CITY OF STURGIS, MICHIGAN

STORM WATER
DESIGN CRITERIA MANUAL

City of Sturgis
130 N. Nottawa
Sturgis, Michigan 49091

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Prepared by:

Fishbeck, Thompson, Carr & Huber, Inc.
1515 Arboretum Drive, SE
Grand Rapids, MI 49546
616.575.3824
www.ftch.com
Project No. G07063SW

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BACKGROUND

The City of Sturgis (City) published a *Storm Water Design Criteria Manual* in 1998, after completion of a *Storm Water Master Plan* designed to optimize the use of existing storm sewer infrastructure, provide a reliable storm water system for future growth and development, and protect groundwater and surface water resources.

This 2011 update to the *Storm Water Design Criteria Manual* was funded by a United States Environmental Protection Agency (US EPA) Section 319 Implementation Grant under the federal Clean Water Act as one component of the City of Sturgis Sustainable Storm Water Demonstration Project (Tracking Code 2007-0152). The Michigan Department of Environmental Quality (MDEQ) supported this project under the St. Joseph River Watershed Management Plan (WMP) to provide water quality improvements in the Fawn River Subwatershed, and more specifically the Nye Drain subshed, which was identified as a critical area in the WMP. According to the WMP, the Fawn River has accelerated sedimentation and flow fluctuations caused by increased impervious surfaces due to urbanization resulting in impairments to the river and its tributaries.

Revisions to the manual provide closer alignment of water quality and stream protection standards with MDEQ guidance as presented in the *Low Impact Development Manual for Michigan* (SEMCOG, 2008) and provide direction for designing with a wide variety of Low Impact Development (LID) practices.

AUTHORITY

A. State Law and Code of City Ordinances

Under state law (MCL 117.3(k)), the City Commission has the power to enact, amend and repeal all ordinances that may be necessary or proper for carrying out the powers conferred and the duties imposed upon the City by the charter and by the laws of the State.

The Code of City Ordinances, Chapter 50 Subdivisions and Other Divisions, establishes the site plan review procedure under the Land Division Act (MCL 560.101 et seq.); Condominium Act, (MCL 559.101 et seq.) and local regulation of condominiums, MCL 559.241. Appendix A Zoning establishes the requirements under the Mobile Home Commission Act (MCL 125.2301 et seq.).

B. Provisions for Requirements in Addition to Minimum Standards

These rules provide minimum standards to be complied with by developers and in no way limit the authority of the City to enforce higher standards based upon review of the site plan.

Any deviations from these standards shall be subject to approval by the City.

Other local, state and federal rules and regulations related to storm water activities also apply to development within the City. A summary of the most applicable regulations is included in ***Appendix 1***.

APPLICABILITY

A. Exemptions

The following development activities are exempt from these standards:

- Construction of individual single and two-family residential structures.
- Additions or modifications to existing single and two-family residential structures.

B. Redevelopment

Redevelopment and additions requiring either a building permit or a soil erosion and sedimentation control permit shall comply with the current standards for the redeveloped or newly constructed portion of the site.

The City reserves the right to require that the entire site be brought up to the current standards in known problem areas.

DEFINITIONS

City: The City of Sturgis, County of St. Joseph, State of Michigan.

Developer: Any person, landowner, firm, association, partnership, corporation, or combination of any of them, who submits a site plan for drainage.

ABBREVIATIONS

A. Acronyms

ASTM – American Society for Testing and Materials
BMP – Best Management Practice
CN – Curve Number
ET – Evapotranspiration
HSG – Hydrologic Soil Group
LID – Low Impact Development
MCL – Michigan Compiled Laws
MDEQ – Michigan Department of Environmental Quality
MDOT – Michigan Department of Transportation
NPDES – National Pollutant Discharge Elimination System
NRCS – Natural Resource Conservation Service
PA – Public Act
SEMCOG – Southeast Michigan Council of Governments
TR-55 – Technical Release 55
TSS – Total Suspended Solids
USDA – United States Department of Agriculture
US EPA – United States Environmental Protection Agency
WMP – Watershed Management Plan

B. Units

cfs – cubic feet per second
mg/L – milligrams per liter

Part 1:
Storm Water Management Requirements

I. PURPOSE

The City of Sturgis (City) maintains a storm sewer infrastructure that serves a majority of its 6.4 square mile jurisdictional area. As the City continues to grow, additional storm water drainage systems will be necessary to provide for public safety, convenience, and the protection of property. The future of the City's surface water and groundwater resources also depends to a great extent on the management of storm water runoff. The City takes an active role in protecting these resources through effective storm water management planning and practices.

It is the purpose of this design criteria manual to establish minimum storm water management requirements to meet the following objectives:

- Ensure that storm water drainage systems and BMPs are adequate to address storm water management needs within a proposed development and protect the drainage, property, and water rights of landowners outside of the proposed development.
- Reduce artificially induced flood damage.
- Minimize the degradation of existing watercourses.
- Prevent an increase in non-point source pollution.
- Maintain site hydrology to avoid detrimental changes in the balance between storm water runoff, groundwater recharge and evapo-transpiration.

Further documentation of the impacts of development on land and water resources and the importance of storm water management can be found in Chapter 2 of the *Low Impact Development Manual for Michigan* (SEMCOG, 2008).

http://www.semcog.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_chapter2.pdf

II. GENERAL REQUIREMENTS

The following general storm water management requirements apply to all new and redevelopments in the City of Sturgis (City). Additional rules and regulations related to storm water activities are included in ***Appendix 1***.

A. The design process shall begin by identifying sensitive areas located on the site, and laying out the site to protect the sensitive areas.

B. Best Management Practices (BMPs) that reduce the amount of storm water runoff are encouraged.

C. Onsite retention of storm water is required first and foremost, unless site constraints preclude this approach.

D. Storm water shall be managed using four standards referred to as stream protection, flood control, water quality and pre-treatment to protect both water resources and real property.

E. Stream protection shall be provided for surface water discharges to natural water courses (directly or through pipes or ditches) by retaining onsite the difference in storm water runoff volume between existing and post-development conditions for the 2-year, 24 hour storm (2.42 inches of rain). If site constraints preclude meeting the retention standard, extended detention of the 1-year, 24-hour storm (2.03 inches of rain) will be allowed.

F. Flood control shall be provided for all sites through retention or detention of the 25-year storm. The maximum allowable detention release rate is 0.15 cfs / acre. An alternate release rate may be required/allowed by the City for site specific cases.

G. Overland flow routes and the extent of high water levels for the 100-year storm shall be identified for all sites.

H. Water quality treatment shall be provided for all new developments and significant redevelopments. A minimum treatment volume equal to 0.5-inch of runoff from the directly contributing impervious area is required. A minimum volume of 750 cubic feet per acre is required for directly connected disturbed pervious areas (i.e. lawns).

I. Pre-treatment is recommended for infiltration, filtration and detention BMPs for ease of maintenance and to protect BMP integrity and preserve longevity.

J. Storm water discharges from activities with a high risk for an accidental spill of pollutants (storm water hot spots identified in the City's Wellhead Protection Ordinance) shall provide spill containment.

K. The design maximum release rate, volume or concentration of storm water discharged from a site shall not exceed the capacity of existing infrastructure or cause impairment to the offsite receiving area. An adequate outlet must be identified.

L. The use of many decentralized Low Impact Development (LID) BMPs is not mandated, but is encouraged on private sites.

III. DESIGN PROCESS

The storm water site design process is summarized in the steps below. This process is intended to minimize negative impacts from development sites that could be avoided through proper planning.

A. Identify Sensitive Areas

Identify existing sensitive areas on the site plan that may require special consideration or pose a challenge for storm water management. For the purpose of these rules, sensitive areas include:

- Floodplains (and flood prone areas)
- Riparian areas
- Wetlands
- Streams and natural drainage ways
- Soils and topography (steep, erodible)
- Groundwater supplies (springs, wellhead protection areas)
- Endangered species habitat

Non-structural BMPs such as “Minimize Soil Compaction and Total Disturbed Area,” Protect Natural Flow Pathways,” Protect Sensitive Areas (including Riparian Buffers),” “Native Revegetation” and “Storm Water Disconnection” may be selected for use to reduce the amount of storm water controls necessary for the site.

B. Determine Standards

Adequate storm water runoff controls are required to reduce channel erosion, maintain groundwater recharge, prevent overbank flooding and meet pollutant removal goals. Storm water is managed onsite through all of the following standards:

- Stream Protection
- Flood Control
- Water Quality
- Pre-treatment

A summary of the minimum required storm water standards is provided in ***Table 1*** and shown graphically in ***Figure 1***.

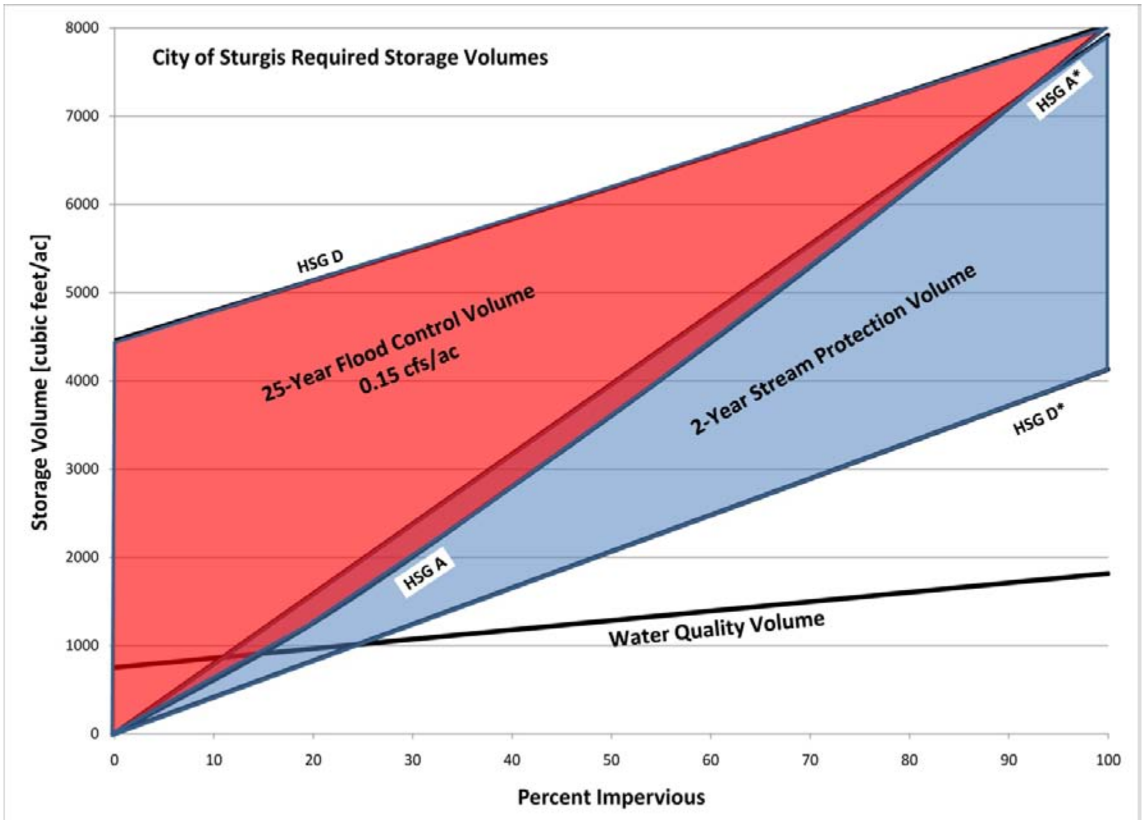
Determine the storm water standards applicable to the site. Use the watershed map in ***Figure 2*** to determine in which storm sewer district the site is located. Use ***Table 2*** to determine which standards apply to the site.

A Storm Water Worksheet for individual sites is included as ***Worksheet 1*** located at the end of this section. A separate worksheet may be needed for each discharge location.

Table 1 – Minimum Required Storm Water Standards

Standard	Sizing Criteria
Stream Protection	Onsite retention: No net increase in the existing runoff volume and rate from the disturbed portion of the site for the 2-year, 24-hour rainfall event (2.42 inches of rain), also provides water quality treatment for most sites. **OR** if site constraints preclude total onsite retention: Extended detention: Storage volume and release rate determined by extended detention of the 1-year, 24-hour rainfall event (2.03 inches of rain) for a period of 24 hours, also provides water quality treatment.
Flood Control	Retention: Store and infiltrate runoff from the 25-year rainfall event, also provides water quality treatment. **OR** if site constraints preclude retention: Detention: Store runoff from the 25-year rainfall event with a maximum release rate of 0.15 cfs/acre. **AND** Identify overland flow routes and the extent of high water levels for the 100-year rainfall event to ensure no adverse impacts offsite or internal to the site.
Water Quality "first flush"	Treat the first 0.5 inch of runoff from the directly connected impervious area through settling (permanent pool or extended detention), infiltration, or filtration. Provide minimum volume of 750 cubic feet per acre for directly connected disturbed pervious areas (i.e. lawns).
Pre-treatment Detention basins Retention basins Infiltration practices Bioretention / rain garden Constructed filters Water quality swales	Sediment forebay: Provide 30% of the water quality volume (can be included in water quality volume). **OR** Vegetated filter strips and vegetated swales meeting minimum length, slope and vegetated cover requirements. **OR** Water quality device

Figure 1 – Comparison of Required Storage Volumes

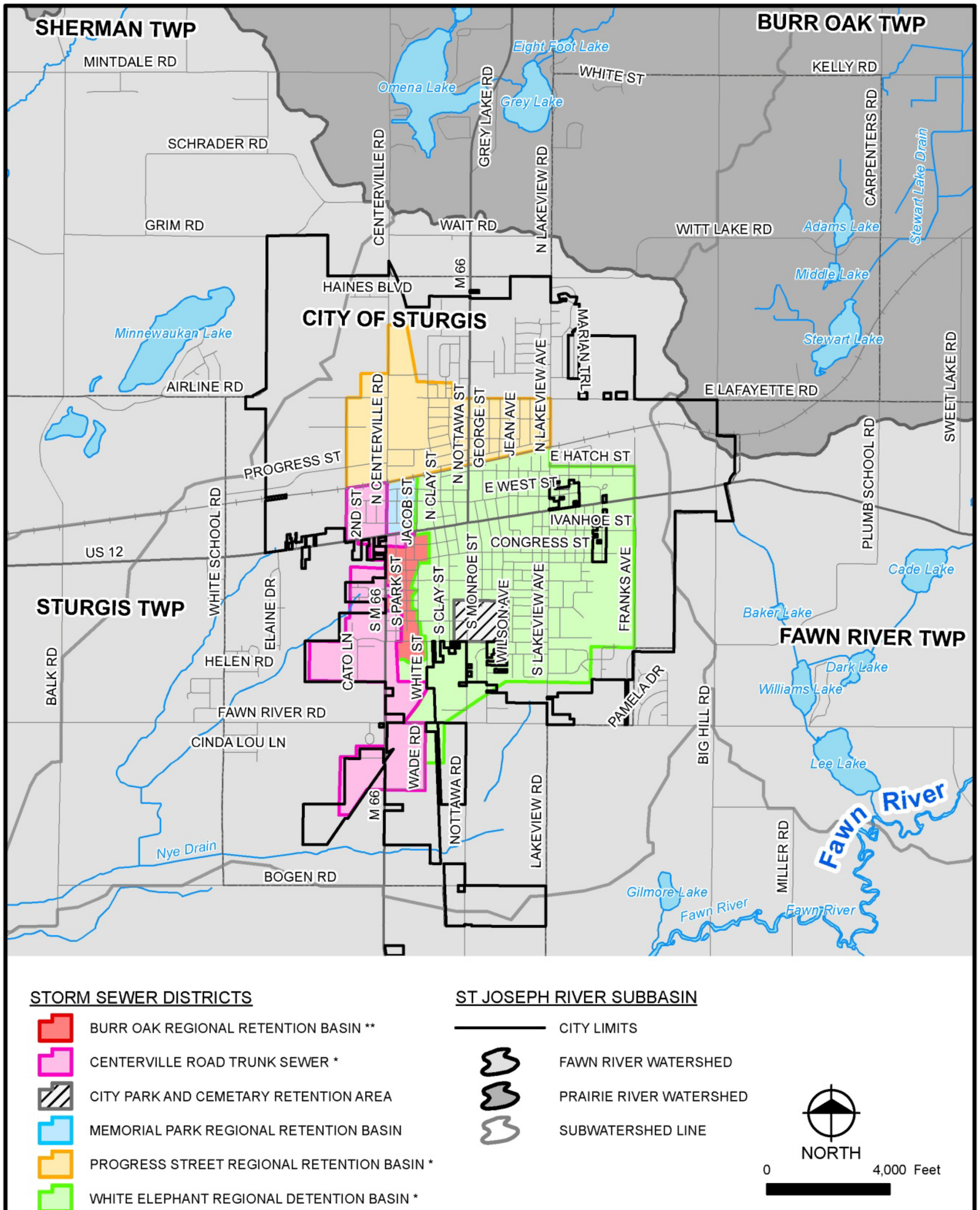


Note that the 2-Year Stream Protection Volume area (blue) assumes existing land use as "open space in fair condition."

Table 2 –Application of Storm Water Standards

Storm Sewer District	Description	Required Standards
Burr Oak	Regional retention basin (groundwater discharge). Flooding occurs along trunk sewer in upstream areas. No new connections to existing storm sewer allowed.	Flood control using retention or detention. Stream protection not required. Water quality treatment provided in regional facility.
Centerville Trunk Sewer	Storm sewer with direct surface water discharge to Nye Drain. Flooding occurs at Centerville Road and US-12. No new connections to existing storm sewer allowed.	Flood control using retention (also provides for stream protection and water quality). **OR** Flood control using detention, stream protection, and water quality treatment.
Memorial Park	Regional retention basin (groundwater discharge). No current flooding problems. Retention sized for present land use. No new connections to existing storm sewer allowed.	Flood Control: Do not exceed existing 10-year peak discharge rate from site. Water quality treatment provided in regional facility
Progress Street	Regional retention basin (groundwater discharge). Flooding occurs in upstream areas. No new connections to existing storm sewer allowed. Basin sized to handle new storm sewer connections from north and west.	Flood control using retention or detention. Stream protection not required. Water quality treatment provided in regional facility.
White Elephant	Regional detention basin with surface water discharge to Nye Drain. Flooding occurs in upstream areas. No new connections allowed.	Flood control using retention (also provides for stream protection and water quality). **OR** Flood control using detention, stream protection, and water quality treatment.
None	City storm water infrastructure is not available.	Flood control using retention (also provides for stream protection and water quality). **OR** Flood control using detention, stream protection if site discharges to a stream (directly, or through a storm sewer or ditch), and water quality treatment.

Figure 2 – Watershed Map



Data Sources:
*Storm Sewer Districts- Refer to Figure 3 Existing Storm Sewer System in City of Sturgis Storm Water Master Plan, June 1998.
** District boundary provided by City of Sturgis Engineering Dept.
Base Map, Michigan Framework V6B. Watersheds, Michigan Department of Environmental Quality, Digital Sheds.

1. Stream Protection

Stream protection is required for discharges to natural watercourses either directly or via a storm sewer or ditch that does not receive any flow or volume mitigation prior to entering the stream (i.e. through a pond or wetland).

Retention of the increase in volume for a 2-year, 24-hour storm (2.42 inches) between existing and post-development conditions is required.

The 2-year storm was selected since 95% or more of the annual average runoff volume will be controlled, including the bankfull event (typically between a 1- to 2-year rainfall). It is these smaller, more frequent events that have the greatest impact on the stability of headwater streams, which are most susceptible to erosion.

Existing conditions means the runoff volume and rate for the last land use prior to the planned development or redevelopment after routing through all existing storm water controls.

Where retention is not possible due to site constraints, extended detention of the stream protection volume may be approved. Detention of the total 1-year, 24-hour storm (2.03 inches) runoff volume for a period of 24 hours is required to mitigate the impact of an increased volume of flow at the bankfull discharge. The idea is that storm water runoff will be stored and released in such a gradual manner (significantly less than the bankfull discharge rate) that critical erosive velocities during the bankfull and near-bankfull events will seldom be exceeded in downstream channels. The smaller storm is selected to avoid releasing extended volumes of runoff from the 2-year storm at or near the bankfull discharge rate, since there is less erosive work done by a slightly higher peak that occurs over a much shorter duration.

2. Flood Control

Flood control is required for all sites. Retention or detention of the 25-year storm with a maximum allowable release rate of 0.15 cfs/acre is required unless an alternate maximum release rate is required/allowed by the City based on site specific conditions (i.e. zero discharge in critical floodprone areas; no greater than existing 10-year peak discharge in areas with adequate infrastructure that discharge to an retention basin).

This approach is overly conservative with the allowable release rate to prevent an increase in peak flow rates further downstream. Although less stringent rate controls may help protect the area immediately downstream from a development site, the increased volume of runoff and the prolonged duration of runoff from multiple development sites can actually increase peak flow rates and duration of flood flows in downstream reaches. The release rate of 0.15 cfs/acre is selected to be generally protective of floodplains in downstream watercourses, and is based on results found in previous hydrologic studies on West Michigan streams.

Overland flow routes and the extent of high water levels for the 100-year storm shall be identified for all sites. Provisions shall be made to ensure no adverse impacts offsite or internal to the site.

3. Water Quality

Water quality volume is required to treat the "first flush" of storm water runoff that typically carries with it the highest concentration of pollutants.

Capturing and treating the first 0.5 inch of runoff from directly connected impervious areas has been found to generally meet pollutant load targets of:

> 80% decrease in total suspended solids (TSS); or
> discharge concentrations of TSS less than 80 mg/L

A majority of these pollutants build up and wash off from the surface of roadways, driveways, and parking areas.

Directly connected disturbed pervious surfaces (primarily lawns) can also contribute pollutant load (i.e., nutrients due to overuse of fertilizer; nutrients and bacteria due to overuse by wild/domestic animals). For these reasons, a minimum water quality volume of 750 cubic feet per acre of directly connected disturbed pervious area is used. This value is a conservative estimate of the amount of runoff produced in loam and clay soils (HSG C & D), and assumes compaction of more pervious soils, using the Small Storm Hydrology Method for 1-inch of rain (approximately equal to the 90-percent non-exceedance storm).

Water quality volume can be provided through one of the following methods:

- Permanent pool
- Extended detention
- Infiltration
- Filtration

The volume of a permanent pool incorporated into a storm water BMP can be counted as water quality volume. This is the volume below the ordinary static water level (also known as dead storage).

Extended detention is defined as holding the storm water runoff volume and releasing it gradually over a longer period of time than provided by conventional detention basins. The minimum extended detention time is 24 hours, and is defined as the time between the centroids of the inflow and outflow hydrographs. The storage volume provided by extended detention can be counted as water quality volume.

The volume of storm water runoff infiltrated into the ground through a storm water BMP can be counted as water quality volume.

The volume of storm water runoff routed through a BMP that provides filtration (i.e. an underdrained BMP) can be counted as water quality volume.

A vegetated filter strip or vegetated swale may also be used to provide filtering of storm water runoff.

4. Pre-Treatment

Pre-treatment provides for the removal of fine sediment, trash and debris, and is recommended to preserve the longevity and function of storm water BMPs, particularly infiltration and filtration practices.

A minimum pre-treatment volume equivalent to 30% of the water quality volume is required for sediment forebays using gravity. This approximates results given by the Hazen Equation for sediment basin sizing using a 50% settling efficiency for a 50-micron particle (silt) and a 1-year peak inflow.

Other methods of pre-treatment including the use of water quality devices and vegetated filter strips or vegetated swales are allowed.

C. Identify Special Cases

Identify any special cases for the site that may modify the storm water standards presented in ***Table 1***. The special cases most frequently encountered include:

- Site Constraints
- Storm Water Hot Spots

1. Site Constraints

Site constraints may inhibit the ability of the Developer to provide full retention of the 2-year volume difference onsite. In many cases, infiltration will likely be used as the primary means of retention. Site constraints that limit the use of infiltration may include:

- Poorly draining soils (< 0.24 inches per hour)
- High groundwater or the potential of mounded groundwater to impair other uses
- Well-head protection areas identified in the City's Wellhead Protection Ordinance
- Brownfield sites and areas of soil or groundwater contamination

a. Additional Criteria

A waiver of the required stream protection retention volume will be granted due to site constraints. The Developer must show the following to use extended detention for stream protection:

- Volume reduction is maximized to the greatest extent practicable.
- The cost to implement additional volume reduction BMPs is prohibitive or would force noncompliance with local zoning ordinances.

The City shall make the final determination on the adequacy of the proof.

b. Required Strategies

It should be noted that the presence of poorly draining soils on a site does not automatically preclude meeting the 2-year retention criteria. BMPs that do not rely on infiltration such as tree planting (evapotranspiration) and storm water reuse should be investigated for feasibility and cost-effectiveness.

2. Storm Water Hot Spots

Land use activities considered to be storm water hot spots are identified in the City's Wellhead Protection Ordinance. These activities involve the production, transfer, and/or storage of hazardous materials in quantities that pose a high risk to surface and groundwater quality.

a. Additional Criteria

Spill containment is only required for the transfer and storage areas of developments meeting the definition of storm water hot spots to provide for capture and containment of a slug discharge of pollutants from an accidental spill.

The spill containment volume is equivalent to the pre-treatment volume with a minimum of 400 gallons required. The minimum volume provides a reasonable capture size (a standard liquid propane truck has a hauling capacity of 1,000 gallons) that can be accommodated with a 6-foot diameter water quality device.

Spill containment facilities must have an impermeable barrier between the treated material and the groundwater and have provisions for the capture of oil, grease and sediments.

b. Required Strategies

Specific storm water management strategies for hot spots include the following:

- Infiltration of runoff from parking lots and road surfaces is discouraged in favor of a surface water discharge.
- Porous pavements that infiltrate into the groundwater are not permitted because they do not allow for any pre-treatment or spill containment.
- Perforated pipes for infiltration are not permitted because of the difficulty in isolating an accidental spill.

D. Confirm an Adequate Outlet

The design criteria specified in this manual is generally protective of the receiving waterbody. However, the Developer must always demonstrate that an adequate outlet exists downstream of the development to receive the design rate, volume and concentration of the post-development site runoff (including offsite discharge from overflow spillways and pipes) without adverse impact to downstream properties or infrastructure.

It is the Developers responsibility to meet the following requirements:

- Post-development discharge shall not exceed the capacity of the existing infrastructure.
- Post-development discharge shall not cause adverse impact to offsite property due to concentrated runoff or ponded water of greater height, area, and duration.
- For a downstream drainage system that is inadequate to handle the proposed design discharge from the site development, it is the Developer's responsibility to:
  - Stabilize or upsize the existing conveyance system, or establish a county drain to provide the needed design level of flood protection.
  - Obtain flooding easements for measurable increases in water levels determined to cause an adverse impact.
  - Provide additional onsite storm water controls.

E. Select Best Management Practices

Select appropriate storm water BMPs from the Storm Water BMP Summary Matrix included in ***Table 3.*** The BMP or combination of BMPs selected must meet minimum volume and peak rate requirements and be designed in accordance with the design criteria provided in Part 2 of this manual. Minimum maintenance guidelines are included in ***Appendix 2***.

Table 3 – Storm Water BMP Matrix

Storm Water BMP	Treatment			
	Pre-treatment Required	Provides Water Quality	Provides Pre-treatment	Provides Spill Containment
Non-Structural BMPs				
Minimize Disturbed Area				
Protect Natural Flow Paths			X	
Protect Sensitive Areas				
Native Revegetation			X	
Storm Water Disconnection				
Structural BMPs – Conveyance and Storage				
Storm Sewer				X
Culvert or Bridge				
Open Channel				
Detention Basins	Y	X*		
Retention Basins	Y	X		
Structural BMPs –LID and Small Site				
Infiltration Practices	Y	X		
Bioretention / Rain Garden	Y	X		
Constructed Filter	Y	X		X
Planter Box		X		
Pervious Pavement		X		
Capture Reuse		X		X
Vegetated Roof			X	
Structural BMPs – Pre-treatment				
Water Quality Device			X	X
Sediment Forebay		X	X	
Spill Containment Cell		X	X	X
Water Quality Swale	Y	X	X	X
Vegetated Swale		X	X	
Vegetated Filter Strip		X	X	
Level Spreader			X	
NOTES: Y = Yes; X = BMP may be used to meet treatment criteria; X* = does not include DRY detention basins				

Worksheet 1
STORM WATER WORKSHEET

Project: ____ **Date:** ____________

Location: ____ **By:** _____________

Storm Sewer District: ____

Site Discharge Location: ____

Storm Water Management Strategy: ____

____

Adequate Outlet Description: ____

____

Standard	Criteria
Stream Protection	___ **Retention of the entire 2-year volume increase.** *check, unless one of the following is allowed:* ___ Extended detention of 1-year runoff volume due to site constraints. ___ Not required.
Flood Control	___ **Retention of the 25-year runoff volume** *check, unless one of the following is allowed:* ___ Detention of the 25-year runoff volume with a maximum release rate of 0.15 cfs/acre. ___ Do not exceed existing 10-year peak discharge rate.
Water Quality	___ **Treat "first flush."** *check, unless the following is allowed:* ___ Provided in an offsite regional facility.
Pre-Treatment	___ **Required.** *check, if using any of the following:* detention and retention basins, infiltration and filtering practices including bioretention/rain gardens and water quality swales. ___ Not required.
Storm Water Hot Spot:	___ **Yes. Spill Containment** for ____________________ *describe activity (i.e. gas station)* ___ No.

