installed along the county road to convey site runoff to a receiving stream to the west. At the connection point, the storm sewer is 36" and has an invert elevation of 818.5 MSL. [For more information on siting and planning an extended detention basin, see section 2.6.]

The stormwater basin includes a permanent pool, an extended detention volume to protect water quality and stream channel stability, and storage necessary to control the peak discharge rate.

The NPDES Storm Water Permit (OEPA, 2008) specifies a wet extended detention basin must include both a permanent pool (designated PPv below) and an extended detention volume (EDv) equal to 75% of the water quality volume (WQv), with an EDv drawdown time of 24 hours. The permit also requires that the permanent pool contain an additional sediment storage volume equal to 20% of the WQv.

EDv = 0.75* WQv = 0.75*0.53 ac-ft = 0.40 ac-ft = 17,400 ft^3 Equation 1-B-8

PPv $\geq$ (0.75 + 0.2)*WQv = 0.95*0.53 ac-ft = 0.50 ac-ft = 22,000 ft^3 Equation 1-B-9

A plan view of the basin layout (Figure 1-B-4) reflects the following:

- extended detention volume equal to 0.75*WQv
- permanent pool with a minimum volume of (0.75+0.2)*WQv and 6 foot minimum depth
- 4:1 sideslopes for safety and ease of maintenance
- shallow, submerged wetland safety benches around the perimeter
- an emergency spillway constructed in native soil
- 3 storm drain outlets draining subareas within the development site (note: the length to width ratio for each of the two drains at the far end of the basin (draining approximately 90% of the site) exceeds 3:1, whereas the storm drain for the clubhouse/parking lot (drains approximately 10% of the site) was located on the other side of the gazebo peninsula to extend flow pathway to minimize short-cutting.

<u>Set elevations for pond structures</u>

- The pond bottom and riser invert are set at elevation 820 MSL
- A pond drain will be included to facilitate drawdown for maintenance or repairs.

<u>Establish permanent pool and WQv water surface elevations</u>

A stage-area-storage table (Table 1.B.4) reflects the geometry of the stormwater basin (Figure 1.B.4) designed to meet permanent pool, extended detention (EDv) and peak discharge control requirements.

- The permanent pool volume (PPv) of 4.5 ac-ft (surface elevation 826.0) exceeds 0.95*WQv
- The extended detention volume (EDv) of 0.40 ac-ft above the permanent pool has a top elevation of approximately 826.26.

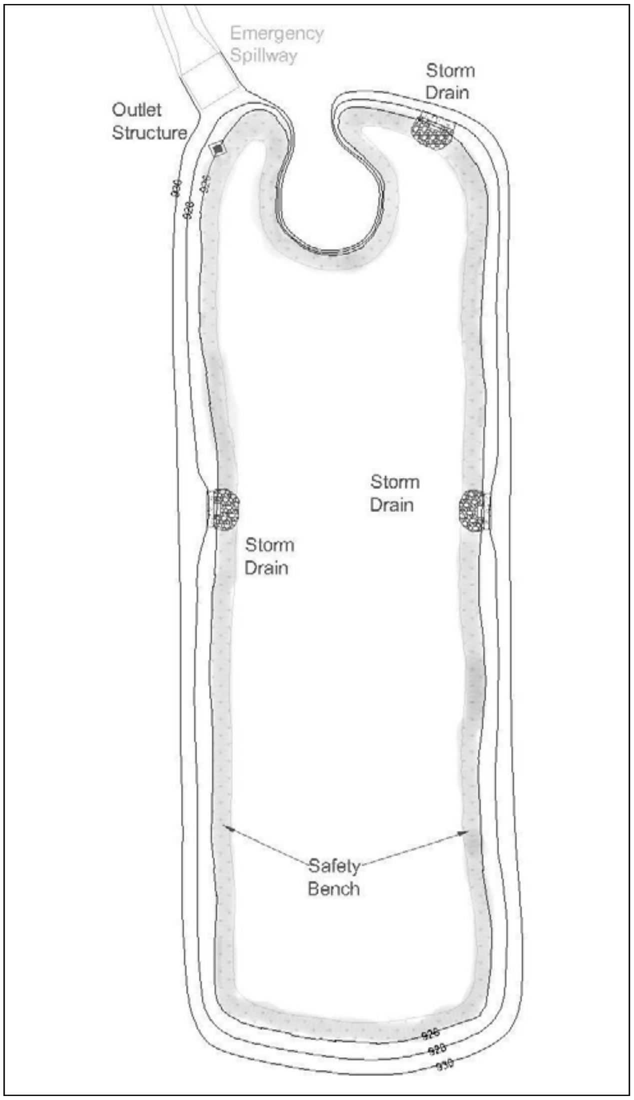


Figure 1.B.4. Preliminary Plan View of Wet Extended Detention Basin (not to scale).

Table 1.B.4. Stage-Area-Storage Information for Wet Extended Detention Basin.

Elevation MSL (ft)	Surface Area (acre)	Average Area (acre)	Incremental Depth (ft)	Incremental Volume (ac-ft)	Cumulative Volume (ac-ft)	Vol above Perm Pool (ac-ft)
820.0	0.004	-	-	-	-	-
826.0	1.50	0.75	6.0	4.5	4.5	-
826.3	1.53	1.51	0.3	0.4	4.9	0.4
827.0	1.61	1.57	0.7	1.2	6.1	1.6
828.0	1.72	1.66	1.0	1.7	7.8	3.3
829.0	1.83	1.78	1.0	1.8	9.6	5.1
830.0	1.98	1.90	1.0	1.9	11.5	7.0
831.0	2.20	2.09	1.0	2.1	13.6	9.1

Determine outlet geometry for 24-hour drawdown of EDv

The controlling parameters are EDv = 0.40 ac-ft, depth of EDv = 0.26 ft, and minimum drain time, T_d = 24 hours. Note that "the outlet structure for the post-construction BMP must not discharge more than the first half of the WQv in less than one-third of the drain time" (p22, NPDES Storm Water Construction General Permit; OEPA, 2008). This same criterion applies to the EDv.

When a wet detention basin has a large surface area (and thus the EDv depth is small), the designer has a wide variety of outlet options that will meet the two criteria above[3]. In this situation, combining a v-notch weir ("V" depth equal to or exceeding the depth of the EDv) with the peak discharge (critical storm) outlet, the designer was able to simplify and optimize the outlet while meeting both EDv criteria (see Figure 1.B.5) and peak discharge criteria (Table 1.B.5).

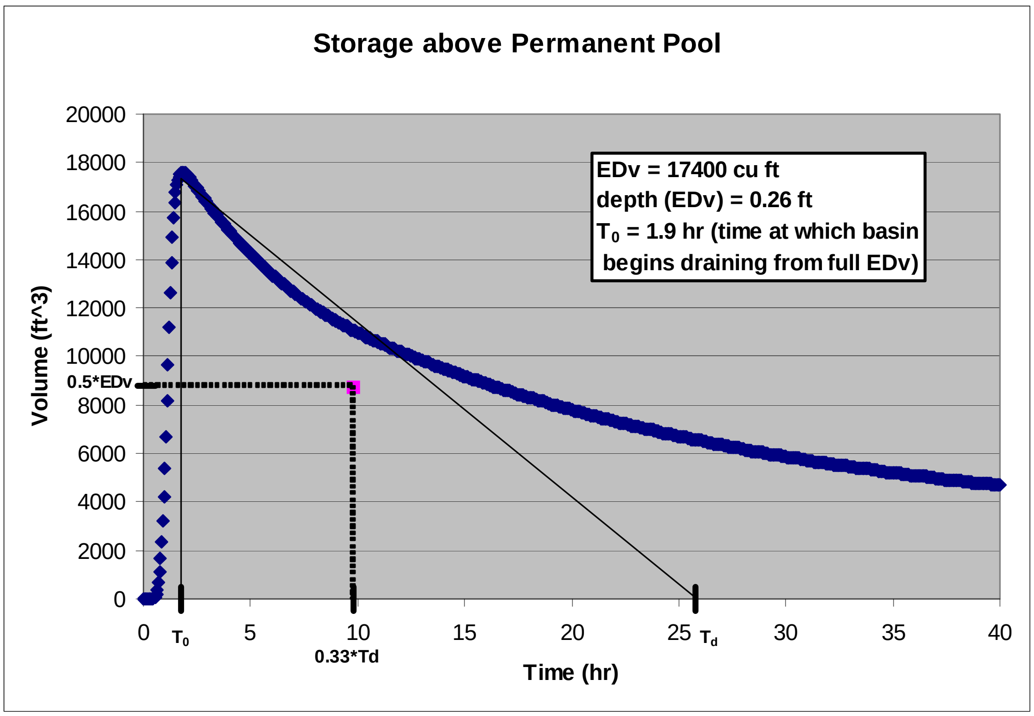


Figure 1.B.5. Wet Extended Detention Basin - Drawdown from Full EDv.

Determine storage and outlet configuration to meet peak discharge requirements

As noted under Step 2, this wet detention basin is designed to meet the Critical Storm Method (CSM) for peak discharge control as well as the WQv requirement. Storage volume must be incorporated that, with appropriate outlet design, will allow the basin to meet the following requirements:

- The peak rate of discharge from the post-construction 5-year, 24-hour event (the *critical storm*) must be less than the existing (pre-development) 1-year, 24-hour discharge peak rate
- The peak rate of discharge from the post-construction 10-, 25-, 50- and 100-year, 24-hour events must be no more than the existing (pre-development) discharge peak rate for the corresponding recurrence interval events

Proprietary stormwater modeling software was used to try a combination of stage-storage and outlet

[3] The methodology laid out in the Ohio NPDES Post Construction Q&A Document (Guidance Regarding Post-Construction Storm Water Management Requirements of Ohio; Ohio EPA, 2007) item #22.is a good starting point for selecting the EDv orifice size because it will always meet the two drawdown requirements: (1) the specified minimum drain time, Td; and (2) the outlet must not discharge more than the first half of the WQv (or EDv) in less than one-third of the drain time. A larger or smaller orifice should be considered if it will help meet other environmental, cost, or maintenance goals but must be tested for the two drawdown criteria.

configurations until the *critical storm* requirement was satisfied while considering the following:

- use best practices outlined in Section 2.6 of the Rainwater and Land Development manual
- optimize cut/fill and grading
- meet safety and aesthetic goals for the "lake" and waterfront properties

The resulting detention basin geometry is presented in Figure 1.B.4 and Table 1.B.4. The resulting outlet configuration is shown in Figure 1.B.6.

The outlet structure (see Figure 1.B.6) consists of a 3 ft by 3 ft concrete catch basin (e.g., ODOT No. 2-3) with invert at 820 MSL and 2.5'x2.5' iron grate at 828 MSL. The following comprise the outlets:

- A 30" wide orifice combined with a V-notch weir (invert 826 MSL) that controls release of both the extended detention volume (EDv) and the *critical storm* (5-year, 24-hour)
- 2.5'x2.5' iron grate (effective orifice area 490 sq. in.; invert 828 MSL) for maintenance access and to help manage discharge between the 10-yr and 100-yr, 24-hr events

The catch basin will be connected - using a 30" diameter conduit - to the 36" diameter storm sewer at the road along the north property boundary. A tailwater analysis was performed using the modeling software and the storm sewer's design elevation (invert at 818.5 MSL; 10-yr full pipe flow at 821.5 MSL) and assumed elevation for the 100-yr event (827.5 MSL).

In addition, this design includes an emergency spillway excavated into native soil with the following characteristics:

- Invert (crest) elevation of 829.2 MSL
- Spillway crest perpendicular to flow
- Level section length of 25 ft, weir length (i.e., width of crest perpendicular to flow) of 25 ft
- Exit channel flows to road ditch at elevation 827.5 MSL
- With all other outlets blocked and starting from the permanent pool elevation of 826 MSL, will safely convey the 100-yr, 24-hr event

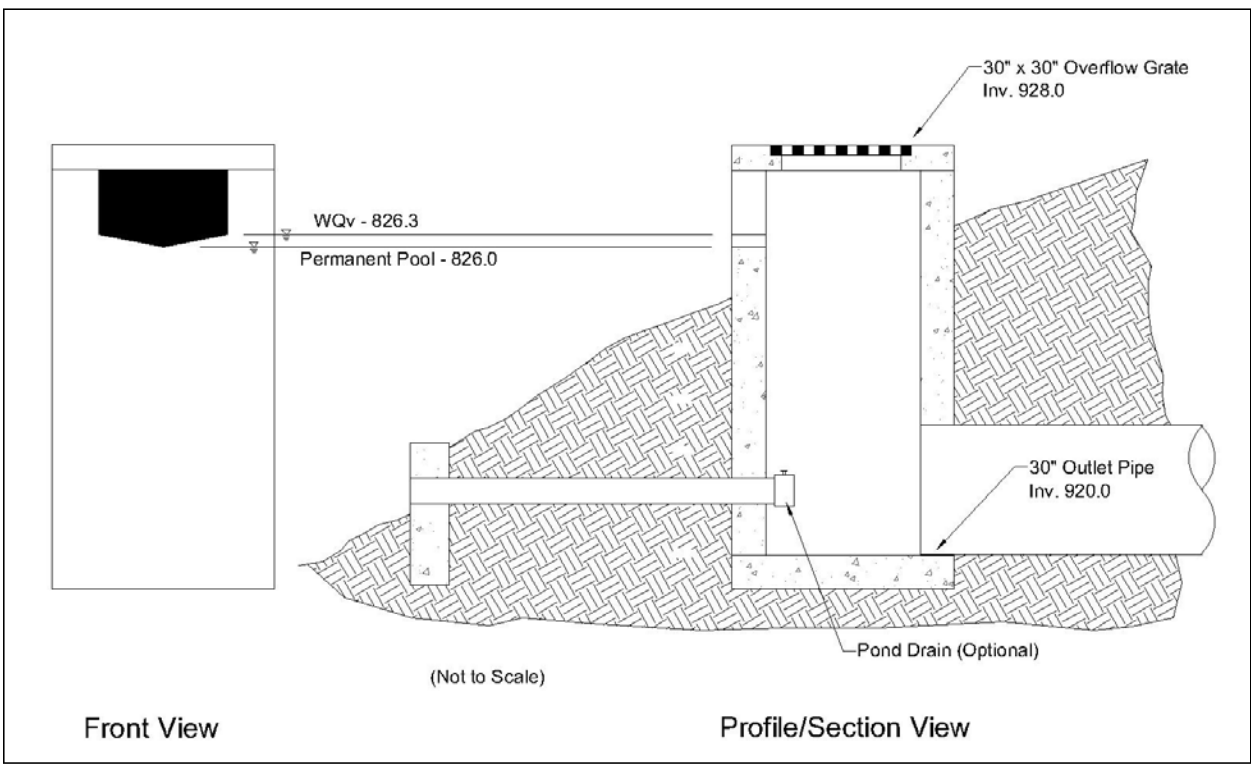


Figure 1.B.6. Outlet Configuration for Wet Extended Detention Basin (not to scale).

Step 6 - Check Design to Ensure All Requirements Are Met

From full EDv, check that EDv meets minimum 24 hour drain time, and discharges no more than 1/2 the extended detention volume, 0.5*EDv (9150 ft^3), in the first 1/3 of the drain time, 0.33*T_d (8 hr). This requirement is met and illustrated in Figure 1.A.5[4].

Check peak discharge for all events (see Table 1.B.5).

RI years	P in	$q_{post-in}$ cfs	Allowed $q_{post-out}$ cfs	Estimated $q_{post-out}$ cfs
1	2.42	38.1	16.1	7.2
2	2.90	50.4	16.1	11.1
5	3.56	67.7	16.1	15.9
10	4.07	81.3	38.6	24.0
25	4.77	100.0	48.6	32.3
50	5.32	114.7	56.6	37.3
100	5.89	130.0	65.0	41.8

Table 1.B.5. Critical Storm Method Peak Discharge Check.

[4] Note - Through trial and error, it was determined using a constant intensity 1-hour rainfall event of 0.83" depth in the hydrologic model would raise the water surface elevation of the wet basin to 826.26 providing a just-full EDv of 0.40 ac-ft (17,400 ft^3) above permanent pool, allowing evaluation of the drawdown from a full EDv (Figure 1.B.5). The depth of rainfall event necessary to just fill the EDv or WQv for other stormwater basins using CN methodology will vary based on watershed characteristics, pond geometry and outlet configuration, but can be determined through trial and error.

Section C: Extended Detention Wetland Basin

This design example illustrates the design of a extended detention wetland basin that provides water quality treatment and peak discharge control for a single family residential development, consisting of 101 residential lots on 46.0 acres (parcel and drainage area). The layout of the Beech Ridge subdivision is shown below in Figure 1.C.1.

The impervious area of the site at completion of construction is estimated to be 13.2 acres. The pre-developed site soils and flow paths are shown in Figure 1.C.2, while the post-developed flow path (limited to that used for calculations) is shown in Figure 1.C.3.   This example assumes that the local community has adopted the Critical Storm Method criteria to control peak discharges.

