# City of Lansing, MI

# STORMWATER MANAGEMENT DESIGN MANUAL

JANUARY 2013 (REV. APRIL 2020)

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City of Lansing, MI

Public Service Department

124 W. Michigan Avenue, 7th Floor

Lansing, MI 48933

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# ACRONYMS

| | |
|---|---|
| BMP | Best Management Practice |
| BOD | Biological Oxygen Demand |
| CDA | Contributing Drainage Area |
| cfs | cubic feet per second |
| CN | Curve Number |
| EGLE | Michigan Department of Environment, Great Lakes and Energy |
| FEMA | Federal Emergency Management Agency |
| fps | feet per second |
| HSG | Hydrologic Soil Group |
| LID | Low Impact Development |
| MDOT | Michigan Department of Transportation |
| MS4 | Municipal Separate Storm Sewer System |
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | Natural Resources Conservation Service (formerly Soil Conservation Service, SCS) |
| O&M | Operations and Maintenance |
| PWSS | Public Water Supply System |
| RCP | Reinforced Concrete Pipe |
| ROW | Right-of-way |
| SCS | Soil Conservation Service (now the NRCS) |
| SCM | Stormwater Control Measure |
| SDWA | Safe Drinking Water Act |
| Tc | Time of Concentration |
| Tt | Travel Time |
| TOT | Time of Travel |
| TR-55 | Technical Reference No. 55 |
| TSS | Total Suspended Solids |
| UH | Unit Hydrograph |
| WHPA | Wellhead Protection Area |
| WHPP | Wellhead Protection Program |

# INTRODUCTION

The purpose of this document is to define minimum requirements, minimum design standards and procedures for stormwater runoff for new and redeveloped projects regulated by the City of Lansing to address stormwater quality and quantity. The requirements apply to physical development within the City. The Michigan Low Impact Development (LID) Manual provides design information on each type of stormwater control and is recommended to be utilized in conjunction with this manual.

It is not intended that these minimum requirements be blindly applied in every situation. Design conditions vary and there is no substitute for the professional judgment of an experienced engineer. In all cases, this judgment should be applied.

There are many computer programs available to help in the design of drainage systems. These programs may use different methods of analysis than those presented herein. Therefore, the designer of the drainage system should check with the City before using a particular software package not identified in this manual.

Drainage infrastructure should normally be designed for a minimum service life of 50-years. A longer service life is recommended whenever possible.

## APPLICABILITY

To prevent an increase in non-point source pollution and stormwater runoff, the requirements in the following sections shall apply to any new development or re-development projects that disturb an area greater than 1,000 square feet.

The City will review all stormwater related submittals for general compliance with these specific standards. An acceptance by the City does not relieve the applicant from the responsibility of ensuring all systems are safe and that calculations, plans, specifications, construction, and record drawings comply with normal engineering standards, this design manual, and other applicable local, state, and federal rules and regulations.

The City Engineer may require more stringent requirements than would normally be required under these standards depending on special conditions and/or environmental constraints.

Applicable policies, site plan submittal process and review requirements, and implementation procedures are discussed in the Policies and Procedures Manual of this document.

## HOW TO USE THIS MANUAL

This design manual specifies drainage requirements for new development and significant redevelopment sites. It will provide the drainage design engineer the resources and information necessary to develop a unique site drainage design for specific site conditions. The remainder of this design manual is organized as follows:

***Design Criteria and Engineering Standards***– Presents the general requirements for managing site stormwater and definitions of when the requirements apply. Specific design requirements for each type of facility are discussed here.

***Hydrology Calculations and Methodology*** – Describes the acceptable methods and calculations in generating stormwater runoff peak flow rates and volumes for a site.

***Additional Design Criteria for Special Situations*** – Details the criteria that shall be applied when proposed development is located adjacent to sensitive receiving waters and how to address stormwater management in an ultra-urban situation, transportation corridors, and designated hotspots. This section will define what qualifies as a sensitive receiving water.

***Best Management Practices*** – Provides guidance on selecting proper BMPs for a site based on specific conditions encountered at the site.

***Detailed BMP Operation and Maintenance Requirements and Checklists*** – Addresses the operation and maintenance considerations for stormwater facilities to ensure successful long-term operation.

## CITY ORDINANCE AND STATE REGULATORY REQUIREMENTS

Similar to other Michigan municipalities in "urbanized areas", the City of Lansing is required by the State of Michigan, Department of Environment Great Lakes and Energy (EGLE), to obtain National Pollutant Discharge Elimination System (NPDES) permit authorization for the discharge of its municipal stormwater to surface water bodies of the State of Michigan, including the Grand River, the Red Cedar River, and Sycamore Creek. One of the requirements of the NPDES permit is to implement and enforce a Post-Construction Storm Water Runoff Program (Program) to address post-construction stormwater runoff from all new development and redevelopment projects. The NPDES permit's associated requirements specify that the Program, at minimum, include:

- a minimum treatment volume standard to minimize the water quality impacts from total suspended solids in the stormwater runoff; and
- channel protection criteria to prevent resource impairment resulting from the higher, peak flow volumes and rates that occur during and/or following wet weather.

These design criteria developed for permit compliance are further specified and discussed in the following sections of this manual.

The City of Lansing's Planning and Zoning Code, Part 12 of the City's Codified Ordinances, provides the authority for implementation and enforcement of this program for post-construction controls for development and redevelopment. City Ordinance 1242.05(b), "Contents of Site Plans", requires that **"**A site plan shall consist of a sealed drawing which is drawn to scale, prepared in a professional manner, and contains all of the following information:……….. a proposed stormwater management plan, including, but not limited to design of sewers, drains, outlets, and retention or detention ponds. Sufficient data regarding sewer material, site runoff estimates and off-site drainage patterns shall be provided to permit review of feasibility and permanence of drainage detention and/or retention, as well as the impact on local surface and groundwater. The point of discharge for all drains and pipes shall be specified on the site plan."

More specific to the implementation and enforcement of the Program, City Ordinance 1242.07(o), requires that, prior to site plan approval, "Storm water detention, retention, transport, and drainage facilities shall, insomuch as feasible, **be designed to use or enhance the natural storm water system on-site, including the storage and filtering capacity of wetlands, watercourses, and water bodies, and/or the infiltration capability of the natural landscape**. Storm water facilities shall **be designed so as to minimize flooding or the potential for pollution of surface or groundwater, on-site or off-site**" (emphasis added to key language).

To further support implementation and enforcement of its Program, the City approved (in 2018) a new chapter under Part 12 of the City's Codified Ordinances, Chapter 1219, "Post-Construction Storm Water Management", which specifies all associated Program requirements. Of note, City Ordinance 1219.08 establishes all Program design standards and criteria consistent with NPDES requirements and the requirements of this Design Manual. Again, the above-described design criteria are specified and discussed further in the following sections of this manual.

## POLICIES AND PROCEDURES MANUAL

In conjunction with this Stormwater Management Design Manual, the City has developed an accompanying document, the Stormwater Management Policies and Procedures Manual. While the purpose of this Design manual is to provide specific criteria for design, including engineering standards, the Policies and Procedures Manual is intended to provide direction on how to incorporate these required stormwater controls as part of the City's site plan review process.

As a result, it is strongly encouraged that the Stormwater Management Policies and Procedures Manual be referenced in conjunction with this manual. A PDF copy of this document can be accessed on the City's website at the following address:
www.lansingmi.gov/pubserv/stormwater/stormwater_controls_for_development.jsp

## LOW IMPACT DEVELOPMENT MANUAL FOR MICHIGAN

In order to aide design professionals and those entities seeking to implement EGLE's required program for post-construction controls for new development and redevelopment projects, federal grant funding and other resources were utilized to create the Low Impact Development (LID) Manual for Michigan with the primary composition of which being attributed to the Southeast Michigan Council of Governments (SEMCOG). This manual provides an exhaustive description and evaluation of various low impact development design parameters and best management practices to achieve the goals and requirements of the program for Post-construction Controls for New Development and Redevelopment Projects.