PART 2:
STORM WATER DESIGN CRITERIA

I. SOILS INVESTIGATION

A. Qualifications

Soils investigation by a qualified geotechnical consultant is required for retention and detention basins, infiltration practices, bioretention /raingardens, constructed filters, planter boxes and pervious pavement to determine the site soil infiltration characteristics and groundwater level.

The geotechnical consultant shall be a professional engineer, soil scientist, or professional geologist.

B. Background Evaluation

An initial feasibility investigation should be conducted to screen proposed BMP sites. The investigation involves review of the following resources:

- County Soil Survey prepared by the NRCS and USDA Hydrologic Soil Group (HSG) classifications.
- Existing soil borings, wells or geotechnical report on the site.
- Onsite septic percolation testing.
- Regional groundwater data (Michigan Groundwater Mapping Project website http://gwmap.rsgis.msu.edu/).
- Cyclical groundwater levels (http://waterdata.usgs.gov/mi/nwis/gw).

C. Test Pit / Soil Boring Requirements

A test pit (excavated hole) or soil boring shall be used for geotechnical investigation. Test pits may typically be selected for shallower investigations in locations where groundwater is sufficiently low. The minimum number of test pits or soil borings shall be determined from ***Table 4***.

Table 4 – Minimum Number of Soil Tests Required

Type of BMP	Test Pit / Soil Boring	Depth of Test Pit / Soil Boring	Field Permeability Test
Retention basins Infiltration beds Rain garden Pervious pavement	1 soil boring per 5,000 square feet of bottom area; 2 minimum	8 feet below proposed bottom	1 test per soil boring
Infiltration trench Bioswale	1 soil boring per 100 linear feet of BMP; 2 minimum	8 feet below proposed bottom	1 test per soil boring
Dry well Planter box	1 soil boring minimum	5 feet below proposed bottom	1 test per soil boring
Detention basins	1 soil boring per 10,000 square feet of bottom area; 1 minimum	5 feet below proposed bottom	Not Applicable

Excavate a test pit or soil boring in the location of the proposed BMP.

At each test pit or soil boring, the following conditions shall be noted and described, referenced from a top-of-ground elevation:

- Depth to groundwater. The groundwater elevation shall be recorded during initial digging or drilling, and again upon completion of drilling.
- Depth to bedrock or hardpan.
- Depth and thickness of each soil horizon, including the presence of mottling.
- USDA soil texture classification for all soil horizons.

Test pit reports and soil boring logs shall include the date(s) data was collected and the location referenced to a site plan.

D. Highest Known Groundwater Elevation

The highest known groundwater elevation shall be determined by adjusting the measured groundwater elevation using indicators such as soil mottling and regional water level data. It should also take into consideration local conditions that may be temporarily altering water levels at the time of measurement. Such conditions could include, but not be limited to: dewatering, irrigation well or large quantity withdrawals in the area, or areas of groundwater infiltration (such as a nearby infiltration basin).

E. Field Permeability Testing

Field permeability testing is not required, but may be performed to determine if a design infiltration rate higher than indicated in ***Table 5*** may be used. The City reserves the right to request that field permeability testing be performed on questionable sites. Acceptable field tests include:

- Infiltration Rate of Soils in Field Using Double-Ring Infiltrometers (ASTM D-3385)
- Percolation Tests

The methodologies and procedures outlined on pages 440-441 in Appendix E of the *Low Impact Development Manual for Michigan* (SEMCOG 2008) shall be followed for each test.

http://www.semcog.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_appendixE.pdf

An additional factor of safety of two (2) shall be applied to the permeability test results by the following equation:

Permeability-test infiltration rate (inches/hour) / 2 = Design infiltration rate (inches/hour)

The minimum number of field permeability tests shall be determined from ***Table 4.***

Tests shall be conducted in the location of the proposed BMP at the proposed bottom elevation. The City may allow an alternate testing depth if material is identical and groundwater is not an issue.

Tests shall not be conducted in the rain or within 24 hours of significant rainfall events (>0.5 inch), or when the temperature is below freezing.

Field permeability testing reports shall include the date(s) data was collected and the location referenced to a site plan.

F. Design Infiltration Rates

A conservative value for the infiltration rate is used in calculating the storage volume of infiltration BMPs due to the uncertanty that the soil will infiltrate at the design rate during the time the basin is filling. The maximum allowable soil infiltration rate used to size the storage volume of the BMP shall be 0.52 inches per hour, except that 1.04 inches per hour may be used where soil borings indicate sand or gravel free of any other soil seams.

Where field permeability testing is not performed, the design infiltration rates provided in ***Table 5*** shall be used to calculate the minimum infiltration area of the BMP necessary to drain in the allotted drawdown time.

Table 5 – Design Infiltration Rates by USDA Soil Texture Class

Soil Texture Class	Effective Water Capacity[1] (inches per inch)	Design Infiltration Rate[2] (inches per hour)	Hydrologic Soil Group[1]
Gravel	0.40	3.60	A
Sand	0.35	3.60	A
Loamy Sand	0.31	1.63	A
Sandy Loam	0.25	0.50	A
(Medium) Loam	0.19	0.24	B
Silty Loam / (Silt)	0.17	0.13	B
Sandy Clay Loam	0.14	0.11	C
Clay Loam	0.14	0.03	D
Silty Clay Loam	0.11	0.04	D
Sandy Clay	0.09	0.04	D
Silty Clay	0.09	0.07	D
Clay	0.08	0.07	D

[1]Source: Appendix D.13, Table D.13.1, *Maryland Stormwater Design Manual*, Maryland Department of Environment, 2000. (Rawls, Brakensiek and Saxton, 1982.)
[2]Source: Table 2, *Site Evaluation for Stormwater Infiltration (1002),* Wisconsin Department of Natural Resources, Conservation Practice Standards, 2004. (Rawls, 1998.)

Infiltration is the process by which water on the ground surface enters the soil. *Infiltration rate* is a measure of the rate at which soil is able to absorb rainfall or irrigation in inches per hour. The rate decreases as the soil becomes saturated. The design infiltration rate assumes saturated conditions and closely approximates the *hydraulic conductivity* (typically given in feet per day) of the near-surface soil.

The *effective water capacity* of a soil is the fraction of the void spaces available for water storage, measured in inches per inch.

Table 5 provides design values of the effective water capacity (void ratio) and the infiltration rate of the specific soil textural groups. The soil textures presented in ***Table 5*** correspond to the soil textures of the USDA Soil Textural Triangle included as ***Figure 3***.

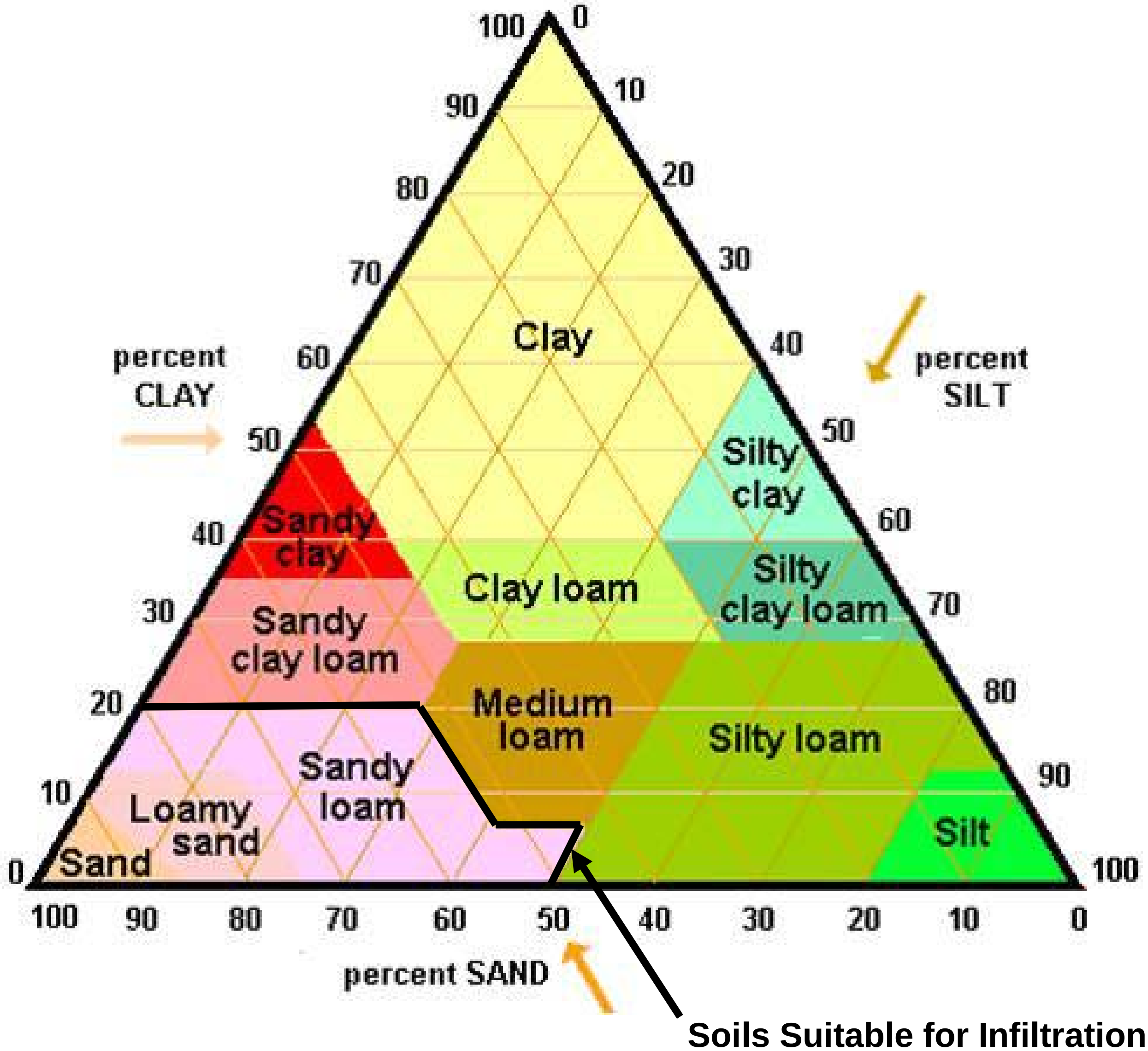
The least permeable soil horizon within four (4) feet below the proposed BMP bottom elevation shall be used to select the design infiltration rate.

G. Minimum Allowable Infiltration Rate

Soil textures with design infiltration rates less than 0.50 inches per hour are not suitable for infiltration BMPs. Modifications to the BMP design through the use of underdrains or subsoil amendment, or selection of an alternative BMP shall be required.

For design infiltration rates between 0.24 and 0.50 inches per hour (medium loam), BMP design may include an underdrain placed at the top of the storage bed layer.

Figure 3 – USDA Soil Textural Triangle



II. CALCULATION METHODOLOGY

A. Calculating Runoff

1. Rainfall Loss Equations and Runoff Coefficients

a. **The Rational Method** may be used to calculate storm water runoff and generate peak discharges to size conveyance and storage systems. The peak runoff rate is given by the equation:

$$Q = C\ I\ A$$

where:
Q = peak runoff rate (cubic feet per second)
C = weighted runoff coefficient of the drainage area
I = average rainfall intensity for a storm with a duration equal to the time-of-concentration of the drainage area (inches per hour)
A = drainage area (acres)

Runoff coefficients for various land uses and surface types are included in ***Table 6***.

Table 6 – Rational Method Runoff Coefficients

Type of Development	Runoff Coefficients
Downtown Business Neighborhood Business	0.70 to 0.95 0.50 to 0.70
Single family Residential Multi-units (detached) Multi-units (attached)	0.30 to 0.50 0.40 to 0.60 0.60 to 0.75
Residential (suburban)	0.25 to 0.40
Apartment	0.50 to 0.70
Light Industrial Heavy Industrial	0.50 to 0.80 0.60 to 0.90
Park, Cemeteries	0.10 to 0.25
Playgrounds	0.20 to 0.35
Railroad Yard	0.20 to 0.35
Unimproved	0.10 to 0.30
Character of Surface	
Asphalt and Concrete Pavement Brick Pavement	0.70 to 0.95 0.70 to 0.85
Roofs	0.75 to 0.95
Lawns, Sandy Soil Flat 2% Lawns, Sandy Soil Average 2% to 7% Lawns, Sandy Soil Steep 7%	0.05 to 0.10 0.10 to 0.15 0.15 to 0.20
Lawns, Heavy Soil Flat 2% Lawns, Heavy Soil Average 2% to 7% Lawns, Heavy Soil Steep 7%	0.13 to 0.17 0.18 to 0.22 0.25 to 0.35

Source: *Design and Construction of Sanitary and Storm Sewers*, American Society of Civil Engineers and the Water Pollution Control Federation, 1969.

b. **The Runoff Curve Number Method**, developed by the NRCS, may be used to calculate storm water runoff to generate peak discharges and runoff volumes. This method must be used when it is necessary to calculate runoff volumes for stream protection. The formulas are as follows:

$$Q_v = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

where:
Q_V = surface runoff volume (inches)
P = rainfall (inches);
S = potential maximum retention after runoff begins (inches)

and where:

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

Surface runoff volumes (Qv) are calculated separately for impervious and pervious areas.

Curve Number (CN) values shall be taken from Technical Release No. 55 (TR-55). Standard values are summarized in ***Table 7*** for convenience.

(1) Open space in "fair" condition shall be used for post-development pervious areas that are not receiving non-structural BMP credits.

c. **The Michigan Modified Unit Hydrograph** formula shall be used with the Runoff Curve Number Method to generate peak storm water runoff rates:

$$Q = 238.6\ A\ Qv\ Tc^{-0.82}$$

where:
Q = peak runoff rate (cubic feet per second)
K = 238.6 constant reflecting shape of the unit hydrograph including unit conversion factors
A = drainage area (square miles)
Qv = surface runoff volume (inches)
Tc = time-of-concentration (hours)

Table 7 – Curve Numbers (CNs) from TR-55

Land Use Description		Curve Number[1]			
		Hydrologic Soil Group			
Cover Type	Condition[2]	A	B	C	D
Cultivated land	Poor	72	81	88	91
	Good	62	71	78	81
Pasture or range land	Poor	68	79	86	89
	Fair*	49	69	79	84
	Good	39	61	74	80
Meadow	Good	30	58	71	78
Orchard or tree farm (50% woods / 50% pasture)	Poor*	57	73	82	86
	Fair*	43	65	76	82
	Good*	32	58	72	79
Woods	Poor	45	66	77	83
	Fair*	36	60	73	79
	Good	30*	55	70	77
Open spaces (grass cover)	Poor*	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Paved parking lot, roof, driveway		98	98	98	98
Gravel		76	85	89	91
Dirt		72	82	87	89

Source: *Urban Hydrology for Small Watersheds*, *Technical Release No. 55*, U.S. Department of Agriculture Soil Conservation Service, 1986.

[1]Antecedent moisture condition II and $I_a = 0.2S$

[2]Good Condition: cultivated land with conservation treatment; pasture, meadow or open space with 75% or more grass cover; woods with good cover of trees protected from grazing with litter and brush over soil

Fair Condition: pasture or open space with 50% to 75% grass cover; woods are grazed with some litter over soil

Poor Condition: cultivated land without conservation treatment; pasture or open space with less than 50% grass cover; woods with litter and brush destroyed by heavy grazing or burning

*From *Low Impact Development Manual for Michigan,* SEMCOG 2008

2. Time-of-Concentration

a. **Rational Method:** Overland flow time may be calculated using the nomograph shown as ***Figure 4***. A minimum of 15 minutes shall be used. Channel flow shall be calculated using Manning's equation.

b. **Runoff Curve Number Method:** Travel time shall be calculated using NRCS TR-55 methodology as outlined below.

The flow path is split into three sections – sheet flow, shallow concentrated flow, and open channel flow. In each flow regime the velocity and/or travel time are computed. The time-of-concentration is the sum of the travel times.

(1) For sheet flow the travel time (in hours) is given as:

$$\frac{0.007(nL)^{0.8}}{P_2^{0.5}s^{0.4}}$$

where n is Manning's factor, L is the flow length (feet), P_2 is the 2-year precipitation depth, and s is the slope (feet/foot).

(2) Shallow concentrated flow velocities are calculated for paved and unpaved surfaces. The velocities are given as:

$$v = \begin{matrix} 16.1345s^{.0.5} & Unpaved \\ 20.3282s^{0.5} & Paved \end{matrix}$$

where s is the slope (feet/foot) and v is the velocity in feet per second. The flow length (feet) is then divided by the velocity (feet per second) to obtain travel time in hours.

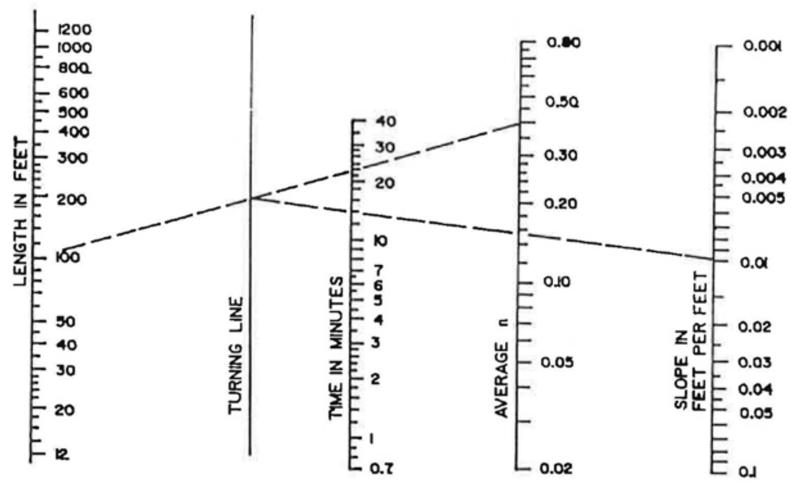
(3) Open channel flow uses Manning's equation to calculate the velocity based on slope, flow area, and wetted perimeter. The flow length (feet) is then divided by the velocity (feet per second) to obtain travel time in hours.

c. **BMP residence time** shall be calculated as the storage volume divided by the 10-year peak flow rate.

Figure 4 – Nomograph to Comupte Time of Concentration for Overland Flow

The following is a table used for determining n.

TYPE OF SURFACE	n VALUE
Smooth impervious Surface	0.02
Smooth bare packed soil	0.10
Poor grass, cultivated row crops or moderately rough bare surface	0.20
Pasture or average grass	0.40
Deciduous Timberland	0.60
Conifer Timberland, Deciduous Timberland with deep forest litter or dense grass	0.80



Example: N=0.40, L=100', S=0.01 feet/foot and tc=13.6 minutes

Chart is printed from the following equation.

$$tc = \left(\frac{2\,Ln}{3\sqrt{S}}\right)^{x} \qquad x = \frac{1}{2.14}$$

Taken from ENGINEER'S NOTEBOOK

"Time of concentration for overland flow" W.S. Kerby, J.M. Asce, Hydrologist, Servis, Van Doren & Hazard, Engineers, Topeka, Kansas.

The variables needed to compute time of concentration for a proposed development are its length, slope, and surface retardants. These variables can be computed from field survey notes.

The length L is the distance from the extremity of the development area in a direction parallel to the slope until a defined channel is reached. The units are in feet. Overland flow will become channel flow within 1,200 feet in almost all cases. Time of concentration is the sum of overland flow and channel flow.

The slope S is the difference in elevation between the extremity of the drainage area and the point in question divided by the horizontal distance. The units are in feet/foot.

The surface retardants coefficient, n, is the average surface retardants value of the overland flow.

3. Rainfall

a. The rainfall duration-frequency table provided in ***Table 8*** shall be used with the Rational Method to determine rainfall intensity for rainfall duration equal to the time-of-concentration.

b. The 24-hour rainfall amounts provided in ***Table 8*** shall be used with the Runoff Curve Number Method.

c. A Type II rainfall distribution shall be used when a unit hydrograph approach is used.

Table 8 – Rainfall Amounts

Duration	1-year	2-year	5-year	10-year	25-year	50-year	100-year
24-hr	2.03	2.42	2.98	3.43	4.09	4.63	5.20
18-hr	1.91	2.27	2.80	3.22	3.84	4.35	4.89
12-hr	1.77	2.11	2.59	2.98	3.56	4.03	4.52
6-hr	1.52	1.82	2.24	2.57	3.07	3.47	3.90
3-hr	1.3	1.55	1.91	2.20	2.62	2.96	3.33
2-hr	1.18	1.40	1.73	1.99	2.37	2.69	3.02
1-hr	0.95	1.14	1.40	1.61	1.92	2.18	2.44
30-min	0.75	0.90	1.10	1.27	1.51	1.71	1.92
15-min	0.55	0.65	0.80	0.93	1.10	1.25	1.40
10-min	0.43	0.51	0.63	0.72	0.86	0.97	1.09
5-min	0.24	0.29	0.36	0.41	0.49	0.56	0.62

Source: Table 5 – Michigan, Section 9, *Rainfall Frequency Atlas of the Midwest, Bulletin 71*, Huff and Angel, 1992.

B. Calculating Storage Volumes and Release Rates

1. Stream Protection Using Onsite Retention

a. Stream protection volume shall consist of retaining the 2-year runoff volume increase between existing and proposed development conditions. The minimum required stream protection volume is calculated by the formula:

$$V_{sp} = V_{dev} - V_{ex}$$

where:

$$V_{dev} = A\ (Qv_{perv} + Qv_{imp})\ /\ 12$$

$$V_{ex} = A\ (Qv_{perv} + Qv_{imp})\ /\ 12$$

and where:
V_{sp} = minimum required stream protection volume (cubic feet)
V_{dev} = runoff volume of the 2-year, 24 hour storm for proposed development conditions
V_{ex}= runoff volume of the 2-year, 24-hour storm under existing conditions
A = contributing disturbed site area (acres)
Qv = surface runoff volume (inches) by Runoff Curve Number Method, calculated separately for pervious and impervious surfaces.
12 = factor to convert inches to feet

b. The stream protection volume must be retained onsite. This may be accomplished through infiltration, interception with storm water reuse, and/or interception with evapotranspiration (i.e. trees, wetlands).

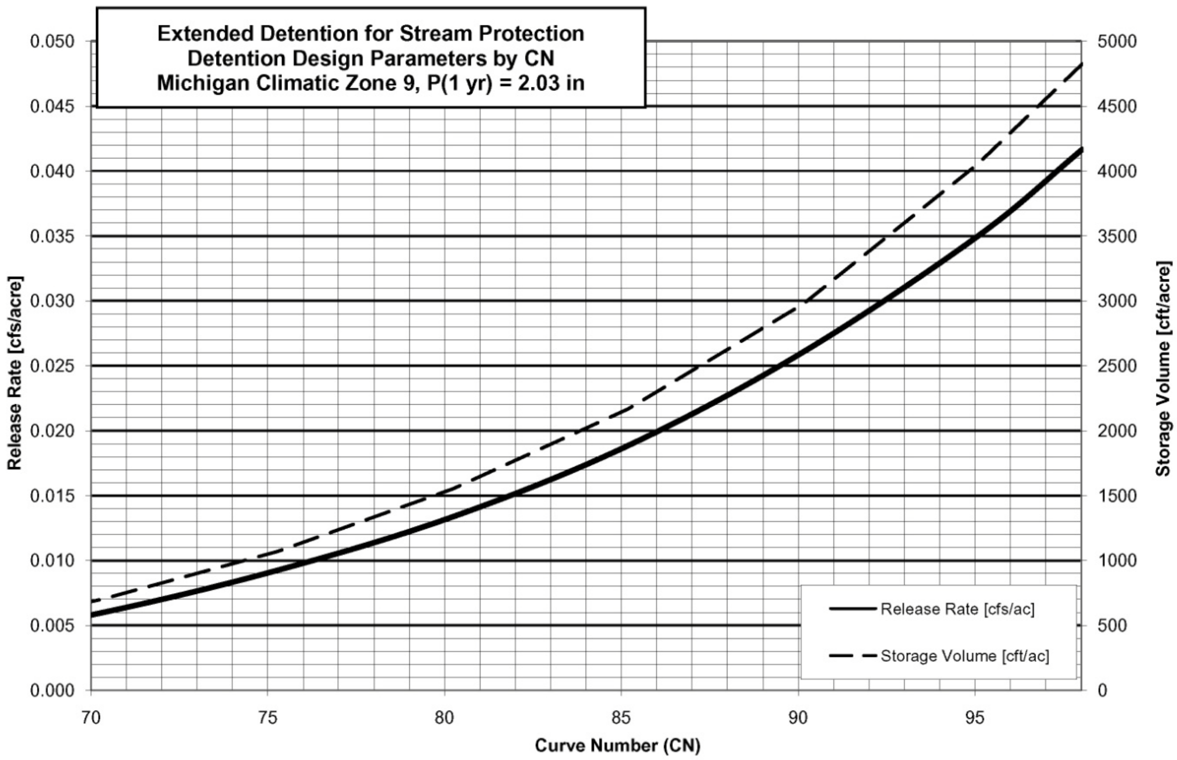
c. If the required stream protection volume is not able to be met through retention, the remainder may be provided through extended detention. In this case, use the Extended Detention Curves in ***Figure 5***, calculate a weighted CN for the site, and reduce the total site area by the fraction of stream protection volume provided through retention. (For example, if 75% of the required stream protection volume is met by retention, then 25% of the site area would be used with the extended detention curves.)

> **Green Calculator.** The Green Calculator is a Microsoft Excel spreadsheet application that uses a unit hydrograph storm water runoff method with NRCS Curve Numbers (CN) and time-of-concentration formulas. It calculates required treatment volumes and detention release rates for a single treatment train on the site. A site with multiple (parallel) treatment trains requires one spreadsheet for each treatment train. The spreadsheet then allows the user to select non-structural and structural BMPs to meet required runoff rates and volumes. Output is graphed as hydrographs and summarized in tabular form for a range of rainfall frequencies (2, 10, and 25 year). A copy is provided with this manual.
>
> The Green Calculator can be used to compute the required stream protection volume and the required extended detention volume and release rate.

2. Stream Protection using Extended Detention

a. Extended detention shall consist of detaining the total runoff from the 1-year, 24-hour rainfall event to achieve a 24-hour lag between the centroid of the outflow hydrograph and the inflow hydrograph, determined by reservoir routing. When extended detention is required, allowable release rates and storage volumes per acre can be selected from the curves provided in ***Figure 5.***

Figure 5 – Extended Detention Curves for Stream Protection



Source: *Lower Grand River Watershed, Stormwater Management for Stream Protection: Development of Michigan Statewide Rating Curves for Extended Detention Control of the Stream Protection Volume*, FTC&H, 2009.

b. Where the allowable release rate is so small that construction of a properly-sized orifice outlet is not feasible, an underdrained bioretention / raingarden, planter box, water quality swale or constructed filter, sized for the required storage volume in ***Figure 5,*** may be used to meet stream protection requirements.

3. Flood Control using Detention Basins

a. The standard flood control criteria shall consist of detention of the 25-year rainfall event with a maximum allowable release rate of 0.15 cfs/acre.

b. If the Rational Method is used, the required storage volume shall be calculated by the “Modified Chicago” Method in a spreadsheet application. A factor of safety of 1.25 shall be applied because this method tends to underestimate the storage volume when compared to pond routing, particularly for short times-of-concentrations (15 to 30 minutes). A Microsoft Excel spreadsheet application (Rational Method spreadsheet) is provided with this manual.

> The Green Calculator can be used to compute the required 25-year detention storage volume using the Runoff Curve Number Method with a Michigan Unit Hydrograph and the Modified Puls Method for reservoir routing (see MDOT Drainage Manual, Section 8.4.8) given a user-specified release rate.
>
> When using the Green Calculator, the area of a detention basin (if required at the end of a treatment train) should be counted as a protected area or not included in the total site area since it is not part of the contributing area requiring stream protection or water quality treatment. This allows the user to match existing and developed site areas without having to provide additional "treatment" for a detention area.

c. When the Developer wants to receive credit for the reduction in runoff volume provided through site BMPs without using the Green Calculator, the Rational Method spreadsheet may be used with the Runoff Curve Number Method by “backing into” a weighted runoff coefficient. The following procedure can be used:

(1) Determine the 25-year, 24-hour runoff volume of developed site (Qv) by the CN Method.

(2) Convert this volume to cubic feet by multiplying by the area and a unit conversion factor of 3,630.

(3) Subtract the volume of runoff retained by storm water BMPs.

(4) Convert the resulting net runoff volume (Qvn) to inches by dividing by the area and a unit conversion factor of 3,630.

(5) Calculate a weighted Rational Coefficient by the equation:

$$C = Qvn / P$$

where:
C = weighted runoff coefficient
Qvn = net surface runoff volume (inches)
P = 25-year, 24-hour rainfall amount (4.09 inches)

(6) Use this weighted runoff coefficient in a Rational Method spreadsheet application to determine the required detention storage volume.

Note: A factor of safety does not need to be included if more than 25% of the runoff volume is being retained and the time-of-concentration is 0.5 hour or greater.

4. Flood Control using Retention Basins

a. The maximum allowable soil infiltration rate used to size the storage volume of the BMP shall be 0.52 inches per hour, except that 1.04 inches per hour may be used where soil borings indicate sand or gravel free of any other soil seams.

b. If the Rational Method is used, retention basins shall be sized to store and infiltration a minimum of 3,630 cubic feet per acre, or the total runoff from a rainfall determined to be equivalent to the storage volume for the 25-year, 24-hour rainfall event with the maximum allowable design outflow (0.52 or 1.04 inches per hour) by the formula:

$$V_s = CAP(3630)$$

where:
V_s = storage volume (cubic feet)
C = weighted runoff coefficient
A = area (acres)
P = 3.25 rainfall amount (inches) for 0.52 in/hr, or
P = 2.70 rainfall amount (inches) for 1.04 in/hr
3630 = factor to convert acre-inches to cubic feet

The detention function of the Green Calculator can be used to calculate the 25-year storage volume required when retention basins are used to provide flood control.

