Part A. PURPOSE & INTRODUCTION

Both onsite water quantity and quality must be managed to control flooding, reduce downstream erosion and protect water quality. Infiltration will be required for the difference between the pre-development bankfull flood and the proposed post development bankfull flood or the first flush volume, whichever is greater. Note: Projects/sites that cannot achieve the required infiltration volume must increase the required detention volume by up to an additional 20%. To manage that portion of proposed runoff that is not managed through infiltration or other upline BMPs, detention basins must be designed to capture and treat up to a 100-year recurrence interval storm event. Retention basins with no outlet will be capable of storing two consecutive 100-year recurrence interval storms.

In developments that have county drainage districts and drains established, the maintenance of standard stormwater infrastructure and stormwater BMPs is the responsibility of the governing association of the development. In the event that the governing association does not complete the required maintenance, the Water Resources Commissioner will complete maintenance that is deemed necessary to assure appropriate operation of the stormwater system. Maintenance that is required solely for aesthetic purposes will not be completed by the Water Resources Commissioner.

1. EASEMENTS

Wording relative to easements will be specifically required by the Water Resources Commissioner. If a county drain is to be established under the Michigan Drain Code, related easement language will be depicted on final plats and condominium Exhibit B drawings (in pdf format) as follows: “__ foot wide private easement to Washtenaw County Water Resources Commissioner and the _____ Homeowner’s (or Condominium) Association for drainage.”

The typical easement language specified in Appendix I will be included in the subdivision deed restrictions or condominium master deed. The location and purpose of drainage easements should be clearly described in subdivision deed restriction or condominium master deeds. Language will be included within the subdivision deed restriction or condominium master deed that clearly notifies property owners of the presence of stormwater management facilities and accompanying easements, as well as restrictions on the use or modification of these areas.

Easement widths will be determined by the Water Resources Commissioner and be situated in such a way as to allow maximum maintenance access, for example, offsetting them from the centerline. In general, easement widths will conform to the following:

a. Open channels and watercourses: A minimum of 50 feet total width. Additional width may be required in some cases, including but not limited to: watercourse with floodplains delineated by FEMA; sandy soils, steep slopes, at access points from road crossings.

b. Open swales (cross lot drainage): minimum of 30 feet total width.

c. Enclosed storm drains: A minimum of 20 feet will be required, situated in such a way as to allow maximum maintenance access. Additional width will be required in some cases. These may include but are not limited to, pipe depths exceeding 4 feet from the top of pipe, sandy soils and steep slopes.

d. Retention/detention basins or other stormwater management facilities will have sufficient easements for maintenance purposes. Easements will be sized and located to accommodate access and operation of equipment, spoils, deposition and other activities identified in the development’s stormwater management plan.

Drain fields (septic areas) must not be located within drainage easements.

2. MAINTENANCE

Stormwater Management System Maintenance Plans

Maintenance plans will be submitted with all construction plans and included in the subdivision agreement or master deed documents of all subdivisions and site condominiums. These plans must include the following information:

a. An annual maintenance budget itemized in detail by task. The financing mechanism must also be described.

b. A copy of the final approved drainage plan for the development that delineates the facilities and all easements, maintenance access, and buffer areas.

c. A listing of appropriate tasks defined for each component of the system, and a schedule for their implementation. The following areas will be covered:
**Section V: Design Requirements For Stormwater Management Systems**

i. Maintenance of facilities such as pipes, channels, outflow control structures, infiltration devices and other structures.

ii. Debris removal from catch basins, channels and basins.

iii. Dredging operations for both channels and basins to remove sediment accumulation. Stormwater system maintenance plans must require sediment removal when sediment reaches a depth of equal to 50% of the depth of the forebay or 12 inches, whichever is less.

d. The party responsible for performing each of the various maintenance activities described will be recorded with final approved plans and plats.

e. A detailed description of the procedure for both preventative and corrective maintenance activities. The preventative maintenance component will include:
   i. Periodic inspections (at least annually), adjustments and replacements.
   ii. Record-keeping of operations and expenditures.

f. Provision for the routine and non-routine inspection of all components within the system:
   i. Wet weather inspections of structural elements and inspection for sediment accumulation in detention basins must be conducted annually, with as-built plans in hand. Inspections should be carried out by the appropriate party reporting to the responsible agency or owner.
   ii. Housekeeping inspections, such as checking for trash, should take place at least twice per year.

g. A description of ongoing landscape maintenance needs. Landscaping must consist of locally adapted plants. The proprietor will monitor the viability of plantings for at least one year after establishment and plantings will be replaced as needed. Subsequent monitoring must be conducted by the landowner or development association. The Water Resources Commissioner is not responsible for landscape maintenance.

h. Provision for the maintenance of vegetative buffers by landowner, development associations, conservation groups or public agencies. Buffers must be inspected annually for evidence of erosion or concentrated flows through or around the buffer.

i. A sample maintenance plan and annual budget is illustrated in Appendix K.

**Maintenance Responsibility**

a. Property deed restrictions or condominium master deed documents will specify the entities responsible for inspection and maintenance of the stormwater management facilities and the timeframe for these activities. Primary responsibility will fall upon the Homeowners Association or Condominium Association with a governmental agency having secondary responsibility. The restrictions or documents will also specify that the governmental entity with secondary responsibility may perform inspections and complete maintenance in lieu of the primary when it is found to be necessary and assess costs associated with these activities against the property owners within the subdivision or condominium and other entities as determined appropriate.

i. Routine maintenance of stormwater management facilities will be completed per the schedule submitted with the construction plans or within 30 days of receipt of written notification by the responsible governmental entity that action is required, unless other acceptable arrangements are made with the supervising governmental entity.

ii. Emergency maintenance will be completed within 36 hours of written notification unless threat to public health, safety and welfare requires immediate action.

b. For systems with multiple individual users, such as site condominiums or subdivisions, the proprietor may fulfill the obligation to ensure that a governmental entity will be responsible for drainage system maintenance by establishing a county drainage district, or any other similar mechanism approved by the Water Resources Commissioner, to provide for the permanent maintenance of stormwater management facilities and necessary funding.

If a county drain is not established, the proprietor will submit evidence of a legally binding agreement with another governmental agency responsible for maintenance oversight.

c. A legally binding maintenance agreement will be executed before final project approval is granted. The agreement must be included in the property deed restrictions or condominium master deed documents so that it is binding on all subsequent property owners.
Section V: Design Requirements For Stormwater Management Systems

Part B.

DESIGN REQUIREMENTS NATURAL WETLANDS & FLOODPLAINS

1. WETLANDS

This section governs natural wetlands (as distinct from stormwater wetland systems that are constructed expressly for stormwater management purposes), when a natural wetland is incorporated in an overall stormwater management scheme.

a. Wetlands will be protected from damaging modification and adverse changes in runoff quality and quantity associated with land developments. Approval of the final plan will be contingent upon securing all necessary wetland permits from MDEQ and local governments.

b. Direct discharge of untreated stormwater to a natural wetland is prohibited. All runoff from the development will be pre-treated to remove sediment and other pollutants prior to discharge to a wetland. Such treatment facilities will be constructed before property grading begins, and proved to be fully functional prior to acceptance.

c. Site drainage patterns will not be altered in ways that will modify existing water levels in protected wetlands without proof that all applicable permits from the MDEQ and/or local government agencies have been obtained.

d. A qualified professional with specific wetland expertise will oversee wetland construction, re-construction, and/or modification, and provide professional certification of construction in accordance with the approved plans.

e. A fifteen (15) foot permanent buffer strip, vegetated with locally adapted plants, will be maintained or restored around the periphery of wetlands. See Appendix M, General Guide to Native Plant Species to begin development of wetland buffer planting plans.

f. Wetlands shall be protected during construction by appropriate soil erosion and sediment control measures.

2. FLOODPLAINS

a. All necessary floodplain permits from the MDEQ and local governments must be in place prior to final plan approval.

b. It is the responsibility of the developer to demonstrate that any activity proposed within a 100-year floodplain will not diminish flood storage capacity.

c. In certain instances an analysis to determine the 100-year floodplain may be required. Where available, the community Flood Insurance Study shall be used.

d. Compensatory storage will be required for all lost floodplain storage.

e. The placement of storage facilities or infiltration BMPs within the 100-year floodplain is prohibited.
All runoff generated by proposed development surfaces must be conveyed into a stormwater BMP or storage facility for water quality treatment and retention/detention prior to being discharged from the site. The following criteria will apply to the design of all stormwater BMPs, retention and detention facilities.

**a. Utilization of Low Impact Development stormwater BMPs, green roofs, infiltration trenches or water reuse cisterns are preferred options for mitigation.** At a minimum, BMPs must be used for infiltration of the first flush or the difference between the pre-development bankfull and the developed bankfull, whichever is the largest calculated runoff volume.

**b. Stormwater must be pre-treated by passage through a sediment forebay prior to entering into retention/detention facilities.** Sediment forebays function to reduce incoming water velocity, and to trap and localize incoming sediments making their removal easier during maintenance. Sediment forebays may extend the flow path of stormwater, increasing its residence time. Infiltrating water requires more extensive pre-treatment prior to discharge to an infiltration system. Acceptable pretreatment measures include vegetative channels, vegetative filter strips, filter fabric and/or other methods.

**c. Whereas detention basin design for flood control is concerned with relatively infrequent, severe runoff events, such as the 25-, 50- or 100-year recurrence interval storms, design for water quality benefit is concerned with controlling the more frequent storm events (e.g. 2-year recurrence interval storm or less).** The negative impacts of erosive “bankfull” floods are reduced by capturing and detaining the 2-year recurrence interval storm.

**d. Also of importance to water quality is the capture and treatment of the “first flush”, a term used to describe the initial washing action that stormwater has on impervious surfaces.** Pollutants that have accumulated on these surfaces are flushed clean by the early stages of runoff, which then carries a shock loading of these pollutants into receiving waterways.

The majority of all pollutants that are washed off the land can be removed from stormwater before it leaves the site by capturing and treating the first inch of runoff.

**e. Treatment of the “bankfull” flood and “first flush” may be accomplished via the design of three stage basins (bankfull, first flush and “100-year” recurrence interval storm).** These basins control stormwater discharge rates for both extreme events to prevent flooding and more frequent events to mitigate water quality impacts and channel erosion.

**f. Public safety will be a paramount consideration in stormwater system and retention/detention facility design.** Providing a safe design for stormwater storage is the engineer’s responsibility. Retention/detention facility designs will incorporate gradual side slopes, vegetative and barrier plantings, and safety shelves. Where further safety measures are required, the proprietor is expected to include them within the proposed development plans.

**g. BMPs and retention/detention facilities must be located on common-owned property in multi-ownership developments such as subdivisions and site condominiums, and not on private lots or condominium units.**

**h. For land divisions, the retention/detention system must be located in a drain easement.**

**i. When discharge is within a watershed where thermal impacts are a primary concern, deep wet retention/detention facilities or dry retention/detention facilities may be preferred.** In addition for extended dry detention/retention facilities, first flush and bankfull requirements may be reduced to twelve (12) hours. See Section VI, Areas of Special Concern. Shade plantings on the west and south sides of facilities are encouraged. Infiltration of stormwater must be considered where site conditions allow.

**j. Requirements for stormwater quantity control may be waived with computational justification for developments in the downstream-most locations of a watershed, although quality management will still be necessary.** Determinations will be made on an individual site basis. Proposals for waivers must be presented at the pre-application or conceptual design phase.

**k. Additional water quality measures must be installed at sites where land uses are identified as pollutant hotspots.** See Appendix C. Stormwater Pollutant Hotspots.

**l. An adequate area shall be provided for future temporary staging of spoils from maintenance of storage facilities, prior to ultimate disposal.** This area
will be protected such that no runoff will be directed back into the stormwater management system or onto private property. For subdivisions and site condominiums, a permanent easement dedicated to the Water Resources Commissioner or other governmental agency with long-term maintenance responsibility must be provided over the staging area.

m. Where finished grades indicate a substantial amount of drainage across adjoining lots, a drainage swale of sufficient width, depth and slope will be provided on the lot line to intercept this drainage. To ensure that property owners do not alter or fill drainage swales, easements will be required over areas deemed necessary by the Water Resources Commissioner, as stipulated in Section II, Part C, Subsection 3. Areas within open drain easements that have been cleaned, reshaped or distributed in any manner will be stabilized with appropriate protection and vegetation measures immediately.

2. PROHIBITIONS

a. Stormwater management systems incorporating pumps are not permitted in developments with multiple owners, such as subdivisions and site condominiums.
b. In-line detention basins are strongly discouraged in all circumstances, and are prohibited on watercourses greater than 2 square miles upstream or on a county drain. In-line basins are also prohibited if the waterway to be impounded traverses any area outside of the proposed development.
c. The placement of retention/detention basins within a 100-year floodplain is prohibited.
d. Storage within regulated local, state or federal wetlands is prohibited.

e. Where a pipe outlet or orifice plate is to be used to control discharge, it will have a minimum diameter of 4 inches. If this minimum orifice size permits release rates greater than those specified in these rules, an alternative outlet design that incorporates self-cleaning flow restrictors will be required. Examples include perforated risers and “V” notch orifice plates that provide the required release rate. Calculations verifying this rate will be submitted to the Water Resources Commissioner for approval.
f. Any backwater effects on the outlet structure caused by the downstream drainage system will be evaluated when designing the outlet.
g. The minimum detention time for the first flush volume is 24 hours, but it can be detained indefinitely if desired.
h. The bankfull volume must be detained for a minimum of 36 hours and a maximum of 48 hours for 3-stage outlet designs or a minimum of 24 hours and a maximum of 36 hours for 2-stage outlet designs where the entire required infiltration volume has been achieved.
i. The maximum detention time for the 100-year storm volume is 72 hours.

3. TESTING REQUIREMENTS – DETENTION/RETENTION SYSTEMS

For detention/retention systems, the proprietor must submit a soil boring log, taken within the basin bottom area to a depth of 25 feet below existing ground or 20 feet below proposed basin bottom elevation. Information regarding the seasonal groundwater elevations must also be provided.

4. BASIN INLET/OUTLET DESIGN REQUIREMENTS INLET/OUTLET DESIGN

a. Outlets must be designed for the protection of the receiving waterway.
b. Velocity dissipation measures will be incorporated into basin designs to minimize erosion at inlets and outlets, and to minimize the resuspension of pollutants.
c. The distance between inlets and outlets will be maximized. The length and depth of the flow path across basins and marsh systems can be maximized by:
i. Increasing the length to width ratio of the entire design.
ii. Increasing the dry weather flow path within the system to attain maximum sinuosity. Inlets and outlets should be offset at opposite longitudinal ends of the basin.
d. The use of dual outlets, risers, V-notched weirs or other designs that assure an appropriate detention time from all storm events is required.
e. Where a pipe outlet or orifice plate is to be used to control discharge, it will have a minimum diameter of 4 inches. If this minimum orifice size permits release rates greater than those specified in these rules, an alternative outlet design that incorporates self-cleaning flow restrictors will be required. Examples include perforated risers and “V” notch orifice plates that provide the required release rate. Calculations verifying this rate will be submitted to the Water Resources Commissioner for approval.

Riser Design

a. Inlet and outlet barrels and risers will be constructed of reinforced concrete, corrugated metal or smooth lined corrugated plastic pipe. The minimum diameter for riser pipes is 48".
b. Riser pipes must be set into a cast-in-place concrete base or properly grouted to a pre-cast concrete base. All riser pipes constructed of material other than concrete must be set into a cast-in-place base.

c. All orifice configurations must consist of the minimum number of holes with the largest diameter that meet the detention requirements. The minimum acceptable orifice size is 0.75”.

d. A gravel filtration jacket consisting of 3” washed stone and 1” washed stone must be placed around all riser pipes. The orifice configuration must be wrapped with hard wire mesh with an appropriate opening size to prevent any stone from passing through the orifice. The 3” stone must be placed immediately adjacent to the riser pipe with the 1” stone covering the larger stone. The gravel jacket must extend sufficiently above all orifice patterns.

e. Hoods or trash racks must be installed on the riser to prevent clogging. Grate openings must be a maximum of 3 inches, center to center.

f. The riser must be placed near or within the embankment, to provide for ready maintenance access.

g. Where feasible, a drain for completely de-watering wet retention/detention facilities should be installed for maintenance purposes.

h. All outlets will be designed to be easily accessible by heavy equipment required for maintenance purposes.

Piping Requirements

a. Anti-seep collars should be installed on any piping passing through the sides or bottom of the basin to prevent leakage through the embankment.

b. Pipe inverts will be such that all sections will drain completely during dry weather.

Spillway
All basins will have provisions for a defined emergency spillway, routed such that it will flow unobstructed to the main outflow channel.

i. The emergency spillway elevation will be set at the elevation of the maximum retention/detention facility design volume.

ii. The spillway will be sized to pass the maximum design flow tributary to the retention/detention facility.

