Post-Construction Q&A Document

Ohio EPA
Division of Surface Water

RE: Guidance Regarding Post-Construction Storm Water Management Requirements of Ohio EPA's Storm Water Construction General Permit #OHC000002

Date: March 20, 2007

On April 21, 2003, Ohio EPA renewed the storm water NPDES Construction General Permit (CGP). The new CGP contains requirements for post-construction Best Management Practices (BMPs) on all sites where the larger common plan of development or sale calls for 1 or more acres of land disturbance. Since the renewal of the CGP, Ohio EPA has received a number of questions regarding the requirements. It is the intention of this document to clarify and provide guidance regarding those requirements.

1. When are post-construction BMPs required?

Post-construction BMPs are required on all sites where the larger common plan of development or sale calls for 1 or more acres of land disturbance except:

(1) Linear projects that do not create impervious surfaces (e.g., installation of a gas pipeline), or
(2) Road construction projects by public entities where construction activities are initiated prior to March 10, 2006.

The exemption for public road projects is not automatic. Part III.G.2.e of the CGP states that post-construction BMPs must be implemented on these projects as of April 21, 2003, where practicable (see Question 2).

All other projects are subject to these requirements at this time and must include post-construction BMPs in the Storm Water Pollution Prevention Plan (SWP3).

2. How do I determine if a public transportation project is exempt from post-construction requirements prior to March 10, 2006?

Since many public transportation projects have been financed and planned years in advance of the CGP renewal (OHC000002), additional time has been provided for public transportation projects to include post-construction BMPs that comply with the requirements of Part III.G.2.e of the CGP. Public transportation projects often involve unique planning challenges, such as the use of eminent domain and obtaining easements. Therefore, public entities (i.e., the State of Ohio, counties, townships, cities or villages) shall comply with the post-construction storm water management requirements of Part III.G.2.e on roadway construction projects initiated after March 10, 2006, and where practicable for projects initiated as of the effective date of the CGP and thereafter. Ohio EPA considers "where practicable" to mean that if financing and planning for the public road projects occur after

April 21, 2003 (the effective date of the CGP renewal), then structural post-construction BMPs which comply with the design parameters set forth in the CGP renewal must be included. If any of the following planning issues were finalized by April 21, 2003, the project will be granted the exemption where construction starts prior to March 10, 2006: (a) final approval of detail drawings by relevant agencies has occurred, (b) drainage easements have been obtained, (c) eminent domain hearings have been held (where applicable), or (d) plat and deed changes have been recorded. The SWP3 for these projects shall include a statement as to why the permittee feels the exemption is applicable.

Non-road construction projects by public entities, e.g., developing a highway rest area, maintenance facility, recreation center, or wastewater and water treatment plants, are not eligible for the exemption and are subject to post-construction BMP requirements of the CGP at this time.

3. Are non-linear projects that do not create impervious surfaces, e.g., construction of a new soccer field, exempt for the post-construction requirements?

No. Even though these projects do not typically create impervious surfaces, they do result in greater compaction of the soil than was present prior to development (Schueler 1995, Schueler 2000). Also, underdrain systems are typically installed to improve drainage from these sites. As such, more runoff will be generated within the boundaries of the project.

4. Why is Ohio EPA requiring the implementation of post-construction BMPs?

The intent of post-construction BMPs is to assure that storm water runoff from developed land does not negatively impact receiving streams, either through hydrologic impacts or pollutant discharges. Thus, traditional storm water controls which simply address the peak rate of storm water discharge from flood-producing storm events are not adequate. As land is developed, it becomes more impervious. Vegetation in open fields and forests is replaced with paved surfaces and rooftops. This results in more rainfall becoming storm water runoff. In addition, conveyance systems are installed to drain the site more efficiently resulting in storm water runoff with more energy than the runoff from undeveloped land. These hydrologic impacts, coupled with the increased concentration of pollutants contained in storm water runoff from developed land use, result in degradation of the water resources to which the storm water is discharged. The smaller the receiving stream, the greater the importance of controlling the hydrologic and subsequent hydraulic impacts of the construction project.

5. What are structural and non-structural post-construction BMPs?

Post-construction BMPs fall into one of two categories. Either they are (a) Non-Structural or (b) Structural. Non-Structural BMPs consist of preservation, planning or procedures that direct development away from water resources or limit the creation of impervious surfaces. Examples include conservation easements, riparian and wetland setbacks, rain barrels to capture and reuse storm water, breaking up the connectivity between impervious surfaces, use of permeable pavements, and conservation subdivision design (subdivisions which leave 40-50% of the land area in open space and place developed areas away from important water resources, yet still allows the same lot yield as traditional subdivision design). Structural BMPs are practices that must be built to provide treatment of storm water either through storage, filtration or infiltration. Examples include extended detention basins, bioretention cells, sand filters, vegetated filter strips, water quality swales and infiltration trenches. Low Impact Development (LID) is a design philosophy that combines both structural and non-structural BMPs (http://www.lid-stormwater.net) and is increasing in popularity.

Ohio EPA strongly encourages that all sites implement a mix of structural and non-structural post-construction BMPs. However, the CGP has not specified any non-structural BMPs which must be implemented. This was intentional, as most of these practices are controlled on the local government level. Over the next few years, communities located in urbanized areas are required to adopt strategies regarding non-structural BMPs. Ohio EPA did not want to inhibit local governments' ability to adopt non-structural BMPs most appropriate for their watersheds by setting a general requirement across the State. However, Ohio EPA has set a minimum requirement for the design of structural post-construction BMPs and requires their use on large construction projects.

If non-structural BMPs such as setbacks are to be used, it must be assured that they will remain in perpetuity. Thus, formal documentation must be recorded so that subsequent property owners are made aware of and do not alter non-structural post-construction BMPs. It should be noted that the intent of many non-structural BMPs is to change the location of development within a parcel, not its density. Also, it should be noted that by increasing the use of non-structural BMPs in site design, the size of structural post-construction BMPs will be decreased. This primarily occurs because the resulting runoff coefficient of the developed area will be lower. The use of non-structural BMPs often results in decreased initial capital investment during construction, decreased maintenance costs, enhanced aesthetics, and higher property values (NEMO 1999). In essence, implementing non-structural BMPs results in a "credit" toward structural post-construction BMP requirements.

6. Are structural post-construction BMPs only required on construction projects that disturb 5 or more acres?

No. When establishing post-construction BMP requirements, Ohio EPA did draw a distinction between small construction sites and large construction sites, however, this does not mean that structural post-construction BMPs are inappropriate for small construction sites. In fact, several structural post-construction BMPs such as sand filters, bioretention cells and infiltration trenches are designed to control drainage areas no larger than 5 acres. The distinction between "small" and "large" construction sites was made to allow more flexibility in BMP selection for small sites. Small construction sites are defined as those where the larger common plan of development or sale is from 1 to 5 acres of earth disturbance. Large construction projects are those that result in disturbances of 5 or more acres in the larger common plan of development or sale. Structural post-construction BMPs are required on all large construction projects and will also be used on most small construction projects as well (see Question 14).