Figure 1.C.1. Beech Ridge Subdivision Site Plan.

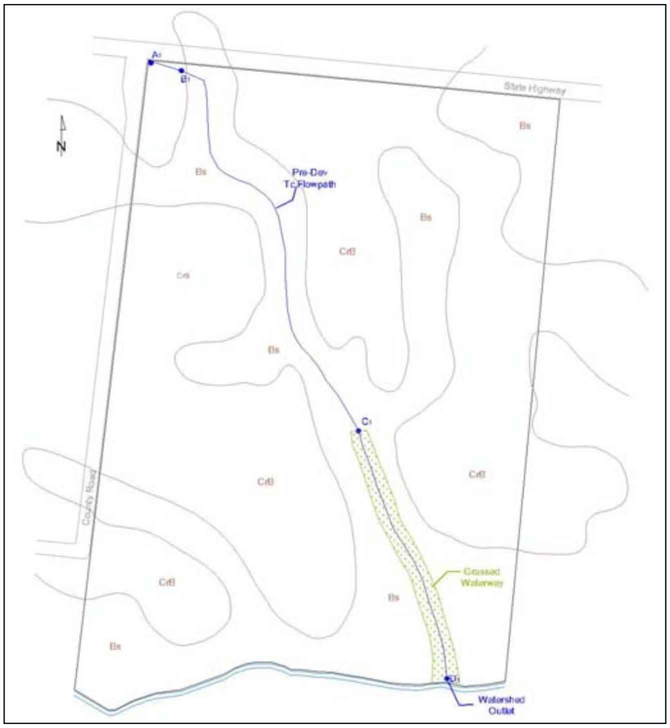


Figure 1.C.2. Pre-Development and Soils and Flow Path.

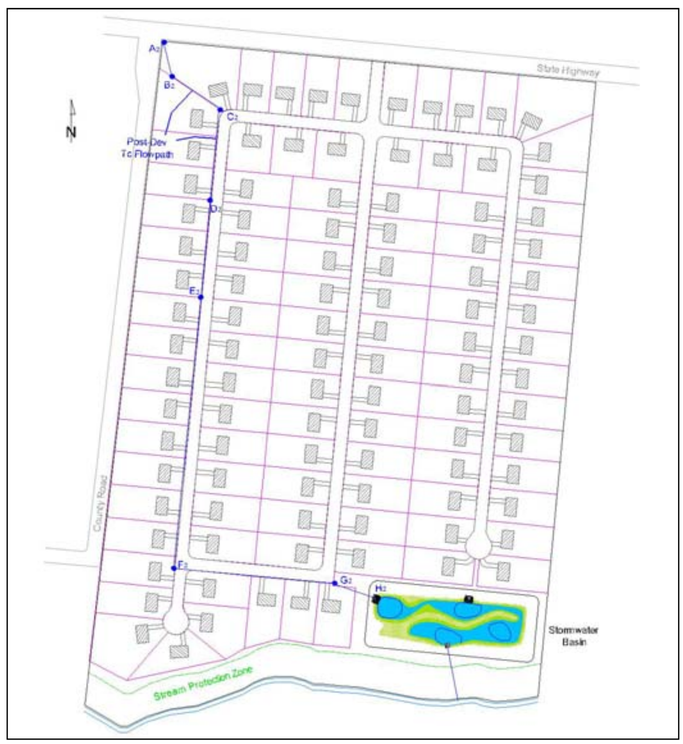


Figure 1.C.3. Post-Development Flow Path and Proposed Basin Location

<u>Site Data</u>
Zoning: Residential, 16,000 ft^2 minimum lot size (0.37 ac)
Total Drainage Area (A) = 46.0 ac
Estimated Impervious Area = 13.2 ac
Pre-Development Soil Types: 60% HSG-C, 40% HSG-B/D

<u>Summary Hydrologic Data</u>
WQv = 0.69 ac-ft

	Pre	Post
CN =	79	86
Tc =	69.5 min	25.4 min

Calculation of Preliminary Stormwater Storage Volumes and Peak Discharges

Step 1 - Calculate Water Quality Volume (WQv)

The water quality volume (WQv) is a post-construction stormwater control requirement in Ohio (OEPA-CGP, 2008). The WQv is determined according to the following equation:

$$WQv = C*P*A \qquad \text{Equation 1.C.1}$$

where:

C = runoff coefficient

P = 0.75 inch precipitation depth

A = drainage area

For open water, C = 1. At this site, the surface area of the detention basin at full WQv is estimated to be 1.2 acres.

For the remainder of the site, the runoff coefficient can either be selected from Table 1 of the NPDES Storm Water Permit, or calculated using the following equation:

$$C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04 \qquad \text{Equation 1.C.2}$$

where i is the fraction of post-construction impervious surface.

For this site, total impervious area = 13.2 acres from a drainage area of 44.8 acres (i.e., total site drainage area - surface area of detention basin).

$$i = 13.2/44.8 = 0.295 \qquad \text{Equation 1.C.3}$$

$$C = 0.858(0.295)^3 - 0.78(0.295)^2 + 0.774(0.295) + 0.04 = 0.22 \qquad \text{Equation 1.C.4}$$

Therefore, the WQv is:

$$WQv = [(1.0 * 0.75 \text{ in} * 1.2 \text{ ac}) + (0.22 * 0.75 \text{ in} * 44.8 \text{ ac})] * (1 \text{ ft}/12 \text{ in}) \qquad \text{Equation 1.C.5}$$

$$= \underline{0.69 \text{ ac-ft}}$$

$$= 30{,}100 \text{ ft}^3$$

Step 2 - Compute Peak Discharge Requirements

> Note: Peak discharge control is typically regulated through local entities (e.g. stormwater district, municipal, township or county governments). The state of Ohio recommends use of the Critical Storm Method[1] for peak discharge control, but the requirements will vary by community. Check local stormwater regulations to determine which peak discharge control method you must use.

This example uses the SCS Curve Number Methodology to perform hydrologic calculations. TR-20, HEC-HMS or other software that uses SCS procedures should provide similar results.

Tables 1.C.1 and 1.C.2 summarize the inputs necessary to determine the curve number (CN) and time of concentration (Tc) for the existing (pre-development) and proposed (post-development) conditions. The property receives no runoff from off-site. Table 1.C.3 summarizes the existing and proposed runoff depths and peak discharges for the 1-year, 24-hr through 100-year, 24-hr rainfall events.

The *critical storm* is determined from the percent increase in runoff volume from the 1-year, 24-hr storm for the proposed (post-developed) conditions when compared to the existing (pre-developed) conditions (Goettemoeller et al., 1980):

$$Percent\ \ Increase = \frac{Q_{post} - Q_{pre}}{Q_{pre}}\, x\, 100$$

Equation 1.C.6

From Table 1.C.3, the percent increase in the 1-year, 24-hr runoff for the proposed development is:

$$Percent\ \ Increase\ = \frac{0.98 - 0.62}{0.62}\, x\ \ 100 = 58.1\%$$

Equation 1.C.7

For a percentage increase between 50% and 100%, the critical storm for peak discharge control is the 10-year, 24-hr event—that is, the 10-year, 24-hr post-developed peak discharge must be less than the existing (pre-developed) 1-year, 24-hr peak discharge. These values are shown in bold type in Table 1.C.3. In addition, the post-developed peak discharge from the 25, 50 and 100 year events must be less than the existing peak discharge for each of those events.

Step 3 - Identify Other Local Development Criteria/Requirements

This site is located within a community that has incorporated a stream corridor protection requirement (i.e., stream setback) in its subdivision regulations. Review of the regulations has determined that the stream protection zone at this site extends 100 ft from the ordinary high water mark of the adjacent stream. This protection zone is noted on the map in Figure 1.C.1. All construction activities, including the wetland stormwater basin and embankment, must be outside of the stream protection zone. Also note this stream protection area, since it does not drain to the detention facility, was excluded from the hydrologic analysis.

[1] The Critical Storm Method is a set of criteria for controlling the peak discharge of stormwater from large storm events (1 - 100 yr recurrence interval) recommended by ODNR-DSWC since 1980. See Goettemoeller, R.L., D.P. Hanselmann, and J.H. Bassett. 1980. Ohio Stormwater Control Guidebook. Ohio Department of Natural Resources, Division of Soil and Water Districts, p47.

Peak Discharge Summary

Project: Beech Ridge Subdivision

	Cover Description	Soil Name	Hydrologic Group	Drainage Y/N	CN	Area (acres)
Existing Condition Site Only	Row crop, SR + CR (good condition)	Crosby	C		82	27.6
	Row crop, SR + CR (good condition)	Brookston	B/D	Y	75	18.4
	Pre-development Conditions - All				**79**	**46.0**
Proposed Condition Site Only	**Cover Description**	**Soil Name**	**Hydrologic Group**		**CN**	**Area (acres)**
	Impervious Area				98	13.2
	Open space (good condition)	Crosby	D		80	18.5
	Open space (good condition)	Brookston	D		80	12.3
	Open Water				98	2.0
	Post-development Conditions - All				**86**	**46.0**

Table 1.C.1. Curve Number (CN) for existing (pre-developed) condition.

	Segment	Flow Type	Surface Cover	Mannings n	Length ft	Slope %	Velocity ft/s	Tt min
Existing Condition Site Only	A_1 to B_1	Overland - sheet	Min Tillage	0.17	100	1.2		14.8
	B_1 to C_1	Overland - shallow conc	Min Tillage	0.1	1250	0.75	0.44	47.6
	C_1 to D_1	Overland - shallow conc	Grassed waterway	0.05	750	1.2	1.8	7.1
	Total	**Pre-developed**			**2100**			**69.5**
Proposed Condition Site Only	**Segment**	**Flow Type**	**Surface Cover**	**Mannings n**	**Length ft**	**Slope %**	**Velocity ft/s**	**Tt min**
	A_2 to B_2	Overland - sheet	Grass	0.24	100	1.5		17.8
	B_2 to C_2	Overland - shallow conc	Grassed waterway	0.05	160	1.5	2.0	1.3
	C_2 to D_2	Pipe - storm drain (15")	Pipe	0.013	250	0.5	3.7	1.1
	D_2 to E_2	Pipe - storm drain (18")	Pipe	0.013	270	0.5	4.2	1.1
	E_2 to F_2	Pipe - storm drain (24")	Pipe	0.013	750	0.5	5.1	2.5
	F_2 to G_2	Pipe - storm drain (30")	Pipe	0.013	450	0.5	5.9	1.3
	G_2 to H_2	Pipe - storm drain (36")	Pipe	0.013	130	0.5	6.7	0.3
	Total	**Post-developed**			**2150**			**25.4**

Table 1.C.2. Time of Concentration (Tc) for existing (pre-developed) and proposed (post-developed) condition.

RI years	P in	Q_{pre} in/acre	Q_{post} in/acre	q_{pre} cfs	q_{post} cfs
1	2.17	0.62	0.98	12.1	42.8
2	2.59	0.90	1.32	18.3	58.0
5	3.18	1.32	1.82	28.1	80.4
10	3.67	1.70	2.25	36.7	99.4
25	4.35	2.25	2.87	49.2	126.2
50	4.91	2.72	3.38	59.9	148.4
100	5.50	3.24	3.94	71.3	171.9

Table 1.C.3. Summary runoff depth (Q) and peak discharge (q) for existing (pre-developed) and proposed (post-developed) condition with critical storm (bold type).

Step 4 - Determine if the Development Site and Soils Are Appropriate for the Use of an Extended Detention Wetland Basin

The site drainage area is 46.0 acres. Brookston and Crosby soils are suitable for creation of an extended detention wetland. The subsoil is silty clay loam derived from high-lime glacial till and has slow permeability. This subsoil is suitable material for construction of the embankment for the stormwater basin.

It is known that subsurface tiles currently drain the proposed property. All tiles need to be removed from the wetland basin site[2].

Step 5 - Determine Pond Location and Develop Preliminary Geometry to Meet WQv and Peak Discharge Requirements

The proposed location of the stormwater basin (see Figure 1.C.3) reflects the best combination of characteristics (landscape position, access to outlet, minimize earth moving, appropriate soils, etc.) for siting the basin. Existing ground elevation at the proposed pond outlet is 907 MSL. The invert of the receiving stream at the proposed discharge point is 896 MSL.

The basin will be designed to include a permanent pool, an extended detention volume equivalent to the WQv, and the storage necessary to control the peak discharge rate. [For more information on siting and planning a wetland basin, see section 2.6.]

An analysis of site hydrology (drainage area/wetland surface area ratio >>20, HSG-D soil with seasonal high water table, etc.) has determined that a permanent pool equivalent to the WQv (~0.69 ac-ft) up to 2 ac-ft should be sufficient to maintain basic wetland hydrology and function. In addition, an additional sediment storage volume equal to 20% of the WQv (0.2*WQv = 0.2*0.69 = 0.14 ac-ft) is added to the permanent pool with this volume concentrated in the forebay.

A preliminary plan view of the basin layout (Figure 1.C.4) reflects the following:

- permanent pool (includes forebay and outlet micropool) with a volume in excess of 1.2*WQv
- permanent pool forebay equal to 0.2* WQv and a minimum depth of 3 ft
- permanent micropool at outlet with a minimum depth of 3 ft
- total area of deep pools (including forebay and outlet mircropool) representing between 20 and 25 percent of total permanent pool surface area with deep pools interspersed through wetland to provide refugia and wetland function during drought periods - depth of deep pools should range between 18 and 36 (or more) inches[3]
- balance of permanent pool with average depth of 0.75 ft, and range of depths from 6” to 18”
- a low constructed peninsula, with an elevation approximately 1 ft above the extended detention (WQv) storage volume, to extend the flow path and minimize short-circuiting during the WQv event
- maximum 4:1 side slopes for safety and maintenance
- an emergency spillway constructed in native soil (i.e., not located in the constructed embankment)

Note: The high organic matter topsoil should be removed and stockpiled before excavation and construction of the wetland, and then replaced on peninsulas and benches.

[2] Functional drainage systems are essential for the productivity of agriculture in much of Ohio, and to prevent flooding of upgradient property. It is the responsibility of the developer to maintain drainage infrastructure (surface and subsurface drainage mains) disrupted by construction activities. As an example, if a subsurface tile main conveys water from upgradient properties, that main should be protected or re-routed to maintain the same drainage capacity.

[3] Recent guidance from North Carolina (Hunt et al, 2007) recommends “deep pools (including the forebay) should occupy between 20 and 25 percent of the total wetland surface area”. For most wetlands this will result in a permanent pool volume (ac-ft) between about 1.1 and 1.3 times the surface area (acres) of the permanent pool.

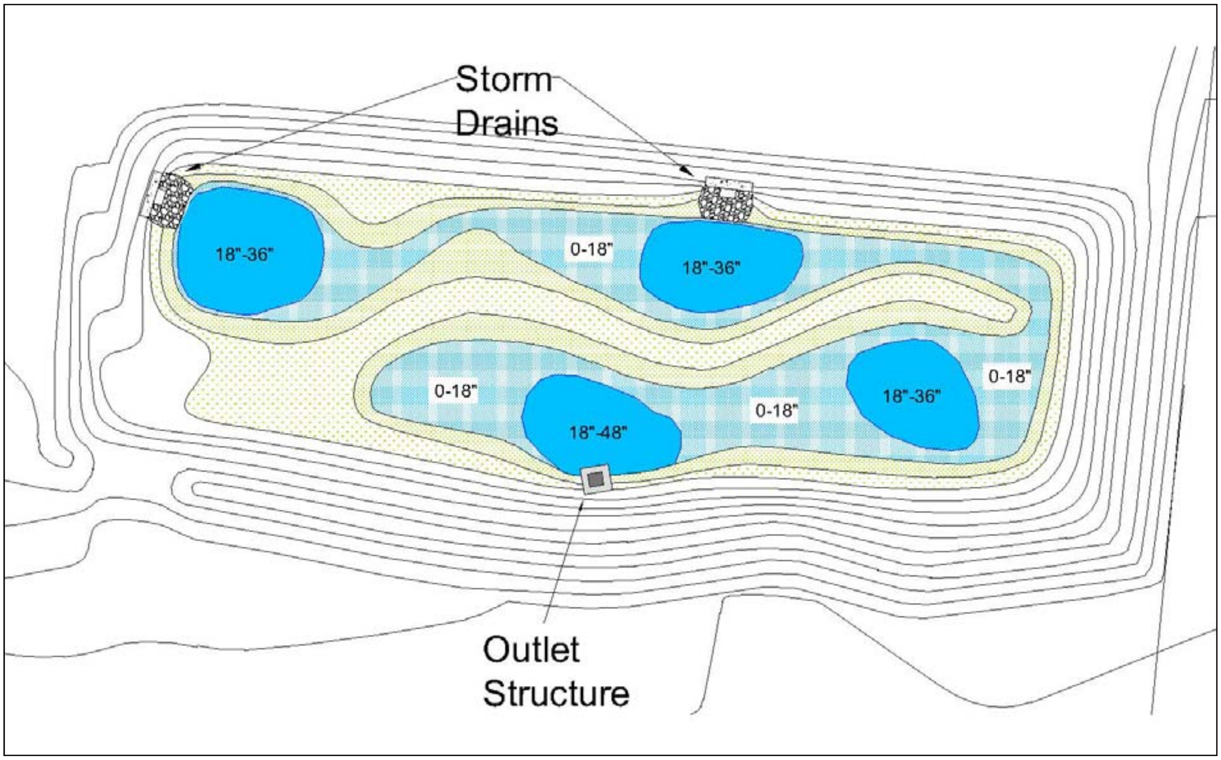


Figure 1.C.4. Preliminary Plan View of Wetland (not to scale).