The release rate shall be calculated as the maximum allowable infiltration rate times an assumed basin bottom area, given by the following equation:

$$Q_{out} = (i_{max} \times V / d) / (3600)(12)$$

where:
Q_{out} = average outflow from basin bottom (cubic feet per second)
i_{max} = maximum allowable infiltration rate (inches per hour)
V/d = total 25-year, 24-hour inflow volume divided by design high water depth or a maximum of 3 feet for i_{max} = 0.52 and 6 feet for i_{max} = 1.04 (equivalent to an assumed basin bottom area required to drain in 72 hours using maximum allowable infiltration rate)
3600 = factor to convert hours to seconds
12 = factor to convert inches to feet

CAUTION: The Green Calculator assumes that the resulting outflow volume is routed offsite when it is really infiltrated. When the detention function is used in this way, the user must be aware that this volume will be wrongly reflected in the discharge hydrographs.

5. Water Quality

a. Treatment of runoff by settling (permanent pool or extended detention), infiltration, or filtration is required from directly connected impervious areas for the first 0.5-inch of runoff. Water quality volume is calculated by the formula:

$$V_{wq} = 1815\ (DCIA)$$

where:
V_{wq} = minimum required water quality volume (cubic feet)
DCIA = directly connected impervious area (acres)
1815 = product of 0.5 inch and 3630 factor to convert acre-inches to cubic feet

b. For directly connected disturbed pervious areas (i.e. lawns) a minimum water quality volume of 750 cubic feet per acre shall be provided.

c. If a vegetated filter strip or vegetated swale is used, the filtering area must meet minimum standards for slope, length, and vegetative cover specified for the BMP.

6. Pre-treatment

a. Pre-treatment is recommended for detention and retention basins, infiltration practices, constructed filters and bioretention / rain gardens.

b. Pre-treatment can be provided by any of the following methods:

(1) Sediment forebay:

$$V_{pt} = 0.30\ (V_{wq})$$

where:
V_{pt} = minimum required pre-treatment volume (cubic feet)
V_{wq} = water quality volume (cubic feet)

(2) Vegetated filter strips: Provide a 5-foot minimum sheet-flow length at a maximum slope of 2%.

(3) Vegetated swales: Provide a 15-foot minimum sheet-flow length at a maximum slope of 2%.

(4) Water quality device: Configured to trap floatables and sediment. Follow manufacturer’s guidelines.

c. Pre-treatment volume may be included in the total water quality volume.

III. NON-STRUCTURAL BEST MANAGEMENT PRACTICES

Non-structural Best Management Practices (BMPs) consist of protection and restoration measures that reduce the volume of storm water runoff from the site. This differs from the goal of many structural BMPs which is to help mitigate the impact of storm water runoff.

The City has adopted standards for the following non-structural BMPs:

- Minimize Soil Compaction and Total Disturbed Area
- Protect Natural Flow Pathways
- Protect Sensitive Areas (including Riparian Buffers)
- Native Revegetation
- Storm Water Disconnection

Further information and examples are provided in the BMP Fact Sheets in Chapter 6 of the *Low Impact Development Manual for Michigan* (SEMCOG 2008):

http://www.semcog.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_chapter6.pdf

All of the following criteria must be met to receive credit for each non-structural BMP selected for use.

Minimize Soil Compaction and Total Disturbed Area

A. Summary

Pretreatment Required:		No
Calculation Credits:		
	Volume Reduction	Assign a CN reflecting open space in “good” condition, or woods in “fair” condition, instead of open space in “fair” condition as required for disturbed pervious areas. For small sites, individual trees can receive a credit of 800 square feet per tree, counted as woods in “fair” condition. Woods in “good” condition may be used if trees are protected by a local tree ordinance.
	Rate Reduction	By virtue of lower CN
	Water Quality	Exempt from water quality treatment criteria

B. Criteria

This BMP applies to those portions of buildable lots located outside of lot building zones, construction traffic areas and staging areas that can be maintained as “minimal disturbance areas” during construction (i.e. wooded back portions of residential lots, green space required by ordinance).

Minimal disturbance area – Construction disturbance is limited to clearing and some grading, but no cutting, filling, stockpiling of material or construction traffic. Area is vegetated after disturbance (if any).

1. Identify “minimal disturbance areas” on site plan and construction drawings.
2. Minimal disturbance areas must be protected by having the limits delineated/flagged/fenced in the field. Notes to this effect must be included on construction drawings.
3. Minimal disturbance areas must not be subject to excessive equipment movement. Vehicle traffic and storage of equipment and/or materials is not permitted.
4. Pruning or other required maintenance of vegetation is permitted. Additional planting with site-appropriate plants, including turf grass is permitted.
5. Areas receiving credit must be located on the development project.

Protect Natural Flow Pathways

A. Summary

Pretreatment Required:	No. This BMP can provide pre-treatment
Calculation Credits:	
Volume Reduction	None
Rate Reduction	Due to longer time-of-concentration for natural flow pathway
Water Quality	Exempt from water quality treatment criteria

B. Criteria

1. Identify all existing natural flow pathways on site plan.

2. Identify natural flow pathways to be protected on site plan and construction drawings.

3. Natural flow pathways to be protected must have the limits delineated/flagged/ fenced in the field. Notes to this effect must be included on construction drawings.

4. Identify flow pathways designed as part of the storm water management system including strategies such as:

   a. Increased length
   b. Increased roughness
   c. Decreased slope

5. Ensure adequacy of flow pathway for post-development flows.

Protect Sensitive Areas (including Riparian Buffers)

A. Summary

Pretreatment Required:	No
Calculation Credits:	Remove protected sensitive areas from storm water management calculations. (The area must still be included in storm water runoff calculations if it is necessary to determine the total downstream discharge from the site for sizing conveyance systems.)
Volume Reduction	Exempt from stream protection criteria
Rate Reduction	Exempt from flood control criteria
Water Quality	Exempt from water quality treatment criteria

B. Criteria

This BMP includes protected areas on the development property located on separate out lots or set-asides that restrict land uses to those that do not increase runoff.

1. Identify all sensitive areas on site plan.
2. Identify all sensitive areas to be protected on the site plan and construction drawings.
3. Sensitive areas to be protected must have the limits delineated/flagged/ fenced in the field during construction and visible permanent boundary markers set to minimize encroachment (as appropriate). Notes and details to this effect must be included on construction drawings.
4. City standards for riparian buffers shall consist of:
   a. Variable width depending on topography, minimum 25-foot width (Zone 1)
   b. Naturally vegetated
5. Minimal clearing is allowed for lot access and fire protection.

Native Revegetation

A. Summary

Pretreatment Required:	No. This BMP can provide pre-treatment
Calculation Credits:	Assign a CN reflecting a meadow instead of open space in “fair” condition as required for other disturbed pervious areas. For small sites, individual trees can receive a credit of 200 square feet per tree, counted as woods in “good” condition.
Volume Reduction	None
Rate Reduction	By virtue of lower CN
Water Quality	Exempt from water quality treatment criteria

B. Criteria

1. Identify native revegetation areas on site plan and construction drawings.

2. Native revegetation areas must be protected by having the limits delineated/flagged/fenced in the field. Notes to this effect must be included on construction drawings.

3. City standards shall consist of:

   a. Variable width depending on topography, minimum 25-foot width (Zone 1)

   b. Native revegetation selected from the *Low Impact Development Manual for Michigan* (SEMCOG 2008), Appendix C

   http://www.semcog.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_appendixC.pdf

4. Areas receiving credit must be located on the development project.

Storm Water Disconnection

A. Summary

Pretreatment Required:	No
Calculation Credits:	
Volume Reduction	Weight impervious runoff coefficient with pervious area runoff coefficient
Rate Reduction	Multiply time-of-concentration by a 1.25 factor to account for paved areas flowing onto pervious areas
Water Quality	Exempt from water quality treatment criteria

B. Criteria

1. Storm water from rooftops and other impervious areas is considered disconnected if it is routed to a stabilized vegetated area including onsite swales and bioretention areas, or an onsite depression storage area that meets the following criteria:

   a. Disconnection must ensure no basement seepage.

   b. Roof downspouts and curb cuts must be at least 10 feet away from the nearest connected impervious surface to discourage "re-connections."

   c. Disconnection in less permeable soils (HSGs C and D) may require the use of dry wells, french drains, or other temporary storage device to compensate for poor infiltration capability if ponding of water for extended period of time becomes problematic.

   d. For disconnects to stabilized vegetated areas:

      (1) Size of disconnect area shall be twice the size of the contributing impervious area.

      (2) Length of disconnect area must be at least the length of the flow path of the contributing impervious area (maximum 75 feet).

      (3) Slope of disconnect area must be no greater than 5%.

      (4) Disconnect area may be a "minimal disturbance" area.

2. Identify disconnect areas on site plan and construction drawings.

IV. STRUCTURAL BEST MANAGEMENT PRACTICES

Structural Best Management Practices (BMPs) are constructed measures that convey, store and treat storm water in a site-specific location and help mitigate the impact of storm water runoff.

The City has adopted standards for the following structural BMPs:

Conveyance and Storage

- Storm Sewer
- Culvert or Bridge
- Open Channel
- Detention Basins
- Retention Basins

LID and Small Site

- Infiltration Practices
- Bioretention / Rain Garden
- Constructed Filter
- Planter Box
- Pervious Pavement
- Capture Reuse
- Vegetated Roof

Pre-treatment

- Water Quality Device
- Sediment Forebay
- Spill Containment Cell
- Water Quality Swale
- Vegetated Swale
- Vegetated Filter Strip
- Level Spreader

BMPs shall be designed in accordance these standards.

Further information and examples of LID and pre-treatment BMPs are provided in the BMP Fact Sheets in Chapter 7 the *Low Impact Development Manual for Michigan* (SEMCOG 2008):

http://www.semcog.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_chapter7.pdf

Storm Sewer

A. Summary

Description:	Provides storm water conveyance in an enclosed system
Types:	Pipe (solid wall, perforated)
Pretreatment Required:	No. This BMP can provide spill containment
Calculation Credits:	
Volume Reduction	Solid wall pipe: None Perforated pipe (with slope): None Perforated pipe or leaching basin: Count storage volume below outlet pipe invert.
Rate Reduction	None
Water Quality	None

B. Design Requirements

1. Sizing and Configuration

   a. The storm sewer system shall be designed to convey runoff from a 10-year frequency rainfall event. A Microsoft Excel spreadsheet for storm sewer design is provided with this manual.

   b. Storm sewer design velocities, capacities, and friction losses shall be based on Manning's equation:

$$Q = \frac{1.49 A R^{\frac{2}{3}} S^{\frac{1}{2}}}{n}$$

   where:
   Q = discharge (cubic feet per second)
   A = wetted area (square feet)
   R = hydraulic radius (feet)
   S = slope (feet per foot)
   n = Manning's Coefficient

   c. Manning's coefficients for closed conduit are included in ***Table 9***

   d. Acceptable slopes for circular pipe ("n" = 0.013) are included in ***Table 10.*** Minimum and maximum grade for other Manning's n values must be calculated based on allowable minimum and maximum velocities (V).

   e. As a general rule, surcharging the pipe will be allowed to 1 foot below the top of casting. However, minor losses must be considered in hydraulic grade line calculations.

   f. Storm sewer pipe shall have a minimum diameter of 12 inches.

   g. The minimum depth of cover shall be 24 inches from grade to the top of pipe.

2. End Treatment

   a. Outlet pipes shall require energy dissipation. Riprap protection or equivalent erosion control measures shall be used where the velocity exceeds 4 feet per second, up to maximum allowable design velocity of 10 feet per second.

Storm Sewer (continued)

Table 9 - Manning's Roughness Coefficients

Conduit	Manning's Coefficients
Closed Conduits	
Asbestos-Cement Pipe	0.011 to 0.015
Brick	0.013 to 0.017
Cast Iron Pipe	
Cement-lined and seal-coated	0.011 to 0.015
Concrete (Monolithic)	
Smooth forms	0.012 to 0.014
Rough forms	0.015 to 0.017
Concrete Pipe	0.011 to 0.015
Corrugated-Metal Pipe (1/2-inch corrg.)	
Plain	0.022 to 0.026
Paved invert	0.018 to 0.022
Spun asphalt-lined	0.011 to 0.015
Plastic Pipe (Smooth)	0.011 to 0.015
Vitrified Clay	
Pipes	0.011 to 0.015
Liner channels	0.013 to 0.017
Open Channels	
Lined Channels	
Asphalt	0.013 to 0.017
Brick	0.012 to 0.018
Concrete	0.011 to 0.020
Rubble or riprap	0.020 to 0.035
Vegetal	0.030 to 0.040
Excavated or Dredged	
Earth, straight and uniform	0.020 to 0.030
Earth, winding, fairly uniform	0.025 to 0.040
Rock	0.030 to 0.045
Unmaintained	0.050 to 0.140
Natural Channels (minor streams, top width at flood state < 100 feet)	
Fairly regular section	0.030 to 0.070
Irregular section with pools	0.040 to 0.100

Source: *Design and Construction of Sanitary and Storm Sewers*, American Society of Civil Engineers and the Water Pollution Control Federation, 1969.

Storm Sewer (continued)

Table 10 - Minimum and Maximum Slopes for Storm Sewers

Pipe Size	Minimum % of Grade (V = 2.5 feet/second)	Maximum % of Grade (V = 10 feet/second)
12"	0.32	4.88
15"	0.24	3.62
18"	0.20	2.84
21"	0.16	2.30
24"	0.14	1.94
27"	0.12	1.66
30"	0.10	1.44
36"	0.08	1.12
42"	0.06	0.92
48"	0.06	0.76
54"	0.04	0.60
60"	0.04	0.54
66"	0.04	0.48

(Manning's "n" = 0.013)

3. Manholes and Catch Basins

   a. Manhole spacing shall not exceed 400 feet for sewers less than 42 inches in diameter and 600 feet for larger sewers.

   b. Manholes shall be placed at all changes in pipe direction, pipe size, all inlet connection locations, and at the end of the storm sewer.

   c. Pipe inverts at junctions shall be designed to minimize junction losses (match 0.8 points of pipe diameters).

   d. Minimum inside diameter of all manholes, catch basins, and inlet structures shall be 48 inches.

   e. Inlet structures shall be placed at low points of streets and yards, and be spaced a maximum of 400 feet apart. Spacing and/or number of inlet structures required to accommodate the design flows in streets, private drives, and parking areas shall be provided based on inlet capacity with no ponding occurring during a 10-year storm.

   f. No more than 300 feet of pavement surface drainage will be allowed. No more than 200 feet of surface drainage will be allowed for grades exceeding 4%.

   g. No more than 150 feet of street drainage will be allowed to flow around a corner.

   h. No flow will be allowed across a street intersection.

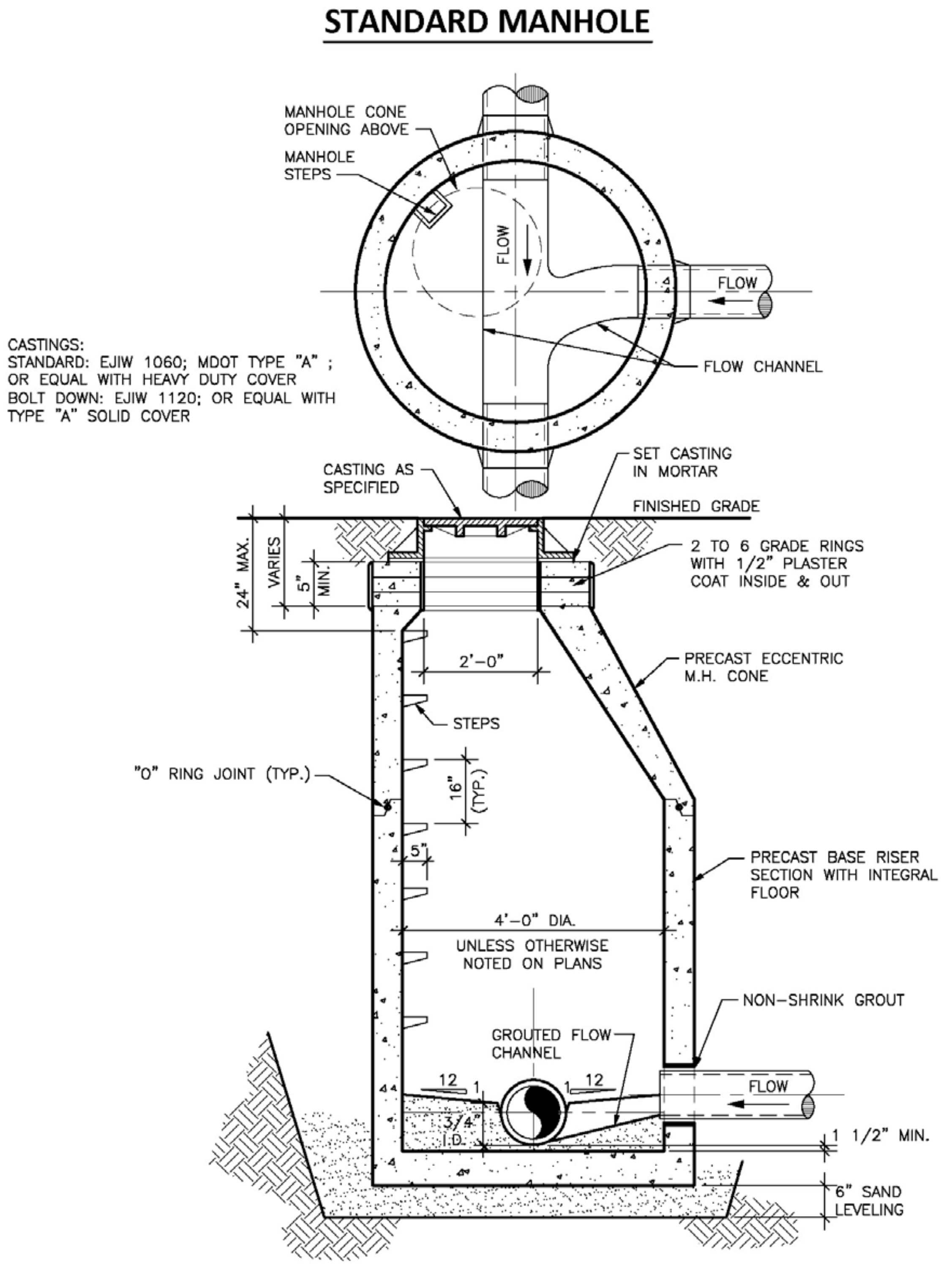
4. Materials

   a. Storm sewer pipe shall be reinforced concrete or smooth interior wall polyethylene in accordance with MDOT Standard Specifications.

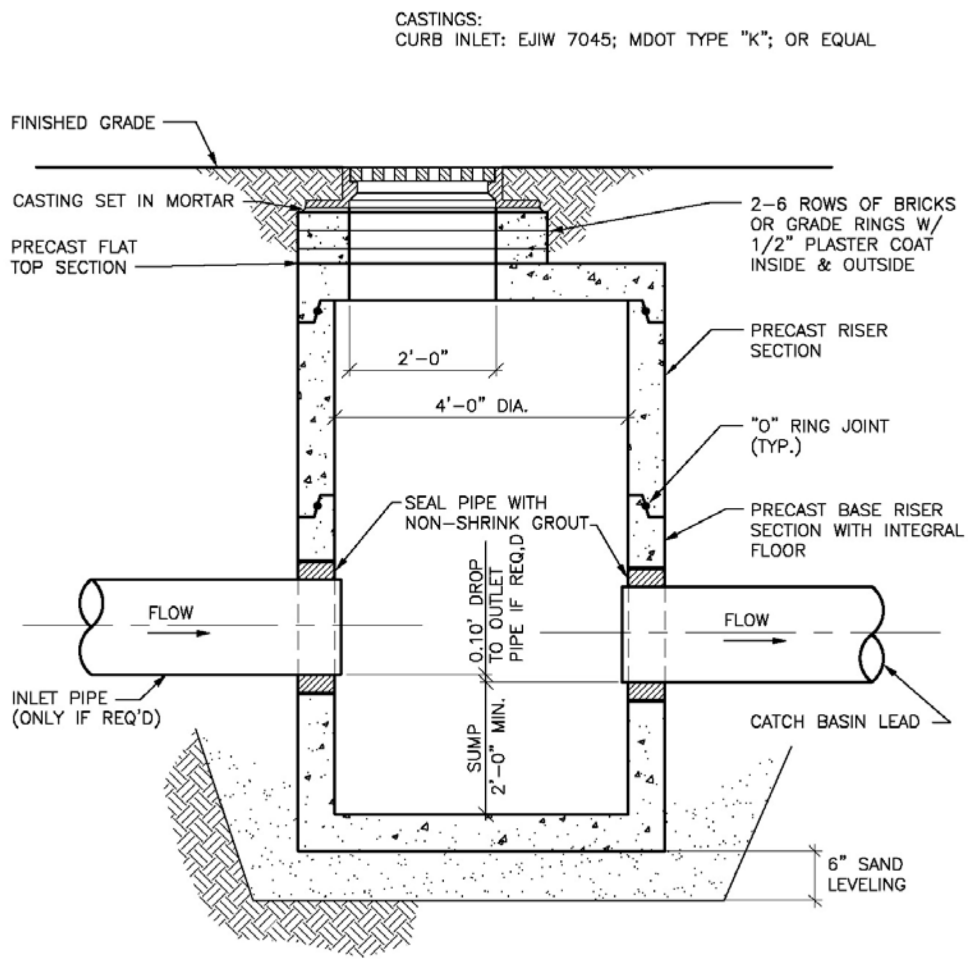
   b. Pipe joints shall be designed to prevent excessive infiltration or exfiltration.

   c. Manholes and catch basins shall be in accordance with MDOT Standard Specifications.

C. Design Schematics

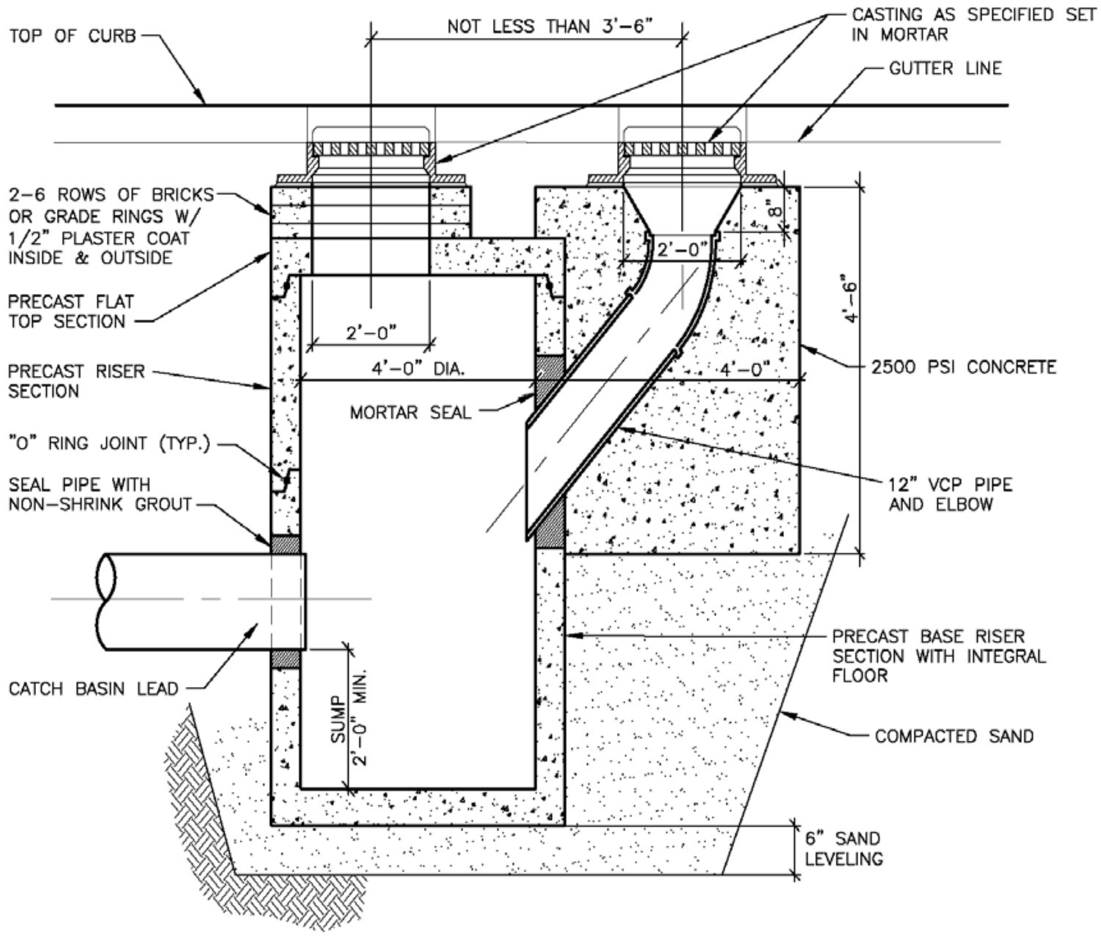


STANDARD CATCH BASIN

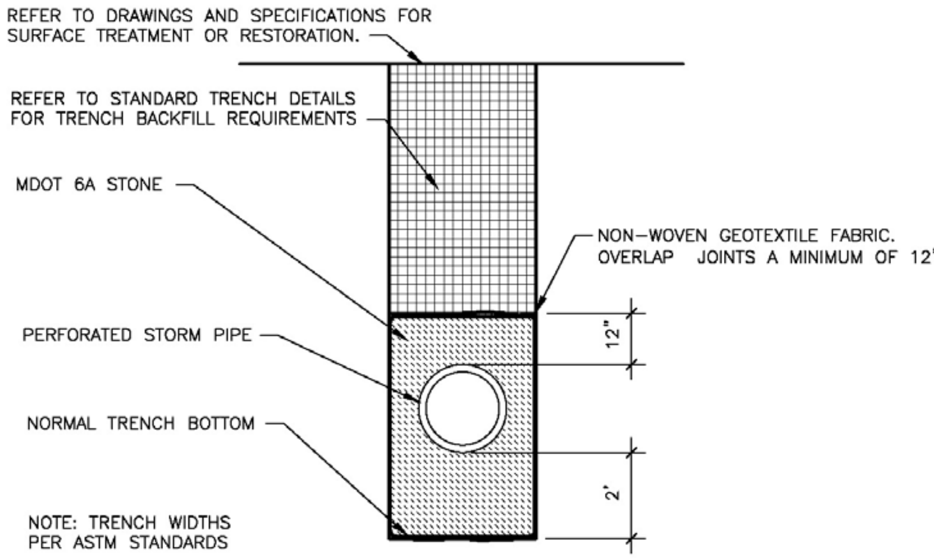


CATCH BASIN AND DROP INLET

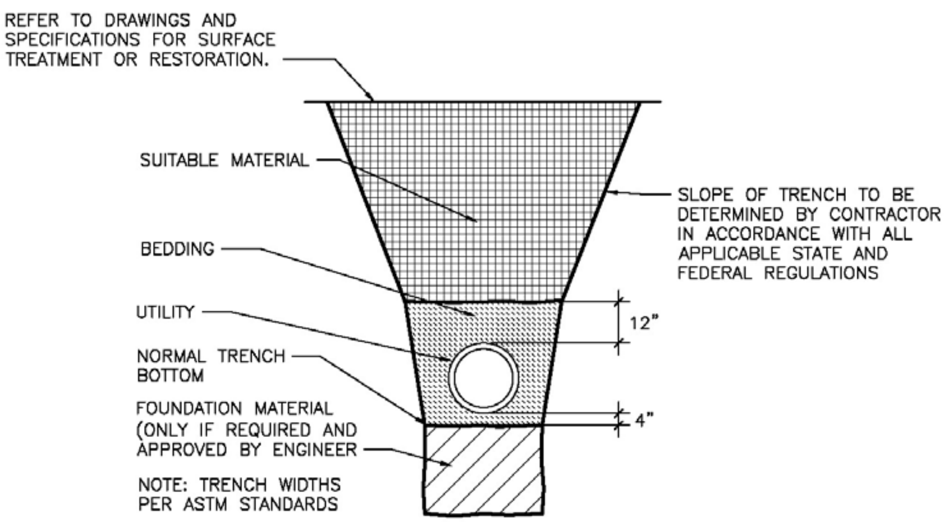
CASTINGS:
CURB INLET: EJIW 7045; MDOT TYPE "K"; OR EQUAL



STORM SEWER TRENCH

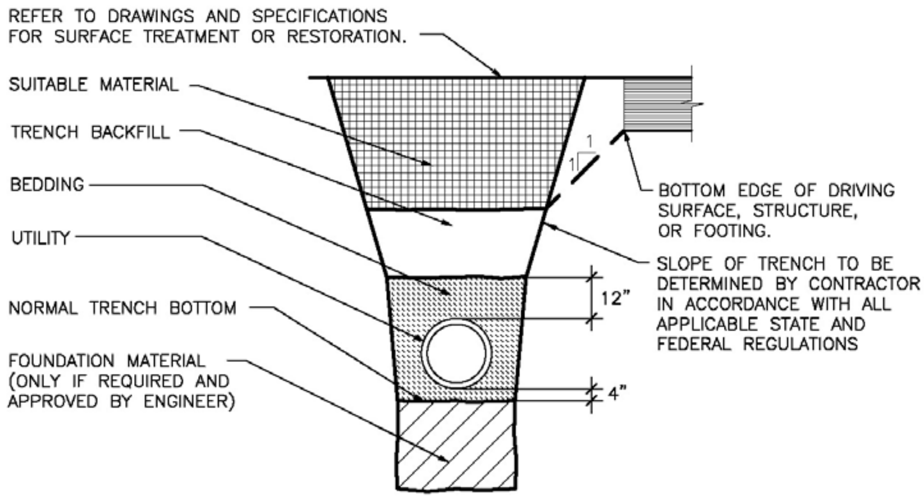


STANDARD PERFORATED STORM SEWER TRENCH

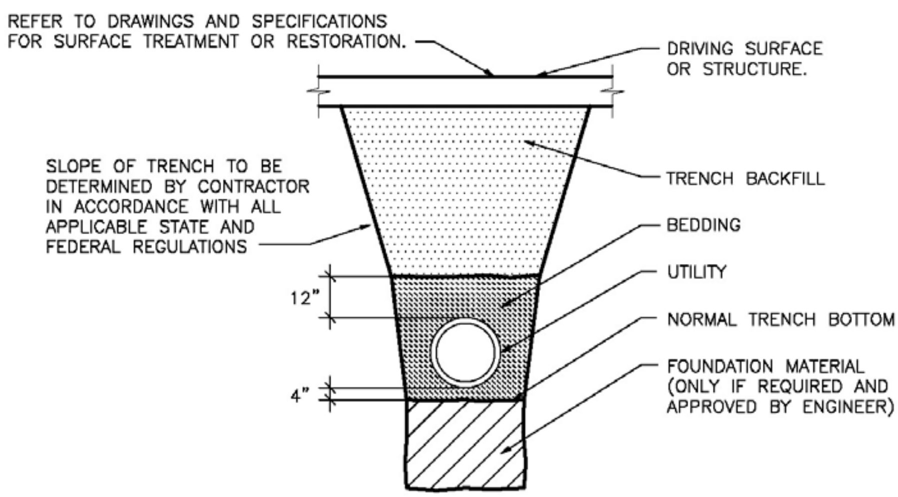


TRENCH NOT ADJACENT TO DRIVING SURFACE OR STRUCTURE

STORM SEWER TRENCH



TRENCH ADJACENT TO DRIVING SURFACE OR STRUCTURE



TRENCH BELOW DRIVING SURFACE OR STRUCTURE

Culvert or Bridge

A. Summary

Description:	Provides storm water conveyance through a crossing structure
Types:	Pipe Culvert; Box Culvert; Bridge
Pretreatment Required:	No
Calculation Credits:	
Volume Reduction	None
Rate Reduction	None
Water Quality	None

B. Design Requirements

1. Sizing and Configuration

   a. Bridges shall be designed to provide a 2-foot-minimum freeboard to the underside (low chord) of the bridge for a 100-year flood.

   b. Footings shall extend at least 4 feet below the bottom of the channel.

   c. Culverts serving a drainage area of less than 2 square miles shall be designed for the 10-year peak discharge in the developed watershed with a maximum outlet velocity of 8 feet per second. A maximum of 1 foot of inlet submergence may be permitted, if this does not back up water out of the easement.

   d. The effect of the 100-year storm shall be reviewed to ensure no adverse increase in water elevation off of the development property or flooding of structures within the development.

   e. Sizing of culverts and bridges shall be performed using the Bernouli Equation and include consideration of inlet and outlet control, entrance and exit losses, and tailwater condition. Published culvert nomographs and other computer software may be used.

   f. Minimum diameter of a drive culvert shall be 12 inches.

   g. Minimum diameter of a road crossing culvert shall be 18 inches or equivalent pipe arch.

