

ORDINANCE NO. 2023-45

***AN ORDINANCE TO REGULATE STORMWATER
DISCHARGE QUANTITY, EROSION & SEDIMENT
CONTROL AND STORMWATER QUALITY FOR ALL
DEVELOPMENT AND REDEVELOPMENT OCCURRING
WITHIN HENDRICKS COUNTY, INDIANA***

WHEREAS, the Board of County Commissioners of Hendricks County, Indiana is required to establish a regulatory mechanism for regulating both stormwater quantity and stormwater quality management, and

WHEREAS, the Hendricks County Board of Commissioners adopted Ordinance No. 2001-33 in December 2001, in order to govern the control of runoff of stormwater and to protect, conserve and promote the orderly development of the land in Hendricks County and its water resources, and

WHEREAS, the Hendricks County Board of Commissioners adopted Ordinance No. 2004-43 on December 27, 2004, in order to govern the control of runoff of stormwater and to protect, conserve and promote the orderly development of the land in Hendricks County and its water resources, and

WHEREAS, Hendricks County was granted statutory authority under "Home Rule", and further required by Phase II of the National Pollution Discharge Elimination System program (FR Doc. 99-29181) authorized by the 1972 amendments to the Clean Water Act, the Indiana Department of Environmental Management's Rule 13 (327 IAC 15-13), and the Indiana Department of Environmental Management's Rule 5 (327 IAC 15-5), and

WHEREAS, 327 IAC 15-13 (Rule 13), specified by State regulation, requires Hendricks County to develop and implement a comprehensive Storm Water Quality Management Plan (SWQMP) and allows the County the ability to self-fund such a program.


NOW THEREFORE, BE IT ORDAINED by the Hendricks County Board of Commissioners that Hendricks County will be responsible for meeting all State and Federal requirements of the Rule 13 permit program. This Ordinance is to provide for the health, safety, and general welfare of the citizens of Hendricks County through the

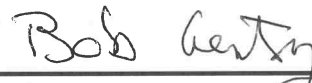
regulation of stormwater and non-stormwater discharges to the storm drainage system and to protect, conserve and promote the orderly development of land and water resources within Hendricks County. This Ordinance will be known as the Hendricks County Stormwater Management Ordinance.


This Ordinance shall be in full force and effect from and after its passage and approval.

Presented to the Board of Commissioners of Hendricks County, Indiana, and approved on this 12th day of December, 2023.

**BOARD OF COMMISSIONERS
OF HENDRICKS COUNTY:**


Phyllis A. Palmer President


Bob Gentry Vice President


Dennis W. Dawes, Member

ATTEST:


David L. Gaston P.S. Hendricks County Surveyor


Nancy Marsh Hendricks County Auditor

HENDRICKS COUNTY STORMWATER MANAGEMENT ORDINANCE



OCTOBER 2023 EDITION (Effective April 2024)

Developed by Christopher B. Burke Engineering, LLC



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**CHAPTER ONE****GENERAL INFORMATION**

1. AUTHORITY AND TITLE

This Ordinance is adopted in accordance with statutory authority granted to Hendricks County under “Home Rule”, and further required by Phase II of the National Pollution Discharge Elimination System program (FR Doc. 99–29181) authorized by the 1972 amendments to the Clean Water Act, the Indiana Department of Environmental (IDEM) Municipal Separate Storm Sewer System (MS4) General Permit (MS4 GP) and Construction Stormwater General Permit (CSGP). . Based on this authority and these requirements, this Ordinance regulates:

- A. Discharges of prohibited non-stormwater flows into the storm drain system.
- B. Stormwater drainage improvements related to development of lands located within Hendricks County.
- C. Drainage control systems installed during new construction and grading of lots and other parcels of land.
- D. Erosion and sediment control systems installed during new construction and grading of lots and other parcels of land.
- E. The design, construction, and maintenance of stormwater drainage facilities and systems.
- F. The design, construction, and maintenance of stormwater quality facilities and systems.
- G. The design, construction, and maintenance of new dams
- H. The development downstream of existing dams
- I. Development within floodways, floodplains, fluvial erosion hazard corridors, and bluff zones

This Ordinance shall be known and may be cited as the Hendricks County Stormwater Management Ordinance.

2. APPLICABILITY AND EXEMPTIONS

This Ordinance shall regulate all development and redevelopment occurring within Hendricks County, Indiana, falling under the jurisdictional authority of the Hendricks County Drainage Board, the Hendricks County Surveyor, and the Clean Water Department. No building permit shall be issued and no land disturbance started for any construction in a development, as defined in Appendix A, until the plans required by this Ordinance for such construction have been accepted in writing by Hendricks County. With the exception of the requirements of Chapter Two and Chapter Seven – Section 4 of this Ordinance, single-family dwelling houses in accepted subdivisions, new buildings (or cumulative building additions) with less than 500 square feet of area, and land-disturbing activities affecting less than 5,000 square feet of area shall be exempt from the requirements of this Ordinance. Also exempt from this Ordinance shall be the agricultural land-disturbing activities.

Hendricks County government projects shall be required to obtain a Stormwater Permit and are expected to meet all applicable technical requirements of this Ordinance and the Hendricks County Stormwater Technical Standards Manual.

Any construction project which has had its final secondary drainage plan accepted by Hendricks County within a 2-year period prior to the effective date of this Ordinance or the Technical Standards shall be required to only abide by those provisions that were in effect prior to this update.

It is the policy of the Hendricks County Drainage Board that any primary approval application received by the Drainage Board for development of real estate shall comply with all existing ordinances at the time of application to the Drainage Board.

It is the policy of the Hendricks County Drainage Board that all primary approvals by the Board are good for 24 months from the date of approval by the Board. After which time the Hendricks County Drainage Board, based on the recommendation of the Hendricks County Surveyor, may require a revised primary approval for said development.

It is the policy of the Hendricks County Drainage Board that all primary applications shall adhere to and comply with release rates determined by a detailed watershed study or additional information, if more restrictive than what is required in this Ordinance or its updates effective at the time of application.

It is the policy of the Hendricks County Drainage Board that all secondary approval applications shall adhere to and comply with the drainage ordinances effective at the time of application if the application is received within 24 months of the primary application approval.

It is the policy of the Hendricks County Drainage Board that all secondary applications shall adhere to and comply with release rates determined by a detailed watershed study or additional information, if more restrictive than what is required in this Ordinance or its updates effective at the time of application.

Hendricks County Drainage Board and/or the Hendricks County Surveyor has the authority to modify, add to, grant exemptions, and/or waive any and all the requirements of this Ordinance and its associated technical standards document. A pre-submittal meeting with Hendricks County staff may be requested by the applicant to discuss the applicability of various provisions of the Ordinance and its associated technical standards document with regards to unique or unusual circumstances relating to a project. However, any initial determination of such applicability shall not be binding on future determinations of Hendricks County staff that may be based on the review of more detailed information and plans.

3. BACKGROUND

The Board of Commissioners of Hendricks County, State of Indiana, adopted Ordinance No. 2001-33 in December 2001 which established "Storm Drainage, Erosion, and Sediment Control Ordinance of Hendricks County", commonly known as the "Hendricks County Drainage Code", in order to govern the control of runoff of stormwater and to protect, conserve and promote the orderly development of the land in Hendricks County and its water resources. This code was primarily targeted at stormwater discharge quantity, and erosion and sediment control.

On December 8, 1999, Phase II of the National Pollutant Discharge Elimination System (NPDES) permit program, was published in the Federal Register. The NPDES program, as authorized by the 1972 amendments to the Clean Water Act, controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Phase II of NPDES requires permit coverage for stormwater discharges from regulated small municipal separate storm sewer systems (MS4s) and for small construction activity that results in the disturbance of equal to or greater than one acre. This Federal regulation went into effect on March 10, 2003. In response to Phase II of NPDES, the Indiana Department of Environmental Management enacted Rule 13 (327 IAC 15-13) and revised Rule 5 (327 IAC 15-5).

Under these new State and Federal regulations, Hendricks County was required to establish a regulatory mechanism for regulating stormwater quality management. Therefore, the "Hendricks County Drainage Code" was replaced in 2004 with a document that included new requirements for management of stormwater quality in addition to quantity. The Stormwater Management Ordinance and its companion Stormwater Technical Standards Manual were further updated in 2016.

In December 2021, IDEM finalized two new permits, Municipal Separate Storm Sewer System (MS4) General Permit (MS4 GP) and Construction Stormwater General Permit (CSGP), which replaced the

previous IDEM's Rule 13 and Rule 5. These new permits require the County to update its Stormwater Management Ordinance to incorporate new requirements contained in the 2021 permits. The 2023 Stormwater Management Ordinance of Hendricks County and its companion document, the 2023 Hendricks County Stormwater Technical Standards Manual, incorporate the IDEM-required changes and other necessary periodic updates.

4. FINDINGS

The Hendricks County Board of Commissioners finds that:

- A. Water bodies, roadways, structures, and other property within and downstream of Hendricks County are at times subjected to flooding;
- B. Flooding is a danger to the lives and property of the public and is also a danger to the natural resources of the region;
- C. Land development alters the hydrologic response of watersheds, resulting in increased stormwater runoff rates and volumes, increased flooding, increased stream channel erosion, and increased sediment transport and deposition;
- D. Soil erosion resulting from land-disturbing activities causes a significant amount of sediment and other pollutants to be transported off-site and deposited in ditches, streams, wetlands, lakes, and reservoirs;
- E. Increased stormwater runoff rates and volumes, and the sediments and pollutants associated with stormwater runoff from future development projects within Hendricks County will, absent reasonable regulation and control, adversely affect the Hendricks County's water bodies and water resources;
- F. Pollutant contributions from illicit discharges within Hendricks County will, absent reasonable regulation, monitoring, and enforcement, adversely affect the Hendricks County's water bodies and water resources;
- G. Stormwater runoff, soil erosion, non-point source pollution, and illicit sources of pollution can be controlled and minimized by the regulation of stormwater management;
- H. Preventing further encroachment into the FEH corridors will minimize fluvial erosion hazards and property loss from flooding, enhance public safety, maximize channel stability, and maintain or improve water quality and habitat function;
- I. Adopting the standards, criteria, and procedures contained and referenced in this Ordinance and implementing the same will address many of the deleterious effects of stormwater runoff, illicit discharges, and fluvial erosion hazards;
- J. Adopting this Ordinance is necessary for the protection of property, preservation of the public health, safety, and welfare, for the conservation of our natural resources, and for compliance with State and Federal regulations.
- K. Adopting this Ordinance is necessary for the protection of mutual and private drains.

5. PURPOSE

The purpose of this Ordinance is to provide for the health, safety, and general welfare of the citizens of Hendricks County through the regulation of stormwater and non-stormwater discharges to the storm drainage system and to protect, conserve and promote the orderly development of land and water resources within Hendricks County. This Ordinance establishes methods for managing the quantity and quality of stormwater entering into the storm drain system in order to comply with State and Federal requirements. The objectives of this Ordinance are:

- A. To reduce the hazard to public health and safety caused by excessive stormwater runoff.
- B. To regulate the contribution of pollutants to the storm drain system from construction site runoff.
- C. To regulate the contribution of pollutants to the storm drain system from runoff from new development and re-development.
- D. To prohibit illicit discharges into the storm drain system.

- E. To establish legal authority to carry out all inspection, monitoring, and enforcement procedures necessary to ensure compliance with this Ordinance.

6. ABBREVIATIONS AND DEFINITIONS

For the purpose of this Ordinance, the abbreviations and definitions provided in Appendix A shall apply.

7. RESPONSIBILITY FOR ADMINISTRATION

Hendricks County Drainage Board and/or Hendricks County Surveyor, as well as the Hendricks County Clean water Department, shall administer, implement, and enforce the provisions of this Ordinance. The Hendricks County Drainage Board and/or the Hendricks County Surveyor is authorized to adopt or update the Stormwater Technical Standards or other technical specifications, which shall be on file in Hendricks County Surveyor's offices for public inspection. Any powers granted or duties imposed upon the authorized enforcement agency may be delegated in writing by Hendricks County to qualified persons or entities acting in the beneficial interest of or in the employ of Hendricks County.

8. CONFLICTING ORDINANCES

The provisions of this Ordinance shall be deemed as additional requirements to minimum standards required by other Hendricks County ordinances, and as supplemental requirements to Municipal Separate Storm Sewer System (MS4) General Permit (MS4 GP) and Indiana's Construction Stormwater General Permit (CSGP). In case of conflicting requirements, the most restrictive shall apply.

9. INTERPRETATION

Words and phrases in this Ordinance shall be construed according to their common and accepted meanings, except that words and phrases defined in Appendix A shall be construed according to the respective definitions given in that section. Technical words and technical phrases that are not defined in this Ordinance but which have acquired particular meanings in law or in technical usage shall be construed according to such meanings.

10. SEVERABILITY

The provisions of this Ordinance are hereby declared severable, and if any court of competent jurisdiction should declare any part or provision of this Ordinance invalid or unenforceable, such invalidity or unenforceability shall not affect any other part or provision of this Ordinance.

11. EFFECTIVE DATE

This Ordinance shall become effective after its final passage, approval, and publication as required by law.

12. DISCLAIMER OF LIABILITY

The degree of protection required by this Ordinance is considered reasonable for regulatory purposes and is based on historical records, engineering, and scientific methods of study. Larger storms may occur or stormwater runoff amounts may be increased by man-made or natural causes. This Ordinance does not

imply that land uses permitted will be free from stormwater damage. This Ordinance shall not create liability on the part of any Hendricks County agency or any officer, representative, or employee thereof, for any damage which may result from reliance on this Ordinance or on any administrative decision lawfully made there under.

The words “approve” and “accept”, and their common derivations as used in this Ordinance in relation to plans, reports, calculations, and permits shall mean that Hendricks County has reviewed the material produced and submitted by the applicant or his/her agents for general compliance with this Ordinance and the Hendricks County Stormwater Technical Standards Manual, and that such a compliance would qualify the applicant to receive a stormwater Management approval or permit. Such an “approval” or “acceptance” is based on the assumption that the project engineer has followed all appropriate engineering methods in the design. Any stormwater quality or stormwater quantity (drainage) problems associated with the project caused by poor construction by the contractor and/or poor engineering design or judgment, either on-site or off-site, are the responsibility of the developer and the project engineer.



CHAPTER TWO

PROHIBITED DISCHARGES AND CONNECTIONS

1. APPLICABILITY AND EXEMPTIONS

This Chapter shall apply to all discharges, including illegal dumping, entering the storm drain system under the control of Hendricks County, regardless of whether the discharge originates from developed or undeveloped lands, and regardless of whether the discharge is generated from an active construction site or a stabilized site. These discharges include flows from direct connections to the storm drain system, illegal dumping, and contaminated runoff.

Stormwater runoff from agricultural, timber harvesting, and mining activities is exempted from the requirements of this chapter unless determined to contain pollutants not associated with such activities or in excess of standard practices. Farm residences are **not** included in this exemption.

Any non-stormwater discharge permitted under an NPDES permit, waiver, or waste discharge order issued to the discharger and administered under the authority of the Federal Environmental Protection Agency, provided that the discharger is in full compliance with all requirements of the permit, waiver, or order and other applicable laws and regulations, and provided that written acceptance has been granted for the subject discharge to the storm drain system, is also exempted from this Chapter.

Finally, any construction project which has had its drainage plan approved by Hendricks County prior to the effective date of this ordinance shall be exempt from all requirements of this ordinance that are in excess of the requirements of ordinances in effect at the time of approval.

2. PROHIBITED DISCHARGES AND CONNECTIONS

No person shall discharge or illegally dump to a MS4 conveyance, watercourse, or waterbody, directly or indirectly, any substance other than stormwater or an exempted discharge. Any person discharging stormwater shall effectively minimize pollutants from also being discharged with the stormwater, through the use of best management practices (BMPs).

Hendricks County is authorized to require dischargers to implement pollution prevention measures, utilizing BMPs, necessary to prevent or reduce the discharge of pollutants into Hendricks County's stormwater drainage system.

3. EXEMPTED DISCHARGES AND CONNECTIONS

Notwithstanding other requirements in this Ordinance, stormwater comingled with other discharges either regulated by other NPDES permits or determined by the Hendrick County Surveyor, Hendricks County Drainage Board, or the Hendricks County Clean Water Department to not be a significant source of pollutants, including the following, are exempt from the requirements of this Section:

- i. Water line and hydrant flushing for maintenance
- ii. Irrigation water
- iii. Footing, foundation, and crawl Space drains (uncontaminated)
- iv. Excess storm sewer cleaning water not collected by a vacuum truck (uncontaminated)
- v. Fire suppression activities
- vi. Uncontaminated pumped groundwater
- vii. Springs
- viii. Residential car washing

- ix. Non-commercial car washing by community organizations
- x. External building washdown, without detergents
- xi. Dechlorinated/debrominated residential swimming pool discharges
- xii. Uncontaminated groundwater infiltration (as defined at 40 CFR 35.2005(20))
- xiii. Pavement wash waters provided spills or leaks of toxic or hazardous materials have not occurred (unless all spill material has been removed) and where detergents are not used
- xiv. Uncontaminated condensate from air conditioning units, coolers, and other compressors, and from outside storage of refrigerated gases or liquids

4. STORAGE OF HAZARDOUS OR TOXIC MATERIAL

Storage or stockpiling of hazardous or toxic material within any watercourse, or in its associated floodway or floodplain, is strictly prohibited. Storage or stockpiling of hazardous or toxic material, including sewage treatment plant stockpiles, on active construction sites shall include adequate protection and/or containment so as to prevent any such materials from entering any temporary or permanent stormwater conveyance or watercourse.

5. PRIVATE PROPERTY MAINTENANCE DUTIES

Every person owning property through which a watercourse passes, or such person's lessee, shall keep and maintain that part of the watercourse located within their property boundaries free of trash, debris, vegetation, and other obstacles that would pollute, contaminate, or significantly retard the flow of water through the watercourse. In addition, the owner or lessee shall maintain existing privately owned structures or farm debris within or adjacent to a watercourse and/or Regulated Drain Easements, so that such structures or farm debris will not become a hazard to the use, function, or physical integrity of the watercourse. The Homeowners Association and or private homeowners are required to keep all curb inlets clear from debris.

6. SPILL REPORTING

Any discharger who accidentally discharges into a waterbody any substance other than stormwater or an exempted discharge shall immediately inform the Hendricks County Health Department and Hendricks County Emergency Management agency concerning the discharge. A written report concerning the discharge shall be filed with the Hendricks County Surveyor's Office and IDEM, by the discharger, within five (5) days. The written report shall specify:

- A. The composition of the discharge and the cause thereof;
- B. The date, time, and estimated volume of the discharge;
- C. All measures taken to clean up the accidental discharge, and all measures proposed to be taken to prevent any recurrence;
- D. The name and telephone number of the person making the report, and the name and telephone number of a person who may be contacted for additional information on the matter.

A properly reported accidental discharge shall be an affirmative defense to a civil infraction proceeding brought under this Ordinance against a discharger for such discharge. It shall not, however, be a defense to a legal action brought to obtain an injunction, to obtain recovery of costs or to obtain other relief because of or arising out of the discharge. A discharge shall be considered properly reported only if the discharger complies with all the requirements of this Section. This requirement does not relieve discharger from notifying other entities as required by State or Federal regulations.

7. INSPECTIONS AND MONITORING

A. Storm Drainage System

Hendricks County has the authority to periodically inspect that portion of the storm drainage system under Hendricks County's control, in an effort to detect and eliminate illicit connections and discharges into the system. This inspection will include a screening of discharges from outfalls connected to the system in order to determine if prohibited flows are being conveyed into the storm drainage system. It could also include spot testing of waters contained in the storm drainage system itself to detect the introduction of pollutants into the system by means other than a defined outfall, such as dumping or contaminated sheet runoff.

B. Potential Polluters

If, as a result of the storm drainage system inspection, a discharger is suspected of an illicit discharge, Hendricks County may inspect and/or obtain stormwater samples from stormwater runoff facilities of the subject discharger, to determine compliance with the requirements of this Ordinance. Upon request, the discharger shall allow Hendricks County's properly identified representative to enter upon the premises of the discharger at all hours necessary for the purposes of such inspection or sampling. Hendricks County or its properly identified representative may place on the discharger's property the equipment or devices used for such sampling or inspection. Identified illicit connections or discharges shall be subject to enforcement action as described in Chapter 8 of this Ordinance.

C. New Development and Re-Development

Following the final completion of construction and the receipt of as-built drawings, Hendricks County has the authority to inspect new development and re-development sites to verify that all on-site stormwater conveyances and connections to the storm drainage system are in compliance with this Chapter.

**CHAPTER THREE****STORMWATER QUANTITY MANAGEMENT**

1. APPLICABILITY AND EXEMPTIONS

The storage and controlled release rate of excess stormwater runoff shall be required for all new business, commercial and industrial developments, residential subdivisions, planned development, rural estate subdivisions, and any redevelopment or other new construction located within Hendricks County. Hendricks County Drainage Board and/or Hendricks County Surveyor, after thorough investigation and evaluation, may waive the requirement of controlled runoff for minor subdivisions and parcelization. Additional potential exemptions regarding the detention requirements are provided under Section 2.B.

2. POLICY ON STORMWATER QUANTITY MANAGEMENT**A. Detention Policy**

It is recognized that most streams and drainage channels serving Hendricks County do not have sufficient capacity to receive and convey stormwater runoff resulting from continued urbanization. Accordingly, the storage and controlled release of excess stormwater runoff as well as compensation for loss of floodplain storage shall be required for all developments and redevelopments (as defined in Appendix A) located within Hendricks County. Release rate requirements, downstream restriction considerations, acceptable outlet, adjoining property impact considerations, policy on dams and levees, and compensatory floodplain storage rates are detailed in the Hendricks County Stormwater Technical Standards Manual.

B. Direct Release Provisions

Due to unknowns regarding the future development patterns and the associated proposed stormwater quantity and quality management systems within a watershed, it is the policy of the Hendricks County Drainage Board to discourage direct release of runoff from a new development or redevelopment without providing detention. However, in rare circumstances, where a comprehensive watershed-wide hydrologic study or watershed plan of a major stream adopted by the Hendricks County Drainage Board and/or the Hendricks County Surveyor (not a “beat the peak” analysis) substantiates the benefits of (or allows for) direct release for a proposed development located adjacent to a major stream, the detention requirements set in this Ordinance may be waived. Other special circumstances when such a waiver may be considered by Hendricks County include situations where the design of a regional pond has already taken into account the provision of direct release in certain areas in the watershed.

3. CALCULATIONS AND DESIGN STANDARDS AND SPECIFICATIONS

The calculation methods as well as the type, sizing, and placement of all stormwater facilities shall meet the design criteria, standards, and specifications outlined in the Hendricks County Stormwater Technical Standards Manual. The methods and procedures in the Stormwater Technical Standards Manual are consistent with the policy stated above.

4. DRAINAGE EASEMENT REQUIREMENTS

Regulated Drainage Easements (RDEs) are stormwater easements and drainage rights of way that are dedicated to the public and trusted to the Hendricks County Drainage Board and the County Surveyor for the sole and exclusive purpose of controlling surface water and/or for the installation, operation, and

maintenance of storm sewers as defined in the Hendricks County Stormwater Management Ordinance. These drainage easements are established under authority of the Indiana Drainage Code and the said Board and County Surveyor may exercise powers and duties as provided in said code (e.g., annual drainage assessment per lot). All other storm drainage easements have not been accepted into the County's system.

There shall be no trees or shrubs planted, nor any structures or fences erected in any drainage easement, or and utility lines appurtenances above ground or underground erected, unless otherwise accepted by the Hendricks County Drainage Board and/or the Hendricks County Surveyor. All stormwater systems, including detention or retention basins, conveyance systems, structures and appurtenances, located outside of the right-of-way may be incorporated into the Hendricks County system at the discretion of Hendricks County Drainage Board and/or the Hendricks County Surveyor. The developer shall petition to incorporate the storm system into the Hendricks County system. The stormwater management approval shall not be granted until such petition is submitted in a form accepted by the Hendricks County Drainage Board and/or the Hendricks County Surveyor.