Elevation MSL (ft)	Surface Area (acre)	Average Area (acre)	Incremental Depth (ft)	Incremental Volume (ac-ft)	Cumulative Volume (ac-ft)	Vol above Perm Pool (ac-ft)
900.0	0.08	-	-	-	-	-
902.5	0.16	0.12	2.5	0.30	0.30	-
903.0	0.24	0.20	0.5	0.10	0.40	-
903.5	0.48	0.36	0.5	0.18	0.58	-
904.0	0.74	0.61	0.5	0.31	0.89	-
904.7	1.24	0.99	0.7	0.69	1.58	0.69
905.0	1.50	1.37	0.3	0.41	1.99	1.10
906.0	1.60	1.55	1.0	1.55	3.54	2.65
907.0	1.71	1.65	1.0	1.65	5.19	4.30
908.0	1.82	1.76	1.0	1.76	6.95	6.07
909.0	1.93	1.87	1.0	1.87	8.82	7.94
910.0	2.05	1.99	1.0	1.99	10.81	9.93
911.0	2.20	2.13	1.0	2.13	12.94	12.05

Table 1.C.4. Stage-Area-Storage Information for Wetland Basin.

Set elevations for pond structures

- The basin bottom is set at elevation 900.0
- To allow gravity flow for the pond drain, set the riser invert at 898.0
- The outfall at the receiving stream has invert elevation 896.5

Set permanent pool and WQv water surface elevations

A stage-area-storage table (Table 1-4) reflects geometry of the stormwater wetland basin (Figure 1-3) designed to meet permanent pool, extended detention WQv and peak discharge control requirements.

- To meet NPDES Construction Stormwater Permit minimums, the permanent pool, surface elevation 904.0, is sized to exceed 1.2*WQv = 1.2*0.69 ac-ft = 0.83 ac-ft (see footnote below)
- The extended detention WQv of 0.69 ac-ft above permanent pool has a top elevation of approximately 904.7

Calculate required orifice size for 24-hour drawdown of WQv

The controlling parameters are WQv = 0.69 ac-ft, depth of WQv = 0.7 ft, and minimum drain time, t_d, of 24 hours. Note that "the outlet structure for the post-construction BMP must not discharge more than the first half of the WQv in less than one-third of the drain time" (p22, NPDES Storm Water Construction General Permit).

The average discharge rate for the WQv is:

$$Q_{avg} = \frac{WQv}{t_d} = \frac{(0.69\ ac \cdot ft)\left(\frac{43560\ ft^2}{1\ ac}\right)}{(24\ hr)\left(3600\ \frac{s}{hr}\right)} = 0.35\ cfs$$ Equation 1-C-8

The discharge equation for an orifice is:

$$Q = ca\sqrt{2gh}$$ Equation 1-C-9

By rearranging, we can estimate needed orifice area:

$$a = \frac{Q}{c\sqrt{2gh}}$$ Equation 1-C-10

Using an orifice coefficient, c = 0.6, and average head, h = d/2 = (0.7 ft)/2 = 0.35 ft, the required orifice size is:

$$a = \frac{0.35\ \frac{ft^3}{s}}{0.6\sqrt{2(32.2\ \frac{ft}{s^2})(0.35\ ft)}} = 0.12\ ft^2$$ Equation 1-C-11

Resulting in an orifice diameter of:

$$d = \left(\frac{4a}{3.14}\right)^{0.5} = \left[\frac{4(0.12\ ft^2)}{3.14}\right]^{0.5} = 0.39\ ft \times \frac{12}{1\ ft} = 4.7\ in$$ Equation 1-C-12

This estimate is a good starting point for selecting the WQv or EDv orifice size because it will always meet the two drawdown requirements: (1) the specified minimum drain time, Td; and (2) the outlet must discharge less than the first half of the WQv in the first one-third of the drain time (8 hours in this case). A larger or smaller orifice should be considered if it will help meet other environmental, cost, or maintenance goals but must be tested for the two drawdown criteria. In this situation, trial and error showed that a 6.0" diameter orifice will meet the above two drawdown requirements (see Figure 1.C.4) and will be used as the WQv outlet.

Determine storage and outlet configuration to meet peak discharge requirements

As noted under Step 2, this wetland basin is designed to meet the Critical Storm Method (CSM) for peak discharge control as well as the WQv requirement. Additional storage volume must be added that, with appropriate outlet design, will allow the basin to meet the following requirements:

- The peak rate of discharge from the post-construction 10-year, 24-hour event (the *critical storm*) must be released at the existing (pre-development) 1-year, 24-hour discharge rate
- The peak rate of discharge from the post-construction 25-, 50- and 100-year, 24-hour events must be released at the existing (pre-development) discharge rate for the corresponding recurrence interval events

Proprietary stormwater modeling software was used to try a combination of stage-storage and outlet configurations until the Table 1.C.5 requirements were satisfied while considering the following:

- maximize wetland function
- minimize the "footprint" of the basin
- optimize cut/fill

RI years	P in	$q_{post\text{-}in}$ cfs	Allowed $q_{post\text{-}out}$ cfs
1	2.17	42.7	12.1
2	2.59	57.9	12.1
5	3.18	80.2	12.1
10	3.67	99.1	12.1
25	4.35	125.9	49.2
50	4.91	148.0	59.9
100	5.50	171.4	71.3

Table 1.C.5. Critical Storm Method Peak Discharge Requirements.

The resulting wetland basin geometry is presented in Figure 1.C.3 and Table 1.C.4. The resulting outlet configuration is shown in Figure 1.C.5.

The outlet structure consists of a 4 ft by 4 ft concrete catch basin (e.g., ODOT No 2-4) with invert at 899 MSL and 3.7'x3.7' iron grate at 908.33 MSL. The following comprise the outlets:

- 36" barrel outlet with invert at 899 MSL
- 6.0" extended detention (WQv) orifice (invert 904 MSL) with submerged entrance
- Two (2) 12" diameter orifices (invert 904.7 MSL) that control release of the *critical storm* (10-year, 24-hour)
- Four 36" L x 9" H rectangular orifices (invert 907.25 MSL) and 3.7'x3.7' iron grate (invert 908.33) with 868 in^2 of clear opening area that control release of the 25- through 100-year, 24-hour events

In addition, this design includes an emergency spillway excavated into native soil that has the following characteristics:

- Invert (crest) elevation of 909.3 MSL
- Level section length of 25 ft, weir length (i.e., crest width) of 30 ft
- Spillway crest perpendicular to flow
- Exit channel aligned with level section well beyond downstream toe of dam, and a 4 percent slope
- With all other outlets blocked and starting from the permanent pool elevation of 904 MSL, will safely convey the 100-yr, 24-hr event with 1 ft freeboard from top of embankment

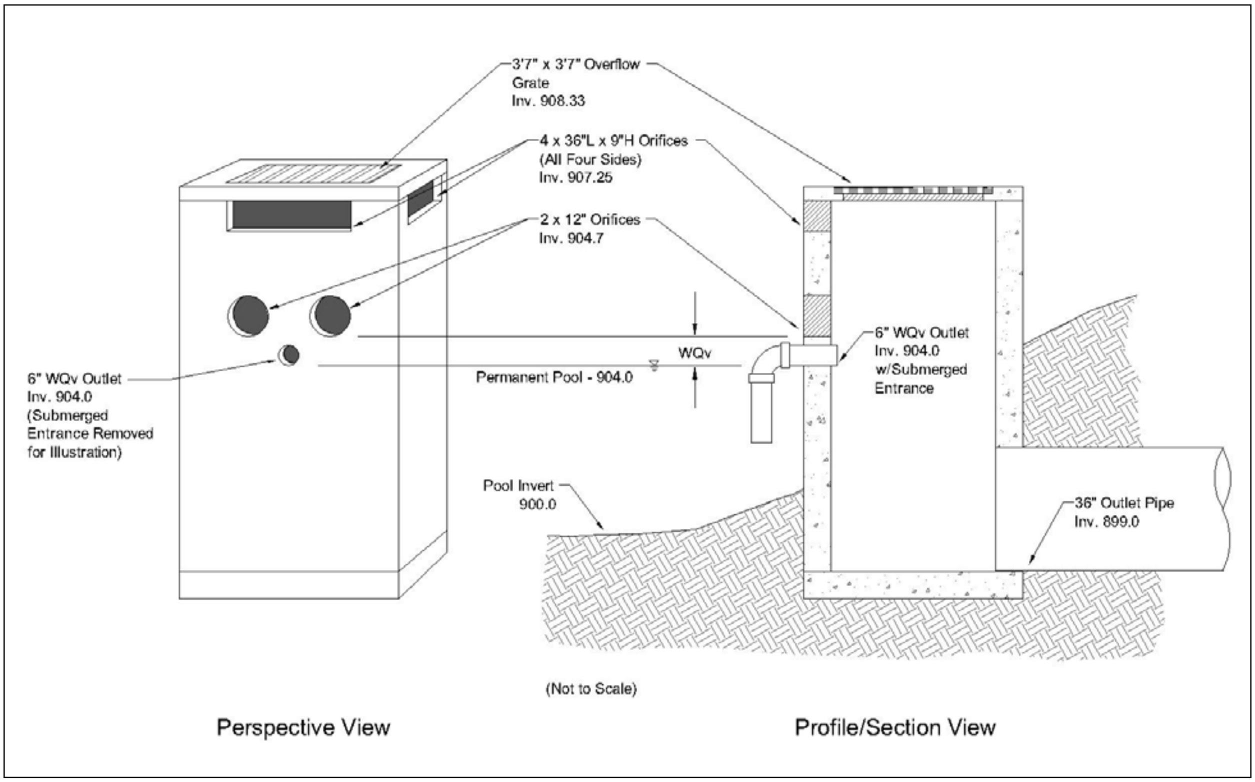


Figure 1.C.5. Outlet configuration for Wetland Basin (not to scale).

Step 6 - Check Design to Ensure All Requirements Are Met

From "brimfull", check that WQv meets minimum 24 hour drain time, and discharges no more than 1/2 the water quality volume, 0.5*WQv (= 15,550 ft^3), in the first 1/3 of the drain time, 0.33*T_d (8 hr). Figure 1.C.4 shows the wetland basin meets this requirement.

Check peak discharge for all events. Table 1.C.6 shows the wetland basin meets the peak discharge requirements.

RI years	P in	$q_{post\text{-}in}$ cfs	Allowed $q_{post\text{-}out}$ cfs	Estimated $q_{post\text{-}out}$ cfs
1	2.17	42.7	12.1	5.1
2	2.59	57.9	12.1	7.6
5	3.18	80.2	12.1	10.2
10	3.67	99.1	12.1	12.1
25	4.35	125.9	49.2	26.5
50	4.91	148.0	59.9	42.7
100	5.50	171.4	71.3	62.4

Table 1.C.6. Critical Storm Method Peak Discharge Check.

References:

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Appendix 4: Overview of Stream/Wetland Regulations

According to the federal Clean Water Act, anyone who wishes to discharge dredged or fill material into the waters of the U.S., must obtain a Section 404 permit from the U.S. Army Corps of Engineers (Corps) and a Section 401 Water Quality Certification (WQC) from the state. The Corps will also require a Section 10 permit if the fill is located in a navigable water.

Section 404 Permits

Section 404 of the Clean Water Act requires approval prior to discharging dredged or fill material into the waters of the United States. Typical activities requiring Section 404 permits are:

- Depositing of fill or dredged material in waters of the U.S. or adjacent wetlands.
- Site development fill for residential, commercial, or recreational developments.
- Construction of revetments, groins, breakwaters, levees, dams, dikes, and weirs.
- Placement of riprap and road fills.

Waters of the United States

Waters of the United States includes essentially all surface waters such as all navigable waters and their tributaries, all interstate waters and their tributaries, all wetlands adjacent to these waters, and all impoundments of these waters.

"Wetlands" are areas characterized by growth of wetland vegetation (bulrush, cattails, rushes, sedges, willows, pickleweed) where the soil is saturated during a portion of the growing season or the surface is flooded during some part of most years. Wetlands generally include swamps, marshes, bogs, and similar areas.

The landward regulatory limit for non-tidal waters (in the absence of adjacent wetlands) is the *ordinary high water mark*. The ordinary high water mark is the line on the shores established by the fluctuations of water and indicated by physical characteristics such as:

- a clear natural line impressed on the bank;
- shelving;
- changes in the character of the soil;
- destruction of terrestrial vegetation;
- the presence of litter and debris;
- or other appropriate means that consider the characteristics of the surrounding areas.

Navigable Waters

Navigable waters are defined as waters that have been used in the past, are now used, or are susceptible to use as a means to transport interstate or foreign commerce up to the head of navigation. Section 10 and/or Section 404 permits are required for construction activities in these waters. A complete list is available from the Army Corps of Engineers District Office.

Section 401 Water Quality Certification

The 401 Water Quality Certification (WQC) is required from Ohio EPA prior to the Corps approval of a Section 404 permit. Essentially these permitting processes work in tandem and include much of the same information. The 401 WQC requires an anti-degradation analysis investigating three alternatives: preferred alternative, minimum degradation alternative, and non-degradation alternative. The preferred alternative would include impacts that allow the applicant to develop the property in a preferred development plan. The minimum degradation alternative must minimize the impacts to water resources while still allowing the project to be constructed in an economically viable fashion. The non-degradation alternative must propose a site development plan, which includes zero water quality impacts to surface waters of the state. 401 WQC will be reviewed with varying levels of scrutiny based on the amount of impacts and quality of water resources. For example, a public need must be demonstrated to allow for impacts to category 3 wetlands, but this review is not necessary for impacts to category 1 or 2 wetlands. Fees are required at the time of application and for review of Ohio 401 Water Quality Certification applications.

Generally there are two types of 404 permits applicable to most entities in the State of Ohio, depending on the amount of linear feet of stream, linear feet of shoreline or acres of wetland proposed to be impacted. The types of permits include Individual Permits and Nationwide Permits. Additionally the Ohio Department of Transportation has been issued a Regional General Permits for for transportation projects meeting prescribed conditions.

Individual Permits

Individual permits are issued following a full public interest review of an individual application for a Department of the Army permit. A public notice is distributed to all known interested persons. After evaluating all comments and information received, final decision on the application is made.

The permit decision is generally based on the outcome of a public interest balancing process where the benefits of the project are balanced against the detriments. A permit will be granted unless the proposal is found to be contrary to the public interest. Processing time may take at least 120 days, although the Army Corps of Engineers is allowed up to 1 year to process permits.

Individual permits will require an individual 401 WQC from the Ohio EPA including a full antidegradation review.

Nationwide Permits

A nationwide permit is a form of general permit, which authorizes a category of activities throughout the nation. Nationwide Permits are for certain types of projects that are similar in nature and cause minimal degradation to waters of the state. These permits substantially expedite the permitting process. These permits are valid only if the conditions applicable to the permits are met. If the conditions cannot be met, an individual permit will be required.

Ohio EPA has pre-granted Section 401 Water Quality Certifications to Nationwide Permits with general and specific conditions. To determine if your project qualifies for Nationwide Permit coverage, or requires an individual Section 401 WQC from Ohio EPA, applicants should contact the Corps first to discuss the project.

Isolated Wetland Permits

In January 2001, the United States Supreme Court Decision in the case of Solid Waste Agency of

Northern Cook County (SWANCC) v. United States Army Corps of Engineers stated that the Corps did not have authority to regulate isolated wetlands under Section 404 of the Clean Water Act. Prior to that ruling, the Corps regulated activities in all streams and wetlands through the issuance of 404 Permits.

As a result of this decision, the Ohio EPA adopted emergency rules in April of 2001 to establish a state-permitting program, but these rules were effective for only ninety days. On July 17, 2001, Governor Bob Taft signed House Bill 231 into law. The bill establishes a permanent permitting process for isolated wetlands. The Army Corps of Engineers has maintained the authority to determine whether a wetland is isolated. If the determination by the Corps is that the wetland is isolated, applicants must contact the Ohio EPA to determine the correct level of Isolated Wetland Permit. More information can be found on the Ohio EPA web site.