2. End Treatment

   Headwalls, wingwalls, and all other end treatments shall be designed to ensure the stability of the surrounding soil. MDOT, County Road Commission, or manufacturer's designs may be used.

3. Materials

   Culverts may be reinforced concrete pipe, corrugated steel pipe, or pipe arch in accordance with MDOT Standard Specifications.

Open Channel

A. Summary

Description:	Storm water conveyance in an excavated channel
Types:	Ditch
Pretreatment Required:	No
Calculation Credits:	
Volume Reduction	None
Rate Reduction	None
Water Quality	None

B. Design Requirements

1. Sizing and Configuration

   a. The open channel shall be designed to convey the 10-year peak discharge with 1-foot of freeboard to top of bank.

   b. Open channel design velocities, capacities, and friction losses shall be based on Manning's equation:

$$Q = \frac{1.49 A R^{\frac{2}{3}} S^{\frac{1}{2}}}{n}$$

   where:
   Q = discharge (cubic feet per second)
   A = wetted area (square feet)
   R = hydraulic radius (feet)
   S = slope (feet per foot)
   n = Manning’s Coefficient

   c. Manning’s Coefficients shall be determined from ***Table 9***. A minimum Manning’s Coefficient of 0.035 shall be used for open channels, unless special treatment is given to the bottom and sides (riprap, paving, mown sod, etc.).

   d. Minimum bottom width shall be 2 feet.

   e. Minimum longitudinal slope shall be 0.10%.

   f. Side slopes shall be no steeper than 2:1 (horizontal to vertical).

   g. Open channel flow velocities shall be neither siltative nor erosive. The minimum velocity for open channels shall be 1.5 feet per second. The maximum velocity shall be 4 feet per second. Riprap protection or equivalent erosion control measures shall be used where the velocity exceeds 4 feet per second, up to maximum allowable design velocity of 10 feet per second.

2. Connections and Crossings

   a. Outlets into the open channel shall enter at an angle of 90 degrees or less with the direction of flow.

   b. A minimum clearance of 4 feet is required between open channel inverts and underground utilities unless special provisions are approved.

Detention Basins

A. Summary

Description:	Provides storm water storage with a surface outlet
Types:	Dry Basin; Underground Vault; Wet Pond; Constructed Wetland; Extended Detention
Pretreatment Required:	Yes
Calculation Credits:	
Volume Reduction	None
Rate Reduction	Calculated release rate
Water Quality	Dry Basin: None Underground Vaults: None Wet Pond: Count volume of permanent pool Constructed Wetland: Count volume of permanent pool Extended Detention: Count volume detained 24 hours

B. Sizing Calculations

1. Determine contributing site drainage area.

2. Calculate allowable release rate.

3. Determine a Rational Method weighted runoff coefficient, or select CNs for the developed site as outlined in "Calculating Runoff" (page 22).

4. Use the Rational Method spreadsheet, or the Green Calculator to calculate the required storage volumes for flood control as outlined in "Flood Control Using Detention Basins" (page 30).

5. Where stream protection and water quality treatment are provided through detention, these volumes may be included in the flood control volume.

6. If stream protection is to be provided as extended detention, calculate the required storage volume and release rate from ***Figure 5*** using a weighted CN for the developed site as outlined in "Stream Protection using Extended Detention" (page 29). Extended detention can be included as the first stage of a two-stage detention basin.

7. If extended detention is used, water quality standards are also met. Otherwise, water quality standards can met through a permanent pool, or underdrain (i.e. gravel filter) in the bottom of a dry detention basin. Determine water quality volume using equation given in "Calculating Storage Volumes and Release Rates" (page 32).

8. Size forebay(s) for pre-treatment using equation given in "Calculating Storage Volumes and Release Rates" (page 32).

Detention Basins (continued)

C. Design Requirements

1. Siting

   a. Soil borings are required as outlined in "Soils Investigation" (page 18).

      (1) A minimum of 2 feet is required between the bottom of dry detention basins and the highest known groundwater elevation.

      (2) Wet ponds and constructed wetlands shall have a reliable supply of baseflow or groundwater to support a permanent pool.

      (3) Wet ponds and constructed wetlands proposed in HSG A and HSG B soils above the groundwater table shall have a clay or synthetic liner to minimize infiltration.

2. Sizing and Configuration

   a. General

      (1) Distances of flow paths between inlets and outlets shall be maximized. A minimum basin length-to-width ratio of 3 to 1 is required.

      (2) If site constraints preclude placing pipes at opposite ends of the basin or meeting the length-to-width ratio, baffles may be used to lengthen the flow path.

      (3) Where steeper side slopes than those specified are unavoidable, safety railing, fencing or other access barriers may be approved.

   b. Dry Basin

      (1) The design high water depth should generally not exceed 10 feet above the bottom of the basin.

      (2) Side slopes shall not be steeper than 3:1 (H:V). Where basins are to be maintained as a mown lawn, the City may require side slopes no steeper than 4:1 (H:V) to facilitate mowing.

      (3) The bottom of dry detention basins shall be graded to provide positive flow to the pipe outlet. A minimum flow line bottom slope of 1% should be provided. Cross slopes should be 2% minimum. If continuous flow is anticipated, a low-flow channel shall be provided, with necessary crossings, and sloped to eliminate standing water. If site grades prohibit achieving these minimum slopes, the City may approve the use of an underdrain with flatter slopes.

Detention Basins (continued)

c. Wet Pond

(1) At a minimum, the volume of the permanent pool for wet ponds shall be 2.5 times the water quality treatment volume to account for reduced settling efficiency due to turbulence caused by wind.

(2) Wet ponds shall generally be wedge-shaped with inflow at the narrow end to prevent short-circuiting and stagnation. However, other shapes meeting the design intent may be approved.

(3) Permanent pools shall have a minimum depth of 3 feet across the deepest part of the basin to discourage aquatic plant infill and provide open water.

(4) The design high water depth should generally not exceed 10 feet above the permanent pool elevation.

(5) Side slopes shall not be steeper than 3:1 (H:V). Where basins are to be maintained as a mown lawn to the water's edge, the City may require side slopes no steeper than 4:1 (H:V) to facilitate mowing.

(6) Permanent pools deeper than 4 feet shall have two safety ledges each between 6 and 8 feet wide. One shall start at the normal water surface and extend up to the pond side slopes at a maximum slope of 15%. The other shall extend from the water surface into the pond to a depth of 12 inches at a slope of 15%.

(7) Warning signs prohibiting swimming and skating shall be posted for wet ponds.

d. Constructed Wetland

(1) The emergent vegetation zone shall comprise 60 to 65% of the total surface area. Half shall be high marsh with a normal water depth of 6-inches or less, and half shall be low marsh with a normal water depth between 6 and 18 inches.

(2) The open water zone shall comprise 35 to 40% of the total surface area with a normal water depth of between 18 inches and 6 feet.

(3) At a minimum, the volume of the permanent pool for the open water zone shall be 2.5 times the water quality treatment volume to account for reduced settling efficiency due to turbulence caused by wind.

(4) The 2-year water surface elevation shall not exceed the normal water surface elevation by more than 3 feet.

(5) Side slopes shall not be steeper than 3:1 (H:V).

(6) Open water deeper than 4 feet shall have two safety ledges each between 4 and 6 feet wide. One shall be situated 12 to 18 inches above the normal water surface and the other 24 to 30 inches below the water surface.

Detention Basins (continued)

(7) A micro pool shall be located at the outlet of the storm water wetland to protect the low flow pipe from clogging and prevent sediment resuspension. The micro pool shall be 3 to 6 foot deep and have a minimum surface area equivalent to the forebay.

3. Inlet Design

   a. Inlet pipes shall not be fully submerged at normal pool elevations.

   b. Inlet pipes shall require energy dissipation. Riprap protection or equivalent erosion control measures shall be used where the velocity exceeds 4 feet per second, up to maximum allowable design velocity of 10 feet per second.

   c. Pre-treatment is required for each inlet, unless the inlet supplies less than 10% of the total design flow to the detention basin.

   d. Pretreatment can be provided in a sediment forebay or spill containment cell located within the detention basin, or through a water quality device located prior to the basin. Pre-treatment for overland sheet flow entering the basin can be provided through a vegetated filter strip.

   e. When spill containment is required and a spill containment cell is used, all pipes contributing runoff from the high risk area must enter this cell for pre-treatment.

4. Outlet Design

   a. The outlet may be designed using the orifice equation, rearranged to solve for area.

$$A = \frac{Q}{c\sqrt{2gH}}$$

where:
A = required area (square feet)
Q = required outflow (cubic feet per second)
c = orifice coefficient (approximately 0.6)
2g = two times the gravitation constant (g = 32.2 feet per second)
H = height of design high water level above center of orifice outlet (feet)

   b. Other types of outlet devices shall have full design calculations provided for review.

   c. The outlet shall be designed to prevent clogging.

   d. Pipes or orifice plates shall have a minimum diameter of 4 inches.

   e. Orifices used to maintain a permanent pool shall be designed to withdraw water a minimum of 2 feet below the normal water surface.

   f. Riser pipes with holes or slits less than 4 inches in diameter shall have a stone and gravel filter placed around the outside of the pipe.

   g. Hoods and trash racks shall be placed on riser pipes. Grate openings shall be a maximum of 3 inches on center.

   h. Riser pipes shall have a minimum diameter of 24 inches. Riser pipes greater than 4 feet in height shall be 48 inches in diameter.

Detention Basins (continued)

i. Riser pipes shall be constructed of reinforced concrete or corrugated metal and be set in a concrete base. Plastic is not acceptable as a riser material.

j. Outlet control structures shall be placed near or within the embankment to facilitate maintenance access.

k. Outlet pipes shall require energy dissipation. Riprap protection or equivalent erosion control measures shall be used where the velocity exceeds 4 feet per second, up to maximum allowable design velocity of 8 feet per second.

l. A drain for completely dewatering the detention basin shall be installed for maintenance purposes.

m. Pipes placed through embankments shall have anti-seep collars.

5. Emergency Overflow

   a. All detention facilities must have a provision for overflow at the high water level. A spillway shall be designed for the 10-year inflow with a maximum flow depth of 1 foot. The spillway shall be sized using the weir equation.

$$Q = 2.6LH^{\frac{3}{2}}$$

where:
Q = discharge (cubic feet per second)
2.6 = coefficient of discharge
L = length of spillway crest (feet)
H = total head measured above spillway crest (feet)

   b. The top of berm elevation shall be a minimum of 18 inches above the crest of the spillway to allow for at least 6-inches of freeboard between the overflow spillway water elevation and the top of berm.

   c. Overflow spillways shall be protected with concrete, riprap or a permanent erosion control blanket to prevent erosion of the structure.

6. Access

   a. Berm top width shall be a minimum of 16 feet.

   b. A minimum 12-foot wide maintenance access route from a public or private right-of-way shall be provided to the basin. The access way shall have a slope of no greater than 5:1 (H:V) and shall be stabilized to withstand the passage of heavy equipment. Direct access to the forebay, control structures and the outlet shall be provided.

7. Landscaping

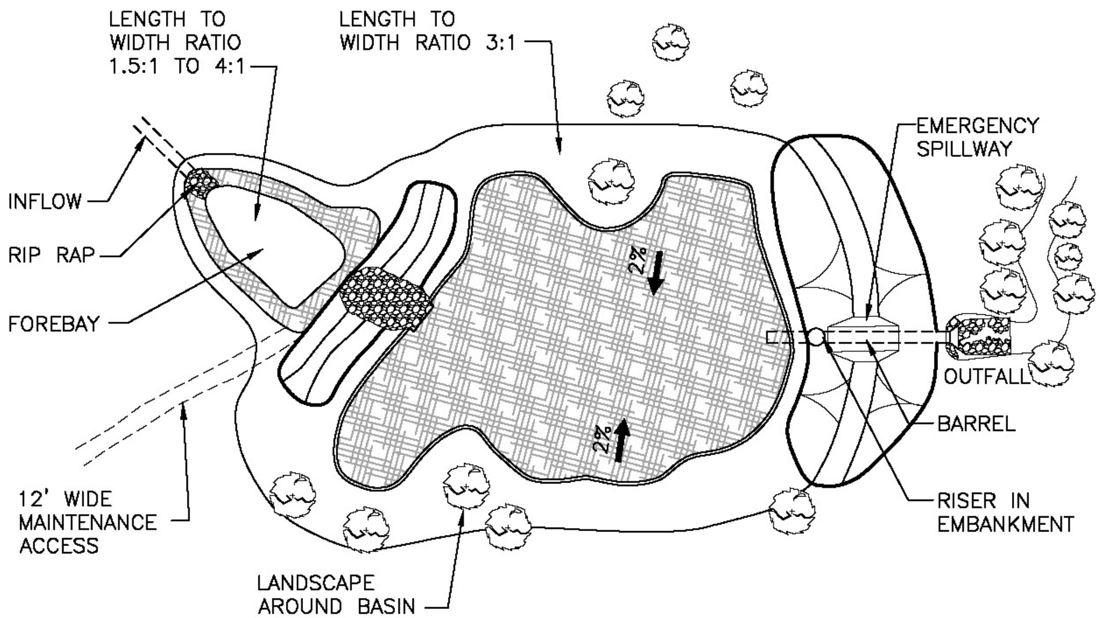
   a. A landscaping plan shall be submitted concurrent with construction drawing submittal.

   b. The plan shall show the location, type and size of all landscaping.

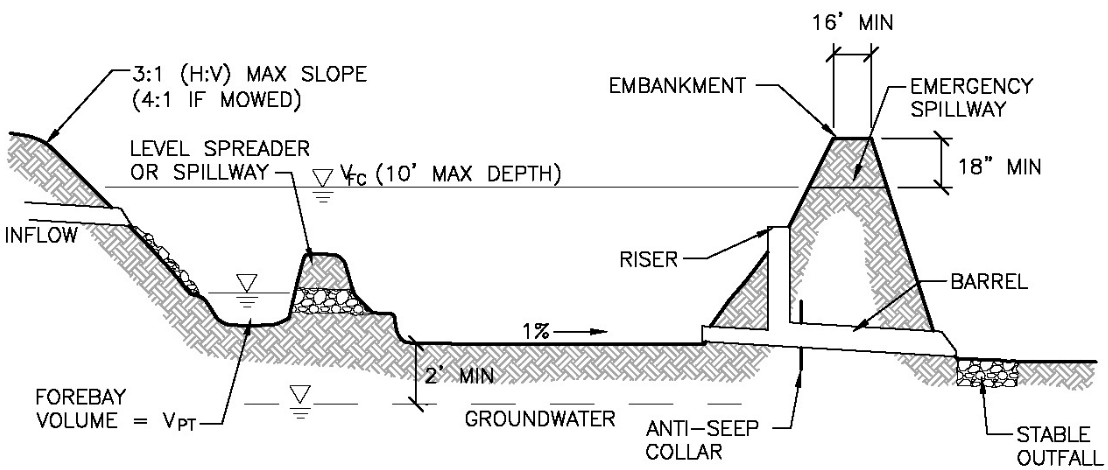
   c. The plan shall indicate the intended look for the basin (i.e. manicured, natural).

D. Design Schematics

DRY DETENTION BASIN



PLAN VIEW

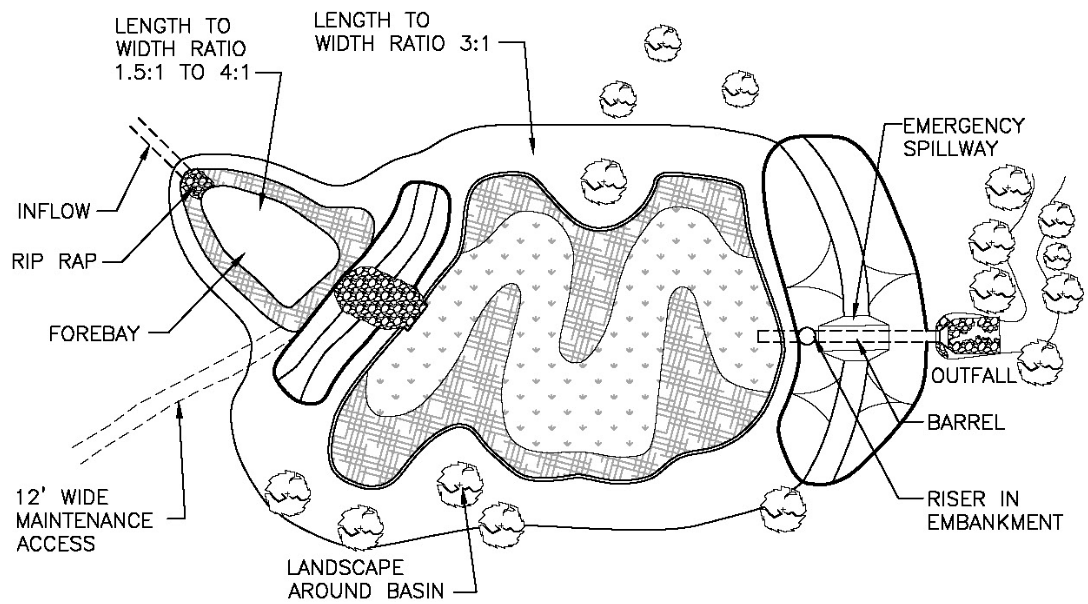


PROFILE

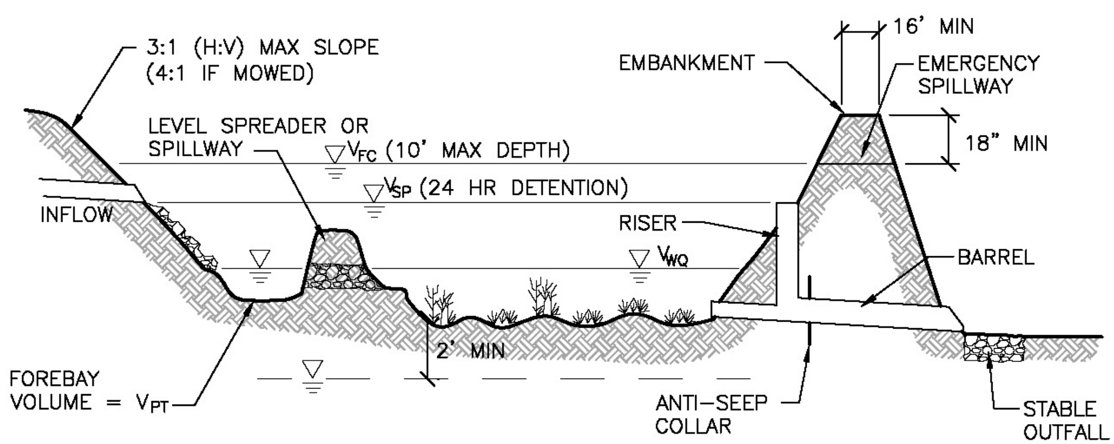
DRY DETENTION BASIN MUST BE COMBINED WITH OTHER BMP'S TO MEET WATER QUALITY VOLUME CRITERIA.

FINAL OUTLET CONFIGURATION MUST BE DESIGNED TO PREVENT CLOGGING

EXTENDED DRY DETENTION BASIN



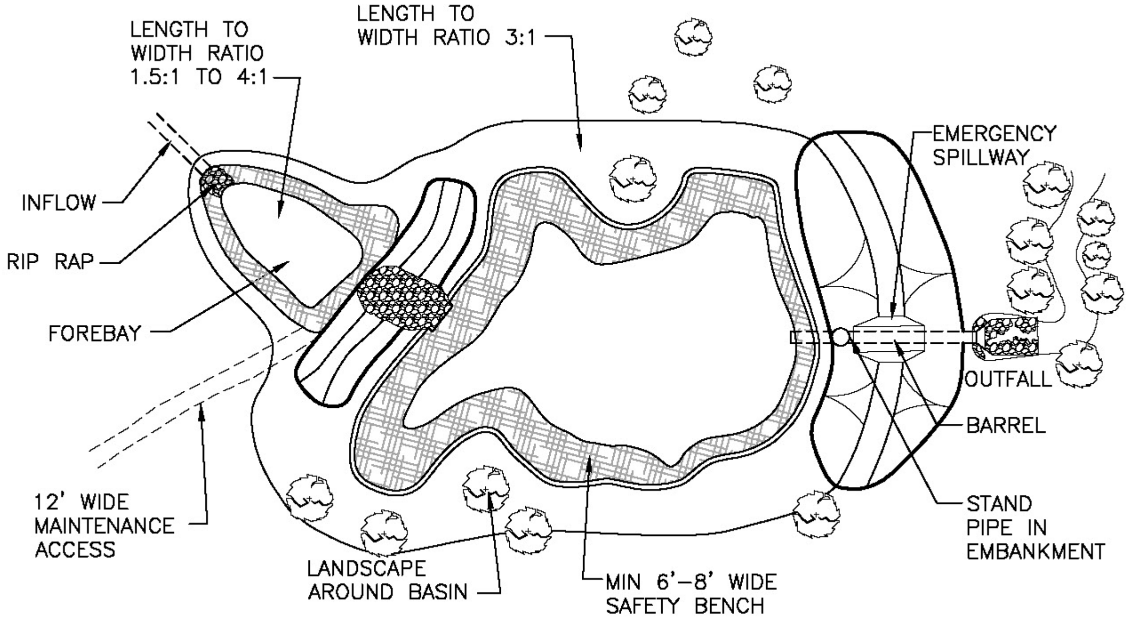
PLAN VIEW



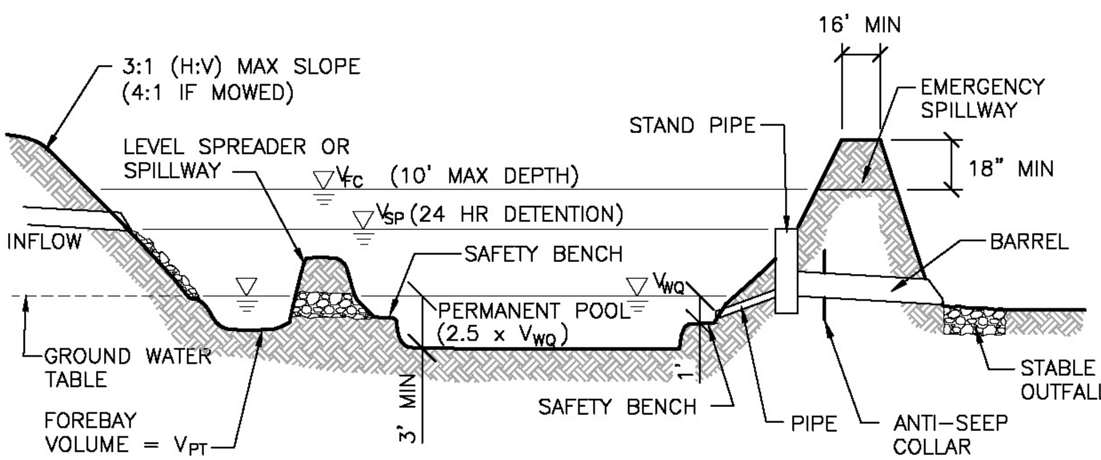
PROFILE

FINAL OUTLET CONFIGURATION MUST BE DESIGNED TO PREVENT CLOGGING

WET DETENTION BASIN (WET POND)



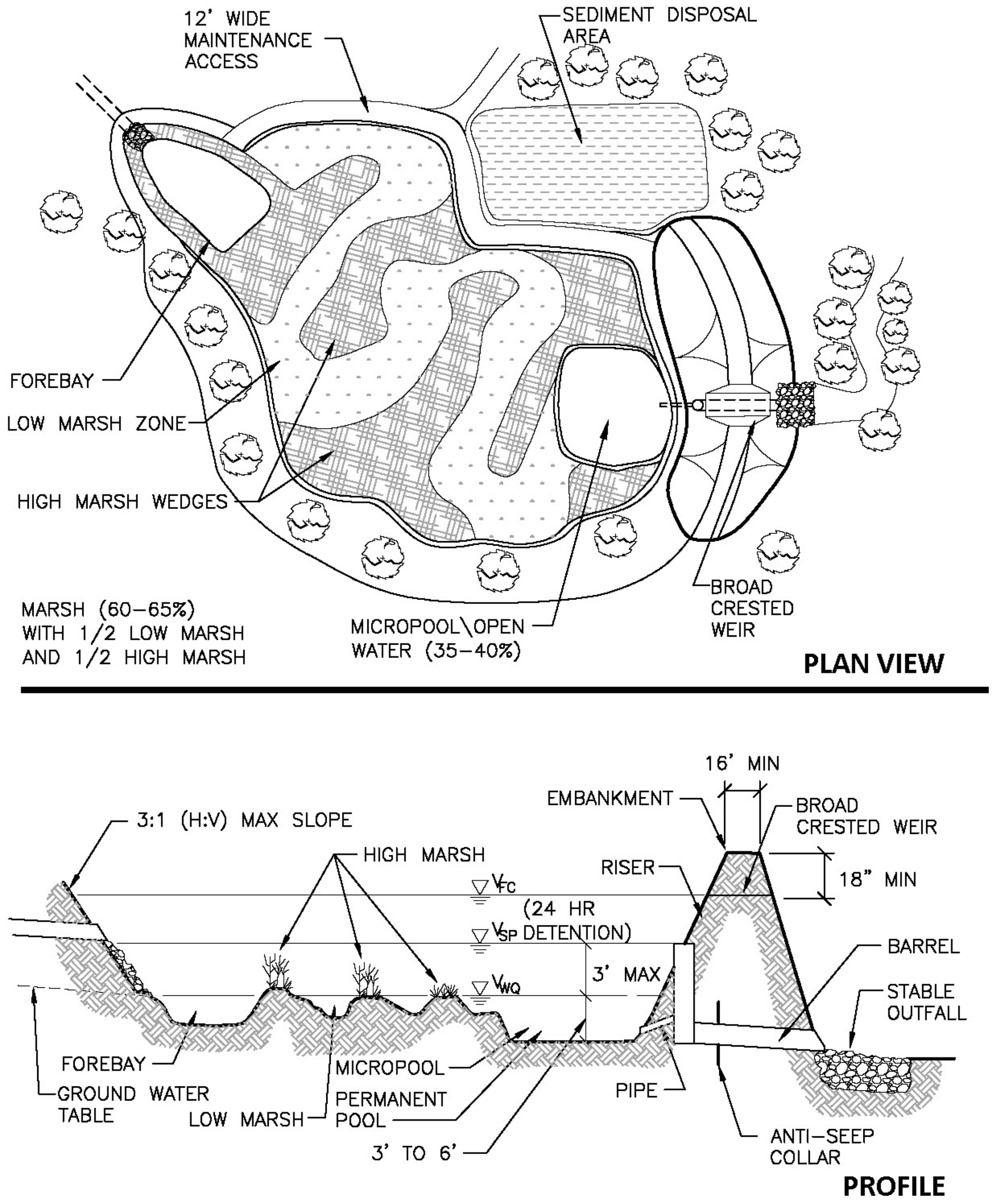
PLAN VIEW



PROFILE

FINAL OUTLET CONFIGURATION MUST BE DESIGNED TO PREVENT CLOGGING

CONSTRUCTED WETLAND



FINAL OUTLET CONFIGURATION MUST BE DESIGNED TO PREVENT CLOGGING

Retention Basins

A. Summary

Description:	Provides storm water storage without a surface outlet
Types:	Dry Basin; Wet Pond
Pretreatment Required:	Yes
Calculation Credits:	
Volume Reduction	Count volume stored and infiltrated
Rate Reduction	Designed for flood control: 100%
Water Quality	Count volume stored and infiltrated

B. Sizing Calculations

1. Determine contributing site drainage area.

2. Use the Rational Method spreadsheet, or the Green Calculator to calculate the required storage volumes for flood control as outlined in "Flood Control Using Retention Basins" (page 31).