Although this Design manual must be referenced for all projects discharging to the City of Lansing's storm sewer system, the length and breadth of the LID Manual for Michigan allows for much greater detail on specific design approaches and decision-making relative to the design of on-site facilities to achieve the goals of the program. Therefore, the LID Manual for Michigan is an indispensable tool that all design professionals will find helpful and useful, and there is no fee associated with the download of this document, which can be located on SEMCOG's website at the following address:

www.semcog.org/LowImpactDevelopment.aspx.

# DESIGN CRITERIA AND ENGINEERING STANDARDS

This section identifies drainage system design requirements for new development or redevelopment projects that are regulated by the City.

## HYDROLOGIC DESIGN CRITERIA

As urban areas continue to develop and sites redevelop the volume of runoff rises because of the increase in impervious areas. Previously, stormwater management philosophy concentrated on only addressing the effects of the additional volume of flow being generated. However, with the enactment of the NPDES Phase II Stormwater Permit regulations the current philosophy of stormwater management now focuses on a more integrated approach that acknowledges the aspects of volume, rate and quality as well as the relationship between ground water and surface water.

In an effort to standardize design procedures for stormwater facilities and adopt the current philosophy of stormwater management, the City of Lansing has developed these standards. It is intended that these standards will facilitate planning and design processes.

The developer shall meet the following minimum design requirements for controlling stormwater runoff in the City:

1. Water quality treatment volume
2. Channel protection
3. Flood control
4. Stormwater conveyance
5. Groundwater recharge
6. Operation and maintenance requirements
7. Enforcement mechanism with recordkeeping procedures

These minimum design requirements apply to all sites of new development and/or redevelopment that result in a discharge of stormwater runoff from the site to the City of Lansing's separate storm sewer system infrastructure. The City Engineer **may** on a case-by-case basis waive the requirements for flood control and/or stormwater conveyance, if it is adequately demonstrated that the stormwater runoff resulting from the project will not negatively impact any existing or projected localized flooding or available storm sewer capacity in the system.

Each design requirement is discussed in more detail in the following sections and summarized in Table 1 on the following page.

**Table 1 Hydrologic Design Criteria Overview**

| Variable | Design Event | Applies to: | Volume Discharge Limit | Peak Flow Limit | Description | Freeboard Requirements | Emergency Overflow | Exceptions |
|---|---|---|---|---|---|---|---|---|
| Water Quality Treatment Volume | 90 % non-exceedance (0.9 inches of rainfall) | Sites (parcels) and roadways | NA | NA | Retain (preferred) or treat runoff from the entire site | NA | Direct overflow to channel protection SCMs | Redevelopment sites are required only to treat runoff from the disturbed area of the proposed redevelopment. |
| Channel Protection | Up to and including the 2-year 24-hour | Sites (parcels) and roadways | Less than or equal to condition prior to development | Less than or equal to condition prior to development | Provide retention as necessary to meet volume and peak flow limits | NA | Direct overflow to flood control SCMs | None |
| Collection System | 10-year 24-hour (non-sag points)<br><br>50-year 24-hour (sag points) | Sites (parcels) | NA | Less than or equal to condition prior to development | Provide detention as necessary to meet peak flow limit | HGL preferred below crown of pipe. HGL at least 1-ft below ground surface | NA | None |
| | | Roadways | NA | Limited by existing downstream capacity | Size conveyance system for design event. Provide detention as necessary based on downstream collection system capacity | HGL preferred below crown of pipe. HGL at least 1-ft below ground surface | NA | None |
| Flood Control | Up to and including the 100-year 24-hour | Sites (parcels) | NA | Less than or equal to condition prior to development | Provide detention as necessary to meet peak flow limit | Provide 1-ft of freeboard between the design flood storage elevation and any nearby structures or other facilities | Provide overflow pathway to prevent flooding of structures | Not required for site within 500-ft of the Grand or Red Cedar rivers if pathway is provided that prevents flooding of structures |
| | | Roadways | NA | NA | Provide overland conveyance or storage capacity to prevent flooding of structures | NA | Provide overland conveyance or storage capacity to prevent flooding of structures | Not required for site within 500-ft of the Grand or Red Cedar rivers if pathway is provided that prevents flooding of structures |

The design criteria for new and redevelopment projects that fall under the applicability requirements above are defined below.

### Water Quality Treatment Volume

As per Table 1, the SCMs must be designed to treat or capture the runoff from 90 percent of all runoff-producing storms, which for the Lansing area has been designated by EGLE to be 0.9 inches of rainfall (as per March 24, 2006, DEQ-Dave Fongers memorandum). SCMs shall be designed on a site-specfic basis to achieve a minimum of 80 percent removal of total suspended solids (TSS) as compared with uncontrolled runoff or a discharge concentration of TSS not to exceed 80 milligrams per liter (mg/L). Treatment can be addressed by retaining the minimum required water quality treatment volume, capturing the water quality treatment volume in an SCM, filtering the water then releasing it, or filtering the water through a hydrodynamic device.

In order to calculate the water quality treatment volume, the site area must be used in conjunction with an acceptable and approvable method for calculating the runoff resulting from water quality treatment volume. Acceptable and approvable methods for calculating runoff from site development are discussed in this manual's Hydrology Calculations and Methodology section.

One or more SCMs are to be implemented when necessary in a configuration that results in effective treatment for the required volume.

### Channel Protection Criteria

There is to be no increase in the discharge of runoff volume and peak flow from a site for the channel protection criteria.

Should the required volume control not be achievable at a reasonable cost upon the site and is clearly demonstrated as such, special considerations may be given. One such consideration is providing the requisite control volume off site but within the same watershed. Such approach is deemed an "Offset" and must be applied in a manner acceptable to the City. Specific requirements for using Offsets are covered in the Policy & Procedures Manual.

An example design incorporating the channel protection criteria is provided in the SDST User's Manual.

### Flood Control

The intent of the flood control criteria is to provide for public safety; minimize on-site and downstream flood impacts relating to stream bank protection and stormwater conveyance systems; maintain the boundaries of the mapped 100-year floodplain; and protect the physical integrity of the on-site stormwater controls and the downstream stormwater conveyance and flood control facilities.

Those efforts employed for Channel Protection as described above are deemed sufficient mitigation for storm events up to those addressed in that requirement. However, protection against flooding is sought for storms exceeding the Channel Protection Criteria. As such, additional measures are required to provide sufficient mitigation.

### Flood Control Design

Prior to beginning the design of the on-site stormwater facilities, the developer must contact the City to determine if any downstream restrictions have been identified that would further restrict the discharge of stormwater from the developer's site.

Designs should be based on meeting the Flood Control requirements in Table 1. The volume that is captured and managed in various SCMs occurring on the site may be subtracted. Design should also consider the ability of the downstream facilities to safely transport the stormwater discharge.

Discharge rates more stringent than those derived from the established criteria may be imposed if downstream conditions such as limited capacity for enclosed conveyance pipes, limitations on flows to those used in the FEMA modeling, or other specific restrictions are identified.

Flood control must be provided that accounts for on-site conveyance as well as downstream conditions.

Additional key requirements for flood control include:

- Providing 1-foot of freeboard between the design flood storage elevation and any nearby structures or other facilities that could suffer lasting damage if inundated with stormwater.
- Providing for an emergency overflow pathway from the site to a down gradient receiving water body, such that overflow can occur as long as the potential for permanent damage is minimized.

### Downstream Flood Control

Under no circumstances shall the proposed site development diminish the storage capacity in the 100-year floodplain. Compensatory storage due to a proposed site development will be required for all lost floodplain storage on a 2 to 1 replacement ratio.

### Stormwater Conveyance

Stormwater drainage systems may consist of natural streams, channels, vegetated swales, open ditches, closed conduits or a combination of methods to convey stormwater. Drainage facilities shall be constructed in accordance with the City's minimum specifications presented in this manual. Other standards may apply depending on location of the outlet.