Pre-Application Consultation

Applicants are encouraged to contact the Corps of Engineers and the Ohio EPA for proposed work in waters of the state. By discussing all information prior to application submittal, the application will be processed more efficiently. If an applicant is unsure if an application is required, the Corps will provide an official determination as to the need for a Department of the Army permit upon request.

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Contacts for Ohio EPA and Army Corps of Engineers

Ohio EPA, 401 Water Quality Certifications

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Columbus, Ohio 43216-1049
(614) 644-2013
Tom.Harcarik@epa.state.oh.us
www.epa.state.oh.us/dsw/401/401section.html

For Questions about the Ohio Rapid Assessment Method, contact Brian Gara at the above address or at (614) 836-8787, Brian.Gara@epa.state.oh.us

U.S. Army Corps of Engineers, Section 404 Permits

Buffalo District

1776 Niagara Street
Buffalo, NY 14207-3199
FAX (716) 879-4310
http://www.lrb.usace.army.mil/orgs/reg/index.htm

Louisville District

Attention: Regulatory Branch, OP-F
P.O. Box 59
Louisville, KY 40201-0059
Phone: (502) 315-6733
http://www.lrl.usace.army.mil/

Huntington District

502 Eighth Street
Huntington, WV 25701
(604) 529-5210
http://www.lrh.usace.army.mil/or/permits/

Pittsburgh District

William S. Moorhead Federal Building
1000 Liberty Avenue
Pittsburgh, PA 15222
http://www.lrp.usace.army.mil/or/or-f/permits.htm

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Definitions Associated with 404/401 and Isolated Wetland Permits

Isolated Wetlands – per OAC 3745-1-50

"Hydrologically isolated wetlands" means those wetlands which;

(1) Have no surface water connection to a surface water of the state;

(2) Are outside of, and not contiguous to, any one hundred year "floodplain" as that term is defined in this rule; and

(3) Have no contiguous hydric soil between the wetland and any surface water of the state.

Ordinary High Water Mark

Landward regulatory limit for non-tidal waters (in the absence of adjacent wetlands). Line on the shores or river banks established by the fluctuations of water and indicated by physical characteristics such as:

- a clear natural line impressed on the bank;
- shelving;
- changes in the character of the soil;
- destruction of terrestrial vegetation;
- the presence of litter and debris;
- or other appropriate means that consider the characteristics of the surrounding areas.

Navigable Waters

Waters that have been used in the past, are now used, or are susceptible to use as a means to transport interstate or foreign commerce up to the head of navigation. Section 10 and/or Section 404 permits are required for construction activities in these waters. A complete list is available in the Corps District Offices.

Ohio Rapid Assessment Method (ORAM)

Method which allows an applicant to assess the quality of the wetland without completing detailed vegetative or hydrologic analyses. The outcome of applying this method is the categorization of wetlands as either Category 1, 2 or 3. The Ohio EPA reviews categorization of wetlands. The current manual is ORAM Version 5.0.

Waters of the State

"Surface waters of the state" or "water bodies" mean all streams, lakes, reservoirs, ponds, marshes, wetlands or other waterways which are situated wholly or partially within the boundaries of the state, except those private waters which do not combine or effect a junction with natural surface or underground waters. Waters defined as sewerage system, treatment works or disposal system in section 6111.01 of the Revised Code are not included.

Wetlands – Effective 12/30/2002, Per OAC 3745-1-02

"Wetlands" means those areas that are inundated or saturated by surface or ground water at a frequency and duration that are sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. "Wetlands" includes swamps, marshes, bogs, and similar areas that are delineated in accordance with the 1987 United States Army Corps of Engineers wetland delineation manual and any other procedures and requirements adopted by the United States army corps of engineers for delineating wetlands.

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Wetland Categories – Per, OAC 3745-1-54(C)

Category 1 Wetlands

a) support minimal wildlife habitat, and minimal hydrological and recreational functions as determined by an appropriate wetland evaluation methodology acceptable to the director. Wetlands assigned to category 1 do not provide critical habitat for threatened or endangered species or contain rare, threatened or endangered species.

b) Wetlands assigned to category 1 may be typified by some or all of the following characteristics: hydrologic isolation, low species diversity, a predominance of non-native species (greater than fifty per cent areal cover for vegetative species), no significant habitat or wildlife use, and limited potential to achieve beneficial wetland functions.

c) may include, but are not limited to, wetlands that are acidic ponds created or excavated on mined lands without a connection to other surface waters throughout the year and that have little or no vegetation and wetlands that are hydrologically isolated and comprised of vegetation that is dominated (greater than eighty per cent areal cover) by species including, but not limited to: *Lythrum salicaria; Phalaris arundinacea;* and *Phragmites australis.*

Category 2 Wetlands

a) support moderate wildlife habitat, or hydrological or recreational functions as determined by an appropriate wetland evaluation methodology acceptable to the director or his authorized representative.

b) may include, but are not limited to: wetlands dominated by native species but generally without the presence of, or habitat for, rare, threatened or endangered species; and wetlands which are degraded but have a reasonable potential for reestablishing lost wetland functions.

Category 3 Wetlands

a) support superior habitat, or hydrological or recreational functions as determined by an appropriate wetland evaluation methodology acceptable to the director or his authorized representative.

b) may be typified by some or all of the following characteristics: high levels of diversity, a high proportion of native species, or high functional values.

c) may include, but are not limited to: wetlands which contain or provide habitat for threatened or endangered species; high quality forested wetlands, including old growth forested wetlands, and mature forested riparian wetlands; vernal pools; and wetlands which are scarce regionally and/or statewide including, but not limited to, bogs and fens.

Wetland Delineation

Process utilized to determine the areal extent and boundaries of a jurisdictional wetland. Currently, the 1987 U.S. Army Corps of Engineers Manual details the procedures for performing a wetland delineation. The results of a wetland delineation are reviewed by the Army Corps of Engineers.

Appendix 6: Soils with Greatest Potential Use for Infiltration

The following is a list of Ohio soil map units that have the optimum soil characteristics for infiltration. These soils have a natural drainage class that is well drained, depths to bedrock over 100 inches and an appropriate saturated hydraulic conductivity between the depths of 20-60 inches.

Saturated hydraulic conductivity is the amount of water that would move vertically through a unit of saturated soil per unit time under hydraulic gradient, described in the National Soil Survey Handbook (http://soils.usda.gov/technical/hand¬book/contents/part618p3.html#50).

Of course, site designers must realize that soil map units are not enough information for design. For example, soil map units may have inclusions of other soils types. Some soil map units not listed here, such as the urban soil complex, are too disturbed to characterize consistently in this format. Also note that some of the following soils may have other limitations such as steep slopes and although they may receive water well, these may limit the potential of siting an infiltration practice at the particular area. Therefore on-site measures of soil and site characteristics are always recommended.

The following tables are listed by county, showing the soil map units that meet the 3 criteria for 'greatest potential use' for infiltration. If a county is not listed, that county does not have soil map units that meet all of the criteria. Assistance to identify the potential for infiltration of soils not included in this table can be obtained by contacting soil scientists with the ODNR-Division of Soil & Water Conservation or USDA-Natural Resources Conservation Service.

Adams County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
EkB	Elkinsville silt loam, 1 to 6 percent slopes	4,642	1.2
Ge	Gessie loam, frequently flooded	2,762	0.7
	Total	7,404	2.0

Allen County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
KnA	Knoxdale silt loam, 0 to 2 percent slopes, occasionally flooded	2,750	1.1
	Total	2,750	1.1

Ashland County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
WuB	Wooster-Riddles silt loams, 2 to 6 percent slopes	---	*
WuC	Wooster-Riddles silt loams, 6 to 12 percent slopes	---	*
WuD2	Wooster-Riddles silt loams, 12 to 18 percent slopes, eroded	---	*
	Total	0	0.0

* Less than 0.1 percent.

Ashtabula County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ch	Chagrin silt loam	2,319	0.5
Sm	Steep land, loamy	6,428	1.4
	Total	8,747	1.9

Athens County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Cd	Chagrin loam, rarely flooded	2,090	0.6
Cg	Chagrin silt loam, frequently flooded	14,250	4.4
CmC	Clymer loam, 8 to 15 percent slopes	1,000	0.3
HcA	Hackers silt loam, 0 to 3 percent slopes	820	0.3
Mp	Moshannon silt loam, frequently flooded	470	0.1
PaB	Parke silt loam, 2 to 6 percent slopes	450	0.1
RcC	Richland loam, 8 to 15 percent slopes	310	*
RcD	Richland loam, 15 to 25 percent slopes	3,640	1.1
	Total	23,030	7.1

* Less than 0.1 percent.

Auglaize County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam, occasionally flooded	2,890	1.1
	Total	2,890	1.1

Belmont County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
As	Ashton silt loam, occasionally flooded	319	*
Cf	Chagrin loam, occasionally flooded	2	*
Cg	Chagrin silt loam, occasionally flooded	2,240	0.6
DuB	Duncannon-Urban land complex, 0 to 15 percent slopes	514	0.1
No	Nolin variant silt loam, occasionally flooded	1,813	0.5
Nu	Nolin variant-Urban land complex	291	*
RcC	Richland loam, 8 to 15 percent slopes	684	0.2
RcD	Richland loam, 15 to 25 percent slopes	2,658	0.8
RcE	Richland moderately stony loam, 25 to 40 percent slopes	788	0.2
RkC	Richland channery loam, 8 to 15 percent slopes	39	*
RkD	Richland channery loam, 15 to 25 percent slopes	292	*
	Total	9,640	2.8

* Less than 0.1 percent.

WhC	Westmoreland silt loam, 6 to 15 percent slopes	3,142	0.9
WhD	Westmoreland silt loam, 15 to 25 percent slopes	13,234	3.6
WhE	Westmoreland silt loam, 25 to 35 percent slopes	13,957	3.8
	Total	37,298	10.3

* Less than 0.1 percent.

Crawford County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AdB	Alexandria silt loam, 2 to 6 percent slopes	1,038	0.4
AdC2	Alexandria silt loam, 6 to 12 percent slopes, moderately eroded	2,066	0.8
AdD2	Alexandria silt loam, 12 to 18 percent slopes, moderately eroded	573	0.2
HpE	Hennepin-Alexandria silt loams, 18 to 50 percent slopes	775	0.3
	Total	4,452	1.7

* Less than 0.1 percent.

Cuyahoga County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ch	Chagrin silt loam, occasionally flooded	4,252	1.4
GeF	Geeburg-Mentor silt loams, 25 to 70 percent slopes	5,194	1.8
	Total	9,446	3.2

Defiance County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ge	Genesee loam, occasionally flooded	3,299	1.2
	Total	3,299	1.2

Delaware County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
MaB	Martinsville loam, 2 to 6 percent slopes	24	*
MbB	Martinsville loam, till substratum, 2 to 6 percent slopes	959	0.3
McD2	Mentor silt loam, 12 to 18 percent slopes, eroded	63	*
RoA	Rossburg silt loam, 0 to 2 percent slopes, occasionally flooded	1,464	0.5
	Total	2,510	0.9

* Less than 0.1 percent.

Erie County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
NoA	Nolin silt loam, 0 to 2 percent slopes, occasionally flooded	576	0.3
	Total	576	0.3

Fairfield County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AfB	Alford silt loam, 2 to 6 percent slopes	2,163	0.7
AfC2	Alford silt loam, 6 to 12 percent slopes, eroded	1,860	0.6

Cg	Chagrin silt loam, frequently flooded	625	0.2
Gf	Gessie silt loam, occasionally flooded	1,748	0.5
Gg	Gessie silt loam, frequently flooded	1,841	0.6
HhC2	Hickory silt loam, 6 to 12 percent slopes, eroded	810	0.2
HkE	Hickory-Germano complex, 20 to 35 percent slopes	583	0.2
HmD2	Hickory-Gilpin complex, 12 to 20 percent slopes, eroded	2,889	0.9
PkB	Pike silt loam, 2 to 6 percent slopes	432	0.1
PkC2	Pike silt loam, 6 to 12 percent slopes, eroded	559	0.2
	Total	13,510	4.2

Fayette County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam	826	0.3
Rs	Ross silt loam	1,393	0.5
	Total	2,219	0.9

Franklin County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam, occasionally flooded	2,424	0.7
Uw	Urban land-Genesee complex, occasionally flooded	1,370	0.4
	Total	3,794	1.1

Gallia County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AkB	Allegheny loam, 3 to 8 percent slopes	550	0.2
AkC	Allegheny loam, 8 to 15 percent slopes	652	0.2
AkD	Allegheny loam, 15 to 25 percent slopes	587	0.2
Cg	Chagrin silt loam, frequently flooded	6,780	2.2
Cu	Cuba silt loam, occasionally flooded	1,226	0.4
EkB	Elkinsville silt loam, 1 to 6 percent slopes	2,129	0.7
	Total	11,924	4.0

Greene County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee loam	1,831	0.7
Rs	Ross loam	3,601	1.4
RtA	Rush silt loam, 0 to 2 percent slopes	2,036	0.8
RtB	Rush silt loam, 2 to 6 percent slopes	1,932	0.7
	Total	9,400	3.5

Guernsey County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AgC	Allegheny loam, 8 to 15 percent slopes	407	0.1
MeB	Mentor silt loam, 2 to 8 percent slopes	2,595	0.8

MeC	Mentor silt loam, 8 to 15 percent slopes	1,863	0.6
MeD	Mentor silt loam, 15 to 25 percent slopes	1,567	0.5
MfB	Mentor-Urban land complex, 2 to 8 percent slopes	152	*
MgB	Mentor silt loam, 2 to 6 percent slopes	8	*
RcC	Richland channery loam, 8 to 15 percent slopes	19	*
RcD	Richland channery loam, 15 to 25 percent slopes	471	0.1
	Total	7,082	2.1

* Less than 0.1 percent.

Hamilton County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee loam, occasionally flooded	3,912	1.5
Go	Genesee-Urban land complex, occasionally flooded	1,888	0.7
Hu	Huntington silt loam, occasionally flooded	875	0.3
Ju	Jules silt loam, occasionally flooded	5,635	2.1
McA	Martinsville silt loam, 0 to 2 percent slopes	2,073	0.8
McB	Martinsville silt loam, 2 to 6 percent slopes	616	0.2
PbB2	Parke silt loam, 3 to 8 percent slopes, eroded	575	0.2
PbC2	Parke silt loam, 8 to 15 percent slopes, eroded	914	0.3
PbD	Parke silt loam, 15 to 25 percent slopes	381	0.1
PbE	Parke silt loam, 25 to 35 percent slopes	381	0.1
PcB	Parke-Urban land complex, 3 to 8 percent slopes	519	0.2
PcC	Parke-Urban land complex, 8 to 15 percent slopes	320	0.1
RwB2	Russell silt loam, 3 to 8 percent slopes, eroded	1,621	0.6
RxB	Russell-Urban land complex, 3 to 8 percent slopes	8,304	3.1
UgB	Urban land-Elkinsville complex, 3 to 8 percent slopes	1,117	0.4
UgC	Urban land-Elkinsville complex, 8 to 15 percent slopes	722	0.3
Uh	Urban land-Huntington complex, frequently flooded	4,627	1.8
UmB	Urban land-Martinsville complex, 3 to 8 percent slopes	5,253	2.0
UmC	Urban land-Martinsville complex, 8 to 15 percent slopes	431	0.2
	Total	40,164	15.2

Hardin County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam	14	*
MaB	Martinsville loam, 1 to 4 percent slopes	397	0.1
No	Nolin silt loam, occasionally flooded	810	0.3
	Total	1,221	0.4

* Less than 0.1 percent.

Henry County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gm	Genesee loam	372	0.1
Rs	Ross loam	547	0.2
	Total	919	0.3

Highland County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
EkB	Elkinsville silt loam, 1 to 6 percent slopes	14	*
Gd	Gessie loam, frequently flooded	77	*
Ge	Gessie silt loam, occasionally flooded	8	*
Gn	Genesee silt loam	5,829	1.6
HkC2	Hickory silt loam, 6 to 12 percent slopes, moderately eroded	1,741	0.5
HkD2	Hickory silt loam, 12 to 18 percent slopes, moderately eroded	4,538	1.3
HkE2	Hickory silt loam, 18 to 25 percent slopes, moderately eroded	2,235	0.6
HkF2	Hickory silt loam, 25 to 35 percent slopes, moderately eroded	758	0.2
HyC3	Hickory clay loam, 6 to 12 percent slopes, severely eroded	352	*
HyD3	Hickory clay loam, 12 to 18 percent slopes, severely eroded	2,016	0.6
HyE3	Hickory clay loam, 18 to 25 percent slopes, severely eroded	201	*
OcA	Ockley silt loam, 0 to 2 percent slopes	141	*
OcB	Ockley silt loam, 2 to 6 percent slopes	566	0.2
OcC2	Ockley silt loam, 6 to 12 percent slopes, moderately eroded	444	0.1
OdB	Ockley-Urban land complex, gently sloping	40	*
Rn	Ross silt loam	2,944	0.8
RuB	Russell silt loam, 2 to 6 percent slopes	210	*
WvA	Williamsburg silt loam, 0 to 2 percent slopes	91	*
WvB	Williamsburg silt loam, 2 to 6 percent slopes	350	*
WvC	Williamsburg silt loam, 6 to 12 percent slopes	256	*
	Total	22,811	6.4

* Less than 0.1 percent.

