Michigan Department of Environmental Quality

Water Resources Division

Municipal Separate Storm Sewer System (MS4) Program

Post-Construction Storm Water Runoff Controls Program

Compliance Assistance Document

Quick Page Reference

Overview

Post-construction storm water runoff is the storm water that would flow from a project site to the Municipal Separate Storm Sewer System (MS4) after completion of a development or redevelopment (not during the project). Controls for this type of runoff are necessary to maintain or restore stable hydrology in receiving waters by limiting surface runoff rates and volumes and reducing pollutant loadings from sites that undergo development or significant redevelopment.

> **Background:** Michigan's *National Pollutant Discharge Elimination System (NPDES) Permit Application for Discharge of Storm Water to Surface Waters from a Municipal Separate Storm Sewer System* (Application) requires the applicant to provide a description of the Best Management Practices (BMP) that will be implemented for each minimum control measure and the applicable water quality requirements. These BMPs build the applicant's Storm Water Management Program (SWMP). The applicant shall submit a complete application containing a SWMP to be approved as part of issuance of an individual permit. The applicant may choose the BMPs to meet the application requirements and develop an approvable SWMP. The Post-Construction Storm Water Runoff Program is one of the minimum control measures.

This compliance assistance document addresses the Post-Construction Storm Water Runoff Program minimum control measure. Information provided here is intended both to assist new MS4 permit applicants with developing the post-construction storm water portion of a SWMP and existing MS4 permittees with questions about permit compliance or refining an existing post-construction storm water program. This document primarily references the "permit applicant", although it may be equally relevant to an existing permittee.

It may be easy for the reader of this document to confuse the terms permit applicant and permittee with the project developer. In the context of this document permit applicant and permittee refer to the municipal entity holding or applying for an NPDES MS4 permit. Project developer means the person or entity responsible for developing and implementing project site plans (e.g., development company, individual lot landowner, municipality); that is, the entity subject to the permittee's post-construction storm water runoff program.

The post-construction storm water runoff program includes all of the following components:

- Water Quality Treatment Performance Standard
- Channel Protection Performance Standard
- Site-Specific Requirements for Contaminated Sites and Potential Hot Spots
- Site Plan Review
- Operation and Maintenance (O&M) Requirements for BMPs
- Enforcement Response Procedure (including Tracking)

The post-construction storm water runoff program shall be implemented through an ordinance or other regulatory mechanism. This may be done through a single ordinance or regulatory mechanism or a combination of ordinances and regulatory mechanisms, provided all requirements are covered. Nested jurisdictions may have a post-construction storm water runoff program separate from the applicant or agree to abide by the applicant's post-construction storm water runoff program.

The water quality treatment performance standard, channel protection performance standard, site plan review, site-specific requirements for contaminated sites/hotspots, and the O&M requirements are minimum components of the permit applicant's program that should be applied by the permit applicant to the project developer (including the permit applicant's own development projects).

Enforcement response and tracking procedures are minimum components of the permit applicant's program, but they represent the methods that the permit applicant will use to implement, track, and enforce its program. As part of permit implementation, permittees are required to track and maintain records of their post-construction storm water runoff control program. An effective recordkeeping program ensures that sufficient information is maintained to document implementation and compliance with the permit applicant's post-construction storm water runoff program.

Measurable Goals

Once a permit is issued, the permittee will be required to track implementation of the SWMP. Measurable goals are a means for assessing progress and effectiveness of the BMPs that, together, constitute the permit applicant's SWMP. The Application requires that a measurable goal be provided for each BMP. For the purpose of this measurable goals discussion, BMP refers to the various components of the permit applicant's post-construction storm water runoff program. BMP, in this case, does not refer to individual controls that a project developer may place on a project site. Measurable goals should be selected to fit each post-construction storm water runoff program component and, as appropriate, each measurable goal should include a schedule for component implementation (month and years), including interim milestones and the frequency of the action. Properly selected measurable goals will incorporate a means to assess a component's progress towards reaching the goal. Although a measurable goal is required for each storm water runoff program component (BMP), it does not mean that each component must have a unique measurable goal. Care should be taken to ensure a selected measurable goal fits the targeted component, but it may be appropriate for some components to share a common measurable goal.

Measurable goals may demonstrate: 1) specific actions, such as tracking implementation of the activity itself; 2) results, such as tracking behavioral change or quantifiable targets; and 3) the schedule to complete certain actions or targets. More information on developing measurable goals and measurable goals as they relate to the Post-Construction Storm Water Runoff Program minimum control measure is available in the U.S. Environmental Protection Agency's (EPA) Measurable Goals Guidance for Phase II Small MS4s at https://www3.epa.gov/npdes/pubs/measurablegoals.pdf.

Ordinance or Other Regulatory Mechanism

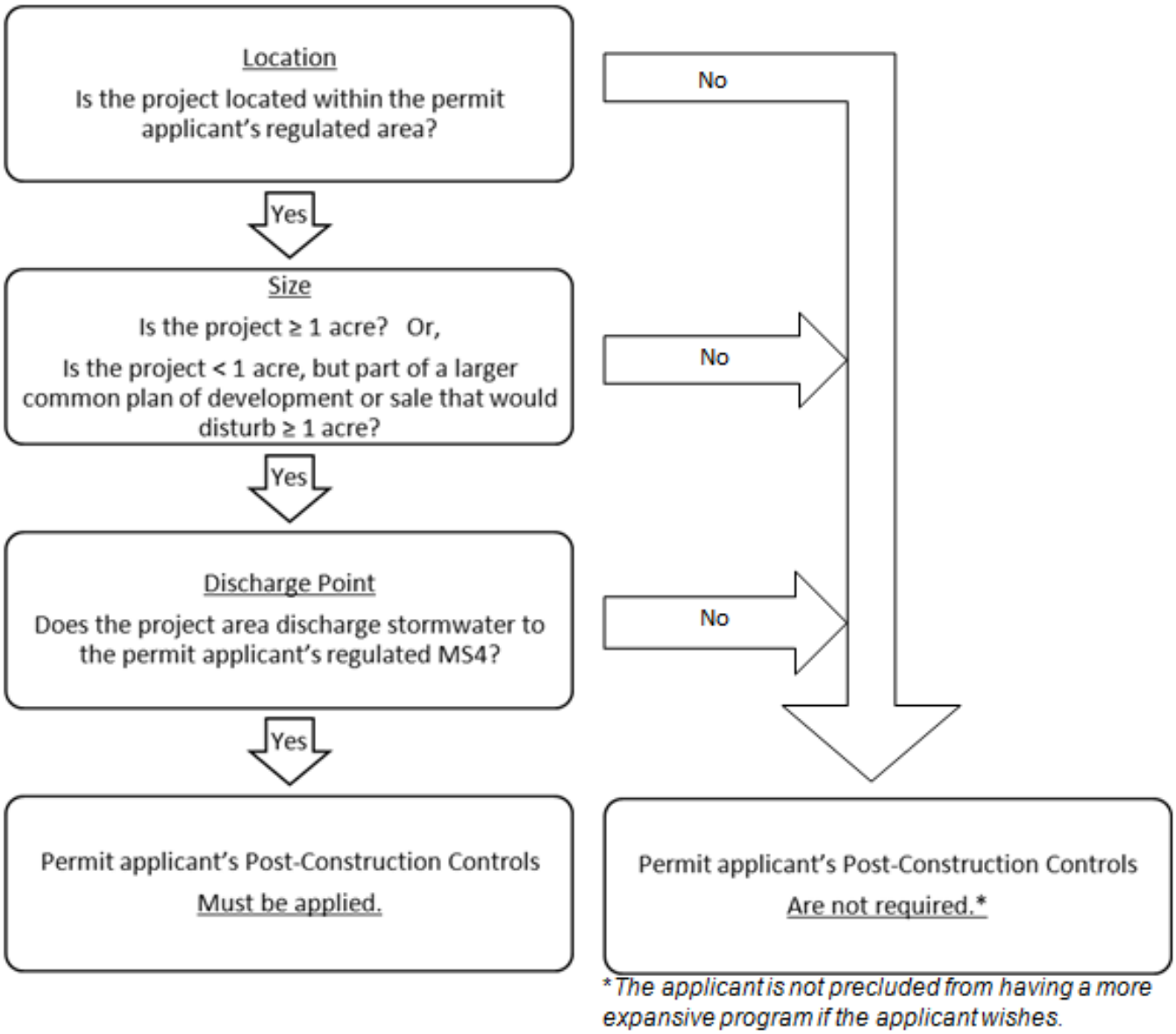
Program Enforcement through an Ordinance and/or Regulatory Mechanism