The full build-out 100-year, 24-hour design storm shall be routed through the on-site storm sewer system and stormwater controls to determine the effects on the on-site system, adjacent property, and downstream areas. Even though the conveyance systems may be designed for smaller storm events, overall the site should be designed appropriately to safely pass the resulting flows from the full build-out 100-year storm event with no flood waters entering habitable structures.

## PRECIPITATION DATA

Accurate rainfall frequency data are necessary to determine a reliable design. As such, the City accepts the Rainfall Frequency Atlas of the Midwest (Huff and Angel, 1992) as the most reliable, up to date source of rainfall frequency data.

This is available for free download at www.sws.uiuc.edu/pubdoc/B/ISWSB-71.pdf. The City is located in Zone 9 of Michigan, the 24-hour event data for which are as follows:

| | **Table 2: Rainfall frequencies, 24-hour duration (rainfall in inches)** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Zone** | 1-year | 2-year | 5-year | 10-year | 25-year | 50-year | 100-year |
| 9 | 2.03 | 2.42 | 2.98 | 3.43 | 4.09 | 4.63 | 5.20 |

## ENGINEERING STANDARDS

### Storm Sewers

The following minimum standards apply to the design of storm sewers.

The design storm used to size storm sewer systems will be a 10-year design storm event assuming a 10-year river level in the receiving waterway. In many instances, the downstream drainage system will have less than a 10-year design capacity, but for many localized storms, the added local capacity will provide frequent drainage benefits for little added construction cost. Table 3 on the following page summarizes the design standards for storm sewer systems.

**Table 3 Storm Sewer Hydraulic Design Standards**

| **Design Variable** | **Design Standard** |
|---|---|
| Minimum Velocity | 2 fps |
| Maximum Velocity | 10 fps<br>For velocities > 10 fps, detailed analysis is required |
| Minimum Pipe Size | 12-inches |
| Inlet Locations | Provide inlets at all street crossings |
| Junction Locations | Provide manholes at all inlets and direction, size, and slope changes |
| Manhole Spacing | < 48-inches = 400 feet max<br>> 48-inches larger spacing allowed |
| Minimum Cover | > 50 feet length = 5 feet to the top of pipe<br>< 50 feet length = 4 feet to the top of pipe |
| Maximum Hydraulic Grade Line Elevation | Shall be below the ground surface for the 10-year storm assuming a 10-year river elevation |
| Manning’s n values<br>Reinforced Concrete Pipe (RCP) | <br>0.013 |
| Minimum Pipe Slopes<br>12-inch<br>15-inch<br>18-inch<br>24-inch<br>30-inch<br>36-inch<br>42-inch<br>48-inch<br>54-inch<br>60-inch<br>66-inch<br>72-inch | ft./100 ft. (percent)<br>0.33<br>0.25<br>0.22<br>0.17<br>0.15<br>0.13<br>0.11<br>0.10<br>0.09<br>0.09<br>0.08<br>0.08 |
| Drop Connections | Not required |
| Private Connections | Stubs are to be left for private storm sewer leads where necessary |

Concrete pipe is used for proposed storm sewers in accordance with the classification requirements below.

Material: RCSP C76, Classes as shown

Main Line Storm Sewers:

| **Diameter in Inches** | **Depth** | |
|---|---|---|
| | 8 to 25 feet | Over 25 feet |
| 12 to 27 | Class IV | Class V |

Catch Basin Leads:

| **Diameter in Inches** | **Depth** | |
|---|---|---|
| | Under 8 feet | Over 8 feet |
| 12 | Class III | Class IV |

## Culverts

Design of culverts shall be in accordance with MDOT Standard Specifications for Construction, Division 4, Section 401.

## Stormwater Storage

The design of stormwater storage facilities shall be to the following minimum standards.

Storage facilities are to fully drain the surface water component within 48 hours following a storm event. The entire cross section should be drained within 72 hours.

### *Geotechnical Report Requirements for Infiltration Facilities*

Geotechnical reports are required for sites where an infiltration facility is proposed and should include enough information to address the following site information requirements:

- Types of soil and subsurface materials underlying the infiltration facility
- Infiltration rates, locations, and test dates at the infiltration facility location
- Permeability test
- Proximity to surface water
- Proximity of the seasonal high ground water table beneath the bottom of the infiltration facility

The infiltration rate shall be measured at a depth equal to the proposed bottom grade of the facility.

### *Infiltration Facilities*

This section contains requirements for facilities that manage stormwater by subsurface infiltration. Inclusion of infiltration facilities into the design of sites of new development and redevelopment is typically necessary in order to meet channel protection criteria; in particular the State requirement for no increase in the discharge of runoff volume from a site for all storm events up to and including the 2-year, 24-hour event. Requirements for infiltration swales and infiltration basins are included in Table 4, below.

Infiltration swales are vegetated depressed landscaped areas designed to collect, treat, and infiltrate stormwater runoff. Swales infiltrate stormwater runoff during storm events and protect groundwater through natural treatment processes.

An infiltration basin impounds water in a surface pond until it infiltrates into the soil. Infiltration basins do not maintain a permanent pool between storm events.

***General Design Criteria***

**Table 4 Infiltration Facility Design Criteria**

| Design Criteria | Infiltration Swale | Infiltration Basin |
|---|---|---|
| Maximum bottom slope | 1% - 6% | Must be flat |
| Bottom Width | 2-8 feet | N/A |
| Under drain | Not required | Not required |
| Side Slopes | 3:1 (H:V) to 5:1 | 3:1 |
| Freeboard | 1 foot | 1 foot |
| Emergency Spillway | Overflow to flood control SCM | Overflow to flood control SCM |
| Pretreatment | Not required | Not required |
| Geotextile | Not required | Not required |
| Soil Permeability/Infiltration Rate | 0.5 inches/hr. minimum | 0.5 inches/hr. minimum |
| Depth from bottom of facility to groundwater table | 2 foot minimum | 2 foot minimum |

Regarding minimum setback requirements for infiltration facilities, these setback requirements will vary depending upon the zoning of the property within the various zoning districts of the City. For parcel-specific setback requirements, please refer to the City's Zoning Code; Part 12, Title 6 of the City's Codified Ordinances.

***Ponds***

Ponds are stormwater facilities designed to retain or detain stormwater runoff. They provide water quantity storage, water quality treatment for stormwater runoff, and may be used to provide peak flow attenuation. Variations include dry ponds, wet ponds, underground detention, and constructed wetlands.

***General Design Criteria***

Ponds may be used at sites where a receiving body or structure can accept pond discharges. Ponds designed to meet on-site detention requirements shall not be located in regulatory floodplains.

- Provide 1-foot of freeboard between the design flood storage elevation and any nearby structures or other facilities that could suffer lasting damage if inundated with stormwater.
- Provide for an emergency overflow pathway from the site to a down gradient receiving water body, such that overflow can occur as long as the potential for permanent damage is minimized.

**Table 5 Detention Pond Design Criteria**

| Design Criteria | Dry Pond | Wet Pond | Underground Detention | Constructed Wetland |
|---|---|---|---|---|
| Side Slopes | 3:1 | 3:1 | N/A | 3:1 |

| Design Criteria | Dry Pond | Wet Pond | Underground Detention | Constructed Wetland |
|---|---|---|---|---|
| Maximum Depth | 1.5 feet wet depth without safety fencing; greater wet depths may be authorized in conjunction with safety fencing | 1.5 feet wet depth without safety fencing; greater wet depths may be authorized in conjunction with safety fencing | N/A | 1.5 feet wet depth without safety fencing; greater wet depths may be authorized in conjunction with safety fencing |
| Freeboard | 1 foot | 1 foot | N/A | N/A |
| Emergency Spillway | yes | yes | yes | yes |
| Pretreatment | Not required | Not required | Not required | Not required |
| Depth from bottom of facility to groundwater table | 2 foot minimum | N/A | N/A | 2 foot minimum |

Regarding minimum setback requirements for detention facilities, these setback requirements will vary depending upon the zoning of the property within the various zoning districts of the City. For parcel-specific setback requirements, please refer to the City's Zoning Code; Part 12, Title 6 of the City's Codified Ordinances.