7. What is the Water Quality Volume (WQv) and how did Ohio EPA determine how to calculate it?

The term "water quality volume" is generally used to define the amount of storm water runoff from any given storm that should be captured and treated in order to remove a majority of storm water pollutants on an average annual basis. Calculation of the WQv is based on findings that a detention basin had to be designed to empty out a volume equal to the average runoff event's volume in no less than 24 hours to be an effective storm water quality enhancement facility (Roesner et al., 1991). In later studies, this was refined to determine a "maximized capture volume" where capture of larger storm events does not significantly result in greater pollutant removal (Urbonas and Stahre, 1993). In determining the "maximized capture volume" for the State of Ohio, Ohio EPA followed the guidelines provided in the American Society of Civil Engineers (ASCE) Manual and Report on Engineering Practice No. 87 and Water Environment Federation (WEF) Manual of Practice No. 23 titled ***Urban Runoff Quality Management***. Long-term analysis of rainfall data indicates that 85% of storm events in Ohio result in a rainfall of 0.50 inches or less. Multiplying this amount by 1.5 (which represents a mid-range regression coefficient for maximizing storm event and volume capture) results in 0.75 being used as the rainfall depth (see pages 175-178 of the ASCE manual). As defined in Ohio, the WQv results in the capture and treatment of the entire volume for 85% of the average annual storm events. Ohio EPA and the Ohio Department of Natural Resources felt that this was a sufficient precipitation depth to control pollutants in runoff, but also minimize channel and stream bank erosion due to runoff from developed areas.

8. How did Ohio EPA determine the target drain down times contained in Table 2, Part III.G.2.e of the NPDES permit?

Target drain down times were based on information from the WEF Manual of Practice No. 23 and ASCE Manual and Report on Engineering Practice No. 87 ***Urban Runoff Quality Management*** along with specific design guidelines from this manual about the various BMPs. The intent of the drawdown time is to:

(1) Allow quiescent conditions to occur following most storms
(2) Provide adequate time for the pollutant removal mechanism of the BMP to occur (e.g., settling, filtering or biodegradation)
(3) Distribute the energy of the increased flow across a longer period of time, reducing erosion forces on the stream bed and bank
(4) Make sure the above three conditions are achieved for all precipitation events up to and including those that generate the WQv. A lesser degree of treatment will also be provided for runoff volumes that exceed the WQv.

(5) Provide sufficient available capacity for subsequent storm events.
(6) Avoid the creation of nuisance conditions.

When combined with the WQv criteria, the target drawdown times in the CGP will provide hydrologic control and pollutant removal from the majority of storm events without creating adverse impacts.

9. Will these prolonged drawdown times inadvertently result in structures that will promote mosquito breeding habitat?

No. The mosquito life cycle consists of four stages: egg, larvae, pupa, adult. Mosquitos must lay their eggs in stagnant water or wet soils that will soon be flooded. It takes 24 to 48 hours for the larvae to emerge from the eggs. The larvae and pupa must have stagnant water in order to survive and reach the adult stage. Studies indicate that this takes 5 to 18 days to occur (Floore, 2002). Properly designed and constructed structural post-construction BMPs are not designed to hold water for longer than 48 hours. In addition, the water within these structures is rarely stagnant. Even in ponds with a permanent pool of water, the habitat which establishes within these structures is not conducive to breeding encephalitis-type mosquitos and provides a number of natural predators of such insects.

According to these studies, it is essential to maintain BMPs so that vegetation, silt and debris, not accumulate because they can contribute to standing water sitting in the practice for longer than 72 hours (Deatrich and Brown, 2002). Thus, a strong long-term maintenance program is needed to assure that post-construction BMPs do not become a breeding habitat for mosquitos. In addition, there are measures that can be taken when designing BMPs with permanent pools of water to minimize mosquito production. In the paper by Deatrich and Brown, when designing extended detention basins with micropools they recommend to:

(1) Avoid shallow depths in micropools. Depths should be sufficient to prevent the growth of wetland vegetation;
(2) Provide steep slopes to micropool banks;
(3) Consider mechanical aeration of permanent pools;
(4) Make the micropool accessible to remove silt and vegetation and to maintain the outlet structure;
(5) Make the micropool accessible to treat with larvicide, if it becomes necessary; and
(6) Avoid rock at the outlet structure (within the basin).

Further, they urge that an inspection of the BMP be performed to assure that it has been built per plan. They noted that in their study of structural BMPs in Colorado, small design details that are critical to the performance and function of the BMP were often overlooked by the contractor.

10. What are the minimum requirements for designing structural post-construction BMPs?

Developers must anticipate the potential impact of the site on downstream resources, particularly impacts such as increased frequency and energy of runoff and pollutant delivery. In addition, BMPs must ensure compliance with Ohio's Water Quality Standards contained in Ohio Administrative Code (OAC) 3745-1. Ohio EPA believes that these requirements will be met if structural post-construction BMPs are designed to treat the Water Quality Volume (WQv) by detaining it for 24 to 48 hours (depending on the BMP selected). As such, these criteria should generally be applied to all development sites, regardless of size.

On large construction sites (see Question 6 for definition), treatment practices must be designed per these criteria. Structural BMPs are to be incorporated into the permanent drainage system of the site. Ohio EPA intends treatment to be provided for the entire developed (disturbed) area. Structural BMPs that can be designed to meet these requirements and that are suitable for use in Ohio are listed in Table 2 Part III.G.2.e of the CGP. A growing body of research has shown that as long as these BMPs are properly selected, sited, designed, constructed and maintained, they are capable of:

(1) Capturing and treating the design WQv;

(2) Removing at least 80% of the average annual total suspended solids (TSS) load and floatable debris, including oil and petroleum products, either alone or in combination with pretreatment; and

(3) Acceptable performance or operational longevity in the field.

(NYDEC, 2001; MD 2000; Connecticut 2004). These performance standards assume that the BMPs are properly selected, designed, constructed and maintained. By and large, the BMPs listed in Table 2 Part III.G.2.e of the CGP provide treatment of runoff by settling suspended solids. TSS is selected as a suitable target pollutant because many other pollutants including heavy metals, bacteria and organic chemicals adsorb to sediment particles. Thus, removing the suspended solids also removes these pollutants. Where dissolved pollutants are a primary concern, BMPs that provide biological absorption should be selected. These include constructed wetlands with extended detention and bioretention cells. Infiltration trenches may also be suitable where contamination of ground water is not a concern.

For small construction sites (see Question 6 for definition), Ohio EPA has not specified the design parameters for structural post-construction BMPs. In part, this was due to the need for greater flexibility in BMP selection. From a practical standpoint, the orifice or weir size required to provide extended detention of the WQv on sites where less than 1 acre of impervious area is created may be too small to effectively operate without clogging. In addition, space constraints on small sites (and redevelopment sites, which often are small construction sites) limit the available land area for such practices. These factors may require the use of BMPs other than those listed in Table 2. But, if a designer has selected a BMP listed in Table 2 for use on a small construction site, it should be designed per the same criteria used on a large construction site to assure proper operation.

Please note that the requirement to provide a structural BMP capable of treating the WQv can apply to parcels less than 5 acres in size if that parcel is part of a larger common plan of development or sale where, cumulatively, 5 or more acres is disturbed. An example of this situation would be an outparcel for a bank or restaurant at a commercial shopping center. Although Ohio EPA would prefer that post-construction BMPs for the outparcels be provided within the larger development, controls can be provided on each outparcel separately. However, where construction on such a parcel occurs within a development that was completed prior to March 10, 2003, then the outparcel site is considered a separate construction activity, apart from the shopping center, and would qualify as a small construction site if the disturbance is less than 5 acres. Another example is a multi-phased development where greater than 5 acres of land is purchased, rezoned and/or replatted. Even though each plat may be less than 5 acres and the operator applies for separate NPDES permit coverage for each plat, the "larger common plan" exceeds 5 acres. Therefore, the post-construction requirement for large construction activity applies.