If the Hendricks County Drainage Board accepts the petition for incorporation into their system, the following statement shall become part of the Restrictive Covenants of every platted subdivision and shown on recorded plat: *"channels, storm sewers, inlets and outlets of detention and retention ponds, and appurtenances thereto within designated Regulated Drainage Easements (RDEs) are extensions of the Hendricks County stormwater drainage system and are the responsibility of Hendricks County Drainage Board. Specific definitions and requirements associated with these RDEs and noted storm drainage systems are contained in Chapter 3, Section 2.4 of the Hendricks County Stormwater Management Ordinance and in the Hendricks County Stormwater Technical Standards Manual. Drainage swales shall be the responsibility of owner or homeowner association."* This statement is not required for any project that does not appear before the Hendricks County Drainage Board.

For petition to the County, the following statement shall be put on each subdivision plat: *"A petition addressed to the Hendricks County Drainage Board has been filed in duplicate with the Drainage Board, requesting that the subdivision's storm drainage system and its easements be accepted into the County's regulated drainage system. The storm drainage system and its easements that are accepted into the County's regulated drainage system are delineated on the plat as Regulated Drainage Easements (RDEs). All other drainage easements have not been accepted into the County's system. All drainage improvements performed relative to the conveyance of stormwater runoff and the perpetual maintenance thereof, within the latter easements, shall be the responsibility of the owner or homeowner association. Within the latter easements, the Hendricks County Drainage Board assumes no responsibility relative to said improvements or the maintenance thereof. Specific definitions and requirements associated with these RDEs and noted storm drainage systems are contained in Hendricks County Stormwater Management Ordinance and in Hendricks County Stormwater Technical Standards Manual. This subdivision contains _____ linear feet of open ditches and _____ linear feet of subsurface drains that will be included in the County's Regulated Drainage System."* All plats shall note the lengths of Regulated Drain, broken down by the length of open and tile drains, shall also be shown in tabular form in a prominent position on the plat.

Any outlet to, crossing, and/or encroachment of a Regulated Drainage Easement requires application and acceptance from the Hendricks County Surveyor's Office.

5. PLACEMENT OF UTILITIES

No utility company may disturb existing storm drainage facilities without the consent of the Hendricks County Surveyor, whose decision may be appealed to the Hendricks County Drainage Board. All existing drainage facilities shall have senior rights and damage to said facilities shall result in penalties as prescribed in Chapter 8 of this Ordinance.

6. STRUCTURES NEAR COUNTY REGULATED DRAINS

For regulated drains not located in platted subdivisions, no permanent structure (including fences and utility structures and appurtenances) shall be erected within seventy-five feet measured at right angles from a) the existing top edge of each bank of a regulated open drain, as determined by Hendricks County; or b) the center line of a tiled Regulated Drain, unless otherwise accepted by Hendricks County. The Indiana Drainage Code may be consulted for further details.

7. INSPECTION, MAINTENANCE, RECORD KEEPING, AND REPORTING

After the stormwater management approval is granted (by Hendricks County) and the commencement of construction activities, Hendricks County has the authority to conduct inspections of the work being done to ensure full compliance with the provisions of this chapter, the Stormwater Technical Standards Manual, and the terms and conditions of the approval.

Hendricks County also has the authority to perform long-term, post-construction inspection of all public or privately owned stormwater quantity facilities. The inspection will cover physical conditions, available storage capacity, and the operational condition of key facility elements. Stormwater quantity facilities shall be maintained in good condition, in accordance with the terms and conditions of the stormwater management approval, and shall not be subsequently altered, revised or replaced except in accordance with the stormwater approval, or in accordance with approved amendments or revisions to the original Stormwater Management approval. If deficiencies are found during the inspection, the owner of the facility will be notified by Hendricks County and will be required to take all necessary measures to correct such deficiencies. If the owner fails to correct the deficiencies within the allowed time period, as specified in the Hendricks County notification, Hendricks County will undertake the work and collect from the owner using lien rights if necessary.

Assignment of responsibility for maintaining facilities, including the retention/detention ponds, serving more than one lot or parcel shall be documented by appropriate covenants to property deeds, unless responsibility is formally accepted by a public body, and determined before the final stormwater approval. Stormwater detention/retention basins may be donated to Hendricks County or another unit of government designated by the Hendricks County Drainage Board for ownership and permanent maintenance, providing the Hendricks County Drainage Board or other governmental unit is willing to accept responsibility.



CHAPTER FOUR

**STORMWATER POLLUTION PREVENTION
FOR CONSTRUCTION SITES**

1. APPLICABILITY AND EXEMPTIONS

Hendricks County will require a Stormwater Pollution Prevention Plan (SWPPP), which includes erosion and sediment control measures and materials handling procedures, to be submitted as part of the construction plans and specifications. Any project located within Hendricks County which falls under the jurisdictional authority of the Hendricks County Drainage Board and/or the Hendricks County Plan Commission, and includes clearing, grading, excavation, and other land disturbing activities resulting in the disturbance of 1 acre or more of total land area is subject to the requirements of this Chapter. This includes both new development and re-development. This chapter also applies to disturbances of less than one 1 acre of land that are part of a larger common plan of development or sale if the larger common plan will ultimately disturb one (1) or more acres of land, within the area under the jurisdictional authority of the Hendricks County Drainage Board. Section 3 of this Chapter provides guidelines for calculating land disturbance. Projects meeting the coverage requirements of 327 IAC 15-5 (Rule 5) shall also be in compliance with 327 IAC 15-5.

The requirements under this Chapter do not apply to the following activities:

- a. agricultural land disturbing activities associated with normal farming practices; or
- b. forest harvesting activities.

The requirements under this Chapter do not apply to the following activities, provided other applicable State permits contain provisions requiring immediate implementation of soil erosion control measures:

- a. Landfills that have been issued a certification of closure under 329 IAC 10.
- b. Coal mining activities permitted under IC 14-34.
- c. Municipal solid waste landfills that are accepting waste pursuant to a permit issued by the Indiana Department of Environmental Management under 329 IAC 10 that contains equivalent stormwater requirements, including the expansion of landfill boundaries and construction of new cells either within or outside the original solid waste permit boundary.

For an individual lot where land disturbance is expected to be one (1) acre or more, the individual lot owner shall complete their own notice of intent letter, apply for stormwater management approval from Hendricks County and ensure that a sufficient construction and stormwater pollution prevention plan is completed and submitted in accordance with Chapter 6 of this Ordinance; regardless of whether the individual lot is part of a larger permitted project site.

An individual lot with land disturbance less than one (1) acre, located within a larger permitted project site, is considered part of the larger permitted project site, and the individual lot operator shall comply with the terms and conditions of the stormwater approval for the larger project site. The stormwater approval application for the larger project site shall include typical detailed erosion and sediment control measures for individual lots. In addition, the builders of these individual lots are required to submit an Individual Lot Plot Plan Permit application along with a SWPPP for that individual lot prior to receiving a building permit. Details of the permitting process for individual lots and parcels are contained in Chapter 6 and additional requirements for individual lots may be found in the Hendricks County Stormwater Technical Standards Manual.

It will be the responsibility of the project site owner to complete a stormwater management approval application and ensure that a sufficient construction plan is completed and submitted to Hendricks County in accordance with Chapter 6 of this Ordinance. It will be the responsibility of the project site owner to ensure compliance with this Ordinance and the Technical Standards during the construction activity and implementation of the construction plan, and to notify Hendricks County with a sufficient notice of

termination letter upon completion of the project and stabilization of the site. However, all persons engaging in construction and land disturbing activities on a permitted project site shall comply with the requirements of this Chapter and this Ordinance as well as the Technical Standards.

2. POLICY ON STORMWATER POLLUTION PREVENTION

Effective stormwater pollution prevention on construction sites is dependent on a combination of preventing movement of soil from its original position (erosion control), intercepting displaced soil prior to entering a waterbody (sediment control), and proper on-site materials handling. The developer shall submit to the Hendricks County, a SWPPP with detailed erosion and sediment control plans as well as a narrative describing materials handling and storage, and construction sequencing. This SWPPP shall be site and project specific. The SWPPP and the project management log shall be retained for at least three (3) years from the date the project permit is terminated.

Detailed requirements for stormwater pollution prevention on construction sites within Hendricks County, which are consistent with IDEM minimum requirements and apply to all land-disturbing activities, are contained in the Hendricks County Stormwater Technical Standards Manual.

3. CALCULATIONS AND DESIGN STANDARDS AND SPECIFICATIONS

In calculating the total area of land disturbance, for the purposes of determining applicability of this Chapter to the project, the following guidelines should be used:

- A. Off-site construction activities that provide services (for example, road extensions, sewer, water, and other utilities) to a land disturbing project site, shall be considered as a part of the total land disturbance calculation for the project site, when the activity is under the control of the project site owner.
- B. Strip developments will be considered as one (1) project site and shall comply with this Chapter unless the total combined disturbance on all individual lots is less than one (1) acre and is not part of a larger common plan of development or sale.
- C. To determine if multi-lot project sites are regulated by the permit, the area of land disturbance shall be calculated by adding the total area of land disturbance for improvements, such as, roads, utilities, or common areas, and the expected total disturbance on each individual lot, as determined by the following:
 - i. For a single-family residential project site where the lots are one-half (0.5) acre or more, one-half (0.5) acre of land disturbance shall be used as the expected lot disturbance.
 - ii. For a single-family residential project site where the lots are less than one half (0.5) acre in size, the total lot shall be calculated as being disturbed.
 - iii. To calculate lot disturbance on all other types of projects sites, such as industrial and commercial project sites, a minimum of one (1) acre of land disturbance shall be used as the expected lot disturbance, unless the lots are less than one (1) acre in size, in which case the total lot shall be calculated as being disturbed.

The calculation methods as well as the type, sizing, and placement of all stormwater pollution prevention measures for construction sites shall meet the design criteria, standards, and specifications outlined in the "Indiana Stormwater Quality Manual" or the Hendricks County Stormwater Technical Standards Manual. The methods and procedures included in these two references are in keeping with the above stated policy and meet the requirements of the IDEM's CSGP. A Copy of the Indiana Stormwater Quality Manual may be obtained online through IDEM.

4. INSPECTION, MAINTENANCE, RECORD KEEPING, AND REPORTING

Following the granting of the stormwater management approval by Hendricks County and commencement of construction activities, Hendricks County has the authority to conduct inspections of the site to ensure full compliance with the provisions of this Chapter, the Technical Standards document, the approved Stormwater Pollution Prevention Plan, the *Indiana Stormwater Quality Manual*, and the terms and conditions of the approval.

A self-monitoring program shall be implemented by the project site owner to ensure the stormwater pollution prevention plan is working effectively. A trained individual, acceptable to Hendricks County, shall perform a written evaluation of the project site by the end of the next business day following each measurable storm event. If there are no measurable storm events within a given week, the site should be monitored at least once in that week. Weekly inspections by the trained individual shall continue until the entire site has been stabilized and a “verified” copy of the Notice of Termination has been issued. The trained individual should look at the maintenance of existing stormwater pollution prevention measures, including erosion and sediment control measures, drainage structures, and construction materials storage/containment facilities, to ensure they are functioning properly. The trained individual should also identify additional measures, beyond those originally identified in the stormwater pollution prevention plan, necessary to remain in compliance with all applicable statutes and regulations.

The resulting evaluation reports shall include the name of the individual performing the evaluation, the date of the evaluation, problems identified at the project site, and details of maintenance, additional measures, and corrective actions recommended and completed.

The stormwater pollution prevention plan shall serve as a guideline for stormwater quality, but should not be interpreted to be the only basis for implementation of stormwater quality measures for a project site. The project site owner is responsible for implementing, in accordance with this Chapter, all measures necessary to adequately prevent polluted stormwater runoff. Recommendations by the trained individual for modified stormwater quality measures should be implemented.

Although self-monitoring reports do not need to be submitted to Hendricks County, Hendricks County has the right to request complete records of maintenance and monitoring activities involving stormwater pollution prevention measures. All evaluation reports for the project site shall be made available to Hendricks County, in an organized fashion, within forty-eight (48) hours upon request.

A project management log shall be maintained at the project site or in the possession of on-site individuals associated with the management and operations of the construction activities. Details regarding requirements related to the project management log are contained in the Hendricks County Stormwater Technical Standards Manual.



CHAPTER FIVE

STORMWATER QUALITY MANAGEMENT FOR POST-CONSTRUCTION

1. APPLICABILITY AND EXEMPTIONS

In addition to the requirements of Chapter 4, the stormwater pollution prevention plan, which is to be submitted to Hendricks County as part of the stormwater management permit application, shall also include post-construction stormwater quality measures. These measures are incorporated as a permanent feature into the site plan and are left in place following completion of construction activities to continuously treat stormwater runoff from the stabilized site. Any project located within Hendricks County which falls under the jurisdictional authority of the Hendricks County and includes clearing, grading, excavation, and other land disturbing activities resulting in the disturbance of 1 acre or more of total land area is subject to the requirements of this Chapter. This includes both new development and re-development, and disturbances of less than one (1) acre of land that are part of a larger common plan of development or sale if the larger common plan will ultimately disturb one (1) or more acres of land, within the area under the jurisdictional authority of the Hendricks County. In addition, regardless of the amount of disturbance, Hendricks County reserves the right to require pre-treatment BMPs for proposed hot spot developments in accordance with provisions contained in the Hendricks County Stormwater Technical Standards Manual.

The requirements under this chapter do not apply to the following activities:

- A. agricultural land disturbing activities; or
- B. forest harvesting activities; or
- C. construction activities associated with a single family residential dwelling disturbing less than 5 acres, when the dwelling is not part of a larger common plan of development or sale; or
- D. single family residential developments consisting of four or less lots; or
- E. a single-family residential strip development where the developer offers for sale or lease without land improvements and the project is not part of a larger common plan of development of sale; or
- F. individual building lots within a larger permitted project.

The requirements under this chapter do not apply to the following activities, provided other applicable State permits contain provisions requiring immediate implementation of soil erosion control measures:

- A. Landfills that have been issued a certification of closure under 329 IAC 10.
- B. Coal mining activities permitted under IC 14-34.
- C. Municipal solid waste landfills that are accepting waste pursuant to a permit issued by the Indiana Department of Environmental Management under 329 IAC 10 that contains equivalent stormwater requirements, including the expansion of landfill boundaries and construction of new cells either within or outside the original solid waste permit boundary.

It will be the responsibility of the project site owner to complete a stormwater management approval application and ensure that a sufficient construction plan is completed and submitted to Hendricks County in accordance with Chapter 6 of this Ordinance and the Technical Standards. It will be the responsibility of the project site owner to ensure proper construction and installation of all stormwater BMPs in compliance with this Ordinance and with the stormwater management approval, and to notify Hendricks County with a Notice of Termination letter upon completion of the project and stabilization of the site. However, all eventual property owners of stormwater quality facilities meeting the applicability requirements shall comply with the requirements of this Chapter and this Ordinance.

2. POLICY ON STORMWATER QUALITY MANAGEMENT

It is recognized that developed areas, as compared to undeveloped areas, generally have increased imperviousness, decreased infiltration rates, increased runoff rates, increased potential for streambank erosion downstream, and increased concentrations of pollutants such as fertilizers, herbicides, greases, oil, salts and other pollutants. As new development and re-development continues in Hendricks County, measures shall be taken to intercept and filter pollutants from stormwater runoff prior to reaching regional creeks, streams, and rivers. Through the use of Best Management Practices (BMP) to treat the Water Quality Volume (WQv) or the Water Quality Flow (Qwq), stormwater runoff will be filtered and harmful amounts of sediment, nutrients, and contaminants will be removed. Hendricks County has adopted a policy that the control of stormwater quality will be based on the management of Total Suspended Solids (TSS).

It is also recognized that another major source of pollution in many Indiana streams, including those within the corporate boundaries of Hendricks County, is the streambank erosion associated with urbanizing watersheds. Stream channels develop their shape in response to the volume and rate of runoff that they receive from their contributing watersheds. Research has shown that in hydrologically stable watersheds, the stream flow responsible for most of the shaping of the channel (called the bankfull flow) occurs between every one to two years. When land is developed, the volume and rate of runoff from that land increases for these comparatively small flooding events that are not normally addressed by the detention practices and the stream channel will adapt by changing its shape. As the stream channel works to reach a new stable shape, excess erosion occurs. As new development and re-development continues within the corporate boundaries of Hendricks County, measures shall be taken to minimize the impact of such development or re-development on streambank erosion. Using appropriate Best Management Practices (BMP's) to retain and/or detain and slowly release the Channel Protection Volume (CPv), the volume and rate of runoff for channel forming flows will be reduced in an attempt to minimize increased streambank erosion in the receiving streams and channels.

The project site owner shall submit to Hendricks County, a Storm Water Pollution Prevention Plan (SWPPP) that would show placement of appropriate BMP(s) from a pre-approved list of BMPs specified in the Hendricks County Stormwater Technical Standards Manual. The SWPPP submittal shall include an Operation and Maintenance Manual for all post-construction BMP(s) included in the project and a notarized Maintenance Agreement, consistent with the sample agreement provided in the Hendricks County Stormwater Technical Standards Manual, providing for the long-term maintenance of those BMPs, both of which shall be recorded with the deed for the property on which the project is located. The noted BMPs shall be designed, constructed, and maintained according to guidelines provided or referenced in the Hendricks County Stormwater Technical Standards Manual. Practices other than those specified in the pre-approved list may be utilized. However, the burden of proof as to whether the performance and ease of maintenance of such practices will be according to guidelines provided in the Hendricks County Stormwater Technical Standards Manual, would be placed with the applicant. Details regarding the procedures and criteria for consideration of acceptance of such BMPs are provided in the Hendricks County Stormwater Technical Standards Manual.

Requirements of this Ordinance and the Technical Standards with regard to post-construction stormwater quality management can be satisfied through a variety of methods broadly categorized under two general approaches:

1. Conventional Approach
2. Low Impact Development (LID) Approach

The site developer and designer are encouraged to review the LID discussion in the Technical Standards prior to site design.

Gasoline outlets and refueling areas shall install appropriate practices (as noted under "Hot Spots" provision in the Technical Standards) to reduce lead, copper, zinc, and hydrocarbons in stormwater runoff. These requirements will apply to all new facilities and existing facilities that replace their tanks, , regardless of the size of the facility.

3. CALCULATIONS AND DESIGN STANDARDS AND SPECIFICATIONS

Calculation of land disturbance should follow the guidelines discussed in Chapter 4, Section 3.

The calculation methods as well as the type, sizing, and placement of all stormwater quality management measures, or BMPs shall meet the design criteria, standards, and specifications outlined in the *Indiana Stormwater Quality Manual* or the Hendricks County Stormwater Technical Standards Manual. The methods and procedures included in these two references are in keeping with the above stated policy and meet the requirements of MS4 GP.

4. EASEMENT REQUIREMENTS

All stormwater quality management systems, including detention or retention basins, filter strips, pocket wetlands, in-line filters, infiltration systems, conveyance systems, structures and appurtenances located outside of the right-of-way shall be incorporated into permanent easements. For developments which fall under the jurisdictional authority of the Hendricks County Drainage Board, the developer may petition to establish the noted system as a portion of regulated drainage system pursuant to the provisions of I.C.-36-9-27-54, and the drainage plan shall not be accepted until such petition is submitted in a form accepted by the County Surveyor and the County Drainage Board. For the purposes of access, monitoring, inspection, and general maintenance activities, the petition should include a 30-foot wide drainage easement beyond the actual footprint of the stormwater quality management facility as well as a 30-foot wide access easement from a public right-of-way to each BMP.

5. INSPECTION, MAINTENANCE, RECORD KEEPING, AND REPORTING

After stormwater management approval and the commencement of construction activities, Hendricks County has the authority to conduct inspections of the work being done to ensure full compliance with the provisions of this chapter, the Stormwater Technical Standards Manual, and the terms and conditions of the approval.

Stormwater quality facilities shall be maintained in good condition, in accordance with the Operation and Maintenance procedures and schedules listed in the *Indiana Stormwater Quality Manual* or the Hendricks County Stormwater Technical Standards Manual, and/or the terms and conditions of the approved stormwater permit, and shall not be subsequently altered, revised, or replaced except in accordance with the stormwater management approval, or in accordance with approved amendments to the original approval.

Following construction completion, maintenance of stormwater quality facilities may be the long-term responsibility of the Hendricks County Drainage Board. Stormwater detention/retention basins may be donated to Hendricks County or another unit of government designated by the Hendricks County Drainage Board for ownership and permanent maintenance, providing the Hendricks County Drainage Board or other governmental unit is willing to accept responsibility.

If Hendricks County accepts the petition for incorporation of post-construction stormwater quality BMPs into their system, the following statement shall become part of the Restrictive Covenants of every platted subdivision and shown on the recorded plat: *"The post-construction stormwater quality BMPs listed in the following table [provide a table below this statement] and located within designated Regulated Drainage Easements (RDEs) are extensions of Hendricks County's stormwater drainage system and are the responsibility of the Hendricks County Drainage Board. Specific definitions and requirements associated with these RDEs and BMPs are contained in Chapter 3, Section 2.4 and Chapter 5 of the Hendricks County Stormwater Management Ordinance and in the Hendricks County Stormwater Technical Standards*

Manual. Every lot owner in the subdivision is responsible for the maintenance costs associated with the noted post-construction stormwater quality BMPs.”

The following statement shall be put on each subdivision plat: *“A petition addressed to the Hendricks County Drainage Board has been filed with the County Surveyor, requesting that the subdivision’s post-construction stormwater quality BMPs, listed in the following table [provide a table below this statement], and their associated easements be accepted into the County’s regulated drainage system. The noted post-construction stormwater quality BMPs and their easements that are accepted into the County’s regulated drainage system are delineated on the plat as Regulated Drainage Easements (RDEs). All other drainage easements have not been accepted into the County’s system. Within the latter easements, the Hendricks County Drainage Board assumes no responsibility relative to said improvements or the maintenance thereof. Specific definitions and requirements associated with these RDEs and BMPs are contained in Chapter 3, Section 2.4 and Chapter 5 of the Hendricks County Stormwater Management Ordinance and in the Hendricks County Stormwater Technical Standards Manual. This subdivision contains the following post-construction stormwater BMPs that will be included in the County’s Regulated Drainage System.”* A table listing the name and location of every post-construction stormwater quality BMPs being accepted into the Hendricks County Regulated Drainage System shall also be included immediately following the above statement on the recorded plat.

All stormwater quality facilities will be inspected by representatives of the project site owner until the project is complete and a Notice of Termination has been approved. Inspection frequency shall follow specifications included in the Operation and Maintenance Manual submitted as part of the stormwater management approval application. Optional inspection checklists for some of the more common BMPs can be found in the Technical Standards. Following project completion, the owner is responsible for inspection and maintenance of the stormwater quality facilities. Hendricks County has the authority to conduct inspections following project completion to ensure full compliance with the provisions of this chapter. Noted deficiencies and recommended corrective action will be included in an inspection report. If deficiencies are found during the inspection, the owner of the stormwater quality facility will be notified by Hendricks County and will be required to take all necessary measures to correct such deficiencies. If the owner fails to correct the deficiencies within the allowed time period, as specified in the Hendricks County notification, Hendricks County will undertake the work and collect from the owner using lien rights if necessary.