The Application requires that the permit applicant, through ordinance or other regulatory mechanism, address post-construction storm water runoff from all new and redevelopment projects, including preventing or minimizing water quality impacts. The post-construction storm water runoff requirement applies to projects that disturb one acre or more. Projects that disturb less than one acre are subject to the requirement if they are part of a larger common plan of development or sale that would disturb one acre or more. The area of disturbance is referred to

as the “project site” throughout the remainder of this document.
The above requirement is applicable to both municipal and non-municipal projects that discharge to the permit applicant’s regulated MS4. For the purposes of this document, all references to the permit applicant’s MS4 refer to the applicant’s regulated MS4. Regulated areas are identified on the 2010 urbanized area maps. These maps are available by going to https://www.michigan.gov/egle/about/organization/water-resources/municipal-storm-water.

The Application does not require the applicant to address post-construction storm water runoff that discharges directly to a surface water of the state (including an open county drain when it is also a surface water of the state). Note, however, that the Application does not preclude the applicant from having a more expansive program if the applicant wishes.

Post-Construction Storm Water Runoff Program Decision Flow Chart



*The applicant is not precluded from having a more expansive program if the applicant wishes.

Ordinance/Regulatory Mechanism Applicability

The permit applicant is required to develop its post-construction storm water runoff control program through an ordinance or other regulatory mechanism to be implemented and enforced during the permit cycle. Examples of non-ordinance regulatory mechanisms include local permit programs and internal policies or procedures.

A number of factors may influence the appropriateness of an ordinance or other regulatory mechanism including whether the permit applicant has ordinance authority. A combination of an ordinance and other regulatory mechanism may also be appropriate. As long as the post-construction storm water runoff control requirements are fully addressed, the requirements may be distributed throughout a combination of several ordinances and/or regulatory mechanisms. In addition, if standards and criteria are contained in a separate specification manual, it is acceptable to adopt the manual by reference in the ordinance or regulatory mechanism.

An ordinance is appropriate for cities and villages regulating discharges from private development or redevelopment to their own MS4. The ordinance may cover development or redevelopment of the city or village's own properties, or these properties could be addressed through an internal policy or procedure.

Townships with more complex MS4s that receive discharges from non-municipal properties (e.g., a township that owns or operates roads) should use an ordinance to address discharges from development or redevelopment of those private properties. Townships addressing development or redevelopment of their own properties, as well as townships with an MS4 that is limited to township-owned buildings and parking lots that do not receive storm water runoff from private properties, may use an internal policy or procedure.

County entities that do not have ordinance authority, but have the authority to regulate discharges to their own MS4, such as road commissions, drain commissioners, and county administrations (e.g., for county facilities such as parks or administration buildings) may use a regulatory mechanism such as a local permit program. County entities also may use an internal written policy for their own projects (e.g., road construction).

Public institutions such as school systems or universities may use a written internal policy because their authority is limited to the institution's own development or redevelopment projects. It is recommended that the internal policy be approved by the institution's Board or governing authority to ensure that the policy is supported and consistently implemented.

Likely scenarios for applicability of ordinance and other regulatory mechanisms, by permit applicant type, are provided in the following table.

Likely Scenarios for Applicability of Ordinance and Other Regulatory Mechanisms				
Permit Applicant Type		Ordinance	Other Regulatory Mechanism	
			Local Permit Program	Internal Written Policy
City		♦		♦
Village		♦		♦
Township	With private discharges to its regulated MS4	♦		♦
	Without private discharges to its regulated MS4			♦
County Road Commission			Both	
County Drain Commissioner			Both	
County Administration			Both	
Public Institution				♦

Adopting Another Entity's Standards by Reference

A number of permit applicants have adopted, or proposed to adopt, another entity's post-construction storm water runoff control standards to meet the Application requirements. Whether the permit applicant has elected to reference the post-construction storm water runoff control requirements of another entity or has simply duplicated that entity's requirements within the permit applicant's own ordinance or regulatory mechanism, the permit applicant should still submit an ordinance or regulatory mechanism in accordance with the Application requirements to ensure that the post-construction storm water runoff controls can be enforced.

Water Quality Treatment Performance Standard

The ordinance or regulatory mechanism shall incorporate the permit applicant's water quality treatment volume performance standard. If the performance standard is contained in a separate specification manual, it is acceptable to adopt the manual by reference in the ordinance or regulatory mechanism. The Application specifies a minimum treatment volume that the permit applicant shall address to reduce or prevent the water quality impacts of storm water runoff. The treatment volumes specified are based on capturing and treating the volume of storm water that is the first to run off in a storm and expected to contain the majority of pollutants. This volume of runoff is often referred to as the "first flush." Sizing the BMPs to meet the Application requirements will ensure acceptable storm water treatment that minimizes water quality impacts.

A permit applicant may choose one or both of the following minimum treatment volume standards specified in the Application:

1) One inch of runoff generated from the entire project site (see below Calculate One Inch of Runoff from the Entire Project Site).
2) The calculated site runoff for the entire project site from the 90 percent annual non-exceedance storm for the region or locality according to one of the following (see below Calculate Runoff Generated by 90 Percent Annual Non-Exceedance Storm):
   a. The statewide analysis by region for the 90 Percent Annual Non-Exceedance Storms summarized in a memorandum dated March 24, 2006, and available on the Internet at https://www.michigan.gov/-/media/Project/Websites/egle/Documents/Programs/WRD/Hydrologic-Data/ninety-percent.pdf.

   b. The analysis of at least ten years of local published rain gauge data following the method in the memo "90 Percent Annual Non-Exceedance Storms" cited above.

Calculate One Inch of Runoff from the Entire Project Site

This is the simplest and most conservative approach. Research has shown that nearly all the pollutants washed off in the "first flush" of runoff from impervious surfaces are contained in the first inch of runoff. To calculate, determine the area of land contributing storm runoff (A) in square feet and multiply by 1/12 feet;

A ft2 X 1/12 ft = Minimum Treatment Volume in cubic feet

Calculate Runoff Generated By 90 Percent Annual Non-exceedance Storm

This method is a more rigorous analysis of the runoff generated from different land types for the entire project site for 90 percent of all the storms that generate runoff. It is a more accurate representation of the runoff from the project site and usually results in a smaller treatment volume than using one inch of runoff from the entire project site.

The 90 percent storms for ten regions of the state (from the memo mentioned above) are shown in the table below. They range in rainfall from 0.77 inch to 1.0 inch. An acceptable substitute for the statewide regional analysis would be an analysis of a minimum of ten years of local published rain gauge data (using the method in the memo mentioned above).

Statistics for storms with more than 0.10" of rainfall at selected weather stations

Weather Station	Kenton	Champion Van Riper	Newberry	Kalkaska	Mio	Baldwin	Alma	Saginaw Airport	Cass City	Gull Lake	Lansing	East Lansing	Detroit Metro
Station Number *	4328	1439	5816	4257	5531	0446	0146	7227	1361	3504	4641	2395	2103
90-Percent Non-exceedance Storm (inches)	**0.95**	**0.87**	**0.84**	**0.77**	**0.78**	**0.93**	**0.93**	**0.92**	**0.87**	**1.00**	**0.90**	**0.91**	**0.90**

*See map in Appendix A for station locations.