11. Does Ohio EPA allow the use of alternative structural BMPs not listed in Table 2 in Part III.G.2.e of the CGP?

BMPs listed in Table 2 have proven track records and have been approved for general use throughout the country. The CGP requires permittees to request approval from Ohio EPA if a structural BMP not listed in Table 2 is selected. Ohio EPA is reviewing these requests on a site-by-site basis. Because post-construction BMPs are a key component of SWP3s, and SWP3s are required to be complete and ready to implement upon submittal of a Notice of Intent (NOI) permit application, approval to use alternative BMPs on large construction sites (see Question 6 for definition) must be obtained from Ohio EPA prior to submitting an NOI. Local governments may request verification from the developers that Ohio EPA has approved alternative controls.

The CGP allows the use of alternative BMPs as long as they are of equivalent effectiveness to the BMPs listed in Table 2. To be of equivalent effectiveness, BMPs must be capable of meeting the intent of the post-construction requirements of the CGP, namely (a) prevent hydrologic impacts to the receiving water(s) and (b) minimize the discharge of pollutants contained in storm water runoff. Alternative BMPs should only be considered after the permittee has demonstrated to Ohio EPA that the BMPs listed in Table 2 are infeasible. To demonstrate that standard practices are infeasible, practical limitations related to physical site constraints or the inability to provide a functional design for the BMPs listed in Table 2 must be documented. Use of alternative BMPs because they allow for a more convenient design is not considered sufficient reason to determine that the BMPs listed in Table 2 are infeasible.

Most alternative BMPs are not suitable as stand-alone treatment because they either are not capable of meeting the water quality treatment performance criteria or have not yet received the thorough evaluation needed to demonstrate the capabilities of meeting the performance criteria. Other concerns regarding alternative practices include lack of field longevity or greater maintenance requirements. These practices have the potential to discharge highly concentrated pollutants if not properly maintained and may, themselves, need authorization under a separate NPDES permit. Perhaps the best use of alternative practices is that as a pretreatment device or supplemental treatment in conjunction with those practices listed in Table 2, or to achieve other objectives such as ground water recharge and peak runoff attenuation.

Ohio EPA may approve the use of alternative BMPs in the following scenarios:

(1) They are proposed for use on small construction sites;

(2) They are proposed for use on redevelopment sites where justification has been provided that a BMP listed in Table 2 is infeasible due to physical site constraints; or

(3) They are proposed on new development sites where hydrologic impacts to the receiving water are negligible (see Question 12).

In all other scenarios, Ohio EPA will require the use of the BMPs listed in Table 2 or require the permittee to demonstrate that the alternative BMP meets the intent of the CGP.

Ohio EPA recommends those wishing to demonstrate equivalent effectiveness of an alternative BMP to follow the protocol outlined in the Technology Acceptance Reciprocity Partnership's (TARP) *Protocol for Stormwater Best Management Practice Demonstrations.* See www.dep.state.pa.us/dep/deputate/pollprev/techservices/tarp/. This protocol has been developed to provide a uniform method of demonstrating storm water technologies and developing test quality assurance plans for verification of performance claims. Endorsed by the states of California, Massachusetts, Maryland, New Jersey, Pennsylvania and Virginia, Ohio EPA believes the use of this protocol will provide credible data for innovative technologies, facilitate evaluation and clarify selection options for regulated entities.

When alternative BMPs are approved, Ohio EPA will expect that a maintenance plan will be provided to the future owners or operators of the site using the BMP. Also, Ohio EPA may require discharges from such structures to be sampled and monitored to ensure compliance with Part III.G.2.e of the CGP.

The following table provides a list of BMPs that Ohio EPA considers to be alternative practices. The table provides a reason why these practices are of limited use and provides guidance on where they may be suitable for use. As a reminder, most of these BMPs are not suitable for use as stand-alone treatment systems and typically must be used in conjunction with other practices as part of a treatment train to meet the objectives of post-construction runoff control.

BMP	Reasons for Limited Use	Suitable Applications
Permeable Pavement	• Reduced performance in cold climates due to clogging by road sand • Porous asphalt or concrete generally not recommended for widespread use in Ohio	• Modular concrete paving blocks, modular concrete or plastic lattice, or cast-in-place concrete grids are suitable for use in spillover parking, parking aisles, residential driveways and roadside right-of-ways
Catch Basin Inserts	• Limited performance data available • High maintenance needs • Susceptible to clogging	• Storm water retrofits on ultra-urban sites • Small drainage areas without excessive solids loadings, where other practices are infeasible • Pretreatment or in combination with other treatment practices, particular on industrial sites
Hydrodynamic Separators	• Limited performance data available • Performance varies with flow rate • Can become net exporter of pollutants if not maintained regularly	• Pretreatment or in combination with other treatment practices • Storm water retrofits on ultra-urban sites
Proprietary Media Filters	• Limited performance data • High maintenance needs	• Pretreatment or in combination with other treatment practices • Storm water retrofits on ultra-urban sites

BMP	Reasons for Limited Use	Suitable Applications
Underground Infiltration Systems	• Limited performance data	• Groundwater recharge • Storm water retrofits
Alum Injection	• Requires ongoing operation and monitoring • Limited performance data • Potential for negative impacts to downstream receiving waters	• Storm water retrofits on ultra-urban sites • Pretreatment or in combination with other treatment practices
Traditional Dry Detention Pond	• Lacks extended detention required for adequate storm water treatment • Settled particulates can be resuspended between storms	• Flood control and channel protection from large storm events
Conventional Oil/Particle Separators	• Limited pollutant removal • No volume control • Resuspension of settled particulates	• Pretreatment or in combination with other storm water practices • Highly impervious areas with substantial vehicle traffic
Underground Detention Facilities	• Not intended for water quality treatment • Particulates can be resuspended between storms	• Flood control and channel protection from large storm events • Space-limited or ultra-urban sites
Dry Wells	• Not intended as a stand-alone runoff quality or quantity control • Potential for clogging/failure • Applicable only to small drainage areas • Potential for groundwater quality impacts	• Infiltration of clean rooftop runoff • Storm water retrofits • Space-limited or ultra-urban sites • Pretreatment or in combination with other storm water treatment practices

BMP	Reasons for Limited Use	Suitable Applications
Vegetated Filter Strips (not designed to provide detention of the WQv)	• Typically, cannot alone achieve an adequate TSS removal	• Pretreatment or in combination with other treatment practices • Limited groundwater recharge • Outer zone of a stream buffer • Residential applications on a lot level and parking lots
Traditional Grass Drainage Channels (not designed to provide detention of the WQv)	• Typically, cannot alone achieve an adequate TSS removal	• Part of runoff conveyance system to provide pretreatment • Replace curb and gutter drainage • Limited ground water recharge

Table adapted from the Connecticut Department of Environmental Protection, 2004

12. As it pertains to the use of alternative post-construction BMPs, under what situations are hydrologic impacts to receiving waters considered negligible?