Slopes
For safety purposes and to minimize erosion, basin side slopes will not be steeper than one-foot vertical to five feet horizontal (5:1). Steeper slopes may be allowed if perimeter fencing at least 6 feet in height is provided. In general, the side slopes must not be flatter than one-foot vertical to 20 feet horizontal (20:1) and must not be steeper than one-foot vertical to 3 feet horizontal (3:1).

A minimum of one foot of freeboard will be required above the 100-year recurrence interval stormwater elevation on all detention/retention facilities.

Wet Detention Facility
Storage volume on a gravity outflow wet basin is defined as, “the volume of detention provided above the invert of the outflow device.” Any volume provided below the invert of the outflow device will not be considered as detention. At a minimum, the volume of the permanent pool should be at least 2.5 times the first flush volume for the area managed.

Volume of Permanent Pool (ft³) = 2.5 x First Flush Volume (ft³)

Wet detention facility configuration will be as follows:

i. Surface area to volume ratio must be maximized to the extent feasible.

ii. In general, depths of the permanent pool must be varied and average a minimum of three (3) feet.

iii. A minimum length to width ratio of 3:1 is preferred unless structural measures are used to extend the flow path.

iv. Wedge-shaped retention/detention facilities that are narrower at the inlet, wider at the outlet and with irregular shorelines are preferred.

v. A shelf, a minimum of 4 feet wide at a depth of one.
foot, will surround the interior of the perimeter to provide suitable conditions for the establishment of aquatic vegetation, and to reduce the potential safety hazard to the public.

vi. To avoid drawdown, a reliable supply of baseflow and/or groundwater will be required.

6. VEGETATIVE PLANTINGS ASSOCIATED WITH RETENTION/DETENTION FACILITIES

Basin designs will be accompanied by a landscaping plan that incorporates plant species adapted to the local region and indicates how aquatic and terrestrial areas will be vegetated, stabilized and maintained.

Locally adapted wetland plants shall be used in the retention/detention facility design, either along the aquatic bench, fringe wetlands, safety shelf and side slopes, or within the shallow areas of the pools.

A permanent buffer strip of natural vegetation extending at least 15 feet in width beyond the freeboard elevation will be maintained or restored around the perimeter of all stormwater storage facilities. No lawn care chemicals may be applied within the buffer area with one exception. Invasive species may be treated with chemicals by a certified applicator. Mowing is allowed twice per year. This requirement is to be cited in the subdivision restrictions of master deed documents.

7. EASEMENTS

Retention/detention basins or other stormwater management facilities will have sufficient easements for maintenance purposes. Easements will be sized and located to accommodate access and operation of equipment, spoils, deposition and other activities identified in the development’s stormwater management plan.

8. MAINTENANCE

Maintenance Access

Adequate maintenance access from a public or private right-of-way to the stormwater storage basin will be provided. The access will be on a slope of 5:1 or less, stabilized to withstand the passage of heavy equipment, and will provide direct access to the forebay, control structure, and the outlet.

Forebay Maintenance

Direct maintenance access to the forebay will be provided for heavy equipment.

A permanent vertical depth marker shall be installed in the forebay to measure sediment deposition over time, with annual documentation. Stormwater system maintenance plans will require that sediment be removed when sediment reaches a depth of equal to 50% of the depth of the forebay or 12 inches, whichever is less.

Sites requiring a permit from WCWRC must notify WCWRC upon receipt of vegetative materials. The site/project must arrange for inspection/review by WCWRC prior to installation of vegetation.
Part D.

DESIGN REQUIREMENTS
– INFILTRATION BMPs

The phrase “infiltration BMPs” describes a wide range of stormwater management practices aimed at infiltrating some fraction of stormwater runoff from developed surfaces into the soil horizon. Infiltration BMPs include several types, based on construction and performance similarities.

• Surface Infiltration Basins
• Subsurface Infiltration Beds
• Bioretention Areas
• Rain Gardens
• Pervious Asphalt, Concrete or Pavers
• Infiltration Trenches
• Other BMPs that provide infiltration: vegetated filter strips, bioswales and dry wells

Specific design requirements for infiltration BMPs as well as other BMPs follow in Parts D-O. Refer to the Soil Infiltration Testing Guidelines below to determine if a site is adequate for infiltration BMPs.

1. ROLE OF INFILTRATION BMPS

Infiltration BMPs are among the most beneficial approaches to stormwater management for a variety of reasons including:

• Reduction of the peak rate of runoff
• Reduction of the volume of runoff
• Removal of a significant portion of particulate-associated pollutants and some portion of solute pollutants.
• Recharge of groundwater and maintenance of stream baseflow.
• Allow for overlay of stormwater system with landscape requirements (such as parking lot islands) for more efficient land use.
• Allow potential use of undevelopable setbacks or road easements for stormwater management.

Quantitatively, infiltration BMPs replicate the natural hydrologic regime. During periods of rainfall, infiltration BMPs reduce the volume of runoff and help to mitigate potential flooding events. During periods of reduced rainfall, recharged water serves to provide baseflow to streams and maintain in-stream water quality. Qualitatively, infiltration BMPs are known to remove non-point source pollutants from runoff through a complex mix of physical, chemical, and biological removal processes. Infiltration promotes maintenance of the natural temperature regimes of stream systems, cooler in summer, warmer in winter, which can be critical to the aquatic ecology. Because of the ability of infiltration BMPs to reduce the volume of runoff, there is also a corresponding reduction in erosive “bankfull” conditions and downstream erosion channel morphology changes.

Infiltration BMPs are designed to infiltrate some portion of runoff during every rainfall event. During small storm events, a large percentage of the runoff may infiltrate, whereas during large storm events, the volume that infiltrates may only be a small portion of the total runoff. However, because most of the local rainfall occurs in small (less than 1-inch) events, the annual benefits of an infiltration system are significant.

2. SOIL INFILTRATION TESTING GUIDELINES

Site design must first include use of all feasible areas for infiltration until the first flush requirement is met. Most sites with enough soils to infiltrate more will likely cost less to build than hard infrastructure. A pre-application meeting with WCWRC is required during the design phase of infiltration BMPs. There must be adequate soil testing at each proposed BMP location and a soil testing plan must be developed. The soil testing plan must be presented to WCWRC for approval prior to performing testing. Tests done without approval by WCWRC may require additional testing. The purpose of the soil infiltration testing is to:

• Determine the type of soil present on a site as NRCS Soil Classifications A, B, C or D.
• Determine which infiltration BMPs are suitable at the site and at what locations.
• Obtain the required data for infiltration BMP design.
• Determine design groundwater elevation.

Soil Testing must be conducted early in the conceptual or preliminary design of the project so that information developed in the testing process can be used to direct the design. There should be a preliminary understanding of potential BMP locations prior to testing, and adjustments can be made as necessary based upon test results.

The soil investigation and evaluation may be conducted by geotechnical engineers, soils scientists, sanitarians, design engineers, licensed geologists, and other qualified professionals and technicians. If the design engineer is not experienced in soils, a professional experienced in observing and evaluating soils conditions, such as a
professional soils scientist, can provide a reliable analysis of the soil conditions. The soil testing report must be certified by a registered geotechnical engineer.

Soil infiltration testing is a process to obtain the necessary data for the design of the stormwater mitigation methods. The requirements for soil testing are:

**Step 1. Background Evaluation**
Prior to performing field testing and compiling a site plan, an inventory and review of the property must occur and include, but not be limited to the following, which shall be presented at the pre-application meeting by the applicant:
- Existing mapped soils and USDA NRCS Hydrologic Soil Group Classifications
- Existing geology
- Existing streams, water bodies, wetlands, hydric soils, floodplains, alluvial soils, stream classifications, headwaters and first order streams
- Existing topography, slope, drainage patterns and watershed boundaries
- Existing land cover/use boundaries
- Other natural or man-made features or conditions that may impact the design, such as historic uses or existing buildings
- Potential locations for infiltration BMPs
- Site environmental history (i.e., Phase I ESA)

**Step 2. Test Pits**
Test pits or deep holes allow visual observation of the soil horizons and conditions both horizontally and vertically. The use of soil borings as substitute for test pits is not allowed, as visual observation is narrowly limited in the boring and soil horizons cannot be observed in-situ.

The test pit will be a backhoe-excavated trench, 2.5 to 3 feet wide at the bottom of the excavation. The test pit should be extended to a minimum depth of 90 inches, unless bedrock or fully saturated conditions are encountered at shallower depths. The test pit may be extended to greater depths depending on the proposed BMP invert elevation, encountered soil conditions, or at the discretion of WCWRC personnel. If infiltration testing is to be performed within the test pit excavation, sides should be sloped or benched in accordance with MIOSHA requirements. The test pit excavation and infiltration testing operations will be directed by the onsite geotechnical engineer and, as such, they are responsible for site safety.

The geotechnical engineer will be responsible for logging encountered test pit conditions. The test pit must include the following information, as at a minimum:
- Soil horizons (measured from ground surface)
- Soil texture and color for each horizon
- Color patterns
- Observance of pores or roots
- Estimated type and percent coarse fragments
- Observance of hardpan or limiting layers
- Depth to water table (measured from ground surface)
- Depth to bedrock (measured from ground surface)

Following all testing, the test pits must be filled with the excavated soil and the topsoil replaced. At no time should the test pit be accessed if there is a presence of unstable material or if site constraints preclude entry.

The test pit must provide information related to the conditions at the bottom of the infiltration BMP. If the proposed BMP will be greater than 90 inches below the existing grade, deeper test pit excavation will be required.

General test pit guidelines are as follows:
- For single-family residential subdivisions with on-lot infiltration BMPs, one test pit per lot is necessary within 100 feet of the proposed BMP area. At the pre-application meeting, the suitability of test pits for septic systems meeting this requirement can be determined.
- For multi-family and high-density residential developments, one test pit per BMP area or acre is necessary.
- For large infiltration areas, such as basins, commercial, institutional and industrial, multiple test pits must be evenly distributed at the rate of four to six pits per acre of BMP area, based on discussions during the pre-application meeting.

Additional soil test pits may be necessary due to subsurface variability, water table depth or topography. The WCWRC will determine if more or fewer test pits will be required.

**Step 3. Infiltration Testing**
Infiltration tests must be conducted in the field within the test pit excavations. Laboratory permeability tests and estimated permeability rates will not be accepted for design purposes. Infiltration tests must not be conducted in the rain, within 24 hours of significant rainfall events (1/2 inch or more) or significant snowmelt, or when the air temperature is below freezing. Precautions such as heated testing water or enclosures may be required to prevent ice formation. At least one test should be conducted at the proposed bottom elevation of an infiltration BMP, and a minimum of two tests per test pit are required. The average of the test results will be used as the infiltration rate for that test pit location.
The methodologies for the tests include:

- Double-ring Infiltrometer test – estimate for vertical movement of water through the bottom of the test area.
- Percolation tests – estimate for vertical movement of water through the bottom and sides of the test area.
- Encased falling head permeability test – estimate for vertical movement of water through the bottom of the test area.

Other acceptable test methods that are available:

- Constant head double-ring infiltrometer
- ASTM D 3385, Standard Test Method for Infiltration Rate of Soils in Field Using a Double-Ring Infiltrometer.
- ASTM D 5093, Standard Method of Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring.
- Guelph permeameter
- Constant head permeameter (Amoozemeter)

### 3. SOIL INFILTRATION TESTING METHODOLOGIES

#### Double-Ring Infiltrometer

A double-ring infiltrometer consists of two concentric metal rings driven into the ground and filled with water. The outer ring helps prevent divergent flow while the drop in water level or volume in the inner ring is used to calculate infiltration rate. The infiltration rate is the amount of water per surface area and time unit which penetrates soils. The diameter of the inner ring should be 50-70 percent of the diameter of the outer ring, with a minimum inner ring diameter of four inches.

**Equipment for double-ring infiltrometer test:**

- Two concentric cylinder rings six inches or greater in height with an inner ring diameter equal to 50-70 percent of the outer ring diameter.
- Water supply
- Stopwatch or timer
- Ruler or measuring tape
- Flat wooden board for driving cylinders uniformly into soil
- Rubber mallet
- Log sheets for recording findings

**Procedure for double-ring infiltrometer:**

- Prepare level testing area
- Place outer ring in testing area; place flat board on ring and drive ring into soil a minimum of two inches.
- Place inner ring in center or outer ring; place flat board on ring and drive ring into soil a minimum of two inches. The bottom rim of both rings should be at the same level.
- The test area should be presoaked immediately prior to testing. Fill both rings with water to the rim at 30-minute intervals for one hour. The minimum water depth should be four inches. The drop in water level during the last 30 minutes of presoaking period should be applied to the following standard to determine the time interval between readings:
  - If water level drop is two inches or more, use 10-minute measure intervals.
  - If water level drop is less than two inches, use 30-minute measurement intervals.
- Obtain a reading of the drop in water level in the center ring at appropriate time intervals. After each reading, refill both rings to water level indicator mark or rim. Measurement to the water level in the center ring should be made from a fixed reference point and should continue at the interval determined until a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of ¼ inch or less of drop between the highest and lowest readings of four consecutive readings.
- The drop that occurs in the center ring during final period or the average stabilized rate, expressed as inches per hour, should represent the measured infiltration rate for that test location divided by a factor of safety of 2.

#### Percolation Test

**Equipment for percolation test:**

- Post hole digger or auger
- Water supply
- Stopwatch or timer
- Ruler or measuring tape
- Log sheets for recording findings
- Knife blade or sharp-pointed instrument (for soil scarification)
- Coarse sand or fine gravel
- Object for fixed reference point during measurement (nail, toothpick, etc.)

**Procedure for percolation test:**

This percolation test methodology is based largely on the criteria for onsite sewage investigation of soils. A 24-hour pre-soak is generally required as infiltration systems, unlike wastewater systems, will not be continuously saturated.

- Prepare level testing area
- Prepare hole having a uniform diameter of 6-10 inches and depth of 8-12 inches. The bottom and sides of the hole should be scarified with a knife blade
Section V: Design Requirements For Stormwater Management Systems

or sharp-pointed instrument to completely remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate. Loose material should be removed from the hole.

- (Optional) Two inches of coarse sand or fine gravel may be placed in the bottom of the hole to protect soil from scouring and clogging of the pores.
- The drop in the water level during the last 30 minutes of the final presoaking period should be applied to the following standard to determine the time interval between readings for each percolation hole:
  - If water remains in the hole, the interval for readings during the percolation test should be 30 minutes.
  - If no water remains in the hole, the interval for readings during the percolation test may be reduced to 10 minutes.
- After the final presoaking period, water in the hole should be again adjusted to a minimum depth of six inches and readjusted when necessary after each reading. A nail or marker should be placed at a fixed reference point to indicate the water refill level. The water level depth and hole diameter should be recorded.
- Measurement to the water level in the individual percolation holes should be made from a fixed reference point and should continue at the interval determined from the previous step for each individual percolation hole until a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of ¼ inch or less of drop between the highest and lowest readings of four consecutive readings.
- The drop that occurs in the percolation hole during the final period, expressed as inches per hour, should represent the percolation rate for that test location.
- The average measured rate must be adjusted to account for the discharge of water from both the sides and bottom of the hole and to develop a representative infiltration rate. The average final percolation rate should be adjusted for each percolation test according to the formula:

\[
\text{Infiltration Rate} = \frac{\text{Percolation Rate}}{R_f}
\]

Where the Reduction Factor is given by:

\[
R_f = \frac{2d_t - \Delta d}{DIA} + 1
\]

Where:

- \(d_t\) = Initial Water Depth (in)
- \(\Delta d\) = Average/Final Water Level Drop (in)
- \(DIA\) = Diameter of the Percolation Hole (in)

The percolation rate is simply divided by the reduction factor, as calculated above, to yield the representative infiltration rate. In most cases, the reduction factor varies from about two to four depending on the percolation hole dimensions and water level drop – wider and shallower tests have lower reduction factors because proportionately less water exfiltrates through the sides.

Encased Falling Head Permeability Test*

The encased falling head procedure is utilized to evaluate the vertical infiltration rate without allowing any lateral infiltration. This test is not appropriate in gravelly soils or in other soils where a good seal with the casing cannot be established.

Equipment for encased falling head permeability test:
- 6-inch diameter casing
- Water supply
- Stopwatch or timer
- Ruler or measuring tape
- Log sheets for recording findings
- Object for fixed reference point during measurement (nail, toothpick, etc.)