The rainfall for the area where the project site is located can be used in a number of computer programs or formulas that calculate runoff by land type. Many appropriate methods are described in Chapter 9 of the *Low Impact Development Manual for Michigan* and available at: https://www.semcog.org/reports/lid/index.html. The Small Storm Hydrology Method is described on page 366 of the *Low Impact Development Manual for Michigan* and is a relatively simple method that may be applied at most project sites.

Total Suspended Solids (TSS) Calculations

The Application requires that the methods selected to treat the volume of water calculated above shall be designed on a site-specific basis to achieve either a minimum of 80 percent removal of TSS, as compared with uncontrolled runoff, or a discharge concentration of TSS that does not exceed 80 Milligram per Liter (mg/l). Where site conditions do not generate TSS concentrations greater than 80 mg/l, water quality treatment of the runoff is not required.

This Application requirement is based on TSS as a surrogate for other pollutants normally found in storm water runoff. Control of TSS to meet this requirement is expected to achieve control of other pollutants to an acceptable level that protects water quality. Determination of runoff quality and application of additional controls for other pollutants may be necessary to meet Application requirements where Total Maximum Daily Loads (TMDL) have been developed.

The chart below was compiled by the Rouge River Wet Weather Demonstration Project with Michigan data and provides the event mean, minimum, and maximum concentration of suspended solids in storm water runoff for several land uses. The data shows that wherever the maximum event concentration was reported it was substantially higher than 80 mg/l. Without site-specific documentation that the suspended solids concentration will not exceed 80 mg/l, treatment (BMPs) must be applied to remove 80 percent of suspended solids from all applicable project sites.

Rouge River (Michigan) Wet Weather Demonstration Project data showing reported maximum event concentrations where TSS concentration exceeded 80 mg/l

Land Use Category	Percent Imperviousness	TSS		
		Mean (mg/l)	Min (mg/l)	**Max (mg/l)**
Forest/Rural Open	2	51		
Urban Open	11	51		
Agricultural/Pasture	2	145		
Low-Density Residential	19	70	2	**367**
Medium-Density Residential	38	70	2	**367**
High-Density Residential	51	97	2	**380**
Commercial	56	77	5	**280**
Industrial	76	149	5	**271**
Highways	53	141	130	**406**

Taken from "Rouge River Wet Weather Demonstration Project, Selection of Stormwater Pollutant Loading Factors", RPO-MOD-TM34.00, October 1994, Table 3-13

The Application does not require monitoring of project sites to determine compliance with this TSS removal requirement. Instead, the expected reduction of suspended solids by BMPs is obtained from the literature and built into the design of the project. The National Pollutant Removal Performance Database, Version 3 contains the expected percent reduction of suspended solids by many common BMPs. Versions 2 and 3 are available at:

Version 2: http://www.stormwatercenter.net/Library/STP-Pollutant-Removal-Database.pdf

Version 3: http://owl.cwp.org/mdocs-posts/fraley-mcneall-_national_pollutant_removal_perf_v3/

The International Stormwater BMP Database reports BMP performance by effluent concentration and is available at:

https://www.bmpdatabase.org

Many BMPs are sufficient individually to achieve the required removal of TSS. Compliance can also be achieved through the use of a system of BMPs each achieving less than the required removal of TSS but, when properly applied as a system, achieve the required removal for the project site.

To achieve the required removal performance, BMPs must be designed, installed, and maintained properly. Accepted design guidance can be found in the Low Impact Development Manual for Michigan available at:

http://semcog.org/Reports/LID/index.html

or the Guidebook of BMPs for Michigan Watersheds available at:

https://www.michigan.gov/egle/about/organization/Water-Resources/nonpoint-source/BMP-manual-and-design-references

Specific site design guidance and efficiency information for proprietary devices are generally obtained from the manufacturer. Devices that do not have third party testing information available should be considered with caution until their performance is confirmed.

A permittee is in compliance with this requirement if the minimum treatment volume from a project site is treated by properly designed BMPs that achieve either 80 percent removal of TSS, or discharge 80 mg/l or less of TSS according to accepted literature. It is also important to note that new development will often meet the water quality treatment performance standard if the volume control specified in the channel protection requirement of this permit is achieved.

Compliance with the water quality treatment performance standard may be shown through calculation or through direct measurement. Calculations or measurements must show reductions to the calculated TSS concentration in uncontrolled runoff using the data provided here or another acceptable literature source.

Channel Protection Performance Standard

The ordinance or regulatory mechanism shall incorporate the permit applicant's channel protection performance standard. If the performance standard is contained in a separate specification manual, it is acceptable to adopt the manual by reference in the ordinance or regulatory mechanism. The Application specifies channel protection criteria that require maintaining the post-development project site runoff volume and peak flow rate at or below pre-development levels for all storms up to the 2-year, 24-hour event. Pre-development level means the runoff flow volume and rate for the last land use prior to the planned new development or redevelopment. One of the biggest threats to stream water quality is excess sediment and channel instability caused by the increased rate and volume of storm water runoff resulting from development. Stream forms and dimensions are determined by the geology and rainfall of the contributing watershed. When development occurs, the land cover is often changed in a way that alters the response of that land to rainfall. Even altering land cover from highly pervious (forest/woods) to less pervious (grass) reduces the ability for storm water runoff to be intercepted. Rainfall that infiltrated into the ground or was evaporated off the leaves and branches of trees or was soaked up by the roots of plants now runs off directly to a stream. The outcome is that the surface runoff from the pervious and impervious areas of development increases in both amount and rate and channel erosion results as the stream adapts to the new flow.

> **Pre-development** means the last land use prior to the planned new development or redevelopment.

Compliance with this requirement is determined by calculating the existing ("pre-development") and post-development runoff volume and rate for the 2-year and smaller storm events. The method is described in the Department of Environmental Quality (DEQ) publication *Computing Flood Discharges for Small Ungaged Watersheds*, dated July 2003 (updated June 2008) and available at, https://www.michigan.gov/-/media/Project/Websites/egle/Documents/Programs/WRD/Hydrologic-Data/scs.pdf. If the post-development volume or rate exceeds the existing volume or rate, then appropriate controls or design changes shall be implemented to make the post-development runoff volume and rate equal to or less than the existing levels for all storms up to the 2-year, 24-hour event.

Acceptable sources of rainfall data for calculating runoff volume and peak flow rate are the *Rainfall Frequency* Atlas of the Midwest, Huff & Angel, National Oceanic and Atmospheric Administration (NOAA) Midwest Climate Center and Illinois State Water Survey, 1992 available at https://www.isws.illinois.edu/pubdoc/B/ISWSB-71.pdf or *NOAA Atlas 14 Precipitation Frequency Estimates*, NOAA National Weather Service, Hydrometeorological Design Studies Center, available at https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=mi.

There may be instances where site conditions (e.g., space limitations or tight soils that prevent infiltration) challenge or prohibit feasibility of maintaining the project site's pre-development runoff levels for all storms up to the 2-year, 24-hour event. The applicant should consider the incorporation of green infrastructure requirements and/or off-site mitigation and payment in lieu options in its post-construction storm water runoff control program, if conditions in the regulated area are likely to present challenges to developers for meeting the channel protection performance standard. Keep in mind that if allowing extended detention as a post-construction storm water runoff control, additional BMPs likely will be needed to maintain the pre-development volume and peak rate levels for all storms up to the 2-year, 24-hour event,

either through green infrastructure on-site or through an appropriate off-site requirement for meeting the performance standards. For additional information, refer to the Green Infrastructure and Low Impact Development section and the Off-Site Mitigation and Payment in Lieu Programs for Redevelopment Projects section later in this document.