3. Calculate the minimum infiltration area required to drain the required storage volume in the specified drawdown time using the design infiltration rate of the underlying soil.

$$A = [V_s / (i \times t_d)] \times 12$$

where:
A = minimum infiltration area (square feet)
V_s = storage volume (cubic feet)
i = design infiltration rate of soil (inches per hour) from ***Table 5***
t_d = maximum allowable drawdown time (hours)
12 = factor to convert inches to feet

4. Drawdown time shall be no more than 72 hours.

5. The infiltration area shall be defined as the bottom of the basin.

6. Stream protection and water quality volumes may be included in the flood control volume.

7. Size forebay(s) for pre-treatment using equation given in "Calculating Storage Volumes and Release Rates" (page 32).

C. Design Requirements

1. Siting

   a. Soil borings are required as outlined in "Soils Investigation" (page 18).

      (1) A minimum of 4 feet is required between the bottom of dry retention basins and the highest known groundwater elevation.

2. Sizing and Configuration

   a. General

      (1) For retention basins that utilize a natural or manmade depression with an existing permanent water level, the infiltration area shall be defined as the horizontal projection of the side slopes above the permanent water elevation.

      (2) Where steeper side slopes than those specified are unavoidable, safety railing, fencing or other access barriers may be approved.

   b. Dry Basin

      (1) The design high water depth should generally not exceed 10 feet above the bottom of the basin.

      (2) Side slopes shall not be steeper than 3:1 (H:V). Where basins are to be maintained as a mown lawn, the City may require side slopes no steeper than 4:1 (H:V) to facilitate mowing.

      (3) The bottom of dry retention basins shall be flat to encourage uniform ponding and infiltration.

      (4) The bottom of dry retention basins shall be scarified to a depth of 4 to 6 inches after final grading has been established.

      (5) Care must be taken during the excavation and finishing process to make sure that soil compaction does not occur.

   c. Wet Pond (no surface water outlet)

      (1) The design high water depth should generally not exceed 10 feet above the permanent pool elevation.

      (2) Where excavation and reshaping of the retention area is necessary, side slopes shall not be steeper than 3:1 (H:V). Where basins are to be maintained as a mown lawn to the water's edge, the City may require side slopes no steeper than 4:1 (H:V) to facilitate mowing.

      (3) Where excavation and reshaping of the retention area is necessary, permanent pools deeper than 4 feet shall have two safety ledges each between 6 and 8 feet wide. One shall start at the normal water surface and extend up to the pond side slopes at a maximum slope of 15%. The other shall extend from the water surface into the pond to a depth of 12 inches at a slope of 15%.

Retention Basins (continued)

3. Inlet Design
   a. Inlet pipes shall not be fully submerged at normal pool elevations.
   b. Inlet pipes shall require energy dissipation. Riprap protection or equivalent erosion control measures shall be used where the velocity exceeds 4 feet per second, up to maximum allowable design velocity of 10 feet per second.
   c. Pre-treatment is required for each inlet and can be provided in a sediment forebay or spill containment cell located within the retention basin, or through a water quality device located prior to the basin. Pre-treatment for overland sheet flow entering the basin can be provided through a vegetated filter strip.
   d. When spill containment is required and a spill containment cell is used, all pipes contributing runoff from the high risk area must enter this cell for pre-treatment.
4. Emergency Overflow
   a. All retention basins must have a provision for overflow at the high water level. A spillway shall be designed for the 10-year inflow with a maximum flow depth of 1 foot. The spillway shall be sized using the weir equation.

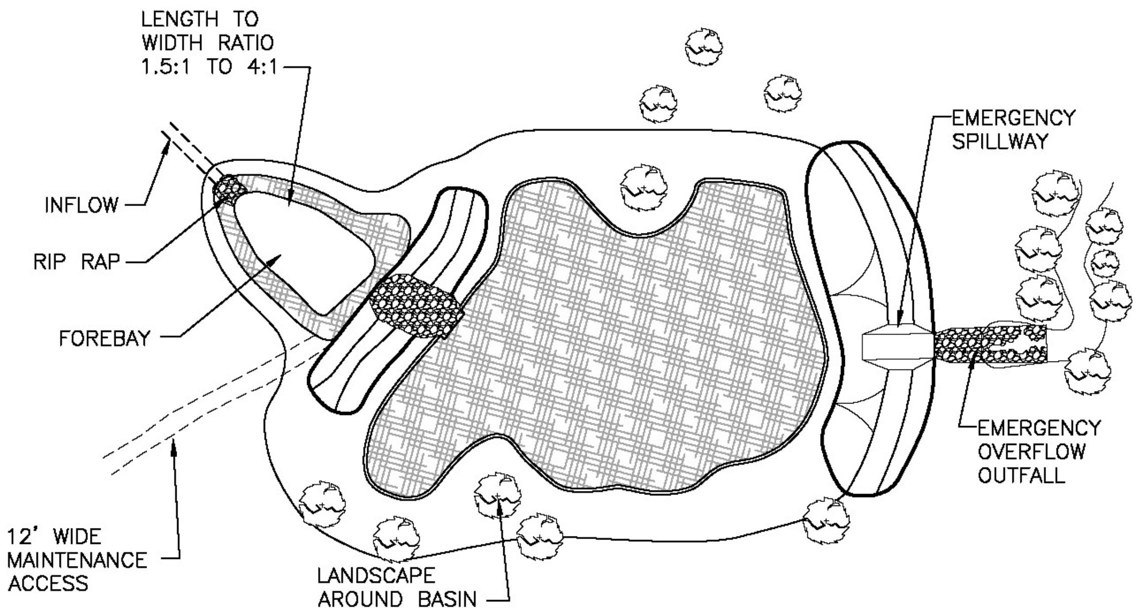
$$Q = 2.6LH^{\frac{3}{2}}$$

   where:
   Q = discharge (cubic feet per second)
   2.6 = coefficient of discharge
   L = length of spillway crest (feet)
   H = total head measured above spillway crest (feet)

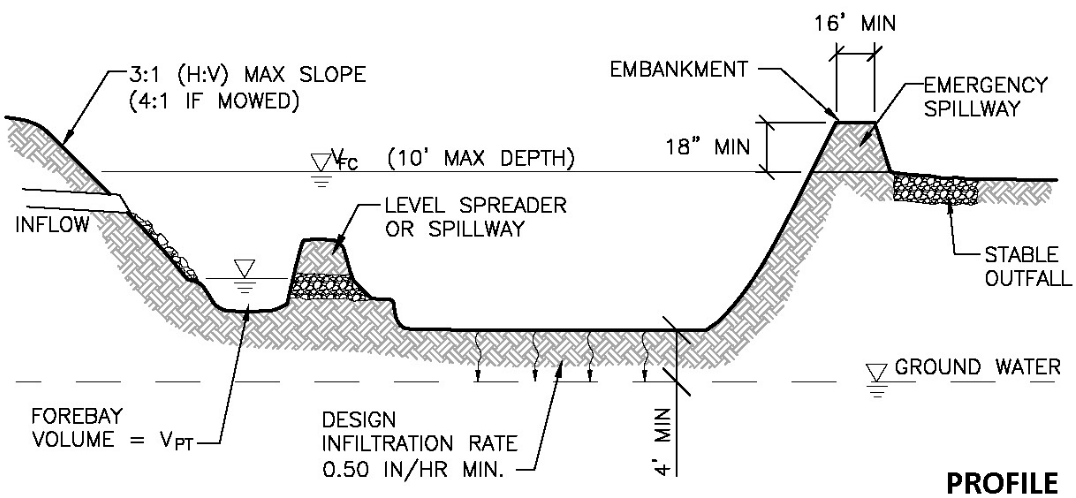
   b. The top of berm elevation shall be a minimum of 18 inches above the design high water level to allow for at least 6-inches of freeboard between the overflow spillway water elevation and the top of berm.
   c. Overflow spillways shall be protected with concrete, riprap or a permanent erosion control blanket to prevent erosion of the structure.
   d. Infiltration basins without an acceptable surface water overflow route shall be designed for 1.5 times the required flood control volume.
5. Access
   a. Berm top width shall be a minimum of 16 feet.
   b. A minimum 12-foot wide maintenance access route from a public or private right-of-way shall be provided to the basin. The access way shall have a slope of no greater than 5:1 (H:V) and shall be stabilized to withstand the passage of heavy equipment. Direct access to the forebay, control structures and the outlet shall be provided.
6. Landscaping
   a. A landscaping plan shall be submitted concurrent with construction drawings.
   b. The plan shall show the location, type and size of all landscaping.
   c. The plan shall indicate the intended look for the basin (i.e. manicured, natural).

D. Design Schematics

DRY RETENTION BASIN



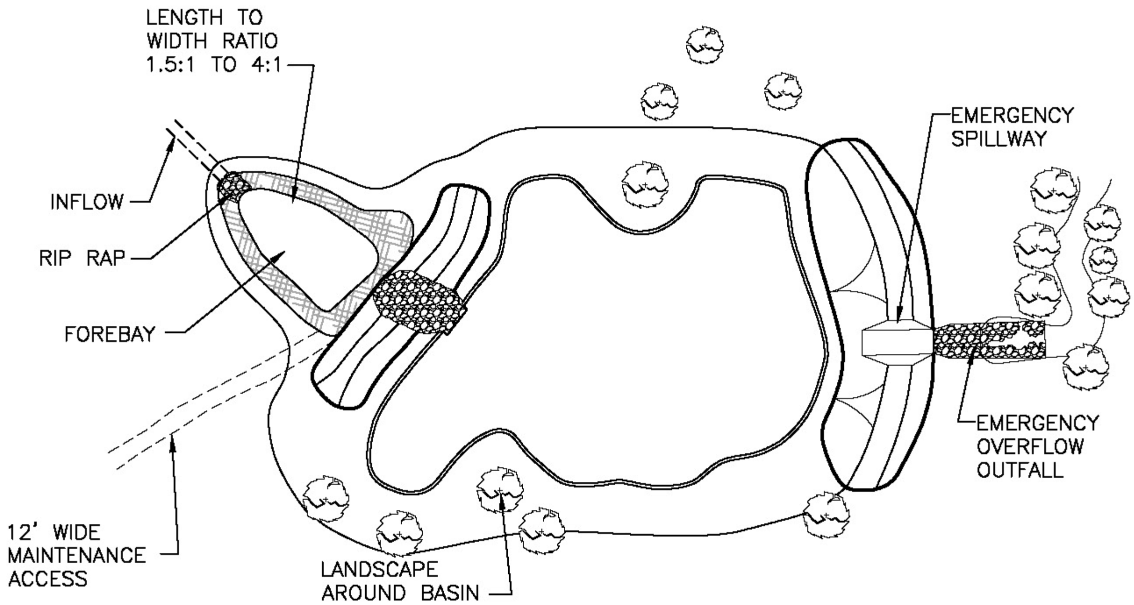
PLAN VIEW



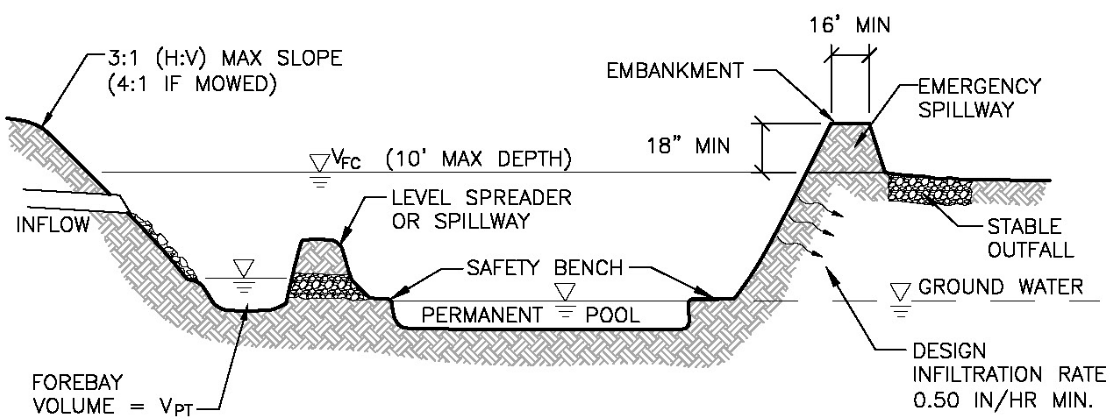
PROFILE

FINAL OUTLET CONFIGURATION MUST BE DESIGNED TO PREVENT CLOGGING

WET RETENTION BASIN



PLAN VIEW



PROFILE

FINAL OUTLET CONFIGURATION MUST BE DESIGNED TO PREVENT CLOGGING

Infiltration Practices

A. Summary

Description:	Storm water treatment and storage without a surface outlet
Types:	Dry Well; Leaching Basin; Infiltration Trench; Infiltration Bed; Infiltration Berm
Pretreatment Required:	Yes
Calculation Credits:	
Volume Reduction	Count volume stored and infiltrated
Rate Reduction	Designed for flood control: 100% Designed for stream protection and/or water quality treatment: Adjust time-of-concentration by dividing storage volume by 10-year peak flow rate; BMP routing using computer software
Water Quality	Count volume stored and infiltrated

B. Sizing Calculations

1. If the infiltration practice is to be sized for stream protection or water quality, use the methods outlined in "Calculating Storage Volumes and Release Rates" (page 28) to calculate the required volumes.

   a. Subtract the volume infiltrated by the BMP during the infiltration period to determine the required storage volume of the BMP. The infiltration volume is calculated as:

      Maximum Allowable Infiltration Rate (inches per hour) x 6 hours x Infiltration Area (square feet) x 1/12 unit conversion

   b. The maximum allowable soil infiltration rate used to size the storage volume of the BMP shall be 0.52 inches per hour, except that 1.04 inches per hour may be used where soil borings indicate clean sand or gravel free of any other soil seams.

   c. The infiltration period is the time when the bed is receiving runoff and is capable of infiltrating at the design rate, which is conservatively estimated as 6 hours.

2. If the infiltration practice is to be sized for flood control, use one of the methods outlined in "Flood Control Using Retention Basins" (page 31) to calculate the required storage volume.

3. Stream protection and water quality volumes may be included in the flood control volume.

Infiltration Practices (continued)

4. Calculate the minimum infiltration area required to drain the required storage volume in the specified drawdown time using the design infiltration rate of the underlying soil.

$$A = [V_s / (i \times t_d)] \times 12$$

where:
A = minimum infiltration area (square feet)
V_s = storage volume (cubic feet)
i = design infiltration rate of soil (inches per hour) from ***Table 5***
t_d = maximum allowable drawdown time (hours)
12 = factor to convert inches to feet

5. Total drawdown time shall be no more than 72 hours. Depth of surface ponding shall be no more than 2 feet and drain within 24 hours.

6. Infiltration area shall be defined as:

   a. Dry Well/Leaching Basin: Bottom and sides (lateral)
   b. Infiltration Trench: Bottom of trench (length x width)
   c. Infiltration Bed: Bottom area of the bed
   d. Infiltration Berm: Ponding area (length of berm x average width of ponding behind berm)

7. Calculate the storage volume of the BMP.

   a. Dry wells, infiltration trenches, infiltration beds:

      Subsurface Storage Volume (cubic feet) = Length (feet) x Width (feet) x Depth (feet) x Void Ratio of Material

      Where perforated pipe is used in the trench or infiltration bed design, the formula is modified:

      Subsurface Storage Volume (cubic feet) = Volume of Pipe (cubic feet) + [Length (feet) x Width (feet) x Depth (feet) – Volume of Pipe (cubic feet)] x Void Ratio of Material

   b. Leaching basins:

      Storage Volume (cubic feet) = $2\,\Pi r^2$ *(square feet) x Depth (feet)*

      where:
      r = radius of leaching basin (feet)
      Π = *pi* (approximately 3.14)

      Volume of storage in stone envelope around leaching basin may also be counted.

   c. Infiltration berm:

      Surface Storage Volume (cubic feet) = Average Ponding Area (square feet) x Design High Water Depth (feet)

Infiltration Practices (continued)

C. Design Requirements

1. Siting

   a. Soil borings are required as outlined in "Soils Investigation" (page 18).

      (1) A minimum of 4 feet is required between the bottom of infiltration practices and the highest known groundwater elevation.

      (2) Void ratio for the imported material shall be based on the USDA soil textural class and effective water capacity in ***Table 5***. A maximum design value of 0.40 shall be used for the void ratio of stone.

   b. Infiltration practices shall be located outside of the drip line of adjacent trees.

2. Sizing and Configuration

   a. General

      (1) A combination of surface and subsurface storage may be used to provide the required storage volume.

   b. Dry wells, infiltration trenches and infiltration beds

      (1) Infiltration trench width shall generally be as follows: 3-foot minimum to 6-foot maximum.

      (2) Course aggregates shall be uniformly graded, washed and wrapped in a non-woven geotextile to provide separation between the aggregate and the surrounding soil and prevent fines from clogging the infiltration surface.

      (3) An observation well shall be provided for each dry well, at each end of an infiltration trench, and at each corner of an infiltration bed with intermediate center wells added so as not to exceed maximum distance of 50 feet between wells.

      (4) Perforated pipes laid flat may be used to distribute runoff over the bottom of infiltration trenches and infiltration beds.

      (5) Cleanouts shall be provided at pipe ends.

      (6) Care must be taken during the excavation and finishing process to make sure that soil compaction does not occur.

c. Leaching Basins (perforated catchbasins)

(1) Leaching basins shall have a minimum diameter of 4 feet with a maximum spacing of 400 feet between basins.

(2) Leaching basins shall have an open bottom and perforations around the circumference of the structure at no greater than 12-inch intervals horizontally and vertically the entire depth of the sump.

(3) Bedding and backfill shall consist of clean stone with nonwoven geotextile fabric placed along the walls of the trench and wrapped around the stone and the basin.

d. Infiltration Berms

(1) Infiltration berms shall be constructed along (parallel to) contours at a constant level elevation.

(2) Maximum berm height shall be 2 feet to prevent excessive ponding behind berm.

(3) Berm top width shall be a minimum of 16 feet.

(4) Side slopes shall not be steeper than 4:1 (H:V) to facilitate mowing and ensure stable side slopes.

(5) Well compacted cohesive soil shall be used to construct the berm.

(6) The berm shall be well vegetated to prevent erosion if overtopped.

6. Inlet Design

   a. Pre-treatment is required for each inlet and for overland flow entering the infiltration practice. Exceptions will be allowed for paved drainage areas contributing directly to a leaching basin.

7. Emergency Overflow

   a. All infiltration practices must have a provision for overflow at the high water level.

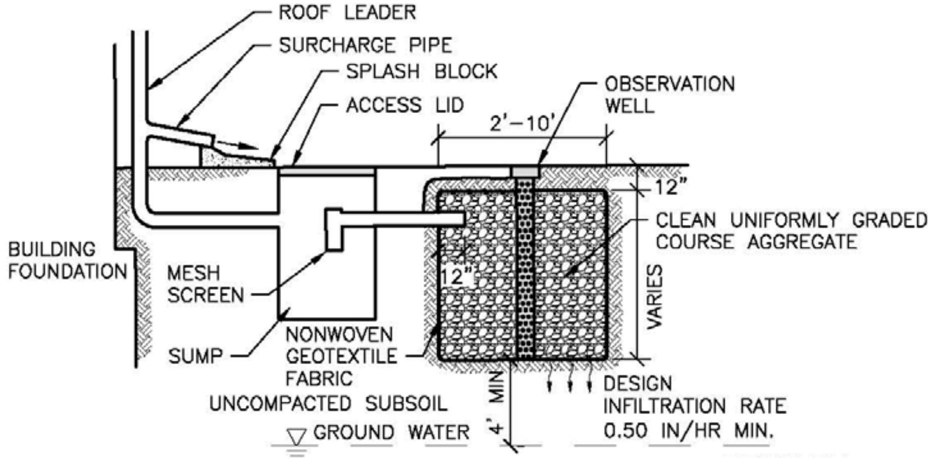
   b. Infiltration practices without an acceptable surface water overflow route shall be designed for 1.5 times the required flood control volume.

8. Access

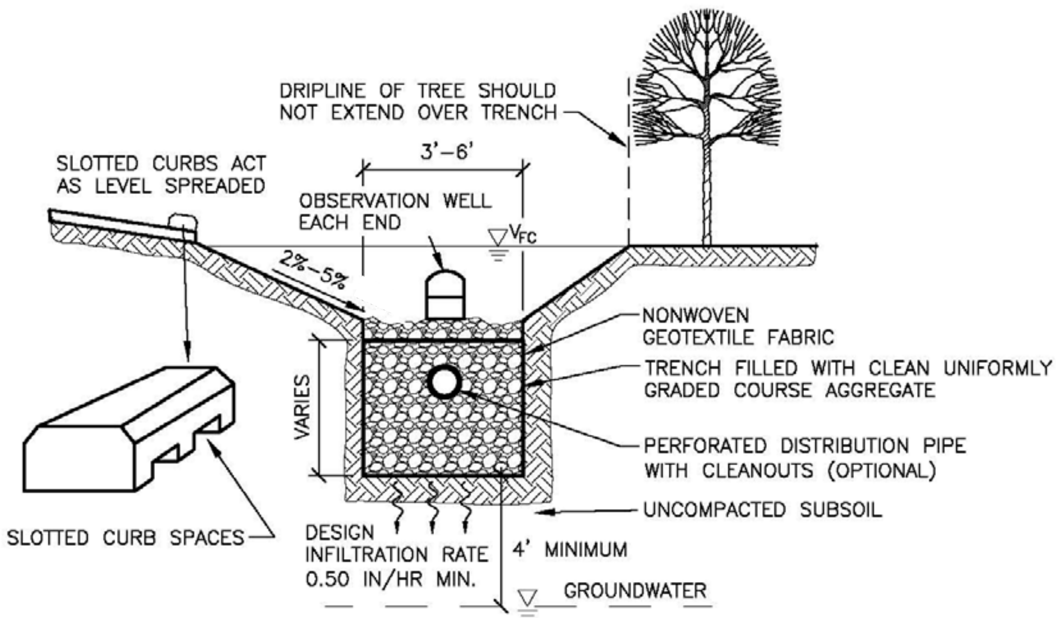
   a. Inspection and maintenance access to the infiltration practice shall be provided.

D. Design Schematics

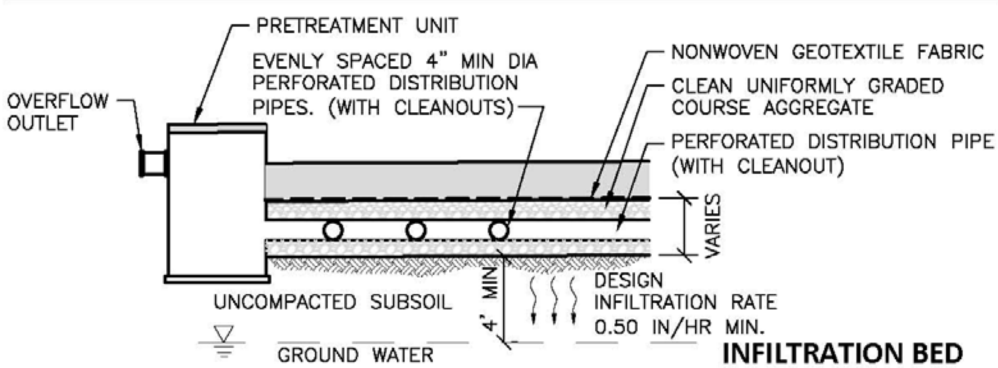
INFILTRATION PRACTICES



DRY WELL

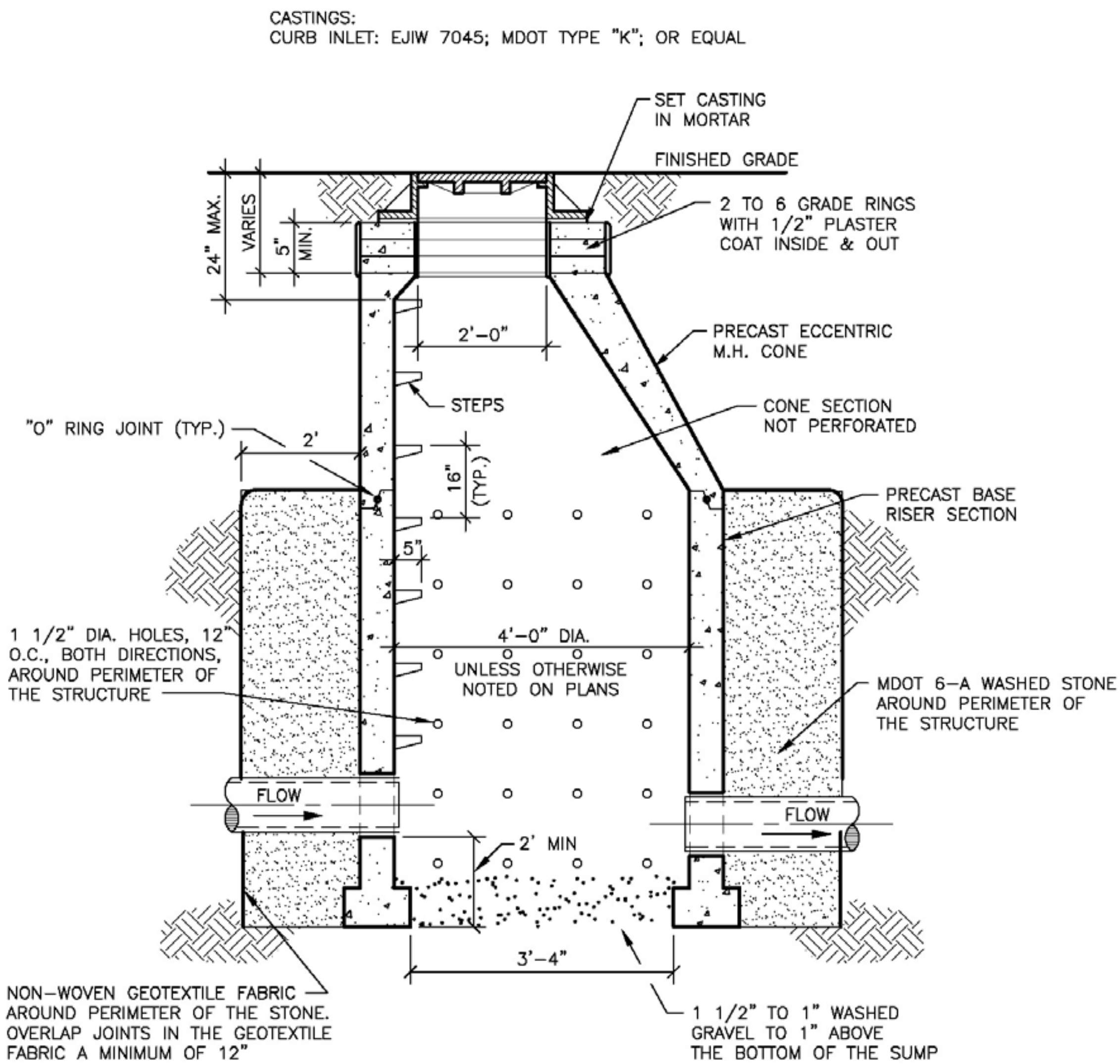


INFILTRATION TRENCH



INFILTRATION BED

STANDARD LEACHING BASIN



Bioretention / Rain Garden

A. *Summary*

Description:	Provides storm water treatment, storage and uptake with or without a surface outlet; Underdrained BMP may be allowed on small sites in lieu of extended detention
Types:	Bioretention: Natural-looking herbacious Rain garden: Landscaped and manicured Infiltration; Underdrain at top of storage layer; Underdrain at bottom of storage layer; Lined
Pretreatment Required:	Yes
Calculation Credits:	
Volume Reduction	Infiltration: Count volume stored and infiltrated Underdrained: Count volume stored and infiltrated between bottom of BMP and invert of underdrain
Rate Reduction	Adjust time-of-concentration by dividing storage volume by 10-year peak flow rate; BMP routing using computer software
Water Quality	Count total volume stored and infiltrated/filtered

B. *Sizing Calculations*

1. For underdrained BMP, follow criteria for "Constructed Filter."

2. Bioretention / rain gardens may be sized for stream protection or water quality treatment. Use the methods outlined in "Calculating Storage Volumes and Release Rates" (page 28) to calculate the required volumes.

   a. Subtract the volume infiltrated by the BMP during the infiltration period to determine the required storage volume of the BMP. The infiltration volume is calculated as:

      Maximum Allowable Infiltration Rate (inches per hour) x 6 hours x Infiltration Area (square feet) x 1/12 unit conversion

   b. The maximum allowable soil infiltration rate used to size the storage volume of the BMP shall be 0.52 inches per hour, except that 1.04 inches per hour may be used where soil borings indicate sand or gravel free of any other soil seams.

   c. The infiltration period is the time when the bed is receiving runoff and is capable of infiltrating at the design rate, which is conservatively estimated as 6 hours.