Procedure for encased falling head permeability test:
- Embed a solid 6-inch diameter casing into the native soil at the elevation of the proposed BMP bottom. Ensure the embedment provides a good seal around the pipe casing so the percolation will be limited to the 6-inch plug of the material within the casing. This method can also be used when testing within hollow stem augers, provided the driller and tester are reasonably certain that a good seal has been achieved between the soil and the auger. Note: Infiltration testing must be performed in conjunction with test pit excavations.
- Fill the pipe with clean water a minimum of one foot above the soil to be tested, and maintain this depth for at least 4 hours (or overnight if the test pit soils are mostly clay) to presoak the native material. Any soil that sloughed into the hole during the soaking...
period should be removed. In sandy soils with little or no clay or silt, the 4 hour pre-soak period may not be necessary. If after filling the hole twice with 12 inches of water, the water drains completely away in less than 10 minutes (per filling), when testing clean, sandy soils, the test can proceed immediately.

- To conduct the first trial of the test, fill the pipe to approximately 12 inches above the soil and measure the water level to the nearest 0.01 foot (1/8 inch). Alternative water head heights may be used for testing provided the presaturation height is adjusted accordingly and the water head height used in infiltration testing is 50% or less than the water head height in the proposed stormwater system during the design storm event. The level should be measured with a tape or other device with reference to a fixed point. The top of the pipe is often a convenient reference point. Record the exact time.

- Measure the water level to the nearest 0.01 foot (1/8 inch) at 10-minute intervals for a total period of 1 hour (or 20-minute intervals for 2-hours in slower soils) or until all of the water has drained. In faster draining soils (sands and gravels), it may be necessary to shorten the measurement interval in order to obtain a well defined infiltration rate curve. Successive trials should be run until the percent change in measured infiltration rate between two successive trials is minimal. The test should be discontinued if the infiltration rate between successive trials increases. At least three trials must be conducted. After each trial, the water level is readjusted to the 12 inch level. Enter results into the data log sheets.

- The average infiltration rate over the last trial should be used to calculate the unfactored infiltration rate. The final rate must be reported in inches per hour.

- Upon completion of the testing, the casing should be pulled and the test pit backfilled.


### 5. CONSIDERATION OF INFILTRATION RATE IN DESIGN AND MODELING APPLICATION

For the purposes of site suitability, areas with tested soil infiltration rates as low as 0.1 inches per hour may be used for infiltration BMPs. However, in the design of these BMPs and the sizing of the BMP, the designer should incorporate a safety factor. A safety factor of two (2) must be used in the design of stormwater infiltration systems. Therefore a measured infiltration rate of 0.5 inches per hour should generally be considered as a rate of 0.25 inches per hour in design.

Infiltration systems can be modeled similarly to traditional detention basins. The marked difference with modeling infiltration systems is the inclusion of the infiltration rate, which can be considered as another outlet. For modeling purposes, it is convenient to develop infiltration rate that vary (based on the infiltration area provided as the system fills with runoff) for inclusion in the Stage-Storage-Discharge table (SSDT).

### 6. INFILTRATION BMP GUIDELINES

The purpose of these guidelines is to provide designers, reviewers, and other interested parties with specific instructions for the successful construction and long-term performance of infiltration BMPs. These guidelines fall into three categories:

- Site conditions and constraints
- Design considerations
- Construction requirements

#### a. Site Conditions and Constraints

i. It is necessary to maintain at least a 3-foot clearance above the seasonally high water table for most BMPs (e.g., basins serving
large areas). This reduces the likelihood that temporary groundwater mounding will affect the system, and allows sufficient distance of water movement through the soil to assure adequate pollutant removal. Note: The clearance above the seasonally high water table for rain gardens can be 2-feet.

ii. Soils underlying infiltration devices should have infiltration rates between 0.1 and 10 inches per hour, which in most developments should result in reasonably sized infiltration systems. Where soil permeability is extremely low, infiltration may still be possible but the surface area required could be large, and other volume reduction methods may be warranted. Undisturbed Hydrologic Soil Groups A, B, and C often fall within the acceptable range and cover most of the state. Soils with rates in excess of 6.0 inches per hour may require an additional soil buffer (such as an organic layer over the bed bottom) if the Caption Exchange Capacity (CEC) is less than 10 and pollutant loading is expected to be significant.

iii. Infiltration BMPs must be sited to minimize any risk to groundwater quality, typically at least 50 horizontal feet from individual water supply wells, 75 horizontal feet from community or municipal Type IIb and III water supply wells and 200 horizontal feet from community or municipal Type I or IIa water supply wells. Horizontal separation distances or buffers may also be appropriate from special geologic features, such as fractures, traces and faults, depending on water supply sources.

iv. Infiltration BMPs should be sited so that they present no threat to sub-surface structures, typically at least 10 feet down gradient or 100 feet up gradient from building basement foundations (see specific BMP for applicable setbacks) and 100 feet from septic system drainfields unless specific circumstances allow for reduced separation distances.

v. In general, soils of Hydrologic Soil Group D will not be suitable for infiltration. Similarly, areas of floodplains and areas in close proximity to wetlands and streams will generally not be suitable for infiltration (due to high water table and/or low permeability). In developing areas that were previously used for agricultural purposes, the designer should consider the past patterns of land use. Areas that were suitable for cultivation without tilling will likely be suitable for some level of infiltration. Areas that were left out of cultivation often indicate locations that are too wet or too rocky, and will likely not be suitable for infiltration.

b. Design Considerations

i. Infiltration facilities may not be placed on compacted fill. Infiltration in native soil without prior fill or disturbance is preferred but not always possible. Areas that have experienced historic disturbance or fill are suitable for infiltration provided sufficient time has elapsed and the soil testing indicates the infiltration is feasible. In disturbed areas it may be necessary to infiltrate at a depth that is beneath soils that have previously been compacted by construction methods or long periods of mowing. Such areas must be tilled to 18 inches or more. If the historical fill contains a significant amount of debris, it may not be considered suitable for infiltration.

ii. A level infiltration area (1.5% or less slope) is preferred. Bed bottoms should always be graded into the existing soil mantle, with terracing as required to construct flat structures. Sloped bottoms tend to pool and concentrate water in small areas, reducing the overall rate of infiltration and longevity of the BMP. Infiltration areas should be flat or nearly so. Note: Bioswales proposed with flat bottoms and grass vegetation do not work and will not be approved.

iii. The soil mantle should be preserved to the maximum extent possible, and excavation should be minimized. Those soils that do not need to be disturbed for development should be left undisturbed. Macropores can provide a significant mechanism for water movement in infiltration systems, and the extent of macropores often decreases with depth. Maximizing the soil mantle also increases the pollutant removal capacity and reduces concerns about groundwater mounding. Therefore, excessive excavation for the construction of infiltration systems is strongly discouraged.

iv. Isolate “hot spot areas.” Site plans that include ‘hot spots’ have special design considerations. ‘Hot spots’ are most often associated with some industrial uses and high traffic – gasoline stations, vehicle maintenance areas, and high intensity commercial uses (fast food restaurants, convenience stores, etc.). These “hot spots” are defined in Section VIII, Part C. Infiltration may occur in areas of hot spots provided pretreatment and pollution prevention measures are suitable to address concerns. Pretreatment requirements
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need to be analyzed, especially for ‘hot spots’ and areas that produce high sediment loading. Pretreatment devices that operate effectively in conjunction with infiltration include grass swales, vegetated filter strips, settling chambers, oil/grit separators, constructed wetlands, sediment sumps, and water quality inserts. Selection of pretreatment should be guided by the pollutants of greatest concern, site by site, depending upon the nature and extent of the land development under consideration. Selection of pretreatment techniques will vary depending upon whether the pollutants are of particulate (sediment, phosphorus, metals, etc.) versus soluble (nitrogen, dissolved phosphorus, and others) nature. Types of pretreatment (i.e., filters) should be matched with the nature of the pollutants expected to be generated. For example gas stations require hydrocarbon filters in all catch basins on the site.

v. The loading ratio of impervious area to bed bottom area must be considered. One possible reason for infiltration system failure is the design of a system that attempts to infiltrate a substantial volume of water in a very small area. Infiltration systems may work better when the water is “spread out”. The loading ratio describes the ratio of impervious drainage area to infiltration area, or the ratio of total drainage area to infiltration area. In general, the following loading ratios are recommended (some situations, such as highly permeable soils, may allow for higher loading ratios):

- Maximum impervious loading ratio of 8:1 relating impervious drainage area to infiltration area.
- A maximum total loading ratio of 10:1 relating total drainage area to infiltration area.

vi. In retention/detention facilities where soil amendments and/or underdrains are present the hydraulic head or depth of water may be required to be limited. The total effective depth of water should generally not be greater than two feet. The design of any infiltration system must avoid any excessive pressure and potential sealing of the bed bottom. Typically the water depth is limited by the loading ratio and the drawdown time, and is not an issue.

vii. Drawdown time must be considered. In general, infiltration BMPs should be designed so that they completely empty within 48 hours.

viii. All infiltration BMPs should be designed with a positive overflow that discharges excess volume in a non-erosive manner, and allows for controlled discharge during extreme rainfall events or frozen bed conditions. Infiltration BMPs should never be closed systems dependent entirely upon infiltration in all situations. Discharge must be directed in a manner to avoid property damage and have an unimpeded route to a receiving channel or outlet.

ix. Geotextiles should be incorporated into the design as necessary in certain infiltration BMPs. Infiltration BMPs that are subject to soil movement and deposition must be constructed with suitably permeable non-woven geotextiles to prevent movement of fines and sediment into the infiltration system. The designer is encouraged to err on the side of caution and use geotextiles as necessary at the soil/BMP interface.

x. For basins, the middle of the basin excavation should include larger diameter rock filters in all catch basins on the site.

c. Construction Requirements

i. Do not compact soil infiltration beds during construction. Prohibit all heavy equipment from the infiltration area and minimize all other traffic. Equipment should be limited to vehicles that will cause the least compaction, such as low ground pressure (maximum 4 pounds per square inch) tracked vehicles.

ii. Protect the infiltration area from sediment until the surrounding site is completely stabilized. Methods to prevent sediment from washing into BMPs should be clearly shown on plans. Runoff from construction areas should be prevented from draining to infiltration BMPs, with techniques such as diversion berms, and immediate vegetative stabilization.

iii. Where vegetation is a component of an infiltration BMP, it must be established prior to putting the device into use.

iv. All infiltration areas shall be tested for permeability after construction by the owner/developer, and must perform to design permeability.
Part E.
DESIGN REQUIREMENTS
– BIORETENTION BASINS

1. GENERAL REQUIREMENTS
Bioretention systems are flexible in design and can vary in complexity according to site conditions and runoff volume requirements. Bioretention areas are not to be confused with constructed wetlands or wet retention/detention facilities, which permanently pond water. Bioretention systems can increase time of concentration and store additional stormwater runoff volume below grade. Bioretention systems have locally adapted vegetation beds atop 3 feet of amended soils over an aggregate base. Sites with favorable infiltration typically don’t call for bioretention. In those cases, rain gardens may provide adequate infiltration volume. Refer to Part F. If an underdrain is used there will be no allowance for infiltration credits. In-situ soils should be decompacted. See Figure 3 for more detail on bioretention systems.

Locally adapted species that are appropriate for the proposed hydric conditions are acceptable. A mix of native grasses, forbs, shrubs and trees is preferred.

Bioretention basins require maintenance a minimum of twice/year, early in the growing season and in the fall, to prevent noxious weed proliferation. This can include hand weeding, burns, herbicide or mowing. Planning tools shall be included to provide management that ensures their long-term functionality (deed restrictions, covenants, easements, budget, etc.). A maintenance plan is required. See Low Impact Development Manual for Michigan for guidance.

Sites requiring a permit from WCWRC must notify WCWRC upon receipt of vegetative materials. The site/project must arrange for inspection/review by WCWRC prior to installation of vegetation.

2. PROHIBITIONS
Bioretention will not be allowed in the following:

a. Within floodplains
b. Where the estimated high ground water elevation will be within 3 feet of the bottom of the facility.

3. SETBACKS

<table>
<thead>
<tr>
<th>Setback from</th>
<th>Minimum Distance (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property Line</td>
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<tr>
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<td>75</td>
</tr>
<tr>
<td>Septic System Drainfield (primary &amp; reserve)</td>
<td>50</td>
</tr>
</tbody>
</table>

*minimum with slopes directed away from building

4. TESTING REQUIREMENTS

a. Follow the Soil Infiltration Testing Guidelines Part D, Design Requirements for Infiltration BMPs.
b. The overall site shall be evaluated for potential infiltration systems early in the design process.

5. BIORETENTION COMPONENTS/CONFIGURATION
The primary components (and subcomponents) of a bioretention system are:

Pretreatment
(where required, See Part D.6, “Infiltration Guidelines”)
Flow enters through a pretreatment device suitable for site conditions and pollutants of concern prior to entry into the bioretention system. The pretreatment device can be a forebay, sump or other design as appropriate. The device
Section V: Design Requirements For Stormwater Management Systems

must be designed to that sediment is captured and that regular removal can occur. The sediment removal method must be included in the maintenance plan.

- Runoff emanating from defined hot spot requires pretreatment
- See Low Impact Development Manual for Michigan, Table 8.2 for guidance.

Flow Entrance
Water may enter via:
- An inlet (e.g. flared end section)
- Sheet flow into the facility over grassed areas
- Curb cuts with grading for sheet flow entrance
- Roof leaders with direct surface connection
- Trench drain
- Pipe
In all cases entering velocities must be non-erosive.

Positive Overflow
- Will discharge runoff during large storm events when the subsurface/surface storage capacity is exceeded or when the ground is frozen. Discharge must be directed in a manner to avoid property damage and have an unimpeded route to a receiving channel or outlet.
- Examples include beehive yard basin, curb inlet, catch basin, weir, etc.

Bioretention Facility Area
- Maximum depth of ponding is 8 inches. However, if sufficient infiltration capacity can be demonstrated, additional ponding may be allowed above grade. Ponding shall not exceed 8" for more than 6 hours after the design event.
- An overflow must be provided and must be directed in a manner to avoid property damage and have an unimpeded route to a receiving channel or outlet.
- Plants must be salt tolerant if in a location that would receive snowmelt chemicals

Planting
Proper plant selection is essential for bioretention areas to be effective. Typically, native floodplain or wet meadow plant species are best suited to the variable environmental conditions encountered in a bioretention system. Live perennial plant material in plug form should be utilized and installed with a maximum spacing of 2 feet on-center. Seed is not an acceptable method for plant establishment below the surface storage elevation unless a method of germination and stabilization is provided. Planting with seed has highly unreliable results due to water flows displacing seed. If seeding is proposed, only natives (as defined by Michigan Flora, michiganflora.net) and annuals are allowable. Annual seed is allowed in an amount necessary to stabilize the limits of disturbance. If live plantings are proposed, native grasses, forbs, shrubs and trees are preferred. Cultivars and non-native perennials are allowable if approved by WCWRC. Plants listed on the WCWRC Rain Garden Plant List are acceptable. Invasive species are not allowed (see the City of Ann Arbor’s invasive species list). Plantings should be locally adapted and appropriate to the hydric conditions proposed. For more information on individual species, see “Plants for Stormwater Design: Species Selection for the Upper Midwest” by Daniel Shaw & Rusty Schmidt.

Plantings should be spaced according to each species size and growth potential to allow for sufficient coverage. If proposed, the application method and seed mix must

Figure 3. Bioretention Design Schematic

Figure adapted from: Prince George’s County Bioretention Manual with modifications by Cahill Associates, 2004
Section V: Design Requirements For Stormwater Management Systems

be submitted for approval. Upon installation, vegetative establishment must be documented and approved as per the soil erosion and sedimentation control permit. Planting periods will vary, but in general, planting should be from mid-March through early June, or mid-September through mid-October.

Planting soil must be a loam topsoil capable of supporting a healthy vegetative cover. Soils must be amended with a composted organic material. Soils must be free of construction debris and subsoils. A recommended soil blend is 20-30% compost.

Soils must have a clay content less than 10% (a small amount of clay is beneficial to absorb pollutants and retain water), be free of toxic substances and unwanted plant material and have a 20-30% organic matter content. Additional organic matter can be added to the soil to increase water holding capacity (tests should be conducted to determine volume storage capacity of amended soils).

Wood chips must be avoided as they tend to float during inundation periods. Shredded mulch is preferred.

6. EASEMENTS

Bioretention systems shall have sufficient easements for maintenance purposes. Easements will be sized and located to accommodate access and operation of equipment, spoils deposition, and other activities identified in the development’s stormwater system maintenance plan.

7. CALCULATIONS

Infiltration Area
The infiltration area is the bottom area of the bioretention system defined as:

\[
\text{Infiltration Area} = \frac{\text{Area of Bioretention System at Ponding Depth} + \text{Bottom Area of Bioretention System}}{2}
\]

This is the area to be considered when evaluating the Loading Rate to the bioretention system.

Volume Reduction Calculations
The storage volume of a bioretention system is defined as the sum total of the surface and subsurface void volumes beneath the level of the discharge invert. Inter-media void volumes may vary considerably based on design variations.