Runoff Volume

Determining the runoff volume of a project site is done by a calculation. The Natural Resources Conservation Service (NRCS) Curve Number (CN) method is a widely used calculation method and is described in *Computing Flood Discharges for Small Ungaged Watersheds* stated above. The recommended model for most project sites is TR-55 available from the NRCS at: https://www.nrcs.usda.gov/resources. This model can be used to calculate both volume and rate. TR-55 uses the CN method to calculate volume of runoff and the unit hydrograph method to calculate peak rate. Although TR-55 is a relatively simple model to run, some training in hydrology is recommended. Other more complex models such as HEC-HMS available from the U.S. Army Corps of Engineers, Storm Water Management Model (SWMM) available from EPA and the Source Loading and Management Model (SLAMM) may be needed to evaluate larger and more complex sites and require more hydrology experience to set up. The model will be run once for the existing site condition and again for the post-development site condition.

Other methods may be acceptable as long as they can predict volume of runoff from a variety of land cover types. A CN represents the runoff potential of a project site based on cover and soils. The lower the CN the less runoff, the higher the CN the more runoff. Using the CN, runoff is calculated using the following formula

where,

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Q = runoff (in.)
P = rainfall (in.)
I_a = initial abstraction (in.) = 0.2
S = potential maximum retention after runoff begins (in.).

S is defined by the following formula

$$S = \frac{1000}{CN} - 10$$

So the volume of runoff can be calculated using only the precipitation, CN and area of the project site.

$$Q_v = Q \text{ x } 1/12 \text{ x } A$$

Where A is the area of the project site in square feet.

The runoff must be calculated for both the impervious area of the project site and the pervious area of the project site and then added together. The calculations can be organized in a spreadsheet or table as shown below. A spreadsheet to assist with these calculations is available at https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Forms/WRD/Storm-Water-Industrial/EQP9278-Calculations-for-Storm-Water-Runoff-Volume-Control.xlsx

Cover Type	Soil Type	Area (sf)	Area (ac)	CN (from TR-55)	S	Q Runoff * (in)	Runoff Volume (ft^3)
					$\frac{1000}{CN} - 10$	$\frac{(P - I_a)^2}{(P - I_a) + S}$	$Q \times 1/12 \times A$
Woods/Meadow	A	**0**		30	23.3	**0.25073734**	**0**
Open Space (Lawn)	A	**0**		39	15.6	**0.03862675**	**0**
Woods	B	**0**		55	8.2	**0.06036959**	**0**
Meadow	B	**0**		58	7.2	**0.10407505**	**0**
Open Space (Lawn)	B	**0**		61	6.4	**0.15911822**	**0**
Woods	C	**0**		70	4.3	**0.394707**	**0**
Meadow	C	**0**		71	4.1	**0.42786165**	**0**
Open Space (Lawn)	C	**0**		74	3.5	**0.53657244**	**0**
Woods	D	**0**		77	3.0	**0.6601594**	**0**
Meadow	D	**1476684**	33.90	78	2.8	**0.70492355**	**86745.7775**
Open Space (Lawn)	D	**0**		80	2.5	**0.80020595**	**0**
Impervious	N/A	**0**		98	0.20	**2.141543**	**0**
Other:		**0**					**0**
TOTAL:	**N/A**		**33.9**	**N/A**	**N/A**	**N/A**	**86,746**

** In this example the rainfall (P), used to calculate Q Runoff, was equal to 2.37 inches. The quantity used for P (and consequently, the calculation for Q) will vary regionally.*

Set up the table and enter the area of the project site for each applicable cover type and soil combination, and for the amount of impervious area. The columns for S, Runoff, and Runoff Volume are calculations based on the formulas at the top of each column and explained in the description above. Use the table to add up the volume of runoff for each applicable CN and show the total volume of runoff from the project site in the bottom right hand corner. The example above is for pre-development conditions where the project site was entirely undeveloped. Prepare separate tables for the existing project site and the post-development project site and compare the total volume of runoff for both conditions.

If the post-development volume of runoff is equal to or less than the volume of runoff from the existing site then the channel protection performance standard is met.

If the volume of runoff from post-development is greater than the volume of runoff from the existing site then the excess runoff volume must be removed to meet the channel protection performance standard. Example mechanisms to remove excess runoff volume include, but are not limited to, infiltration BMPs, capture and reuse, enhancing the project site with vegetation or soil amendments to reduce runoff and design changes such as reducing the amount of imperviousness. See the Green Infrastructure section later in this document for additional information.

Peak Runoff Rate

The peak runoff rate is a function of runoff volume and time of concentration (Tc). Tc is the time it takes a drop of water to move from the hydraulically most distance point in a watershed to a downstream point in the watershed. For the purposes of the calculation, the development project site represents the watershed. In general, if the runoff volume is controlled as described previously (in Runoff Volume above) and the Tc of the existing project site is maintained or increased for the developed condition, then the peak runoff rate will also be controlled. As project sites increase in size, however, the movement of water through them becomes more complex. Project sites that propose change to more than ten acres or have one acre or greater impervious area or have more than 50 percent impervious cover for the project site should not assume that if volume and Tc are controlled that peak runoff rate will be controlled.

If the Tc of the existing project site is not maintained or if the project site size criteria described above is exceeded, then the rate of runoff for the existing project site should be determined and compared to the rate of runoff for post-development. Calculating the rate of runoff requires the use of a hydrologic model. The recommended model for most project sites is TR-55 available from the NRCS at: https://www.nrcs.usda.gov/resources

As with runoff volume, the model will be run once for the existing site condition and again for the post-development site condition.

More detailed descriptions of methods to determine both runoff volume and rate can be found in Chapter 9 of the *Low Impact Development Manual for Michigan* available at: https://www.semcog.org/reports/lid/index.html.

A specific, detailed discussion of the Unit Hydrograph method for calculating peak rate and the CN method for calculating volume is explained in the document *Computing Flood Discharges for Small Ungaged Watersheds* available on the DEQ's website at: https://www.michigan.gov/-/media/Project/Websites/egle/Documents/Programs/WRD/Hydrologic-Data/scs.pdf.

Channel protection criteria shall not be required for the following waterbodies:

- The Great Lakes or connecting channels of the Great Lakes
- The Rouge River downstream of the Turning Basin
- The Saginaw River
- Mona Lake and Muskegon Lake in Muskegon County
- Lake Macatawa and Spring Lake in Ottawa County

Additional resource materials for the topics of minimum treatment volume standard and channel protection criteria are described in Appendix B.

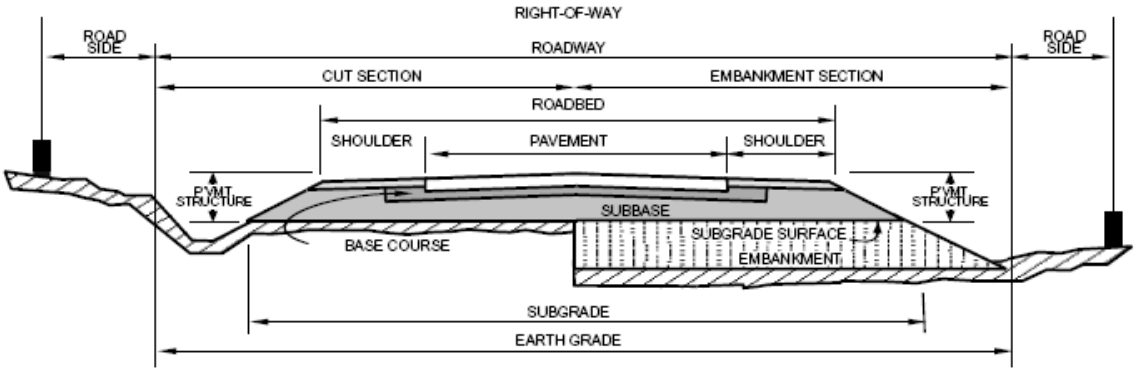
Equivalent Performance Standards

The Application allows for the permit applicant to propose exceptions to the water quality treatment and channel protection performance standards. When presenting exceptions to the standards, the applicant shall demonstrate how the approach provides an equivalent or greater level of protection as the performance standards described in the Application.

Considerations for Linear Projects

The water quality treatment and channel protection performance standards apply to linear projects, such as roads, streets, and trails, as well as to traditional development and redevelopment projects. Assistance with the performance standards is provided in the preceding sections. This section provides supplemental information for linear projects for use in tandem with the performance standard sections.