3. Bioretention / rain gardens may be able to provide flood control on small sites. Use one of the methods outlined in "Flood Control Using Retention Basins" (page 31) to calculate the required storage volume.

4. Calculate the minimum infiltration area required to drain the required storage volume in the specified drawdown time using the design infiltration rate of the underlying soil.

$$A = [V_s / (i \times t_d)] \times 12$$

where:
A = minimum infiltration area (square feet)
V_s = storage volume (cubic feet)
i = design infiltration rate of soil (inches per hour) from ***Table 5***
t_d = maximum allowable drawdown time (hours)
12 = factor to convert inches to feet

5. Total drawdown time shall be no more than 72 hours. Depth of surface ponding shall be no more than 9 inches and drain within 24 hours.

6. Surface ponding depth may be increased up to 18 inches for bioretention areas.

7. The bottom area of the BMP shall be used as the infiltration area.

8. Calculate the storage volume of the BMP.

   Average Bed Area (square feet) = [Area at Design High Water Depth (square feet) + Bottom Area (square feet)] / 2

   Surface Storage Volume (cubic feet) = Average Bed Area (square feet) x Design High Water Depth (feet)

   Subsurface Storage Volume (cubic feet) = Length (feet) x Width (feet) x Depth (feet) x Void Ratio of Material

   Total Storage Volume (cubic feet) = Surface Storage Volume (cubic feet) + Subsurface Storage Volume (cubic feet)

C. Design Requirements

1. Siting

   a. Soil borings are required as outlined in "Soils Investigation" (page 18).

      (1) A minimum of 4 feet is required between the bottom of bioretention / rain gardens capable of infiltration and the highest known groundwater elevation.

      (2) A minimum of 2 feet is required between the bottom of lined or underdrained bioretention / rain gardens and the highest known groundwater elevation.

Bioretention / Rain Garden (continued)

(3) An underdrain shall be provided for design infiltration rates of the underlying native soil less than 0.50 inches per hour, or if bioretention / rain garden will be lined.

(4) Void ratio for the amended soil material shall be based on the USDA soil textural class and effective water capacity in ***Table 5***. A maximum design value of 0.30 shall be used for the void ratio of the amended soil material. A maximum design value of 0.40 shall be used for the void ratio of stone.

2. Sizing and Configuration

   a. General

      (1) The bottom shall be flat to encourage uniform ponding and infiltration.

      (2) Minimum bottom width shall be 3 feet.

      (3) Bioretention / rain gardens located in areas with steep slopes shall be terraced to minimize earth disturbance and maximize infiltration area.

      (4) Care must be taken during the excavation and finishing process to make sure that soil compaction does not occur.

      (5) Bioretention / rain gardens located in areas of existing soil contamination shall be lined to prevent infiltration.

      (6) Underdrains shall have a 4-inch minimum pipe diameter.

      (7) All underground pipes shall have clean-outs accessible from the surface.

      (8) Pipe slopes shall have a minimum slope of 1%.

      (9) Side slopes shall not be steeper than 3:1 (H:V), unless landscape retaining walls are used.

      (10) An observation well shall be provided for each bioretention / rain garden.

   b. Rain gardens

      (1) A landscaping plan shall be submitted concurrent with construction drawing submittal.

3. Inlet Design

   a. Inlet pipes shall require energy dissipation. Riprap protection or equivalent erosion control measures shall be used where the velocity exceeds 4 feet per second, up to maximum allowable design velocity of 10 feet per second.

   b. Pre-treatment is required for each inlet and for overland flow entering the bioretention / rain garden.

4. Emergency Overflow

   a. All bioretention / rain gardens must have a provision for overflow at the high water level.

Bioretention / Rain Garden (continued)

5. Materials

   a. Amended soil material shall consist of 18 to 48 inches of the following materials, evenly mixed: Compost: 30-50%; Sand: 20-40%; Topsoil: 20-30% (maximum clay content of topsoil shall be 20%).

      (1) Alternative mix designs with ratios outside of the limits provided will be considered with justification.

      (2) The soil mix shall have a pH between 5.5 and 7.5.

   b. Stone shall consist of clean, uniformly graded course aggregate.

   c. A nonwoven geotextile fabric shall be placed between the amended soil and the stone, when a stone layer is used.

   d. When used, impermeable liner shall have a maximum permeability of 1×10^{-7} centimeters per second certified by the manufacturer.

   e. Plant selection shall consider exposure and tolerance to salt, sediment and pollutants, and the design depth of surface storage. Native species are encouraged.

      (1) Bioretention: Plugs and seed.

      (2) Rain gardens: Container stock.

   f. Mulch shall be applied after planting.

      (1) Bioretention: Straw mulch or mulch blanket shall be uniformly applied and tacked.

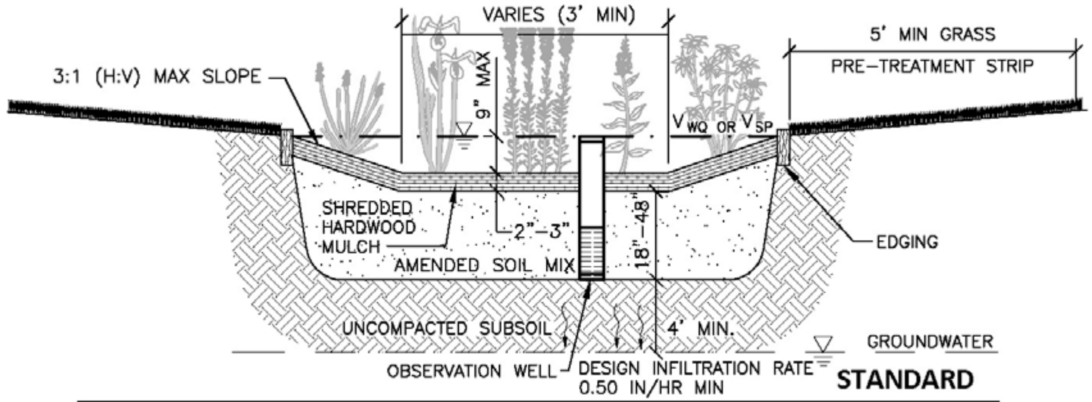
      (2) Rain gardens: Shredded hardwood mulch shall be uniformly applied to a depth of 2 to 3 inches.

6. Access

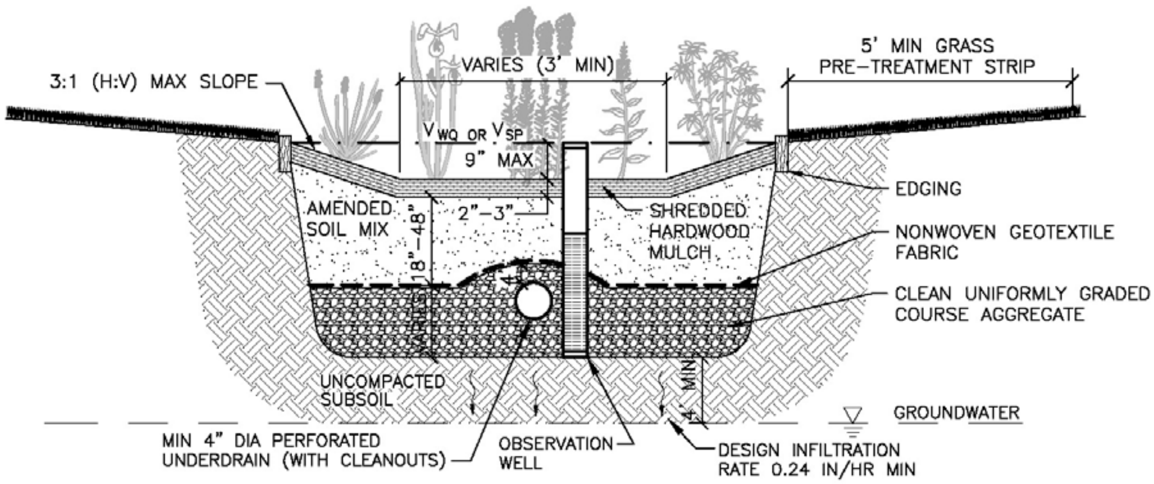
   a. Inspection and maintenance access to the bioretention / rain garden shall be provided.

D. Design Schematics

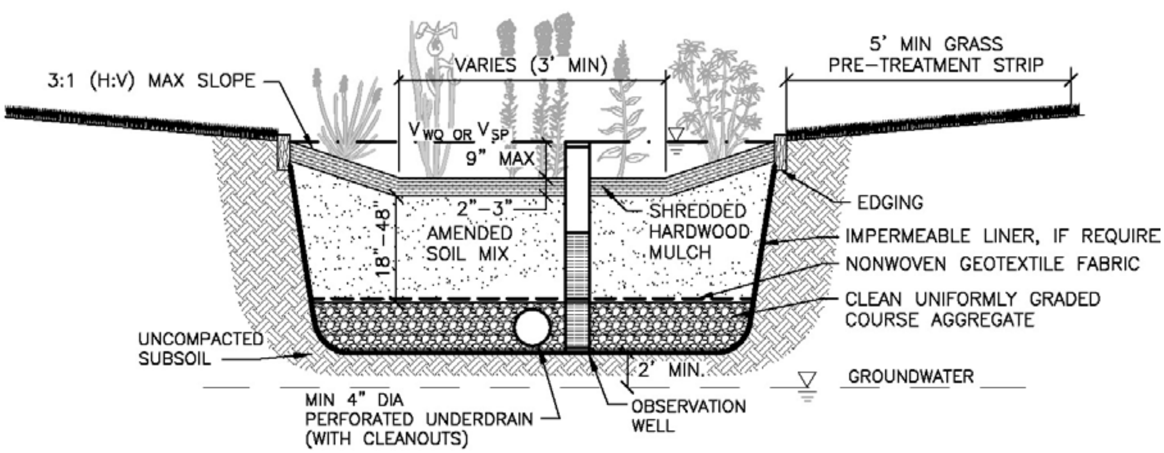
BIORETENTION/RAIN GARDEN



STANDARD



BIORETENTION/RAIN GARDEN WITH STONE STORAGE LAYER



BIORETENTION/RAIN GARDEN WITH BOTTOM DRAIN

Constructed Filter

A. Summary

Description:	Provides storm water treatment and storage with a surface outlet (underdrain); May be allowed on small sites in lieu of extended detention
Types:	Sand; Gravel; Sand/compost mix; Other media
Pretreatment Required:	Yes. This BMP can provide spill containment
Calculation Credits:	
Volume Reduction	None
Rate Reduction	Adjust time-of-concentration by dividing storage volume by 10-year peak flow rate; BMP routing using computer software
Water Quality	Count total volume stored and filtered

B. Sizing Calculations

1. Use the methods outlined in "Calculating Storage Volumes and Release Rates" (page 28) to calculate the required volumes for stream protection, water quality and/or pre-treatment.

2. Calculate filter surface area required to drain the design volume in the specified drawdown time using hydraulic conductivity of filter media.

$$A = V \times d_f / [K \times (h_f + d_f) \times t_d]$$

   where:
   A = minimum surface area of filter (square feet)
   V = design runoff volume (cubic feet)
   d_f = depth of filter media (1.5-foot minimum to 3-foot maximum)
   K = hydraulic conductivity (feet per day)
   h_f = average head; typically ½ of the maximum head on filter media (feet)
   t_d = maximum allowable drawdown time (days)

3. Total drawdown time shall be no more than 72 hours.

4. Check whether soil conductivity or hydraulics of underdrain governs.

Constructed Filter (continued)

C. Design Requirements

1. Siting

   a. Soil borings are required as outlined in "Soils Investigation" (page 18).

      (1) A minimum of 2 feet is required between the bottom of the constructed filter and the highest known groundwater elevation.

      (2) Design values for hydraulic conductivity of the filter media shall be as specified in ***Table 11***, or documented by field tests in accordance with "Soils Investigation" (page 19), or by other sources for other filter media.

Table 11 – Minimum Hydraulic Conductivities for Filter Media

Filter Media	Hydraulic Conductivity (feet per day)
Gravel	20
Course Sand	7.2
Compost (loose)	8.7[1]
Rain Garden Mix (compost, sand, topsoil)	6[2]
Peat	1[3]

Source: From design infiltration rates in ***Table 7.***
[1]*Low Impact Development Manual for Michigan,* SEMCOG, 2008.
[2]Adapted from *An Investigation of Rain Garden Planting Mixtures and the Implications for Design,* D. Carpenter and L. Hallam, 2007
[3]*Dynamics of Fluids in Porous Media,* J. Bear,1972.

2. Sizing and Configuration

   a. Filter media shall have a minimum depth of 18-inches and a maximum depth of 36 inches.

   b. A gravel layer shall be located below the filter media.

   c. A 4-inch minimum diameter underdrain shall be provided in the gravel layer with lateral spacing no more than 10 feet.

   d. All underground pipes shall have clean-outs accessible from the surface.

   e. Pipe slopes shall have a minimum slope of 1%.

   f. Constructed filters located in areas of existing soil contamination shall be lined to prevent infiltration.

3. Inlet Design

   a. A level spreader, distribution pipes or other flow dispersion measure shall be used for energy dissipation and to uniformly distribute the flow.

   a. Pre-treatment is required for each inlet and for overland flow entering the constructed filter.

Constructed Filter (continued)

4. Emergency Overflow

    a. All constructed filters must be designed so that larger storms may safely overflow or bypass the filter. Flow splitters, multi-stage chambers or other devices may be used.

    b. Sufficient space must be provided between the top of the filtering bed and the overflow to allow the maximum design head to be stored for filtration.

5. Materials

    a. Pipe bedding shall consist of at least 3 inches of gravel under the pipe and 6 inches above the pipe.

    b. A nonwoven geotextile fabric shall be placed between the filter media layer(s) and the gravel layer.

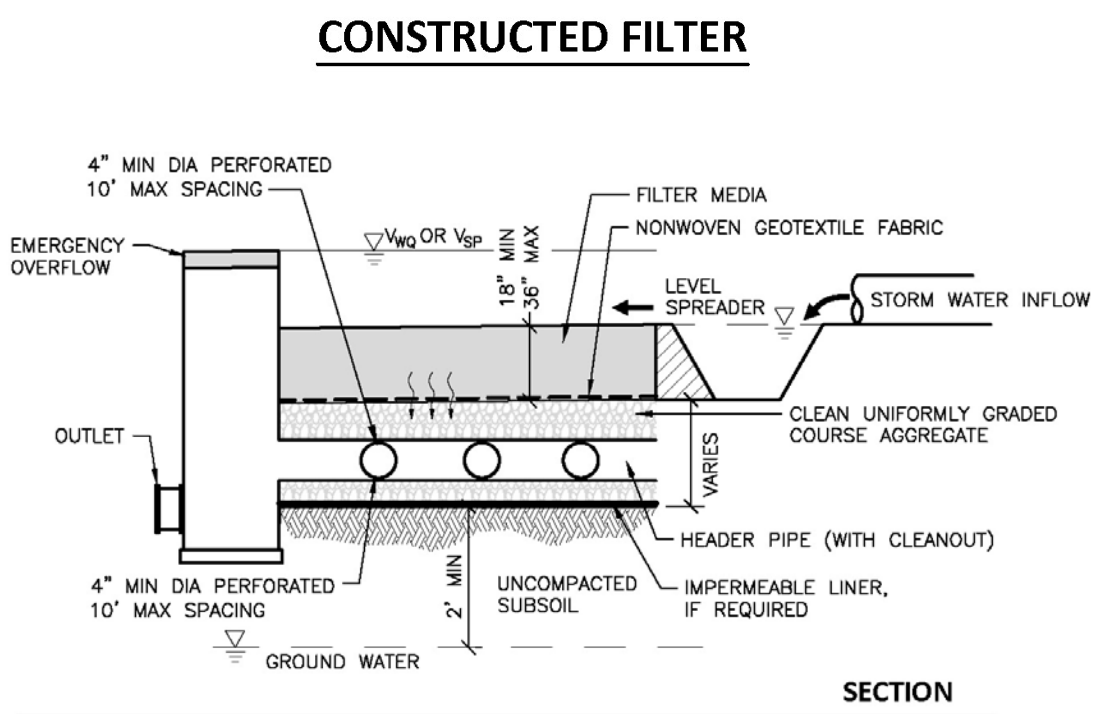
    c. When used, impermeable liner shall have a maximum permeability of 1×10^{-7} centimeters per second certified by the manufacturer.

6. Access

    a. Inspection and maintenance access to the constructed filter shall be provided.

    b. For underground vault heights greater than 4 feet, ladder access shall be provided.

D. Design Schematics



Planter Box

A. Summary

Description:	A type of rain garden applicable for small sites or highly urban areas; Underdrained BMP may be allowed on small sites in lieu of extended detention
Types:	Infiltration; Underdrain at top of storage layer; Underdrain at bottom of storage layer; Lined
Pretreatment Required:	No
Calculation Credits:	
Volume Reduction	Infiltration: Count volume stored and infiltrated Underdrained: Count volume stored and infiltrated between bottom of BMP and invert of underdrain
Rate Reduction	Adjust time-of-concentration by dividing storage volume by 10-year peak flow rate; BMP routing using computer software
Water Quality	Count total volume stored and infiltrated/filtered

B. Sizing Calculations

1. For underdrained BMP, follow criteria for "Constructed Filter."

2. Planter boxes may be sized for stream protection or water quality treatment. Use the methods outlined in "Calculating Storage Volumes and Release Rates" (page 28) to calculate the required volumes.

   a. Subtract the volume infiltrated by the BMP during the infiltration period to determine the required storage volume of the BMP. The infiltration volume is calculated as:

      Maximum Allowable Infiltration Rate (inches per hour) x 6 hours x Infiltration Area (square feet) x 1/12 unit conversion

   b. The maximum allowable soil infiltration rate used to size the storage volume of the BMP shall be 0.52 inches per hour, except that 1.04 inches per hour may be used where soil borings indicate sand or gravel free of any other soil seams.

   c. The infiltration period is the time when the bed is receiving runoff and is capable of infiltrating at the design rate, which is conservatively estimated as 6 hours.

Planter Box (continued)

3. Calculate the minimum infiltration area required to drain the required storage volume in the specified drawdown time using the design infiltration rate of the underlying soil.

$$A = [V_s / (i \times t_d)] \times 12$$

where:
A = minimum infiltration area (square feet)
V_s = storage volume (cubic feet)
i = design infiltration rate of soil (inches per hour) from ***Table 5***
t_d = maximum allowable drawdown time (hours)
12 = factor to convert inches to feet

4. Total drawdown time shall be no more than 12 hours. Depth of surface ponding shall be no more than 1 foot and drain within 4 hours.

5. The bottom area of the BMP shall be used as the infiltration area.

6. Calculate the storage volume of the BMP.

Surface Storage Volume (cubic feet) = Bed Area (square feet) x Design High Water Depth (feet)

Subsurface Storage Volume (cubic feet) = Length (feet) x Width (feet) x Depth (feet) x Void Ratio of Material

Total Storage Volume (cubic feet) = Surface Storage Volume (cubic feet) + Subsurface Storage Volume (cubic feet)

C. Design Requirements

1. Siting

   a. Soil borings are required as outlined in "Soils Investigation" (page 18).

      (1) A minimum of 4 feet is required between the bottom of the planter box and the highest known groundwater elevation.

      (2) An underdrain shall be provided for design infiltration rates less than 0.50 inches per hour, or if planter box will be lined.

      (3) Void ratio for the amended soil material shall be based on the USDA soil textural class and effective water capacity in ***Table 5***. A maximum design value of 0.30 shall be used for the void ratio of the amended soil material. A maximum design value of 0.40 shall be used for the void ratio of stone.

2. Sizing and Configuration

   a. A combination of surface and subsurface storage may be used to provide the required storage volume.

   b. Minimum width of planter boxes shall be 18 inches.

Planter Box (continued)

c. Care must be taken during the excavation and finishing process to make sure that soil compaction does not occur.

d. Planter boxes located in areas of existing soil contamination shall be lined to prevent infiltration.

e. Underdrains shall have a 4-inch minimum pipe diameter.

f. All underground pipes shall have clean-outs accessible from the surface.

g. Pipe slopes shall have a minimum slope of 1%.

h. A planting plan shall be provided concurrent with construction drawing submittal.

3. Inlet Design

   a. Inlet pipes shall require energy dissipation. Riprap protection or equivalent erosion control measures shall be used where the velocity exceeds 4 feet per second, up to a maximum allowable design velocity of 10 feet per second.

4. Emergency Overflow

   a. All planter boxes must have a provision for overflow at the high water level.

5. Materials

   a. Suggested structural elements of planter boxes are stone, concrete, brick or pressure-treated wood.

   b. Amended soil material shall consist of 12 to 36 inches of the following materials, evenly mixed: Compost: 20-40%; Sand: 30-50%; Topsoil: 20-30% (with a clay content of 0-10%).

      (1) Alternative mix designs with ratios outside of the limits provided will be considered with justification.

      (2) The soil mix shall have a pH between 5.5 and 6.5.

   c. Stone bedding shall consist of clean, uniformly graded course aggregate.

   d. A nonwoven geotextile fabric shall be placed between the amended soil and the stone.

   e. Impermeable liner shall have a maximum permeability of 1×10^{-7} centimeters per second certified by the manufacturer.

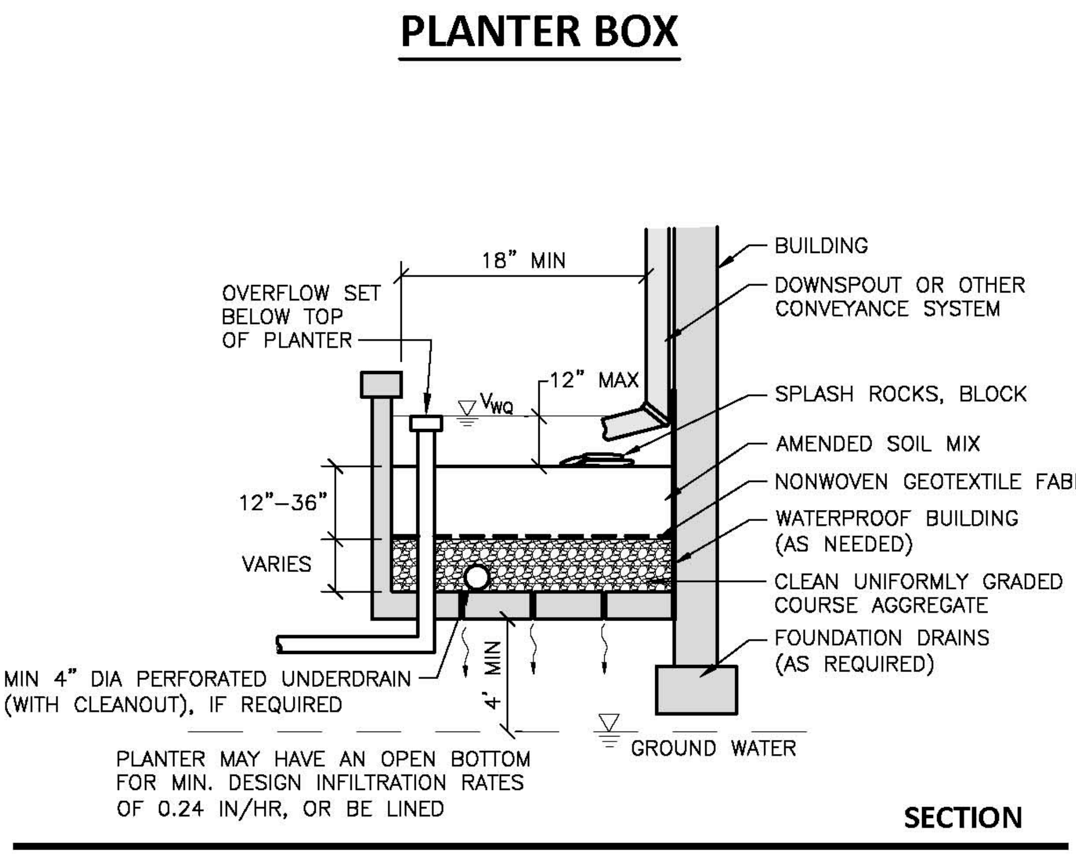
   f. Plant selection shall consider exposure and tolerance to salt, sediment and pollutants, and the design depth of surface storage. Native species are encouraged.

   g. Plants shall be container stock.

6. Access

   a. Inspection and maintenance access to the planter box shall be provided.

D. Design Schematics



Pervious Pavement

A. Summary

Description:	Provides storm water treatment and storage with or without a surface outlet
Types:	Infiltration; Underdrain at top of storage layer; Underdrain at bottom of storage layer; Lined
Pretreatment Required:	No
Calculation Credits:	
Volume Reduction	Infiltration: Count volume stored and infiltrated Underdrained: Count volume stored and infiltrated between bottom of BMP and invert of underdrain
Rate Reduction	Infiltration: 100% Underdrained: Calculated allowable release rate
Water Quality	Count total volume stored and infiltrated/filtered

B. Sizing Calculations

1. Use the methods outlined in "Calculating Storage Volumes and Release Rates" (page 28) to calculate the required volume for stream protection (if necessary).
2. The required storage volume shall be equal to the volume from a 25-year, 24 hour rainfall event from the contributing surface area (porous pavement, roof).
3. The bottom area of the BMP shall be used as the infiltration area.
4. Maximum allowable drawdown time shall be 72 hours.
5. Calculate the subsurface storage volume of the BMP.

   Subsurface Storage Volume (cubic feet) = Length (feet) x Width (feet) x Depth (feet) x Void Ratio of Material

6. For underdrained BMP, follow criteria for "Constructed Filter."

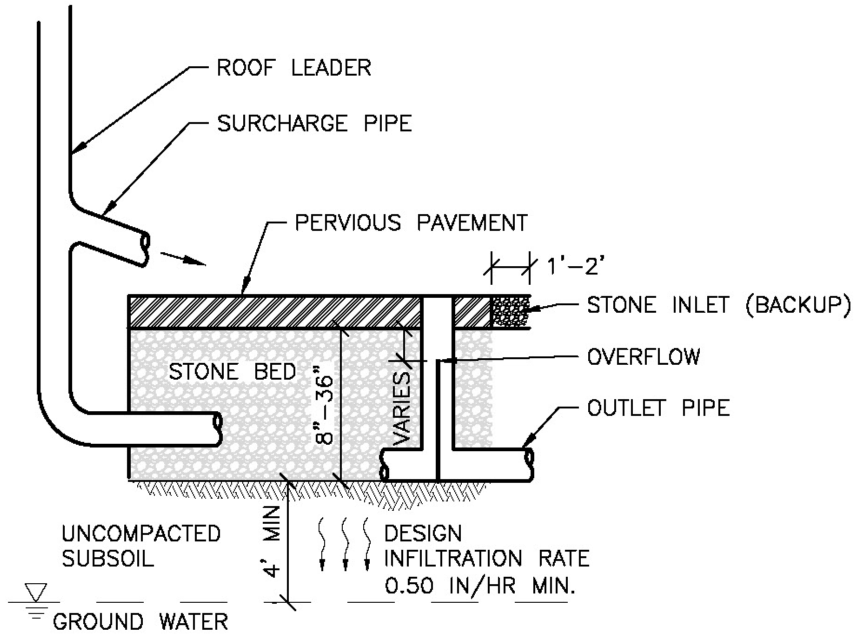
Pervious Pavement (continued)

C. Design Requirements

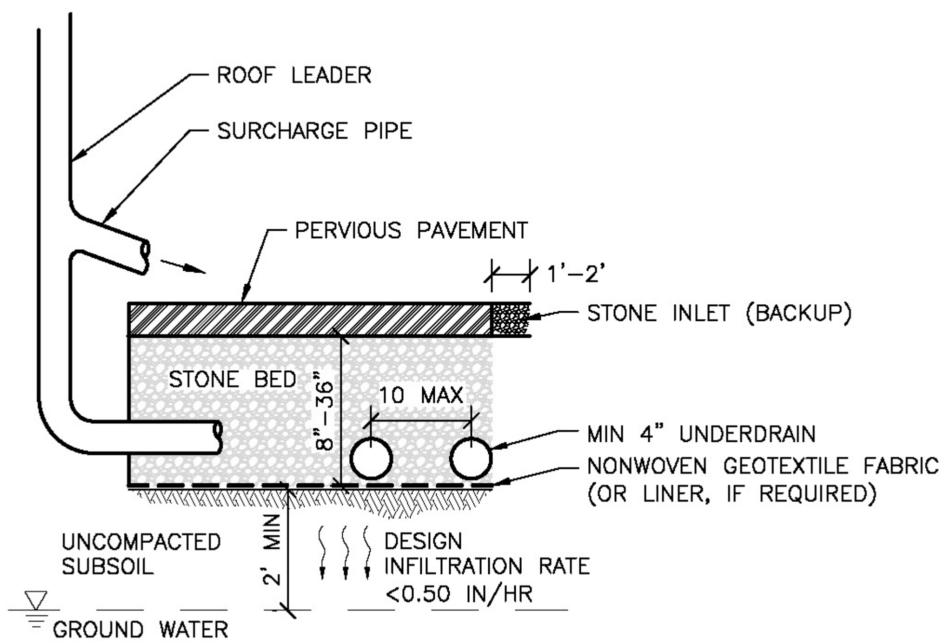
1. Siting
   a. Soil borings are required as outlined in "Soils Investigation" (page 18).
      (1) A minimum of 4 feet is required between the bottom of pervious pavement capable of infiltration and the highest known groundwater elevation.
      (2) A minimum of 2 feet is required between the bottom of lined or pervious pavement and the highest known groundwater elevation.
      (3) An underdrain shall be provided for design infiltration rates less than 0.50 inches per hour, or if stone bed will be lined.
      (4) A maximum design value of 0.40 shall be used for the void ratio of stone.
   b. Runoff from offsite areas shall not be directed onto pervious pavement surface.
2. Sizing and Configuration
   a. The stone bed shall be flat to encourage uniform ponding and infiltration.
   b. For pervious pavements located in areas with steep slopes, stone beds shall be terraced to maximize infiltration area.
   c. Pervious pavements located in areas of existing soil contamination shall be lined to prevent infiltration.
   d. Underdrains shall have a 4-inch minimum pipe diameter with lateral spacing no more than 10 feet
   e. All underground pipes shall have clean-outs accessible from the surface.
   f. Pipe slopes shall have a minimum slope of 1%.
3. Inlet Design
   a. Pervious pavements shall have a backup method for water to enter the storage bed. Backup drainage may consist of an unpaved 1- to 2-foot wide stone edge or inlets with sediment traps.
4. Emergency Overflow
   a. Stone beds must have a provision for overflow below the level of the pavement surface when an underdrain is not already provided.
5. Materials
   a. Stone bed shall consist of 8 to 36 inches of clean, uniformly graded aggregate.
   b. A nonwoven geotextile fabric shall be placed between the stone bed and the subsoil.
   c. Impermeable liner shall have a maximum permeability of 1×10^{-7} centimeters per second certified by the manufacturer.