Studies have shown that channel protection is generally not required when sites discharge to a large receiving water body (Brown and Caraco, 2001). Also, application of channel protection criteria on sites where less than 1 acre of impervious area is created is problematic due to practical limitations on weir or orifice sizing. As such, hydrologic impacts shall be considered negligible under the following conditions:

(1) The entire WQv is recharged to groundwater;

(2) Sites where one or less acre of impervious area is created;

(3) Site is a redevelopment project within an ultra-urban setting (such as a downtown area and storm water discharges are directed into an existing storm sewer system); or

(4) Sites which discharge directly to a large river (fourth order or greater) or to a lake and where the development area is less than 5 percent of the watershed area upstream of the development site, unless known water quality problems exist in the receiving waters.

Stream order indicates the relative size of a stream based on Strahler's (1952) method. Streams with no tributaries are first order streams, represented as the start of a solid line on a 1:24,000 USGS Quadrangle Sheet. A second order stream is formed at the confluence of two first order streams, and so on. Fourth Order streams and larger tend to average 100 square miles or more of drainage area. The effect of a development which is less than 5% of the upstream watershed area, on the stability of a fourth order stream, is minimal (Cappuccitti and Page 2000; Center for Watershed Protection). Approximately 9.1% of Ohio's stream miles have watersheds of greater than 100 square miles (Zimmerman 2001). The map in Appendix A of this document indicates the location of fourth order streams or larger in Ohio.

Please refer to the latest edition of the Ohio EPA document titled ***Integrated Water Quality Monitoring and Assessment Report*** (www.epa.state.oh.us/dsw/document_index/305b.html) to determine if there are known water quality problems due to urban storm water sources and causes in the receiving stream in question. If the stream in question has not been assessed, the designer can assume that there is no known water quality problem.

When alternative BMPs are selected for use on a project using these criteria, the basis for making this determination must be clearly described and approved by Ohio EPA prior to the submission of the NOI.

13. Are there any exceptions to providing structural BMPs on large construction sites?

No, unless the site meets one of the two exceptions in Question 1. However, the NPDES permit does allow the requirement to be met within the larger common plan of development or sale or within a regional or local storm water management facility that has been designed to capture and treat the WQv. Thus, in the example of a commercial shopping center, a structural BMP is required for all outparcels, however the BMP does not have to be physically located on the outparcel itself. Drainage from the outparcel can be routed through the structural post-construction BMP installed to address runoff from the shopping center, so long as the BMP is sized to take in both the shopping center and the outparcel. Likewise, if a community provides treatment of the WQv within a regional storm water basin, developments (or portions of developments) draining through the regional basin would not require separate post-construction BMPs within the development. In either situation, the SWP3 must clearly describe and demonstrate how the post-construction requirement will be met. Also, the structural control must be in place before submitting the Notice of Termination (NOT).

14. What are the requirements for small construction sites?

Post-construction BMPs are required on small construction sites (see definition under Question 6). The post-construction BMPs that will be installed must still address the anticipated impacts on the channel and floodplain morphology, hydrology and water quality.

BMPs should be selected to treat the pollutants and storm water concerns associated with the proposed land use. Ohio EPA believes that this goal is best reached by implementing the BMPs listed in Table 2 of Part III.G.2.e of the CGP (Page 22). However, because Ohio EPA does not explicitly require that BMPs selected for small construction sites be designed to treat the WQv and drain it down over a prescribed time period, alternative BMPs may be selected for use on these sites. In some instances, a strictly non-structural approach may be appropriate. This allows the SWP3 designer greater flexibility in selecting BMPs. However, if the BMP selected for use on a small site is one found in Table 2 of Part III.G.2.e of the CGP, the WQv and draindown criteria should still be applied to the design of the BMP to assure proper operation. Velocity dissipation devices must be placed at discharge locations and along the length of any outfall channel to provide non-erosive flow velocities from the site. Examples of BMPs that may be suitable for small construction sites include conservation easements, riparian setbacks, vegetative filter strips, preservation of green spaces, grassy swales, infiltration trenches, sand filters, bioretention cells, rain barrels, use of permeable pavements, roof gardens, catch basin inserts, hydrodynamic separators, and/or media filters.

15. What are the requirements for redevelopment projects where structural BMPs were not previously required?

Redevelopment criteria apply primarily to sites already located within an urban setting. Ohio EPA interprets redevelopment to mean construction projects on land where impervious surfaces had previously been developed and where the new land use will not increase the runoff coefficient. For purposes of this discussion, Table 1 in Part III.G.2.e of the CGP may be used to determine if the runoff coefficient will increase. If it will, then the project is considered to be a new development project rather than a redevelopment project. Examples of redevelopment projects include construction of a building on an existing parking lot and demolition of a building to construct a new structure in its place. Adding a third lane of pavement to a highway or building condominiums on land where single-family homes stood is considered new development.

Post-construction BMPs are required on projects that qualify as redevelopment. Structural BMPs are still required on large construction sites (see definition in Question 6). However, due to the site constraints typically incurred in redevelopment situations, the CGP provides three options for meeting post-construction requirements:

(1) Treatment must be provided for 20% of the WQv;

(2) The impervious area of the proposed redevelopment project will be 20% less than the impervious area on the existing site prior to the construction activity; or

(3) A combination of (1) and (2)

If Option (1) is chosen, Ohio EPA will accept treatment of 100% of the WQv for 20% of the site as an alternative to providing treatment of 20% of the WQv over 100% of the site. However, if this approach is taken, treatment should be provided for the portion of the site with the greatest post-construction runoff quality concerns. The SWP3 must provide the basis by which the area to be treated was selected.

Further, if Option (1) is chosen, the draindown times as prescribed in the CGP must still be met in order to provide the time necessary to remove pollutants. Thus, the draindown times cannot be reduced to 20% of those stated in the CGP. Because this results in very small orifice or weir sizes, there are practical limitations to using this option. Wherever possible, designers should attempt to implement Option (2) prior to resorting to Option (1). When determining the percent reduction in impervious area, designers should look at the change in total imperviousness of the site. Total imperviousness shall be the total impervious area divided by total site area.

16. What if a portion of my project area has been developed in the past and a portion has not? Does this qualify as a redevelopment project?

In most cases, these situations occur within a single, larger common plan of development or sale. As such, please refer to Question 15 to determine if the project is considered redevelopment. However, sometimes this situation occurs when adjacent land is purchased and added to an existing larger common plan of development or sale. When this is the case, these types of projects are partially redevelopment projects and partially new development projects. To determine the WQv that must be treated, a weighted average of the WQv should be calculated using acreage as a basis. Using the example of a 10-acre parking lot that will be removed and replaced with a larger 15-acre parking lot by buying or transferring ownership of an adjacent 5-acre parcel to expand the site, the WQv that must be treated would be:

	Redevelopment = [10 acres/15 total acres] x 20% x WQv =	.133 x WQv
+	New development = [5 acres/15 total acres] x WQv =	.333 x WQv
	REQUIRED WQv =	**.466 x WQv**

However, remember: the drawdown time must remain the same as that specified in the CGP.