CHAPTER SIX

STORMWATER MANAGEMENT PERMITTING REQUIREMENTS AND PROCEDURES

1. PRIMARY DRAINAGE PLAN APPROVAL

In order to establish that an adequate drainage outlet(s) exists for a proposed subdivision seeking a Primary Plat approval from the Hendricks County Drainage Board and the Hendricks County Plan Commission, or for certain commercial developments as determined by the Hendricks County Surveyor, a developer shall first apply for a preliminary drainage approval from Hendricks County. As part of the noted Primary Drainage Approval application, a developer shall submit conceptual drainage plans for review by the Hendricks County Surveyor prior to the Drainage Board meeting and Plan Commission hearing. Note that any preliminary drainage approval by the Hendricks County as a result of such a review is based on preliminary data and shall not be construed as a final drainage approval or considered binding on either party. Once a development receives Primary Drainage Approval from the Hendricks County Drainage Board, all subsequent processing for the necessary stormwater approvals will remain with the Hendricks County Drainage Board, including all individual sections or phases of the development. The following is a general listing of minimum data requirements for the review of conceptual drainage plans, all of which shall be on a CD or other acceptable media acceptable to Hendricks County:

A. Letter of Intent for obtaining any needed consents, off-site easements, or right-of-way.

B. Project Narrative and Supporting Documents:

- i. Description of the nature and purpose of the project.
- ii. General description of the existing and proposed drainage systems in narrative form.
- iii. General description of regulated drains, farm drains, inlets and outfalls in narrative form, if any of record.
- iv. General description of all existing storm, sanitary, combined sewer, and septic tank systems and outfalls in narrative form.
- v. Two (2) copies of drainage calculations showing existing and proposed discharges for various storm events.
- vi. Vicinity map depicting the project site location in relation to recognizable local landmarks, towns, and major roads, such as a USGS topographic quadrangle map or county or municipal road map.
- vii. A map showing the location, name, and normal water level of all wetlands, lakes, ponds, and water courses on or adjacent to the project site.
- viii. A map showing one hundred (100) year floodplains, floodway fringes, and floodways. Please note if none exists.
- ix. A map showing watershed boundaries with USGS contours or best information possible.
- x. A map showing existing watercourse or regulated drains.
- xi. Proof that the project has an adequate outlet as determined by the Hendricks County Surveyor.

C. Conceptual Plans:

- i. One complete set of conceptual plans showing general project layout, including existing and proposed drainage systems and proposed outlets. The plan sets should be 24" by 36" in size.

All the required information shall be submitted in electronic format compatible with Hendricks County GIS. All mapping and survey data shall be in State Plane Coordinates with the following metadata requirements:

- a. Indiana west
- b. US Survey feet
- c. GNS 80 Ellipsoid
- d. NAVD 88
- e. GEOID 09
- f. NAD 83
- g. CORS 96
- h. EPOCH 2002 or later

2. PERMITTING PROCEDURES

This section applies to all development or re-development of land, under the jurisdictional authority of the Hendricks County, which results in land disturbance of one (1) acre or more. Individual lots with land disturbance less than one (1) acre that are developed within a larger permitted project site should refer to Section 5 for plan review requirements and procedures.

There are two scenarios for approval or permit application and processing procedures. One process is followed for projects located within unincorporated areas of Hendricks County; the other process is for projects that impact Hendricks County regulated drains but are located within the jurisdictional areas of the incorporated towns and cities within the County.

A. Within Unincorporated Areas of Hendricks County

For projects located within unincorporated areas of Hendricks County, the project site owner shall submit an application for a stormwater management approval to the Hendricks County Drainage Board, the County Surveyor, and the Clean Water Department. The application will include a completed application form, construction plan sheets, stormwater drainage technical report, a stormwater pollution prevention plan, and any other necessary support information. Specific information to be included in the application can be found in Section 4 below. Two copies of each application shall be submitted to the Hendricks County Drainage Board. Additionally, a digital copy of the construction plans is required in a format approved by the Hendricks County Drainage Board.

If the project shall go through a scheduled meeting, all information shall be submitted at least thirty (30) days prior to the regularly scheduled meeting. The Hendricks County Drainage Board shall furnish the applicant a written list of objections to the plans and supporting data submitted by the applicant. A resubmittal from the applicant addressing the list of objections shall be provided to the Hendricks County Drainage Board at least ten (10) days prior to the scheduled meeting. Plans in substantial compliance with the requirements of this Ordinance and the Technical Standards that need to go through a scheduled meeting shall be placed on the agenda with a recommendation for Conditional Approval or Construction Approval. If the Hendricks County Drainage Board approves the project, the plans will be signed by the Hendricks County Surveyor's Office after Construction Approval has been granted.

If the project does not require Drainage Board approval at a scheduled meeting, the Hendricks County Surveyor's Office will provide written comments and sign the plans after Construction Approval has been granted. Once the plans have been signed, and after a pre-construction meeting has been held, construction can commence.

The project site owner shall notify the Hendricks County Surveyor's Office and the Clean Water Department and IDEM before beginning construction. Notification to the Hendricks County Surveyor and the Clean Water Department shall be in the form of an email while notification to IDEM shall be in the form of an online IDEM NOI submittal. Once a permit has been issued and the pending construction notifications submitted to the Hendricks County Surveyor and the Clean Water Department and IDEM before the beginning of construction, construction may commence 48 hours after the NOI is submitted to IDEM. Once construction starts, the project owner shall monitor construction activities and inspect all stormwater pollution prevention measures in compliance with this ordinance and the terms and conditions of the stormwater management approval. Upon completion of construction activities, a Certification of Completion and Compliance and as-built plans shall be submitted to the Hendricks County Surveyor's Office in hardcopy and in an electronic format compatible with the Hendricks County Geographic Information System (GIS). Once the construction site has been stabilized and all temporary erosion and sediment control measures have been removed, a notification shall be sent to the Hendricks County Clean Water Department, requesting a termination inspection. The Hendricks County Clean Water Department, or representative, shall inspect the construction site to that the completed project is fully stabilized and meets the requirements of Hendricks County stormwater Ordinance and its technical standards as well as the terms and conditions of the approval. Once the applicant receives a signed copy of the Termination Inspection Checklist confirming compliance, they shall forward a copy to IDEM along with the required IDEM NOT form. Permits issued under this scenario will expire 5 years from the date of issuance. If construction is not completed within 5 years, an updated permit application shall be submitted to Hendricks County Surveyor and an updated NOI shall be resubmitted to IDEM at least 90 days prior to expiration. Figure 1 is a flowchart summarizing the plan review/permit approval process and can be found at the end of this Chapter.

B. Within Other Jurisdictional Areas

For projects located within other jurisdictional areas, but impacting Hendricks County regulated drains, the project site owner shall submit one copy of the construction plans (which include drainage plans), erosion and sediment control plans, and a stormwater drainage technical report to the Hendricks County Drainage Board. Additionally, a digital copy of the construction plans is required in a format approved by the Hendricks County Surveyor. If the project must go through a scheduled meeting, all information shall be submitted at least thirty (30) days prior to its regularly scheduled meeting. The Hendricks County Drainage Board shall furnish the applicant a written list of objections to the plans and supporting data submitted by the applicant. This list of objections, if any, will be related only to the project's impact on Hendricks County regulated drains. A resubmittal from the applicant addressing the list of objections shall be provided to the Hendricks County Surveyor at least ten (10) days prior to the scheduled meeting. Plans in substantial compliance with the requirements of this Ordinance and the Technical Standards that need to go through a scheduled meeting shall be placed on the agenda with a recommendation for Conditional Approval or Construction Approval. If the Hendricks County Drainage Board approves the project, the applicant shall satisfactorily address all issues listed in the conditional approval to obtain construction approval. This approval does *not* alleviate the applicant's responsibility to comply with Ordinance, policy, or resolution requirements of the local jurisdictional entity.

3 SWPPP REVIEW TIME LIMITS

Pursuant to IC 13-18-27, an MS4-designated entity or other review authority such as SWCD shall make a preliminary determination as to whether the construction plan associated with SWPPP is substantially complete before the end of the tenth (10th) working day (for sites with less than 5 acres of land disturbance) after the day on which the SWPPP is submitted to the review authority or the fourteenth (14th) working day (for sites with 5 acres or larger of land disturbance) after the day on which the SWPPP is submitted to the review authority.

Note that the above time limits only apply to the SWPPP portion of the overall stormwater approval submittal and does not affect any official or non-official approval review timelines set by the Hendricks County Drainage Board and/or the Surveyor for other aspects of the stormwater approval application.

4. SECONDARY STORMWATER APPROVAL REQUIREMENTS

Specific projects or activities may be exempt from all or part of the informational requirements listed below. Exemptions are detailed in the “Applicability and Exemptions” Sections of Chapters 2 through 5. If a project or activity is exempt from any or all requirements of this Ordinance, an application should be filed listing the exemption criteria met, in lieu of the information requirements listed below. This level of detailed information is not required from individual lots, disturbing less than 1 acre of land, developed within a larger permitted project site. Review and acceptance of such lots is covered under Section 4 of this Chapter.

The different elements of a permit/approval submittal for a Secondary Stormwater Plan approval include an application form, proof of publication of a public notice, construction plans, a stormwater drainage technical report, a stormwater pollution prevention plan for active construction sites, a post-construction stormwater pollution prevention plan, and any other necessary supporting information. All plans, reports, calculations, and narratives shall be signed and sealed by a professional engineer or a licensed surveyor, registered in the State of Indiana who also meets the definition of a Trained Individual found in Appendix A.

A. Application Form

As part of the Hendricks County Stormwater Management Permit application package, the application form provided in the Technical Standards Manual shall be completed by the applicant and provided along with other required supporting material.

B. Construction Plans

Construction plan sheets and an accompanying narrative report shall describe and depict the existing and proposed conditions. Note that in order to gain an understanding of and to evaluate the relationship between the proposed improvements for a specific project section/phase and the proposed improvements for an overall multi-section (phased) project, the detailed information requested herein for the first section/phase being permitted shall be accompanied by an overall project plan that includes the location, dimensions, and supporting analyses of all detention/retention facilities, primary conveyance facilities, and outlet conditions. Construction plans need to include items listed in the Required Information List provided in the Hendricks County Stormwater Technical Standards Manual.

C. Stormwater Drainage Technical Report

A written stormwater drainage technical report shall contain a discussion of the steps taken in the design of the stormwater drainage system. Note that in order to gain an understanding of and to evaluate the relationship between the proposed improvements for a specific project section/phase and the proposed improvements for an overall multi-section (phased) project, the detailed information requested herein for the first section/phase being permitted shall be accompanied by an overall project plan that includes the location, dimensions, and supporting analyses of all detention/retention facilities, primary conveyance facilities, and outlet conditions. The technical report needs to include items listed in the Required Information List provided in the Hendricks County Stormwater Technical Standards Manual.

D. Stormwater Pollution Prevention Plan for Construction Sites

For sites with total disturbance of land in an amount that would be governed by this Ordinance, a stormwater pollution prevention plan associated with construction activities shall be designed to, at least, meet the requirements of this Ordinance. For land disturbances totaling less than 1 acre but greater than an amount that would be governed by this Ordinance, appropriate erosion and sediment control measures that are consistent with the Hendricks County Technical Standards shall be

designed and shown on the plans. The SWPPP shall include items listed in the Required Information List provided in the Hendricks County Stormwater Technical Standards Manual.

E. Post-Construction Storm Water Pollution Prevention Plan

For sites with total disturbance of land in an amount that would be governed by this Ordinance, a post-construction stormwater pollution prevention plan shall be designed to, at least, meet the requirements of this Ordinance and shall include the information provided in the Hendricks County Stormwater Technical Standards Manual. The post-construction storm water pollution prevention plan shall include items listed in the Required Information List provided in the Hendricks County Stormwater Technical Standards Manual.

F. Operation and Maintenance Manual

An operations and maintenance (O&M) manual for all private infrastructure, including but not limited to pipes, ponds, ditches, and BMPs (when required), shall be submitted for the final plan approval and permit process. The detailed requirements for O&M manual are provided in the Hendricks County Stormwater Technical Standards Manual.

G. Maintenance Agreement

A formal BMP maintenance agreement will need to be prepared and notarized consistent with the sample agreement provided in the Hendricks County Stormwater Technical Standards Manual, providing for the long-term maintenance of those BMPs. This maintenance agreement shall be recorded with the deed for the property on which the project is located.

5. REVIEW OF INDIVIDUAL LOTS AND PARCELS

For individual lots disturbing less than 1 acre, developed within a larger permitted project, or larger than 1 acre individual parcels that are not part of a larger permitted project, a formal review and issuance of an Individual Lot Plot Plan Clean Water Permit will be required before a building permit can be issued. If part of a larger permitted project, all stormwater management measures necessary to comply with this Ordinance shall be implemented in accordance with permitted plan for the larger project. All Individual Lot Plot Plans shall also receive the Hendricks County Surveyor's approval based on, but not limited to the following criteria:

- A. 1' Contours and how they were derived.
- B. All Easements shown and labeled correctly.
- C. Sump pumps labeled near where it will be during construction. If no sump pump is being installed, then it will need to be annotated on the plan as such.
- D. Sub-surface drains (SSD) labeled (Including the sump pump outlets).
- E. Sump pump outlets (connection or day lighted to open ditch or surface outlet) shall be shown.
- F. Perimeter drain for septic system, if required, shall be shown.
- G. Outlet for all perimeter drains with proper outlet protection.
- H. All invert elevations of pipe outlets shall be labeled.
- I. Swales annotated with arrows showing the direction of surface flow.
- J. First floor elevations (FFE or Slab Height) shall be 2 feet or greater above the emergency over-flow at the house.
- K. First floor elevations (FFE or Slab Height) shall be no greater than 2 feet higher, or lower, than any adjoining house elevation in a platted subdivision unless the proposed house is located in a subdivision and has been approved to be greater than 2 feet higher than an adjoining lot at the approval process of said subdivision plat

Note: Every site is unique and may require information and criteria specific to the site. The Hendricks County Surveyor has the authority to modify, add to or amend any of these requirements based on the individual site of the proposed plot plan.

The following information shall be submitted to the Hendricks County for review and acceptance, by the individual lot operator, whether owning the property or acting as the agent of the property owner, as part of a request for review and issuance of an Individual Lot Plot Plan Clean Water Permit that shall be obtained prior to the issuance of a building permit.

- A. The individual lot operator shall complete an Individual Lot Clean Water Permit Request and pay the applicable fee.
- B. A certified site layout for the subject lot and all adjacent lots showing elevation contours and its source, building pad location, dimensions, elevations, proposed sump pump connections (not to road sub-drains), and the drainage patterns and swales (including side yard swales).
- C. Erosion and sediment control plan that, at a minimum, includes the following measures:
 - i. Installation and maintenance of a stable construction site access.
 - ii. Installation and maintenance of appropriate perimeter erosion and sediment control measures prior to land disturbance.
 - iii. Minimization of sediment discharge and tracking from the lot.
 - iv. Clean-up of sediment that is either tracked or washed onto roads. Bulk clearing of sediment shall not include flushing the area with water. Cleared sediment shall be redistributed or disposed of in a manner that is in compliance with all applicable statutes and rules.
 - v. Implementation of concrete or cementitious wash water practices that securely contain and allow for the proper disposal of concrete or cementitious wash water.
 - vi. Adjacent lots disturbed by an individual lot operator shall be repaired and stabilized with temporary or permanent surface stabilization.
 - vii. Self-monitoring program including plan and procedures.
- D. Name, address, telephone number, and list of qualifications of the trained individual in charge of the mandatory stormwater pollution prevention self-monitoring program for the project site.

The individual lot operator is responsible for installation and maintenance of all erosion and sediment control measures until the site is stabilized. Additional details are provided in the Hendricks County Stormwater Technical Standards Manual.

6. CHANGES TO PLANS

Any changes or deviations in the detailed plans and specifications after approval of the applicable stormwater management approval/permit shall be filed with, and accepted by, Hendricks County prior to the land development involving the change. Copies of the changes, if accepted, shall be attached to the original plans and specifications.

7. FEE STRUCTURE

A. Fee Amount

As a condition of the submittal and the review of development plans by Hendricks County, the applicant shall agree to pay Hendricks County the applicable fee, as set by the Hendricks County Drainage Board with respect to the review of all drainage submittals, preliminary plans, final plans, construction plans and accompanying information and data, as well as pre-paid inspection fees.

B. Time of Payment

After the meeting at which Hendricks County is scheduled to consider acceptance of the applicant's final stormwater management plan, Hendricks County will furnish a written statement to the applicant specifying the total amount due Hendricks County in connection with the review of the applicant's submittals, plans and accompanying information and data, including the amount required to be paid by applicant for review and pre-paid inspection fees.

As a condition of acceptance of final drainage plans by Hendricks County, applicant shall pay to Hendricks County the sum set forth in said statement. Hendricks County may issue such a billing statement before the project advances to the final acceptance stage, and such payment is due by applicant upon receipt of said billing statement regardless of whether the project is advanced to the final acceptance stage.

Hendricks County shall have the right to not accept the drainage improvements or to not accept the advancement of any project for which the applicable fees have not been paid.

C. Method of Payment

Fees shall be paid by one of the following methods:

- Certified Check
- Cashier's Check
- Money Order
- Electronic payment (if applicable)

All checks shall be made payable to the: Hendricks County Drainage Board
355 S. Washington Street, Suite 214
Danville, Indiana 46122

D. Refund of Payment

Fees are refundable **only** if Hendricks County determines that compliance by the development to this Ordinance is not necessary.

8. REQUIRED ASSURANCES

As a condition of approval and issuance of the approval/permit, Hendricks County shall require the applicant to provide assurance in form of an irrevocable letter of credit or a bond when the stormwater management plan has been accepted, all applicable fees paid, and before construction begins. Said assurance will guarantee a good faith execution of the stormwater drainage plan, the stormwater pollution prevention plan, the stormwater quality management plan, and any approval/permit conditions. The assurance shall be for an amount equal to 110 percent of the total costs of all stormwater management measures for the entire project. The above mentioned costs shall be based on an estimate as prepared by a registered engineer or land surveyor. Said costs shall be for the installation and ongoing monitoring and maintenance of erosion control measures and the construction and ongoing monitoring and maintenance of storm drainage infrastructure, detention/retention facilities, and stormwater quality BMPs, as regulated under this Ordinance, until the construction is completed, site is stabilized, and as-built plans are accepted by the Hendricks County. Assurances shall be for a minimum of \$5,000. Local governmental jurisdictions may require additional performance and/or maintenance assurances. The intent of this assurance is not only to complete the installation of storm drain infrastructure for the project, but also to assure that adequate stormwater pollution prevention measures are properly installed and maintained. If adequate assurances are set aside by the project site owner for the overall project, proof of total assurance can be submitted in place of an individual stormwater assurance.

9. TERMS AND CONDITIONS OF APPROVALS OR PERMITS

In granting a stormwater management approval, Hendricks County may impose such terms and conditions as are reasonably necessary to meet the purposes of this Ordinance. The project site owner shall ensure compliance with such terms and conditions. Non-compliance with the terms and conditions of approvals will be subject to enforcement as described in Chapter 8.

The project site owner shall inform all general contractor, construction management firms, grading or excavating contractors, utility contractors, and the contractors that have primary oversight on individual

building lots of the terms and conditions of the stormwater management approval/permit and the schedule for proposed implementation.

In the event that a project site is determined to impact or discharge to a Sensitive Area or is located in an Impact Drainage Area, Hendricks County may require more stringent stormwater quantity and quality measures than detailed in this Ordinance or in the *Indiana Stormwater Quality Manual*.

A. Determination of Sensitive Areas

Sensitive Areas include highly erodible soils, wetlands, threatened or endangered species habitat, outstanding waters, impaired waters, recreational waters, and surface drinking water sources. A listing of highly erodible soils, outstanding water, impaired water, recreation water, and surface drinking water sources can be found in the Hendricks County Storm Water Quality Management Plan (SWQMP) - Part B, dated November 2004 and its updates. If wetlands are suspected on a site, wetland delineation should be completed by the applicant in accordance with the methodology established by the U.S. Army Corps of Engineers (COE) and the wetland addressed in accordance to the requirements of Chapter 6 of this Ordinance. The presence of threatened or endangered species habitat will be evaluated by the Hendricks County Surveyor during the approval/permit review process. Special terms and conditions for development determined to impact or discharge to any Sensitive Area shall be included in the stormwater management approval.

B. Determination of Impact Drainage Areas

The Hendricks County Drainage Board is authorized, but is not required, to classify certain geographical areas as Impact Drainage Areas. In determining Impact Drainage Areas, the Hendricks County Drainage Board shall consider such factors as topography, soil type, capacity of existing drains, and distance from adequate drainage facility. The following areas shall be designated as Impact Drainage Areas, unless good reason for not including them is presented to the Hendricks County Drainage Board.

- i. A floodway or floodplain as designated by the most updated Hendricks County Code dealing with floodplain regulation and/or by the Best Available Data through IDNR.
- ii. Land within a Fluvial Erosion Hazard (FEH) corridor of Hendricks County streams as shown on the FEH maps created by the Indiana Silver Jackets Fluvial Erosion Hazard Program or any updates, currently hosted on the Hendricks County GIS website.
- iii. Land within 75 feet of each bank of any ditch within the Hendricks County's Regulated Drainage System.
- iv. Land within 75 feet of the centerline of any drain tile or enclosed conduit within the Hendricks County's Regulated Drainage System.
- v. Land within the expected breach inundation zone of an existing or proposed new dam, and areas protected from flooding by a levee.

Land that does not have an adequate outlet, taking into consideration the capacity and depth of the outlet, may be designated as an Impact Drainage Area by the Hendricks County Drainage Board. Specific requirements for development within Impact Drainage Areas are contained in Hendricks County Stormwater Technical Standards Manual. Additional special terms and conditions for development within any Impact Drainage Area shall be included in the stormwater management approval.

C. Designated Drainage Areas Served by Regional Facilities

The Hendricks County Drainage Board and/or Hendricks County Surveyor is authorized, but is not required, to classify certain geographical areas as Designated Drainage Areas that are or will be served by regional facilities, such as a regional pond. In such cases, an Infrastructure Development Fee (IDF) rate may be established for the Designated Drainage Area. The basis for determining

such a fee for a proposed development or re-development within a Designated Drainage Area will be as detailed in the Hendricks County Stormwater Technical Standards Manual.

10. CERTIFICATION OF AS-BUILT PLANS

After completion of construction of the project and before final project acceptance, a professionally prepared and certified 'as-built' set of plans shall be submitted to the Hendricks County Surveyor for review. Additionally, a digital copy of the 'as-built' plans is required in a format accepted by the Hendricks County Surveyor that shall meet metadata requirements for as-built plans. These plans shall include all pertinent data relevant to the completed storm drainage system and stormwater management facilities, and shall include:

- A. Pipe size and pipe material
- B. Invert elevations
- C. Top rim elevations
- D. Elevation of the emergency overflow (spillway) for ponds
- E. Pipe structure lengths
- F. BMP types, dimensions, and boundaries/easements
- G. "As-planted" plans for BMPs, as applicable
- H. Data and calculations showing detention basin storage volume
- I. Data and calculations showing BMP treatment capacity
- J. Certified statement on plans stating the completed storm drainage system and stormwater management facilities substantially comply with construction plans and the stormwater management approval by the Hendricks County Drainage Board. (See certificate in Stormwater Technical Standards Manual.)