New linear projects are development projects. Projects that change the existing footprint (e.g., increase impervious surface) or offer new opportunities for storm water control (e.g., reconstruction to the subbase layer with a change in underdrainage) are considered redevelopment projects. Projects that do not disturb the underlying or surrounding soil (e.g., overlays), remove surrounding vegetation, or increase the area of impervious surface are not considered redevelopment projects. **To determine the area disturbed by a project, calculate the linear area of the project.**



Roadway Nomenclature

Image courtesy of Michigan Department of Transportation

Examples of linear development and redevelopment projects and how to determine the disturbance area are presented in the following table. These general examples may be used as a starting point; however, the unique features of each project must be factored in on a case-by-case basis.

Example Linear Projects		
Project	**Development or Redevelopment?**	**Disturbance Area**
New road (which may include new adjacent trails or sidewalks)	Development	Linear area of new road project (including any new adjacent trails or sidewalks)
New trail or sidewalk (without a change to an existing adjacent road)	Development	Linear area of new trail or sidewalk project
Re-pave; with re-construction to the subbase layer and a change in drainage	Redevelopment	Linear area of reconstruction plus any new additional impervious surface
Re-pave; overlay with no milling and no increase in impervious area or removal of surrounding vegetation or mill and overlay to the existing subbase layer with no change in drainage	Neither	Not applicable
Pave existing gravel shoulders; no additional center-road work	Redevelopment	Linear area of the shoulder paving (center-road excluded)
Convert raised center island in a boulevard to bioretention (no other changes to boulevard)	Neither. This would be considered a retrofit.	Not applicable

Projects sites with contamination constraints or right-of-way limitations may require alternative approaches to the performance standards. Refer to the Site-Specific Requirements section and the Off-Site Mitigation and Payment in Lieu Programs section below for additional information.

Green Infrastructure and Low Impact Development

The DEQ encourages green infrastructure planning and implementation as means for achieving water quality goals and benefits that align with those of the post-construction storm water runoff control program. Green infrastructure refers to the "network of open space, woodlands, wildlife, habitat, parks, and other natural areas which sustain clean air, water, and natural resources, and enhance quality of life" (*Low Impact Development Manual for Michigan* https://www.semcog.org/reports/lid/index.html). Generally, green infrastructure reduces runoff by allowing storm water to soak into the ground or to be taken up by vegetation, pathways which are greatly diminished in urban landscapes by the dominance of hard surfaces designed to shed water.

Of note is that green infrastructure is not limited to entirely natural areas offering traditional storm water infiltration. Green infrastructure also incorporates the use of manmade features and other alternatives for the purpose of intercepting and reducing storm water runoff. Rain gardens, green (vegetated) roofs, permeable pavement, impervious cover removal, use of trees instead of grass, reuse, and storage are all green infrastructure options.

Green infrastructure offers flexible options to meet the post-construction storm water runoff control program requirements. In a broad sense, green infrastructure can be incorporated into municipal planning efforts to protect and promote natural infiltration of storm water. On a site-specific basis, incorporating green infrastructure may help address sites where traditional infiltration will not work. Sites with soil or groundwater contamination and sites where land use activities have a potentially greater risk of polluted runoff than others ("hot spots") may not be suitable for storm water infiltration, due to the potential for new or exacerbated contamination of soils and aquifers. At these sites, use of manmade green infrastructure features may be appropriate. On sites with limited space available to implement traditional BMPs, such as a detention basin, green infrastructure can be implemented in various locations throughout the site that together achieve the post-construction storm water runoff control program requirements.

To be most effective, the planning, policy, and regulatory framework developed to support Green Infrastructure and the Post-Construction Storm Water Runoff Control program should be done so that they complement each other's objectives. A useful resource for getting started with Green Infrastructure planning is a recent publication entitled *Upgrade Your Infrastructure – Green Infrastructure Portfolio Standard* at https://www.cnt.org/sites/default/files/publications/CNT_UpgradeYourInfrastructure.pdf (American Rivers; The Center for Neighborhood Technology; and, The Great Lakes and St. Lawrence Cities Initiative).

For additional information on integrating and/or promoting green infrastructure, a number of resources may be found online including the Low Impact Development Manual for Michigan (https://www.semcog.org/reports/lid/index.html), the EPA's Green Infrastructure website (www.epa.gov/greeninfrastructure), the Center for Neighborhood Technology's website (www.cnt.org/water) and Green Values® Stormwater Toolbox (http://greenvalues.cnt.org), and/or by contacting DEQ staff.

Site-Specific Requirements

The following section discusses the use of storm water infiltration at contaminated sites, as well as storm water considerations to address pollutants associated with land uses of greater potential risk than others (i.e., hot spots).

Soil and/or Groundwater Contamination

Redevelopment of previously degraded sites offers benefits for minimizing land disturbance and impervious cover, as well as associated economic benefits. The DEQ encourages environmentally protective reuse of these areas; however, permit applicants should consider the potential impact of storm water infiltration at project sites with soil and/or groundwater contamination. Storm water infiltration and other storm water BMPs at such sites have the potential to mobilize contaminants, creating risk to groundwater, nearby surface waters, and human health.

The Application requires the permit applicant's procedure for reviewing the use of infiltration BMPs to meet the water quality treatment and channel protection standards for new development or redevelopment projects, in areas of soil or groundwater contamination, in a manner that does not exacerbate existing conditions. In its publication *Implementing Stormwater Infiltration Practices at Vacant Parcels and Brownfield Sites,* the U.S. Environmental Protection Agency recommends considering the following questions in determining whether infiltration is appropriate at a potentially contaminated property:

- Is a light non-aqueous phase liquid *(LNAPL)*, dense non-aqueous phase liquid *(DNAPL)*, biodegradable waste, or leachable contaminant source present at the site? Avoid infiltration in areas with these substances present.

- *Is groundwater beneath the property impacted or could it become impacted?* Avoid infiltration practices at sites where groundwater beneath the site is known to be contaminated.

- *Are areas or parts of the property not impacted?* These areas may be appropriate for infiltration when combined with other measures.

- *Are there State standards I can refer to as a guide in making decisions about infiltration practices?* Michigan's Natural Resource and Environmental Protection Act, 1994 PA 451, as amended (Act 451) revised Part 201, Environmental Remediation (Part 201), Cleanup Criteria and Part 213, Leaking Underground Storage Tanks (Part 213), Risk-based Screening Levels are available at https://www.michigan.gov/egle/about/organization/Remediation-and-Redevelopment/Remediation-and-Investigation/cleanup-criteria

- *Will infiltration interfere with required remediation?* For example, infiltration could increase hydraulic pressure on an installed vertical barrier potentially increasing leakage through the vertical barrier.

- *How does the site interact with other sites or land uses nearby?* For example, consider whether the site is located near sensitive wellhead protection zones or ecosystems and whether infiltration and gradient will impact the surrounding land.

Implementing Storm Water Infiltration Practices at Vacant Parcels and Brownfield Sites provides additional information regarding site characterization, detailed considerations for the above questions (including a decision flowchart), and options for storm water management without infiltration (see also Green Infrastructure section above).

Michigan's contaminated site information is available at https://www.michigan.gov/egle/public/learn/making-contaminated-sites-for-reuse. For additional information regarding brownfield and other contaminated sites the DEQ's Remediation and Redevelopment Division may be contacted (https://www.michigan.gov/egle/about/organization/remediation-and-redevelopment). Permit applicants are encouraged to incorporate into their procedure the process for coordinating with DEQ Part 201 and Part 213 staff as appropriate.

Hot Spots

Some land use activities have a potentially greater risk of polluted runoff than others. Project sites with these types of activities are referred to as "hot spots" and include uses such as gas stations, commercial vehicle maintenance and repair, auto recyclers, recycling centers, and scrap yards. Hot spots also include areas with the potential for contaminating public water supply intakes.