## Groundwater Recharge

Recharge can be achieved through a combination of natural recharge over the developed site's pervious surfaces and artificial recharge through groundwater recharge SCMs constructed at the site. Ideally, the planning and design of the proposed site will have incorporated nonstructural measures to such an extent that the need for structural facilities is reduced to a practical minimum.

### *Exceptions*

Infiltration and recharge of polluted stormwater runoff is not always desirable or even possible at some development sites. Therefore, recharge and/or infiltration requirements need to reflect special site conditions, protect ground water quality, and avoid common nuisance issues. For example:

- Some form of special pre-treatment of stormwater runoff may be required prior to infiltration for some land cover types and pollution source areas (e.g. Parking lots).
- Recharge should be restricted or prohibited at specific industrial, commercial and transport-related operations designated as potential stormwater hotspots.
- Recharge may be prohibited or otherwise restricted within the vicinity of ground water aquifers, wellhead protection areas, individual wells, structures and basins.
- Recharge should be discouraged within certain geological zones such as active bedrock, and adjacent to steep or unstable slopes.
- Recharge should be reduced or waived for minor redevelopment projects that have previously compacted soil structures.

***Groundwater Recharge Design Criteria***

There are currently no stormwater recharge requirements in the City of Lansing. However, recharge and infiltration are highly recommended tools for addressing permanent stormwater management goals. Recharge and infiltration are strongly encouraged from the very beginning of a site design. In addition, recharge and infiltration are encouraged as a means for earning stormwater credits as discussed in the Policy and Procedures Manual.

Recharge and/or infiltration are strongly recommended as part of an effective stormwater strategy to protect sensitive receiving waters, as discussed in the "Additional Design Criteria for Special Situations" section of this manual.

***Stormwater Credits***

Recharge and/or infiltration help promote more on-site infiltration/filtration of stormwater runoff and enables communities to offer stormwater credits. Recharge credits provide real incentives to apply better site design techniques at development sites that can reduce the size and cost of stormwater SCMs needed at some sites. To maximize recharge, designers should explore how to use pervious areas for infiltration early in the site layout process.

The recharge volume is considered to be part of the total water quality volume provided at a site and is not an additional requirement. Recharge can be achieved either by a structural SCM (e.g., infiltration, bioretention, filter, etc.), better site design techniques, or a combination of both. Stormwater credits are discussed in further detail in the Policy and Procedures Manual.

# HYDROLOGY CALCULATIONS AND METHODOLOGY

This section indicates the methods that are acceptable to calculate the hydrologic response associated with land use change.

In general, required control and treatment are intended to maintain the predevelopment hydrology as it relates to stream channel stability, and flooding, while preventing degradation of water quality within the watershed and ideally reducing degradation from those sites that have been previously altered.

## CALCULATING RUNOFF

Many different methods are available to calculate the runoff from site development. Calculations are required for the condition prior to development, the uncontrolled runoff, and the runoff after including stormwater controls. Calculations showing the complete runoff hydrographs of each condition are required.

Table 6 identifies the approved methodologies for calculating and routing the runoff, the rainfall distribution to use. Other methodologies may be allowed as approved by the City Engineer.

**Table 6 Approved Calculation Methodologies**

| **Process Description** | **Approved Methodologies*** |
|---|---|
| Rainfall Hyetograph | NRCS Type II Distribution |
| Surface Runoff Generation | NRCS Curve Number approach<br>EPA SWMM hydrology |
| Routing Flow on site through SCMs and stormwater controls | Lansing Site Development Spreadsheet<br>EPA SWMM |
| Routing Flow offsite through municipal collection system | EPA SWMM |

*Or as approved by City Engineer

The City has developed a spreadsheet tool which may be used to assist with the runoff calculations for site development. The spreadsheet tool incorporates the rainfall generation using the NRCS Type II distribution, flow generation based on the NRCS Curve Number approach and routing of the water based on a non-linear reservoir routing technique. A copy of the spreadsheet may be obtained from the City Engineer. The City periodically updates the spreadsheet. The most recent version of the spreadsheet should be used for each design analysis. The spreadsheet is limited on its computational capabilities and is not applicable for every design scenario. The City reserves the right to specify the computational requirements for any given drainage design.

Additional information is available from the NRCS in the *National Engineering Handbook Part 630, Hydrology*. Chapters within the handbook address topics such as hydrologic soil groups, hydrologic soil-cover complexes, time of concentration, and hydrographs.

## EXAMPLE DESIGN CALCULATIONS PROCESS

An example design calculation is provided in the SDST user's manual. The example calculation details the steps necessary to perform a site analysis and also provides the user with instructions on data entry and design methods for the SDST spreadsheet.

# ADDITIONAL DESIGN CRITERIA FOR SPECIAL SITUATIONS

## BACKGROUND

The State of Michigan has established various water quality requirements to protect public health and welfare, to enhance and maintain the quality of water, to protect the state's natural resources, and to serve Public Law 92-500 and the Great Lakes water quality agreement. These standards place requirements on high risk areas that require special considerations.

For the purposes of this manual, "High Risk Areas" refer to those water sources which may require special protection from new or increased stormwater discharges. Stormwater discharges into high risk areas and sensitive waters may either need to be eliminated or their effects lessened through additional pre-treatment or other methods of abatement in order to protect living organisms and maintain a healthy ecosystem. The special high risk areas include sensitive groundwater sites, sensitive surface water sites, wetlands, and waters subject to site based pollutant load reductions.

## SENSITIVE GROUNDWATER SITES

Sensitive groundwater protection areas within the City include any development or redevelopment site adjacent to a state regulated water supply or any development or redevelopment site located within the City's designated wellhead protection area.

EGLE established minimum isolation distances around State regulated wells as regulated under Public Acts 368 and 399. These minimum isolation distances vary in accordance with the potential contamination threat posed by the site's usage.

The City's Wellhead Protection Plans was recently updated in 2010 to reflect the new 10 year time of travel wellhead delineation area as determined by USGS. For a map of the City's wellhead protection areas, contact the Tri-County Regional Planning Commission.

The design engineer must comply with all federal, state, and local regulations regarding groundwater protection. SCMs must be designed to remove pollutants from stormwater that is to be infiltrated in close proximity to public or private water supply wells, and be sufficiently isolated from groundwater supply sources. Additionally, stormwater runoff should never be infiltrated into the soil from sites designated as a potential stormwater hotspot.

## SENSITIVE SURFACE WATER SITES

Special protection waters as defined by EGLE must adhere to all of the anti-degradation requirements established by EGLE. Sensitive surface water conditions must be considered where stormwater discharges from development or redevelopment sites may directly impact surface waters that are designated for full body or partial body contact. Within the City, these include the Grand River and the Red Cedar River.

As such, any development or redevelopment project discharging stormwater to the Grand River and Red Cedar Watersheds shall be designed to:

- Minimize the amount of impervious area on site
- Where appropriate, the stormwater discharge from the site should be infiltrated to the maximum extent possible
- Water quantity and water quality treatment SCMs should be employed for all stormwater that is discharged
- Stormwater SCMs should be planned so that where possible, the stormwater discharge is spread out to a number of locations rather than conveyed and concentrated in just a few places
- The volume and rate of any stormwater discharge must be managed to prevent the physical degradation of the receiving water.

Surface water supplies for municipal potable water usage must adhere to the specific requirements established by EGLE. There are no municipal water supply intakes from surface waters located anywhere within the City.