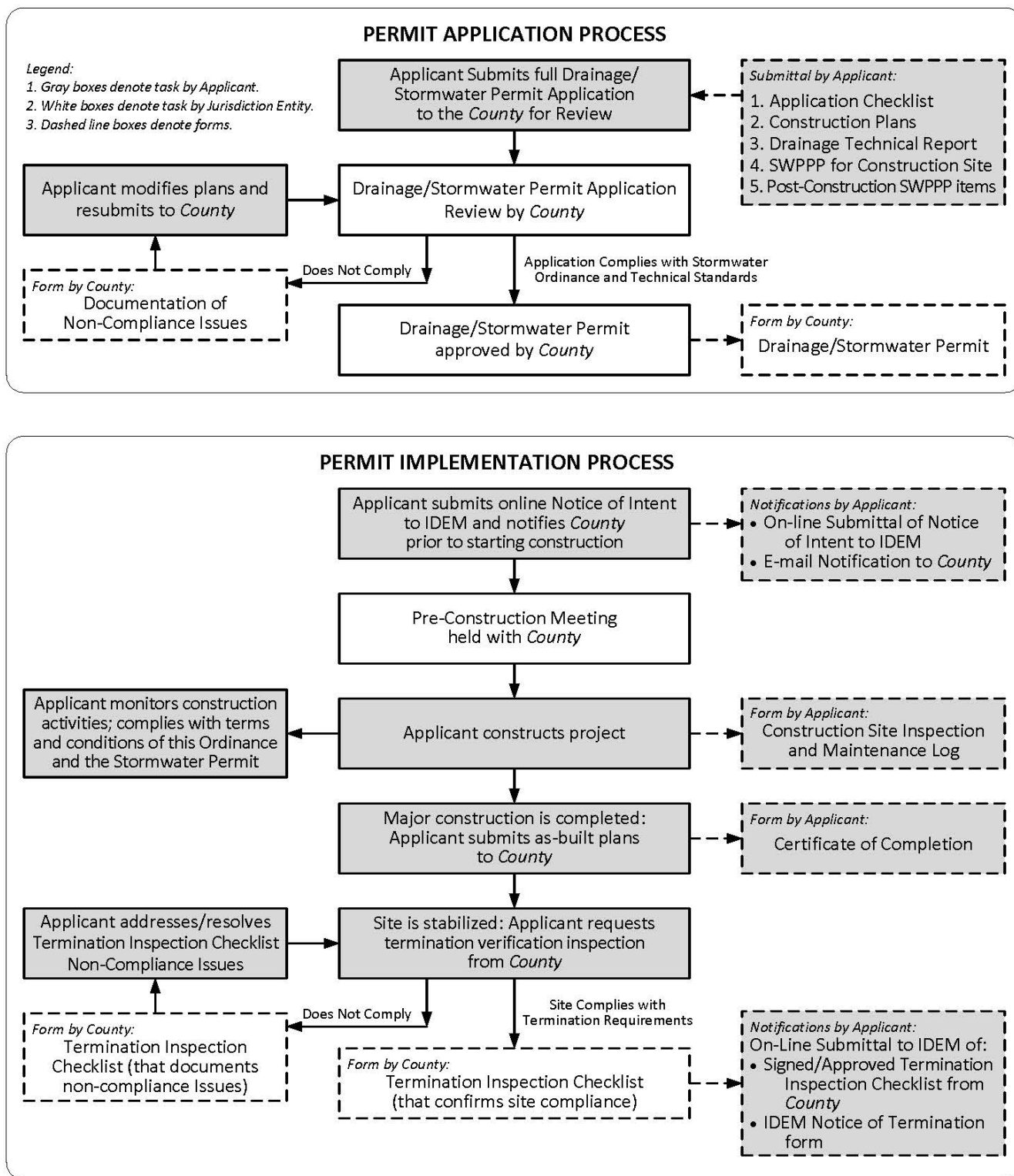
In addition to the digital copy of as-built plans, digital copies of all reports and plans noted in Sections 4 and 5 of this Chapter shall be submitted in their final accepted forms to the Hendricks County Surveyor's Office so that they can be electronically filed for any future reference.

If a Maintenance Bond and a Performance Bond is required by the Hendricks County Drainage Board or the Hendricks County Surveyor, then the property owner, developer, or contractor shall be required to file a five-year maintenance bond or other acceptable guarantee with Hendricks County, prior to final project acceptance, in an amount not to exceed twenty five percent (25%) of the cost of the stormwater drainage system located outside the public road right-of-ways, and in a form satisfactory to the Hendricks County Drainage Board's attorney in order to assure that such stormwater system installation was done according to standards of good workmanship, that the materials used in the construction and installation were of good quality and construction, that such project was done in accordance with the accepted plans and this Ordinance, and that any off-site drainage problems that may arise, whether upstream or downstream of such project, will be corrected if such drainage problems are determined by Hendricks County to have been caused by the development of such project. The bond or other acceptable guarantee shall be in effect for a period of five years after the date of the final project acceptance by Hendricks County.

To verify that all regulated drain tiles are functioning properly, visual recordings (via closed circuit television) of such tile drains shall be required, once following the completion of installation (including the installation

of all utility mains) and the second time before release of maintenance bond. These visual recordings will be scheduled by the Hendricks County Surveyor and paid for by the developer. Notices shall be provided to Hendricks County within 72 hours following the completion of installation and again at least 60 days prior to the expiration date of the maintenance bond so that the noted recordings may be scheduled. Reports summarizing the results of the noted visual recordings shall be reviewed and accepted by Hendricks County before the plat is recommended for recording and again before maintenance bond would be recommended to be released.

Figure 1: Permit Approval Process (Within Unincorporated Areas)





CHAPTER SEVEN

COMPLIANCE AND ENFORCEMENT

1. COMPLIANCE WITH THIS ORDINANCE

To secure compliance with the requirements of this Ordinance, violations thereof shall be subject to the enforcement provisions set forth under (b) following. Additionally, compliance with all applicable ordinances of Hendricks County as well as with applicable State of Indiana statutes and regulations shall also be required. Unless otherwise stated, all other specifications referred to in this Ordinance shall be the most recent edition available.

A. Definitions

- i. **Violation.** Any action or inaction which violates the provisions of this Ordinance, the requirements of an approved stormwater management design plan or approval/permit, and/or the requirements of a recorded stormwater maintenance agreement may be subject to the enforcement actions outlined in this Section. Any such action or inaction is deemed to be a public nuisance and may be abated by injunctive or other equitable relief in addition to and separate from the imposition of any of the enforcement actions described below.
- ii. **Compliance.** The act of correcting a violation or violations within the time frame specified by the Hendricks County.
- iii. **Offence.** Both a violation and a failure of compliance on a particular project constitute an "offense." If there are multiple violations or multiple failures of compliance on the same project, each shall be considered a separate offense as further stated in section (b)(3).

B. Warning Notice

When Hendricks County finds that any person has violated, or continues to violate, any provision of this ordinance, or any order issued hereunder, Hendricks County may serve upon that person a written Warning Notice, specifying the particular violation believed to have occurred and requesting the discharger to immediately investigate the matter and to seek a resolution whereby any offending discharge will cease. Investigation and/or resolution of the matter in response to the Warning Notice in no way relieves the alleged violator of liability for any violations occurring before or after receipt of the Warning Notice. Nothing in this subsection shall limit the authority of Hendricks County to take any action, including emergency action or any other enforcement action, without first issuing a Warning Notice.

2. ENFORCEMENT OF THIS ORDINANCE**A. Notice of Violation**

If Hendricks County determines that an applicant or other responsible person has failed to comply with the terms and conditions of a permit/approval, an approved stormwater management design plan, a recorded stormwater management maintenance agreement, or the provisions of this ordinance, it shall issue a written Notice of Violation to such applicant or other responsible person and the owner of the property. Where a person is engaged in activity covered by this ordinance without having first secured a permit/approval therefore, the notice of violation shall be served on the owner or the responsible person in charge of the activity being conducted on the site.

The notice of violation shall contain detailed inspection findings, conclusions of law, disposition of warning or fines assessed, stipulated remedial actions as discussed with the responsible party representative, reasonable deadlines for those remedial actions, and the date of re-inspection.

B. Compensatory Action

In lieu of enforcement proceedings, penalties, and remedies authorized by this ordinance, Hendricks County may impose upon a violator alternative compensatory actions, such as storm drain stenciling, attendance at compliance workshops, creek cleanup, etc.

C. Civil Penalties for Violations

Any person who commits an offense under this Ordinance commits a civil infraction and subject to the minimum fines as specified in the latest version of penalty matrix approved by the Hendricks County Drainage Board, plus costs, damages, and expenses. Each day such violation occurs or continues without a compliance action that is satisfactory to Hendricks County may be deemed a separate offense and shall make the violator liable for the imposition of a fine for each day. The rights and remedies provided for in this section are cumulative and in addition to any other remedies provided by law. An admission or determination of responsibility shall not exempt the offender from compliance with the requirements of this Ordinance.

Any person who aids or abets a person in a violation of this Ordinance shall be subject to the penalties provided in this section.

D. Stop Work Order

In addition to the penalties listed above, if land disturbance activities are conducted contrary to the provisions of this Ordinance or accepted final stormwater management plans, Hendricks County may order the work stopped by notice in writing served on any person engaged in the doing or causing of such work to be done, and any such persons shall forthwith stop such work until authorized by Hendricks County to proceed with the work. A Stop Work Order will be posted on the site by Hendricks County and it is unlawful for any person to remove the notice or continue any work on the site without permission from Hendricks County. Hendricks County may also undertake or cause to be undertaken, any necessary or advisable protective measures to prevent violations of this Ordinance or to avoid or reduce the effects of noncompliance herewith. The cost of any such protective measures shall be the responsibility of the owner of the property upon which the work is being done and the responsibility of any person carrying out or participating in the work.

The Jurisdiction Entity may bring an action under IC 34-28-5-1 (b), to be read together with IC 34-6-2-86(1)(B) and 13-21-3-12(4), to enforce a stop work order against any person who neglects or fails to comply with a stop work order.

For construction projects that are operating under a SWPPP approved by the Hendricks County, if a Stop Work Order is issued on the grounds that the erosion and sediment control measures included in the construction plan are not adequate, the project site owner shall be notified in writing of the inadequacies in the erosion and sediment control measures and the project site owner has seventy-two (72) hours after receiving written notice to resolve the identified inadequacies before the Stop Work Order can take effect.

The seventy-two (72) hour period to resolve identified inadequacies on a construction project does not apply if the Stop Work Order is issued to a construction project where the project site owner is creating a public health hazard or safety hazard.

E. Withhold Certificate of Occupancy

If applicable, Hendricks County may refuse to issue a certificate of occupancy for the building or other improvements constructed or being constructed on the site until the applicant or other responsible person has taken the remedial measures set forth in the notice of violation or has otherwise cured the violations described therein.

F. Suspension, Revocation, of Modification of Approvals/Permits

Hendricks County may suspend, revoke, or modify any existing permit/approval that the violator may also have been previously granted. A suspended, revoked, or modified permit/approval may be reinstated after the applicant or other responsible person has taken the remedial measures set forth in the notice of violation or has otherwise cured the violations described therein, provided such permit/approval may be reinstated

upon such conditions as Hendricks County may deem necessary to enable the applicant or other responsible person to take the necessary remedial measures to cure such violations.

G. Suspension of Access to the Stormwater Drainage System

i. Emergency Cease and Desist Orders

When Hendricks County finds that any person has violated, or continues to violate, any provision of this ordinance, or any order issued hereunder, or that the person's past violations are likely to recur, and that the person's violation(s) has (have) caused or contributed to an actual or threatened discharge to the MS4 or waters of the United States which reasonably appears to present an imminent or substantial endangerment to the health or welfare of persons or to the environment, Hendricks County may issue an order to the violator directing it immediately to cease and desist all such violations and directing the violator to immediately comply with all ordinance requirements and take such appropriate preventive action as may be needed to properly address a continuing or threatened violation, including immediately halting operations and/or terminating the discharge.

Any person notified of an emergency order directed to it under this Subsection shall immediately comply and stop or eliminate its endangering discharge. In the event of a discharger's failure to immediately comply voluntarily with the emergency order, Hendricks County may commence court action against such person under IC 34-28-5-1 (b), to be read together with IC 34-6-2-86(1)(B) and 13-21-3-12(4), to enforce a stop work order.

Hendricks County may allow the person to recommence its discharge when it has demonstrated to the satisfaction of Hendricks County that the period of endangerment has passed, unless further termination proceedings are initiated against the discharger under this ordinance. A person that is responsible, in whole or in part, for any discharge presenting imminent endangerment shall submit a detailed written statement, describing the causes of the harmful discharge and the measures taken to prevent any future occurrence, to Hendricks County within 5 days of receipt of the emergency order. Issuance of an emergency cease and desist order shall not be a bar against, or a prerequisite for, taking any other action against the violator.

ii. Suspension Due to Illicit Discharges in Emergency Situations

Hendricks County may, without prior notice, suspend stormwater drainage system discharge access to a person when such suspension is necessary to stop an actual or threatened discharge which presents or may present imminent and substantial danger to the environment, or to the health or welfare of persons, or to the stormwater drainage system or waters of the state if the violator fails to comply with a suspension order issued in an emergency, Hendricks County may take such steps as deemed necessary to prevent or minimize damage to the stormwater drainage system or waters of the state, or to minimize danger to persons.

iii. Suspension Due to the Detection of Illicit Discharge

Any person discharging to the stormwater drainage system in violation of this ordinance may have their stormwater drainage system access terminated if such termination would abate or reduce an illicit discharge. Hendricks County will notify a violator of the proposed termination of its stormwater drainage system access. The violator may petition Hendricks County for a reconsideration and hearing. A person commits an offense if the person reinstates stormwater drainage system access to premises terminated pursuant to this Section, without the prior approval of Hendricks County.

3. COST OF ABATEMENT OF THE VIOLATION

In addition to any other remedies, should any owner fail to comply with the provisions of this ordinance, Hendricks County may, after giving notice and opportunity for compliance, have the necessary work done, and the owner shall be required to promptly reimburse Hendricks County for all costs of such work.

Nothing herein contained shall prevent Hendricks County from taking such other lawful action as may be necessary to prevent or remedy any violation. All costs connected therewith shall accrue to the person or persons responsible. Costs include, but are not limited to, repairs to the stormwater drainage system made necessary by the violation, as well as those penalties levied by the EPA or IDEM for violation of Hendricks County's NPDES permit, administrative costs, attorney fees, court costs, and other costs and expenses associated with the enforcement of this Ordinance, including sampling and monitoring expenses.

If the amount due for abatement of the violation is not paid within a timely manner as determined by the decision of Hendricks County or by the expiration of the time in which to file an appeal, Hendricks County may commence a court action to recover the costs assessed under IC 34-28-5-1 (b), to be read together with IC 34-6-2-86(1)(B) and 13-21-3-12(4)

4. APPEALS

A. Appeal of Notice of Violation

Any person to whom any provision of this Ordinance has been applied may appeal in writing, not later than 30 days after the action or decision being appealed from, to the Hendricks County Board of Commissioners the action or decision whereby any such provision was so applied. Such appeal shall identify the matter being appealed, and the basis for the appeal. The Hendricks County Board of Commissioners shall consider the appeal and make a decision whereby it affirms, rejects or modifies the action being appealed. In considering any such appeal, the Hendricks County Board of Commissioners may consider the recommendations of the Hendricks County Staff and the comments of other persons having knowledge of the matter. In considering any such appeal, the Hendricks County Board of Commissioners may grant a variance from the terms of this Ordinance to provide relief, in whole or in part, from the action being appealed, but only upon finding that the following requirements are satisfied:

- i. The application of the Ordinance provisions being appealed will present or cause practical difficulties for a development or development site; provided, however, that practical difficulties shall not include the need for the developer to incur additional reasonable expenses in order to comply with the Ordinance; and
- ii. The granting of the relief requested will not substantially prevent the goals and purposes of this Ordinance, nor result in less effective management of stormwater runoff.
- iii. Any person who has appealed a violation to the Hendricks County Board of Commissioners may appeal an adverse decision of the Board to the Hendricks County court within 60 days of the Board's order, all pursuant to IC 36-1-6-9 (e) & (f).

B. Enforcement Measures After Appeal

If the violation has not been corrected pursuant to the requirements set forth in the Notice of Violation, or, in the event of an appeal, within 5 days of the decision of Hendricks County upholding the decision of Hendricks County, then representatives of Hendricks County shall enter upon the subject private property and are authorized to take any and all measures necessary to abate the violation and/or restore the property, including the commencing of a court action under IC 34-28-5-1 (b), to be read together with IC 34-6-2-86(1)(B) and 13-21-3-12(4), to enforce the order of the Hendricks County Board of Commissioners.



APPENDIX A

ABBREVIATIONS AND DEFINITIONS

ABBREVIATIONS

BMP	Best Management Practice
COE	United States Army Corps of Engineers
CWA	Clean Water Act
EPA	Environmental Protection Agency
GIS	Geographical Information System
IDEM	Indiana Department of Environmental Management
MS4	Municipal Separate Storm Sewer System
NRCS	USDA-Natural Resources Conservation Service
NPDES	National Pollution Discharge Elimination System
POTW	Publicly Owned Treatment Works
SWCD	Soil and Water Conservation District
SWPPP	Stormwater Pollution Prevention Plan
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service

DEFINITIONS

Adequate Outlet. An outlet (as defined in this document) that based on an assessment of the current condition of the downstream system (including known flooding, designated floodways and floodplains, channel stability, culvert capacity, water control structures, and dams) or the judgement of the Hendricks County Surveyor or the Hendricks County Drainage Board can accept the increased or more sustained peak flows or volume of flows entering the outlet from a proposed development or re-development without being negatively impacted.

Agricultural land disturbing activity. Tillage, planting, cultivation, or harvesting operations for the production of agricultural or nursery vegetative crops. The term also includes pasture renovation and establishment, the construction of agricultural conservation practices, and the installation and maintenance of agricultural drainage tile. For purposes of this rule, the term does not include land disturbing activities for the construction of agricultural related facilities, such as barns, buildings to house livestock, roads associated with infrastructure, agricultural waste lagoons and facilities, lakes and ponds, wetlands; and other infrastructure.

Base Flow. Stream discharge derived from groundwater sources as differentiated from surface runoff. Sometimes considered to include flows from regulated lakes or reservoirs.

Best Management Practices. Design, construction, and maintenance practices and criteria for stormwater facilities that minimize the impact of stormwater runoff rates and volumes, prevent erosion, and capture pollutants.

Buffer Strip. An existing, variable width strip of vegetated land intended to protect water quality and habitat.

Capacity (of a Storm Drainage Facility). The maximum flow that can be conveyed or stored by a storm drainage facility without causing damage to public or private property.

Catch Basin. A chamber usually built at the curb line of a street for the admission of surface water to a storm drain or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.

Channel. A portion of a natural or artificial watercourse which periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. It has a defined bed and banks which serve to confine the water.

Compliance. The act of correcting a violation or violations within the time frame specified by Hendricks County.

Comprehensive Stormwater Management. A comprehensive stormwater program for effective management of stormwater quantity and quality throughout the community.

Constructed Wetland. A manmade shallow pool that creates growing conditions suitable for wetland vegetation and is designed to maximize pollutant removal.

Construction activity. Land disturbing activities associated with the construction of infrastructure and structures. This term does not include routine ditch or road maintenance or minor landscaping projects.

Construction site access. A stabilized stone surface at all points of ingress or egress to a project site, for the purpose of capturing and detaining sediment carried by tires of vehicles or other equipment entering or exiting the project site.

Contiguous. Adjoining or in actual contact with.

Contour. An imaginary line on the surface of the earth connecting points of the same elevation.

Contour Line. Line on a map which represents a contour or points of equal elevation.

Contractor or subcontractor. An individual or company hired by the project site or individual lot owner, their agent, or the individual lot operator to perform services on the project site.

Conveyance. Any structural method for transferring stormwater between at least two points. The term includes piping, ditches, swales, curbs, gutters, catch basins, channels, storm drains, and roadways.

Cross Section. A graph or plot of ground elevation across a stream valley or a portion of it, usually along a line perpendicular to the stream or direction of flow.

Culvert. A closed conduit used for the conveyance of surface drainage water under a roadway, railroad, canal or other impediment.

Dechlorinated swimming pool discharge. Chlorinated water that has either sat idle for seven (7) days following chlorination prior to discharge to the MS4 conveyance, or, by analysis, does not contain detectable concentrations (less than five-hundredths (0.05) milligram per liter) of chlorinated residual.

Design Storm. A selected storm event, described in terms of the probability of occurring once within a given number of years, for which drainage or flood control improvements are designed and built.

Detention. Managing stormwater runoff by temporary holding and controlled release.

Detention Basin. A facility constructed or modified to restrict the flow of storm water to a prescribed maximum rate, and to detain concurrently the excess waters that accumulate behind the outlet.

Detention Storage. The temporary detaining of stormwater in storage facilities, on rooftops, in streets, parking lots, school yards, parks, open spaces or other areas under predetermined and controlled conditions, with the rate of release regulated by appropriately installed devices.

Detention Time. The theoretical time required to displace the contents of a tank or unit at a given rate of discharge (volume divided by rate of discharge).

Detritus. Dead or decaying organic matter; generally contributed to stormwater as fallen leaves and sticks or as dead aquatic organisms.

Developer. Any person financially responsible for construction activity, or an owner of property who sells or leases, or offers for sale or lease, any lots in a subdivision.

Development. Any man-made change to improved or unimproved real estate including but not limited to:

1. Construction, reconstruction, or placement of a building or any addition to a building;
2. Construction of flood control structures such as levees, dikes, dams or channel improvements;
3. Construction or reconstruction of bridges or culverts;
4. Installing a manufactured home on a site, preparing a site for a manufactured home, or installing a recreational vehicle on a site for more than hundred eight (180) days;
5. Installing utilities, erection of walls, construction of roads, or similar projects;
6. Mining, dredging, filling, grading, excavation, or drilling operations;
7. Storage of materials; or
8. Any other activity that might change the direction, height, or velocity of flood or surface waters.

“Development” does not include activities such as the maintenance of existing buildings and facilities such as painting, re-roofing, resurfacing roads, or gardening, plowing and similar agricultural practices that do not involve filling, grading, excavation, or the construction of permanent buildings.

Discharge. In the context of water quantity provisions, usually the rate of water flow, i.e., a volume of fluid passing a point per unit time commonly expressed as cubic feet per second, cubic meters per second, gallons per minute, or millions of gallons per day. In the context of water quality provisions, the discharge means any addition of liquids or solids to a water body or a flow conveyance facility.

Disposal. The discharge, deposit, injection, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that the solid waste or hazardous waste, or any constituent of the waste, may enter the environment, be emitted into the air, or be discharged into any waters, including ground waters.

Ditch. A man-made, open watercourse in or into which excess surface water or groundwater drained from land, stormwater runoff, or floodwaters flow either continuously or intermittently.

Drain. A buried slotted or perforated pipe or other conduit (subsurface drain) or a ditch (open drain) for carrying off surplus groundwater or surface water.

Drainage. The removal of excess surface water or groundwater from land by means of ditches or subsurface drains. Also see Natural drainage.

Drainage Area. The area draining into a stream at a given point. It may be of different sizes for surface runoff, subsurface flow and base flow, but generally the surface runoff area is considered as the drainage area.

Dry Well. A type of infiltration practice that allows stormwater runoff to flow directly into the ground via a bored or otherwise excavated opening in the ground surface.

Duration. The time period of a rainfall event.

Environment. The sum total of all the external conditions that may act upon a living organism or community to influence its development or existence.

Erodibility Index (EI). The soil erodibility index (EI) provides a numerical expression of the potential for a soil to erode considering the physical and chemical properties of the soil and the climatic conditions where it is located. The higher the index, the greater the investment needed to maintain the sustainability of the soil resource base if intensively cropped. It is defined to be the maximum of $(R \times K \times LS)/T$ (from the Universal Soil Loss Equation) and $(C \times I)/T$ (from the Wind Erosion Equation), where R is a measure of rainfall and runoff, K is a factor of the susceptibility of the soil to water erosion, LS is a measure of the combined effects of slope length and steepness, C is a climatic characterization of windspeed and surface soil moisture and I is a measure of the susceptibility of the soil to wind erosion. Erodibility Index scores equal to or greater than 8 are considered highly erodible land.

Erosion. The wearing away of the land surface by water, wind, ice, gravity, or other geological agents. The following terms are used to describe different types of water erosion:

- *Accelerated erosion*--Erosion much more rapid than normal or geologic erosion, primarily as a result of the activities of man.
- *Channel erosion*--An erosion process whereby the volume and velocity of flow wears away the bed and/or banks of a well-defined channel.
- *Gully erosion*--An erosion process whereby runoff water accumulates in narrow channels and, over relatively short periods, removes the soil to considerable depths, ranging from 1-2 ft. to as much as 75-100 ft.
- *Rill erosion*--An erosion process in which numerous small channels only several inches deep are formed; occurs mainly on recently disturbed and exposed soils (see Rill).
- *Splash erosion*--The spattering of small soil particles caused by the impact of raindrops on wet soils; the loosened and spattered particles may or may not be subsequently removed by surface runoff.
- *Sheet erosion*--The gradual removal of a fairly uniform layer of soil from the land surface by runoff water.

Erosion and sediment control. A practice, or a combination of practices, to minimize sedimentation by first reducing or eliminating erosion at the source and then as necessary, trapping sediment to prevent it from being discharged from or within a project site.

Filter Strip. Usually a long, relatively narrow area (usually, 20-75 feet wide) of undisturbed or planted vegetation used near disturbed or impervious surfaces to filter stormwater pollutants for the protection of watercourses, reservoirs, or adjacent properties.

Floatable. Any solid waste that will float on the surface of the water.

Flood (or Flood Waters). A general and temporary condition of partial or complete inundation of normally dry land areas from the overflow, the unusual and rapid accumulation, or the runoff of surface waters from any source.