Hocking County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AfB	Alford silt loam, 2 to 6 percent slopes	269	*
AfC	Alford silt loam, 6 to 12 percent slopes	638	0.2
AgB	Allegheny loam, 2 to 6 percent slopes	235	*
AgC	Allegheny loam, 6 to 12 percent slopes	242	*
Cg	Chagrin silt loam, frequently flooded	13,498	5.0
HcD2	Hickory-Gilpin complex, 12 to 20 percent slopes, eroded	62	*
HkD2	Hickory silt loam, 12 to 20 percent slopes, eroded	2	*
HkE2	Hickory silt loam, 20 to 35 percent slopes, eroded	46	*
HmC2	Hickory silt loam, 6 to 12 percent slopes, eroded	1	*
HmD2	Hickory silt loam, 12 to 18 percent slopes, eroded	1,380	0.5
HmE	Hickory silt loam, 20 to 35 percent slopes, eroded	746	0.3
HmF	Hickory silt loam, 25 to 40 percent slopes	464	0.2
HrE	Hickory-Germano complex, 20 to 35 percent slopes	13	*
PkC2	Pike silt loam, 6 to 12 percent slopes, eroded	2	*
Po	Pope loam, occasionally flooded	2,169	0.8
RcD	Richland loam, 15 to 25 percent slopes	5	*
	Total	19,772	7.3

* Less than 0.1 percent.

Jackson County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AkB	Allegheny loam, 3 to 8 percent slopes	319	0.1
AkC	Allegheny loam, 8 to 15 percent slopes	766	0.3
AkD	Allegheny loam, 15 to 25 percent slopes	2,166	0.8
Cu	Cuba silt loam, occasionally flooded	752	0.3
Ha	Haymond silt loam, occasionally flooded	10	*
	Total	4,013	1.5

* Less than 0.1 percent.

Jefferson County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
RaB	Richland silt loam, 2 to 6 percent slopes	68	*
RcB	Richland silt loam, 1 to 7 percent slopes	3,975	1.5
RcC	Richland silt loam, 7 to 15 percent slopes	200	*
	Total	4,243	1.6

* Less than 0.1 percent.

Lawrence County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Cg	Chagrin loam, frequently flooded	3,863	1.3
Ch	Chagrin silt loam, frequently flooded	63	*
Cu	Cuba silt loam, occasionally flooded	3,570	1.2
EkB	Elkinsville silt loam, 1 to 6 percent slopes	3,050	1.0
EkE	Elkinsville silt loam, 15 to 40 percent slopes	366	0.1
EmB	Elkinsville-Urban land complex, 1 to 8 percent slopes	3,657	1.3
	Total	14,569	5.0

* Less than 0.1 percent.

Licking County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AcB	Alford silt loam, 2 to 8 percent slopes	35	*
AcC2	Alford silt loam, 8 to 15 percent slopes, eroded	5	*
AfA	Alford silt loam, 0 to 2 percent slopes	610	0.1
AfB	Alford silt loam, 2 to 6 percent slopes	3,105	0.7
AfC2	Alford silt loam, 6 to 12 percent slopes, eroded	705	0.2
AhB	Alford-Urban land complex, 2 to 6 percent slopes	500	0.1
HkC2	Hickory silt loam, 6 to 12 percent slopes, eroded	490	0.1
HkD2	Hickory silt loam, 12 to 18 percent slopes, eroded	265	*
MnA	Mentor silt loam, 0 to 2 percent slopes	520	0.1
MnB	Mentor silt loam, 2 to 6 percent slopes	3,405	0.8
MnC2	Mentor silt loam, 6 to 12 percent slopes, eroded	4,080	0.9
MnD2	Mentor silt loam, 12 to 18 percent slopes, eroded	370	*
PaC2	Parke silt loam, 6 to 12 percent slopes, eroded	2,250	0.5
RsA	Rush silt loam, 0 to 2 percent slopes	975	0.2
	Total	17,315	3.9

* Less than 0.1 percent.

Logan County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam	1,371	0.5
	Total	1,371	0.5

Lorain County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
MnB	Mentor silt loam, 2 to 6 percent slopes	434	0.1
MnC	Mentor silt loam, 6 to 12 percent slopes	127	*
MnE	Mentor silt loam, 12 to 25 percent slopes	104	*
	Total	665	0.2

* Less than 0.1 percent.

Lucas County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
SmB	Sisson loam, 2 to 6 percent slopes	451	0.2
SmC	Sisson loam, 6 to 12 percent slopes	614	0.3
SmD	Sisson loam, 12 to 18 percent slopes	826	0.4
SnB	Sisson-Urban land complex, 2 to 12 percent slopes	1,546	0.7
	Total	3,437	1.5

Madison County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Rs	Ross silt loam, occasionally flooded	987	0.3
	Total	987	0.3

Mahoning County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
WrF2	Wooster loam, 25 to 50 percent slopes, moderately eroded	247	*
WsB	Wooster silt loam, 2 to 6 percent slopes	2,068	0.8
WsC2	Wooster silt loam, 6 to 12 percent slopes, moderately eroded	3,837	1.4
WsD2	Wooster silt loam, 12 to 18 percent slopes, moderately eroded	571	0.2
WsE2	Wooster silt loam, 18 to 25 percent slopes, moderately eroded	88	*
	Total	6,811	2.5

* Less than 0.1 percent.

Marion County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
MaA	Martinsville loam, 0 to 2 percent slopes	880	0.3
MaB	Martinsville loam, 2 to 6 percent slopes	477	0.2
No	Nolin silt loam, occasionally flooded	3,773	1.5
Ro	Rossburg silt loam, 0 to 2 percent slopes, occasionally flooded	4	*
	Total	5,134	2.0

* Less than 0.1 percent.

Medina County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Cr	Chagrin silt loam, occasionally flooded	59	*
MoB	Mentor silt loam, 2 to 6 percent slopes	4	*
WvB	Wooster-Riddles silt loams, 2 to 6 percent slopes	49	*
WvC2	Wooster-Riddles silt loams, 6 to 12 percent slopes, eroded	188	*
WvD2	Wooster-Riddles silt loams, 12 to 18 percent slopes, eroded	11	*
	Total	311	0.1

* Less than 0.1 percent.

Meigs County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Cg	Chagrin silt loam, frequently flooded	10,689	3.9
DuC	Duncannon silt loam, 6 to 12 percent slopes	227	*
EkA	Elkinsville silt loam, 0 to 2 percent slopes	261	*
GaC	Gallia loam, 6 to 12 percent slopes	802	0.3
GaD	Gallia loam, 12 to 18 percent slopes	255	*
Mo	Moshannon silt loam, frequently flooded	1,264	0.5
RcB	Richland silt loam, 2 to 6 percent slopes	1,071	0.4
RdD	Richland loam, 15 to 25 percent slopes	3	*
RdE	Richland loam, 25 to 40 percent slopes	1	*
	Total	14,573	5.3

* Less than 0.1 percent.

Mercer County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam	1,816	0.6
	Total	1,816	0.6

Miami County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Rs	Ross silt loam	2,876	1.1
	Total	2,876	1.1

Monroe County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AlD	Allegheny silt loam, 12 to 18 percent slopes	1	*
AsA	Ashton silt loam, 0 to 3 percent slopes	192	*
Cg	Chagrin silt loam	5,942	2.0
Hu	Huntington silt loam	737	0.3
	Total	6,872	2.3

* Less than 0.1 percent.

Montgomery County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Rs	Ross silt loam	10,731	3.6
Rt	Ross-Urban land complex	3,786	1.3
	Total	14,517	4.9

Morgan County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ca	Chagrin silt loam, frequently flooded	327	0.1
RvE	Richland-Vandalia complex, 20 to 35 percent slopes	53	*
	Total	380	0.1

* Less than 0.1 percent.

Morrow County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
ObA	Ockley loam, 0 to 2 percent slopes	3	*
ObB	Ockley loam, 2 to 6 percent slopes	69	*
	Total	72	0.0

* Less than 0.1 percent.

Muskingum County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AfB	Alford silt loam, 2 to 8 percent slopes	5,395	1.3
AfC2	Alford silt loam, 8 to 15 percent slopes, eroded	5,545	1.3
Cb	Chagrin loam, rarely flooded	2,277	0.5
LcD	Lakin-Alford complex, 15 to 25 percent slopes	541	0.1
No	Nolin silt loam, occasionally flooded	4,638	1.1
UtA	Urban land-Nolin complex, rarely flooded	593	0.1
	Total	18,989	4.4

Noble County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AlD	Allegheny silt loam, 12 to 18 percent slopes	9	*
Ch	Chagrin silt loam, occasionally flooded	1,990	0.8
RcD	Richland channery loam, 15 to 25 percent slopes	16	*
	Total	2,015	0.8

* Less than 0.1 percent.

Ottawa County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam, frequently flooded	1,041	0.6
	Total	1,041	0.6

Perry County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AfB	Alford silt loam, 1 to 8 percent slopes	6,773	2.6
AfC	Alford silt loam, 8 to 15 percent slopes	1,862	0.7
AfC2	Alford silt loam, 8 to 15 percent slopes, eroded	107	*
AfD	Alford silt loam, 15 to 25 percent slopes	282	0.1
AgB	Alford silt loam, 2 to 8 percent slopes	3	*
MeB	Mentor silt loam, gravelly substratum, 1 to 8 percent slopes	836	0.3
MeC	Mentor silt loam, gravelly substratum, 8 to 15 percent slopes	1,137	0.4
No	Nolin silt loam, occasionally flooded	3,510	1.3
SfD	Shelocta-Cruze complex, 15 to 25 percent slopes	1	*
SfE	Shelocta-Cruze complex, 25 to 40 percent slopes	26	*
	Total	14,537	5.5

* Less than 0.1 percent.

Pickaway County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam, occasionally flooded	9,332	2.9
Gs	Gessie silt loam, occasionally flooded	47	*
Rt	Ross silt loam, overwash, frequently flooded	801	0.2
WeA	Wea silt loam, 0 to 2 percent slopes	1,965	0.6
WeB	Wea silt loam, 2 to 6 percent slopes	476	0.1
	Total	12,621	3.9

* Less than 0.1 percent.

Pike County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
En	Elkinsville silt loam, rarely flooded	2,182	0.8
Ge	Genesee silt loam, occasionally flooded	6,699	2.4
Gf	Gessie silt loam, occasionally flooded	72	*
Ha	Haymond silt loam, occasionally flooded	2,705	1.0
Hu	Huntington silt loam, occasionally flooded	3,637	1.3
Mh	Martinsville loam, rarely flooded	727	0.3
Mt	Mentor silt loam, rarely flooded	117	*
PaA	Parke silt loam, 0 to 3 percent slopes	639	0.2
PaB	Parke silt loam, 3 to 8 percent slopes	212	*
SuB	Spargus channery silt loam, 2 to 6 percent slopes	7	*
	Total	16,997	6.0

* Less than 0.1 percent.

Portage County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Tg	Tioga loam	1,055	0.3
	Total	1,055	0.3

Preble County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
RuB	Russell silt loam, 2 to 6 percent slopes	2,857	1.0
	Total	2,857	1.0

Putnam County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam	1,807	0.6
Kw	Knoxdale silt loam, occasionally flooded	10	*
Rw	Rossburg silt loam, occasionally flooded	33	*
	Total	1,850	0.6

* Less than 0.1 percent.

Richland County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
MeB	Mentor silt loam, 2 to 6 percent slopes	267	*
MeC	Mentor silt loam, 6 to 12 percent slopes	198	*
WeD	Westmoreland silt loam, 12 to 18 percent slopes	102	*
WmD	Wheeling and Mentor silt loams, 12 to 18 percent slopes	301	*
	Total	868	0.3

* Less than 0.1 percent

Ross County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ge	Gessie silt loam, occasionally flooded	17,914	4.0
Gf	Gessie silt loam, frequently flooded	5,601	1.3
Hd	Haymond silt loam, occasionally flooded	2,911	0.7
HkD2	Hickory silt loam, 12 to 20 percent slopes, eroded	131	*
HkE2	Hickory silt loam, 20 to 35 percent slopes, eroded	329	*
Ht	Huntington silt loam, occasionally flooded	245	*
McA	Martinsville loam, rarely flooded	166	*
MeC2	Mentor silt loam, 6 to 12 percent slopes, eroded	702	0.2
MeD2	Mentor silt loam, 12 to 20 percent slopes, eroded	512	0.1
MfA	Mentor silt loam, rarely flooded	561	0.1
MgA	Mentor silt loam, gravelly substratum, 0 to 2 percent slopes	2,914	0.7
MgB	Mentor silt loam, gravelly substratum, 2 to 6 percent slopes	657	0.1
PkA	Pike silt loam, 0 to 2 percent slopes	1,873	0.4
PkB	Pike silt loam, 2 to 6 percent slopes	1,355	0.3
SuB	Spargus channery silt loam, 2 to 6 percent slopes	1,259	0.3
	Total	37,130	8.4

* Less than 0.1 percent.

Sandusky County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
MeB	Mentor silt loam, 1 to 4 percent slopes	1,277	0.5
MeF	Mentor silt loam, 25 to 50 percent slopes	756	0.3

	Total	2,033	0.8

Scioto County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AfD	Alford silt loam, 10 to 25 percent slopes	660	0.2
Cu	Cuba silt loam, occasionally flooded	1,280	0.3
EhB	Elkinsville silt loam, 1 to 6 percent slopes	12	*
EkB	Elkinsville silt loam, 1 to 8 percent slopes	2,768	0.7
EkE	Elkinsville silt loam, 25 to 40 percent slopes	1,679	0.4
EmB	Elkinsville-Urban land complex, 1 to 8 percent slopes	1,541	0.4
Ge	Genesee silt loam, occasionally flooded	2,365	0.6
Ha	Haymond silt loam, occasionally flooded	3,054	0.8
Hu	Huntington silt loam, occasionally flooded	522	0.1
No	Nolin silt loam, occasionally flooded	12,086	3.1
SbB	Shelocta silt loam, 3 to 8 percent slopes	10,880	2.8
SbC	Shelocta silt loam, 8 to 15 percent slopes	2,119	0.5
SbD	Shelocta silt loam, 15 to 25 percent slopes	3,584	0.9
WmB	Wheeling silt loam, 1 to 8 percent slopes	1,450	0.4
	Total	44,000	11.2

* Less than 0.1 percent.

Seneca County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ch	Chagrin silt loam, occasionally flooded	5,427	1.5
Ge	Genesee silt loam, occasionally flooded	157	*
Ru	Ross silt loam, occasionally flooded	1,170	0.3
	Total	6,754	1.9

* Less than 0.1 percent.

Shelby County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ge	Genesee silt loam, occasionally flooded	1,108	0.4
	Total	1,108	0.4

Stark County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
MeA	Mentor silt loam, 0 to 2 percent slopes	270	*
MeB	Mentor silt loam, 2 to 6 percent slopes	447	0.1
MeC	Mentor silt loam, 6 to 12 percent slopes	237	*
MeD	Mentor silt loam, 12 to 18 percent slopes	176	*
RuA	Rush silt loam, 0 to 3 percent slopes	---	*
WuB	Wooster silt loam, 2 to 6 percent slopes	6,487	1.7
WuC	Wooster silt loam, 6 to 12 percent slopes	3,816	1.0

WuC2	Wooster silt loam, 6 to 12 percent slopes, moderately eroded	10,791	2.9
WuD2	Wooster silt loam, 12 to 18 percent slopes, moderately eroded	6,137	1.7
WuE2	Wooster silt loam, 18 to 25 percent slopes, moderately eroded	1,538	0.4
WuF2	Wooster silt loam, 25 to 50 percent slopes, moderately eroded	143	*
WvD	Wooster-Urban land complex, steep	305	*
WxB	Wooster-Riddles silt loams, 2 to 6 percent slopes	---	*
WxC	Wooster-Riddles silt loams, 6 to 12 percent slopes	---	*
WxC2	Wooster-Riddles silt loams, 6 to 12 percent slopes, eroded	---	*
WxD2	Wooster-Riddles silt loams, 12 to 18 percent slopes, eroded	---	*
	Total	30,347	8.2

* Less than 0.1 percent.