D. Design Schematics

PERVIOUS PAVEMENT



STANDARD



PERVIOUS PAVEMENT WITH BOTTOM DRAIN

Capture Reuse

A. Summary

Description:	Storm water capture, storage and removal from storm flow by reuse for irrigation or as greywater
Types:	Rain barrels; Cisterns (both above ground and underground); Tanks; Ponds
Pretreatment Required:	No. This BMP can provide spill containment
Calculation Credits:	
Volume Reduction	Count storage volume provided
Rate Reduction	Adjust time-of-concentration by dividing storage volume by 10-year peak flow rate; BMP routing using computer software
Water Quality	Count total volume stored

B. Sizing Calculations

1. Determine water use (gallons per day) and add up for each month of the year.
2. Obtain average monthly precipitation (inches) and evapo-transpiration (ET) in inches. www.enviroweather.msu.edu
3. Multiply average monthly precipitation by contributing area and area-weighted Small Storm Hydrology Method runoff coefficient (assuming 90% of the storms produce 1 inch of rain or less) to obtain volume of recharge. The Small Storm Hydrology Method is given below:

$$V = PR_vA(3630)$$

where:
V = recharge volume (cubic feet)
P = rainfall (inches)
R_v = area-weighted volumetric runoff coefficient (individual runoff coefficients are given in ***Table 12***.)
A = contributing area (acres)
3630 = factor to convert acre-inches to cubic feet

Table 12 – Runoff Coefficients for Small Storm Hydrology Method

Rainfall Amount (inches)	Volumetric Runoff Coefficient, R_v					
	Directly Connected Impervious Area			Disturbed Pervious Area		
	Flat Roofs / Unpaved	Pitched Roofs	Paved	Sandy Soils (HSG A)	Silty Soils (HSG B)	Clayey Soils (HSG C&D)
1.0	0.815	0.965	0.980	0.035	0.120	0.205

Source: Adapted from Table 9.3, *Low Impact Development Manual for Michigan,* SEMCOG, 2008. (Adapted from *The Source Loading and Management Model (WinSLAMM): Introduction and Basic Uses,* R. Pitt, 2003.)

4. Multiply recharge volume by 7.48 gallons per cubic foot to convert to gallons.
5. Calculate ET for open water surfaces. Multiply average monthly ET (inches) by surface area of pond (square feet) and divide by 12 to calculate the volume of water evaporated in cubic feet. Multiply by 7.48 gallons per cubic foot to convert to gallons.

Capture Reuse (continued)

6. Select trial size container or pond volume.
7. Calculate the water balance. A tabular method may be used similar to that illustrated below:

   Volume of Water in Storage at End of Month = Storage Volume at Start of Month + Recharge from Monthly Precipitation - ET - Monthly Water Use

Month	Vstart	+Recharge	- ET	- Use	= Vend*	Lost
1						
2	=Vend1					
Total	--				--	

* Limited by total volume of the selected container or pond. If value is greater than container volume, surplus is lost to overflow. If value is negative, it means that amount must be supplemented.

8. Adjust size of container or pond to balance reuse efficiency and cost.

C. Design Requirements

1. Siting
   a. Storage units shall be positioned to receive rooftop runoff.
   b. Protect storage units from direct sunlight to minimize algae growth.
   c. Discharge points and storage units shall be clearly marked "Caution: Untreated Rainwater. Do Not Drink."
2. Sizing and Configuration
   a. If storage units are used to supplement greywater needs, a parallel conveyance system must be installed to separate greywater from other potable water piping systems.
   b. Storage units shall be watertight with a smooth interior surface.
   c. Covers and lids shall have a tight fit to keep out surface water, insects, animals, dust and light.
   d. Observation risers shall be provided for buried storage units.
   e. Pumps and pressure tanks may be used to add pressure (most irrigation systems require at least 15 pounds per square inch).
3. Inlet Design
   a. Screens may be used to filter debris from runoff flowing into the storage unit.
4. Emergency Overflow
   a. A positive outlet for overflow shall be provided a few inches from the top of the storage unit and sized to safely discharge the peak flow from the 10-year design storm when the storage unit is full.
   b. Above-ground storage units shall have a release mechanism to drain and empty the unit between storm events.

Vegetated Roof

A. Summary

Description:	Provides storm water treatment and storage with a surface overflow
Types:	Intensive (> 4 inches, wide variety of plants, public use); Extensive (≤ 4 inches, plants are herbs, mosses, succulents and grasses)
Pretreatment Required:	No. This BMP can provide pre-treatment
Calculation Credits:	
Volume Reduction	Count storage volume (limited by design rainfall on roof)
Rate Reduction	Adjust CN to 65
Water Quality	Exempt from water quality treatment criteria

B. Sizing Calculations

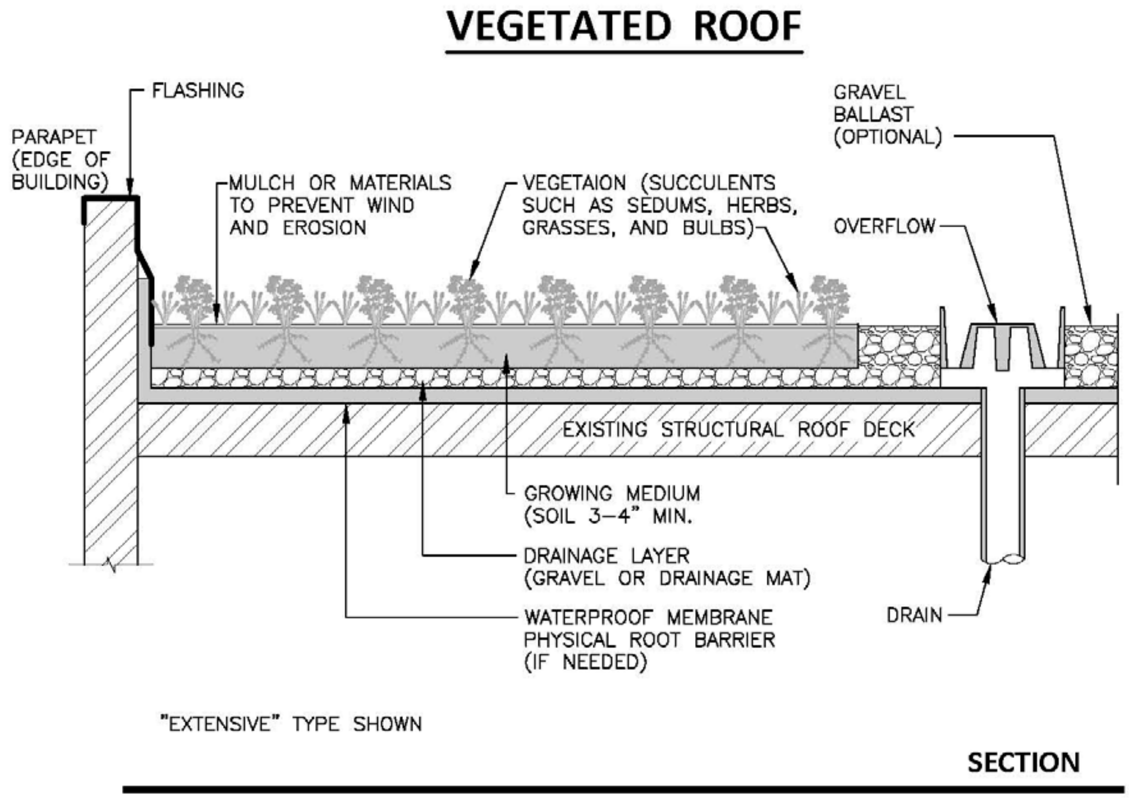
1. Use the methods outlined in "Calculating Storage Volumes and Release Rates" (page 28) to calculate the required volume for stream protection.
2. The required storage volume shall be equal to the design volume from the rain falling on the roof area.
3. Calculate the subsurface storage volume of the BMP.

   Subsurface Storage Volume (cubic feet) = Length (feet) x Width (feet) x Depth (feet) x Void Ratio of Material

C. Design Requirements

1. Sizing and Configuration
   a. Follow manufacturer's and structural engineer's guidelines.
2. Emergency Overflow
   a. A positive outlet for overflow shall be provided.

D. Design Schematics



Water Quality Device

A. Summary

Description:	Storm water pre-treatment unit
Types:	Filtration; Settling; Hydrodynamic Separator
Pretreatment Required:	No. This BMP can provide pre-treatment and spill containment
Calculation Credits:	
Volume Reduction	None
Rate Reduction	None
Water Quality	Does not provide sufficient treatment, except on small sites where volume of unit equals required water quality treatment volume

B. Sizing Calculations

1. Select water quality device unit/model based on manufacturer's recommendations.

C. Design Requirements

1. Sizing and Configuration

   a. The geometry of the water quality device shall promote the trapping of floatables, sediments and capture of a slug pollutant load from accidental spills of toxic materials.

   b. The water quality device shall be designed to prevent surcharging in pipes upstream of the device.

2. Emergency Overflow

   a. A bypass overflow shall be designed to convey the 10-year peak discharge at a minimum without release of trapped sediments and pollutants.

   b. The outlet from the overflow shall not be submerged under normal conditions.

Sediment Forebay

A. Summary

Description:	Storm water pre-treatment practice
Types:	Wet basin; Dry basin; Level spreader
Pretreatment Required:	No. This BMP can provide pre-treatment
Calculation Credits:	
Volume Reduction	None
Rate Reduction	None
Water Quality	Count permanent pool volume if sized to meet water quality treatment standards

B. Sizing Calculations

1. Size for pre-treatment using equation given in "Calculating Storage Volumes and Release Rates" (page 32).

C. Design Requirements

1. Siting

    a. A sediment forebay is typically used with a detention or retention basin.

    b. Where more than one inlet pipe is required, the calculated forebay volume shall be pro-rated by flow contribution of each inlet.

2. Sizing and Configuration

    a. The minimum sediment forebay volume shall be equivalent to the pre-treatment volume.

    b. The sediment forebay shall be a separate sump, which can be formed by grading.

    c. The length-to-width ratio shall be a minimum of 1.5:1 and a maximum of 4:1.

    d. The overflow berm or spillway shall be designed to prevent erosion.

D. Design Schematics

See "Detention Basin" and "Retention Basin" BMPs.

Spill Containment Cell

A. Summary

Description:	Storm water pre-treatment practice
Types:	Lined wet basin
Pretreatment Required:	No. This BMP can provide pre-treatment and spill containment
Calculation Credits:	
Volume Reduction	None
Rate Reduction	None
Water Quality	Count permanent pool volume if sized to meet water quality treatment standards

B. Sizing Calculations

1. Size for pre-treatment using equation given in "Calculating Storage Volumes and Release Rates" (page 32).

C. Design Requirements

1. Siting

   a. Where spill containment is required, all inlets shall enter the spill containment cell unless the inlet collects storm water exclusively from non-hot-spot areas (i.e. office parking, courtyard, roof).

2. Sizing and Configuration

   a. The minimum spill containment cell volume shall be equivalent to the pre-treatment volume.

   b. The minimum surface area shall be 25% of the required volume (with a maximum depth of 4 feet).

   c. The length-to-width ratio shall be a minimum of 3:1, and a maximum of 4:1 to allow for adequate hydraulic length yet minimize scour velocities.

   d. The minimum hydraulic length shall be equal to the length specified in the length-to-width ratio.

   e. The minimum diameter of the transfer pipe between the spill containment cell and the basin shall be 12 inches.

   f. The overflow structure from the spill containment cell shall be sized for the peak inflow from a 10-year rainfall event.

Spill Containment Cell (continued)

g. The top-of-berm elevation between the spill containment cell and the basin shall be a minimum of 1 foot below the outer berm elevation.

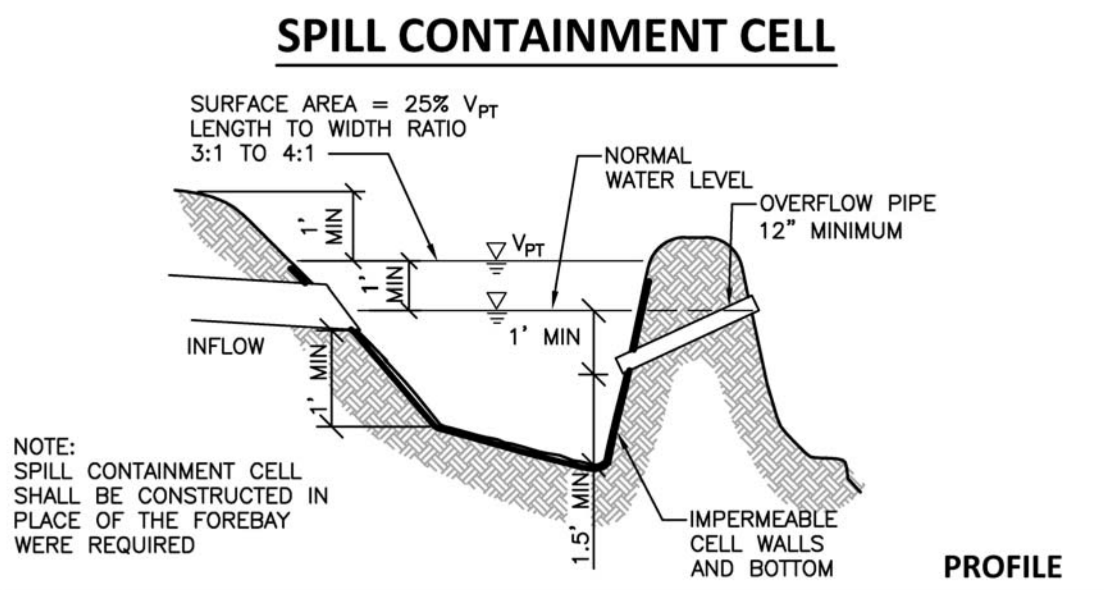
h. The spill containment cell shall have a minimum 1-foot-deep sump below the inlet pipe for sediment accumulation.

i. The outlet structure from the spill containment cell shall be designed to draw water from the central portion of the water column within the cell to trap floatables and contain sediments. The inlet side of the structure shall be located a minimum of 1 foot below the normal water level, and a minimum of 1.5 feet from the bottom of the spill containment cell. Minimum depth of the permanent pool is 2.5 feet.

3. Materials

a. The spill containment cell shall be lined with impermeable materials extending up to the design high water elevation. A minimum 18-inch-thick clay layer, or an impermeable liner protected with a minimum 12 inches of soil cover are acceptable alternatives. Maximum allowable permeability shall be 1×10^{-7} centimeters per second as determined by the geotechnical consultant for clay placement, or manufacturer's certificate for liner products.

D. Design Schematics



Water Quality Swale

A. Summary

Description:	Lined storm water filter designed to provide spill containment; May be allowed on small sites in lieu of extended detention
Types:	Dry swale
Pretreatment Required:	Yes. This BMP can also provide pre-treatment and spill containment
Calculation Credits:	
Volume Reduction	None
Rate Reduction	Adjust time-of-concentration by dividing storage volume by 10-year peak flow rate; BMP routing using computer software
Water Quality	Count storage volume if sized to meet water quality treatment standards

B. Sizing Calculations

1. Size for pre-treatment using equation given in "Calculating Storage Volumes and Release Rates" (page 32).

C. Design Requirements

1. Siting

   a. Water quality swales can be used where spill containment is required on small sites or in lieu of a spill containment cell.

   b. Where spill containment is required, all inlets shall enter the water quality swale unless the inlet collects storm water exclusively from non-hot-spot areas (i.e. office parking, courtyard, roof).

2. Sizing and Configuration

   a. The minimum water quality swale volume shall be equivalent to the pre-treatment volume.

   b. The swale shall be designed for a maximum water depth of 3 feet.

   c. The swale shall have a minimum bottom width of 2 feet and a maximum bottom width of 8 feet.

   d. Side slopes shall be 3:1 (H:V) or flatter.

   e. Minimum thickness of the sand filter shall be 24 inches with a minimum of 6 inches of stone bedding.

Water Quality Swale (continued)

3. Inlet Design

   a. Inlets shall enter a water quality device or forebay.

4. Outlet Design

   a. The outlet structure shall be constructed within a catchbasin and be designed to draw water from the central portion of the water column within the catchbasin to trap floatables and contain sediments in a minimum 2-foot sump.

   b. The rim elevation of the catchbasin shall be designed high enough to contain the required volume of water within the swale (pre-treatment volume, water quality treatment volume, etc.)

   c. The swale and outlet shall be designed to pass the 10-year peak discharge.

5. Emergency Overflow

   a. A positive outlet for overflow shall be provided a few inches from the top of the storage unit and sized to safely discharge the peak flow from the 10-year design storm when the storage unit is full.

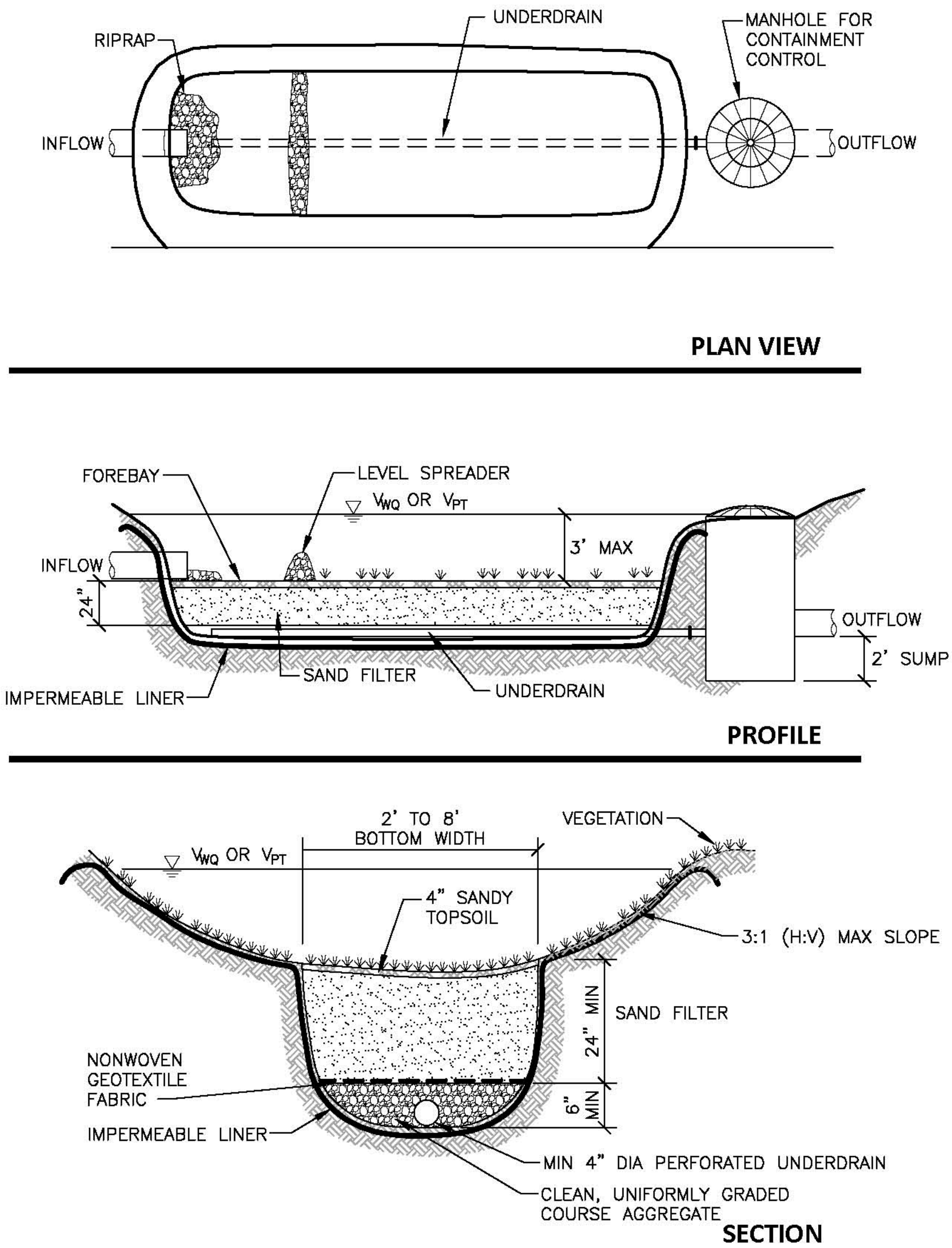
6. Materials

   a. A 4-inch perforated underdrain shall be placed along the center length of the swale and bedded in stone.

   b. The water quality swale shall be lined with impermeable materials extending up to the design high water elevation. A minimum 18-inch-thick clay layer, or an impermeable liner below the stone layer are acceptable alternatives. Maximum allowable permeability shall be 1×10^{-7} centimeters per second as determined by the geotechnical consultant for clay placement, or manufacturer's certificate for liner products.

D. Design Schematics

WATER QUALITY SWALE



Vegetated Swale

A. Summary

Description:	Storm water conveyance designed to slow, filter and infiltrate storm water
Types:	Dry swale; Wetland swale
Pretreatment Required:	No. This BMP provides pre-treatment
Calculation Credits:	
Volume Reduction	Count storage volume behind check dams (if any)
Rate Reduction	Due to longer time-of-concentration for swale
Water Quality	Count storage volume behind check dams; Count as being met if vegetated swale meets filter strip length and slope requirements

B. Sizing Calculations

1. Channel

   a. The vegetated swale shall be sized to pass the 10-year peak flow.

   b. Calculate 10-year peak flow rate using the equations given in "Calculating Runoff" (page 22).

   c. Size swale using Manning's Equation:

$$Q = \frac{1.49AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$$

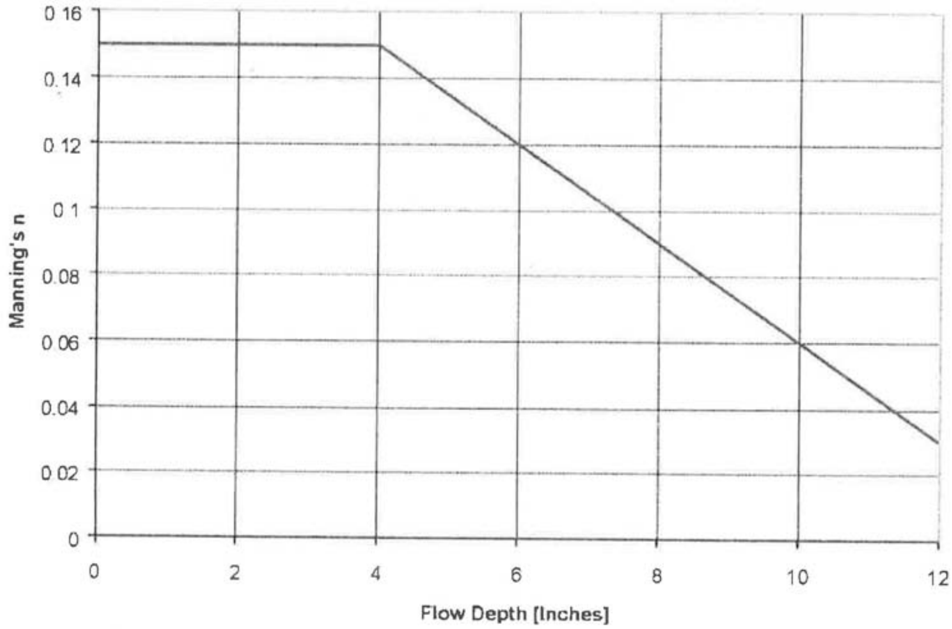
where:
Q = discharge (cubic feet per second)
A = wetted area (square feet)
R = hydraulic radius (feet)
S = slope (feet per foot)
n = Manning's Coefficient

   d. Select the more conservative value of Manning's Roughness Coefficient from ***Table 9*** or ***Figure 6***.

   e. Check that flow velocities are within acceptable limits. The minimum velocity for open channels shall be 1.5 feet per second. The maximum velocity shall be 4 feet per second.

Vegetated Swale (continued)

Figure 6 – Manning's Roughness Coefficients for Vegetated Swales



Source: Figure 7.62, *Low Impact Development Manual for Michigan,* SEMCOG, 2008. (Schueler and Claytor, 1996.)

2. Volume Behind Check Dam (if used)

   a. Calculate the wedge-shaped storage volume behind each check dam.

      Storage Volume (cubic feet) = 0.5 x Length of Swale Impoundment Area per Check Dam (feet) x Depth of Check Dam (feet) x [Top Width of Check Dam (feet) + Bottom Width of Check Dam (feet)] / 2

C. Design Requirements

1. Siting

   a. Vegetated swales can be used for drainage areas up to 5 acres. Drainage areas greater than this may require open channels.

2. Sizing and Configuration

   a. The swale shall have a minimum bottom width of 2 feet and a maximum bottom width of 8 feet.

   b. The maximum bottom width to depth ratio for a trapezoidal swale shall be 12:1.

   c. Side slopes shall be 3:1 (H:V) or flatter.

   d. Longitudinal slope shall be a minimum of 1% and a maximum of 6%. Flatter slopes may be allowed on permeable soils.

Vegetated Swale (continued)

3. Check Dam Design

   a. Check dams may be used along vegetated swales with longitudinal slopes greater than 3%, or to encourage ponding and infiltration on flatter slopes.

   b. Maximum ponding depth behind check dams shall be 18 inches.

   c. Check dams shall be keyed into the bottom and sides of the swale a minimum of 1-foot on all sides. The height of the key must exceed the 10-year water surface elevation by a minimum of 6 inches on both sides.

   d. The center of the check dam crest must be below the sides of the check dam by a minimum of 12 inches.

4. Materials

   Establishment of vegetation shall follow the guidelines outlined in ***Table 13.***

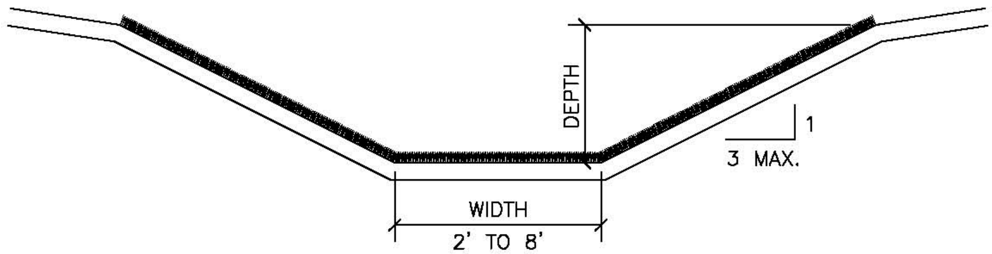
Table 13 – Permanent Stabilization Treatment for Vegetated Swales

Swale Bottom Treatment	Swale Grade
Seed and Mulch	0.3% to 0.5%
Standard Mulch Blanket	0.5% to 1.5%
High Velocity Mulch Blanket or Sod	1.5% to 3.0%
Turf Reinforcement Mat or Check Dams	3.0% to 6.0%
Specific Design Required	> 6.0%

Source: *Michigan Department of Transportation Drainage Manual,* 2006.