Floodplain. The channel proper and the areas adjoining the channel which have been or hereafter may be covered by the regulatory or 100-year flood. Any normally dry land area that is susceptible to being inundated by water from any natural source. The floodplain includes both the floodway and the floodway fringe districts.

Floodway. The channel of a river or stream and those portions of the floodplains adjoining the channel which are reasonably required to efficiently carry and discharge the peak flow of the regulatory flood of any river or stream.

Floodway Fringe. That portion of the flood plain lying outside the floodway, which is inundated by the regulatory flood.

Footing Drain. A drain pipe installed around the exterior of a basement wall foundation to relieve water pressure caused by high groundwater elevation.

Fluvial Erosion Hazard (FEH) Corridor. Fluvial (riverine) Erosion Hazard corridors represent the areas along the streams (including the channel and immediate overbanks areas) that are believed to be subject to stream movement or streambank erosion. These corridors have been delineated for most actively migrating and relatively stationary streams in Indiana through an Indiana Silver Jackets initiative. The corridor maps associated with the Hendricks County streams are available on the Hendricks County GIS website. More detailed mapping than that used as part of the Indiana Silver Jackets erosion hazard mapping program may be provided by the applicant if it is based on detailed field assessment acceptable to the Hendricks County Surveyor.

Garbage. All putrescible animal solid, vegetable solid, and semisolid wastes resulting from the processing, handling, preparation, cooking, serving, or consumption of food or food materials.

Gasoline outlet. An operating gasoline or diesel fueling facility whose primary function is the resale of fuels. The term applies to facilities that create five thousand (5,000) or more square feet of impervious surfaces, or generate an average daily traffic count of one hundred (100) vehicles per one thousand (1,000) square feet of land area.

Geographical Information System. A computer system capable of assembling, storing, manipulation, and displaying geographically referenced information. This technology can be used for resource management and development planning.

Grade. (1) The inclination or slope of a channel, canal, conduit, etc., or natural ground surface usually expressed in terms of the percentage the vertical rise (or fall) bears to the corresponding horizontal distance. (2) The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared to a design elevation for the support of construction, such as paving or the laying of a conduit. (3) To finish the surface of a canal bed, roadbed, top of embankment, or bottom of excavation, or other land area to a smooth, even condition.

Grading. The cutting and filling of the land surface to a desired slope or elevation.

Grass. A member of the botanical family Graminae, characterized by blade-like leaves that originate as a sheath wrapped around the stem.

Groundwater. Accumulation of underground water, natural or artificial. The term does not include manmade underground storage or conveyance structures.

Habitat. The environment in which the life needs of a plant or animal are supplied.

Highly Erodible Land (HEL). Land that has an erodibility index of eight or more.

Hydrologic Unit Code. A numeric United States Geologic Survey code that corresponds to a watershed area. Each area also has a text description associated with the numeric code.

Hydrology. The science of the behavior of water in the atmosphere, on the surface of the earth, and underground. A typical hydrologic study is undertaken to compute flow rates associated with specified flood events.

Illicit Discharge. Any discharge to a conveyance that is not composed entirely of stormwater except naturally occurring floatables, such as leaves or tree limbs. Illicit discharges include polluted flows from direct and indirect connections to the MS4 conveyance, illegal dumping, and contaminated runoff.

Impaired Waters. Waters that do not or are not expected to meet applicable water quality standards, as included on IDEM's CWA Section 303(d) List of Impaired Waters.

Impervious surface. Surfaces, such as pavement and rooftops, which prevent the infiltration of stormwater into the soil.

Individual building lot. A single parcel of land within a multi-parcel development.

Individual lot operator. A contractor or subcontractor working on an individual lot.

Individual lot owner. A person who has financial control of construction activities for an individual lot.

Infiltration. Passage or movement of water into the soil. Infiltration practices include any structural BMP designed to facilitate the percolation of run-off through the soil to groundwater. Examples include infiltration basins or trenches, dry wells, and porous pavement.

Inlet. An opening into a storm drain system for the entrance of surface storm water runoff, more completely described as a storm drain inlet.

Land-disturbing Activity. Any man-made change of the land surface, including removing vegetative cover that exposes the underlying soil, excavating, filling, transporting and grading.

Land Surveyor. A person licensed under the laws of the State of Indiana to practice land surveying.

Larger common plan of development or sale. A plan, undertaken by a single project site owner or a group of project site owners acting in concert, to offer lots for sale or lease; where such land is contiguous, or is known, designated, purchased or advertised as a common unit or by a common name, such land shall be presumed as being offered for sale or lease as part of a larger common plan. The term also includes phased or other construction activity by a single entity for its own use.

Lowest Adjacent Grade. The elevation of the lowest grade adjacent to a structure, where the soil meets the foundation around the outside of the structure (including structural members such as basement walkout, patios, decks, porches, support posts or piers, and rim of the window well.

Lowest Floor. Refers to the lowest of the following:

1. The top of the basement floor;
2. The top of the garage floor, if the garage is the lowest level of the building;
3. The top of the first floor of buildings constructed on a slab or of buildings elevated on pilings or constructed on a crawl space with permanent openings; or
4. The top of the floor level of any enclosure below an elevated building where the walls of the enclosure provide any resistance to the flow of flood waters unless:
 - a] The walls are designed to automatically equalize the hydrostatic flood forces on the walls by allowing for the entry and exit of flood waters, by providing a minimum of two opening (in addition to doorways and windows) having a total area of one (1) square foot for every two (2) square feet of enclosed area subject to flooding. The bottom of all such openings shall be no higher than one (1) foot above grade.
 - b] Such enclosed space shall be usable only for the parking of vehicles or building access.

Manhole. Storm drain structure through which a person may enter to gain access to an underground storm drain or enclosed structure.

Measurable storm event. A precipitation event that results in a total measured precipitation accumulation equal to, or greater than, one-half (0.5) inch of rainfall.

Mulch. A natural or artificial layer of plant residue or other materials covering the land surface which conserves moisture, holds soil in place, aids in establishing plant cover, and minimizes temperature fluctuations.

Municipal Separate Storm Sewer System. An MS4 meets all the following criteria: (1) is a conveyance or system of conveyances owned by the state, county, city, town, or other public entity; (2) discharges to waters of the U.S.; (3) is designed or used for collecting or conveying stormwater; (4) is not a combined sewer; and, (5) is not part of a Publicly Owned Treatment Works (POTW).

National Pollution Discharge Elimination System. A permit developed by the U.S. EPA through the Clean Water Act. In Indiana, the permitting process has been delegated to IDEM. This permit covers aspects of municipal stormwater quality.

Natural Drainage. The flow patterns of stormwater run-off over the land in its pre-development state.

Nutrient(s). (1) A substance necessary for the growth and reproduction of organisms. (2) In water, those substances (chiefly nitrates and phosphates) that promote growth of algae and bacteria.

Offense. Both a violation and a failure of compliance on a particular project. If there are multiple violations or multiple failures of compliance on the same project, each shall be considered a separate Offense.

Open Drain. A natural watercourse or constructed open channel that conveys drainage water.

Open Space. Any land area devoid of any disturbed or impervious surfaces created by industrial, commercial, residential, agricultural, or other manmade activities.

Outfall. The point, location, or structure where a pipe or open drain discharges to a receiving body of water.

Outlet. A river, creek, lake, pond, altered watercourse or another public drainage system that receives the final outflow of the drainage system under consideration (inclusive of proposed improvements or new construction).

Peak Discharge (or Peak Flow). The maximum instantaneous flow from a given storm condition at a specific location.

Percolation. The movement of water through soil.

Permanent stabilization. The establishment, at a uniform density of seventy percent (70%) across the disturbed area, of vegetative cover or permanent non-erosive material that will ensure the resistance of the soil to erosion, sliding, or other movement.

Pervious. Allowing movement of water.

Point Source. Any discernible, confined, and discrete conveyance including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, or container from which pollutants are or maybe discharged (P.L. 92-500, Section 502[14]).

Porous pavement. A type of infiltration practice to improve the quality and reduce the quantity of storm water run-off via the use of manmade, pervious pavement which allows run-off to percolate through the pavement and into underlying soils

Professional Engineer. A person licensed under the laws of the State of Indiana to practice professional engineering.

Project site. The entire area on which construction activity is to be performed.

Project site owner. The person required to submit a stormwater permit/approval application, and required to comply with the terms of this Ordinance, including a developer or a person who has financial and operational control of construction activities, and project plans and specifications, including the ability to make modifications to those plans and specifications.

Rain garden. A vegetative practice used to alter impervious surfaces, such as roofs, into pervious surfaces for absorption and treatment of rainfall.

Receiving Stream, Receiving Channel, or Receiving Water. The body of water into which runoff or effluent is discharged. The term does not include private drains, unnamed conveyances, retention and detention basins, or constructed wetlands used as treatment.

Recharge. Replenishment of groundwater reservoirs by infiltration and transmission from the outcrop of an aquifer or from permeable soils.

Redevelopment. Alterations of a property that change a site or building in such a way that there is disturbances of one (1) acre or more of land. The term does not include such activities as exterior remodeling.

Refueling area. An operating gasoline or diesel fueling area whose primary function is to provide fuel to equipment or vehicles.

Regulatory Flood. The discharge or elevation associated with the 100-year flood as calculated by a method and procedure which is acceptable to and accepted by the Indiana Department of Natural Resources and the Federal Emergency Management Agency. The "regulatory flood" is also known as the "base flood".

Regulatory Floodway. See Floodway.

Release Rate - The amount of storm water release from a storm water control facility per unit of time.

Reservoir. A natural or artificially created pond, lake or other space used for storage, regulation or control of water. May be either permanent or temporary. The term is also used in the hydrologic modeling of storage facilities.

Retention. The storage of stormwater to prevent it from leaving the development site. May be temporary or permanent.

Retention basin. A type of storage practice, that has no positive outlet, used to retain storm water run-off for an indefinite amount of time. Runoff from this type of basin is removed only by infiltration through a porous bottom or by evaporation.

Return Period - The average interval of time within which a given rainfall event will be equaled or exceeded once. A flood having a return period of 100 years has a one percent probability of being equaled or exceeded in any one year.

Riparian zone. Of, on, or pertaining to the banks of a stream, river, or pond.

Riparian habitat. A land area adjacent to a waterbody that supports animal and plant life associated with that waterbody.

Runoff. That portion of precipitation that flows from a drainage area on the land surface, in open channels, or in stormwater conveyance systems.

Runoff Coefficient - A decimal fraction relating the amount of rain which appears as runoff and reaches the storm drain system to the total amount of rain falling. A coefficient of 0.5 implies that 50 percent of the rain falling on a given surface appears as storm water runoff.

Sediment. Solid material (both mineral and organic) that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface.

Sedimentation. The process that deposits soils, debris and other unconsolidated materials either on the ground surfaces or in bodies of water or watercourses.

Sensitive Water. A waterbody in need of priority protection or remediation base on its:
providing habitat for threatened or endangered species,
usage as a public water supply intake,
relevant community value,
usage for full body contact recreation,
exceptional use classification as found in 327 IAC 2-1-11(b), outstanding State resource water
classification as found in 327 IAC 2-1-2(3) and 327 IAC 2-1.5-19(b).

Site. The entire area included in the legal description of the land on which land disturbing activity is to be performed.

Slope. Degree of deviation of a surface from the horizontal, measured as a numerical ratio or percent. Expressed as a ratio, the first number is commonly the horizontal distance (run) and the second is the vertical distance (rise)--e.g., 2:1. However, the preferred method for designation of slopes is to clearly identify the horizontal (H) and vertical (V) components (length (L) and Width (W) components for horizontal angles). Also note that according to international standards (Metric), the slopes are presented as the vertical or width component shown on the numerator--e.g., 1V:2H. Slope expressions in this Ordinance follow the common presentation of slopes--e.g., 2:1 with the metric presentation shown in parenthesis--e.g., (1V:2H). Slopes can also be expressed in "percents". Slopes given in percents are always expressed as (100*V/H) --e.g., a 2:1 (1V:2H) slope is a 50% slope.

Soil. The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants.

Soil and Water Conservation District. A public organization created under State law as a special-purpose district to develop and carry out a program of soil, water, and related resource conservation, use, and development within its boundaries. A subdivision of State government with a local governing body, established under IC 14-32.

Solid Waste. Any garbage, refuse, debris, or other discarded material.

Spill. The unexpected, unintended, abnormal, or unapproved dumping, leakage, drainage, seepage, discharge, or other loss of petroleum, hazardous substances, extremely hazardous substances, or objectionable substances. The term does not include releases to impervious surfaces when the substance does not migrate off the surface or penetrate the surface and enter the soil.

Storm Duration. The length of time that water may be stored in any stormwater control facility, computed from the time water first begins to be stored.

Storm Event. An estimate of the expected amount of precipitation within a given period of time. For example, a 10-yr. frequency, 24-hr. duration storm event is a storm that has a 10% probability of occurring in any one year. Precipitation is measured over a 24-hr. period.

Storm Sewer. A closed conduit for conveying collected storm water, while excluding sewage and industrial wastes. Also called a storm drain.

Stormwater. Water resulting from rain, melting or melted snow, hail, or sleet.

Stormwater Pollution Prevention Plan. A plan developed to minimize the impact of storm water pollutants resulting from construction activities.

Stormwater Runoff. The water derived from rains falling within a tributary basin, flowing over the surface of the ground or collected in channels or conduits.

Stormwater Quality Management Plan. A comprehensive written document that addresses stormwater runoff quality.

Stormwater Quality Measure. A practice, or a combination of practices, to control or minimize pollutants associated with storm water runoff.

Stormwater Drainage System - All means, natural or man-made, used for conducting storm water to, through or from a drainage area to any of the following: conduits and appurtenant features, canals, channels, ditches, storage facilities, swales, streams, culverts, streets and pumping stations.

Strip development. A multi-lot project where building lots front on an existing road.

Subdivision. Any land that is divided or proposed to be divided into lots, whether contiguous or subject to zoning requirements, for the purpose of sale or lease as part of a larger common plan of development or sale.

Subsurface Drain. A pervious backfield trench, usually containing stone and perforated pipe, for intercepting groundwater or seepage.

Surface Runoff. Precipitation that flows onto the surfaces of roofs, streets, the ground, etc., and is not absorbed or retained by that surface but collects and runs off.

Swale. An elongated depression in the land surface that is at least seasonally wet, is usually heavily vegetated, and is normally without flowing water. Swales conduct stormwater into primary drainage channels and may provide some groundwater recharge.

Temporary Stabilization. The covering of soil to ensure its resistance to erosion, sliding, or other movement. The term includes vegetative cover, anchored mulch, or other non-erosive material applied at a uniform density of seventy percent (70%) across the disturbed area.

Tile Drain. Pipe made of perforated plastic, burned clay, concrete, or similar material, laid to a designed grade and depth, to collect and carry excess water from the soil.

Topographic Map. Graphical portrayal of the topographic features of a land area, showing both the horizontal distances between the features and their elevations above a given datum.

Topography. The representation of a portion of the earth's surface showing natural and man-made features of a give locality such as rivers, streams, ditches, lakes, roads, buildings and most importantly, variations in ground elevations for the terrain of the area.

Trained individual. An individual who is trained and experienced in the principles of storm water quality, including erosion and sediment control as may be demonstrated by state registration, professional certification, experience, or completion of coursework that enable the individual to make judgments regarding storm water control or treatment and monitoring.

Urban Drain. A drain defined as “Urban Drain” in Indiana Drainage Code.

Urbanization The development, change or improvement of any parcel of land consisting of one or more lots for residential, commercial, industrial, institutional, recreational or public utility purposes.

Vegetated swale. A type of vegetative practice used to filter stormwater runoff via a vegetated, shallow-channel conveyance.

Violation. Any action or inaction which violates the provisions of this Ordinance or the Technical Standards, the requirements of an approved stormwater management design plan or permit, and/or the requirements of a recorded stormwater maintenance agreement may be subject to the enforcement actions outlined in Section 7 of this Ordinance. Any such action or inaction is deemed to be a public nuisance and may be abated by injunctive or other equitable relief in addition to, and separate from, the imposition of any of the enforcement actions described in Section 7 of this Ordinance.

Water Quality. A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Water Resources. The supply of groundwater and surface water in a given area.

Waterbody. Any accumulation of water, surface, or underground, natural or artificial, excluding water features designed and designated as water pollution control facilities.

Watercourse. Any river, stream, creek, brook, branch, natural or man-made drainageway in or into which stormwater runoff or floodwaters flow either continuously or intermittently.

Watershed. The region drained by or contributing water to a specific point that could be along a stream, lake or other stormwater facilities. Watersheds are often broken down into subareas for the purpose of hydrologic modeling.

Watershed Area. All land and water within the confines of a drainage divide. See also Watershed.

Wetlands. Areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions.

STORMWATER TECHNICAL STANDARDS MANUAL HENDRICKS COUNTY, INDIANA

October 2023 (Effective April 2024)

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Chapter One

INTRODUCTION

This document, the Hendricks County Stormwater Technical Standards Manual, which generally follows the Indiana LTAP Model Stormwater Technical Standards document, prepared by Christopher B. Burke Engineering, LLC, contains the necessary technical standards for administering the requirements of IDEM MS4 GP and the Hendricks County Stormwater Management Ordinance. This document should be considered as a companion document to the Ordinance. Whereas the Ordinance contains the majority of the regulatory authority and general requirements of comprehensive stormwater management, this document contains the necessary means and methods for achieving compliance with the Ordinance. In case there are conflicts between the requirements contained in this document and the ordinance, the requirements of the Ordinance should prevail.

This document contains formulas and methodologies for the review and design of both stormwater quantity and stormwater quality facilities. Chapters 2 through 6 contain stormwater conveyance and detention calculations and requirements. Chapter 7 contains information on erosion control requirements and other pollution prevention measures for active construction sites. Chapters 8 through 9 cover calculations required to properly size and design stormwater quality features that will treat runoff long-term following construction completion. This includes both Conventional and Low Impact Development (LID) approaches. Chapter 10 contains miscellaneous standards regarding grading and building pad elevations, acceptable outlet and adjoining property impact requirements, no net loss floodplain storage requirements, Floodway and FEH requirements, the requirements associated with proposed dams or levees, development downstream of existing dams, and special stormwater requirements for solar farms. A comprehensive glossary of terms is provided in Appendix A. Appendix B contains several useful and necessary standard forms. Best Management Practices (BMPs) for erosion control measures during the construction phase are contained in Appendix C. It is the intent of the Hendricks County Drainage Board and/or Hendricks County Surveyor that material presented in Appendices C will be revised or eliminated once the Indiana Storm Water Quality Manual (ISWQM) is updated to include details regarding the BMPs currently included in Appendix C. Appendix D contains non-structural and structural post-construction BMP Fact Sheets as well as Recommended Plant Lists, Recommended Materials, Soil Infiltration Testing Protocol, BMP Maintenance Checklists, and Maintenance Agreement for post-construction BMPs.

The site designer is encouraged to review the LID discussion in Chapter 8 prior to the site design to take advantage of runoff reduction recognitions provided towards water quantity calculations if LID practices are utilized as part of the site design.

These technical standards are general in nature. Every project site is unique and may require provisions specific to the site. Hendricks County Drainage Board and/or the Hendricks County Surveyor has the authority to modify, add to, grant exemptions, and/or waive any and all the requirements of this technical standards document on a case-by-case basis.



Chapter Two

METHODOLOGY FOR DETERMINATION OF RUNOFF RATES

Runoff rates shall be computed for the area of the parcel under development plus the area of the watershed flowing into the parcel under development. The rate of runoff which is generated as the result of a given rainfall intensity may be calculated as follows:

A. Development Sites Less than or Equal to 5 Acres in Size, With a Contributing Drainage Area Less than or Equal to 25 Acres and No Depressional Storage

The Rational Method may be used. A computer model, such as TR-55 (NRCS), TR-20 (NRCS), HEC-HMS (COE), and HEC-1 (COE), that can generate hydrographs based on the NRCS TR-55 time of concentration and curve number calculation methodologies may also be used along with a 24-hour duration NRCS Type 2 storm. Note that for the purpose of determining the post-developed conditions curve numbers, due to significant disturbance to the upper soil layers during the construction activities, the initially determined hydrologic soil group for disturbed areas should be changed to the next less infiltrating capacity category (i.e., A to B, B to C, and C to D).

LID Exception: If Low Impact Development (LID) approach is pursued in satisfying the requirements noted in Chapter 8 (Post-Construction Stormwater Quality Management Standards), the post-developed CN for the protected undisturbed or restored disturbed areas meeting the requirements described in Chapter 8 and BMP fact sheets may be determined based on pre-development underlying soil layer.

In the Rational Method, the peak rate of runoff, Q , in cubic feet per second (cfs) is computed as:

$$Q = CIA$$

Where: C = Runoff coefficient, representing the characteristics of the drainage area and defined as the ratio of runoff to rainfall.

I = Average intensity of rainfall in inches per hour for a duration equal to the time of concentration (t_c) for a selected rainfall frequency.

A = Tributary drainage area in acres.

Values for the runoff coefficient "C" are provided in **Tables 2-1** and **2-2**, which show values for different types of surfaces and local soil characteristics. The composite "C" value used for a given drainage area with various surface types shall be the weighted average value for the total area calculated from a breakdown of individual areas having different surface types. **Table 2-3** provides runoff coefficients and inlet times for different land use classifications.

Rainfall intensity shall be determined from the rainfall frequency data shown in **Table 2-4**.

In general, the time of concentration (t_c) methodology to be used for all stormwater management projects within Hendricks County shall be as outlined in the U.S. Department of Agriculture (USDA) - NRCS TR-55 Manual. In urban or developed areas, the methodology to be used shall be the sum of the inlet time and flow time in the stormwater facility from the most remote part of the drainage area to the point under consideration. The flow time in the storm sewers may be estimated by the distance in feet divided by velocity of flow in feet per second. The velocity shall be determined by the Manning's Equation (see Chapter 4). Inlet time is the combined time required for the runoff to reach the inlet of the storm sewer. It includes overland flow time and flow time through established surface drainage channels such as swales, ditches, and sheet flow across such areas as lawns, fields, and other graded surfaces.

TABLE 2-1

Urban Runoff Coefficients				
<i>Type of Surface</i>	<i>Runoff Coefficient "C"</i> <i>(by Storm Recurrence Interval)</i>			
	<i>< 25 year</i>	<i>25 year</i>	<i>50 year</i>	<i>100 year</i>
◆ Hard Surfaces				
Asphalt	0.82	0.90	1.00	1.00
Gravel	0.85	0.94	1.00	1.00
Concrete	0.85	0.94	1.00	1.00
Roof	0.85	0.94	1.00	1.00
◆ Lawns (Sandy)				
Flat (0-2% Slope)	0.07	0.08	0.09	0.12
Rolling (2-7% Slope)	0.12	0.13	0.16	0.20
Steep (Greater than 7% Slope)	0.17	0.19	0.22	0.28
◆ Lawns (Clay)				
Flat (0-2% Slope)	0.16	0.18	0.21	0.26
Rolling (2-7% Slope)	0.21	0.23	0.28	0.35
Steep (Greater than 7% Slope)	0.30	0.33	0.40	0.50

Source: HERPICC Stormwater Drainage Manual, July 1995, and other sources.