Summit County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
CwC2	Chili-Wooster complex 6 to 12 percent slopes, moderately eroded	449	0.2
CwD2	Chili-Wooster complex, 12 to 18 percent slopes, moderately eroded	275	0.1
CwE2	Chili-Wooster complex, 18 to 25 percent slopes, moderately eroded	232	*
WwD	Wooster-Urban land complex, hilly	300	0.1
WyC2	Wooster-Riddles silt loams, 6 to 12 percent slopes, eroded	4	*
	Total	1,260	0.5

* Less than 0.1 percent.

Tuscarawas County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
EkA	Elkinsville silt loam, 0 to 3 percent slopes	600	0.2
MeB	Mentor silt loam, 2 to 6 percent slopes	2	*
RuA	Rush silt loam, 0 to 3 percent slopes	3,322	0.9
	Total	3,924	1.1

* Less than 0.1 percent.

Union County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gn	Genesee silt loam	3,006	1.1
No	Nolin silt loam, 0 to 2 percent slopes, occasionally flooded	35	*
RpA	Rossburg silt loam, 0 to 2 percent slopes, occasionally flooded	2	*
	Total	3,043	1.1

* Less than 0.1 percent.

Vinton County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Cg	Chagrin silt loam, 0 to 2 percent slopes, frequently flooded	4,434	1.7
RcD	Richland loam, 15 to 25 percent slopes	29	*
RcE	Richland loam, 25 to 40 percent slopes	48	*
	Total	4,511	1.7

* Less than 0.1 percent.

Warren County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
CqC2	Crouse-Miamian silt loams, 6 to 12 percent slopes, eroded	94	*
CrB	Crider silt loam, 2 to 6 percent slopes	333	0.1
Gd	Genesee fine sandy loam	4,515	1.7
Gn	Genesee loam	4,612	1.8
HiD2	Hickory silt loam, 12 to 18 percent slopes, eroded	220	*
HiE2	Hickory silt loam, 18 to 25 percent slopes, eroded	7	*
HiF2	Hickory silt loam, 25 to 35 percent slopes, eroded	279	0.1
HmE	Hennepin-Miamian silt loams, 18 to 25 percent slopes	240	*
HmE2	Hennepin-Miamian silt loams, 18 to 25 percent slopes, moderately eroded	1,654	0.6
HnD3	Hennepin-Miamian complex, 12 to 18 percent slopes, severely eroded	399	0.2
HuE2	Hickory-Morrisville silt loams, 18 to 25 percent slopes, eroded	27	*
PaB	Parke silt loam, 2 to 6 percent slopes	224	*
PaD2	Parke silt loam, 6 to 18 percent slopes, moderately eroded	183	*
Rn	Ross loam	3,598	1.4
WlA	Williamsburg silt loam, 0 to 2 percent slopes	156	*
WlB	Williamsburg silt loam, 2 to 6 percent slopes	529	0.2
WlC2	Williamsburg silt loam, 6 to 12 percent slopes, moderately eroded	166	*
	Total	17,236	6.6

* Less than 0.1 percent.

Washington County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AlB	Allegheny silt loam, 2 to 6 percent slopes	536	0.1
AlC	Allegheny silt loam, 6 to 12 percent slopes	1,801	0.4
AlD	Allegheny silt loam, 12 to 18 percent slopes	1,479	0.4
AlG	Allegheny silt loam, 18 to 50 percent slopes	497	0.1
AsA	Ashton silt loam, 0 to 2 percent slopes	631	0.2
AsB	Ashton silt loam, 2 to 6 percent slopes	101	*
Cg	Chagrin silt loam	7,284	1.8
DtB	Duncannon silt loam, 2 to 6 percent slopes	156	*
DtC	Duncannon silt loam, 6 to 12 percent slopes	147	*
DuD	Duncannon-Lakin complex, 12 to 18 percent slopes	205	*
DuE	Duncannon-Lakin complex, 18 to 25 percent slopes	373	*
GaB	Gallia silt loam, 2 to 6 percent slopes	441	0.1
GaC	Gallia silt loam, 6 to 12 percent slopes	1,433	0.4
GaD	Gallia silt loam, 12 to 18 percent slopes	341	*
HcA	Hackers silt loam, 0 to 2 percent slopes	948	0.2
HcB	Hackers silt loam, 2 to 6 percent slopes	1,758	0.4
HcC	Hackers silt loam, 6 to 12 percent slopes	198	*
Hu	Huntington silt loam	852	0.2
MeA	Mentor silt loam, 0 to 2 percent slopes	2,182	0.5
MeB	Mentor silt loam, 2 to 6 percent slopes	1,991	0.5
MeC	Mentor silt loam, 6 to 12 percent slopes	611	0.1
Mp	Moshannon silt loam	6,621	1.6
No	Nolin silt loam	2,891	0.7
	Total	33,477	8.2

* Less than 0.1 percent.

Wayne County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
RhB	Riddles silt loam, 2 to 6 percent slopes	2,444	0.7
RhC	Riddles silt loam, 6 to 12 percent slopes	2,359	0.7
RhD2	Riddles silt loam, 12 to 18 percent, eroded	1,069	0.3
RhE	Riddles silt loam, 18 to 25 percent slopes	2,500	0.7
WuB	Wooster-Riddles silt loams, 2 to 6 percent slopes	23,623	6.6
WuC	Wooster-Riddles silt loams, 6 to 12 percent slopes	6,927	1.9
WuC2	Wooster-Riddles silt loams, 6 to 12 percent slopes, eroded	15,191	4.3
WuD2	Wooster-Riddles silt loams, 12 to 18 percent slopes, eroded	6,816	1.9
	Total	60,929	17.1

Williams County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Ge	Genesee loam	1,396	0.5
	Total	1,396	0.5

Wood County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
Gm	Genesee loam	385	*
Gn	Genesee silt loam	777	0.2
	Total	1,162	0.3

* Less than 0.1 percent.

Wyandot County, Ohio

Map Symbol	Soil Name	Acres	Percent of County
AdC2	Alexandria silt loam, 6 to 12 percent slopes, moderately eroded	1	*
Cm	Chagrin silt loam, rarely flooded	871	0.3
Ge	Genesee silt loam, occasionally flooded	4,143	1.6
HpE	Hennepin-Alexandria silt loams, 18 to 50 percent slopes	1	*
MaB	Martinsville fine sandy loam, 2 to 6 percent slopes	591	0.2
SfC2	Shinrock-Martinsville complex, 6 to 12 percent slopes, eroded	1,638	0.6
SfD2	Shinrock-Martinsville complex, 12 to 18 percent slopes, eroded	246	*
	Total	7,501	2.9

* Less than 0.1 percent.

Appendix 9: Adjusting Hydrologic Soil Group for Construction

This appendix provides hydrologic soil group (HSG) values for undisturbed Ohio soils and predictable HSG values for Ohio soils that are altered by construction practices.

Hydrologic soil groups are used to assign a Curve Number (CN) when performing runoff calculations or in hydrologic models. Soil map units have been assigned to the four Hydrologic Soil Groups in technical resources and soil resources published by the USDA Natural Resource Conservation Service[1] (NRCS). NRCS HSG values are based on undisturbed, naturally-occurring soils. In contrast, soils at development sites are typically changed dramatically by construction practices that remove topsoil, change the soil profile and compact soils with heavy equipment. The runoff potential of a site is significantly impacted by these changes and should be reflected in hydrologic modeling and runoff calculations.

The following tables contain the HSGs and predicted HSGs for post-construction that were developed by applying the HSG criteria to modeled representative post-construction soil profiles. The modeled scenario consisted of the removal of the topsoil and subsoil to a depth of 18 inches and the compaction of the zone from 0 to 6 inches at the new surface. A fuller explanation of this process is available at the end of this appendix.

Soil Map Unit Component	HSG[1]	Post-Const HSG
Aaron	C	D
Abscota Variant (Warren)	A	No Eval.
Adrian	A/D	D
Aetna	B/D	D
Alexandria	C	D
Alford	B	D
Algansee	A/D	D
Algiers	B/D	D
Allegheny	B	C
Allegheny Variant (Belmont, Pike)	B	No Eval.
Allis	D	D
Alvada	B/D	D
Amanda	C	D
Amanda Variant (Licking)	B	No Eval.
Arkport	A	A
Ashton	B	D
Atlas	D	D
Aurand	C/D	D
Ava	C	D
Avonburg	D	D
Barkcamp	A	No Eval.

Soil Map Unit Component	HSG[1]	Post-Const HSG
Barkcamp (CL surface)	A	A
Barkcamp (L surface)	A	B
Beasley	C	No Eval.
Beaucoup	C/D	D
Belmore	B	C
Belpre	C	No Eval.
Bennington	C/D	D
Berks	B	D
Bethesda	C	D
Biglick	D	D
Birkbeck	B	D
Bixler	B	D
Blairton	C	No Eval.
Blakeslee	B/D	D
Blanchester	C/D	D
Blount	C/D	D
Bogart	B/D	D
Bogart Variant (Mahoning)	C	No Eval.
Bonnell	C	D
Bonnie	C/D	D
Bono	C/D	D

Notes: CL = clay loam; L = loam; substr = substratum; limestne substr = limestone substratum; Dual classes in Ohio, such as A/D, B/D, C/D are given for drained or undrained condition; No Eval. = No evaluation performed.

1. Hydrologic Soil Groups (HSGs) for Ohio (for undisturbed naturally-occuring sites) were updated in 2008 and should be used rather than HSGs from earlier publications (http://www.oh.nrcs.usda.gov/technical/soils/OH_hsg.pdf or contact the USDA Natural Resources Conservation Service in Columbus, Ohio). You may also utilize www.OhioERIN.com to find site specific HSG (unaltered).

Soil Map Unit Component	HSG[1]	Post-Const HSG
Boston	C	D
Boyer	A	B
Braceville	C/D	D
Brady	B	No Eval.
Bratton	C	D
Brecksville	D	D
Brenton	B	No Eval.
Bronson	B	No Eval.
Brooke	D	D
Brookside	C	D
Brookston	B/D	D
Broughton	D	D
Brownsville	A	D
Brushcreek	C	D
Calcutta	C/D	D
Cambridge	D	D
Cana	C	D
Cana Variant	C	No Eval.
Canadice	D	D
Canal	C/D	D
Caneadea	D	D
Canfield	C	D
Canfield (Summit)	D	D
Canfield Variant (Stark)	C	No Eval.
Captina	C	No Eval.
Cardinal	C/D	D
Cardington	C	D
Carlisle	A/D	D
Casco	B	A
Castalia	A	D
Cedarfalls	A	No Eval.
Celina	C	D
Celina Variant	C	No Eval.
Centerburg	C	D
Ceresco	A/D	D
Chagrin	B	C
Channahon	D	D
Chavies	A	B
Chenango	A	A
Chili	B	C
Cidermill	B	D
Cincinnati	C	D
Clarksburg	C	D
Claysville	C/D	D

Soil Map Unit Component	HSG[1]	Post-Const HSG
Clermont	D	D
Clifty	A	C
Clymer	B	C
Coblen	B	No Eval.
Cohoctah	A/D	D
Colonie	A	A
Colwood	B/D	D
Colwood (Erie)	C/D	D
Colyer	D	D
Colyer Variant	C	No Eval.
Condit	C/D	D
Conneaut	C/D	D
Conotton	A	C
Conotton Variant	A	No Eval.
Coolville	C	D
Corwin	C	D
Coshocton	C	D
Crane	B/D	D
Crider	B	No Eval.
Crosby	C/D	D
Crouse	B	No Eval.
Cruze	C	D
Cuba	B	C
Culleoka	B	D
Cyclone	B/D	D
Cygnet	B/D	D
Damascus	B/D	D
Damascus (Stark)	C/D	D
Dana	B	D
Darien	C/D	D
Darroch	B/D	D
Defiance	C/D	D
Dekalb	B	D
Del Rey	C/D	D
Del Rey Variant	C/D	D
Digby	B/D	D
Digby (till substr) (Wood)	C/D	D
Digby Variant (Auglaize, Putnam)	C/D	D
Dixboro	B/D	D
Doles	C/D	D
Donnelsville	B	No Eval.
Drummer	B/D	D
Dubois	C/D	D
Dunbridge	B	D

Notes: CL = clay loam; L = loam; substr = substratum; limestne substr = limestone substratum; Dual classes in Ohio, such as A/D, B/D, C/D are given for drained or undrained condition; No Eval. = No evaluation performed.

1. Hydrologic Soil Groups (HSGs) for Ohio (for undisturbed naturally-occuring sites) were updated in 2008 and should be used rather than HSGs from earlier publications (http://www.oh.nrcs.usda.gov/technical/soils/OH_hsg.pdf or contact the USDA Natural Resources Conservation Service in Columbus, Ohio). You may also utilize www.OhioERIN.com to find site specific HSG (unaltered).

Soil Map Unit Component	HSG[1]	Post-Const HSG
Duncannon	B	C
Dunham	B/D	D
Eden	D	D
Edenton	C	D
Edwards	C/D	D
Eel	B/D	D
Eel moderately deep	C/D	D
Eel Variant (Shelby)	C	No Eval.
Elba	C	D
Eldean	B	D
Elkinsville	B	D
Elliott	C/D	D
Ellsworth	C	D
Elnora	A/D	D
Endoaquents	D	D
Enoch	C	C
Ernest	C	D
Euclid	C/D	D
Fairmount	D	D
Fairmount Variant (Greene)	C	No Eval.
Fairpoint	C	D
Farmerstown	C	C
Faywood	C	D
Fincastle	C/D	D
Fitchville	C/D	D
Fitchville Variant	C/D	D
Flatrock	B/D	D
Flatrock (limestne substr)	B/D	D
Fluvaquents	D	D
Fox	B	D
Frankstown Variant	C	No Eval.
Fredericktown	B	No Eval.
Frenchtown	D	D
Fries	D	D
Fulton	C/D	D
Fulton (till substr)	C/D	D
Fulton Variant	C/D	D
Fulton (till substr)	C/D	D
Gageville	C/D	D
Galen	A/D	D
Gallia	B	C
Gallipolis	C	C
Gallman	B	C
Gasconade	D	D

Soil Map Unit Component	HSG[1]	Post-Const HSG
Gavers	C/D	D
Geeburg	D	D
Genesee	B	C
Genesee Variant (Ottawa)	C	No Eval.
Germano	B	D
Gessie	B	C
Gilford	A/D	D
Gilpin	C	D
Ginat	C/D	D
Glendora	A/D	D
Glenford	C/D	D
Glynwood	D	D
Glynwood (limestne substr) (Hancock)	C/D	D
Gosport	D	D
Granby	A/D	D
Granby (till substr)	A/D	D
Grayford	B	No Eval.
Gresham	C/D	D
Guernsey	C	D
Hackers	B	D
Haney	B	D
Hanover	C	D
Harbor	B/D	D
Harrod	C/D	D
Hartshorn	B	D
Hartshorn Variant (Monroe)	B/D	D
Haskins	C/D	D
Haubstadt	D	D
Haymond	B	C
Hayter	A	C
Hazleton	A	C
Hennepin	D	D
Henshaw	C/D	D
Henshaw Variant	C/D	D
Heverlo	C	No Eval.
Hickory	B	C
Holly	B/D	D
Holton	B/D	D
Homer	B/D	D
Homewood	C	D
Homeworth	B/D	D
Hornell	D	D
Houcktown	C/D	D
Hoytville	C/D	D

Notes: CL = clay loam; L = loam; substr = substratum; limestne substr = limestone substratum; Dual classes in Ohio, such as A/D, B/D, C/D are given for drained or undrained condition; No Eval. = No evaluation performed.

1. Hydrologic Soil Groups (HSGs) for Ohio (for undisturbed naturally-occuring sites) were updated in 2008 and should be used rather than HSGs from earlier publications (http://www.oh.nrcs.usda.gov/technical/soils/OH_hsg.pdf or contact the USDA Natural Resources Conservation Service in Columbus, Ohio). You may also utilize www.OhioERIN.com to find site specific HSG (unaltered).