The permit applicant is required to have a means for requiring BMPs to address pollutants associated with potential hot spots as part of meeting the water quality treatment and channel protection standards for new development or redevelopment projects. Recognizing the intended use of a project site is a critical part of the process for evaluating appropriateness of proposed BMPs. Treatment for specific pollutants, such as an oil and water separator, may be warranted. In some cases, infiltration may not be suitable for hot spots or portions of hot spot project sites. Alternatives to storm water infiltration may be considered in these cases. For example, where conditions allow, a rain garden with an impermeable liner and an overflow pipe to an appropriate receiving area allows for some treatment via filtration through soil and plants without allowing excess water to infiltrate through a contaminated layer. In other areas, green (vegetated) roofs or collection of rainwater (e.g., cisterns) for reuse may be appropriate. Diversion and subsurface storage of rainwater also may be appropriate. The Green Infrastructure and Low Impact Development section above offers additional resources regarding alternatives to traditional storm water infiltration.

Off-Site Mitigation and Payment in Lieu Programs for Redevelopment Projects

The water quality treatment and channel protection performance standards focus on maintaining or restoring stable hydrology. When developing a post-construction program for redevelopment, the permit applicant may want to consider potential physical constraints that may limit the ability to fully meet the post-construction requirements at the project site. Redevelopment can reduce regional land consumption and minimize new land disturbance; however, redevelopment may also present site-specific challenges such as land use that is not conducive to capture and use of storm water, limited space available, or contaminated soils. When these physical constraints limit the feasibility of maintaining or restoring hydrology the application includes an option for establishing a program to move off site for these types of redevelopment projects.

The Application includes the following options for moving off site:

- **Off-site mitigation** refers to BMPs implemented at a location different from the original project site.

- **A payment in lieu program** refers to the developer paying a fee to the applicant (i.e., municipality) that is applied to a public storm water management project. The storm water management project may be either a new BMP or a retrofit to an existing BMP and developed in accordance with the municipality's performance standards.

A permit applicant may choose one or both options as part of its post-construction storm water runoff control program. The Application requires that these options be incorporated into the permit applicant's ordinance or other regulatory mechanism to ensure an enforcement mechanism. Both off-site mitigation and payment in lieu require that the off-site location be located within the same jurisdiction and watershed/sewershed as the original project. The highest preference for an off-site location should be given to locations that yield benefits to the same receiving water that received runoff from the original project site.

Watershed
Area represented by a 10-digit Hydrologic Unit Code

Sewershed
Area where storm water is conveyed by an MS4 to a common outfall or point of discharge

The permit applicant should establish and enforce through an ordinance or regulatory mechanism criteria for determining the conditions under which the option to move off site would be available, as well as, a requirement for the project developer to submit a justification as to the infeasibility of fully meeting the post-construction storm water runoff control requirements on site. The permit applicant should not solely consider the difficulty or cost of implementing BMPs on site as part of the determination. Multiple criteria should be established identifying the physical constraints of the project site.

The following are examples of criteria that should be considered when allowing a developer to move off site to meet all or parts of the post-construction storm water runoff control requirements:

- Limited size of the lot outside of the building footprint to create the necessary infiltration capacity even with amended soils
- Soil instability as documented by a thorough geotechnical analysis
- A site use that is inconsistent with capture and reuse of storm water
- Too much shade or other physical conditions that preclude adequate use of plants.
- The potential water quality impact from the original project site and the benefits realized at the off-site location. For example, the water quality impact from a site with a discharge to a small-sized stream would be greater than a site on a larger river and an offset downstream of the project site may provide less water quality benefit.

If a developer is approved to move off-site, the permit applicant should require the following offset ratio for the amount of storm water not managed on-site in relation to the amount of storm water required to be mitigated at another site or for which in-lieu payments will be made. The offset ratio should be applied as a tiered approach to encourage management of storm water runoff on site to the maximum extent practicable.

First Tier	Second Tier
Establish a minimum amount of storm water to be managed on-site (e.g., a minimum of 0.4 inches of storm water runoff). Require an offset ratio of 1:2 if the developer demonstrates to the applicant that this amount of runoff is completely infeasible to manage on site.	Require an off-set ratio of 1:1.5 for the amount of storm water above the first tier.

The applicant will need to establish a schedule for completing off-site mitigation and in-lieu projects. The recommended schedule is to complete these projects within 24 months after the start of the original site construction. A permit applicant who chooses to pursue a payment in lieu program may have "credits" available at the time the site plan is approved which could be offered to the developer. Upon completion of construction of projects or purchase of "credits," the permit applicant will need to require that offsets and in-lieu projects be preserved and maintained in perpetuity and a tracking system established.

Beyond cities and villages, road agencies may find these options useful to address projects with limited rights-of-way. A road agency may be able to identify other nearby locations to move offsite or opt to construct a storm water management project in a different location to use as "credit" to fulfill the application requirements. For example, if a road agency is adding an additional lane and the right-of-way was maximized by implementing multiple BMPs but the post-construction performance standards were not met, the road agency may opt to move offsite or buy "credits" from a storm water management project to fully meet the performance standards.

Site Plan Review

Site Plans

The Application requires that the permit applicant's post-construction storm water runoff control ordinance include a requirement that the developer prepare and submit a site plan for review and approval for each project subject to the post-construction storm water runoff control requirements. In general, site plan review allows the permit applicant to require and evaluate a suite of project construction and design details, including storm water management practices, during the project planning stage.

"A site plan is a plan, drawn to scale, showing the layout of proposed uses and structures. Site plans include lot lines, streets, building sites, existing structures, reserved open space, utilities, and any other required information." (Ardizone, K. A. and M.A. Wyckoff, 2003)

More specifically, review and approval of the site plan according to the permit applicant's established program provides the permit applicant with a foundation for ensuring that the finished project will sufficiently meet post-construction storm water runoff program requirements and ensuring long-term O&M of BMPs. Construction inspections, evaluation of as-built plans, and as-built inspections should be used to confirm that completed projects meet requirements.

In order to ensure that site plans are reviewed consistently and adequately incorporate post-construction storm water runoff program requirements, a procedure for site plan review and approval is required. The permit applicant should have a checklist or specific criteria to be used by plan reviewers. The checklist and/or criteria should include all the standard conditions of the permit applicant's post-construction storm water runoff program—from installation through O&M. At a minimum, the checklist and/or criteria should prompt the permit applicant to assess whether:

- MS4 and waterbodies are accurately represented;
- Adequate BMPs are shown on the plans;
- Standard conditions are followed;
- Performance standards are met;
- Appropriate requirements are specified to ensure long-term O&M; and
- BMP placement would obstruct adequate O&M.

Although projects proposed for both private properties and municipal properties are subject to the site plan requirement, the review process may vary. For example, the review process for private properties may be delineated in an ordinance, whereas the review process for a permit applicant's own projects (e.g., road commission project, city project) may be via an internal policy or procedure. As long as the processes equivalently ensure that permit requirements are met, this is acceptable. In addition, some entities, such as county drain commissioners or road commissions, may have a slightly different, but equivalent site plan requirement that occurs through a local permitting process.

Tracking the Developer Site Plan Requirement

To document the developer site plan process, records shall be maintained of the site plans and information that demonstrates the site plan process was used to implement the post-construction storm water runoff program requirements such as, copies of the reviewer's completed checklist and/or the review criteria used during the review process, copies of correspondence between the permit applicant and the developer, a copy of the final approved design, and any other relevant information.

Further, since the purpose of the site plan requirement is to ensure that proposed and completed projects comply with the permit applicant's post-construction storm water runoff program requirements, it is important for permit applicants to have a construction and as-built inspection program. A construction and as-built inspection program will help to ensure that projects are constructed and completed in accordance with approved site plans. Proper BMP installation is critical to optimizing the effectiveness of post-construction BMPs. Performance bonds can be used to provide a financial incentive for proper BMP construction. Following construction, the permit applicant should complete an inspection or require a self-certification process to ensure the BMP was constructed in accordance with the approved final site plan. It is recommended that inspection records or logs be maintained by the permit applicant and document the site conditions, proper construction of BMPs in accordance with approved plans, and any non-compliance issues or violations observed at the time of the inspection. The enforcement actions taken to resolve the violations shall be documented.