TABLE 2-2

Rural Runoff Coefficients				
<i>Type of Surface</i>	<i>Runoff Coefficient "C" (by Storm Recurrence Interval)</i>			
	<i>< 25 year</i>	<i>25 year</i>	<i>50 year</i>	<i>100 year</i>
◆ Woodland (Sandy)				
Flat (0-2% Slope)	0.10	0.11	0.13	0.17
Rolling (2-7% Slope)	0.25	0.28	0.33	0.41
Steep (Greater than 7% Slope)	0.30	0.33	0.40	0.50
◆ Woodland (Clay)				
Flat (0-2% Slope)	0.30	0.33	0.40	0.50
Rolling (2-7% Slope)	0.35	0.39	0.46	0.58
Steep (Greater than 7% Slope)	0.50	0.55	0.66	0.83
◆ Pasture (Sandy)				
Flat (0-2% Slope)	0.10	0.11	0.13	0.17
Rolling (2-7% Slope)	0.16	0.18	0.21	0.26
Steep (Greater than 7% Slope)	0.22	0.24	0.29	0.36
◆ Pasture (Clay)				
Flat (0-2% Slope)	0.30	0.33	0.40	0.50
Rolling (2-7% Slope)	0.36	0.40	0.48	0.59
Steep (Greater than 7% Slope)	0.42	0.46	0.55	0.69
◆ Cultivated (Sandy)				
Flat (0-2% Slope)	0.30	0.33	0.40	0.50
Rolling (2-7% Slope)	0.40	0.44	0.53	0.66
Steep (Greater than 7% Slope)	0.52	0.57	0.69	0.86
◆ Cultivated (Clay)				
Flat (0-2% Slope)	0.50	0.55	0.66	0.83
Rolling (2-7% Slope)	0.60	0.66	0.79	0.99
Steep (Greater than 7% Slope)	0.72	0.79	0.95	1.00

Source: HERPICC Stormwater Drainage Manual, July 1995, and other sources.

TABLE 2-3

Runoff Coefficients by Land Use, Typical Inlet Times, and Storm Recurrence Interval													
Land Use	Runoff Coefficients "C" (by Storm Recurrence Interval)												Inlet Time (Minutes) (4)
	Flat (1)				Rolling (2)				Steep (3)				
	< 25 year	25 year	50 year	100 year	< 25 year	25 year	50 year	100 year	< 25 year	25 year	50 year	100 year	
Commercial (CBD)	0.75	0.83	0.99	1.00	0.83	0.91	1.00	1.00	0.91	1.00	1.00	1.00	5
Commercial (Neighborhood)	0.54	0.59	0.71	0.89	0.60	0.66	0.79	0.99	0.66	0.73	0.87	1.00	5 - 10
Industrial	0.63	0.69	0.83	1.00	0.70	0.77	0.92	1.00	0.77	0.85	1.00	1.00	
Garden Apartments	0.54	0.59	0.71	0.89	0.60	0.66	0.79	0.99	0.66	0.73	0.87	1.00	
Churches	0.54	0.59	0.71	0.89	0.60	0.66	0.79	0.99	0.66	0.73	0.87	1.00	
Schools	0.31	0.34	0.41	0.51	0.35	0.39	0.46	0.58	0.39	0.43	0.51	0.64	10 - 15
Semi Detached Residential	0.45	0.50	0.59	0.74	0.50	0.55	0.66	0.83	0.55	0.61	0.73	0.91	
Detached Residential	0.40	0.44	0.53	0.66	0.45	0.50	0.59	0.74	0.50	0.55	0.66	0.83	
Quarter Acre Lots	0.36	0.40	0.48	0.59	0.40	0.44	0.53	0.66	0.44	0.48	0.58	0.73	
Half Acre Lots	0.31	0.34	0.41	0.51	0.35	0.39	0.46	0.58	0.39	0.43	0.51	0.64	
Parkland	0.18	0.20	0.24	0.30	0.20	0.22	0.26	0.33	0.22	0.24	0.29	0.36	To be Computed

Source: HERPICC Stormwater Drainage Manual, July 1995, and other sources.

- (1) Flat terrain involves slopes of 0-2%.
- (2) Rolling terrain involves slopes of 2-7%.
- (3) Steep terrain involves slopes greater than 7%.
- (4) Interpolation, extrapolation and adjustment for local conditions shall be based on engineering experience and judgment.

B. Development Sites Greater Than 5 Acres in Size or Contributing Drainage Area Greater than 25 Acres or With Significant Depressional Storage

The runoff rate for these development sites and contributing drainage areas shall be determined by a computer model that can generate hydrographs based on the NRCS TR-55 time of concentration and curve number calculation methodologies. Note that for the purpose of determining the post-developed conditions curve numbers, due to significant disturbance to the upper soil layers during the construction activities, the initially determined hydrologic soil group for disturbed areas should be changed to the next less infiltrating capacity category (i.e., A to B, B to C, and C to D).

LID Exception: If Low Impact Development (LID) approach is pursued in satisfying the requirements noted in Chapter 8 (Post-Construction Stormwater Quality Management Standards), the post-developed CN for the protected undisturbed or restored disturbed areas meeting the requirements described in Chapter 8 and BMP fact sheets may be determined based on pre-development underlying soil layer.

The 24-hour NRCS Type 2 Rainfall Distribution shall be utilized for runoff calculations. 24-hour Rainfall depth for various frequencies shall be taken from **Table 2-5**. The NRCS Type 2 distribution ordinates are found in **Table 2-6**. Examples of computer models that can generate such hydrographs include TR-55 (NRCS), TR-20 (NRCS), HEC-HMS (COE), and HEC-1 (COE). These programs may be downloaded free of charge from the associated agencies' web sites. Other models may be acceptable and should be accepted by the Hendricks County Drainage Board and/or Hendricks County Surveyor prior to their utilization.

TABLE 2-4

Rainfall Intensities for Various Return Periods and Storm Durations						
<i>Duration</i>	<i>Intensity (Inches/Hour)</i>					
	<i>Return Period (Years)</i>					
	2	5	10	25	50	100
5 min	5.57	6.7	7.58	8.76	9.68	10.6
10 min	4.35	5.2	5.85	6.7	7.34	7.98
15 min	3.54	4.26	4.8	5.52	6.06	6.61
30 min	2.37	2.92	3.33	3.89	4.33	4.77
1 hr	1.46	1.83	2.12	2.53	2.85	3.19
2 hr	0.851	1.08	1.25	1.51	1.72	1.95
3 hr	0.603	0.762	0.893	1.08	1.24	1.41
6 hr	0.359	0.455	0.535	0.65	0.747	0.853
12 hr	0.211	0.263	0.306	0.368	0.418	0.473
24 hr	0.126	0.155	0.178	0.21	0.236	0.262

Source: NOAA, National Weather Service, "Precipitation-Frequency Atlas of the United States", NOAA Atlas 14, Volume 2, Version 2, 2004, for Danville, Indiana. (values for intermediate durations can be logarithmically interpolated.) (All rainfall intensities are based on annual maximum series)

TABLE 2-5

Rainfall Depths for Various Return Periods							
<i>Duration</i>	<i>Depth (Inches)</i>						
	<i>Return Period (Years)</i>						
	1	2	5	10	25	50	100
24 Hrs.	2.51	3.02	3.72	4.28	5.04	5.66	6.3

Source: NOAA, National Weather Service, "Precipitation-Frequency Atlas of the United States", NOAA Atlas 14, Volume 2, Version 2, 2004, for Danville, Indiana. (Rainfall depths for 2- through 100-year storm are based on annual maximum series. 1-year rainfall depth is based on partial duration series)

TABLE 2-6

NRCS Type II Rainfall Distribution Ordinates					
<i>Cumulative Storm Time (hr)</i>	<i>Cumulative Percent of Storm Depth</i>	<i>Cumulative Storm Time (hr)</i>	<i>Cumulative Percent of Storm Depth</i>	<i>Cumulative Storm Time (hr)</i>	<i>Cumulative Percent of Storm Depth</i>
0.00	0	8.25	12.6	16.50	89.3
0.25	0.2	8.50	13.3	16.75	89.8
0.50	0.5	8.75	14	17.00	90.3
0.75	0.8	9.00	14.7	17.25	90.8
1.00	1.1	9.25	15.5	17.50	91.3
1.25	1.4	9.50	16.3	17.75	91.8
1.50	1.7	9.75	17.2	18.00	92.2
1.75	2	10.00	18.1	18.25	92.6
2.00	2.3	10.25	19.1	18.50	93
2.25	2.6	10.50	20.3	18.75	93.4
2.50	2.9	10.75	21.8	19.00	93.8
2.75	3.2	11.00	23.6	19.25	94.2
3.00	3.5	11.25	25.7	19.50	94.6
3.25	3.8	11.50	28.3	19.75	95
3.50	4.1	11.75	38.7	20.00	95.3
3.75	4.4	12.00	66.3	20.25	95.6
4.00	4.8	12.25	70.7	20.50	95.9
4.25	5.2	12.50	73.5	20.75	96.2
4.50	5.6	12.75	75.8	21.00	96.5
4.75	6	13.00	77.6	21.25	96.8
5.00	6.4	13.25	79.1	21.50	97.1
5.25	6.8	13.50	80.4	21.75	97.4
5.50	7.2	13.75	81.5	22.00	97.7
5.75	7.6	14.00	82.5	22.25	98
6.00	8	14.25	83.4	22.50	98.3
6.25	8.5	14.50	84.2	22.75	98.6
6.50	9	14.75	84.9	23.00	98.9
6.75	9.5	15.00	85.6	23.25	99.2
7.00	10	15.25	86.3	23.50	99.5
7.25	10.5	15.50	86.9	23.75	99.8
7.50	11	15.75	87.5	24.00	100
7.75	11.5	16.00	88.1		
8.00	12	16.25	88.7		

Source: National Resources Conservation Service (NRCS), "TR-20 Computer Program for Project Formulation Hydrology", page F9, May 1982.

NOTE: For use only when SCS Type II rainfall distribution is not a default option in the computer program.

C. Development Sites with Drainage Areas Greater than or Equal to One square Mile

For the design of any major drainage system, as defined in **Appendix A**, the discharge must be obtained from, or be accepted by, the IDNR. Other portions of the site must use the discharge methodology in the applicable section of this Chapter.



Chapter Three

METHODOLOGY FOR DETERMINATION OF RETENTION/DETENTION STORAGE VOLUMES

The required volume of stormwater storage for all development sites shall be computed using a computer model that can generate hydrographs based on the NRCS TR-55 time of concentration and curve number calculation methodologies. Examples of computer models that can generate such hydrographs include TR-55 (NRCS), TR-20 (NRCS), HEC-HMS (COE), and HEC-1 (COE). Other models may be acceptable and should be accepted by the Hendricks County Drainage Board and/or Hendricks County Surveyor prior to their utilization.

A. Post-Development Hydrologic Parameters

Note that for the purpose of determining the post-developed conditions curve numbers, due to significant disturbance to the upper soil layers during the construction activities, the initially determined hydrologic soil group for disturbed areas should be changed to the next less infiltrating capacity category (i.e., A to B, B to C, and C to D).

LID Exception: If Low Impact Development (LID) approach is pursued in satisfying the requirements noted in Chapter 8 (Post-Construction Stormwater Quality Management Standards), the post-developed CN for the protected undisturbed or restored disturbed areas meeting the requirements described in Chapter 8 and BMP fact sheets may be determined based on pre-development underlying soil layer.

B. Design Storm & Allowable Release Rates for Development Sites with On-site Detention Facilities

The 24-hour NRCS Type 2 Rainfall Distribution shall be utilized to determine the required storage volume. The allowable release rates shall be determined based on methodologies provided in Chapter 6 of these Technical Standards document.

C. Design Storm & Allowable Release Rates for Development Sites within a Designated Drainage Area Serviced by a Regional Detention facility

Development sites within Designated Drainage Areas making use of regional detention ponds are typically not required to provide on-site detention; as a

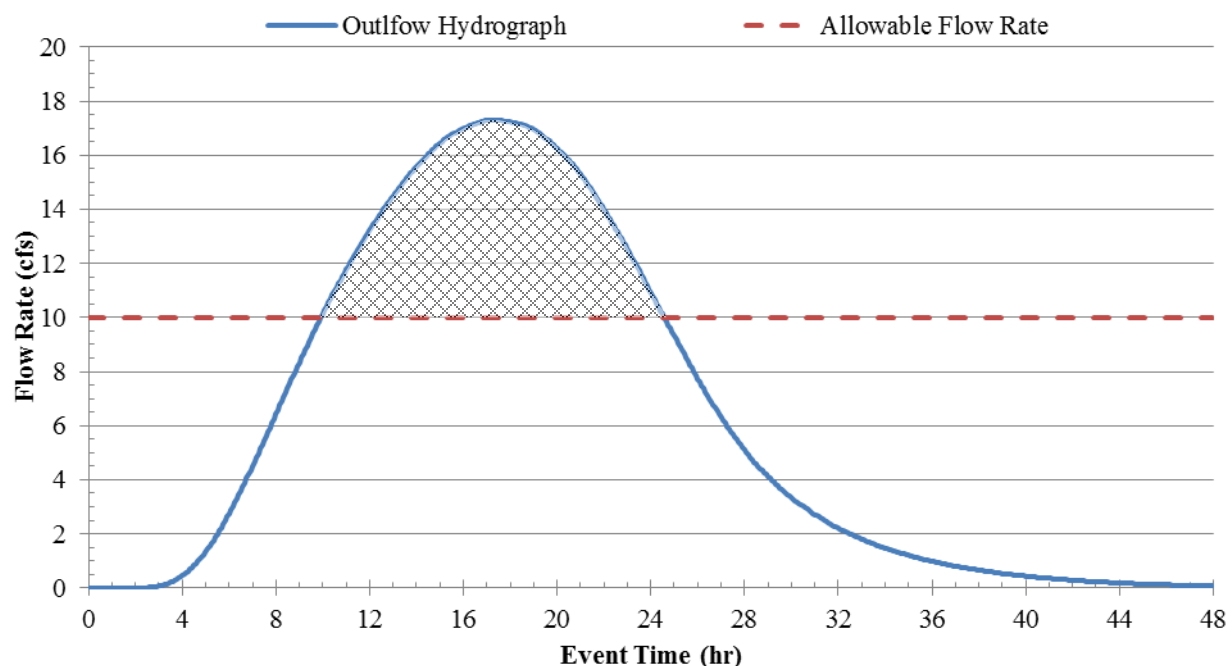
result, the requirements of Chapter 6 of these Stormwater Technical Standards do not apply to development sites where no on-site detention is planned.

Where a regional detention facility is servicing or is planned to service a sub-watershed area, and that sub-watershed has been declared a Designated Drainage Area to raise the necessary Infrastructure Development Fees in lieu of providing on-site detention, the following method shall be used to determine the size of storage space that would have been required on-site.

The 24-hour NRCS Type 2 Rainfall Distribution shall be utilized to determine the required storage volume. The stormwater model should not include an on-site detention facility. The outflow hydrograph at the downstream-most point in the site's stormwater system shall be compared to the allowable release rate for the Designated Drainage Area to determine the required storage volume. The allowable release rate for a Designated Drainage Area shall be as defined by the resolution forming the Designated Drainage Area.

The storage volume shall be determined by calculating the volume of outflow from the site that exceeds the given allowable release rate. For example, if a 50-acre site is located in a Designated Drainage Area that has an allowable post-development 100-year release rate of 0.2 cfs/acre, the required storage volume for the site would be equal to the volume of water represented by the cross-hatched area in **Figure 3-1**.

FIGURE 3-1
Required Storage Volume Determination Example





Chapter Four

STORM SEWER DESIGN STANDARDS AND SPECIFICATIONS

All storm sewers, whether private or public, and whether constructed on private or public property shall conform to the design standards and other requirements contained herein.

A. Design Storm Frequencies

1. All storm sewers, inlets, catch basins, and street gutters shall accommodate (subject to the “allowable spread” provisions discussed later in this Section), as a minimum, peak runoff from a 10-year return frequency storm calculated based on methodology described in Chapter 2. Additional discharges to storm sewer systems allowed in Section L below of this Section must be considered in all design calculations. For Rational Method analysis, the duration shall be equal to the time of concentration for the drainage area. In computer based analysis, the duration is as noted in the applicable methodology associated with the computer program.
2. Culvert capacities for conveyance under interior local, collector, or arterial streets without roadway overtopping shall be the runoff resulting from the 25-year, 50-year, and 100-year frequency storms, respectively, for off-site areas under existing condition and on-site areas under post-developed conditions. Driveway culvert capacities shall be capacities required for the street classification to which the driveway connects. Greater culvert capacity shall be required to protect the finished floor elevation of buildings from the post-developed 100-year frequency storm when, in the opinion of the design engineer or the Hendricks County Drainage Board and/or Hendricks County Surveyor, the finished floor elevation is threatened. If the street or road provides the only access to or from any portion of any commercial or residential development, the crossing shall be designed for a minimum of 100-year frequency storm.
3. For portions of the system considered minor drainage systems, the allowable spread of water on Collector Streets for the design storm is limited to maintaining two clear 10-foot moving lanes of traffic. One lane is to be maintained on Local Roads, while other access lanes (such as a subdivision cul-de-sac) can have a water spread equal to one-half of their total width.
4. To ensure access to buildings and allow the use of the roadway by emergency vehicles during storms larger than the design storm, an overflow channel/swale between sag inlets and overflow paths or basin shall be provided at sag inlets

so that the maximum depth of water that might be ponded in the street sag shall not exceed 7 inches measured from elevation of gutter. All water shall be contained in the right-of-way for a 100-year storm.

5. Facilities functioning as a major drainage system as defined in **Appendix A** must also meet IDNR design standards in addition to the Hendricks County standards. In case of discrepancy, the most restrictive requirements shall apply.
6. Pipe, 12 inches or larger in diameter, shall be placed in a minimum 30-foot easement (15 feet from centerline on each side) and shall be designated on the record plat as 30-foot drain easement. Minimum easements widths based on pipe size and depth are to be determined by the following equation:

$$\text{Minimum Easement Width} = \text{Pipe size} + 2 \text{ feet} + (\text{Depth of pipe} \times 2.5) + 15 \text{ feet}$$

Where:

Pipe size = inner pipe diameter (feet)

Depth of pipe = depth (feet) at pipe invert + 1 foot (accounts for excavation under pipe)

Easement widths should be rounded up to nearest 5 feet for calculated widths above 2.5 feet and rounded down to nearest 5 feet at 2.5 feet or below (for example, a calculated easement width of 33 feet should round up to 35 feet and a calculated easement width of 32.5 feet should be rounded down to 30 feet). **Table 4-1** provides minimum drain easement widths for various pipe sizes and depths.

TABLE 4-1

Easement Widths (feet) Based on Pipe Size and Depth								
Pipe size (ft.)	Depth to pipe invert (ft.)							
	3	4	5	6	7	8	9	10
1	30	30	35	35	40	40	45	45
1.5	N/A	30	35	35	40	40	45	45
2	N/A	30	35	35	40	40	45	45
3	N/A	N/A	35	35	40	40	45	45
4	N/A	N/A	N/A	49	40	45	45	50
5	N/A	N/A	N/A	N/A	40	45	45	50

B. Manning's Equation

Determination of hydraulic capacity for storm sewers sized by the

Rational Method analysis must be done using Manning's Equation. where:

$$V = (1.486/n)(R^{2/3})(S^{1/2})$$

Then:

$$Q = (V)(A)$$

Where:

Q = capacity in cubic feet per second

V = mean velocity of flow in feet per second

A = cross sectional area in square feet

R = hydraulic radius in feet

S = slope of the energy grade line in feet per foot

n = Manning's "n" or roughness coefficient

The hydraulic radius, R, is defined as the cross-sectional area of flow divided by the wetted flow surface or wetted perimeter. Allowable "n" values and full-flow maximum permissible velocities for storm sewer materials are listed in **Table 4-2**.

TABLE 4-2

Typical Values of Manning's "n"		
<i>Material</i>	<i>Manning's "n"</i>	<i>Maximum Velocities (feet/second)</i>
□ Closed Conduits		
Concrete	0.013	10
Vitrified Clay	0.013	10
HDPE	0.012	10
PVC	0.012	10
□ Circular CMP, Annular Corrugations, 2 2/3 x 1/2 inch		
Unpaved	0.024	7
25% Paved	0.021	7
50% Paved	0.018	7
100% Paved	0.013	7
Concrete Culverts	0.013	10
HDPE or PVC	0.012	10
□ Open Channels		
Concrete, Trowel Finish	0.013	10
Concrete, Broom Finish	0.015	10
Gunite	0.018	10
Riprap Placed	0.030	10
Riprap Dumped	0.035	10
Gabion	0.028	10
New Earth (1)	0.025	4
Existing Earth (2)	0.030	4
Dense Growth of Weeds	0.040	4
Dense Weeds and Brush	0.040	4
Swale with Grass	0.035	4

Source of manning "n" values: HERPICC Stormwater Drainage Manual, July 1995.

- (1) New earth (uniform, sodded, clay soil)
- (2) Existing earth (fairly uniform, with some weeds).

C. Backwater Method for Pipe System Analysis

For hydraulic analysis of existing or proposed storm drains which possess submerged outfalls, a more sophisticated design/analysis methodology than Manning's equation will be required. The backwater analysis method provides a more accurate estimate of pipe flow by calculating individual head losses in pipe systems that are surcharged and/or have submerged outlets. These head losses are added to a known downstream water surface elevation to give a design water surface elevation for a given flow at the desired upstream location.

Tailwater conditions assumed for this computation should be verified by appropriate calculations. Total head losses may be determined as follows:

Total head loss = frictional loss + manhole loss + velocity head loss + junction loss

Various computer modeling programs such as HYDRA, ILLUDRAIN, and STORMCAD are available for analysis of storm drains under these conditions. Computer models to be utilized, other than those listed, must be accepted by the Hendricks County Drainage Board and/or Hendricks County Surveyor or designee.

D. Minimum Size for Storm Sewers

The minimum diameter of all storm sewers shall be 12 inches. When the minimum 12-inch diameter pipe will not limit the rate of release to the required amount, the rate of release for detention storage shall be controlled by an orifice plate or other device, subject to acceptance of the Hendricks County Drainage Board and/or Hendricks County Surveyor.

E. Pipe Cover, Grade, and Separation from Sanitary Sewers and County Regulated Drainage System

Pipe grade shall be such that, in general, a minimum of 2.0 feet of cover is maintained over the top of the pipe. If the pipe is to be placed under pavement, or within 5 feet of the pavement, then the minimum pipe cover shall be 2.5 feet from top of pavement to top of pipe. Uniform slopes shall be maintained between inlets, manholes and inlets to manholes. Final grade shall be set with full consideration of the capacity required, sedimentation problems, and other design parameters. Minimum and maximum allowable slopes shall be those capable of producing velocities of between 2.5 and 10 feet per second, respectively, when the sewer is flowing full. Maximum permissible velocities for various storm sewer materials are listed in **Table 4-2**. A minimum of 2.0 feet of vertical separation between storm sewers and sanitary sewers shall be required. When this is not possible, the sanitary sewer must be encased in concrete or ductile steel within 5 feet, each side, of the

crossing centerline. Additional risk reduction measures, such as a fiberglass slip liner, shall be considered and may be required on a case-by-case basis.

A minimum of 5 feet of vertical separation between any proposed utility line/pipe crossing and a county regulated drainage system (an enclosed county regulated drain or a regulated county open ditch) shall be required.

F. Alignment

Storm sewers shall be straight between manholes and/or inlets.

G. Manholes/Inlets

Manholes and/or inlets shall be installed to provide human access to continuous underground storm sewers for the purpose of inspection and maintenance. The casting access minimum inside diameter shall be no less than 22 inches or a rectangular opening of no less than 22 inches by 22 inches. Steps shall be provided in structures deeper than 4 feet, with the first step at the depth of 2 feet and the following steps spaced every 1 foot until the bottom is reached. When grade adjustments of manholes and inlets are required in the field to meet finish design or existing curb grade, adjustment rings with a maximum height of 12 inches may be used. Manholes shall be provided at the following locations:

1. Where two or more storm sewers converge.
2. Where pipe size or the pipe material changes.
3. Where a change in horizontal alignment occurs.
4. Where a change in pipe slope occurs.
5. At intervals in straight sections of sewer, not to exceed the maximum allowed. The maximum distance between storm sewer manholes shall be as shown in **Table 4-3**.

TABLE 4-3

Maximum Distance Between Manholes	
Size of Pipe (Inches)	Maximum Distance (Feet)
12 through 42	400
48 and larger	600

Manhole/inlet inside sizing shall be according to the Hendricks County Standard Construction Details.

In addition to the above requirements, a minimum drop of 0.1 foot through manholes and inlet structures should be provided. When changing pipe size, match crowns of pipes, unless detailed modeling of hydraulic grade line shows that another arrangement would be as effective. Pipe slope should not be so steep that inlets surcharge (i.e. hydraulic grade line should remain below rim elevation).

Plans should note that all Inlets and castings must be pre-stamped with a "clean water" message.