The volume of a bioretention system has three components:

1. Surface Storage Volume \( (\text{ft}^3) = \text{Bed Area (ft}^2) \times \text{Average Design Water Depth} \)
2. Soil Storage Volume \( (\text{ft}^3) = \text{Length} \times \text{Width} \times \text{Depth} \times \text{Void Ratio of Storage Material} \)
3. Infiltration Volume = Bed Bottom Area \( (\text{ft}^2) \) \times \text{Infiltration design rate (in/hr)} \times 6^* (hr) \times (1/12)

*Infiltration Period is the time when bed is receiving runoff and capable of infiltrating at the design rate. This has been conservatively estimated as 6 hours.

\[
\text{Bioretention System Volume} = \text{Surface Storage Volume} + \text{Soil Storage Volume} + \text{Infiltration Volume}
\]

Sizing Criteria
a. **Surface area** is dependent upon storage volume requirements but should generally not exceed a maximum loading ratio of 8:1 (impervious drainage area to infiltration area; see Design Requirements for Infiltration Systems for additional guidance on loading rates.)
b. **Surface side slopes** must be gradual. The maximum allowable slope for bioretention systems is 5:1.
c. **Surface ponding depth** must not exceed 8 inches and will empty within 6 hours.
d. **Ponding area** must provide sufficient surface area to meet required storage volume without exceeding the design ponding depth. The subsurface storage/infiltration bed is used to supplement surface storage where appropriate.

8. CONSTRUCTION

The following is a typical construction sequence; alterations will be necessary depending on design variations.

Note for all construction steps: Erosion and sediment control methods must adhere to the latest requirements of the Michigan DEQs Soil Erosion and Sedimentation Control Program.

a. Install temporary sediment control BMPs as shown on the plans.
b. Complete site grading, minimizing compaction as much as possible. If applicable, construct curb cuts or other inflow entrances but provide protection so that
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- Drainage is prohibited from entering the bioretention system construction area.
- Excavate the bioretention system to the proposed invert depth and scarify the existing soil surfaces. Do not compact in-situ soils.
- Backfill the bioretention system with amended soil as shown on plans and specifications. Overfilling is recommended to account for settlement. Light hand tamping is acceptable if necessary.
- Presoak the planting soil prior to planting vegetation to aid in settlement.
- Complete final grading to achieve proposed design elevations, leaving space for upper layer of compost, mulch or topsoil as specified on plans. Decompact in-situ soils.
- Mulch and install erosion protection at surface flow entrances where necessary.
- Plant vegetation according to planting plan.
- Once the drainage area is completely and permanently stabilized, the bioretention system should be brought online.
- Removal of weeds and unwanted species is usually needed in the first 1-3 years following installation. Replant bare areas greater than 10 square feet.
- Permeability shall be reverified by infiltration prior to acceptance.

9. MAINTENANCE

Properly designed and installed bioretention systems require regular maintenance.
- While vegetation is being established, hand weeding or other weed control methods will be required. Thereafter, twice annual weeding is typical. Invasive plants should be controlled early in their establishment before they spread.
- Fall and spring cleanup must be performed including cutting down dead perennials, removal of weeds and removal or mulching of leaves and stems.
- Mulch must be re-spread when erosion is evident and be replenished annually. Once every 2 to 3 years the entire area may require mulch replacement.
- Bioretention systems must be inspected at least two times per year for sediment buildup, erosion, vegetative conditions, etc. Sediment must be removed from forebay and riprap/stone protected areas at least twice per year. Sediment should be removed before its accumulation negatively impacts the performance of the pretreatment device.
- During periods of extreme drought, bioretention systems may require watering.
- Bioretention systems can be mowed twice per year.
- Trees and shrubs must be inspected twice per year to evaluate health.
- Invasive species must be removed on an annual basis and disposed of in compliance with local, state and federal regulations. No chemical shall be used with one exception. Invasive species can be treated chemically by a certified applicator.
Part E.

DESIGN REQUIREMENTS – RAIN GARDENS

1. GENERAL REQUIREMENTS

Rain gardens can be useful in new construction or retrofit projects. They are shallow detention areas that are sized to store small storms and overflow in larger events. Rain gardens can pool up to 8" of runoff. Typically, soils in Washtenaw County allow these basins to infiltrate their design storage in a short period of time. Deeper-rooted vegetation expedites this process. Under-drainage is not typical. Construction typically involves grading, amendment with compost and a controlled overflow.

Locally adapted species that are appropriate for the proposed hydric conditions are acceptable. A mix of native grasses, forbs, shrubs and trees is preferred.

Rain gardens require maintenance a minimum of twice / year, early in the growing season and in the fall, to prevent noxious weed proliferation. This can include hand weeding, burns, herbicide or mowing. Sediment traps will need to be cleaned out twice per year. Planning tools shall be included to provide management that ensures their long-term functionality (deed restrictions, covenants, easements, budget, etc.). A maintenance plan is required. See Low Impact Development Manual for Michigan for guidance.

Figure 4.
Rain Garden Schematic

Illustration by InSite Design Studio, Inc.
Section V: Design Requirements For Stormwater Management Systems

2. PROHIBITIONS

Rain Gardens will not be allowed in the following:

a. Areas with known pollution as identified by the MDEQ.
b. Where the estimated high ground water elevation will be within 2 feet of the bottom of the facility.
c. Where snow removal activities will repeatedly pile snow and salt, which may damage plants.

3. SETBACKS

Setback Distances

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*minimum with slopes directed away from building

4. TESTING REQUIREMENTS

a. Follow the Soil Infiltration Testing Guidelines for testing requirements within the Design Requirements for Infiltration BMPs section.
b. The overall site must be evaluated for potential infiltration systems early in the design process.

5. RAIN GARDEN COMPONENTS/CONFIGURATION

The primary components (and subcomponents) of a rain garden system are:

Pretreatment (where required See Part D.6 “Infiltration Guidelines”)
- Flow through a sediment trap suitable for site conditions and pollutants of concern prior to entry into the rain garden.
- Runoff emanating from defined hot spot requires pre-treatment See Low Impact Development Manual for Michigan, Table 8.2 for guidance.
  • Runoff emanating from paved surfaces requires a sediment trap sufficient for heavy sands to drop out. This can be a small depression or stone berm sufficient to dissipate energy.
  • Rooftop runoff requires no pre-treatment.

Flow Entrance
- Water may enter via an inlet (e.g. flared or stone end section), sheet flow, curb cuts, roof leaders, swale, etc.
- Entering velocities must be non-erosive

Positive Overflow
- Rain gardens will require an overflow outlet, for periods when the subsurface/surface storage capacity is exceeded.
- Examples include beehive yard basin, curb inlet, catch basin, weir, road right-of-way, etc.
- An overflow area is required to convey discharge safely within an easement to the storage facility, road right-of-way, swale, drain, or other adequate drainage facility. Discharge must be directed in a manner to avoid property damage and have an unimpeded route to a receiving channel or outlet.

Ponding Area
- Maximum depth of ponding is 8 inches.
- Soils within infiltration areas should be turned to a depth of 18” and amended with compost and/or topsoil to create planting soils with a minimum 20-30% organic material (compost), 70-80% topsoil.

Planting
- Plant species shall be selected to tolerate saturated spring conditions and dry summer conditions. See

- Live perennial plant material in plug form should be utilized and installed with a maximum spacing of 2 feet on-center. Seed is not an acceptable method for plant establishment below the surface storage elevation unless a method of germination and stabilization is provided. Planting with seed has highly unreliable results due to water flows displacing seed. Establishment by seed is appropriate only in the zone above the first flush elevation.
- If seeding is proposed, only natives (as defined by Michigan Flora, michiganflora.net) and annuals are allowable. Annual seed is allowed in an amount necessary to stabilize the limits of disturbance. If live plantings are proposed, native grasses, forbs, shrubs and trees are preferred. Cultivars and non-native perennials are allowable if approved by WCWRC. Plants listed on the WCWRC Rain Garden Plant List are acceptable. Invasive species are not allowed (see the City of Ann Arbor’s invasive species list). Plantings should be locally adapted and appropriate to the hydric conditions proposed. For more information on individual species, see “Plants for Stormwater Design: Species Selection for the Upper Midwest” by Daniel Shaw & Rusty Schmidt.
- Upon installation, vegetative establishment must be documented and approved as per the soil erosion and sedimentation control permit.
- Optimal planting time is between mid-May and mid-June or mid-September to mid-October. Other planting times require irrigation for plant establishment.
- Plants shall be planted at a density sufficient to achieve cover within the first two years.
- A minimum of 2” depth shredded mulch shall be required to retain soil moisture and control weeds in year 1. The second growing season, the garden should be densely covered with plants and should inhibit weeds without additional mulch.

6. EASEMENTS

Rain Gardens shall have sufficient easements for maintenance purposes. Easements will be sized and located to accommodate access and other activities identified in the development’s stormwater system maintenance plan.

7. CALCULATIONS

Infiltration Area
The infiltration area is the bottom area of the rain garden defined as:

\[
\text{Infiltration Area} = \frac{\text{Area of Rain Garden at Ponding Depth} + \text{Bottom Area of Rain Garden}}{2}
\]

This is the area to be considered when evaluating the Loading Rate to the rain garden.

Volume Reduction Calculations
The storage volume of a rain garden is defined as the sum of the surface and subsurface void volumes beneath the level of the discharge invert. Inter-media void volumes may vary considerably based on design variations.

The volume of a Rain Garden has three components:
1. Surface Storage Volume (ft\(^3\)) = Bed Area (ft\(^2\)) x Average Design Water Depth
2. Soil Storage Volume (ft\(^3\)) = Length x Width x Depth x Void Ratio of Storage Material
3. Infiltration Volume = Bed Bottom Area (ft\(^2\)) x Infiltration design rate (in/hr) x 6*(hr) x (1/12)

*Infiltration Period is the time when bed is receiving runoff and capable of infiltrating at the design rate. This has been conservatively estimated as 6 hours.

\[
\text{Rain Garden Volume} = \text{Surface Storage Volume} + \text{Subsurface Storage} + \text{Infiltration Volume}
\]

Sizing Criteria
a. **Surface area** is dependent upon storage volume requirements but should generally not exceed a maximum loading ratio of 8:1 (impervious drainage area to infiltration area; see Design Requirements for Infiltration Systems for additional guidance on loading rates.)
b. **Surface Side slopes** must be gradual. The maximum allowable slope for a rain garden is 3:1.
c. **Surface ponding depth** must not exceed 8 inches.
d. **Ponding area** must provide sufficient surface area to meet required storage volume without exceeding the design ponding depth. The subsurface storage/infiltration bed is used to supplement surface storage where appropriate.
e. **Planting soil depth** must be at least 18 inches where only herbaceous plant species will be utilized. If trees and woody shrubs will be used, soil media depth may be increased depending on plant species (native soils can be used as planting soil or modified on many sites).
8. CONSTRUCTION

The following is a typical construction sequence; however alterations will be necessary depending on design variations.

Note for all construction steps: Erosion and sediment control methods must adhere to the latest requirements of the Michigan DEQs Soil Erosion and Sedimentation Control Program.

a. Install temporary sediment control BMPs as shown on the plans.
b. Complete site grading, minimizing compaction as much as possible. If applicable, construct curb cuts or other inflow entrances but provide protection so that drainage is prohibited from entering the rain garden construction area.
c. Excavate the rain garden to the proposed invert depth and scarify the existing soil surfaces. Do not compact in-situ soils.
d. Backfill the rain garden with amended soil as shown on plans and specifications. Overfilling is recommended to account for settlement. Light hand tamping is acceptable if necessary.
e. Presoak the planting soil prior to planting vegetation to aid in settlement.
f. Complete final grading to achieve proposed design elevations, leaving space for upper layer of compost, mulch or topsoil as specified on plans.
g. Plant vegetation according to planting plan.
h. Mulch and install erosion protection at surface flow entrances where necessary.
i. Once the drainage area is completely and permanently stabilized, the rain garden should be brought online.
j. Removal of weeds and unwanted species is usually needed in the first 1-3 years following installation.

9. MAINTENANCE

Properly designed and installed rain garden systems require regular maintenance.

a. While vegetation is being established, hand weeding or other weed control methods will be required. Thereafter, twice annual weeding is typical. Invasive plants should be controlled early in their establishment before they spread.
b. Fall and spring cleanup must be performed including cutting down dead perennials, removal of weeds and removal or mulching of leaves and stems.
c. Mulch must be re-spread when erosion is evident and be replenished annually. Once every 2 to 3 years the entire area may require mulch replacement.
d. Rain garden systems must be inspected at least two times per year for sediment buildup, erosion, vegetative conditions, etc. Sediment must be removed from forebay and riprap/stone protected areas at least twice per year. Sediment should be removed before its accumulation negatively impacts the performance of the pretreatment device.
e. During periods of extreme drought, rain garden systems may require watering.
f. Rain Garden systems can be mowed twice per year.
g. Trees and shrubs must be inspected twice per year to evaluate health.
h. Invasive species must be removed on an annual basis and disposed of in compliance with local, state and federal regulations. No chemical shall be used with one exception. Invasive species can be treated chemically by a certified applicator.

Figure 5. Rain Garden Conceptual Design

Sites requiring a permit from WCWRC must notify WCWRC upon receipt of vegetative materials. The site/project must arrange for inspection/review by WCWRC prior to installation of vegetation.
1. GENERAL REQUIREMENTS

Pervious pavement is an infiltration technique that combines stormwater infiltration, storage, and structural pavement. It consists of permeable surface underlain by a storage reservoir. Pervious pavement is well suited for parking lots, walking paths, sidewalks, plazas, athletic courts, and other similar uses. It has also been successful on roadways. Variations on the surface material include: Pervious Asphalt, Pervious Concrete, Permeable Paver Blocks, or Reinforced Turf (see Figure 6 and Figure 7).

a. Pervious pavement and infiltration beds must not be placed on areas of recent fill or compacted fill. Any grade adjustments requiring fill must be done using the stone sub-base material. Areas of historical fill (>5 years) may be considered for pervious pavement.

b. The bed bottom is not compacted; however the stone sub-base is placed in lifts and lightly rolled according to specifications.

c. Bed bottoms must be level or nearly level. Sloping bed bottoms will lead to areas of ponding and reduced stormwater distribution within the bed.

d. All systems must be designed with an overflow system. Water within the subsurface stone bed must never rise to the level of pavement surface. Inlets can be used for cost-effective overflow structures. All beds must empty within 48 hours.

e. Infiltration beds must also be able to convey and mitigate the peak of less-frequent, more intense storms such as the 100-year recurrence interval. Control in beds is usually provided in the form of an outlet control structure. A modified inlet box with an internal weir and low-flow orifice is a common type of control structure. The specific design of these structures may vary, depending on factors such as allowable discharge rate and storage requirements, but it always must include positive overflow from the system.

f. The subsurface bed and overflow may be designed and evaluated in the same manner as a detention basin to demonstrate the mitigation of peak flow rates. In this manner, the need for a detention basin may be eliminated or the basin may be significantly reduced in size.

g. A weir plate or weir within an inlet or overflow control structure may be used to maximize the water level in the stone bed while providing sufficient cover for overflow pipes.

h. Perforated pipes may be used to evenly distribute runoff over the entire bed bottom. Continuously perforated pipes must connect structures (such as cleanouts and inlets). Pipes must lay flat and provide the uniform distribution of water. Depending on size, these pipes may provide additional storage volume.

i. Infiltration areas must be located within the immediate project area in order to control runoff at its source. Expected use and traffic demands must also be considered in pervious pavement placement.

j. An impervious water stop should be placed along infiltration bed edges where pervious pavement meets standard impervious pavements.

k. The underlying infiltration bed is typically 12 to 36 inches deep and comprised of clean, uniformly-graded aggregate. A maximum of 30% will be approved for void space when determining storage volumes. AASHTO No. 3, which ranges 1.5 – 2.5 inch in gradation, is often used. Depending on local aggregate availability, both larger and smaller sized aggregate have been used. The critical requirements are that the aggregate be uniformly-graded, clean washed, and contain a significant void content. The depth of the bed is a function of stormwater storage requirements, frost depth considerations, site grading, and anticipated loading.

l. While most pervious pavement installations are underlain by an aggregate bed, alternative subsurface storage products may also be employed.

m. All pervious pavement installations must have a backup method for water to enter the stone storage bed in the event that the pavement fails or is altered. In uncurbed lots, this backup drainage may consist of an unpaved 2 ft wide stone edge drain connected directly to the bed. In curbed lots, inlets with sediment traps may be required at low spots. Backup drainage elements will ensure that functionality of the infiltration system if the pervious pavement is compromised.

n. In those areas where the threat of spills and groundwater contamination is likely, pretreatment systems may be required before any infiltration occurs. In hot spots, such as truck stops and fueling stations, the appropriateness of pervious pavement must be carefully considered. A stone infiltration bed located beneath standard pavement, preceded by spill control and water quality treatment, may be more appropriate.
Section V: Design Requirements For Stormwater Management Systems

2. PROHIBITIONS

Pervious pavement will not be allowed in the following:

a. Areas with known pollution as identified by the MDEQ
b. Within floodplains
c. Where the estimated high ground water elevation will be within 3 feet of the bottom of the facility

3. SETBACKS

Setback Distances

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*minimum with slopes directed away from building

4. TESTING REQUIREMENTS

a. Follow the Soil Infiltration Testing Guidelines for testing requirements (*Part D*).
b. The overall site must be evaluated for potential infiltration systems early in the design process.