In addition, permit applicants should consider maintaining records of employee trainings to document that the appropriate municipal staff, contract staff, or engineers are adequately trained to implement the site plan process and ensure long-term O&M of BMPs.

Long-Term O&M of BMPs

Ordinance Requirements

The Application requires that the permit applicant's post-construction storm water runoff program ordinance or regulatory mechanism include a requirement for long-term O&M of all structural and vegetative BMPs installed and implemented to meet the performance standards in perpetuity. In addition, the ordinance or other regulatory mechanism shall require a maintenance agreement between the permit applicant and the owners or operators responsible for long-term O&M of the BMPs. The maintenance agreement or another legal mechanism shall allow the permit applicant to:

> An example of a maintenance agreement is available in Appendix G of the *Low Impact Development Manual for Michigan* (SEMCOG, 2008).

1) inspect the structural or vegetative BMP; 2) perform necessary maintenance or corrective actions neglected by the BMP owner or operator; and 3) track the transfer of the O&M responsibility of the BMP. If the ordinance or regulatory mechanism does not require a maintenance agreement and/or the maintenance agreement does not include the aforementioned three items, the permit applicant should describe the requirements in an alternative ordinance or regulatory mechanism and explain how the maintenance agreement or other legal binding mechanism allows the applicant to verify and ensure maintenance of the BMP. Ultimately, the permit applicant should have authority to address inadequate BMP performance if necessary, which may include the ability to access BMPs. For example, a storm water easement may be necessary to establish a legal contract to access and maintain a BMP. Permit applicants should include a tracking and enforcement requirement in an ordinance or other regulatory mechanism to ensure maintenance of the BMP to meet the performance standards in perpetuity.

As part of the site plan review process, the permit applicant should review the O&M plan to ensure long-term O&M of the BMP such that the permit applicant's standards for water quality treatment and channel protection are met in perpetuity. Factors to consider when reviewing an O&M plan may include:

- Operating instructions for the outlet component;
- Vegetation maintenance schedule;
- Responsible party designation;
- Inspection checklists;
- Maintenance checklists; and
- Tracking requirements.

Permittees shall maintain records documenting the O&M plans, and information that demonstrates the O&M plan review process, such as copies of the reviewer's checklist and/or the review criteria used during the review process, copies of correspondence between the permit applicant and the developer, a copy of the final approved plan, and any other relevant information. Permittees may use other agencies or contract staff to review and approve the O&M plans. It is important for permittees to review the O&M plans approved by other agencies and contract staff to ensure consistency.

For permit applicants' own projects, the permit applicant may choose to state that the permit applicant is the owner/operator of the BMP and is responsible for the long-term operation and maintenance of all structural and vegetative BMPs installed and implemented to meet the performance standards. The requirement to maintain BMPs owned/operated by the permit applicant would fall under the Pollution Prevention and Good Housekeeping Program.

<u>O&M Inspections</u>

Routine inspections are critical to ensure BMPs are performing as designed and the permit applicant's performance standards for water quality treatment and channel protection are being met. BMPs should be inspected in accordance with the approved O&M agreement. This includes the BMPs owned/operated by the permit applicant. Based on the results of the inspection, short-term (routine or more frequent), long-term (non-routine or less frequent), and major (rare) actions may be necessary to ensure proper maintenance. Also, emergency maintenance may be necessary to address unexpected problems.

Storm Water BMP O&M Frequency Guidelines	
Short-term (more frequent)	Routine Visual assessment, litter and debris removal, vegetation management
Long-term (less frequent)	Non-routine Clean out trash and solids, structural repairs, partial rehabilitation
Rare	Major Rehabilitation or rebuild

Tracking O&M

A good tracking system would include documentation of the O&M plans along with the locations, conditions, and ages of BMPs and could be developed through the use of geographical information systems, databases, spreadsheets, or lists.

It is recommended that permittees also track inspection findings by permittee staff and the BMP owner/operator to ensure proper O&M occurs in perpetuity. Depending on the requirements of the permit applicant's ordinance or other regulatory mechanism for ensuring the O&M plans, the BMP owner/operator could be required to 1) submit documentation identifying inspection dates and details as well as maintenance performed or 2) maintain inspection and maintenance information and make this information available to permit applicant staff during an inspection.

Enforcement Response Procedure

Violations of the Ordinance or Regulatory Mechanism

The Application requires delineation of measures for resolving noncompliance when a project developer or the BMP owner/operator is not achieving requirements of the post-construction storm water runoff program (e.g., failure to construct a BMP in accordance with the approved site plan or a home owner's association failing to implement their O&M plan). The ability to impose these enforcement measures shall be supported by the permit applicant's ordinance or regulatory mechanism.

Enforcement measures include, but are not limited to:

- Right of entry for inspections
- Notices of violation
- Mandatory abatement
- Authorization of the permit applicant to conduct BMP maintenance and re-coup costs from the developer or the BMP owner/operator when BMPs are not properly inspected and/or maintained
- Ability to issue civil penalties
- Ability to issue monetary fines proportionate to the violation

Tracking Enforcement

The Application requires a method for tracking instances of non-compliance with the post-construction storm water runoff ordinance or other regulatory mechanism. The tracking documentation may be kept as an electronic file or a hard copy file. The tracking procedure should ensure that detailed information about non-compliance and follow up enforcement action is adequately documented.

Enforcement records should document, as appropriate:

- Name of the person responsible for violating the ordinance or regulatory mechanism
- Date and location of the violation
- Description of the violation (which may include how the violation was identified such as during construction inspections, O&M inspections, referral, complaint, etc.)
- Description of the enforcement response used (e.g., stop work orders, violation notices, civil and criminal penalties, etc.)
- Schedule for returning to compliance
- Date the violation was resolved

References

Ardizone, Katherine A. and Mark A. Wyckoff, FAICP. FILLING the GAPS: Environmental Protection Options for Local Governments, Michigan Department of Environmental Quality Coastal Management Program with financial assistance from the National Oceanic and Atmospheric Administration, authorized by the Coastal Zone Management Act of 1972. June 2003.

Managing Stormwater in Your Community. A Guide for Building an Effective Post-Construction Program. Center for Watershed Protection. EPA Publication No.: 833 R 08-001. July 2008