17. What is storm water retrofitting? Do redevelopment criteria apply to these types of projects?

Storm water retrofitting is one form of redevelopment project typically undertaken by local government to remedy problems associated with, and improve the water quality mitigation functions of, older, and possibly poorly maintained storm water management systems. A majority of the storm water detention facilities throughout Ohio have been designed to control peak flows, without regard for water quality treatment. Modifying such a basin to provide extended detention is an example of storm water retrofitting. Incorporating storm water retrofits into existing developed sites or into redevelopment projects can reduce the adverse impacts of uncontrolled storm water runoff. This can be accomplished through reduction in unnecessary impervious cover, incorporation of small-scale Low Impact Development (LID) management practices, and construction of new or improved structural storm water treatment practices. Storm water retrofits can also remedy local nuisance conditions and maintenance problems in older areas, and improve the appearance of existing facilities through landscape amenities and additional vegetation. Where these types of retrofit projects are undertaken, Ohio EPA will consider them to be redevelopment projects.

Whenever a new development is proposed within the watershed of a regional storm water basin, the full WQv of the new development must be treated. If the existing regional basin has not been retrofitted for water quality, additional structural BMPs will be required on the project site to treat the WQv. If the existing basin has been retrofitted to detain the WQv for the entire area draining into it for the appropriate time in Table 2of Part III.G.2.e, then a site specific BMP is not necessary so long as the runoff coefficient used to calculate the WQv is the regional basin anticipated for the density of the new development.

18. Is treatment of the WQv required for areas of the development that will not drain into the permanent drainage system of the site?

Treatment of the WQv is required for all portions of the site being developed. Thus, all runoff from the entire site should be routed through a structural BMP before being discharged. Vegetated buffer strips, water quality swales or bioretention cells can be used as the structural BMP to address runoff along perimeter areas that may not be able to be routed to storm sewers. Rear-yard lawns may be designed as vegetated filter strips so as to capture and treat the WQv. However, easements and deed restrictions may be necessary to assure access when maintenance must be performed and to assure that homeowners do not install structures which could impede the function of the filter strip. Stream setbacks or riparian protection areas may also be used for perimeter areas where drainage areas are limited in size. However, the size of stream setbacks or riparian protection areas should be justified based on the size of the stream, and must meet local riparian setback requirements as a minimum. The SWP3 must include documentation that setbacks will remain in perpetuity.

Ohio EPA understands that there may be unusual situations where it will not be possible to establish BMPs for perimeter areas or for small, isolated drainage areas of the site. In these situations, please consult with Ohio EPA for guidance. At a minimum, Ohio EPA will require you to demonstrate that a site design to provide the required BMPs for these perimeter areas cannot be achieved.

19. Am I required to include runoff generated from off-site areas or undeveloped portions of the site when determining the WQv?

The area used in calculating the WQv is the total contributing drainage area to the BMP, i.e., the "watershed" directed to the practice. Ohio EPA does not require off-site areas and undeveloped portions of the site to be routed through structural post-construction BMPs and, where no adverse downstream impact would occur, Ohio EPA encourages diverting such areas away from the BMP(s). However, local government may have other preferences or may ask the developer to provide detention of off-site areas or undeveloped portions of the site for flood control reasons. If this occurs, whenever possible, structural post-construction BMPs for water quality should be located at the point just prior to where runoff from developed portions co-mingles with these other sources of runoff. This will allow the post-construction BMP to be sized only for developed portions of the site. Where this is not possible or where these areas must be routed through the post-construction practice, the SWP3 designer must account for off-site acreage and/or the acreage of undeveloped areas when calculating the WQv.

20. How is the requirement to provide an additional 20% of the WQv incorporated into structural BMP design?

The purpose of the additional volume is to provide storage for pollutants which will accumulate within the structural BMP. Thus, the additional volume should be incorporated into the BMP wherever pollutants are intended to settle within the structure. For example, in a wet basin, the pollutants will accumulate within the wet pool. Thus, the additional 20% of the WQv must be added to the volume of the wet pool only. For a bioretention cell, pollutants settle on the surface of the cell. Thus, the additional 20% of the WQv must be added to the storage volume between the surface of the cell and the overflow connected to the storm sewer system.

21. If the local government requires a developer to include a detention or retention basin to manage the flood control volume and the peak rate of storm water discharge from his site, can Ohio EPA's requirements for post-construction control for water quality be incorporated into the basin?

Yes. In fact, this appears to be the method of choice for meeting Ohio EPA's structural BMP requirement. If the basin will serve the multiple functions of water quality and water quantity management, a staged outlet structure with multiple orifices or weirs will be needed. Ohio EPA recommends that when designing structures for both WQv and flood/peak discharge control, the flood/peak control volume be stacked on top of the WQv (in other words, use the top of the WQv as the base elevation for the flood control volume). This will assure that there is ample storage when back-to-back storms occur. However, please consult with the Engineer of local jurisdiction for their preference regarding this matter.

Dry basins consist of an extended detention volume (EDv) and additional storage above the EDv for flood control. The EDv is equal to the WQv. Ohio EPA recommends that the additional 20% of the WQv that must be incorporated within the basin for storage of accumulated pollutants be incorporated within forebays and/or micropools in the basin. An orifice to drain down the EDv in 48 hours must be incorporated at the bottom of the outlet structure (above the micropool if one is included in the design). A separate orifice to control the peak rate of discharge from flood-producing storms must be provided at the top of the EDv elevation. The size of this orifice is determined by local flood control regulations. Dry basins are generally appropriate where the total contributing drainage area is 10 acres or greater. Where the total contributing drainage area is less than 10 acres, other structural BMPs should be considered, primarily because the size of the EDv orifice will be very small and prone to clogging.

Wet basins consist of a wet pool, an extended detention volume (EDv) above the wet pool, and additional storage for flood control above the EDv. The volume of the wet pool must be at least 75% of the WQv plus the additional 20% of the WQv for storage of accumulated pollutants, i.e., 95% of the WQv. The volume of the EDv above the wet pool is equal to 75% of the WQv. An orifice to drain down the EDv in 24 hours must be provided at the normal wet pool elevation. A separate orifice to control the peak rate of discharge from flood-producing storms must be provided at the top of the EDv elevation. The size of this orifice is determined by local flood control regulations. Wet basins are generally appropriate where the total contributing drainage area is 20 acres or larger. Where the total contributing drainage area is less than 20 acres, there may not be sufficient watershed to support a permanent wet pool, and as such, other BMPs should be considered.

22. How to determine (A) the orifice size needed to drain the WQv and (B) the maximum release rate for a wet or dry extended detention basin?

(A) In an extended detention facility for water quality treatment, the storage volume is detained and released over a specified amount of time (24 hours for a wet basin and 48 hours for a dry basin). The release period is a “brimful” drawdown time, beginning at the time of peak storage of the WQv until the entire calculated volume drains out of the basin. This assumes that the brim volume is present in the basin prior to any discharge. In reality, however, water is flowing out of the basin prior to the brim volume being reached. Therefore, the extended detention outlet can be sized using either of the following methods:

(1) Use the maximum hydraulic head associated with the storage volume and maximum flow, and calculate the orifice size needed to achieve the required drawdown time, and route the volume through the basin to verify the actual storage volume used and the drawdown time.

(2) Approximate the orifice size using the average hydraulic head associated with the storage volume and the required drawdown time.