5. CALCULATIONS

Infiltration Area
The minimum infiltration area must be based on the following equation:

Minimum Infiltration Area = Contributing impervious area (including pervious pavement) / 8

Volume Reduction

Runoff Volume = Depth*(ft) x Area (ft²) x Void Space (i.e. 0.30 for aggregate)

*Depth is the depth of the water stored during a storm event, depending on the drainage area, conveyance to the bed, and outlet control.
6. CONSTRUCTION

The following is a typical construction sequence; however, alternations will be necessary depending on design variations.

a. Due to the nature of construction sites, pervious pavement and other infiltration measures must be installed toward the end of the construction period. Once the site is stabilized and erosion control is no longer required, the bed is excavated to its final grade and the pervious pavement system is installed.

b. The existing subgrade under the bed areas must NOT be compacted or subject to excessive construction equipment traffic prior to geotextile and stone bed placement. Completed subgrade must be approved by the jurisdiction having authority prior to geotechnical installation.

c. Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material must be removed with light equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake (or equivalent) and light tractor. All fine grading must be done by hand. All bed bottoms must be at level grade.

d. Earthen berms (if used) between infiltration beds must be left in place during excavation. These berms do not require compaction if proven stable during construction.

e. Geotextile bed aggregate must be placed immediately after approval of subgrade preparation. Geotextile is to be placed in accordance with manufacturer’s standards and recommendations. Adjacent strips of geotextile must overlap a minimum of 18 inches. It must also be secured at least 4 feet outside of bed in order to prevent any runoff or sediment from entering the storage bed. This edge strip must remain in place until all bare soils contiguous to beds are stabilized and vegetated. As the site is fully stabilized, excess geotextile along bed edges can be cut back to bed edge.

f. Clean (washed) uniformly-graded aggregate is to be placed in the bed in 8-inch lifts. Each layer must be lightly compacted, with the construction equipment kept off the bed bottom. Once bed aggregate is installed to the desired grade, a +/- 1 in. layer of choker base course aggregate (AASHTO #57) must be installed uniformly over the surface in order to provide an even surface for paving.

g. After final pervious asphalt or concrete installation, no vehicular traffic of any kind must be permitted on the pavement surface until cooling and hardening or curing has taken place, and in no case within the first 72 hours.

h. The full permeability of the pavement surface must be tested by application of clean water at the rate of at least 5 gpm over the surface, using a hose or other distribution device. All applied water must infiltrate directly without puddle formation or surface runoff.

i. Control of sediment is critical. Rigorous installation and maintenance of erosion and sediment control measures is required to prevent sediment deposition on the pavement surface or within the stone bed. Non-woven geotextile may be folded over the edge of the pavement until the site is stabilized. The designer should consider the site placement of pervious pavement to reduce likelihood of sediment deposition. Surface sediment must be removed by a vacuum sweeper and must not be power-washed into the bed.

7. MAINTENANCE

a. In developments that have county drainage districts and drains established, pervious pavement stormwater credits will be provided as determined by the calculations set forth in these standards. Maintenance of pervious pavement will be the responsibility of the owner or governing association of the development and the deed restrictions and covenants for the development shall state such, including the annual testing and recording of permeability. The Water Resources Commissioner will not maintain nor accept easements over pervious pavement. In the event that pervious pavement in the drainage district is not maintained, the Water Resources Commissioner will take the appropriate legal action to enforce the deed and covenants.

b. Prevent Clogging of Pavement Surface with Sediment

i. Vacuum pavement twice per year

ii. Maintain planted areas adjacent to pavement

iii. Immediately clean any soil deposited on pavement

iv. Do not allow construction staging, soil/mulch storage, etc. on unprotected pavement surface

v. Clean inlets draining to the subsurface bed twice per year

\[ \text{Infiltration Volume} = \text{Bed Bottom Area} \times \text{Infiltration design rate} \times 6 \times 1 \times \left( \frac{1}{12} \right) \]

*Infiltration Period (6) is the time when bed is receiving runoff and capable of infiltrating at the design rate. This has been conservatively estimated as 6 hours.
c. Snow/Ice Removal
   i. Do not apply abrasives such as sand or cinders on or adjacent to pervious pavement
   ii. Snow plowing is fine but should be done carefully (i.e. set the blade slightly higher than usual)
   iii. Salt application is acceptable, although more environmentally-benign deicers are preferable. The need for application of salt and other deicers should be minimal, as water does not pond and freeze on top of properly operating pervious pavement.

d. Repairs
   i. Surface shall never be seal-coated
   ii. Damaged areas less than 50 sq. ft. can be patched with pervious or standard pavement
   iii. Larger areas should be patched with an approved pervious asphalt or pervious concrete, or as approved by the Washtenaw County Water Resources Commissioner
   iv. Pervious pavers must be repaired/replaced with similar pervious paver block material or turf reinforcement system
   v. Pervious pavers and gravel pavers may require the addition of aggregate on an annual basis or as needed, in order to replenish material used to fill in the open areas of the pavers. Turf pavers may require reseeding as needed if bare areas appear
1. GENERAL REQUIREMENTS

a. Dry Wells are sized to temporarily retain and infiltrate stormwater runoff from roofs of structures. A dry well usually provides stormwater management for a limited roof area. Care should be taken not to hydraulically overload a dry well based on bottom area and drainage area. (See Part D, Design Requirements for Infiltration Systems)

b. Dry Wells must drain-down within 48 hours. Longer drain-down times reduce Dry Well efficiency and can lead to anaerobic conditions, odor and other problems.

c. Dry Wells are not recommended when their installation would create a significant risk for basement seepage or flooding. Ten feet of separation is required between Dry Wells and building foundations. However, this distance may be reduced with permission from the Water Resources Commissioner. Reduced separation distances may warrant that an impermeable liner be installed on the building side of the Dry Well and/or the bottom of the dry well to be sloped away from the building.

d. The design depth of a Dry Well must take into account frost depth to prevent frost heave.

e. A removable filter with a screened bottom must be installed in the roof leader below the surcharge pipe in order to screen out leaves and other debris. (See Figure 8.)

f. Adequate inspection and maintenance access to the Dry Well will be provided. Observation wells not only provide the necessary access to the well, but they also provide a conduit through which pumping of stored runoff can be accomplished in case of slowed infiltration.

Figure 8. Dry Well Detail with sediment pretreatment catch basin

Source: LID Manual for Michigan
Section V: Design Requirements For Stormwater Management Systems

2. PROHIBITIONS
Infiltration facilities will not be allowed in the areas that follow
a. Areas with known pollution as identified by the MDEQ
b. Within floodplains
c. Where the estimated high ground water elevation will be within 3 feet of the bottom of the facility.

As with other infiltration practices, Dry Wells may not be appropriate for “hot spots” or other areas where high pollutant or sediment loading is expected without additional design considerations. Dry Wells are not recommended within a specified distance to structures or subsurface sewage disposal systems. (See Infiltration System Guidelines)

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*minimum with slopes directed away from building

4. TESTING REQUIREMENTS
a. Follow the Soil Infiltration Testing Guidelines for testing requirements within Part D.
b. The overall site must be evaluated for potential infiltration systems early in the design process.

5. INLET/OUTLET DESIGN
A Dry Well is a subsurface storage facility that temporarily stores and infiltrates stormwater runoff from the roofs of structures. Roof leaders usually connect directly into the Dry Well.

All Dry Wells must be able to convey system overflows to downstream drainage systems. System overflows can be incorporated either as surcharge (or overflow) pipes extending from roof leaders or via connections to more substantial infiltration areas.

6. DRY WELL COMPONENTS/ CONFIGURATION
Dry Wells typically consist of 18 to 48 inches of clean washed, uniformly graded aggregate with 30% void capacity (AASHTO No. 3, or similar). Typically 40% void space is acceptable; however, a 25% reduction was incorporated as a safety factor. Dry Well aggregate is wrapped in a non-woven geotextile, which provides separation between the aggregate and the surrounding soil. Typically, Dry Wells will be covered in at least 12-inches of soil or 6-inches of gravel or riverstone. An alternative form of Dry Well is a subsurface, prefabricated chamber. A variety of prefabricated Dry Wells are currently available on the market.

7. EASEMENTS
Dry Wells will have sufficient easements for maintenance purposes. Easements will be sized and located to accommodate access and operation of equipment, and other activities identified in the development’s stormwater system maintenance plan.

8. CALCULATIONS
Volume Reduction Calculations
The storage volume of a Dry Well is defined as the volume beneath the discharge invert. The following equation can be used to determine the approximate storage volume of an aggregate Dry Well:

\[
\text{Storage Volume} = \text{Dry well area (ft}^2\text{)} \times \text{Dry well water depth (ft) } \times 30\% \text{ (if stone filled)}
\]

*Depth is the depth of the water stored during a storm event, depending on the drainage area, conveyance to the bed, and outlet control.
Section V: Design Requirements For Stormwater Management Systems

Infiltration Volume = Bed Bottom Area (ft²) x Infiltration design rate (in/hr) x Infiltration period* (hr) x (1/12)

*Infiltration Period is the time when bed is receiving runoff and capable of infiltrating at the design rate, not to exceed 48 hours.

Infiltration Area
A dry well may consider both bottom and side (lateral) infiltration according to design.

9. CONSTRUCTION
The following is a typical construction sequence; however, alterations will be necessary depending on design variations.

a. The infiltration area must be protected from compaction prior to installation.
b. Dry wells must not be placed on areas of recent fill or compacted fill. Any grade adjustments requiring fill must be done using the stone sub-base material. Areas of historical fill (>5 years) may be considered for Dry Wells.
c. Install Dry Wells during later phases of site construction to prevent sedimentation and/or damage from construction activity.
d. Installation and maintenance of proper Erosion and Sediment Control Measures must be followed during construction.
e. Excavate Dry Well bottom to a uniform, level uncompacted subgrade free from rocks and debris. Do NOT compact subgrade. To the greatest extent possible, excavation should be performed with the lightest practical equipment. Excavation equipment should be placed outside the limits of the Dry Well.
f. Completely wrap Dry Well with nonwoven geotextile. (If sediment and/or debris have accumulated in Dry Well bottom, remove prior to geotextile placement.) Geotextile rolls must overlap by a minimum of 24 inches within the trench. Fold back and secure excess geotextile during stone placement.
g. Install continuously perforated pipe, observation wells, and all other Dry Well structures. Connect roof leaders to structures as indicated on plans.
h. Clean-washed uniformly grated aggregate is to be placed in 6 inch lifts. Each layer must be lightly compacted with the construction equipment kept off the bed bottom.
i. Fold and secure nonwoven geotextile over trench with a minimum overlap of 12 inches.
j. Place a 12 inch lift of approved topsoil over trench, as indicated on plans.
k. Topsoil stabilization and seed must be applied to the disturbed area.
l. Connect surcharge pipe to roof leader and position over splashboard.
m. Do not remove Erosion and Sediment Control measures until site is fully stabilized.

10. MAINTENANCE
As with all infiltration practices, Dry Wells require regular and effective maintenance to ensure prolonged functioning. The following represent minimum maintenance requirements for Dry Wells:

a. Inspect Dry Wells at least four times a year, as well as after every storm exceeding one inch.
b. Dispose of sediment, debris/trash, and any other waste material removed from a Dry Well at suitable disposal/recycling sites and in compliance with local, state, and federal waste regulations.
c. Evaluate the drain-down time of the Dry Well to ensure the maximum time of 48 hours is not being exceeded. If drain-down times are exceeding the maximum, drain the Dry Well via pumping and clean out perforated piping, if included. If slow drainage persists, the system may need replacing.
d. Regularly clean out gutters and ensure proper connections to facilitate the effectiveness of the dry well.
e. Replace filter screen that intercepts roof runoff as necessary.
f. If an intermediate sump box exists, clean it out at least once per year.
1. GENERAL REQUIREMENTS

a. Infiltration Basins are sized to temporarily retain and infiltrate stormwater runoff from areas five to 50 acres with slopes less than 20 percent. An Infiltration Basin is typically one large or several small impoundments meant to detain and infiltrate runoff. (See Figure 9) Care should be taken not to hydraulically overload an Infiltration Basin based on bottom area and drainage area. (See Design Requirements for Infiltration Systems, Part D.)

b. Infiltration Basins must drain-down within 48 hours. Longer drain-down times reduce Infiltration Basin efficiency and can lead to anaerobic conditions, odor and other problems.

c. Infiltration Basins are not recommended when their installation would create a significant risk for basement seepage or flooding. 15 feet of separation is required between Infiltration Basins and building foundations.

d. A 6-inch interceptor layer of sand must be applied to the bottom of the basin to filter out sediment and debris.

e. Adequate inspection and maintenance access to the Infiltration Basin will be provided.

f. A maintainable engineered structure, such as an infiltration trench, must be placed in the bottom of the Infiltration Basin.

2. PROHIBITIONS

Infiltration facilities will not be allowed in the areas that follow:

a. Areas with known pollution as identified by the MDEQ
b. Within a floodplain
c. Where the estimated high ground water elevation will be within 3 feet of the bottom of the facility.

As with other infiltration practices, Infiltration Basins may not be appropriate for “hot spots” or other areas where high pollutant or sediment loading is expected without additional design considerations. Infiltration Basins are not recommended within a specified distance to structures of subsurface sewage disposal systems. (See Infiltration System Guidelines)

3. SETBACKS

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*minimum with slopes directed away from building
**50 feet from septic systems with a design flow less than 1,000 gallons per day

Figure 9. Infiltration Basin Schematic
Section V: Design Requirements For Stormwater Management Systems

4. TESTING REQUIREMENTS
   a. Follow the Soil Infiltration Testing Guidelines for testing requirements within Part D.
   b. The overall site must be evaluated for potential infiltration systems early in the design process.

5. STRUCTURAL INFILTRATION BASIN COMPONENTS/CONFIGURATION

The primary components (and subcomponents) of an Infiltration Basin system are:

Pretreatment (where required)
   • Flow through a vegetated buffer strip, water quality inlet, etc. prior to entry into the Infiltration Basin System.

Flow Entrance
   Water may enter via:
   • An inlet (e.g. flared end section)
   • Sheet flow into the facility over grassed areas
   • Curb cuts with grading for sheet flow entrance
   • Roof leaders with direct surface connection
   • Trench drain

In all cases entering velocities must be non-erosive.

Positive Overflow
   Infiltration basin design will include a positive overflow that will discharge runoff during large storm events when the subsurface/surface storage capacity is exceeded.
   • Examples include a structural outlet or emergency spillway.
   • Discharge must be directed in a manner to avoid property damage and have an unimpeded route to a receiving channel or outlet.

Ponding Area
   • Slopes will not exceed 5:1
   • Top of berm widths must be at least two feet wide
   • An overflow must be provided
   • Plants must be salt tolerant if in a location that would receive snowmelt chemicals

Planting
   Proper plant selection is essential for Infiltration Basins to be effective. Typically, native floodplain or wet meadow plant species are best suited to the variable environmental conditions encountered in an Infiltration Basin system. Establishment by seed is appropriate only for larger gardens distant from points of viewing.

Planting with seed has highly unreliable results due to water flows displacing seed. If proposed, the application method and seed mix must be submitted for approval. Upon installation, vegetative establishment must be documented and approved as per the soil erosion and sedimentation control permit. Infiltration basins planted close to entryways and pedestrian gathering spaces should be planted with nursery-grown plants.
   • Live perennial plant material in plug form should be utilized and installed with a maximum spacing of 2 feet on-center. Seed is not an acceptable method for plant establishment below the surface storage elevation unless a method of germination and stabilization is provided. Planting with seed has highly unreliable results due to water flows displacing seed. Establishment by seed is appropriate only in the zone above the first flush elevation.
   • If seeding is proposed, only natives (as defined by Michigan Flora, michiganflora.net) and annuals are allowable. Annual seed is allowed in an amount necessary to stabilize the limits of disturbance. If live plantings are proposed, native grasses, forbs, shrubs and trees are preferred. Cultivars and non-native perennials are allowable if approved by WCWRC. Plants listed on the WCWRC Rain Garden Plant List are acceptable. Invasive species are not allowed (see the City of Ann Arbor’s invasive species list). Plantings should be locally adapted and appropriate to the hydric conditions proposed. For more information on individual species, see “Plants for Stormwater Design: Species Selection for the Upper Midwest” by Daniel Shaw & Rusty Schmidt.
   • Optimal planting time is between mid-May and mid-June or mid-September to mid-October. Other planting times require irrigation for plant establishment.
   • Plants shall be planted at a density sufficient to achieve cover within the first two years. A guideline to achieve this is to plant them at distances “on center” equal to their expected ultimate height.