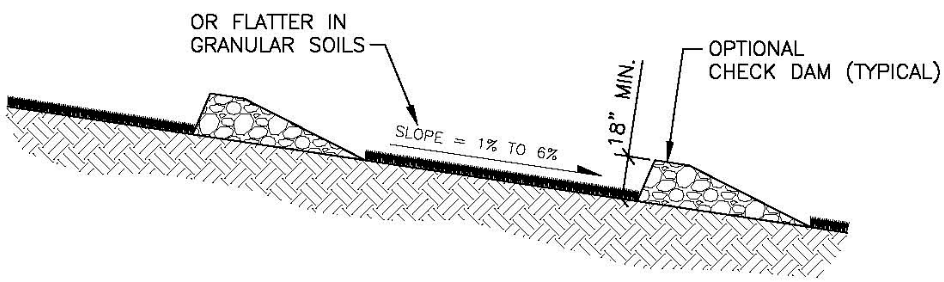
D. Design Schematics

VEGETATED SWALE

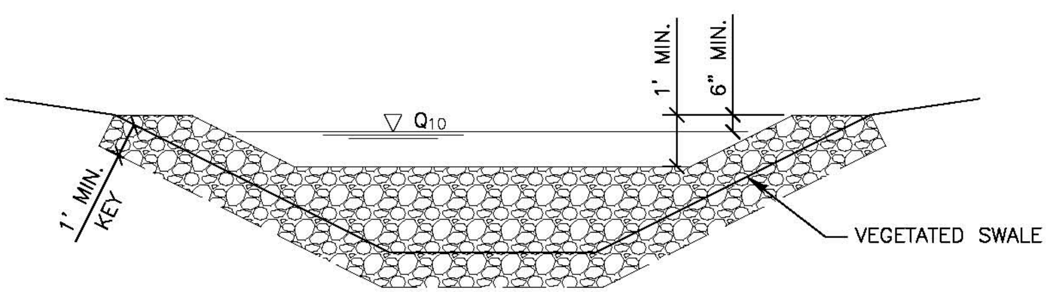


MAX. WIDTH TO DEPTH RATIO = 12:1

SECTION



PROFILE



CHECK DAM DETAIL

Vegetated Filter Strip

A. Summary

Description:	Overland flow path designed to slow and filter storm water
Types:	Turf grass; other dense herbaceous groundcover vegetation
Pretreatment Required:	No. This BMP provides pre-treatment
Calculation Credits:	
Volume Reduction	None
Rate Reduction	Adjust time-of-concentration
Water Quality	Count as being met if filter strip meets area, length and slope requirements

B. Sizing Calculations

1. Calculate the area contributing storm water runoff.
2. Calculate the minimum required filter strip area by the equation:

$$A_{fs} = A / 6$$

   where:
   A_{fs} = area of filter strip (square feet)
   A = contributing drainage area (square feet)

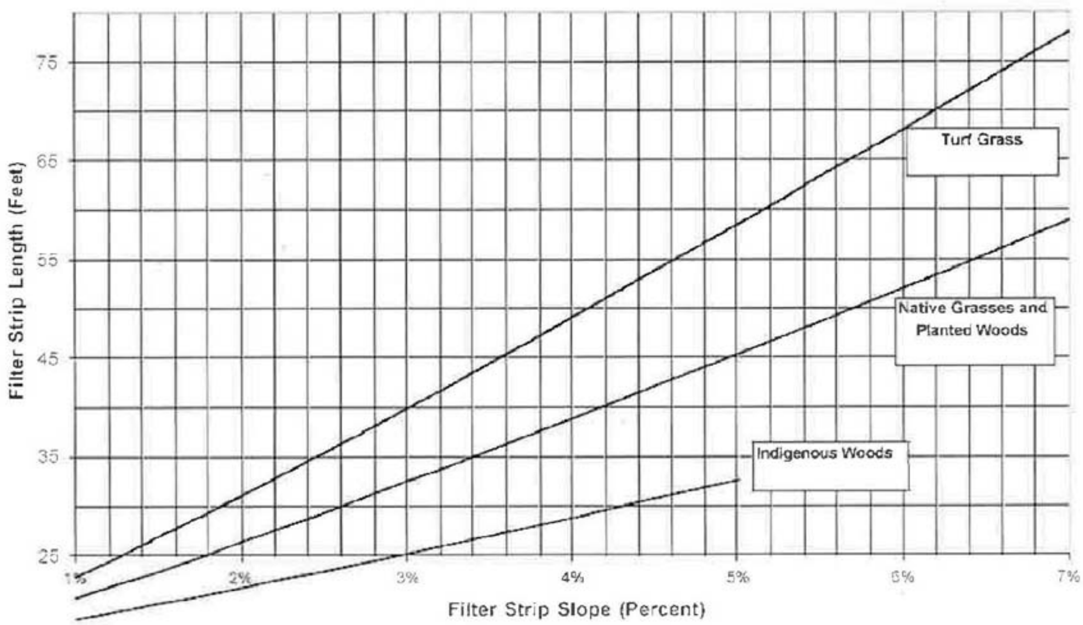
3. Calculate minimum required longitudinal length based on slope and type of vegetation using the graphs in ***Figures 7a*** through ***7d***.

C. Design Requirements

1. Siting
   a. Maximum upstream drainage area shall generally be 100 feet impervious or 200 feet pervious upgradient.
2. Sizing and Configuration
   a. The upstream edge of the filter strip shall be level and at an elevation at least 1 inch below the adjacent pavement.
   b. A level spreader may also be required to evenly distribute flow across filter strip.
   c. Slopes shall range from a minimum of 1% to a maximum of 8%. Optimal slopes range from 2% to 5%.
   d. The maximum lateral slope shall be 1%.
   e. Berms and curbs may be installed along the sides of the filter strip parallel to the direction of flow to prohibit runoff from laterally bypassing the filter strip.

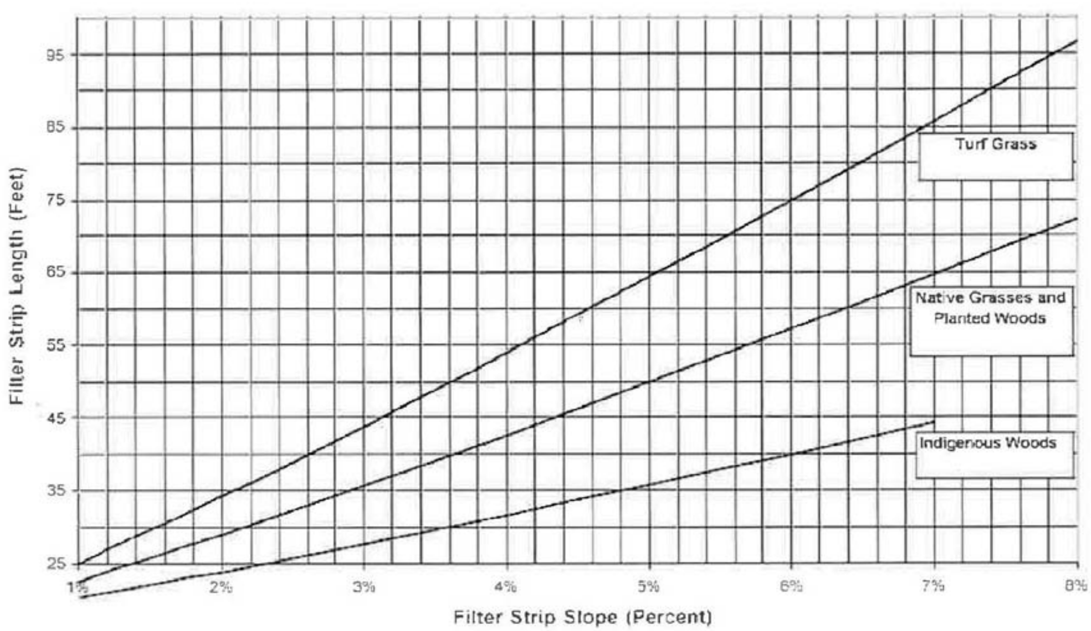
Vegetated Filter Strip (continued)

Figure 7a – Filter Strip Length (Sandy soils with HSG A)



Source: Figure 7.52, *Low Impact Development Manual for Michigan,* SEMCOG, 2008. (*New Jersey Stormwater Best Management Practices Manual*, 2004)

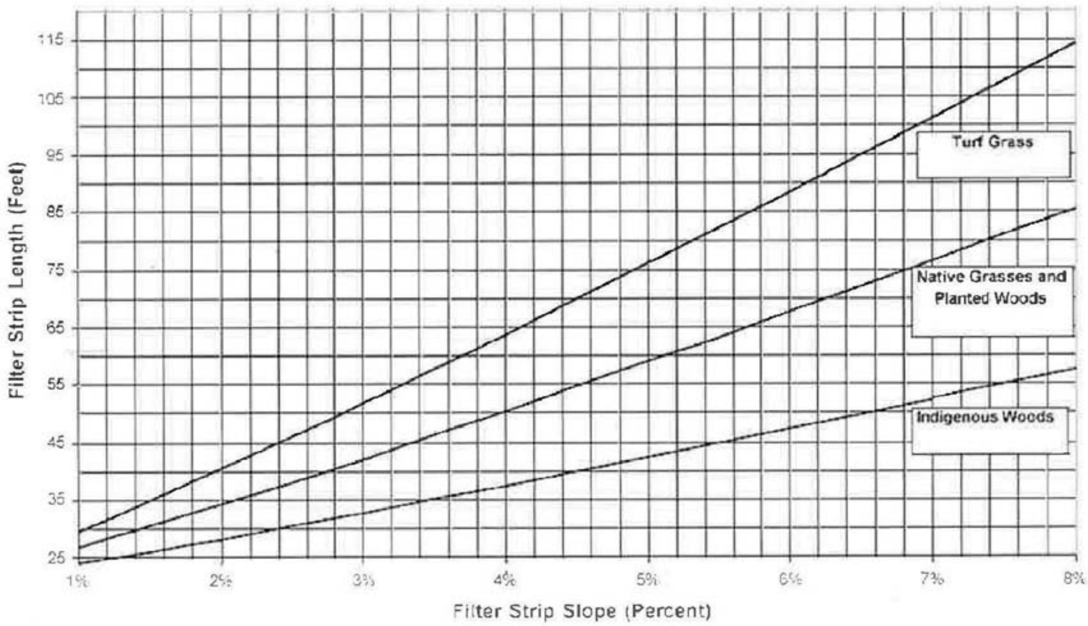
Figure 7b1 – Filter Strip Length (Sandy Loam soils with HSG B)



Source: Figure 7.53, *Low Impact Development Manual for Michigan,* SEMCOG, 2008. (*New Jersey Stormwater Best Management Practices Manual*, 2004)

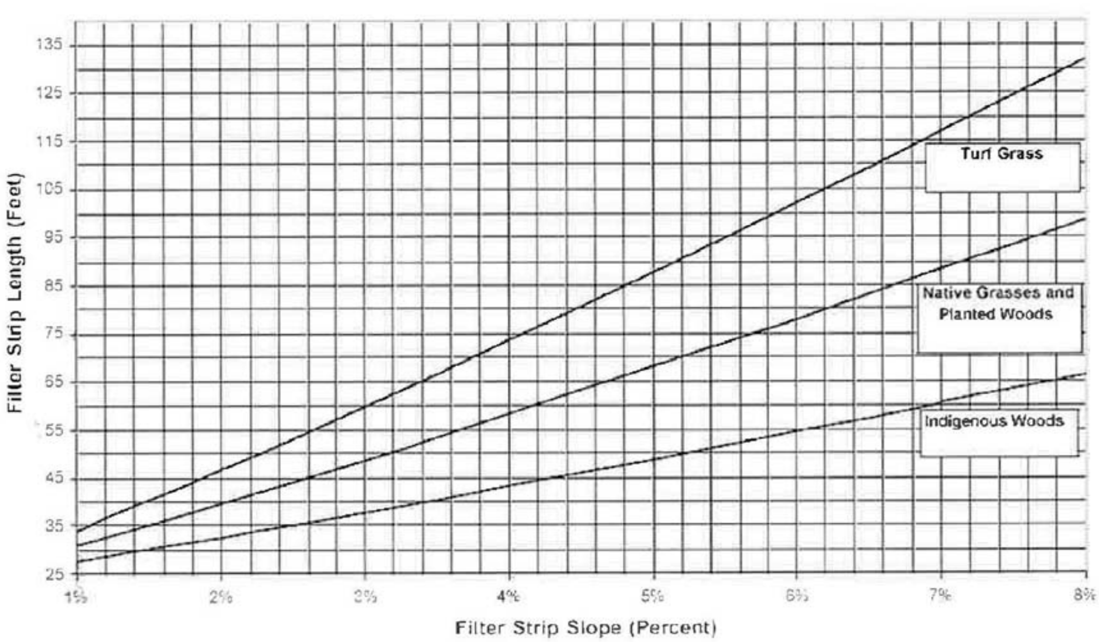
Vegetated Filter Strip (continued)

Figure 7b2 – Filter Strip Length (Loam, Silt-Loam soils with HSG B)



Source: Figure 7.54, *Low Impact Development Manual for Michigan,* SEMCOG, 2008. (*New Jersey Stormwater Best Management Practices Manual*, 2004)

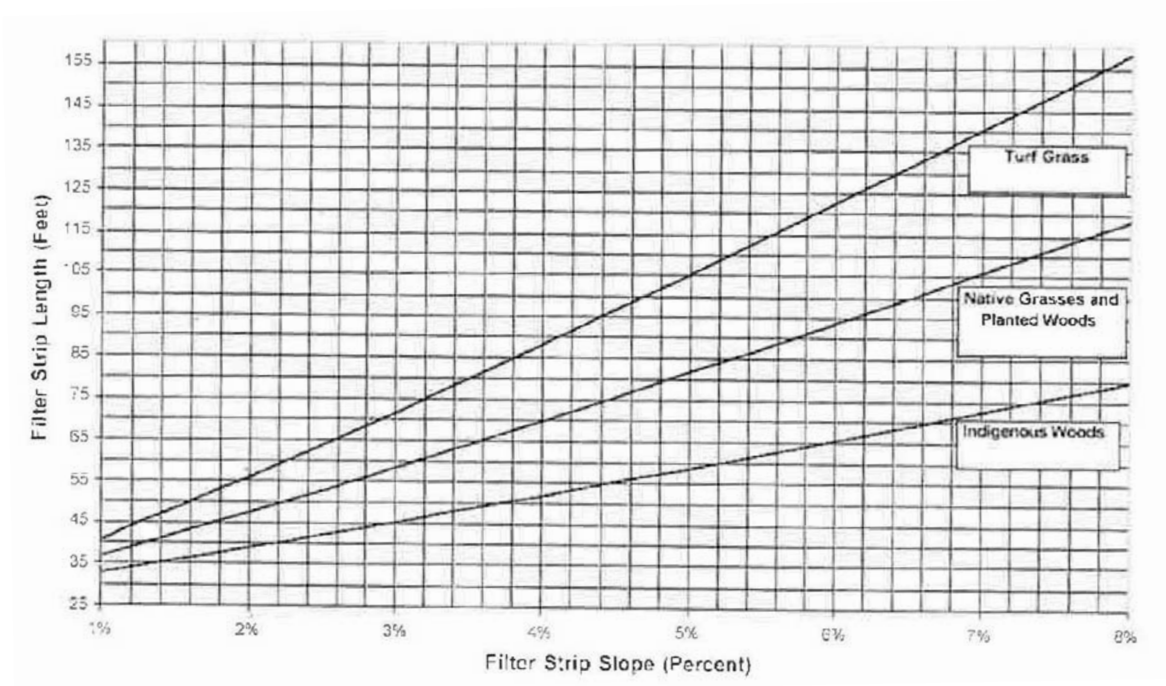
Figure 7c – Filter Strip Length (Sandy Clay Loam soils with HSG C)



Source: Figure 7.55, *Low Impact Development Manual for Michigan,* SEMCOG, 2008. (*New Jersey Stormwater Best Management Practices Manual*, 2004)

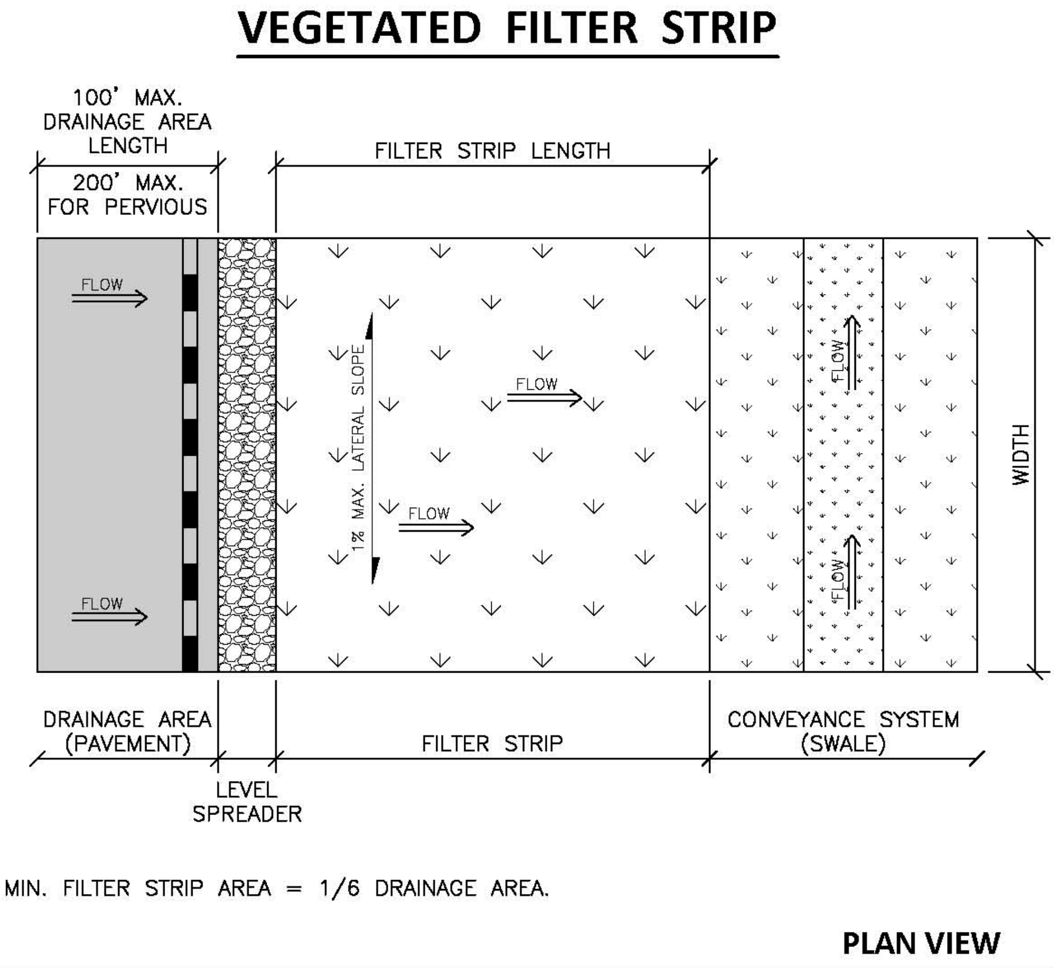
Vegetated Filter Strip (continued)

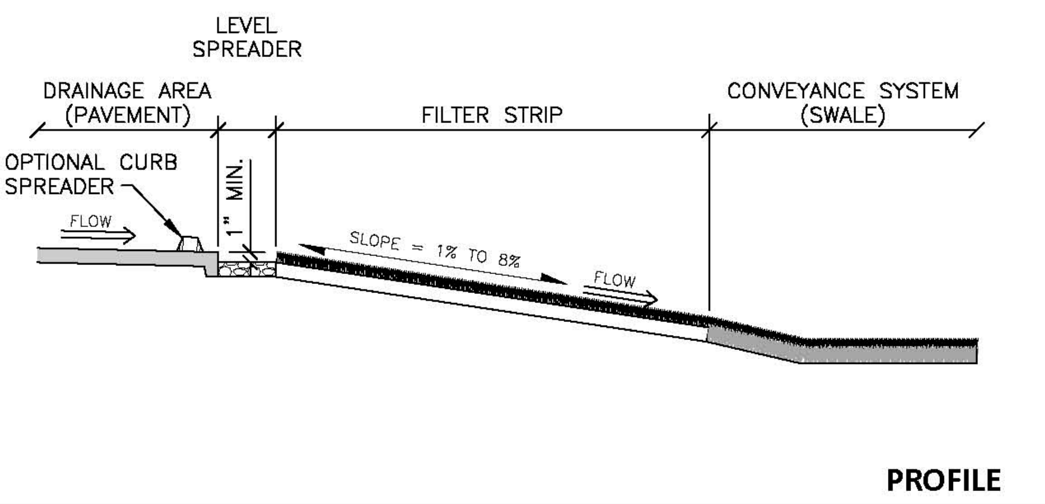
Figure 7d – Filter Strip Length (Clay Loam, Silty Clay, Clay soils with HSG D)



Source: Figure 7.56, *Low Impact Development Manual for Michigan,* SEMCOG, 2008. (*New Jersey Stormwater Best Management Practices Manual*, 2004)

D. Design Schematics





Level Spreader

A. Summary

Description:	Used with other BMPs to disperse concentrated storm water flows
Types:	Inflow (prior to BMP); Outflow (at outlet of BMP)
Pretreatment Required:	No. This BMP provides pre-treatment
Calculation Credits:	
Volume Reduction	None
Rate Reduction	None
Water Quality	None

B. Sizing Calculations

1. The level spreader shall be sized to pass the 10-year peak flow.

2. Calculate 10-year peak flow rate using the equations given in "Calculating Runoff" (page 22).

C. Design Requirements

1. Siting

   a. Slopes below outflow level spreaders should be no greater than 8% in the direction of flow to discourage channelization.

2. Sizing and Configuration

   a. Construct level spreaders in compacted fill or of other non-erodible material.

   b. Minimum length: 10 feet.

   c. A bypass may be required for higher flows.

3. Material

   a. Level spreaders may be constructed of compacted earth, rock, stone, concrete, treated timber or perforated pipe in stone.

Appendix 1
Environmental Laws and Regulations

Appendix 1
Environmental Laws and Regulations Related to Storm Water Management

Law / Regulation	Application	Enforcing Agency
Federal		
National Pollution Discharge Elimination System (NPDES) Industrial Storm Water permits under the Clean Water Act (CWA)	Point source discharges to surface waters from industrial activities, including construction sites over 1 acre. Requires a Certified Stormwater Operator.	Michigan Department of Environmental Quality (MDEQ) Water Resources Division Storm Water Permits Unit Lansing, Michigan
Superfund Amendments and Reauthorization Act (SARA) Title III	Regulates and requires reporting or critical material spills.	Environmental Protection Agency (EPA)
Spill Prevention, Countermeasures and Control (SPCC)	Regulates oil-based materials stored onsite and requires reporting of critical material spills.	EPA Emergency Response Branch Oil Planning and Response Section
National Flood Insurance Program (NFIP)	Prohibits new construction within floodway. Lowest floor for new construction may be at or above the 100-year floodplain elevation. Existing structures eligible for flood insurance in participating communities. Sturgis is a participating community.	Federal Emergency Management Agency (FEMA), Region V Chicago, IL
State		
Groundwater Discharge (Part 22 Rules Part 31, Act 451, PA 1994)	Regulates the discharge of wastewater (including industrial NPDES discharges) to groundwater and the storage of hazardous materials. Storm water is exempt if discharged through surface infiltration.	MDEQ Water Resources Division, Groundwater Permits Unit Lansing, Michigan
Pollution Incident Prevention Plan (Part 31, Act 451, PA 1994)	Critical materials released to the soil, air, or waters of the state have to be reported. A pollution prevention plan needs to be made if any critical materials are stored at a site. These facilities are required to have secondary containment of critical materials. A critical materials list is available from MDEQ.	MDEQ Resource Management Division Kalamazoo, Michigan

Environmental Laws and Regulations Related to Storm Water Management

Law / Regulation	Application	Enforcing Agency
Floodplain Protection Act (Part 31, Act 451, PA 1994)	Construction or fill within the 100-year floodplain of watercourses with a drainage area over 2 square miles.	MDEQ Water Resources Division, Floodplain Unit Kalamazoo, Michigan
Soil Erosion and Sedimentation Control Act (Part 91, Act 451, PA 1994)	Erosion control for earth change activities disturbing 1 or more acres of land or within 500 feet of a lake or stream.	St. Joseph County Conservation District Centreville, Michigan MDEQ Water Resources Division Soil Erosion and Sedimentation Control Unit Lansing, Michigan
Inland Lakes and Streams Act (Part 301, Act 451, PA 1994)	Construction activities within 500 feet of the ordinary high water mark of inland lakes and streams.	MDEQ Water Resources Division Kalamazoo, Michigan
Wetland Protection Act (Part 303, Act 451, PA 1994)	Construction Activities in regulated wetlands over 5 acres in surface area or contiguous to a lake or stream.	MDEQ Water Resources Division Kalamazoo, Michigan U.S. Army Corps of Engineers Detroit District Engineers Office
Dam Safety Act (Part 315, Act 451, PA 1994)	Detention and retention basins impounding more than 5 acres and with a height (hydraulic head) of 6 feet or more.	MDEQ Water Resources Division, Dam Safety Unit Lansing, Michigan
State Highway Authority	Construction activities within state highway rights-of-way. (US-12 and M-66)	Michigan Department of Transportation Southwest Region Kalamazoo, Michigan
Local		
City Ordinances	Construction activities within the City limits.	City of Sturgis, Building Department
City Specifications	Construction activities within the City limits.	City of Sturgis, Engineering Department
County Road Authority	Construction activities within county road rights-of-way.	St. Joseph County Road Commission Centreville, Michigan
County Drains	Construction activities within county drain rights-of-way, or developments within a county drain drainage district.	St. Joseph County Drain Commissioner Centreville, Michigan
This list is provided as a summary of the most common environmental laws and regulations related to storm water activities and is not all inclusive.		

Appendix 2
Minimum Maintenance Guidelines

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STORM WATER MANAGEMENT SYSTEM
MAINTENANCE TASKS AND SCHEDULE

Tasks	Protect Natural Flow Paths	Native Revegetation	Storm Sewer	Culvert or Bridge	Open Channel	Detention Basins	Retention Basins	Infiltration Practices	Bioretention / Rain Garden	Constructed Filter	Planter Box	Pervious Pavement	Capture Reuse	Vegetated Roof	Water Quality Device	Sediment Forebay	Spill Containment Cell	Water Quality Swale	Vegetated Swale	Vegetated Filter Strip	Level Spreader
Removals																					
Remove sediment accumulation	X		X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
Remove trash and debris accumulation	X		X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X
Clean catch basins, inlets and pretreatment devices			X			X	X	X				X					X	X			
Pump and haul from spill containment																	X	X			
Vacuum surface												X									
Repair potholes												X									
Repair/Replace																					
Repair erosion	X			X	X	X	X	X	X			X				X		X	X	X	X
Replace riprap			X	X	X	X	X	X								X		X			X
Repair/replace structural components			X	X	X	X	X	X		X	X	X	X				X	X			
Brush and disinfect inside surfaces													X								
Refresh/replace infiltration/organic/filter media									X	X	X							X			
Till and/or aerate filter media/infiltration bottom							X	X		X								X			
Inspection Schedule	Twice a year (April and Oct)	Mow/burn every 2 - 5 years	Twice a year (April and Oct)	Twice a year (April and Oct)	Twice a year (April and Oct)	Twice a year (April and Oct)	Twice a year (April and Oct)	Twice a year (April and Oct)	Inspect monthly for first year (April - Oct), twice a year thereafter	Twice a year (April and Oct)	Often (high maintenance required)	Once a year (April)	Twice a year (April and Oct)	Monthly for first year (April - Oct), twice a year thereafter (April Oct)	Twice a year (April and Oct)	Twice a year (April and Oct)	Twice a year (April and Oct)	Twice a year (April and Oct)	Twice a year (April and Oct)	Monthly for first year (April - Oct), once a year thereafter (July)	Twice a year (April and Oct)

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Minimum Maintenance Guidelines

STORM WATER MANAGEMENT SYSTEM
MAINTENANCE TASKS AND SCHEDULE

Tasks	Protect Natural Flow Paths	Native Revegetation	Storm Sewer	Culvert or Bridge	Open Channel	Detention Basins	Retention Basins	Infiltration Practices	Bioretention / Rain Garden	Constructed Filter	Planter Box	Pervious Pavement	Capture Reuse	Vegetated Roof	Water Quality Device	Sediment Forebay	Spill Containment Cell	Water Quality Swale	Vegetated Swale	Vegetated Filter Strip	Level Spreader
Vegetation Management																					
Maintain vegetation/remove invasive species	X			X	X	X	X		X		X			X		X		X	X	X	
Water Vegetation									X		X			X						X	
Prune and/or weed vegetation/cut down perennial plantings at end of season		X							X		X			X							
Re-spread and/or replenish mulch									X		X										
Mowing/burning		X					X									X		X	X	X	
Trim or remove brush/trees	X			X	X		X		X							X			X	X	
Maintenance of wetland vegetation						X															
Apply herbicide		X			X																
Inspections																					
Assess bank stability	X			X	X	X	X									X					X
Inspect and drain containers													X								
Inspect underground bed and outlet (for underground systems)						X			X	X		X						X			
Evaluate drain-down time (max 72 hours allowed)							X	X	X	X		X						X			
Inspection Schedule	Twice a year (April and Oct)	Mow/burn every 2 - 5 years	Twice a year (April and Oct)	Twice a year (April and Oct)	Twice a year (April and Oct)	Twice a year (April and Oct)	Twice a year (April and Oct)	Twice a year (April and Oct)	Inspect monthly for first year (April - Oct), twice a year thereafter	Twice a year (April and Oct)	Often (high maintenance required)	Once a year (April)	Twice a year (April and Oct)	Monthly for first year (April - Oct), twice a year thereafter (April Oct)	Twice a year (April and Oct)	Twice a year (April and Oct)	Twice a year (April and Oct)	Twice a year (April and Oct)	Twice a year (April and Oct)	Monthly for first year (April - Oct), once a year thereafter (July)	Twice a year (April and Oct)