The developer and/or design professional must ensure that any post-construction stormwater discharges will not degrade the physical, chemical or biological characteristics of the receiving waters.

## WETLAND PROTECTION

Wetlands provide many water quality functions such as nutrient retention, filtration, and the storage and delay of flood and runoff waters. Wetlands also serve as habitat for fish and wildlife. Approximately 30% of Michigan's threatened and endangered plants, and approximately 60% of the 65 threatened and endangered animals, are wetland species. It is therefore vital to protect them.

In watersheds with a lot of development pressures and/or sensitive wetland communities, a major objective should be to protect wetlands from upstream stormwater impacts. Because sensitive wetlands are affected by even small changes in inundation and water quality, special stormwater criteria may be needed when working near a wetland or within its contributing drainage area (CDA). The stormwater management strategies that have typically been used to protect wetlands range from merely requiring pretreatment of the discharges into the wetland to excluding 100% of all new discharges into a wetland.

### Protection of Natural Wetlands

This section governs "natural wetlands" (as distinct from stormwater wetland systems that are constructed expressly for stormwater management purposes). When a natural wetland is incorporated into the overall stormwater management scheme, the following general stipulations should be adhered to:

1. Wetlands must be protected from the damaging modifications and adverse changes in runoff quality and quantity associated with land developments. Before approval of the final site plan, all necessary wetland permits from EGLE and City must be in place.
2. Direct discharge of untreated stormwater to a natural wetland is prohibited. All runoff from the development must be pre-treated to remove sediment and other pollutants prior to discharge to a wetland. Such treatment facilities will be constructed before property grading begins. All basins must be cleaned and stabilized prior to final acceptance.
3. Site drainage patterns will not be altered in any way that will modify existing water levels in protected wetlands without proof that all applicable permits from EGLE and/or City have been obtained.
4. A qualified professional with specific wetland expertise will oversee wetland construction, reconstruction, or modification.
5. Whenever possible, a permanent buffer strip, vegetated with native plant species, will be maintained or restored around the periphery of wetlands.
6. Wetlands will be protected during construction by appropriate soil erosion and sediment control measures.

For projects subject to jurisdiction under the Wetlands Protection Act, the applicant shall demonstrate to the issuing authority that the discharge velocities will not cause erosion or scouring at the point of discharge or downstream.

## Pretreatment of Flow Prior to Entering Wetlands

The required water quality treatment volume should be fully treated before any stormwater is discharged to a down-gradient wetland within the watershed. While this level of water quality treatment is sufficient for most wetlands, it is inadequate to protect nutrient-sensitive natural wetlands including bogs and calcareous fens. The City may, on a site by site basis, choose to require a higher level of stormwater treatment for these sensitive natural wetlands. This may include requiring that no net increase in phosphorus loading be permitted in the discharge for the portion of the development site within the wetland's CDA.

In order to protect wetlands from the indirect impacts of stormwater runoff, the City may require the developer to conduct additional field investigations and testing of any wetlands present at a development site to determine their sensitivity, delineate the CDA, and evaluate the effects of additional runoff that will be delivered to the wetland as a result of the proposed project. This will allow decisions to be easily made regarding the use of special sizing criteria to protect sensitive wetlands.

For specific details on the design, construction and selection of various SCMs to protect wetlands, see the Michigan LID manual.

## SITE BASED POLLUTANT LOAD REDUCTION

The NPDES Phase II Stormwater Permit provides for certain communities to address specific pollutant loading requirements, particularly total maximum daily loads (TMDLs), where they have already been established by EGLE. TMDLs are being established throughout the state and are anticipated to be issued for the Greater Lansing area within the next 5 years. In 2012, the State of Michigan, Dept. of Environmental Quality, developed an E. coli TMDL for the Grand River and Red Cedar River Watersheds; including Sycamore Creek. Consequently, the watershed area of this TMDL encompasses all of the locations where the City of Lansing's stormwater outfalls discharge to these receiving streams. It is expected that U.S EPA Region V will provide final approval of this TMDL during calendar year 2013.

Once TMDLs are established, the actual loading allowed to any water of the state from a development or redevelopment site may require that lesser amounts of individual pollutants than existed prior to development of the site may need to be stipulated. Thus, the treatment requirements associated with development and redevelopment may escalate.

The surface waters of the state are, however, already protected from pollutant loadings through the state's existing regulations- in particular the Part 4. Water Quality Standards and its anti-degradation rule. These standards are the minimum water quality requirements by which the surface waters of the state shall be managed. They include specific limits for plant nutrients (particularly phosphorous), microorganisms (especially E. coli), dissolved oxygen, and temperature.

The anti-degradation rules are a result of federal and state requirements associated with any NPDES permit action that is anticipated to result in a new or increased loading of pollutants to the surface waters of the state. Under the anti-degradation rules, the level of water quality necessary to protect existing uses shall be maintained and protected.

# SPECIAL CRITERIA FOR COMPLEX DEVELOPMENT SITUATIONS

Federal, state, and local agencies responsible for watershed management and pollution control programs are increasingly becoming aware of the significant effects that urbanization has on the natural balance between stormwater runoff and the ecosystem of wetland and stream systems.

In response to these detrimental ecological stresses that urbanization places on a watershed, SCMs have been developed to reduce water quantity impacts and water quality constituents normally associated with stormwater runoff from urbanization.

## ULTRA-URBAN SETTINGS

Ultra-urban areas are characterized by high densities of paved surfaces or buildings that result in a high degree of imperviousness. Buildings, parking facilities, urban streets, highways, or walkways cover a majority of the land area, with imperviousness typically greater than 50 percent in ultra-urban areas, and up to 100 percent in some cases.

Traffic characteristics are another major influence on constituent loadings in stormwater runoff. Traffic densities are highest in urban areas, due to commuter traffic and people traveling to commercial/business areas for personal business. Increased automobile usage contributes to the constituent loadings deposited in the urban environment.

### Water Quality

Water Quality requirements of the NPDES Phase II Stormwater Permit have been addressed by the City through the water quality treatment volume (see Table 1 of this manual).

Suitable areas for structural treatment systems are often unavailable in heavily urbanized areas. In those instances when on-site water quality or water quantity requirements cannot be met due to constraints of the site, provisions have been made to allow the requirements to be addressed off-site. These off-site provisions are discussed in detail in the Policy & Procedures Manual.

### Ultra Urban SCMs

Examples of applicable ultra-urban SCM's include bioretention facilities, vegetated swales, and porous pavement can be found in the Michigan LID manual.

## TRANSPORATION CORRIDORS

Past practice for stormwater management on transportation corridors has been to remove stormwater from the roadway as swiftly as possible to ensure public safety and the integrity of the road system. This presents a challenge to incorporating LID practices.

Public agencies with certificates of coverage for their NPDES Stormwater Phase II Permits are required to comply with the conditions of the permit for applicable road construction projects. This means that for road construction projects that disturb one acre or more, and are considered either development or redevelopment the limits adopted by the City to meet water quality and water quantity requirements under the permit must also be met.

A road will be considered under "redevelopment" if it either expands the size of the roadway by one acre or more or modifies the drainage system of an existing roadway in the course of reconstruction. Normal road reconstruction, even if the road is completely removed and replaced, will not be considered redevelopment unless one of the 2 conditions above is met. All applicable requirements in Table 1 must be met under these conditions.

For additional information on stormwater runoff and typical pollutants from transportation corridors, and considerations for implementing SCMs that adequately address pollutants of concern, refer to the Michigan LID manual.

## POLLUTION CONTROL/HOTSPOTS

Stormwater “hotspots” are defined as land uses that generate higher than normal concentrations of hydrocarbons, trace metals, or toxicants. These land uses include manufacturing and commercial areas; high use vehicle parking lots; material storage and handling; vehicle/equipment fueling, washing, maintenance and repair areas; and deicing activities. Increased constituent loadings from these areas may generate concerns about sediment toxicity, groundwater contamination, or toxicity discharging into the receiving surface waters. More effective stormwater treatment may be required in these areas. In addition, further regulatory requirements may be imposed by state or local agencies in the form of pollution prevention plans.