If shrubs and trees are included in an Infiltration Basins area, at least three species of shrub and tree should be planted. Shrub to tree ratio should be between 2:1 and 3:1. Use an experienced landscape architect to design a locally adapted planting layout.

Planting soil must be a loam soil capable of supporting a healthy vegetative cover. Soils must be amended with a composted organic material. A recommended soil blend is 20-30% organic material (compost), 20-30% sand, and 20-30% topsoil. Planting soil must be 4 inches deeper than the planting depth.
Section V: Design Requirements For Stormwater Management Systems

Soils must have clay content less than 10% (a small amount of clay is beneficial to absorb pollutants and retain water), be free of toxic substances and unwanted plant material and have a 5-10% organic matter content. Additional organic matter can be added to the soil to increase water holding capacity (tests should be conducted to determine storage capacity of amended soils).

6. EASEMENTS

Infiltration Basins will have sufficient easements for maintenance purposes. Easements will be sized and located to accommodate access and operation of equipment spoils deposition, and other activities identified in the development’s stormwater system maintenance plan.

7. CALCULATIONS

Volume Reduction Calculations

The following equation can be used to determine the approximate storage volume of an Infiltration Basin:

\[
\text{Storage Volume (ft}^3\text{)} = \text{Average bed area (ft}^2\text{)} \times \text{Maximum design water depth (ft)}
\]

Subsurface storage/infiltration bed volume (ft³) = Infiltration area (ft²) x Depth of underdrain material (ft) x Void ratio of storage material (%)

*Depth is the depth of the water stored during a storm event, depending on the drainage area, conveyance to the bed, and outlet control.

\[
\text{Infiltration Volume (ft}^3\text{)} = \text{Bed bottom area (ft}^2\text{)} \times [\text{Infiltration design rate (in/hr)} \times \text{Infiltration period}^* (\text{hr})] \times (1/12)
\]

*Infiltration Period is the time when bed is receiving runoff and capable of infiltrating at the design rate. Not to exceed 48 hours.

Infiltration Area

The minimum infiltration area of the Infiltration Basin is defined as:

Minimum surface area = Contributing impervious area / 8*

*May be increased at the discretion of the Water Resources Commissioner depending on soil infiltration rate, e.g. where soils are Type A or rapidly draining.

8. CONSTRUCTION

The following is a typical construction sequence; however, alterations will be necessary depending on design variations.

a. The infiltration area must be protected from compaction prior to installation.

b. Infiltration Basins must not be placed on areas of recent fill or compacted fill. Any grade adjustments requiring fill must be done using the stone sub-base material. Areas of historical fill (>5 years) may be considered for infiltration basins.

c. Installation and maintenance of proper Erosion and Sediment Control Measures must be followed during construction.

d. Excavate Infiltration Basin bottom to a uniform, level uncompacted subgrade free from rocks and debris. Do NOT compact subgrade. Excavation should be performed with the lightest practical equipment. Excavation equipment should be placed outside the limits of the Infiltration Basin.

e. Topsoil stabilization and seed must be applied to the disturbed area.

f. Do not remove Erosion and Sediment Control measures until site is fully stabilized.

g. Permeability shall be reverified by infiltration prior to acceptance.

9. MAINTENANCE

As with all infiltration practices Infiltration Basins require regular and effective maintenance to ensure prolonged functioning. The following represent minimum maintenance requirements for Infiltration Basins:

a. Inspect Infiltration Basins after every storm exceeding one inch.

b. Inspect for sediment accumulation, outlet control structure damage, erosion control measures, signs of water contamination/spills and slope/berm stability.

c. Mowing should occur only as required for vegetative cover.

d. Dispose of sediment, debris/trash, and any other waste material removed from the Infiltration Basins at a suitable disposal/recycling site and in compliance with local, state, and federal waste regulations.

e. Evaluate the drain-down time of the Infiltration Basin to ensure the maximum time of 48 hours is not being exceeded. If slow drainage persists, the system may need rehabilitation.
Section V: Design Requirements For Stormwater Management Systems

Part J.

DESIGN REQUIREMENTS – SUBSURFACE INFILTRATION BEDS

1. GENERAL REQUIREMENTS

a. Subsurface Infiltration Beds are sized to temporarily retain and infiltrate stormwater runoff from areas no greater than 10 acres. A Subsurface Infiltration Bed is typically a rock storage bed below the surface mean to detain and infiltrate runoff. (See Figure 10.)

b. Subsurface Infiltration Beds must drain-down within 48 hours. Longer drain-down times reduce Subsurface Infiltration Bed efficiency and can lead to anaerobic conditions, odor and other problems.

c. Subsurface Infiltration Beds are not recommended when their installation would create a significant risk for basement seepage or flooding. Fifteen feet of separation is required between Subsurface Infiltration Beds and building foundations.

d. The Subsurface Infiltration Bed must be wrapped in non-woven geotextile filter fabric to prevent the migration of the subsoils into the stone voids.

e. The underlying infiltration bed is typically 12-36 inches deep and comprised of clean, uniformly graded aggregate with approximately 30% void space. Typically 40% void space is acceptable; a 25% reduction is incorporated as a safety factor. AASHTO No. 3, which ranges 1.5-2.5 inches in gradation, is often used. Depending on local aggregate availability, both larger and smaller size aggregate has been used. The critical requirements are that the aggregate be uniformly graded, clean washed, and contain a significant void content. The depth of the bed is a function of stormwater storage requirements, frost depth considerations, site grading, and anticipated loading. Infiltration beds are typically sized to mitigate the increased runoff volume from a 2-yr design storm.

f. An overflow device must be incorporated into the design of the subsurface infiltration bed.

g. Perforated pipes may be used to evenly distribute runoff over the entire bed bottom. Continuously perforated pipes must connect structures (such as cleanouts and inlets). Pipes must lay flat and provide for uniform distribution of water. Depending on size, these pipes may provide additional storage volume.

h. Adequate inspection and maintenance access or perforated pipe cleanouts to the Subsurface Infiltration Bed will be provided.

Figure 10. Subsurface Infiltration Bed Schematic
Source: LID Manual for Michigan
Section V: Design Requirements For Stormwater Management Systems

2. PROHIBITIONS

Infiltration facilities will not be allowed in the following areas:

a. Areas with known pollution as identified by the MDEQ
b. Within floodplains
c. Where the estimated high ground water elevation will be within 3 feet of the bottom of the facility.

As with other infiltration practices, Subsurface Infiltration Beds may not be appropriate for “hot spots” or other areas where high pollutant or sediment loading is expected without additional design considerations. Subsurface Infiltration Beds are not recommended within a specified distance to structures of subsurface sewage disposal systems. (See Infiltration System Guidelines)

3. SETBACKS

<table>
<thead>
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*minimum with slopes directed away from building
**50 feet from septic systems with a design flow less than 1,000 gallons per day

4. TESTING REQUIREMENTS

a. Follow the Soil Infiltration Testing Guidelines for testing requirements within the Design Requirements for Infiltration BMPs section.

b. The overall site shall be evaluated for potential infiltration systems early in the design process.

5. INLET/OUTLET DESIGN

A Subsurface Infiltration Bed is a subsurface storage facility that temporarily stores and infiltrates stormwater runoff from nearby impervious areas. Roof leaders, inlets and catch basins usually connect directly into the Subsurface Infiltration Bed.

6. SUBSURFACE INFILTRATION BED COMPONENTS/CONFIGURATION

Subsurface Infiltration Beds typically consist of 12 to 36 inches of clean washed, uniformly graded aggregate with 30% void capacity (AASHTO No. 3 or similar). Typically 40% void space is acceptable; however a 25% reduction was incorporated as a safety factor. Subsurface Infiltration Bed aggregate is wrapped in a non-woven geotextile, which provides separation between the aggregate and the surrounding soil. Typically, Subsurface Infiltration Bed will be covered in at least 12-inches of soil or 6-inches of gravel or riverstone. An alternative form of Subsurface Infiltration Beds is a subsurface, prefabricated perforate pipe chamber. A variety of prefabricated perforated pipes are currently available on the market for Subsurface Infiltration Bed applications.

7. EASEMENTS

Subsurface Infiltration beds will have sufficient easements for maintenance purposes. Easements will be sized and located to accommodate access and operation of equipment spoils deposition, and other activities identified in the development’s stormwater system maintenance plan.

8. CALCULATIONS

Volume Reduction Calculations

The following can be used to determine the approximate storage volume of a Subsurface Infiltration Bed:

Subsurface storage/infiltration bed volume (ft$^3$) =
Infiltration area (ft$^2$) x Depth of underdrain material (ft) x Void ratio of storage material (%)

*Depth is the depth of the water stored during a storm event, depending on the drainage area, conveyance to the bed, and outlet control.

Infiltration Volume (ft$^3$) = Bed bottom area (ft$^2$) x [Infiltration design rate (in/hr) x Infiltration period* (hr)] x (1/12)

*Infiltration Period is the time when bed is receiving runoff and capable of infiltrating at the design rate. Not to exceed 48 hours.
Section V: Design Requirements For Stormwater Management Systems

Infiltration Area
The minimum infiltration area of the Subsurface Infiltration Bed is defined as:

\[
\text{Minimum surface area} = \frac{\text{Contributing impervious area}}{8}\]

*May be increased at the discretion of the Water Resources Commissioner depending on soil infiltration rate, e.g. where soils are Type A or rapidly draining.

9. CONSTRUCTION

The following is a typical construction sequence; however, alterations will be necessary depending on design variations.

a. The infiltration area must be protected from compaction prior to installation.

b. Subsurface Infiltration Beds must not be placed on areas of recent fill or compacted fill. Any grade adjustments requiring fill must be done using the stone sub-base material. Areas of historical fill (>5 years) may be considered for Subsurface Infiltration Beds.

c. Install Subsurface Infiltration Beds during later phases of site construction to prevent sedimentation and/or damage from construction activity.

d. Installation and maintenance of proper Erosion and Sediment Control Measures must be followed during construction.

e. Excavate Subsurface Infiltration Bed bottom to a uniform, level uncompacted subgrade free from rocks and debris. Do NOT compact subgrade. To the greatest extent possible, excavation should be performed with the lightest practical equipment. Excavation equipment should be placed outside the limits of the Subsurface Infiltration Bed.

f. Completely line Subsurface Infiltration Bed with non-woven geotextile filter fabric. (If sediment and/or debris have accumulated in the Subsurface Infiltration Bed bottom, remove prior to geotextile placement.) Geotextile rolls must overlap by a minimum of 18 inches within the trench. Fold back and secure excess geotextile during stone placement.

g. Observation wells must be installed on both ends of the Subsurface Infiltration Bed. Connect inlets, catch basins and roof leaders to the Subsurface Infiltration Bed as indicated on plans.

h. Clean-washed uniformly grated aggregate is to be placed in 6-inch lifts. Each layer must be lightly compacted with the construction equipment kept off the bed bottom.

i. Fold and secure non-woven geotextile over trench with a minimum overlap of 18-inches.

j. Place a 6-inch lift of approved topsoil over trench, as indicated on plans.

k. Topsoil stabilization and seed must be applied to the disturbed area.

l. Do not remove Erosion and Sediment Control measures until site is fully stabilized.

10. MAINTENANCE

As with all infiltration practices, Subsurface Infiltration Beds require regular and effective maintenance to ensure prolonged functioning. The following represent minimum maintenance requirements for Subsurface Infiltration Beds:

a. Dispose of sediment, debris/trash, and any other waste material removed from a Subsurface Infiltration Bed at suitable disposal/recycling sites and in compliance with local, state, and federal waste regulations.

b. Evaluate the drain-down time of the Subsurface Infiltration Bed to ensure the maximum time of 48 hours is not being exceeded. If drain-down time are exceeding the maximum, drain the Subsurface Infiltration Bed via pumping and clean out perforated piping, if included. If slow drainage persists, the system may need replacing.

c. Regularly clean out inlets, catch basins and gutters to ensure proper connections to facilitate the effectiveness of the Subsurface Infiltration Bed.

d. Replace filter screen that intercepts roof runoff as necessary.

e. If an intermediate sump box exists, clean it out at least once per year.
Section V: Design Requirements For Stormwater Management Systems

Part K.

DESIGN REQUIREMENTS – INFILTRATION TRENCHES

1. GENERAL REQUIREMENTS

a. Infiltration Trenches are sized to temporarily retain, infiltrate and convey stormwater runoff from areas no greater than five (5) acres. An Infiltration Trench is typically a linear trench with a rock storage bed below the surface.

b. Infiltration Trenches must drain-down within 48 hours. Longer drain-down times reduce Infiltration Trench efficiency and can lead to anaerobic conditions, odor and other problems.

c. Infiltration Trenches are not recommended when their installation would create a significant risk for basement seepage or flooding. Fifteen feet of separation is required between Infiltration Trenches and building foundations.

d. The Infiltration Trench must be wrapped in non-woven geotextile filter fabric to prevent the migration of the subsoils into the stone voids.

e. The underlying infiltration bed is typically comprised of clean, uniformly-graded aggregate with approximately 30% void space. Typically 40% void space is acceptable; however, a 25% reduction was incorporated as a safety factor. AASHTO No.3, which ranges 1.5-2.5in in gradation, is often used. Depending on local aggregate availability, both larger and smaller size aggregate may be used. The critical requirements are that the aggregate be uniformly graded, clean washed, and contain a significant void content. The depth of the bed is a function of stormwater storage requirements, frost depth considerations, site grading, and anticipated loading. Infiltration Trenches are typically sized to mitigate the increased runoff volume from a 2-yr design storm.

f. A water quality inlet or catch basin with sump is required for all surface inlets to avoid standing water for periods greater than 48 hours.

g. Perforated pipes along the bottom of the bed may be used to evenly distribute runoff over the entire bed bottom. Continuously perforated pipes must connect structures (such as cleanouts and inlets). Pipes must lay flat along the bed bottom and provide for uniform distribution of water. Depending on size, these pipes may provide additional storage volume.

h. Adequate inspection and maintenance accesses or cleanouts to the Subsurface Infiltration Bed will be provided.

---

Figure 11.
Infiltration Trench Cross Section
Source: LID Manual for Michigan
Section V: Design Requirements For Stormwater Management Systems

2. PROHIBITIONS

Infiltration facilities will not be allowed in the following areas:

a. Areas with known pollution as identified by the MDEQ
b. Within floodplains
c. Where the estimated high ground water elevation will be within 3 feet of the bottom of the facility.

As with other infiltration practices, Infiltration Trenches may not be appropriate for “hot spots” or other areas where high pollutant or sediment loading is expected without additional design considerations. Infiltration Trenches are not recommended within a specified distance to structures of subsurface sewage disposal systems. (See Infiltration System Guidelines)

3. SETBACKS

Setback Distances

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*minimum with slopes directed away from building

**50 feet from septic systems with a design flow less than 1,000 gallons per day

4. TESTING REQUIREMENTS

a. Follow the Soil Infiltration Testing Guidelines for testing requirements within Part D.
b. The overall site must be evaluated for potential infiltration systems early in the design process.

5. INLET/OUTLET DESIGN

An Infiltration Trench is a subsurface storage facility that temporarily stores, infiltrates and conveys stormwater runoff from nearby impervious areas. Inlets and catch basins with sumps connect directly to the Infiltration Trench.

All Infiltration Trenches must be able to convey system overflows to downstream drainage systems. System overflows can be incorporated either through surcharge (or overflow) pipes or via connections to more substantial infiltration areas.

6. INFILTRATION TRENCH COMPONENTS/ CONFIGURATION

Infiltration Trenches typically consists of clean washed, uniformly graded aggregate with 30% void capacity (AASHTO No.3, or similar). Typically 40% void space is acceptable; however, a 25% reduction was incorporated as a safety factor. Infiltration Trench aggregate is wrapped in a non-woven geotextile, which provides separation between the aggregate and the surrounding soil. Typically, Infiltration Trenches will be covered in at least 12-inches of soil or 6-inches of gravel or river stone. An alternative form of Infiltration Trench is a subsurface, prefabricated perforated pipe chamber. A variety of prefabricated perforated pipes are currently available on the market for Infiltration Trench applications.

7. EASEMENTS

Infiltration Trenches will have sufficient easements for maintenance purposes. Easements will be sized and located to accommodate access and operation of equipment, spoils deposition, and other activities identified in the development’s stormwater system maintenance plan.