To illustrate these two procedures, the following example will be used: a wet pond with extended detention where the WQv has been calculated to be 0.76 acre-ft (33,106 ft^3) and the maximum hydraulic head (H_{max}) is 5.0 ft (from stage vs. storage data). A circular orifice will be used as the outlet structure. (Example courtesy of the Georgia Stormwater Manual, Atlanta Regional Commission, 2001.)

Method 1. Maximum Hydraulic Head with Routing

NOTE: This is a simplified method that will provide you with a starting point from which to design the orifice size. You must route the extended detention volume through the basin to assure that actual drawdown times meet requirements.

Step1. Determine the maximum discharge resulting from the 24-hour drawdown requirement. For a wet pond, the extended detention volume (EDv) above the permanent pool is equivalent to 0.75 times the WQv (per requirements of the NPDES permit). Thus, divide the EDv by the required drawdown time. Then, multiply by two to obtain the maximum discharge.

$EDv = 0.75 * WQv = (0.75)(33{,}106\ ft^3) = 24{,}830\ ft^3 = 0.57$ ac-ft
$Q_{avg} = EDv/t_d = 24{,}830\ ft^3/(24\ hrs)(3{,}600\ sec/hr) = 0.29\ ft^3/sec$
where t_d is the drawdown time (24 hours per requirements of the NPDES permit)

Thus, $Q_{max} = 2 * Q_{avg} = 2 * 0.29 = 0.58\ ft^3/sec$

Step 2. Determine the required orifice diameter by using the orifice equation and Q_{max} and H_{max}.

$Q = CA(2gH)^{0.5}$ orifice equation
Thus, $A = Q/C(2gH)^{0.5}$

where A = area of the orifice [ft^2]
$Q = Q_{max}$ = maximum flow rate
C = coefficient of discharge (0.6 for sharp-edged orifice)
g = acceleration of gravity (always 32.2 ft/sec^2)
$H = H_{max}$ = maximum hydraulic head

$A = 0.58/0.6[(2)(32.2)(5.0)]^{0.5} = 0.054\ ft^2$

The formula for the area of a circle (assuming the cross-section of the orifice pipe is a circle) is $A = \Pi r^2$, where Π is the constant 3.14 and r is the radius of the circle = one-half the diameter (D). Thus,

$D = (4A/\Pi)^{0.5} = [(4)(0.054)/3.14]^{0.5} = 0.26$ ft = 3.15 inches

Step 3. Using the calculated orifice size (3.15-inch), route the EDv (0.57 ac-ft) to verify the drawdown time, as well as the maximum hydraulic head elevation. If the routing effect results in the actual drawdown time being less than the calculated 24 hours, the orifice size must be reduced to achieve the required 24 hours. If the 24 hour drawdown time is met, select a 3-inch diameter pipe as the water quality orifice.

Method 2. Average Hydraulic Head and Average Discharge

Step 1. Using the same information as above, but assuming that the average hydraulic head (H_{avg}) is equal to one-half the maximum hydraulic head (H_{max}), determine the average release rate to release the EDv over 24 hours.

$$Q_{avg} = EDv/t_d = 24{,}830 \text{ ft}^3/(24 \text{ hrs})(3600 \text{ sec/hr}) = 0.29 \text{ ft}^3/\text{sec}$$

Step 2. Determine the orifice diameter using the same orifice equation as above, but using Q_{avg} and H_{avg} in the formula.

$$A = Q/C(2gH)^{0.5}$$

Where A = area [ft^2]
$Q = Q_{avg}$ = average flow rate
C = coefficient of discharge (0.6 for sharp-edge orifice)
g = acceleration of gravity (always 32.2 ft/sec^2)
$H = H_{avg} = H_{max}/2 = 5.0/2 = 2.5$ ft (average hydraulic head)

Thus, $A = 0.29/0.6[(2)(32.2)(2.5)]^{0.5} = 0.038 \text{ ft}^2$

And, $D = [4(0.038)/3.14]^{0.5} = 0.22 \text{ ft} = 2.64$ inches

Method 2 results in a slightly smaller orifice. Often the optimal water quality orifice will fall within the range of values obtained by using Method 1 and Method 2. In this particular example, choosing a water quality orifice of 3 inches would be acceptable to meet requirements.

To demonstrate compliance with the post-construction sizing requirements when designing extended detention basins, the method used to calculate orifice sizing must be clearly indicated in the SWP3. Calculations should be provided for the orifice sizing. Ohio EPA recommends including Stage-Storage data or Elevation-Area-Capacity tables indicating the elevation at which the EDv is achieved. This data must match the elevations indicated on the profile view of the outlet structure.

When designing extended detention basins (wet or dry), it is important to design the Water Quality Orifice to minimize the likelihood of clogging. This may include a:

(1) Submerged, reverse-slope pipe that extends downward from the riser to a release point one foot below the normal pool elevation, or

(2) Broad-crested weirs protected by a half-round corrugated metal pipe (CMP), extending at least 18 inches below the normal pool.

Where the Water Quality Orifice is less than 2 inches, due to maintenance concerns, other structural post-construction BMPs should be considered instead of extended detention basins, or the long-term maintenance plan must call for frequent inspection of the orifice. Local governments or jurisdictions are cautioned that Ohio EPA does not monitor the maintenance of post-construction BMPs once NPDES permit coverage is terminated, i.e., construction activities at the site are complete and the site is brought to final stabilization. Communities that operate regulated Small Municipal Separate Storm Sewer Systems (Small MS4s) are required to develop procedures for assuring that long-term maintenance of these facilities occurs. However, within communities without regulated Small MS4s, it may be prudent to establish similar procedures.

(B) The WQv is designed to capture and treat the first flush of runoff. This requires a measured release of the WQv from the "brimful" condition. Though orifices larger than those calculated by the above methods may meet the target drawdown period for the WQv basin, a greater release rate will reduce the pollutant removal efficiency and increase the hydraulic impacts to receiving streams. As such, before finalizing the design of an extended detention basin outlet, the engineer should verify that the outlet structure for the post-construction BMP will not discharge more than the first half of the WQv or EDv in less than one-third of the drawdown time. The graph in Appendix B of this document shows the desired WQv or EDv release rate from the post-construction BMP.

23. Are there any alternatives to using the WQv formula, runoff coefficients or drawdown times listed in the NPDES permit?

The NPDES Permit states that the WQv shall be equivalent to the volume of runoff from a 0.75-inch rainfall. The permit provides two methods to calculate this volume. Designers may use the formula provided in the NPDES permit. If the formula is used, the designer must use the runoff coefficients and drawdown times listed in Tables 1 and 2 of the NPDES permit. The ASCE ***Urban Runoff Quality Management*** manual provides a formula based on imperviousness for calculating the runoff coefficients. In fact, this formula provides a more accurate method by which to determine the runoff coefficient and may lead to slightly smaller water quality volumes in certain instances. The formula is:

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

where **i** is the watershed imperviousness ratio (percent total imperviousness divided by 100).

The value of **i** used must be specific to the watershed that will be controlled by the practice. Ohio EPA will accept use of this formula as an alternative to using the runoff coefficients listed in Table 1 of the NPDES permit. However, if this formula is used, the Storm Water Pollution Prevention Plan should clearly indicate how the runoff coefficient was calculated.