Reduction or the elimination of stormwater pollutants can be achieved by implementing “operational source control SCMs” including good housekeeping, employee training, spill prevention and cleanup, preventive maintenance, regular inspections, and record keeping. These SCMs can be combined with impervious containments and covers, i.e., “structural source control SCMs.” If operational and structural source control SCMs are not feasible or adequate then stormwater treatment SCMs will be necessary.

Identifying "hotspot" areas will also aid in determining the most effective SCM, in terms of constituent removal capability, in addition to determining the most appropriate location for the SCM. A list of potential stormwater hotspots and LID techniques that are applicable for hotspots can be found in the Michigan Lid manual.

# STORMWATER CONTROL MEASURES

For detailed information on structural and non-structural Stormwater Control Measures (SCMs) and guidance on selecting the proper SCMs for a site, refer to the Michigan LID manual.

## SCM SELECTION PROCESS

The proper selection and implementation of SCMs is paramount to achieving specified stormwater management criteria. As such, the following information is provided as a guide.

Table **7**7 is a matrix correlating a given SCM to: effective application for various land uses; relative water quantity and quality functions; relative cost; relative required maintenance effort; and relative winter performance. This matrix is provided to help expedite the effort required to compare and select appropriate SCMs.

Acceptable design and construction specifications for each of the SCMs may be found in chapters 6 and 7 of the Michigan LID Manual. Should use of a SCM not listed in the Michigan LID Manual be desired, the design professional will need to provide sufficient documentation validating both effectiveness and proper implementation of such SCM.

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## Table 7 SCM Selection Matrix

| | | Residential | Commercial | Ultra Urban | Industrial | Retrofit | Road | Rec |
|---|---|---|---|---|---|---|---|---|
| Runoff Volume/Infiltration | Bioretention | Yes | Yes | Limited | Limited | Yes | Yes | Yes |
| | Vegetated Filter Strip | Yes | Yes | Limited[2] | Limited | Yes | Yes | Yes |
| | Vegetated Swale | Yes | Yes | Limited[2] | Yes | Limited | Yes | Yes |
| | Pervious Pavement | Yes[3] | Yes | Yes | Yes[3] | Yes[3] | Limited[3] | Yes |
| | Infiltration Basin | Yes | Yes | Limited[2] | Yes | Limited | Limited | No |
| | Subsurface Infiltration Bed | Yes | Yes | Yes | Yes | Yes | Limited | No |
| | Infiltration Trench | Yes | Yes | Yes | Yes | Yes | Yes | No |
| | Dry Well | Yes | Yes | Yes | Limited | Yes | N | No |
| | Level Spreaders | Yes | Yes | No | Yes | Yes | Yes | Yes |
| | Berms | Yes | Yes | Limited[2] | Yes | Yes | Yes | No |
| | Planter Box | Yes | Yes | Yes | Limited | Yes | N | Limited |
| Runoff Volume/Non-infiltration | Vegetated Roof | Limited | Yes | Yes | Yes | Yes | N/A | Yes |
| | Capture/Reuse | Yes | Yes | Yes | Yes | Yes | N | Yes |
| Runoff Quality/Non-infiltration | Constructed Wetland | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | Wet Ponds/Retention Basins | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | Constructed Filters | Limited | Yes | Yes | Yes | Yes | Yes | Yes |
| | Water Quality Devices | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | Underground Detention | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | Extended Detention/Dry Pond | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Restoration | Riparian Buffer Restoration | Yes | Yes | Yes | Yes | Yes | Limited | Yes |
| | Native Revegetation | Yes | Yes | Limited | Yes | Yes | Limited | Yes |
| | Soil Restoration | Yes | Yes | Yes | Yes | Limited | Yes | Yes |

Notes:

1. Reported as TN except as noted (NO3)
2. Difficult to apply due to space limitations typically associated with these land uses
3. Applicable with special design considerations.
4. This assumes TSS loads and their debris have been managed properly before entering the SCM to prevent clogging.
5. Requires infiltration planter box.

| Stormwater Quantity Function | | | Stormwater Quality Functions | | | | Cost | Maintenance | Winter Perform. |
|---|---|---|---|---|---|---|---|---|---|
| Volume | GW Recharge | Peak Rate | TSS | TP | Nitrogen[1] | Temp | | | |
| M/H | M/H | MED | HIGH | MED | MED | HIGH | MED | MED | MED |
| LOW | LOW | LOW | M/H | M/H | M/H | M/H | LOW | L/M | HIGH |
| L/M | L/M | L/M | M/H | L/H | MED | MED | L/M | L/M | MED |
| HIGH | HIGH | M/H | HIGH[4] | M/H | LOW | HIGH | MED | HIGH | MED |
| HIGH | HIGH | HIGH | HIGH[4] | M/ | MED | HIGH | L/M | L/M | M/H |
| HIGH | HIGH | HIGH | HIGH[4] | M/H | LOW | HIGH | HIGH | MED | HIGH |
| MED | HIGH | L/M | HIGH[4] | M/H | L/M | HIGH | MED | L/M | HIGH |
| MED | HIGH | MED | HIGH[4] | M/H | L/M | HIGH | MED | L/M | HIGH |
| LOW | LOW | LOW | LOW | LOW | LOW | LOW | LOW | LOW | LOW |
| L/M | L/M | MED | M/H | MED | MED | MED | L/M | L/M | M/H |
| L/M | MED[5] | MED | MED | L/M | L/M | HIGH | MED | MED | MED |
| M/H | LOW[6] | MED | MED | L/M | L/M | HIGH | HIGH | MED | MED |
| HIGH | LOW | LOW[3] | MED[4] | MED | MED (NO3) | MED | RB-L<br>CIS-M | MED | MED |
| LOW | LOW | HIGH | HIGH | MED | MED | L/M | HIGH | L/M | M/H |
| LOW | LOW | HIGH | HIGH | MED | MED | L/M | HIGH | L/M | M/H |
| LOW[8] | LOW[8] | LOW[8] | HIGH[7] | MED[7] | MED[7] | LOW | M/H | HIGH | MED |
| N/A | N/A | N/A | VARIES | VARIES | VARIES (NO3) | NONE | VARIES | VARIES | HIGH |
| LOW | LOW | HIGH | N/A | N/A | N/A | N/A | HIGH | M/H | M/H |
| LOW | LOW | HIGH | MED | MED | LOW | LOW | HIGH | SED - LOW<br>VEG - HIGH | M/H |
| L/M | L/M | L/M | M/H | M/H | M/H (NO3) | M/H | L/M | LOW | HIGH |
| L/M/H | L/M/H | L/M | HIGH | HIGH | M/H | MED | L/M | LOW | MED |
| MED | LOW | MED | HIGH | HIGH | MED (NO3) | MED | MED | LOW | HIGH |

Notes:
6 Although vegetated roofs can be used very successfully in combination with infiltration systems.
7 Sand filters only (For filters with infiltration, see Subsurface Infiltration Bed section, or other infiltration SCM sections. For manufactured systems, see manufacturer's information, as well as results from independent verification.)
8 Increases with infiltration

# OPERATION AND MAINTENANCE

## INTRODUCTION

An effective inspection and maintenance program begins with a complete understanding of a construction plan and how it was designed to meet water quality goals. Regardless of who will be responsible for maintaining the facilities, a number of factors should be considered.

***An inspector must be familiar with the physical requirements of a SCM***

Even before construction begins, the individual(s) responsible for construction and maintenance inspections should become familiar with the various components of each SCM in a treatment train. For manufactured water quality devices, this might include studying a manufacturer's installation and maintenance manual for information on how a device operates, proper assembly, and life expectancy of any removable or replacement components. For other control measures, knowledge of specific aspects of each SCM (e.g. open or sealed joints, by-pass structures and alignment, potential access concerns for cleaning, overflow operations) may be more important. The Fact Sheets in Section D of this Manual are a good source of general information.