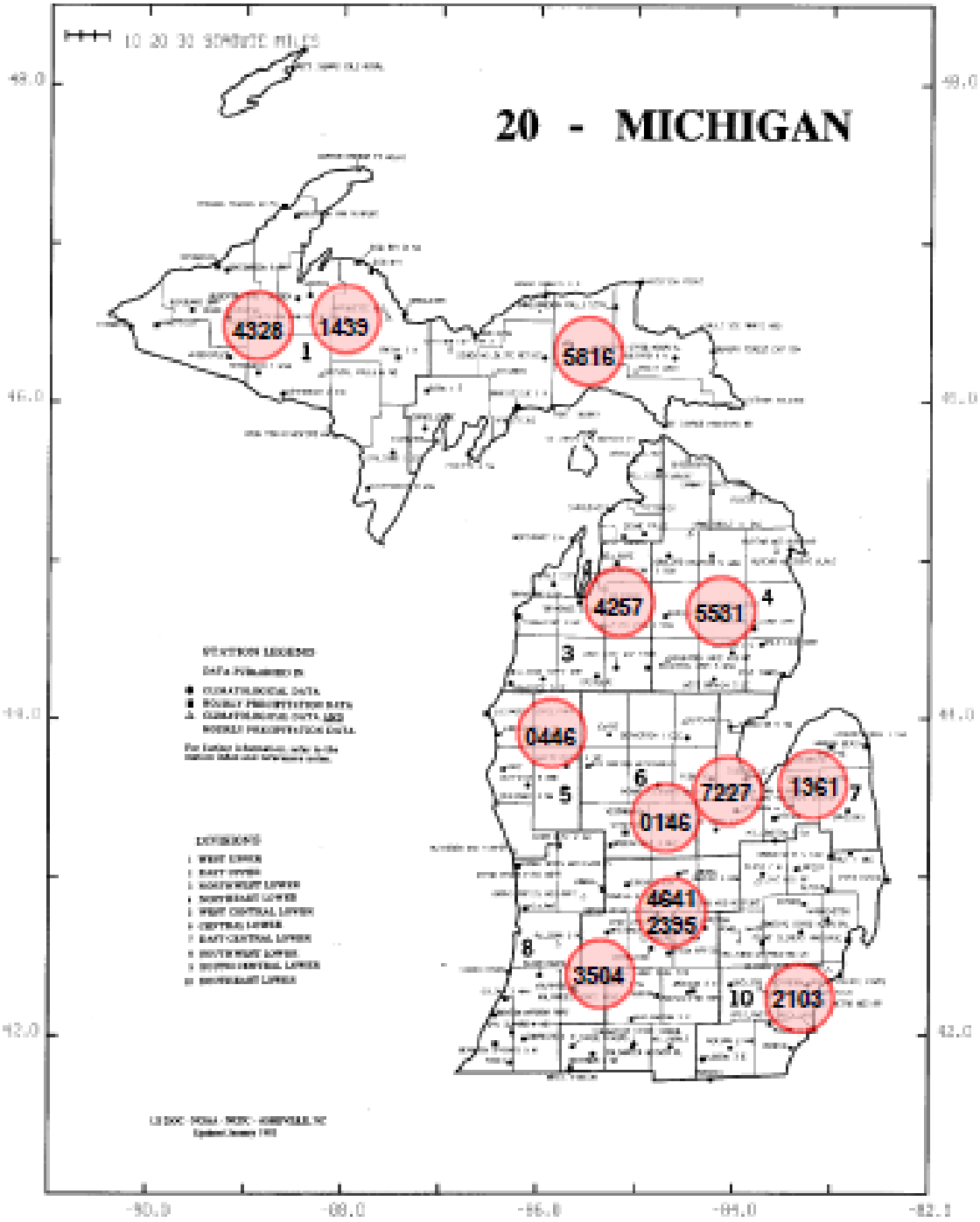
Minnesota Stormwater Manual, 2006. Minnesota Pollution Control Agency, St. Paul, MN.

SEMCOG, the Southeast Michigan Council of Governments. Low Impact Development Manual for Michigan: A Design Guide for Implementors and Reviewers. 2008.

U.S. EPA. MS4 Program Evaluation Guidance. U.S. Environmental Protection Agency, Office of Wastewater Management. January 2007 References

Appendix A

Weather Stations



(from the statewide analysis by region for the 90 Percent Annual Non-Exceedance Storms summarized in a memorandum dated March 24, 2006, and available at https://www.michigan.gov/-/media/Project/Websites/egle/Documents/Programs/WRD/Hydrologic-Data/ninety-percent.pdf)

Appendix B

Resource List

90-Percent Annual Non-Exceedance Storms Memorandum, March 24, 2006, Michigan Department of Environmental Quality.
https://www.michigan.gov/-/media/Project/Websites/egle/Documents/Programs/WRD/Hydrologic-Data/ninety-percent.pdf

This memorandum provides a statewide analysis, by region, for the 90 percent annual non-exceedance storms.

Computing Flood Discharges for Small Ungaged Watersheds, July 2003 (updated June 2008, Michigan Department of Environmental Quality.
https://www.michigan.gov/-/media/Project/Websites/egle/Documents/Programs/WRD/Hydrologic-Data/scs.pdf

This report presents a method for computing flood discharges using unit hydrograph (UH) and Curve Number (CN) techniques. It contains methods for estimating pre- and post-development runoff volume and peak flow rate.

DEQ Guidebook of BMPs, Michigan Department of Environmental Quality. https://www.michigan.gov/egle/about/organization/Water-Resources/nonpoint-source/BMP-manual-and-design-references

This document contains design guidance for a suite of BMPs appropriate for Michigan. Site-level and watershed-level BMPs are included.

Implementing Stormwater Infiltration Practices at Vacant Parcels and Brownfield Sites, July 2013, U.S. Environmental Protection Agency, Office of Water and Office of Solid Waste and Emergency Response, EPA Publication Number 905F13001.
https://www.epa.gov/sites/default/files/2015-10/documents/brownfield_infiltration_decision_tool.pdf

This document presents information to assist communities, developers, and other stakeholders in determining the appropriateness of implementing storm water management practices that promote infiltration at vacant parcels and brownfield sites.

International Stormwater Best Management Practice (BMP) Database, several sponsors, including the U.S. Environmental Protection Agency
http://www.bmpdatabase.org/

The purpose of the site is to provide scientifically sound information to improve the design, selection, and performance of BMPs. Includes technical documents, software and a database developed over the past decade.

Low Impact Development Manual for Michigan: A Design Guide for Implementors and Reviewers, Southeast Michigan Council of Governments.
https://www.semcog.org/reports/lid/index.html

This manual provides communities, agencies, builders, developers, and the public with guidance on how to apply LID to new, existing, and redevelopment sites. The manual provides information on integrating LID from the community level down to the site level. It outlines technical details of BMPs and provides a larger scope of managing storm water through policy decision, including ordinances, master plans, and watershed plans. Example ordinances, worksheets, and checklists are provided.

Measurable Goals Guidance for Phase II Small MS4s, U.S. Environmental Protection Agency
https://www3.epa.gov/npdes/pubs/measurablegoals.pdf.

This document provides information and example approaches for developing measurable goals for a SWMP.

National Stormwater Calculator, U.S. Environmental Protection Agency
https://www.epa.gov/water-research/national-stormwater-calculator

This is a tool for calculating small site hydrology aimed at helping site developers and property owners explore how to meet a desired storm water retention target under different development scenarios. The calculator estimates the amount of storm water runoff generated from a site over a long term using historical rainfall data. Runoff can be calculated and compared by "applying" various low impact development (LID) practices to help capture and retain rainfall on-site.

NOAA Atlas 14 Precipitation Frequency Estimates, NOAA National Weather Service, Hydrometeorological Design Studies Center
https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=mi.

This is an acceptable source of rainfall data for calculating runoff volume and peak flow rate.

Rainfall Frequency Atlas of the Midwest, Huff & Angel, NOAA Midwest Climate Center and Illinois State Water Survey, 1992
https://www.isws.illinois.edu/pubdoc/B/ISWSB-71.pdf.

This is an acceptable source of rainfall data for calculating runoff volume and peak flow rate.

The National Pollutant Removal Performance Database, Version 3, September 2007, Center for Watershed Protection
http://owl.cwp.org/mdocs-posts/fraley-mcneall-_national_pollutant_removal_perf_v3/

The National Pollutant Removal Performance Database contains the expected percent reduction of TSS for many common BMPs. Version 2 of the database (http://www.stormwatercenter.net/Library/STP-Pollutant-Removal-Database.pdf) consisted of 139 individual BMP performance studies published through 2000. Version 3 updated the database with an additional 27 studies published through 2006.

TR-55, U.S. Department of Agriculture, Natural Resources Conservation Service
https://www.nrcs.usda.gov/resources

This hydrologic model can be used to calculate both runoff volume and rate. TR-55 uses the CN method to calculate volume of runoff and the UH method to calculate peak rate. Although TR-55 is a relatively simple model to run, some training in hydrology is recommended.

Upgrade Your Infrastructure – Green Infrastructure Portfolio Standard, American Rivers; The Center for Neighborhood Technology; and, The Great Lakes and St. Lawrence Cities Initiative
https://www.cnt.org/sites/default/files/publications/CNT_UpgradeYourInfrastructure.pdf

This document outlines a process for developing a green infrastructure portfolio standard and presents a case study of the City of Grand Rapids, Michigan.