Ohio EPA will not accept designs based on TR-55, TR-20, and HydroCAD. The TR-55 model effectively predicts runoff volumes during large storm events (say 3 inches or more), but underestimates runoff volumes from the more frequent and smaller storms that Ohio EPA's post-construction criteria address (Schueler, 1995; Claytor and Schueler, 1996). Since TR-20 and HydroCAD both use the same method and similar assumptions as TR-55, both programs also tend to underestimate runoff from rainfall less than the two-year storm event (Cappuccitti and Page, 2000).

Ohio EPA will also accept water quality volumes determined through a site hydrologic study approved by the local municipal permitting authority that uses continuous hydrologic simulation and local long-term hourly precipitation records. Ohio EPA intended this study to encompass long-term actual rainfall and stream flow data specific to the project location. A time period of at least 50 years should be analyzed. Guidance on how to conduct a hydrologic study is provided in Chapter 3 of the ASCE ***Urban Runoff Quality Management*** manual. Ohio EPA does not expect this method to provide a significantly different water quality volume than the formula provided in the permit.

The ASCE manual also provides what some may view as alternative design procedures for "flow-through" BMPs such as vegetated filter strips and water quality swales (aka "enhanced swales"). The criteria in the NPDES permit intends for these practices to provide extended detention of the WQv by constructing these facilities to have a storage volume equal to the WQv and providing either earthen dams or permeable berms with orifices or weirs to meet the required drawdown time. The ASCE manual suggests that berms and dams are not always necessary. Instead, these facilities can be constructed such that the peak flow through the swale or filter strip from all storms producing runoff up to and including the WQv is no greater than 1 cfs and that the depth of flow is no greater than the height of the dense turf grass with which these facilities are planted (typically no more than 3 inches). This is determined by calculating a time of concentration for the watershed draining to the swale or filter strip and defining the peak intensity of the design storm producing the WQv from an intensity-duration-frequency (IDF) curve using a 24-hour duration. Then, the Rational Method and runoff coefficients found in Table 1 of Part III.G.2.e of the NPDES permit are used to determine the peak flow through the swale or filter strip. Manning's equation is then used to design the swale or filter strip. Both swales and filter strips must receive runoff as sheet flow and be quite flat (2% to 6% slope, maximum) in order to provide a water quality benefit. As such, a level spreader must often precede these BMPs to assure uniform dispersion through the practice. These criteria often result in filter strip areas that are equal to the area to be treated and wider-bottom swales than swales that are not designed for water quality. This approach is often referred to as using the Water Quality Flow (WQf). There are several efforts across the state trying to more fully develop this criteria. Once it is fully developed, Ohio EPA will accept its use as an alternative to the criteria contained in the NPDES permit for designing grass filter strips and water quality swales.

Drawdown times provided in the CGP cannot be altered. These times are required to allow the practice enough time to settle pollutants out of runoff. Decreasing the drawdown times will make the practice less efficient.

24. How were the runoff coefficients in the CGP determined?

The runoff coefficients contained in the CGP are categorized based on the density of development and were derived from the formula contained in the ASCE manual (see Question 23). The categories are somewhat broad and the runoff coefficients selected were meant to provide an average within the range contained within each category. As such, the further the density of the development is from the mid-point of the range, the more skewed the runoff coefficient is from what it would actually be if the ASCE formula were used. It has been demonstrated to Ohio EPA that the skew is especially wide for very low density developments. This is why Ohio EPA will accept use of the ASCE formula directly. However, be sure to check with local regulations as many of them have been drafted and adopted based on the information contained in the NPDES permit. Thus, local regulations may preclude use of the ASCE formula.

25. Are post-construction requirements applicable to discharges regulated under other NPDES permits?

Yes, unless the other NPDES permit specifically addresses quality and quantity issues of the runoff associated with a newly developed area. For example, an industry expands its facility by disturbing one or more acres of land. The runoff from this newly developed area is directed to a pipe covered by an individual NPDES permit, but the individual permit does not address storm water associated with construction activities. The conditions of both the individual NPDES permit and CGP must be met.

26. What design manual should be used for structural post-construction BMPs?

The NPDES permit states that the Ohio Department of Natural Resources (ODNR) manual titled ***Rainwater and Land Development*** should be used. Although it does not discuss calculation of the WQv, the current edition does provide guidance on the design considerations of water quality ponds that provide extended detention, infiltration trenches and grass filter strips. ODNR is presently updating the manual to reflect Ohio EPA's WQv criteria to include design criteria for additional post-construction BMPs including bioretention cells, sand filters and water quality swales. Ohio EPA has found a number of manuals from other states, available free on-line, that are acceptable for use on an interim basis until the ***Rainwater*** manual is updated. These include:

Title	Publisher (Year)	Where to Obtain Copy
California Stormwater Best Management Practice Handbook for New Development and Redevelopment	California Stormwater Quality Association (2003)	http://www.cabmphandbooks.com/
Georgia Stormwater Management Manual	Atlanta Regional Commission (2001)	http://www.georgiastormwater.com/
2004 Connecticut Stormwater Quality Manual	Connecticut Department of Environmental Protection (2004)	http://www.dep.state.ct.us/wtr/stormwater/strmwtrman.htm
Guidance Manual for On-Site Stormwater Quality Control Measures	City of Sacramento, CA (2000)	http://www.sacstormwater.org/const/manuals/dl-on_site.html
Urban Small Sites Best Management Practices Manual	Minneapolis-St. Paul Metropolitan Council (2003)	http://www.metrocouncil.org/environment/Watershed/bmp/manual.htm
New York State Stormwater Management Design Manual	NY Dept of Env. Conservation (2003)	http://www.dec.state.ny.us/website/dow/toolbox/swmanual

Ohio EPA has also found the manual titled ***Operation, Maintenance & Management of Stormwater Management Systems*** (Watershed Management Institute, 1997) helpful for developing long-term maintenance plans for post-construction BMPs. The manual includes inspection checklists for not only on-going maintenance requirements of the various practices, but also while the structures are being constructed. The manual also contains information that operators of regulated Small MS4s will find useful when setting up their local long-term maintenance programs required under the post-construction Minimum Control Measure of their Storm Water Management Programs.

In addition, Ohio EPA is aware that there are several local governments in the State working on developing technical manuals on post-construction BMP design criteria. As these are developed, Ohio EPA will review them to assure that they meet state requirements and will update this document to include them in this table.

When referencing manuals from other states, Ohio EPA cautions readers that the methodology used to calculate the WQv in most of these manuals varies from the method used in Ohio. Most East Coast states use the Unified Sizing Criteria developed by the State of Maryland and the Center for Watershed Protection rather than the ASCE method. Some drawdown times required by other states vary from those required in Ohio. However, as long as SWP3 designers use the WQv and drawdown times contained in the Ohio EPA NPDES permit, the general design considerations and criteria found in these manuals are applicable in Ohio.