***An inspector must understand why a particular control measure was included and how it fits into the treatment train.***

The Fact Sheets in Section D provide a board overview of classes of devices with minimal detail concerning applicability to a particular site. The sheets help to create an understanding of design criteria and benefits, as well as how they may be beneficial for achieving water quality and quantity goals. Effective inspection requires more exacting detail and must be based on how a SCM fits into a specific site, as well as its relationship to other control measures. The checklists that follow are base on application and are not organized in the same manner as the fact sheets. Each checklist however does refer to the appropriate SCM Fact Sheet for background information. The lists are designed to assist in developing a calculated inspection program for each device.

***During construction an inspector must become familiar with the abilities of the installation contractor***

Attention to detail when a device is being installed can provide meaningful insight into how effectively a device will operate in the future. A contractor who doesn't understand the total concept- or who fails to follow an approved plan- will likely make mistakes that reduce efficiency or life expectancy. Proposed field changes should be referred to the reviewing engineer, as well as any observations that suggest a contractor may not be fully qualified to install the treatment devices.

***An inspector must be an advocate***

Construction is often complicated by unforeseen problems, and the construction inspector responsible for implementation should be fully prepared to support the approved plan. This may mean confronting a contractor (or even a developer's engineer) when deviations are observed, or when unsafe construction practices are noted. All changes must be accepted by the engineer who approved the initial plan. The construction inspector must be aware of contractual procedures for addressing deficiencies- including stopping work if necessary- as well as any legal enforcement remedies available to a municipality.

***An inspector is responsible for compiling detailed records***

Although most control devices have been thoroughly tested, they may react differently under different circumstances. A detailed record of how a device was installed, noting any problems encountered and how they were resolved, may lead to design improvements for subsequent applications at other sites. And without written documentation, legal recourse in contractual disputes may be impossible. Access to installation records can also be valuable during subsequent maintenance and maintenance inspection activity.

Checklists for the plan reviewer, inspection sheets that may be used by the municipal or private inspectors during construction, and maintenance review checklists are provided with the PP Manual.

# GLOSSARY

***Aquifer.*** A porous water-bearing formation of permeable rock, sand, or gravel capable of yielding a significant quantity of groundwater.

***Bankfull Flow.*** The condition where streamflow fills a stream channel to the top of the bank and at a point where the water begins to overflow onto a floodplain. For incised channels, where the channel has been downcutting, bankfull flow may no longer reach the floodplain.

***Baseflow.*** Streamflow that is the result of discharge from groundwater not due to stormwater runoff.

***Berm.*** A shelf that breaks the continuity of a slope; a linear embankment.

***Best Management Practice (BMP).*** This term is used interchangeably with Stormwater Control Measure (SCM). Both refer to structural and non-structural practices and techniques that mitigate the adverse impacts caused by land development on water quality and/or water quantity.

***Biochemical Oxygen Demand (BOD).*** A measure of the quantity of organic material in water as measured by its decomposition by oxidation mediated by microorganisms.

***Bioretention.*** A water quality practice that utilizes landscaping and soils to treat stormwater runoff by collecting it in shallow depressions before filtering through a fabricated planting soil media.

***Buffer.*** A zone of variable width located along both sides of a natural feature (e.g., stream or forested area) and designed to provide a protective area along a corridor.

***Cation Exchange Capacity (CEC).*** The capacity of a soil for ion exchange of positively charged ions between the soil and the soil solution. (A positively-charged ion, which has fewer electrons than protons, is known as a cation.) Cation exchange capacity is used as a measure of fertility, nutrient retention capacity, and the capacity to protect groundwater from cation contamination.

***Channel.*** A natural stream that conveys water; a ditch excavated for the flow of water.

***Channel Protection Volume.*** A volume of precipitation to be held on a piece of land, not to be released as runoff to a stream or river. The volume is selected that best protects the stream or river banks against erosion. Typically it is the volume based on a 2-year 24-hour storm for post-construction development minus predevelopment.

***Check Dam***. Small temporary dam constructed across a swale or drainage ditch to reduce the velocity of concentrated stormwater flow.

***Cistern.*** Containers that store large quantities of stormwater above or below ground. They can be used on residential, commercial, and industrial sites.

***Clustering.*** A land use planning term that describes the development pattern of clustering buildings and supportive facilities in one area of a site to conserve open space and natural features.

***Constructed filter.*** Structures or excavated areas containing a layer of sand, compost, organic material, peat, or other filter media that reduce pollutant levels in stormwater runoff by filtering sediments, metals, hydrocarbons, and other pollutants.

***Contributing drainage area (CDA).*** The drainage area that contributes to a constructed or natural wetland.

***Credit.*** Used in the design process to emphasize the use of SCMs that, when applied, alter the disturbed area in a way that reduces the volume of runoff from that area.

***Curve Number.*** Also CN. Determines the volume of stormwater removed from rainfall before runoff begins. It's based on land cover type, hydrologic condition, antecedent runoff condition and hydrologic soil group (HSG). The CN is a component in the NRCS Curve Number method for calculating storm runoff.

***Deicers.*** Materials applied to reduce icing on paved surfaces. These consist of salts and other formulated materials that lower the melting point of ice, including sodium chloride, calcium chloride, and blended products consisting of various combinations of sodium, calcium, magnesium, chloride, and other chemicals.

***Detention.*** The stormwater management practice of temporarily detaining runoff, typically in a detention basin on site, before releasing it downstream at a controlled rate.

***Disturbed Area.*** An area in which the natural vegetative soil cover has been removed or altered and is susceptible to erosion.

***Earth Change.*** A human-made change in the natural cover or topography of land, including cut and fill activities, which may result in or contribute to soil erosion or sedimentation of the waters of the state. Earth change does not include the practice of plowing and tilling soil for the purpose of crop production.

***Erosion.*** The wearing away of land surface by running water, wind, ice, or other geological agents.

***Erosion and Sedimentation Control Program.*** The activities of a county or local enforcing agency or authorized public agency for staff training, developing and reviewing development plans, issuing permits, conducting inspections, and initiating compliance and enforcement actions to effectively minimize erosion and off-site sedimentation.

***Evaporation.*** Phase change of liquid water to water vapor.

***Evapotranspiration.*** The combined process of evaporation and transpiration (transpiration is the conversion of liquid water to water vapor through plant tissue).

***Floodplain.*** Areas adjacent to a stream or river that are subject to flooding during a storm event that has a likelihood of occurrence of 1/100 in any given year.

***Freeboard.*** The distance between the maximum water surface elevation anticipated in design and the top of retaining banks or structures. Freeboard is provided to prevent overtopping due to unforeseen conditions.

***Green Infrastructure.*** 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.

***Green Roof.*** Rooftops that include a thin covering of vegetation allowing the roof to function more like a vegetated surface. The layer thickness varies between 2-6 inches and consists of vegetation, waterproofing, insulation, fabrics, growth media, and other synthetic components.

***Groundwater Recharge.*** The replenishment of existing natural water bearing subsurface layers of porous stone, sand, gravel, silt or clay via infiltration.

***H:V.*** Horizontal to vertical ratio.

***Headwater Stream.*** The source of a river or stream. Typically a very small, permenantly flowing or intermittent, waterway from which the water in a river or stream originates.

***Herbaceous.*** Plants whose stem die back to the ground after each growing season.

***Hotspot.*** Areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater.

***Hydrologic Soil Group (HSG).*** A soil series rating developed by the Natural Resources Conservation Service which describes the physical drainage and textural properties of each soil type.

***Impervious Surface.*** A surface that prevents the infiltration of water into the ground such as roofs, streets, sidewalks, driveways, parking lots, and highly compacted soils.

***Infiltration Practices.*** Best management practices (bed, trench, basin, well, etc.) that allow for rainfall to soak into the soil mantle.