Soil Map Unit Component	HSG[1]	Post-Const HSG
Hoytville Variant	C/D	D
Huntington	B	D
Hyatts	C/D	D
Ionia	B	No Eval.
Iva	C/D	D
Jenera	C/D	D
Jeneva	B	No Eval.
Jessup	C	D
Jimtown	B/D	D
Johnsburg	D	D
Joliet	D	D
Jonesboro	C	D
Jules	B	No Eval.
Kanawha	B	C
Kane	B/D	D
Keene	C	D
Kendallville	C	C
Kensington	B	C/D
Kerston	C/D	D
Kibbie	B/D	D
Killbuck	C/D	D
Kings Variant	C/D	D
Kingsville	A/D	D
Kinn	B	No Eval.
Knoxdale	B	No Eval.
Kokomo	C/D	D
Kyger	A/D	D
Lakin	A	A
Lamberjack	B/D	D
Lamson	A/D	D
Landes	A	A
Lanier	A	A
Latham	D	D
Latty	C/D	D
Latty (till substr)	C/D	D
Lawshe	D	D
Lenawee	C/D	D
Lenawee Variant	C/D	D
Leoni	A	No Eval.
Lewisburg	D	D
Library Variant	C/D	D
Libre	C	No Eval.
Licking	C	D
Lily	B	D

Soil Map Unit Component	HSG[1]	Post-Const HSG
Lindside	C	D
Linwood	B/D	D
Lippincott	B/D	D
Lobdell	C	D
Lockport	D	D
Lorain	C/D	D
Lordstown	C	D
Lorenzo	A	No Eval.
Losantville	D	D
Loudon	C	D
Loudonville	C	D
Lowell	C	D
Lucas	D	D
Lumberton	B	D
Luray	C/D	D
Luray Variant (Stark)	B/D	D
Lybrand	C	D
Lykens	C	D
Mahalasville	B/D	D
Mahoning	C/D	D
Marblehead	D	D
Marengo	B/D	D
Markland	C	D
Martinsville	B	D
Martisco	B/D	D
Martisco Variant (Logan)	C/D	D
McGary	C/D	D
McGary Variant	C/D	D
McGuffey	D	D
Mechanicsburg	B	C
Medway	C	D
Medway Variant	C	D
Medway (limestne substr)	B/D	D
Melvin	B/D	D
Mentor	B	D
Mermill	C/D	D
Mermill Variant	C/D	D
Mertz	C	C
Metamora	B/D	D
Miami	C	D
Miami Variant	C	No Eval.
Miamian	C	D
Miamian Variant	C	No Eval.
Milford	C/D	D

Notes: CL = clay loam; L = loam; substr = substratum; limestne substr = limestone substratum; Dual classes in Ohio, such as A/D, B/D, C/D are given for drained or undrained condition; No Eval. = No evaluation performed.

1. Hydrologic Soil Groups (HSGs) for Ohio (for undisturbed naturally-occuring sites) were updated in 2008 and should be used rather than HSGs from earlier publications (http://www.oh.nrcs.usda.gov/technical/soils/OH_hsg.pdf or contact the USDA Natural Resources Conservation Service in Columbus, Ohio). You may also utilize www.OhioERIN.com to find site specific HSG (unaltered).

Soil Map Unit Component	HSG[1]	Post-Const HSG
Mill	C/D	D
Millgrove	B/D	D
Millsdale	C/D	D
Milton	C	D
Milton Variant	C	No Eval.
Miner	C/D	D
Minoa	B/D	D
Mitiwanga	C/D	D
Mitiwanga Variant	D	D
Monongahela	D	D
Montgomery	C/D	D
Montgomery Variant (Pike)	D	D
Morley	D	D
Morley (limestone substr)	C	No Eval.
Morningsun	B	No Eval.
Morristown	C	C
Morrisville	C	No Eval.
Mortimer	C/D	D
Moshannon	B	D
Muck	B/D	D
Muse	C	D
Muskego	C/D	D
Muskingum	C	C
Nappanee	D	D
Negley	A	C
Neotoma	A	No Eval.
Newark	B/D	D
Newark Variant	B/D	D
Nicely	C	No Eval.
Nicholson	C	No Eval.
Nineveh	B	No Eval.
Nolin	B	D
Nolin Variant	B	No Eval.
Oakville	A	A
Ockley	B	C
Odell	C/D	D
Ogontz	B	No Eval.
Olentangy	B/D	D
Olmsted	B/D	D
Omulga	D	D
Opequon	D	D
Orrville	B/D	D
Orrville Variant (Richland)	A/D	D
Orrville Variant (Ashland)	C/D	D

Soil Map Unit Component	HSG[1]	Post-Const HSG
Oshtemo	A	A
Oshtemo (till substr)	A	C
Otego	B/D	D
Otisville	A	A
Ottokee	A	D
Ottokee (till substr)	A	No Eval.
Otwell	D	D
Pacer	B	No Eval.
Painesville	C/D	D
Pandora	C/D	D
Papakating	C/D	D
Parke	B	D
Parr	B	No Eval.
Pate	D	D
Patton	B/D	D
Patton Variant	B/D	D
Paulding	D	D
Pekin	D	D
Peoga	C/D	D
Perrin	A	No Eval.
Pewamo	C/D	D
Pewamo Variant	C/D	D
Philo	B	D
Pierpont	C	D
Pike	B	D
Pinegrove	A	A
Pinnebog	A/D	D
Piopolis	C/D	D
Plainfield	A	A
Platea	D	D
Plattville	C	No Eval.
Plumbrook	A/D	D
Pope	B	A
Princeton	B	B
Prout	C/D	D
Purdy Variant	C/D	D
Pyrmont	D	D
Ragsdale	C/D	D
Rainsboro	C	D
Rainsville	C	No Eval.
Ramsey	D	D
Randolph	C/D	D
Rarden	D	D
Raub	B/D	D

Notes: CL = clay loam; L = loam; substr = substratum; limestne substr = limestone substratum; Dual classes in Ohio, such as A/D, B/D, C/D are given for drained or undrained condition; No Eval. = No evaluation performed.

1. Hydrologic Soil Groups (HSGs) for Ohio (for undisturbed naturally-occuring sites) were updated in 2008 and should be used rather than HSGs from earlier publications (http://www.oh.nrcs.usda.gov/technical/soils/OH_hsg.pdf or contact the USDA Natural Resources Conservation Service in Columbus, Ohio). You may also utilize www.OhioERIN.com to find site specific HSG (unaltered).

Soil Map Unit Component	HSG[1]	Post-Const HSG
Ravenna	D	D
Rawson	D	D
Red Hook	B/D	D
Reesville	B/D	D
Remsen	D	D
Rensselaer	B/D	D
Rensselaer (till substr)	B/D	D
Richland	B	D
Riddles	B	C
Rigley	A	A
Rigley Variant	A	No Eval.
Rimer	A/D	D
Rimer (deep phase)	A/D	D
Risingsun	C/D	D
Ritchey	D	D
Rittman	D	D
Rockmill	B/D	D
Rodman	A	A
Rollersville	C/D	D
Romeo	D	D
Roselms	D	D
Ross	B	C
Ross Variant	D	D
Rossburg	B	D
Rossmoyne	C	D
Roundhead	C/D	D
Rush	B	D
Russell	B	D
Russell (bedrock substr)	B	No Eval.
Sandusky	B/D	D
Sarahsville	D	D
Saranac	C/D	D
Sardinia	B	D
Savona	B/D	D
Saylesville	C	D
Schaffenaker	A	D
Schaffer	C/D	D
Scioto	B	No Eval.
Sciotoville	C	D
Sebring	C/D	D
Sebring Variant	C/D	D
Secondcreek	C/D	D
Sees	C	D
Senecaville	C/D	D

Soil Map Unit Component	HSG[1]	Post-Const HSG
Seward	A	D
Sewell	A	No Eval.
Shawtown	B	No Eval.
Sheffield	D	D
Shelocta	B	D
Shinrock	C	D
Shinrock Variant (Henry)	C/D	D
Shinrock (till substr)	C/D	D
Shoals	B/D	D
Shoals (mod deep)	C/D	D
Shoals Variant	C/D	D
Sisson	B	D
Skidmore	A	C
Skidmore Variant	A	No Eval.
Sleeth	B/D	D
Sligo	B	No Eval.
Sloan	B/D	D
Sloan (mod deep)	B/D	D
Sloan Variant	B/D	D
Sloan (limestone substr)	B/D	D
Smothers	C/D	D
Spargus	B	No Eval.
Sparta	A	No Eval.
Spinks	A	A
Spinks (deep to limestone)	A	No Eval.
St. Clair	D	D
Stafford	A/D	D
Stanhope	B/D	D
Steinsburg	B	D
Stendal	B/D	D
Stone	C/D	D
Stonelick	A	B
Strawn	D	D
Stringley	A	No Eval.
Sugarvalley	B/D	D
Summitville	C	D
Swanton	B/D	D
Switzerland	B	No Eval.
Taggart	C/D	D
Tarhollow	C	D
Tarlton	C	No Eval.
Tedrow	A/D	D
Tedrow (till substr) (Wood)	C/D	D
Teegarden	C/D	D

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1. Hydrologic Soil Groups (HSGs) for Ohio (for undisturbed naturally-occuring sites) were updated in 2008 and should be used rather than HSGs from earlier publications (http://www.oh.nrcs.usda.gov/technical/soils/OH_hsg.pdf or contact the USDA Natural Resources Conservation Service in Columbus, Ohio). You may also utilize www.OhioERIN.com to find site specific HSG (unaltered).

Soil Map Unit Component	HSG[1]	Post-Const HSG
Thackery	B	D
Thackery Variant	B	No Eval.
Thackery (till substr)	B/D	D
Thrifton	D	D
Tiderishi	C/D	D
Tilsit	D	D
Tioga	A	C
Tioga variant (Cuyahoga)	A	No Eval.
Tioga variant (Lake)	B	No Eval.
Tippecanoe	B	D
Tiro	C/D	D
Titusville	D	D
Toledo	C/D	D
Towerville	C/D	D
Trappist	C	D
Treaty	B/D	D
Tremont	C	D
Trumbull	D	D
Tuscarawas	C	No Eval.
Tuscola	C	D
Tuscola Variant	C	No Eval.
Tygart	C/D	D
Tyler	D	D
Tyner	A	A
Tyner Variant	A	No Eval.
Typic Udorthents	C	No Eval.
Uniontown	C	D
Upshur	C	D
Valley	D	D
Vandalia	C	D
Vandergrift	C/D	D
Vanlue	C/D	D
Vaughnsville	C	D
Venango	C/D	D
Vincent	C	D
Wabasha	C/D	D
Wabasha Variant	D	D
Wadsworth	D	D
Wadsworth Variant	D	D
Wakeland	B	No Eval.
Wakeman	B	No Eval.
Wallkill	B/D	D
Wallkill Variant	C/D	D
Wapahani	D	D

Soil Map Unit Component	HSG[1]	Post-Const HSG
Wappinger	B	No Eval.
Warners	C/D	D
Warsaw	B	C
Warsaw Variant	B	No Eval.
Watertown	A	A
Waupecan	B	No Eval.
Wauseon	A/D	D
Wauseon (deep to till)	A/D	D
Wayland	C/D	D
Waynetown	B/D	D
Wea	B	B
Wea Variant	B	No Eval.
Weikert	D	D
Weinbach	D	D
Wellston	B	D
Wernock	C	No Eval.
Wernock Variant	C	No Eval.
Westboro	C/D	D
Westgate	C	D
Westland	B/D	D
Westmore	C	D
Westmoreland	B	C
Wetzel	C/D	D
Weyers	A/D	D
Wharton	C	D
Wheeling	B	C
Whitaker	B/D	D
Wick	B/D	D
Wilbur	B	No Eval.
Willette	C/D	D
Williamsburg	B	C
Wilmer Variant	C	No Eval.
Woodsfield	C	C
Woolper	C	No Eval.
Wooster	C	D
Wyatt	D	D
Wynn	C	D
Xenia	C	D
Zanesville	C	D
Zepernick	B/D	D
Zipp	C/D	D
Zurich	C	No Eval.

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1. Hydrologic Soil Groups (HSGs) for Ohio (for undisturbed naturally-occuring sites) were updated in 2008 and should be used rather than HSGs from earlier publications (http://www.oh.nrcs.usda.gov/technical/soils/OH_hsg.pdf or contact the USDA Natural Resources Conservation Service in Columbus, Ohio). You may also utilize www.OhioERIN.com to find site specific HSG (unaltered).

Hydrologic Soil Groups for Post-construction Soils

Overview

Hydrologic soil groups were created as a simple means to categorize inherent soil runoff potential and are commonly used to assign an appropriate Curve Number (CN) for hydrologic modeling purposes. Soil types have been assigned to hydrologic soil groups (HSG) in soil survey publications. In Ohio the HSGs are based on undisturbed, naturally occurring soils in an agricultural field or woodland setting. Soils properties at development sites are often changed dramatically by construction practices. Topsoil is removed, soil profiles are truncated or covered by grading activities, and exposed surfaces are compacted by heavy equipment traffic. The runoff potential is significantly impacted by these changes to the soil. This project predicts changes to HSG for soils that are altered by standard construction practices by applying the HSG criteria to modeled post-construction soil profiles.

Data for soil horizons from the USDA National Soil Information System (NASIS[1]) database were used to represent pre-construction profiles. From soil series with HSG = A, B or C, 150 soil series of significant extent in Ohio were selected for evaluation. A representative component was selected from official data sets for each series from commonly occurring map units. The standard construction practices were defined as: the removal of 18 inches of soil material from the top of the soil profile and the compaction of the zone from 0 to 6 inches at the new surface. To mirror the impact of the construction practices, layer depths in the component soil moisture table data were adjusted to reflect the removal of 18 inches (46 cm.) of soil. Similar adjustments were made to layer depths for the component soil moisture (water table) table and the component restrictions (impermeable layers) table. At the new surface, the top 6-inch (15 cm.) layer was modified in the component horizon table to show changes in infiltration caused by compaction at the surface. The USDA SPAW[2] tool was used to populate infiltration rates for the compacted soils utilizing pedon transfer functions. A report generator in NASIS was programmed to assign HSG criteria to each component. A comparison of the model's pre-construction to post-construction HSG values showed that most soils are downgraded by 1 or 2 HSG classes as a result of standard construction practices.

Methods

To calculate post-construction HSG, standard construction practices were defined as: the removal of 18 inches of soil material from the top of the soil profile and the compaction of the zone from 0 to 6 inches at the new surface.

In 2008, USDA-NRCS soil scientists in Ohio revised the HSG assigned to soil map unit data in their NASIS database. HSG were revised because of changes to Part 630 Chapter 7 of the National Engineering Handbook. Criteria for assignment of HSG was revised in Chapter 7. The published data had been compiled from manual calculations of soil profile data for each map unit. The previously published HSGs were computed on a component (soil series) basis, with representative groups based on the series typical pedon description and Soil Interpretation Record (old Soil 5 form) depths. For the revi-

1 Information regarding the USDA National Soil Information System (NASIS) database is available at http://soils.usda.gov/technical/nasis/index.html.

2 SPAW is a daily hydrologic budget model for agricultural fields and ponds developed by Dr. Keith Saxton, USDA-ARS (retired). This model includes a Soil Water Characteristics Hydraulic Properties Calculator, a program developed by Saxton and Dr. Walter Rawls USDA-ARS (retired) that can be used to estimate soil water tension, conductivity and water holding capability based on soil texture, organic matter, gravel content, salinity, and compaction. The model is available at: http://hydrolab.arsusda.gov/SPAW/Index.htm (site last updated on Oct 29, 2009).

sion, they used a report generator that calculated HSGs from published soil layer data. A large number of map units had different groups when calculated with the report generator than what had been published in the official data set. The report generator, which uses the criteria from Chapter 7 of Part 630 NEH, is run on soil map units, not components (series). Because of variation in depth to restrictive features, similar map units could receive different HSG by using the report generator. The differences in HSGs were due to changes in criteria in addition to variations between map units of the same component. In 2008 and 2009, NRCS edited their official data to show the revised HSG values. From the revised HSG values, soil components (series) with HSG = A, B or C, 150 soil series of significant extent in Ohio were selected for evaluation.

Soil component data is published by county soil survey areas in Ohio. To reflect regional variations in soil properties for a single named component, each county's component data set is unique for the occurrence of that soil type in that county – and in some counties, the component data is unique for each occurrence in a map unit. For a single component soil type named, the statewide database may contain a few, several or many unique data sets. An effort was made to select a representative component data set for each component by reviewing map unit characteristics. Map unit extent and distribution was evaluated. Preference was given to map units with larger acreage and to map units centrally located to the geographic distribution.

Layer depths in the component horizon (CH) table data were adjusted to reflect the removal of 18 inches (46 cm.) of soil. Any layer where bottom depth is less than or equal to 46 cm was deleted. Any layer where the bottom depth was greater than 46 cm and the top depth was less than 46 cm, the top depth was set at 0 cm. and 46 cm. was subtracted from the bottom depth. If the resulting layer was less than 6 cm. thick, it was deleted and the top depth of the next lowest layer was set at 0 cm. Where top depth greater than 46 cm, 46 cm was subtracted from both top and bottom depth.

The depth of two soil features that influence HSG are tracked independently of the CH table: soil water tables and soil restrictive features. Depth to soil water tables is stored in the component soil moisture (CSM) table and depth to restrictive features is stored in the component restrictions (CR) table. In both tables, top and bottom layer depths for all layers were edited by subtracting 46 cm, and values less than 0 cm edited as 0 cm.

Layer depths and Ksat values in the CH table data were adjusted to reflect creation of a 6 in. (15 cm.) zone of compacted surface during construction. If the thickness of the surface layer of the cut-soil was less than or equal to 25 cm the entire layer was used to represent the compacted zone. If it was greater than 25 cm, the upper 15 cm was replicated and modified to show compaction. The surface layer of the cut soil was copied and pasted above the original layer. The depths of the pasted layer were set at top equal to 0 cm and bottom equal to 15 cm. The top depth for the copied layer was set at top equal to 15 cm.