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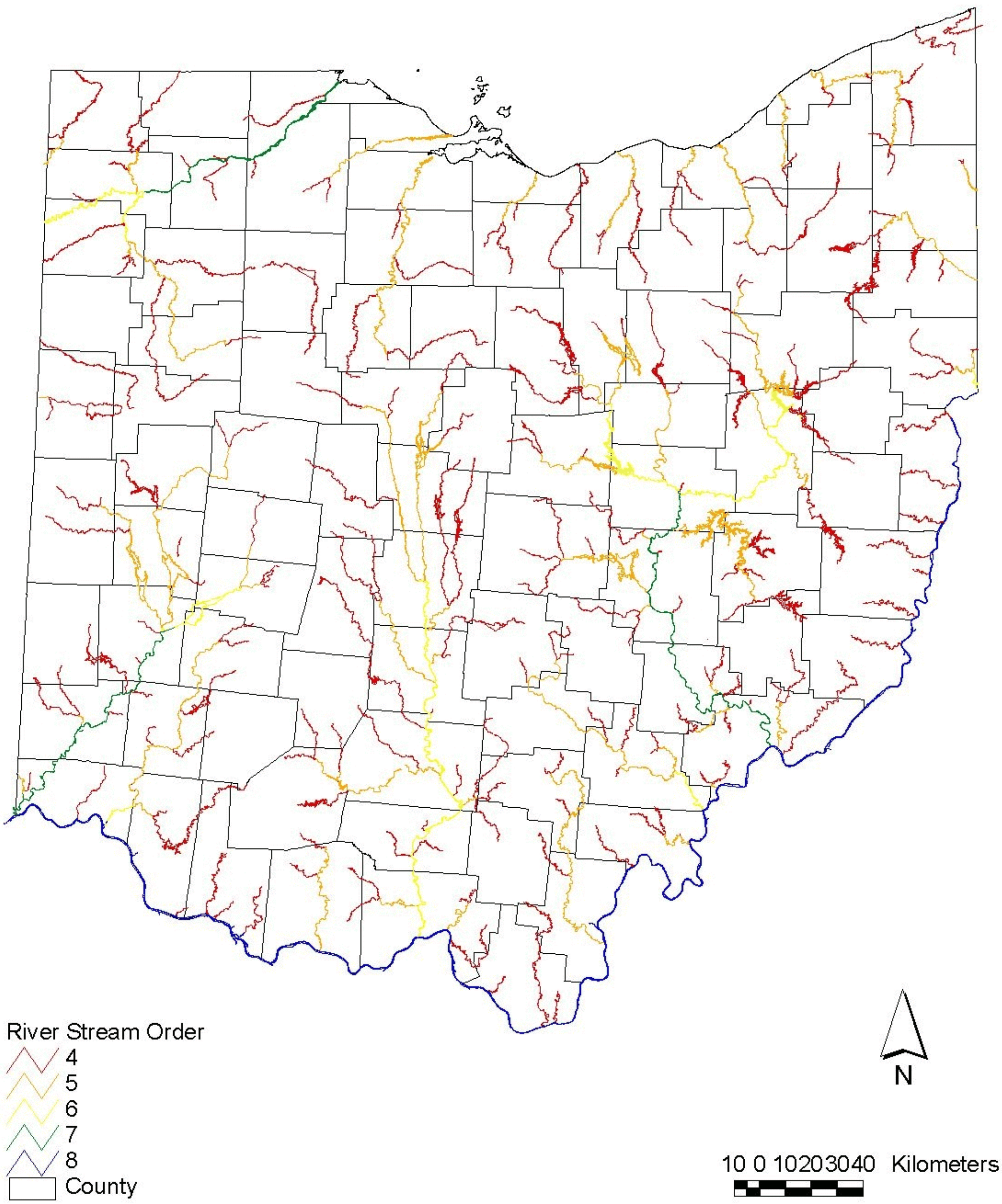
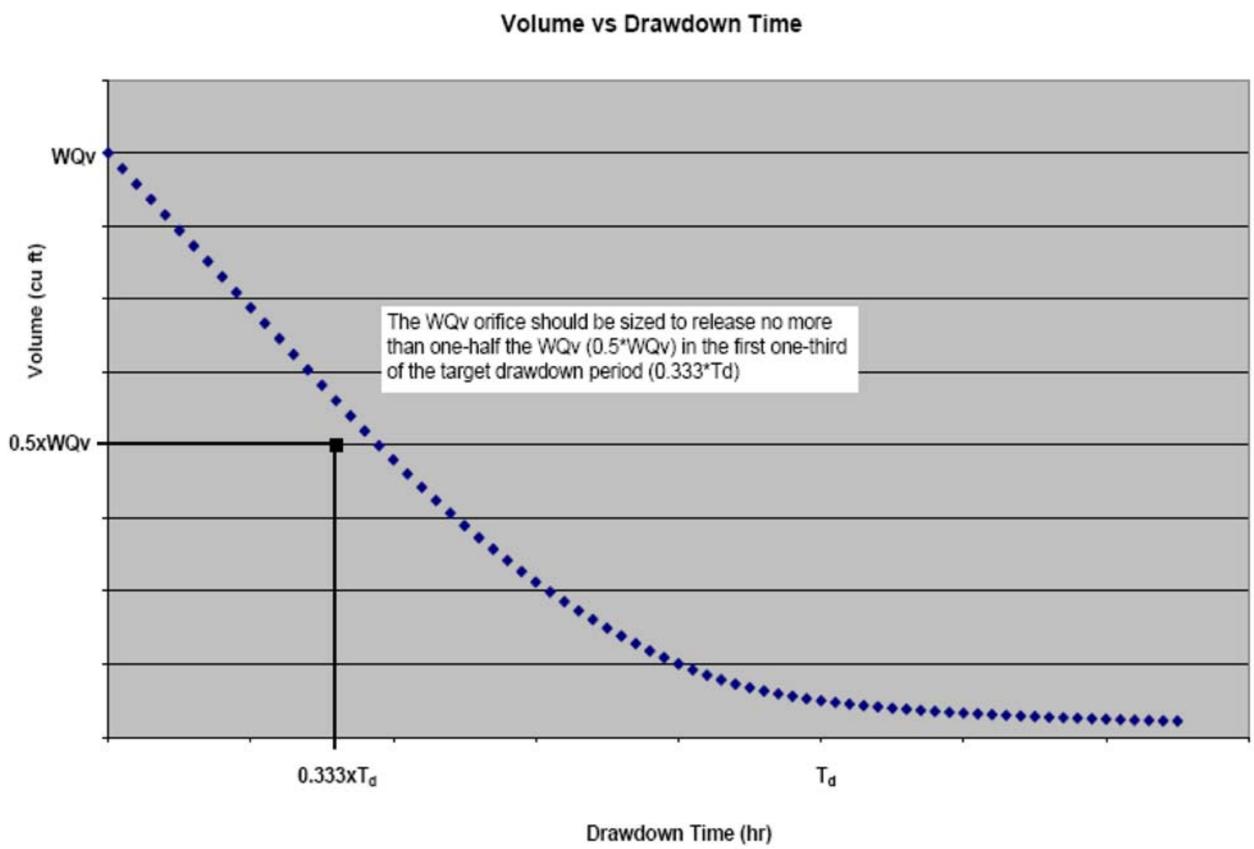
APPENDIX A
Stream Order Map of Ohio

Stream Order for Major Ohio Rivers



NOTE: Ohio EPA will provide a list of fourth order or larger streams.

APPENDIX B
Maximum WQv or EDv Release Rate



Volume vs Drawdown Time
WQv
0.5xWQv
Volume (cu ft)
The WQv orifice should be sized to release no more than one-half the WQv (0.5*WQv) in the first one-third of the target drawdown period (0.333*Td)
0.333xTd
Td
Drawdown Time (hr)