Manhole/inlet inside sizing shall be as shown in **Table 4-4**.

TABLE 4-4

Manhole/Inlet Inside Sizing		
Depth of Structure	Minimum Diameter	Minimum Square Opening
Less than 5 feet	36 inches	36" x 36"
5 feet or more	48 inches	48" x 48"

H. Inlet Sizing and Spacing

Inlets or drainage structures shall be utilized to collect surface water through grated openings and convey it to storm sewers, channels, or culverts. The inlet grate opening provided shall be adequate to pass the design 10-year flow with 50% of the sag inlet areas clogged. Inlets shall be provided so that surface water is not carried across or around any intersection nor for a distance greater than five-hundred (500) feet. An overflow channel from sag inlets to the overflow channel or basin shall be provided at sag inlets. Inlet design and spacing may be done using the hydraulic equations by manufacturers or orifice/weir equations. Use of the U.S. Army Corps of Engineers HEC-12 computer program is also an acceptable method. Gutter spread on continuous grades may be determined using the Manning's equation, or by using **Figure 4-1**. Further guidance regarding gutter spread calculation may be found in the latest edition of HERPICC Stormwater Drainage Manual, available from the Local Technical Assistance Program (LTAP). At the time of printing of this document, contact information for LTAP was:

Indiana LTAP
Purdue University
Toll-Free: (800) 428-7369 (Indiana only)
Phone: (765) 494-2164
Fax: (765) 496-1176

I. Installation and Workmanship

The point of commencement for laying a storm sewer pipe shall be the lowest point in the proposed sewer line. All pipes shall be laid, without break, upgrade from structure to structure. All storm sewer pipe outlets shall have poured in place toewalls with anchor bolts. Bedding and backfill materials around storm sewer pipes, sub-drains, and the associated structures are limited to: #8 crushed stone, hand-tamped or walked-in; flowable fill; and native backfill, compacted to 95% Standard Proctor density. The specific location requirements for the use of these materials are dependent on pipe location in relation to pavement structures and on pipe material as detailed in **Figure 4-2**. If a wheel trencher tiling machine or rounded bucket is used to lay storm sewers, the Bedding and Backfill Standards as detailed in **Figure 4-3** should be followed if this meets pipe manufacturer's installation specifications and the pipe is placed in appropriate clay soil in virgin earth. Bedding and Backfill Standards for Sub-drains under Swales is detailed in **Figure 4-4**.

The specifications for the construction of storm sewers and sub-drains, including backfill requirements, shall not be less stringent than those set forth in the latest edition of the INDOT "Standard Specifications". Additionally, ductile iron pipe shall be laid in accordance with American Water Works Association (AWWA) C-600 and clay pipe shall be laid in accordance with either American Society of Testing Materials (ASTM) C-12 or the appropriate American Association of State Highway and Transportation Officials (AASHTO) specifications. Dips/sags on newly installed storm systems will not be allowed. Also, infiltration from cracks, missing pieces, and joints would not be allowed. Variations from these standards must be justified and receive written acceptance from the Hendricks County Drainage Board and/or Hendricks County Surveyor.

J. Materials

Storm sewer manholes and inlets shall be constructed of cast in place concrete or pre-cast reinforced concrete. Material and construction shall conform to the latest edition of the Indiana Department of Transportation (INDOT) "Standard Specifications", Sections 702 and 720.

Pipe and fittings used in storm sewer construction shall be extra-strength ductile iron pipe (AWWA C-151), poly vinyl chloride pipe (AASHTO M252), polyethylene pipe (AASHTO M252 or AASHTO M294), or concrete pipe (AASHTO M170). Other pipe and fittings not specified herein or in Sections 907-908 of the latest edition of the

INDOT "Standard Specifications" may be used only when specifically authorized by the Hendricks County Drainage Board and/or Hendricks County Surveyor. Pipe joints shall be flexible and watertight and shall conform to the requirements of Section 906, of the latest edition of the INDOT "Standard Specifications". **If the storm sewer pipe is to be placed within a road right-of-way or in an area subject to loading, the pipe and fittings shall be concrete.**

K. Special Hydraulic Structures

Special hydraulic structures required to control the flow of water in storm runoff drainage systems include junction chambers, drop manholes, stilling basins, and other special structures. The use of these structures shall be limited to those locations justified by prudent planning and by careful and thorough hydraulic engineering analysis. Certification of special structures by a certified Structural Engineer may also be required.

L. Connections to Storm Sewer System

To allow any connections to the storm sewer system, provisions for the connections shall be shown in the drainage calculations for the system. Specific language shall be provided in the protective covenants, on the recorded plat, or with the parcel deed of record, noting the ability or inability of the system to accommodate any permitted connections, for example, sump pumps and footing drains.

1. **Sump pumps** installed to receive and discharge groundwater or other stormwater shall outlet directly on to a grass surface or be connected to the storm sewer or connected to a sub-surface drain provided by the developer. Sump pumps shall not be connected to street underdrains or outlet directly onto a surface that is closer than 25 feet to the right-of-way of any street. Sump pumps installed to receive and discharge floor drain flow or other sanitary sewage shall be connected to the sanitary sewers. A stormwater sump pump shall only be used for the discharge of stormwater.
2. **Footing drains and perimeter drains** shall be connected to Manholes or Curb inlets, where possible, or to designated storm sewers, discharged into designated storm drainage channels, or connected to a sub-surface drain provided by the developer.
3. All **roof downspouts**, roof drains, or roof drainage piping of residential developments shall discharge onto a grass surface that is no closer than 25 feet to the right-of-way of any street and shall not be directly connected to the storm drainage system. Variation from this requirement may be requested and granted by the Hendricks County Drainage Board and/or Hendricks County

Surveyor in special circumstances. No downspouts or roof drains shall be connected to the sanitary sewers.

4. **Garage and Basement floor drains** shall not be connected to the storm sewers. These drains may be routed to a properly designed wet well.
5. **Swimming Pool drains** shall not be connected to the storm sewers unless the water is dechlorinated, as defined in Appendix A, prior to being connected to the storm sewer.

In addition, none of the above-mentioned drains shall be connected to any road sub-drain/street underdrains, unless requested as a variance and specifically authorized by the Hendricks County Drainage Board and/or Hendricks County Surveyor and/or Hendricks County Engineer. Sub-drains shall be installed on all new developments by the developer and maintained by the owner or HOA.

M. Drainage System Overflow Design

Overflow path/ponding areas throughout the development resulting from a 100-year storm event, calculated based on all contributing drainage areas, on-site and off-site, in their proposed or reasonably anticipated land use and with storm pipe system assumed completely plugged, shall be determined. The centerline of this 100-year overflow path shall be clearly shown as a distinctive line symbol on the plans, and a minimum width of 30 feet flow width along the centerline of the flow path (15 feet from centerline on each side) designated as permanent drainage easements. A continuous flood route from the sag inlets to the final outfall shall be shown and the minimum 30-feet along the centerline contained within an easement or road right-of-way regardless of the 100-year storm event ponding elevation. This overflow path/easement area shall be shown on the plans as hatched area or another distinctive symbol. No fences or landscaping can be constructed within the easement areas. These areas are easements that are to be maintained by the property owners or be designated as common areas to be maintained by the homeowners association. The minimum adjacent grade of the portion of any residential, commercial, or industrial building (the ground elevation next to the building after construction is completed that sits adjacent to the emergency flood route or may be subject to flooding by the emergency flood route) shall be a minimum of 1 foot above the estimated 100-year elevation of the emergency flood route assuming that all stormwater pipes are fully clogged.

The required minimum adjacent grade of buildings adjacent to an overflow path is provided in **Table 4-5**.

TABLE 4-5

Minimum Building Adjacent Grade with Respect to Overflow Path Invert Elevations		
Drainage Area (Acres)	Minimum Building Adjacent Grade Above Overflow Path Invert (Feet)¹	Minimum Building Adjacent Grade Above Overflow Path Invert, if Overflow Path is in the Street (Feet)¹
Up to 5	2.50	1.50
6-10	3.00	1.50
11-15	3.25	1.75
16-20	3.50	1.75
21-30	4.00	2.00
30-50	4.25	2.00

Notes: ¹ The overflow path Invert refers to the elevation of the flow line of the emergency flow route (typically in the form of a channel, swale, or gutter) nearest to the upstream end of a building

As an alternative to using default values in Table 4-5, the overflow path/ponding may be modeled as successive series of natural ponds and open channel segments. Ponds should be modeled similar to that discussed for modeling depressional areas in Chapter 6. Channels should be modeled according to modeling techniques discussed in Chapter 5. The calculations for determining the 100-year overflow path/ponding elevations may be based on hand calculation methods utilizing normal depth calculations and storage routing techniques or performed by computer models. Examples of computer models that either individually or in combination with other models can handle the required computations include TR-20, HEC-HMS, and HEC-1, combined with HEC-RAS. Other models may be acceptable and should be accepted by the Hendricks County Drainage Board and/or Hendricks County Surveyor prior to their utilization.

Simply using the values in Table 4-5 is preferred over the much more complicated detailed modeling of the overflow/ponding areas. However, regardless of the methodology used, the Hendricks County Drainage Board and/or Hendricks County Surveyor reserves the right to require independent calculations to verify that the proposed building minimum adjacent grade facing the flood route or the portion of building having a potential to be subject to flooding by the flood route provide adequate freeboard above the anticipated overflow path/ponding elevations.

The LAG requirements for buildings adjacent to other flooding sources are discussed in Chapter 10 of this Manual. In case there are more than one flooding sources applicable to a building site, the highest calculated LAG for the building shall govern the placement of the building on that site.

In the case of existing upstream detention, an allowance equivalent to the reduction in flow rate provided may be made for upstream detention only when: (1) such detention and release rate have previously been accepted by the Hendricks County Drainage Board and/or Hendricks County Surveyor or other official charged with the approval authority at the time of the acceptance, and (2) evidence of its construction and maintenance can be shown.

FIGURE 4-1
Street and Gutter Capacities (continuous grade)

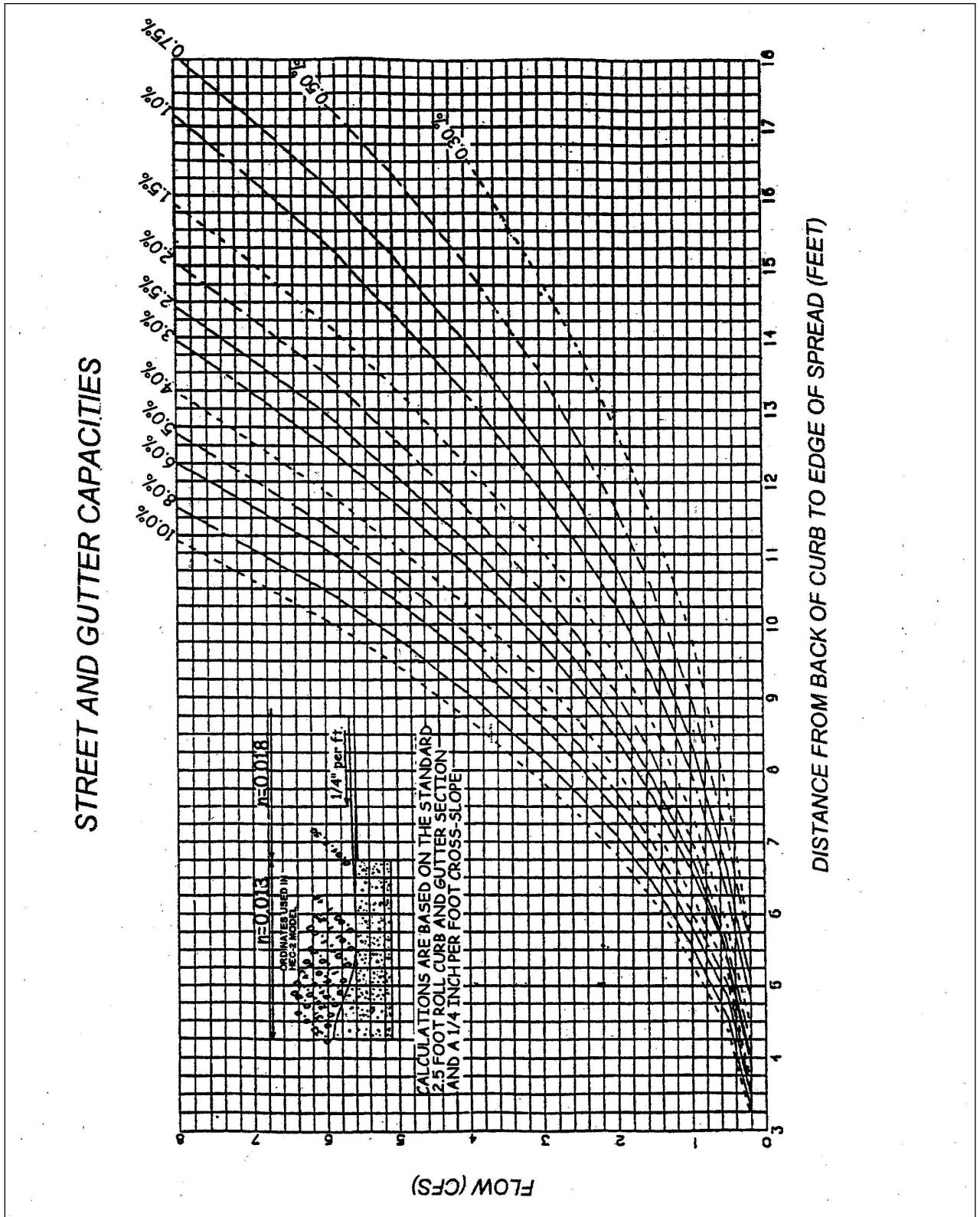


FIGURE 4-2
Bedding and Backfill Standards for Storm Sewers

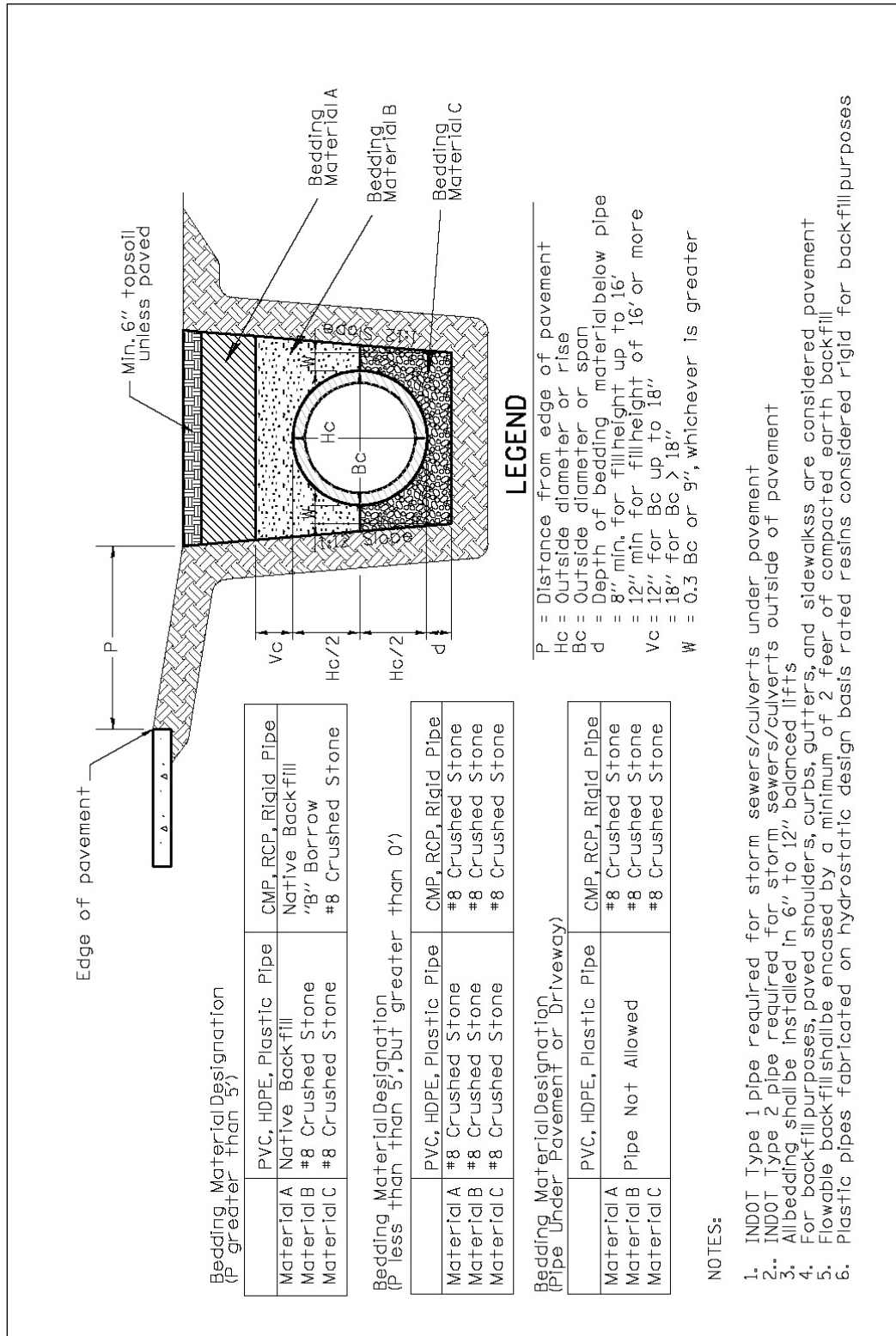


FIGURE 4-3
Bedding and Backfill Standards for Storm Sewers
(If a wheel trencher tiling machine or rounded bucket is used)

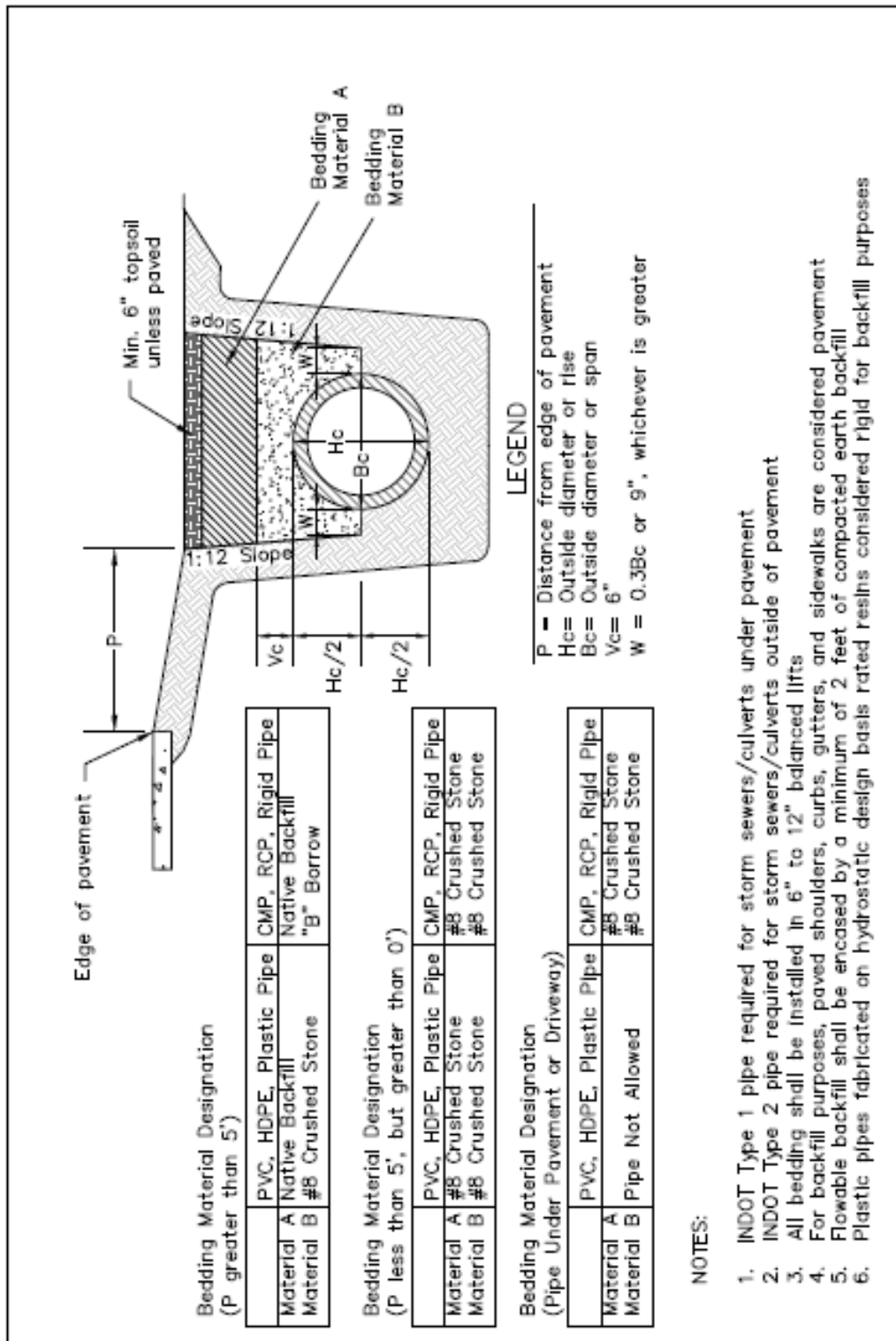
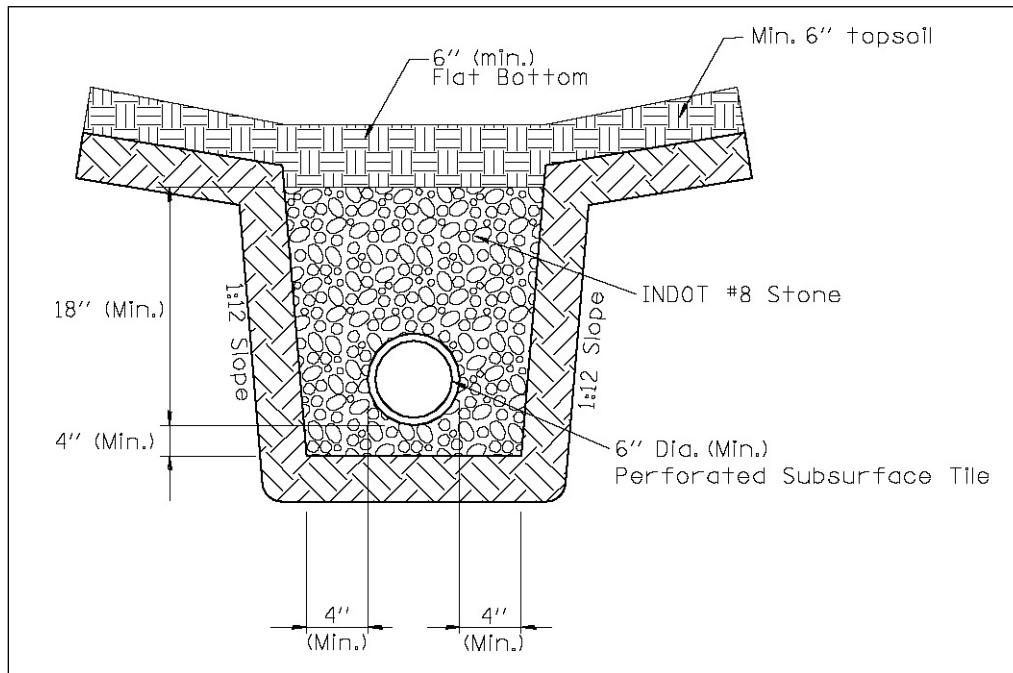


FIGURE 4-4
Bedding and Backfill Standards for Sub-drains under Swales





Chapter Five

OPEN CHANNEL DESIGN STANDARDS AND SPECIFICATIONS

All channels, whether private or public, and whether constructed on private or public land, shall conform to the design standards and other design requirements contained herein. Unless specifically referenced in a particular provision, the standards contained in this Chapter refer to open channels and not swales.