8. CALCULATIONS

Volume Reduction Calculations

The following equation can be used to determine the approximate storage volume of an Infiltration Trench.

\[
\text{Subsurface storage/infiltration bed volume (ft}^3) = \text{Infiltration area (ft}^2) \times \text{Depth of underdrain material (ft) \times Void ratio of storage material (\%)}
\]

*Depth is the depth of the water stored during a storm event, depending on the drainage area, conveyance to the bed, and outlet control.

\[
\text{Infiltration Volume (ft}^3) = \text{Bed bottom area (ft}^2) \times \left[\text{Infiltration design rate (in/hr) \times Infiltration Period* (hr)}\right] \times \left(\frac{1}{12}\right)
\]

*Infiltration Period is the time when bed is receiving runoff and capable of infiltrating at the design rate. Not to exceed 48 hours.
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Infiltration Area
The minimum infiltration area of the Infiltration Trench is defined as:

Minimum surface area = Contributing impervious area / 8*

*May be increased at the discretion of the Water Resources Commissioner depending on soil infiltration rate, e.g. where soils are Type A or rapidly draining.

9. CONSTRUCTION

The following is a typical construction sequence; however alterations will be necessary depending on design variations.

a. The infiltration area must be protected from compaction prior to installation.

b. Infiltration Trenches must not be placed on areas of recent fill or compacted fill. Any grade adjustments requiring fill must be done using the stone sub-base material. Areas of historical fill (>5 years) may be considered for Infiltration Trenches.

c. Install Infiltration Trenches during later phases of site construction to prevent sedimentation and/or damage from construction activity.

d. Installation and maintenance of proper Erosion and Sediment Control Measures must be followed during construction.

e. Excavate Infiltration Trench bottom to a uniform, level uncompacted subgrade free from rocks and debris. Do NOT compact subgrade. To the greatest extent possible, excavation should be performed with the lightest practical equipment. Excavation equipment should be placed outside the limits of the Subsurface Infiltration Bed.

f. Completely wrap Infiltration Trench with non-woven geotextile. (If sediment and/or debris have accumulated in Infiltration Trench bottom, remove prior to geotextile placement.) Geotextile rolls must overlap by a minimum of 24 inches within the trench. Fold back and secure excess geotextile during stone placement.

g. Install continuously perforated pipe, observation wells, and all other Infiltration Trench structures. Connect inlets and catch basins to trench as indicated on approved plans.

h. Clean-washed, uniformly grated aggregate is to be placed in 8-inch lifts. Each layer must be lightly compacted with the construction equipment kept off the bed bottom.

i. Backfill perforated pipe with clean-washed uniformly grated aggregate in 8-inch lifts, lightly compacted between lifts.

j. Fold and secure non-woven geotextile over trench with a minimum overlap of 16-inches.

k. Place a 6-inch lift of approved topsoil over trench, as indicated on approved plans.

l. Topsoil stabilization and seed must be applied to the disturbed area.

m. Do not remove Erosion and Sediment Control measures until site is fully stabilized.

10. MAINTENANCE

As with all infiltration practices, Infiltration Trenches require regular and effective maintenance to ensure prolonged functioning. The following represent minimum maintenance requirements for Infiltration Trenches.

a. Inspect Infiltration Trenches at least four times per year, as well as after every storm exceeding one inch.

b. Dispose of sediment, debris/trash, and any other waste material removed from a Infiltration Trench at suitable disposal/recycling sites and in compliance with local, state, and federal waste regulations.

c. Evaluate the drain-down time of the Infiltration Trench to ensure the maximum time of 48 hours is not being exceeded. If drain-down times are exceeding the maximum, drain the Infiltration Trench via pumping and clean out perforated piping, if included. If slow drainage persists, the system may need replacing.

d. Regularly clean out inlets, catch basins and gutter and ensure proper connections to facilitate the effectiveness of the Infiltration Trench.

e. Replace filter screen that intercepts roof runoff as necessary.

f. If an intermediate sump box exists, clean it out at least once per year.

Sites requiring a permit from WCWRC must notify WCWRC upon receipt of vegetative materials. The site/project must arrange for inspection/review by WCWRC prior to installation of vegetation.
Part L.

DESIGN REQUIREMENTS – VEGETATED FILTER STRIPS

1. GENERAL REQUIREMENTS

Vegetated Filter Strips are planted permanent linear features meant to slow and infiltrate overland runoff as well as filter out sediments. To be effective, stormwater entering the Vegetated Filter Strip must be sheet flow. Typically this type of BMP is used with other BMPs such as a level spreader to increase the stormwater mitigation potential.

2. PROHIBITIONS

Vegetated Filter Strips will not be allowed in the following:

a. Areas with known pollution as identified by the MDEQ
b. Within floodplains
c. Where the estimated high ground water elevation will be within two (2) feet of the bottom of the facility.

3. SETBACKS

Setback Distances - N/A

4. TESTING REQUIREMENTS

a. Follow the Soil Infiltration Testing Guidelines for testing requirements with Part D, Design Requirements for Infiltration BMPs.
b. The overall site must be evaluated for potential infiltration systems early in the design process.

Sites requiring a permit from WCWRC must notify WCWRC upon receipt of vegetative materials. The site/project must arrange for inspection/review by WCWRC prior to installation of vegetation.

Figure 12. Vegetated Filter Strip

Source: LID Manual for Michigan
Section V: Design Requirements For Stormwater Management Systems

5. VEGETATED FILTER STRIP COMPONENTS/CONFIGURATION

Proper plant selection is essential for Vegetated Filter Strip areas to be effective. Native, salt-tolerant, drought tolerant and erosion resistant plant species are suited to the variable environmental conditions encountered in a Vegetated Filter Strip. Locally adapted species that are appropriate for the proposed hydric conditions are acceptable.

If seeding is proposed, only natives (as defined by Michigan Flora, michiganflora.net) and annuals are allowable. Annual seed is allowed in an amount necessary to stabilize the limits of disturbance.

If live plantings are proposed, native grasses, forbs, shrubs and trees are preferred. Cultivars and non-native perennials are allowable if approved by WCWRC. Plants listed on the WCWRC Rain Garden Plant List are acceptable. Invasive species are not allowed (see the City of Ann Arbor’s invasive species list). Plantings should be locally adapted and appropriate to the hydric conditions proposed. For more information on individual species, see “Plants for Stormwater Design: Species Selection for the Upper Midwest” by Daniel Shaw & Rusty Schmidt.

Plantings should be spaced according to each species size and growth potential to allow for sufficient coverage. If proposed, the application method and seed mix must be submitted for approval. Upon installation, vegetative establishment must be documented and approved as per the soil erosion and sedimentation control permit.

See the Low Impact Development Manual for Michigan for a comprehensive list of acceptable Vegetated Filter Strip plants.

Planting periods will vary, but in general vegetation should be planted from mid-March through early June, or mid-September through mid-November.

Planting soil must be a loam soil capable of supporting healthy vegetative cover. A recommended soil blend is 20-30% organic material (compost), 20-30% sand, and 20-30% topsoil. Planting soil must be 4 inches deeper than the planting depth, or native soils in-situ at a depth of eight (8) inches. Root balls of trees and shrubs should rest on the native soil.

Soils must have clay content less than 10% (a small amount of clay is beneficial to absorb pollutants and retain water), and be free of toxic substances and unwanted plant material. (Tests should be conducted to determine volume storage capacity of amended soils.)

6. EASEMENTS

Vegetated Filter Strips will have sufficient easements for maintenance purposes. Easements will be sized and located to accommodate access and operation of equipment, spoils deposition and other activities identified in the development’s stormwater maintenance plan.

7. CALCULATIONS

Volume Reduction Calculation

Typically Vegetated Filter Strips do not have significant volume reducing capacity. However, it is entirely possible to infiltrate and evapotranspirate during a storm event. To account for the volume reduction, it is recommended to weight the curve number of the drainage area with that of the Vegetated Filter Strip.

The cover type of the Vegetated Filter Strip must be considered in the volume reduction calculation. Areas with turf grass should not be used in the volume reduction calculation for a Vegetated Filter Strip.

Sizing Criteria

a. Surface area is dependent upon storage volume requirements but should generally not exceed a maximum loading ratio of 8:1 (impermious drainage area to infiltration area; see Design Requirements for Infiltration Systems for additional guidance on loading rates.)

b. Surface Side slopes must be gradual. The maximum allowable slope for Vegetated Filter Strips is 3:1.

c. Planting soil depth must be at least eight inches where only herbaceous plant species will be utilized. If trees and woody shrubs will be used, soil media depth may be increased depending on plant species.

8. CONSTRUCTION

The following is a typical construction sequence; however, alterations will be necessary depending on design variations.

Note for all construction steps: Erosion and sediment control methods must adhere to the latest requirements of the Michigan DEQs Soil Erosion and Sedimentation Control Program.
Section V: Design Requirements For Stormwater Management Systems

a. Install temporary sediment control BMPs as shown on the plans.
b. Begin construction of the Vegetated Filter Strip only when the upper gradient has been significantly stabilized.
c. Complete site grading, minimizing compaction as much as possible. If applicable, construct curb cuts or other inflow entrances but provide protection so that drainage is prohibited from entering the Vegetated Filter Strip construction area.
d. Grade the Vegetated Filter Strip as proposed on approved plans and scarify the existing soil surfaces. Do not compact in-situ soils.
e. Do not compact the subgrade of gravel trenches.
f. Presoak the planting soil prior to planting vegetation to aid in settlement.
g. If used, sod must be staggered and placed tightly to avoid gaps and channelization. A roller must be used on the sod to remove and prevent any air pockets.
h. Seeded Vegetated Filter Strips must be stabilized with mulch blankets and staked to prevent erosion.
i. Install erosion protection at surface flow entrances where necessary.
j. Erosion control must be present until the site is fully stabilized.
k. Once drainage area and Vegetated Filter Strip are completely and permanently stabilized after one full grow year, the Vegetated Filter Strip should be brought online (opened for use).

9. MAINTENANCE

Properly designed and installed Vegetated Filter Strips require regular maintenance.
a. Removal of weeds and unwanted species is usually needed within the first 1-3 years following installation.
b. If a sediment control device, such as a stone trench or level spreader is installed, it shall be inspected quarterly for the first two years following construction and then twice a year thereafter.
c. Sediment and debris must be removed when build up exceeds two inches in depth in the Vegetated Filter Strip, level spreader or stone trench.
d. Disposal of sediment, debris/trash, and any other waste material shall be disposed/recycled at a suitable site, in compliance with local, state, and federal waste regulations.
e. Rills and gullies must be filled in with topsoil and stabilized with seed and mulch blankets.
f. Detritus (e.g. dead/decomposing leaves) may also need to be removed approximately twice per year. Perennial planting may be cut down at the end of the growing season, or beginning of the next.
g. Invasive species must be removed on an annual basis and disposed of in compliance with local, state, and federal regulations. No chemical shall be used with one exception. Invasive species can be treated chemically by a certified applicator.
h. If used, grass cover must be maintained and mowed at a height of 4-6 inches. Mowing can occur twice per year.
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Part M.

DESIGN REQUIREMENTS – BIOSWALE

1. GENERAL REQUIREMENTS

Bioswales are shallow densely planted channels meant to convey stormwater runoff as well as filter out other sediments. Check dams shall be installed per the Low Impact Development Manual for Michigan to improve sediment capture and increase the time of concentration. If appropriate, clean washed aggregate and perforated pipe can be introduced into the system to enhance the storage capacity of the bioswale. If an underdrain is used there will be no allowance for infiltration credits.

2. PROHIBITIONS

Bioswales will not be allowed in the following:

- Areas with known pollution as identified by the MDEQ

3. SETBACKS

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*minimum with slopes directed away from building

Sites requiring a permit from WCWRC must notify WCWRC upon receipt of vegetative materials. The site/project must arrange for inspection/review by WCWRC prior to installation of vegetation.

Note: If the design incorporates an underdrain, there will be no allowance for infiltration credits.

Figure 13. Bioswale Cross-Section & Profile

4. TESTING REQUIREMENTS

a. Follow the Soil Infiltration Testing Guidelines for testing requirements with Part D, Design Requirements for Infiltration BMPs.

b. The overall site shall be evaluated for potential infiltration systems early in the design process.

5. BIOSWALE COMPONENTS/CONFIGURATION

The primary components (and subcomponents) of a Bioswale are:

Flow Entrance
Water may enter via:
- An inlet (e.g. flared end section)
- Sheet flow into the facility over grassed areas
- Curb cuts with grading for sheet flow entrance
- Roof leaders with direct surface connection through a gravel trench
- Pipe

In all cases entering velocities must be non-erosive sheet flow.

Positive Overflow
- Bioswales will discharge runoff to a suitable downstream conveyance or storage area.
- Bioswales must be designed to include proper overflow paths for events above the 10-year recurrence interval.
- Discharge must be directed in a manner to avoid property damage and have an unimpeded route to a receiving channel or outlet

Ponding Area (Water Surface Level/Elevation)
- Overflow must be provided over check dams
- Maximum ponding depth (water surface level) of 18 inches at the end of channel
- The use must be within banks

Proper plant selection is essential for Bioswales to be effective. Native salt-tolerant, drought tolerant and erosion resistant plant species are suited to the variable environmental conditions encountered in a Bioswale. See Appendix M.

If seeding is proposed, only natives (as defined by Michigan Flora, michiganflora.net) and annuals are allowable. Annual seed is allowed in an amount necessary to stabilize the limits of disturbance. If proposed, the application method and seed mix must be submitted for approval. Upon installation, vegetative establishment must be documented and approved as per the soil erosion and sedimentation control permit.

If live plantings are proposed, native grasses, forbs, shrubs and trees are preferred. Cultivars and non-native perennials are allowable if approved by WCWRC. Plants listed on the WCWRC Rain Garden Plant List are acceptable. Invasive species are not allowed (see the City of Ann Arbor’s invasive species list). Plantings should be locally adapted and appropriate to the hydric conditions proposed. For more information on individual species, see “Plants for Stormwater Design: Species Selection for the Upper Midwest” by Daniel Shaw & Rusty Schmidt.

Plantings should be spaced according to each species size and growth potential to allow for sufficient coverage. Planting periods will vary, but in general vegetation should be planted from mid-March through early June, or mid-September through mid-November.

Planting soil must be a loam soil capable of supporting healthy vegetative cover. A recommended soil blend is 20-30% organic material (compost), 20-30% sand, and 20-30% topsoil. Planting soil must be 12 inches deep along the bottom of the Bioswale.

Soils must have clay content less than 10% (a small amount of clay is beneficial to absorb pollutants and retain water), be free of toxic substances, construction debris and unwanted plant material and have a 5-10% organic matter content. Additional organic matter can be added to the soil to increase water holding capacity. Tests should be conducted to determine volume storage capacity of amended soils.

Establishment should include full erosion control blankets or the equivalent.

6. EASEMENTS

Bioswales will have sufficient WCWRC easements for maintenance purposes. Easements will be sized and located to accommodate access and operation of equipment, spoils deposition and other activities identified in the development’s stormwater system maintenance plan.

7. CALCULATIONS

Volume Reduction Calculations
The following equation can be used to determine the approximate storage volume of a Bioswale:

\[
\text{Storage Volume (ft}^3\text{)} = \text{Average bed area (ft}^2\text{)} \times \text{Maximum design water depth (ft)}
\]
*Depth is the depth of the water stored during a storm event, depending on the drainage area, conveyance to the bed, and outlet control.

Infiltration Volume (ft³) = Bed bottom area (ft²) \times \left[ \text{Infiltration design rate (in/hr)} \times \text{Infiltration Period}^\ast \right] \times \left( \frac{1}{12} \right)

*Infiltration Period is the time when bed is receiving runoff and capable of infiltrating at the design rate. Not to exceed 48 hours.

Infiltration Area

The minimum infiltration area of the Infiltration Trench is defined as:

Minimum surface area = Contributing impervious area / 8^\ast

^\ast May be increased at the discretion of the Water Resources Commissioner depending on soil infiltration rate, e.g. where soils are Type A or rapidly draining.

Sizing and Design Criteria

a. Surface area is dependent upon storage volume requirements (impervious drainage area to infiltration area; see Design Requirements for Infiltration Systems for additional guidance on loading rates.)
b. Surface Side slopes must be gradual. The maximum allowable slope for Bioswales is 3:1.
c. Surface Ponding depth must not exceed 12 inches throughout the Bioswale and 18 inches at the end point and will empty within 24 hours.
d. Ponding area must provide sufficient surface area to meet required storage volume without exceeding the design ponding depth. A subsurface storage/infiltration bed can be used to supplement surface storage where appropriate.
e. Planting soil depth must be at least eight inches where only herbaceous plant species will be utilized. If trees and woody shrubs will be used, soil media depth should be increased depending on plant species. Native soils can be used as planting soil or modified on many sites.

Note for all construction steps: Erosion and sediment control methods must adhere to the latest requirements of the Michigan DEQs Soil Erosion and Sedimentation Control Program.

a. Install temporary sediment control BMPs as shown on the plans.
b. Begin construction on the Bioswale only when upper gradient has been significantly stabilized.
c. Complete site grading, minimizing compaction as much as possible.
d. Rough grade the Bioswale as proposed and scarify the existing soil surfaces. Deposit and spread planting soil. Do not compact in-situ soils.
e. Presoak the planting soil prior to planting vegetation to aid in settlement.
f. Install erosion protection.
g. Erosion control must be present and maintained for the first 75 days following the first storm event of the season.