The USDA-ARS pedon transfer function tool 'SPAW' was used to calculate the Ksat values for the compacted surface. Ksat low range values were calculated using high clay percent and low sand percent and gravel percent; and conversely Ksat high values were calculated using low clay percent and high sand and gravel percent. Organic matter and salinity were assumed to be 0 percent. The compaction level was set at 'dense' resulting in a 110 percent compaction value.

Data used in the post-construction calculations for HSG values can be viewed in NASIS.

Load data from Area Type equal to Ohio Urban; Area equal to Ohio Urban Land; and Area Symbol equal to OHUL. Legend status equal to 'non-project'. An edit setup in the MO13 directory named "Marietta Urban" was created to view layer data that was edited in the post-construction data map units. The standard report named "EXPORT HSG data;" in the MO11 Directory was used to generate HSGs.)

Site Data

As a companion project to the development of the post-construction data set for NASIS, ODNR-DSWC soil scientist planned to gather soil profile descriptions for post-construction soils. The goal was to see how accurately the standard construction practices, as defined in our model (the removal of 18 inches of soil material from the top of the soil profile and the compaction of the zone from 0 to 6 inches at the new surface), matched actual site data gathered from the field.

Urban sites and soil types were identified for sampling. In the field, site disturbances from construction practices were verified and profile descriptions were taken from small hand-dug pits. When site conditions permitted, adjacent, undisturbed soils were also described. The extent of sampling was curtailed by staff reductions that occurred during the project.

From 13 sites, 24 profile descriptions were collected: 14 descriptions were classified as 'post-construction' and the remaining 10 descriptions were natural soils adjacent to the construction sites. The post-construction soils were judged to be cut profiles at 4 sites; fill profiles at 9 sites and 1 site was undetermined. Compaction was evaluated at the sites with a hand held penetrometer and by physical observations. At most sites compaction was rated severe in at least one horizon. The compacted horizon was not always the surface horizon.

Appendix 10: Alternative Pre-treatment Options for Dry Extended Detention Ponds - Rationale and Expectations

Research has shown that of the various mainstream stormwater BMPs (wet ponds, dry ponds, media filters, bioretention, wetlands), the suspended solids removal efficiency of dry ponds is the lowest or worst. The National Pollutant Removal Performance Database for Stormwater Treatment Practice, 2nd Edition (Center for Watershed Protection, 2000) reports the median TSS removal efficiencies for end-of-pipe controls as shown in the table below. Because of their poor water quality performance, several states no longer allow the use of dry ponds.

BMP	Median TSS Removal (%)
Dry Pond	47
Wet Pond	80
Stormwater Wetland	76
Filtering Practices	86
Infiltration Practices	95

Table 1. Median total suspended solids removal efficiences (CWP, 2000).

Ohio EPA has been interested in providing the most flexibility/options to the site designer but, with a 80% TSS removal target, the traditional dry pond designs fall short. Forebays have been shown to be effective pretreatment for all types of end-of-the-pipe stormwater BMPs, improving performance numbers significantly. A WinSLAMM (Source Loading And Management Model) analysis using solely the required 0.1*WQv volume would allow a wet pool forebay to remove upwards of 50% of the annual TSS load from most development types. Needless to say, such a forebay would significantly improve the water quality performance of dry basins.

Ohio EPA and ODNR-DSWR recognize there may be sites where, because of concerns about standing water (e.g. for safety reasons), the designer needs alternatives to a dry basin having wet pool forebays and micropools.

Figure 1. "Dry" extended detention pond with a forebay and a micropool (near the dam and the outlet).

First, the designer should consider whether the WQv requirement can be met through the use of other structural BMPs such as bioretention, enhanced swales, and/ or pervious pavement. Bioretention and enhanced swales pond water only briefly and shallowly, and would not create the same perceived threat as wet forebays and micropools. Pervious pavement does not pond water. If these BMP alternatives can be used to meet the WQv requirement, a dry basin without permanent pools can still be used to meet local peak discharge requirements.

A site can usually be divided into smaller drainage areas for WQv requirements. Bioretention works extremely well for small drainage areas, and often parking lot islands or landscape requirements may offer the needed locations/ area. If these BMP alternatives are deemed unsuitable for the site, the alternative dry basin design used to meet the WQv requirement must show performance and maintainability equivalent to a dry basin with forebay and micropool. The key considerations to address would be:

- pretreatment of runoff such that 50% of the annual TSS load is removed before discharge enters the dry basin;
- the outlet design allows for long-term function of the extended detention volume with minimal maintenance and oversight.

Pretreatment Options

> **Both filter strips and grass channels provide "biofiltering" of stormwater runoff as it flows across the grass surface. However, by themselves these controls cannot the 80% TSS removal performance goal. Consequently, both filter strips and grass channels should only be used as pretreatment measure or as part of a treatment train approach.**
>
> **(*Georgia Stormwater Management Manual*, Page 3.1-3)**

Water quality pre-treatment is provided through practices that slow, spread, filter and/or infiltrate water along its flow path. The needed level of pretreatment can be attained by using a "treatment train" approach, i.e., combining practices such as impervious area disconnection, grass filter strips, and grass swales. Another strategy is to focus these practices on treating runoff from pollutant hot spots such as parking areas driveways and roads. Our observations suggest these opportunities exist on almost every site, in-spite of the engineer's or developer's initial concerns about space limitations.

Preliminary parking lot runoff modeling results using WinSLAMM show that disconnecting the parking lot from the storm sewer system (i.e., placing all storm drain inlets in vegetated/ grassed collection areas with a minimum 15 ft travel distance from the parking lot) reduce both the annual runoff volume and load of total particulate solids by about 25%[1].

Figure 2. Disconnecting parking and storm sewers in order to reduce pollutant loads.

Grass swales can be designed to remove upwards of 50% of total solids. To provide the desired water qual depths and residence times for the water quality event, and maintaining flow velocities that prevent erosion and resuspension.

Guidance for these practices is available in the Rainwater and Land Development Manual. In addition, the Iowa Stormwater Manual provides more detailed calculations for sizing/ designing filter strips (Section 21-4) and grass swales (Section 21-2) to meet water quality targets. The Georgia Stormwater Manual and Lake County, Ohio, Swale Guidance are other useful design references.

One alternative is to incorporate the pretreatment options noted above into the design of the basin itself. The resulting basin will look more like a low, wide swale than the traditional deep-sided detention basin, and can often times be incorporated into the lawn and landscaping of the site (see photo).

Figure 3. Disconnecting parking and storm sewers in order to reduce pollutant loads.

1 WinSLAMM, Dayton 1991 rainfall, 1 Ac parking lot, clay soil

For in-basin pre-treatment, the minimum requirements allow waiving of the requirements:

- flow length that would minimum residence time of 5 minutes above the top of the WQv (see the figure below)
- max flow depth of 4” (0.33 ft)
- use manning’s n=0.15
- for HSG C&D soils, an under drain should be used to help maintain appearance and function
- designs should ensure stability (i.e., maintain flows less than max velocity) for soil, grass mix and method of establishment
- storm drain outfalls should be properly designed for stability and energy dissipation.

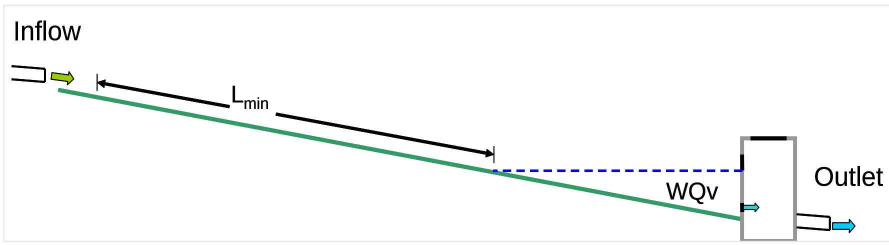

Figure 4. Alternative vegetative pre-treatment requires a flow length that allows a minimum of 5 minutes residence time above the water quality volume.

Outlet Protection

Incorporating a permanent micropool into a dry basin design allows the use of a reverse slope outlet pipe in addition to enhanced water quality treatment,. The advantage of the reverse slope pipe is that it moves the pipe entrance below the water surface protecting it from floatable debris (bottles, bags, styrofoam, leaves, etc.) that commonly blocks small (less than 4”) outlet openings at the water surface (see photos).

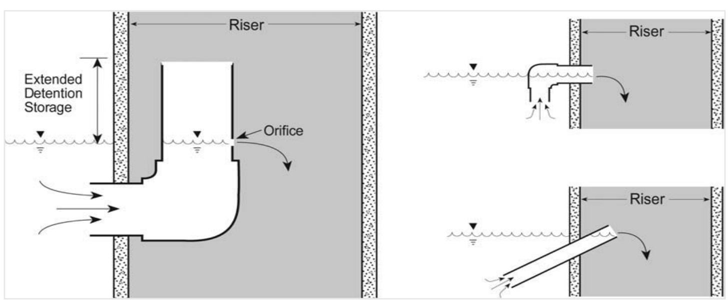

Figure 5. Reverse Slope Outlets


Figure 6. Unprotected Dry Basin Outlets

When eliminating the micropool from a WQv dry basin design, an alternative protected outlet design must be used. The protection comes from removing the controlling orifice inside the catch basin, and using a perforated lateral (or riser) and gravel filter to block any floatable materials (see the figure and photo).

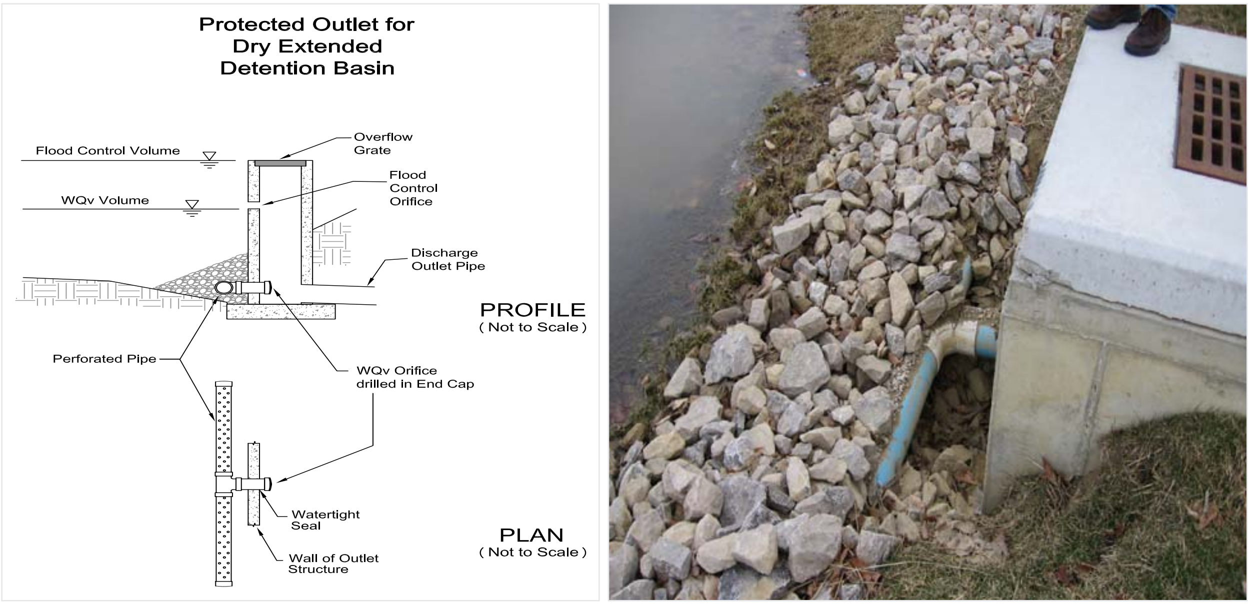

Figure 7. Protected Basin Outlets

Conclusion/Recommendation

There may be situations where a dry basin with: permanent pool forebay and micropool is not an option. In these situations, the designer should first consider alternative BMPs (bioretention, enhanced swales and/ or pervious pavement) for meetjng the WQv requirement.

Pre-treatment and outlet protection options are available that will provide equivalent performance to forebays and micropools. The designer must follow guidance to ensure that performance and maintenance goals are met.

Reference

Biohabitats. 2006. Swale Guidance, Lake County Stormwater Management Department.

CTRE. 2008. Iowa Stormwater Management Manual. Center for Transportation Research and Education, Iowa State University, Ames.

CWP. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practice, 2nd Edition. Center for Watershed Protection, Ellicott City, MD.

Haubner, S. (Editor). 2001. Georgia Stormwater Management Manual, Volume 2 - Technical Handbook. Atlanta Regional Commission.

Appendix 11: Critical Storm Method

The Critical Storm Method is a criteria recommended for controlling the peak discharge of stormwater from larger storm events (1 - 100 yr recurrence interval). It is recommended to protect property from flood damage and channel erosion, and to protect water resources from degradation resulting from accelerated stormwater flows.

In Ohio, most peak discharge control regulations reside in the requirements of a municipal, township or county government or in a stormwater . While the state of Ohio recommends the use of the Critical Storm Method for peak discharge control, actual requirements will vary according to what each community has adopted locally in conjunction with Ohio EPA NPDES permit requirements. This method has previously been included in the Ohio Stormwater Control Guidebook (ODNR, 1980), ODNR-DSWR model regulations and standards to prevent stream channel and floodplain erosion (Ohio Revised Code 1501:15-1-05).

Important Considerations

The use of this or other stormwater management criteria should assume certain conditions for adequate design, construction and continued function of stormwater management practices:

(1) Stormwater management systems must be designed for the ultimate use of the land. Areas developed for subdivisions must provide a stormwater management system for the ultimate plan of development for all of the subdivided lots.

(2) Stormwater management facilities and facilities must be designed so that they will continue to function with the least maintenance necessary.

(3) Stormwater management facilities should be designed to meet multiple objectives as much as possible. For instance pollution control, downstream channel stability, flood control, runoff reduction, and aesthetic quality are sample objectives.

(4) Stormwater management facilities and facilities shall be designed with specific regard to safety.

(5) The design criteria shall be applied to each watershed within the development area. All pre- and post-development runoff rates and volumes shall be calculated using their respective drainage divides.

The Critical Storm Method

A) In order to control pollution of public waters by soil sediment from accelerated stream channel erosion and flood plain erosion caused by accelerated stormwater runoff from development areas, the peak rates of runoff from an area after development may be no greater than the peak rates of runoff from the same area before development for all twenty-four-hour storms from one- to one-hundred-year frequency. Design and development to match the peak rate of runoff for the one, two, five, ten, twenty-five, fifty, and one-hundred year storms may be considered adequate to meet this rule.

(B)

(1) If the volume of runoff from an area after development will be greater than the volume of runoff from the same area before development, it shall be compensated by reducing the peak rate of runoff from the critical storm and all more-frequent storms occurring on the development area to the peak rate of runoff from a one-year frequency, twenty-four-hour storm occurring on the same area under predevelopment conditions. Storms of less-frequent occurrence (longer return periods) than the critical storm up to the one-hundred-year storm shall have peak runoff rates no greater than the peak runoff rates from equivalent size storms under predevelopment conditions.

(2) The critical storm for a specific development area is determined as follows:

(a) Determine the total volume of runoff from a one-year frequency, twenty-four-hour storm, occurring on the development area before and after development.

(b) From the volumes in paragraph (B)(2)(a) of this rule, determine the per cent of increase in volume of runoff due to development and, using this percentage, select the critical storm from this table:

If the percent of increase in runoff volume is		The critical storm for peak rate control will be
equal to or greater than	and less than	
-	10	1 year
10	20	2 year
20	50	5 year
50	100	10 year
100	250	25 year
250	500	50 year
500	-	100 year

Table 1-1 Critical storm determination using percent of increase in runoff volume.

(C) Methods for controlling increases in stormwater runoff peaks and volumes may include but are not limited to:

(1) Retarding flow velocities by increasing friction; for example, grassed road ditches rather than paved street gutters where practical, discharging roof water to vegetated areas, or grass and rock-lined drainage channels.

(2) Grading and use of grade control structure to provide a level of control in flow paths and stream gradients.

(3) Induced infiltration of increased stormwater runoff into the soil where practical; for example, constructing special infiltration areas where soils are suitable, retaining topsoil for all areas to be vegetated, or providing good infiltration areas with proper emergency overflow facilities.

(4) Provisions for detention and retention; for example, permanent ponds and lakes with stormwater basins provided with proper drainage, multiple-use areas for stormwater detention and recreation, wildlife, or transportation, or subsurface storage areas.

Reference: Goettemoeller, R.L., D.P. Hanselmann, and J.H. Bassett. 1980. Ohio Stormwater Control Guidebook. Ohio Department of Natural Resources, Division of Soil and Water Districts, Columbus. http://www.dnr.state.oh.us/soilandwater/water/urbanstormwater/default/tabid/9190/Default.aspx