***Invasive Species.*** An alien plant species whose introduction does or is likely to cause economic or environmental harm or harm to human health.

***Lake.*** The Great Lakes and all natural and artificial inland lakes or impoundments that have definite banks, a bed, visible evidence of a continued occurrence of water, and a surface area of water that is equal to, or greater than, 1 acre. "Lake" does not include sediment basins and basins constructed for the sole purpose of storm water retention, cooling water, or treating polluted water.

***Level Spreader.*** A device for distributing stormwater uniformly over the ground surface as sheet flow to prevent concentrated, erosive flows and promote infiltration.

***Low Impact Development (LID).*** Activities that mimic a site's presettlement hydrology by using design techniques that are spatially distributed, decentralized micro-scale controls that infiltrate, filter, store, evaporate, and detain runoff close to its source.

***Mitigation.*** Making something less harsh or severe. LID mitigates by lessening the impacts of stormwater runoff from impervious surfaces.

***Native Plants.*** Plants that historically co-evolved with the local ecology, geology and climate. EPA has categorized native (presettlement by Europeans) plant groups by Ecoregions.

***Nonpoint Source Pollution.*** Pollution that does not come from a point source, such as a wastewater treatment plant, and are normally associated with precipitation and runoff from the land or percolation.

***Nonstructural SCMs.*** Stormwater runoff treatment techniques that use natural measures to reduce pollution levels that do not involve the construction or installation of devices (e.g., management actions).

***Offset.*** A stormwater management practice that counterbalances, counteracts, or compensates for something else; compensating equivalent.

***Outfall.*** The point where stormwater drainage discharges from a pipe, ditch, or other conveyance system to receiving waters.

***Permeable.*** Allows liquid to pass through. Porous. Also pervious, the opposite of impervious.

***Pervious.*** See Permeable.

***Peak Discharge Rate.*** The maximum instantaneous rate of flow (volume of water passing a given point over a specific duration, such as cubic feet per second) during a storm, usually in reference to a specific design storm event.

***Planter Box.*** A device containing trees and plants near streets and buildings constructed to prevent stormwater from directly draining into sewers.

***Pervious Pavement.*** An infiltration technique that combines stormwater infiltration, storage, and structural pavement that consists of a permeable surface underlain by a storage reservoir.

***Phase II Stormwater Regulations.*** The second phase of the NPDES program which targets small MS4s in densely populated areas and construction activity disturbing between one and five acres of land.

***Positive Overflow.*** A technique that uses a catch basin with a higher inlet than outlet to provide adequate release of stormwater so the underlying bed system of pervious pavement does not overflow and saturate the pavement.

***Predevelopment.*** The conditions that existed prior to the initiation of the land disturbing activity in terms of topography, vegetation, land use and rate, volume or direction of stormwater runoff.

***Presettlement.*** Time period before significant human change to the landscape. For the purpose of this manual, presettlement can also be used as the presettlement site condition. In the LID design calculations, presettlement is further defined as either woods or meadow in good condition. This definition will not represent the actual presettlement condition of all land in Michigan. It does provide a simple, conservative value to use in site design that meets common LID objectives.

***Pretreatment.*** Techniques used to provide storage and removal of course materials, floatables, or other pollutants from stormwater before it is discharged downstream to a water body or another SCM.

***Rain Barrel.*** A barrel designed to retain small volumes of stormwater runoff for reuse for gardening and landscaping.

***Rain Garden.*** Landscape elements that combine plantings and depressions that allow water to pool for a short time (e.g., a few days) after a rainfall then slowly absorbed by the soil and vegetation.

***Riparian Buffer.*** An area next to a stream or river (sometimes also used for lakes). where development is restricted or prohibited. The buffers should be vegetated with herbaceous and woody native plants, or left in their natural state. Buffers filter stormwater before it reaches the waterbody and slow the stormwater velocity.

***Riparian corridor.*** The area adjacent to a stream or river (sometimes also used for lakes).

***Retention.*** The storage of stormwater to prevent it from leaving a developed or developing site.

***Sanitary Sewer Overflows (SSOs).*** Discharge from a sanitary sewer system which contains untreated or partially treated sanitary sewage. This type of overflow comes from systems designed to only carry sanitary sewage, however, overflows can result because of a storm event. This is because stormwater, groundwater inflow, and infiltration can enter sanitary lines through cracks, illicit connections, or undersized systems.

***Seasonally High Water Table (SHWT).*** The highest elevation of the groundwater table typically observed during the year.

***Sheet Flow.*** Overland flow of stormwater across the ground or another surface like a rooftop, taking the form of a thin, continuous layer of water, and not a concentrated flow as in a pipe, culvert, channel, ditch, or stream.

***Soil Erosion.*** The increased loss of the land surface that occurs as a result of the wearing away of land by the action of wind, water, gravity, or a combination of wind, water, gravity or human activities.

***Stabilization.*** The establishment of vegetation or the proper placement, grading, or covering of soil to ensure its resistance to soil erosion, sliding, or other earth movement.

***Stormwater.*** Water consisting of precipitation runoff or snowmelt.

***Stormwater Retention Basin.*** An area which is constructed to capture surface water runoff and which does not discharge directly to a lake or stream through an outlet. Water leaves the basin by infiltration and evaporation.

***Stormwater Runoff.*** Rainfall or snowmelt that runs off the land and is released into our rivers and lakes.

***Stream.*** A river, creek, or other surface watercourse which may or may not be serving as a drain as defined in Act No. 40 of the Public Acts of 1956, as amended, being §280.1 et seq. of the Michigan Compiled Laws, and which has definite banks, a bed, and visible evidence of the continued flow or continued occurrence of water, including the connecting waters of the Great Lakes.

***Structural SCMs.*** Devices constructed for temporary storage and treatment of stormwater runoff.

***Swale.*** A shallow stormwater channel that can be vegetated with some combination of grasses, shrubs, and/or trees designed to slow, filter, and often infiltrate stormwater runoff.

***Time of Concentration.*** Time required for water to flow from the most remote point of a watershed to a downstream outlet. Flow paths, ground surface slope and roughness, and channel characteristics affect this time.

***Total Phosphorous (TP).*** The total amount of phosphorus that is contained in the water column.

***Total Suspended Solids (TSS).*** The total amount of particulate matter that is suspended in the water column.

***Transpiration.*** The conversion of liquid water to water vapor through plant tissue.

***Two-year Storm.*** A stormwater event which occurs on average once every twp years or statistically has a 50% chance of occurring in a given year.

***Vegetated Filter Strip.*** Uniformly graded vegetated surface located between pollutant source areas and downstream receiving waters.

***Water Quality Treatment.*** Capture and treatment of a stormwater event through filtration or retention techniques. Treatment is defined as removing total suspended solids such that the effluent has a maximum concentration of 80 mg/L.

***Waters of the State.*** The Great Lakes and their connecting waters, inland lakes and streams as defined in rules promulgated under Part 31, and wetlands regulated under Part 303 of Michigan's Natural Resources and Environmental Protection Act, Act 451 of 1994, as amended.

***Watershed.*** The geographic area that drains to a specific watercourse outlet. The watershed for a major river may encompass a number of smaller watersheds that ultimately contribute to their common outlet.

***Watershed Plan.*** A plan that identifies and implements actions needed to resolve water quality and quantity concerns. The plan assesses the current nature and status of the watershed ecosystem; identifies short and long-term goals, the actions needed to meet those goals; and includes a method for progress evaluation.

***Wellhead Protection Area (WHPA).*** A protected surface and subsurface zone surrounding a well or well field supplying a public water system to keep contaminants from reaching the well water.

***Wetland.*** As defined by Michigan's wetland statute, Part 303, Wetlands Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended.

***Wet Pond/Constructed Wetland.*** Surface or underground structures that provide temporary storage of stormwater runoff to prevent downstream flooding and the attenuation of runoff peaks.