9. MAINTENANCE

Properly designed and installed Bioswales require regular maintenance.

a. Annually inspect the Bioswale for channel and slope uniformity.
b. Inspect check dams annually and correct when signs of altered water flow are identified.
c. Sediment and debris must be removed when build up exceeds 50% of ponding depth in the Bioswale.
d. Dispose of sediment, debris/trash, and any other waste material removed from a Bioswale at a suitable disposal/recycling site, in compliance with local, state, and federal waste regulations.
e. Rills and gullies must be filled in with topsoil and stabilized with seed and mulch blankets.
f. Detritus (e.g. dead/decomposing leaves) must be removed approximately twice per year. Perennial planting may be cut down at the end of the growing season, or early in the next growing season. Mowing can occur twice per year.
g. Invasive species must be removed on an annual basis and disposed of in compliance with local, state, and federal regulations. No chemical shall be used with one exception. Invasive species can be treated chemically by a certified applicator.
Part N. DESIGN REQUIREMENTS – GREEN ROOFS

1. GENERAL REQUIREMENTS

a. Engineered media must have a high mineral content. Engineered media for extensive vegetated roof covers is typically 80% to 97% non-organic.
b. 2-6 inches of non-soil engineered media; assemblies that are 4 inches and deeper may include more than one type of engineered media
c. Vegetated roof covers intended to achieve water quality benefits should not be fertilized
d. Temporary irrigation may be necessary to establish plants. Thereafter, irrigation is generally not required (or even desirable) for optimal stormwater management using vegetated covers
e. Internal building drainage, including provisions to cover and protect deck drain of scuppers, must anticipate the need to manage large rainfall events without inundating the cover.
f. The roof structure must be evaluated for compatibility with the maximum predicted dead and live loads and documented by a structural engineer on a sealed design. Typical dead loads for wet extensive vegetated covers range from 8 to 36 pounds per square foot. Live load is a function of rainfall retention. For example, 2 inches of rain equals 10.4 lbs. per square foot of live load.
g. Waterproofing underlying a green roof must be resistant to biological and root attack. In many instances a supplemental root fast layer is installed to protect the primary waterproofing membrane from plant roots. Root barriers must be thermoplastic membranes of at least 30 mils bonded by hot-air fusion.
2. CALCULATIONS

Volume Reduction Calculations
All vegetated roof covers have both retention and detention volume components. Benchmarks for these volumes can be developed from the physical properties described below.
- Maximum media water retention
- Field capacity
- Plant cover type
- Saturated hydraulic conductivity
- Non-capillary porosity

Peak Rate Mitigation
Vegetated roof covers can exert a large influence on runoff peak rates derived from roofs. An evaluation of peak runoff rates requires either computer simulation or measurements made using prototype assemblies.

A general rule for vegetated roof covers is that rate of runoff from the covered roof surface will be less than or equal to that of open space on typical soils (i.e., NRCS curve number of about 65) for storm events with total rainfall volumes up to 3 times the maximum media water retention of the assembly. For example, a representative vegetated roof cover with a maximum moisture retention of 1 inch will react like open space for storms up to and including the 3-inch magnitude storm.

Green roof stormwater credits will be provided as determined by the calculations provided by the applicant and approved by the WCWRC.

3. CONSTRUCTION

The following is a typical construction sequence; however, alterations will be necessary depending on design variations.

a. Visually inspect the completed waterproofing to identify any apparent flaws, irregularities, or conditions that will interfere with the security or functionality of the vegetated cover system. The waterproofing should be tested for watertightness by the roofing applicator.
b. Institute a program to safely install the vegetated roof system.
c. Introduce measures to protect the finished waterproofing from physical damage.
d. If the waterproofing materials are not root fast, install a root-barrier layer.
e. Layout key drainage and irrigation components, including drain access chambers, internal drainage conduit, confinement border units, and isolation frames (for rooftop utilities, hatches and penetrations).
f. Walkways and paths must be installed for maintenance projects with public access.
g. Test for irrigation systems (This may be relevant for roof gardens but not for extensive green roofs designed for stormwater management.)
h. Install the drainage layer. Depending on the variation type, this could be a geocomposite drain, mat, or drainage media.
i. Cover the drainage layer with the separation fabric (in some assemblies, the separation fabric is pre-bonded to a synthetic drainage layer). The separation fabric should be readily penetrated by roots, but must provide a durable separation between the drainage and growth media layers.
j. Install the upper growth media layer (dual media assemblies only). Growth media must be a soil-like mixture containing not more than 15% organic content.
k. Establish the cover plantings from cuttings, seed, plugs, pre-grown mats, or trays.
l. Provide protection from wind disruptions as warranted by the project conditions and plant establishment method.

*In some installations slope stabilizing measures can be introduced as part of the roof structure and will be already in-place at the start of the construction sequence.

4. MAINTENANCE

a. It will be the responsibility of the property owner or governing association of the development to maintain the green roof and deed restrictions and covenants for the development shall state such. The Water Resources Commissioner will not accept easements nor maintain green roofs. In the event that a green roof in the drainage district is not maintained, the Water Resources Commissioner will take the appropriate legal action to enforce the deed and covenants.
b. Irrigation will be required as necessary during the plant establishment period and in times of drought.
c. During the plant establishment period, three or four visits to conduct basic weeding, fertilization, and infill planting is recommended. Thereafter, only two visits per year for inspection and light weeding should be required (irrigated assemblies will require more intensive maintenance).
d. The soluble nitrogen content of the soil must be adjusted to between one and five parts per million, based on soil tests.
Part O.

DESIGN REQUIREMENTS – WATER REUSE

1. GENERAL REQUIREMENTS

   a. Identify opportunities where water can be reused for irrigation or used for indoor greywater reuse. From this, calculate the water need for the intended uses. For example, if a 2,000 SF landscaped area requires irrigation for 4 months in the summer at a rate of 1” per week; the designer must determine how much water will be needed to achieve this goal, and how often the storage unit will be refilled via precipitation. The usage requirements and the expected rainfall volume and frequency must be determined.

   b. Rain barrels and cisterns should be positioned to receive rooftop runoff.

   c. Provide for the use or release of stored water between storm events in order for the necessary stormwater storage volume to be available.

   d. If cisterns are used to supplement greywater needs, a parallel conveyance system must be installed to separate reused stormwater or greywater from other potable water piping systems. Do not connect to domestic or commercial potable water systems.

   e. Household water demands must be considered when sizing a system to supplement residential greywater.

   f. Pipes or storage units must be clearly marked “Caution: Reclaimed water, Do Not Drink”.

   g. Screens must be used to filter debris from storage units.

   h. Protect storage elements from direct sunlight by positioning and landscaping. Limit light into devices to minimize algae growth.

   i. The proximity to building foundations must be considered from overflow conditions. Overflow discharge must be a minimum of 10’ from building foundation.

   j. Climate is an important consideration. Capture/reuse systems must be disconnected and emptied during winter to prevent freezing.

   k. Cisterns must be watertight (joints sealed with nontoxic waterproof material) with a smooth interior surface, and capable of receiving water from rainwater harvesting system.

   l. Covers and lids must have a tight fit to keep out surface water, animals, dust and light.

   m. Positive outlet for overflow must be provided a few inches from the top of the cistern.

   n. Observation risers must be at least 6” above grade for buried cisterns.

   o. Reuse may require pressurization. To add pressure, a pump, pressure tank and fine mesh filter can be used which adds to the cost of the system, but creates a more usable system.

   p. Rain barrels require a release mechanism in order to drain empty between storm events. Connect a soaker hose to slowly release stored water to a landscaped area.
2. INLET/OUTLET DESIGN

Stormwater is conveyed to the rain barrel or cistern through a downspout. A small pump affixed to the structure will allow the stored stormwater to be removed and used. Positive outlet for overflow should be provided a few inches from the top of the cistern.

3. WATER REUSE COMPONENTS/CONFIGURATION

Rain Barrels
Commonly, rooftop downspouts are connected to a Rain Barrel (container) that collects runoff and stores water until needed for a specific use. Rain barrels are often used at individual homes where water is reused for garden irrigation, including landscaped beds, trees, or other vegetated surfaces. Other uses include commercial and institutional. See Figure 16 for more detail on Rain Barrels.

Cistern/Above Ground Tank
A Cistern or Above Ground Tank is a container or structure that has a greater capacity than a rain barrel. Cisterns and Above Ground Tanks may be comprised of fiberglass, concrete, plastic, brick or other materials and can be stored underground or on the surface. The storage size can range from 200 gallons to 12,000 gallons. See Figure 17 for more detail on Cisterns/Above Ground Storage Tanks.

4. CALCULATIONS

Volume Reduction
The amount of water stored in the container is equal to the volume reduction.

Water Reuse Structure Capacity:
Rain Barrel 40-125 gallons
Cistern/Above Ground Tank 200-12,000 gallons

Peak Rate Mitigation
Overall, capture and reuse takes a volume of water out of site runoff and puts it back into the ground. This reduction in volume will translate to a lower overall peak rate for the site.

Water Quality
Pollutant removal takes place through filtration of recycled primary storage, and/or natural filtration through soil and vegetation for overflow discharge. Quantifying pollutant removal will depend on design. Sedimentation

Figure 16. Rain Barrel Detail
Figure 17. Cistern Detail
Section V: Design Requirements For Stormwater Management Systems

will depend on the area below outlet that is designed for sediment accumulation, time in storage, and maintenance frequency. Filtration through soil will depend on flow draining to an area of soil, the type of soil (infiltration capacity), and design specifics (stone bed, etc.).

5. MAINTENANCE

Rain Barrels
a. Inspect rain barrels four times per year, and after major storm events.
b. Remove debris from screen as needed.
c. Replace screens, spigots, downspouts and leaders as needed.
d. To avoid damage, drain container prior to winter, so that water is not allowed to freeze in the device.
e. It is the responsibility of the owner to maintain any pumps affixed to the rain barrel.

Cisterns
a. Flush cisterns to remove any sediment.
b. Brush the inside surfaces and thoroughly disinfect twice per year.
c. To avoid damage, drain container prior to winter, so that water is not allowed to freeze in the device.
d. It is the responsibility of the owner to maintain any pumps affixed to the cistern.
Part P.

DESIGN REQUIREMENTS – CONVEYANCE SYSTEMS

1. GENERAL REQUIREMENTS
   a. All structures will be constructed in accordance with governing specifications including Michigan Department of Transportation, Washtenaw County Road Commission, and the City or Township. In the event of no other governing specifications, the latest edition of the Michigan Department of Transportation standards will be observed.
   b. Stormwater conveyance systems incorporating pumps shall not be permitted in developments with multiple owners, such as subdivisions and site condominiums.

2. NATURAL STREAMS AND CHANNELS
   a. Natural streams are to be preserved. Natural swales and channels should be preserved, whenever possible.
   b. If channel modification must occur, the physical characteristics of the modified channel will duplicate the existing channel in length, cross-section, slope, sinuosity, and carrying capacity. For proposed drain modifications, the WCWRC may require restoration/rehabilitation to a more natural (historical) channel design.
   c. Streams and channels will be explored to withstand all events up to the 100-year storm without increased erosion. Armoring banks with riprap and other manufactured materials will be accepted only where erosion cannot be prevented in any other way, such as by the use of vegetation.

3. VEGETATED SWALES/OPEN DITCHES
   Open swale/ditch drainage systems are preferred to enclosed storm sewers where applicable governmental standards and site condominiums permit. Swales will be required to:
   a. Follow natural, pre-development drainage paths insofar as possible.
   b. Be well vegetated, wide and shallow.
   c. Open ditch flow velocities will be neither siltative nor erosive. The minimum acceptable velocity will be 2.0 ft/sec., and the maximum acceptable velocity will be 6.0 ft/sec.
   d. Open ditch slopes will depend on existing soils and vegetation. However, the minimum acceptable slope is 1.5%, unless other techniques such as infiltration devices are implemented. Maintenance for such devices must be detailed in the overall maintenance plan.
   e. Side slopes of ditches shall be no steeper than 3:1. Soil conditions, vegetative cover and maintenance ability will be the governing factors for determining side slope requirements.
   f. Slopes and bottoms of open ditches and swales will be stabilized to prevent erosion.
   g. Swale length shall be a minimum of 200 feet whenever possible, to increase the contact time of stormwater. The maximum length will be based on soil type, slope and catchment area.
   h. A minimum clearance of 5 feet is required between open swale/ditch inverts and underground utilities unless special provisions are employed. Special provisions, for example, could be the encasement of utility lines in concrete when crossing under the channel. In no case will less than 2 feet of clearance be allowed.
   i. Permanent metal or plastic markers will be placed on each side of the drain to show the location of underground utilities.
   j. All bridges will be designed to provide a 2-foot minimum flood stage freeboard to the underside of the bridge. Footings will be at least one foot below the invert grade of the channel. Depending on soils, additional footing depth may be required.
   k. A series of check dams to drop structures across swales shall be provided to enhance water quality performance and reduce velocities.
   l. Designers should consider integrating additional redundant pollutant removal enhancement features such as stilling basins and stone infiltration trenches.

4. ENCLOSED DRAINAGE STRUCTURES
   Enclosed storm drain systems will be sized to accommodate the 10-year storm, with the hydraulic gradient kept below the top of the pipe.
   a. Restricted conveyance systems designed to create backflow into stormwater storage facilities are not permitted.
   b. Drainage structures will be located as follows:
      i. To assure complete positive drainage of all areas of the subdivision.
      ii. At all low points of streets and rear yards.
      iii. Such that there is no flow across a street intersection.
iv. For smaller enclosed pipes, 12 to 24 inches in diameter, manholes will not be spaced more than 400 feet apart. Longer runs may be allowed for larger sized pipe but in all cases maintenance access must be deemed adequate by the Water Resources Commissioner.

c. The catch basin or inlet covers shall be designed to accept the 10-year design storm. No ponding of water should occur during this storm event. All private sump and/or roof drainage lines must connect to a catch basin structure to further prevent surface ponding of water during storm events.

d. Discharge from enclosures will be as follows:
   i. All outlets will be designed so that velocities will be appropriate to, and will not damage, receiving waterways.
   ii. Outlet protection using riprap or other approved materials will be provided as necessary to prevent erosion.
   iii. The soils above and around the outlet will be compacted and stabilized to prevent piping around the structure. Riprap extending 3 feet above the ordinary high water mark is required for all outlets.
   iv. When the outlet empties into a detention/retention facility, channel or other watercourse, it will be designed such that there is no free overfall from the end of the apron to the receiving waterway.

e. Pipe will conform to the following criteria:
   i. The minimum acceptable pipe diameter is 12 inches.
   ii. In order to avoid accumulation of sediment in the drain, pipe will be designed to have minimum velocity flowing full of 3 ft/sec., with the exception of sediment chambers.
   iii. The maximum allowable velocity flowing full will be 10 ft/sec.
   iv. Pipe joints will be such as to prevent excessive infiltration or exfiltration.
   v. All materials will be of such quality as to guarantee a maintenance-free expectancy of at least 50 years and will meet all appropriate A.S.T.M standards.
   vi. The minimum depth of pipe shall be 42 inches from grade to the springline of the pipe.

f. In areas where local ordinance requires sump pump leads to be connected into an enclosed system, these taps shall be made directly into storm sewer structures or into cleanouts approved by the Water Resources Commissioner.

g. Sump pump lines and connections shall not fall under the long term operation and maintenance of the Water Resources Commissioner’s Office and will not become part of an established county drain. Maintenance of such lines will be the responsibility of the property owners, and shall be so specified in subdivision rules or condominium master deed agreements.

Sites requiring a permit from WCWRC must notify WCWRC upon receipt of vegetative materials. The site/project must arrange for inspection/review by WCWRC prior to installation of vegetation.
Part Q. DESIGN REQUIREMENTS – LOT GRADING

1. GENERAL REQUIREMENTS

Approval of final lot grading is the responsibility of the local municipality. The Water Resources Commissioner’s Office is not responsible for the inspection of, or enforcing corrections to, final lot grading. It is the Water Resources Commissioner’s responsibility to ensure that the overall plan is consistent with sound stormwater management and drainage practices. The subdivision stormwater management plan will provide for the following:

a. The grading of lots will be such that surface runoff is away from homes and toward swales, ditches or drainage structures. Provision for drainage through properly graded stormwater conveyance systems will be made for all areas within the proposed subdivision.

b. Where finished grades indicate a substantial amount of drainage across adjoining lots, a drainage swale of sufficient width, depth and slope will be provided on the lot line to intercept this drainage. To ensure that property owners do not alter or fill drainage swales, easements will be required over areas deemed necessary by the Water Resources Commissioner.