A. Design Storm Frequencies

1. All channels and swales shall accommodate, as a minimum, peak runoff from a 10-year return frequency storm calculated based on methodology described in Chapter 2. For Rational Method analysis, the storm duration shall be equal to the time of concentration for the drainage area. In computer-based analysis, the duration is as noted in the applicable methodology associated with the computer program.
2. Channels with a carrying capacity of more than 30 cfs at bank-full stage shall be capable of accommodating peak runoff for a 50-year return frequency storm within the drainage easement.
3. Channel facilities functioning as a major drainage system, as defined in **Appendix A**, must also meet IDNR design standards in addition to the Hendricks County standards. In case of discrepancy, the most restrictive requirements shall apply.
4. The 10-year storm design flow for residential rear and side lot swales shall not exceed 4 cfs. Unless designed as a Post-construction stormwater quality BMP, the maximum length of rear and side lot swales before reaching any inlet shall not exceed 400 feet and shall not convey flow from more than 3 lots.
5. Regardless of minimum design frequencies stated above, the performance of all parts of drainage system shall be checked for the 100-year flow conditions to ensure that all buildings are properly located outside the 100-year flood boundary and that flow paths are confined to designated areas with sufficient easement.
6. A minimum of 25 feet from top of the bank on each side of a new channel shall be designated on the recorded plat as a Regulated Drainage Easement.

No landscaping is allowed within any regulated drainage easement, except for a minimum 25-foot width of filter strip that shall be installed along the top of bank.

B. Manning's Equation

The waterway area for channels shall be determined using Manning's Equation, where:

$$A = Q/V$$

A = Waterway area of channel in square feet

Q = Discharge in cubic feet per second (cfs)

V = Steady-State channel velocity, as defined by Manning's Equation (See Chapter 4)

C. Backwater Method for Drainage System Analysis

The determination of 100-year water surface elevation along channels and swales shall be based on accepted methodology and computer programs designed for this purpose. Computer programs HEC-RAS, HEC-2, and ICPR are preferred programs for conducting such backwater analysis. The use of other computer models must be accepted in advance by the Hendricks County Drainage Board and/or Hendricks County Surveyor.

D. Channel Cross-Section and Grade

1. The required channel cross-section and grade are determined by the design capacity, the material in which the channel is to be constructed, and the requirements for maintenance. A minimum depth may be required to provide adequate outlets for subsurface drains, tributary ditches, or streams. The channel grade shall be such that the velocity in the channel is high enough to prevent siltation but low enough to prevent erosion. Velocities less than 2 feet per second for the design storm are not acceptable, as siltation will take place and ultimately reduce the channel cross-section area. The maximum permissible velocities in vegetated-lined channels are shown in **Table 5-1**. In addition to existing runoff, the channel design should incorporate increased runoff due to the proposed development.

2. Where depth of design flow is slightly below critical depth, channels shall have freeboard adequate to cope with the effect of hydraulic jumps.
3. Along the streets and roads, the bottom of the ditch should be low enough to install adequately sized driveway culverts without creating "speed bumps". The driveway culvert inverts shall be designed to adequately consider upstream and downstream culvert elevations. Use of open channels and swales within the road right of way is only allowed in special circumstances when no other viable option exists. The applicant must consult with the Hendricks County Drainage Board and/or Hendricks County Surveyor prior to design.
4. Flow of a channel into a closed system is prohibited, unless runoff rate and head loss computations demonstrate the closed conduit to be capable of carrying the 100-year channel flow for developed conditions, either entirely or in combination with a defined overflow channel, with no reduction of velocity.

TABLE 5-1

Maximum Permissible Velocities in Vegetal-Lined Channels ⁽¹⁾			
<i>Cover</i>	<i>Channel Slope Range (Percent) ⁽³⁾</i>	<i>Permissible Velocity ⁽²⁾</i>	
		<i>Erosion Resistant Soils (ft. per sec.) ⁽⁴⁾</i>	<i>Easily Eroded Soils (ft. per sec.) ⁽⁴⁾</i>
Bermuda Grass	0-5 5-10 Over 10	8 7 6	6 5 4
Bahia Buffalo Grass Kentucky Bluegrass Smooth Brome Blue Grama	0-5 5-10 Over 10	7 6 5	5 4 3
Grass Mixture Reed Canary Grass	(3) 0-5 5-10	5 4	4 3
Lespedeza Sericea Weeping Lovegrass Yellow Bluestem Redtop Alfalfa Red Fescue	(4) 0-5 5-10	3.4	2.5
Common Lespedeza (5) Sudangrass (5)	(6) 0-5	3.5	2.5

- (1)** From Soil Conservation Service, SCS-TP-61, "Handbook of Channel Design for Soil and Water Conservation".
- (2)** Use velocities exceeding 5 feet per second only where good channel ground covers and proper maintenance can be obtained.
- (3)** Do not use on slopes steeper than 10 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.
- (4)** Do not use on slopes steeper than 5 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.
- (5)** Annuals - use on mild slopes or as temporary protection until permanent covers are established.
- (6)** Use on slopes steeper than 5 percent is not recommended.

D. Side Slopes

1. Earthen channel and swale side slopes shall be no steeper than 3 horizontal to 1 vertical (3:1). Flatter slopes may be required to prevent erosion and for ease of maintenance.
2. Where channels will be lined with riprap, concrete, or other acceptable lining method, side slopes shall be no steeper than 2 horizontal to 1 vertical (2:1) with adequate provisions made for weep holes.
3. Side slopes steeper than 2 horizontal to 1 vertical (2:1) may be used for lined channels provided that the side lining is designed and constructed as a structural retaining wall with provisions for live and dead load surcharge.
4. When the design discharge produces a depth of greater than three (3) feet in the channel, appropriate safety precautions shall be added to the design based on reasonably anticipated safety needs at the site.

F. Channel Stability

1. Characteristics of a stable channel are:
 - a) It neither promotes sedimentation nor degrades the channel bottom and sides.
 - b) The channel banks do not erode to the extent that the channel cross-section is changed appreciably.
 - c) Excessive sediment bars do not develop.
 - d) Excessive erosion does not occur around culverts, bridges, outfalls or elsewhere.
 - e) Gullies do not form or enlarge due to the entry of uncontrolled flow to the channel.
2. Channel stability shall be determined for an aged condition and the velocity shall be based on the design flow or the bankfull flow, whichever is greater, using an "n" value for various channel linings as shown in **Tables 4-1 and 5-1**. In no case is it necessary to check channel stability for discharges greater than that from a 100-year frequency storm.

3. Channel stability shall be checked for conditions representing the period immediately after construction. For this stability analysis, the velocity shall be calculated for the expected flow from a 10-year frequency storm on the watershed, or the bankfull flow, whichever is smaller, and the "n" value for the newly constructed channels in fine-grained soils and sands may be determined in accordance with the "National Engineering Handbook 5, Supplement B, Soil Conservation Service" and shall not exceed 0.025. This reference may be obtained by contacting the National Technical Information Service in Springfield. The allowable velocity in the newly constructed channel may be increased by a maximum of 20 percent to reflect the effects of vegetation to be established under the following conditions:
 - a) The soil and site in which the channel is to be constructed are suitable for rapid establishment and support of erosion controlling vegetation.
 - b) Species of erosion controlling vegetation adapted to the area, and proven methods of establishment are shown.
 - c) The channel design includes detailed plans for establishment of vegetation on the channel side slopes.

G. Drainage of Swales

All swales shall meet the following requirements and the specifications of the Hendricks County Drainage Board and/or Hendricks County Surveyor or designee:

1. Minimum swale flow line slopes are 0.5%. Swales with longitudinal slopes that are flatter than 0.5% shall consist of 6 inch thick rebar-reinforced concrete. The front and back slopes of swales shall not be steeper than a 4 (horizontal) to 1 (vertical) slope.
2. Maximum swale flow line slopes are 7%.
3. Minimum swale width shall be 6 feet.
4. All flow shall be confined to the specific easements associated with each rear and side lot swale that are part of the minor drainage system.
5. Unless designed to act as a stormwater quality BMP, vegetated swales with a slope of less than 1% shall have 6-inch sub-surface drain with a minimum cover of 2 feet to dry the swales. Typical detail of a swale with sub-surface drain is shown on Figure 4-3. Tile lines may be outletted through a drop structure at

the ends of the swale or through a standard tile outlet. Before reaching the outlet, the perforated drain shall be connected to 10 feet of SDR # 40. Also, cleanout risers are to be installed at the high point as well as end of run.

6. A minimum of 30 feet along the swale (15 feet from each side of the centerline) must be designated on the recorded plat as Drainage Easement.
7. Further guidance regarding this subject may be found in the latest edition of the Indiana Drainage Handbook.

H. Appurtenant Structures

The design of channels will include provisions for operation and maintenance and the proper functioning of all channels, laterals, travelways, and structures associated with the project. Recessed inlets and structures needed for entry of surface and subsurface flow into channels without significant erosion or degradation shall be included in the design of channel improvements. The design will also provide for necessary floodgates, water level control devices, and any other appurtenance structure affecting the functioning of the channels and the attainment of the purpose for which they are built.

The effects of channel improvements on existing culverts, bridges, buried cables, pipelines, and inlet structures for surface and subsurface drainage on the channel being improved and laterals thereto shall be evaluated to determine the need for modification or replacement. Culverts and bridges which are modified or added as part of channel improvement projects shall meet reasonable standards for the type of structure, and shall have a minimum capacity equal to the design discharge or governmental agency design requirements, whichever is greater.

I. Disposal of Spoil

Spoil material resulting from clearing, grubbing, and channel excavation shall be disposed of in a manner that will:

1. Minimize overbank wash.
2. Provide for the free flow of water between the channel and floodplain boundary unless the valley routing and water surface profiles are based on continuous dikes being installed.
3. Not hinder the development of travelways for maintenance.
4. Leave the right-of-way in the best condition feasible, consistent with the project purposes, for productive use by the owner.

J. Materials

Materials acceptable for use as channel lining are:

1. Grass
2. Revetment Riprap
3. Concrete
4. Hand Laid Riprap
5. Precast Cement Concrete Riprap
6. Gabions
7. Straw or Coconut Mattings (only until grass is established)

Other lining materials must be accepted in writing by the Hendricks County Drainage Board and/or Hendricks County Surveyor. Materials shall comply with the latest edition of the INDOT "Standard Specifications".

K. Drainage System Overflow Design

See Chapter 4, Section M.



Chapter Six

STORMWATER DETENTION DESIGN STANDARDS FOR PEAK FLOW CONTROL

Basins shall be constructed to retain and/or temporarily detain the stormwater runoff that exceeds the maximum peak release rate authorized by the Ordinance and these technical standards. The required volume of storage provided in these basins, together with such storage as may be authorized in other on-site facilities, shall be sufficient to control excess runoff from the 10-year or 100-year storm as explained below in Section “B.”. Also, basins shall be constructed to provide adequate capacity to allow for sediment accumulation resulting from development and to permit the pond to function for reasonable periods between cleanings.

In addition to the requirement for peak flow control through retention and/or detention, the Stormwater Management Ordinance and Technical Standards require the developer to address Channel Protection and Water Quality Control requirements discussed in Chapter 8. The proper way to accommodate the water quality, channel protection, and peak flow rate control of a site is to first consider addressing the water quality and channel protection volume requirements through conventional or LID approaches (as described in Chapter 8) and then determine the size and dimensions of the required retention or detention storage for peak flow rate control.

Chapter 8 provides several BMPs and options to address the channel protection volume and water quality requirements. However, in many cases, providing some level of extended detention may become necessary to meet those requirements. While such extended detention is best provided in a separate facility, many developers choose to combine the needed extended detention feature with the detention pond needed for peak runoff rate control of the site into one facility.

A combined facility must accommodate the channel protection volume, water quality volume, and design storm detention to meet allowable release rate requirements while also meeting water quality detention time requirements. These requirements can be challenging to meet, especially with additional considerations needed for bypassing runoff from off-site areas. The following are suggested calculation sequences for designing a detention pond for peak flow control only, and for combining extended detention with peak flow control. However, every site is different and depending on the site conditions and the layout of the pond, there may be other ways to design the pond such that all the pond’s objectives are met.

Peak Flow Control Only

1. Determine the main outlet's control elevation.
2. Route the on-site 10-year and 100-year inflow hydrographs through the pond (by temporarily ignoring off-site flows) and size the main outlet to limit peak outflows to the allowable release rates. If an orifice will need to be used to limit the outflow, use the actual orifice size needed to meet the release rate requirements even if it is smaller than the minimum allowable orifice size allowed under this Technical Standards. The resulting maximum water surface elevation is the top of peak flow control storage for on-site flows. If no off-site flows are routed through the detention facility, then this will be the pond's 100-year elevation and the emergency spillway invert elevation is also set at this elevation.
3. Off-site flows that are bypassed (no detention), should be routed through a separate outlet (such as a drop inlet structure) with its control elevation set at the on-site 100-year pond elevation determined in Step 2. The 100-year pond elevation is determined by routing the on-site and off-site 100-year inflow hydrographs through the pond. Ideally, a separate emergency spillway should be provided with an invert elevation set at the combined (on-site and off-site) 100-year ponding elevation. A less desirable option would be to route the off-site flows through the emergency spillway with the invert elevation set at the on-site 100-year ponding elevation as determined in Step 2. However, since this would result in water flowing over the emergency spillway more frequently, this option may require additional erosion control measures based on the estimated frequency of use. Additional discussion on managing off-site runoff is contained in Section B.3 of this chapter.
4. If the calculated orifice size of the main peak flow rate control storage outlet is less than the minimum orifice size allowed in this Technical Standards, designate the minimum orifice size on the construction plans, but do not go back and recalculate/redesign the storage space.

Combined Peak Flow Control and Extended Detention

1. Calculate the extended detention storage volume as needed to address the requirements noted in Chapter 8. Also, note that there may be no need to provide extended detention, depending on the approach used to address water quality and channel protection volume requirements.
2. Determine the outlet control elevation. This will be the bottom of the extended detention storage volume, and the permanent pool elevation if a wet-bottom pond is used.

3. Design the pond to provide the extended detention storage volume determined in Step 1, and assuming no outflow through the pond outlet. The top of this storage volume will be the invert elevation of the main outlet.
4. Route the on-site 10-year and 100-year inflow hydrographs through the pond and size main outlet to limit peak outflows to the allowable release rates. If an orifice will need to be used to limit the outflow, use the actual orifice size needed to meet the release rate requirements even if it is smaller than the minimum allowable orifice size allowed under this Technical Standards. The resulting maximum water surface elevation is the top of peak flow control storage for on-site flows. If no off-site flows are routed through the detention facility, then this will be the pond's 100-year elevation and the emergency spillway invert elevation is also set at this elevation.
5. Off-site flows that are bypassed (no detention), should be routed through a separate outlet (such as a drop inlet structure) with its control elevation set at the on-site 100-year pond elevation determined in Step 2. The 100-year pond elevation is determined by routing the on-site and off-site 100-year inflow hydrographs through the pond. Ideally, a separate emergency spillway should be provided with an invert elevation set at the combined (on-site and off-site) 100-year ponding elevation. A less desirable option would be to route the off-site flows through the emergency spillway with the invert elevation set at the on-site 100-year ponding elevation as determined in Step 2. However, since this would result in water flowing over the emergency spillway more frequently, this option may require additional erosion control measures based on the estimated frequency of use. Additional discussion on managing off-site runoff is contained in Section B.3 of this chapter.
6. Determine the size and design the retention/extended detention storage drain in a manner to meet the extended detention minimum and maximum emptying time requirements discussed in Chapter 8, using both on-site and, if applicable, off-site runoff. Due to typically required clog-free design and maintenance of the extended detention storage drain structures, a smaller orifice than the normal minimum orifice size requirement for the main outlet may be allowed.
7. To make sure that the addition of the release through the drain will not cause the on-site only allowable release rate to be exceeded, reroute the on-site 10-year and 100-year inflow hydrographs through the pond, this time allowing water to also leave through the extended detention storage drain as the pond fills up. If the total peak outflow discharge exceeds the on-site only allowable release rate, the size of the main outlet orifice may need to be reduced or the storage volume increased.
8. If the calculated orifice size of the main peak flow rate control storage outlet is less than the minimum orifice size allowed in these Technical Standards, designate the minimum orifice size on the construction plans, but do not go back and recalculate/redesign the storage spaces.

Note that in some instances such as relatively small development sites (say, less than 5 acres) or sites with highly restrictive site-specific maximum allowable release rates, when the required outlet orifice size and/or the required size of the extended detention drain will be small, the calculated drain time may extend beyond the maximum required 48-hour emptying time. Often times, the situation can be addressed through enlarging the pond volume or reconfiguring the pond's shape. When the situation cannot be resolved in a reasonable manner despite those attempts, the Hendricks County Drainage Board and/or Hendricks County Surveyor or designee may, on a case by case basis, allow deviation from the required orifice size, maximum allowable release, or emptying time after considering reasonable options and examining the potential impacts on downstream or upstream areas.

The following shall govern the design of any improvement with respect to the retention/detention of stormwater runoff for peak flow control.

A. Acceptable Detention Facilities

The increased stormwater runoff resulting from a proposed development should be retained (if possible) and detained on-site (if retention is not feasible due to limited infiltration capacity) by the provisions of appropriate above- or below-ground wet bottom or dry bottom detention facilities, parking lots, or other acceptable techniques. Measures that retard the rate of overland flow and the velocity in runoff channels shall also be used to partially control runoff rates.

B. Allowable Release Rates

1. General Release Rates

Control devices shall limit the discharge to a rate such that the post-developed release rate from the site is no greater than 0.1 cfs per acre of development for 0-10 year return interval storms and 0.3 cfs per acre of developed area for 11 - 100 year return interval storms. The above fixed general release rates may be set at a lower value by the Hendricks County Drainage Board and/or Hendricks County Surveyor for geographical areas determined as Impact Drainage Area. The applicant shall confirm the applicable release rates with the Hendricks County Drainage Board and/or Hendricks County Surveyor or designee prior to initiating the design calculations to determine whether a basin-specific rate has been established for the watershed of their interest due to a Designated or an Impact Drainage Area designation.

For sites where the pre-developed area has more than one (1) outlet, the release rate should be computed based on pre-developed discharge to each outlet point. The computed release rate for each

outlet point shall not be exceeded at the respective outlet point even if the post-developed conditions would involve a different arrangement of outlet points.

2. Site-Specific Release Rates for Sites with Depressional Storage

For sites where depressional storage exists, the general release rates provided above may have to be further reduced. If depressional storage exists at the site, site-specific release rates must be calculated according to methodology described in Chapter 2, accounting for the depressional storage by modeling it as a pond whose outlet is a weir at an elevation that stormwater can currently overflow the depressional storage area. Post developed release rate for sites with depressional storage shall be the 2-year pre-developed peak runoff rate for the post-developed 10-year storm and 10-year pre-developed peak runoff rate for the post-developed 100-year storm. In no case shall the calculated site-specific release rates be larger than general release rates provided above.

Note that by definition, the depressional storage does not have a direct gravity outlet but if in agricultural production, it is more than likely drained by a tile and should be modeled as “empty” at the beginning of a storm. The function of any existing depressional storage should be modeled using an event hydrograph model to determine the volume of storage that exists and its effect on the existing site release rate. To prepare such a model, certain information must be obtained, including delineating the tributary drainage area, the stage-storage relationship and discharge-rating curve, and identifying the capacity and elevation of the outlet(s).

The tributary area should be delineated on the best available topographic data. After determining the tributary area, a hydrologic analysis of the watershed should be performed, including, but not limited to: a calculation of the appropriate composite runoff curve number and time of concentration. Stage-storage data for the depressional area should be obtained from the site topography. The outlet should be clearly marked and any calculations performed to create a stage-discharge rating curve must be included with the stormwater submittal.

Also note that for determining the post-developed peak runoff rates, the depressional storage must be assumed to be filled unless the Hendricks County Drainage Board and/or Hendricks County Surveyor can be assured, through dedicated easement, that the noted storage will be preserved in perpetuity.

3. Management of Off-site Runoff

Runoff from all upstream tributary areas (off-site land areas) may be bypassed around the retention/detention facility without attenuation. Such runoff may also be routed through the detention/retention facility, provided that a separate outlet system or channel is incorporated for the safe passage of such flows, i.e., not through the primary outlet of a detention facility.

Note that the efficiency of the retention/detention facility in controlling the on-site runoff may be severely affected if the off-site area is considerably larger than the on-site area. As a general guidance, on-line detention may not be effective in controlling on-site runoff where the ratio of off-site area to on-site area is larger than 5:1. Additional detention (above and beyond that required for on-site area) may be required by the Hendricks County Drainage Board and/or Hendricks County Surveyor when the ratio of off-site area to on-site area is larger than 5:1.

4. Downstream Restrictions

In the event the downstream receiving channel or storm sewer system is inadequate to accommodate the post-developed release rate provided above, then the allowable release rate shall be reduced to that rate permitted by the capacity of the receiving downstream channel or storm sewer system. Additional detention, as determined by the Hendricks County Drainage Board and/or Hendricks County Surveyor, shall be required to store that portion of the runoff exceeding the capacity of the receiving sewers or waterways. When such downstream restrictions are suspected, the Hendricks County Drainage Board and/or Hendricks County Surveyor may require additional analysis to determine the receiving system's limiting downstream capacity.

If the proposed development makes up only a portion of the undeveloped watershed upstream of the limiting restriction, the allowable release rate for the development shall be in direct proportion to the ratio of its drainage area to the drainage area of the entire watershed upstream of the restriction.

As an alternative to reduction of release rates, the Hendricks County Drainage Board and/or Hendricks County Surveyor may require the applicant to pursue alleviating downstream restrictions. The applicant would be responsible for obtaining all permits and consents required and for incurring all expenses involved in such undertaking.

5. Documentation of Results

The results of the allowable release rate determinations (if retaining the entire required peak flow rate volume is not feasible) as well as

the modeling simulation results must be summarized in a table that shall be included in the Stormwater Drainage Technical Report and on the Drainage Plan. The table must include, for each eventual site outlet, the pre-developed acreage tributary to each eventual site outlet, the unit discharge allowable release rate used, the resulting allowable release rate in cfs for the post-developed 10-year and 100-year events, pre-developed 2-year flow rates in cfs as well as pre- and post-developed flow rates for 2-, 10-, and 100-year events. The worksheet provided as Table 6-1 should be filled for each final site outlet.

TABLE 6-1

SITE OUTLET #	ITEM	PRE-DEVELOPMENT					POST-DEVELOPMENT				
		D.A. (ac)	Depress. Storage? (yes/no)	2- Yr.	10- Yr.	100- Yr.	D.A. (ac)	Depress. Storage? (yes/no)	2- Yr.	10- Yr.	100- Yr.
1	Default Unit Discharge Allowable Release Rate (cfs/acre)									0.1	0.3
	Basin-Specific Unit Discharge Allowable Release Rate, if any (cfs/acre)										
	Unit Discharge Allowable Release Rate Based on D/S Restrictions, if any (cfs/acre)										
	Adopted Unit Discharge Allowable Release Rate (cfs/acre)										
	Contributing Area of Development Site (ac) and Allowable Release Rate (cfs)										
	Total Contributing DA (ac) and Modeling Results (cfs)							no			

C. General Detention Basin Design Requirements

1. The retention/detention facility shall be designed in such a manner that a minimum of 90% of the maximum volume of water stored and subsequently released at the design release rate (if not retaining the entire peak flow rate volume) shall not result in a storage duration in excess of 48 hours from the start of the storm unless additional storms occur within the period. In other words, the design shall ensure that a minimum 90% of the original retention/detention capacity is restored within 48 hours from the start of the design 100-

year storm. When conditions exist such that the detention basin emptying requirement and the allowable release rate from the project site cannot both be met, the applicant shall develop a detention basin design that is as close as possible to meeting both requirements, with the design fully supported in the stormwater drainage technical report. In most cases, when conditions exist as described above, priority should be given to matching the allowable release rate.

2. The 100-year elevation of stormwater retention/detention facilities shall be separated by not less than 25 feet from any building or structure to be occupied. The Lowest Adjacent Grade (including walkout basement floor elevation) for all residential, commercial, or industrial buildings shall be set a minimum of 2 feet above the 100-year pond elevation or 2 feet above the emergency overflow weir elevation, whichever is higher. In addition to the Lowest Adjacent Grade requirements, any basement floor must be at least a foot above the normal water level of any wet-bottom pond or the local groundwater table, whichever is higher, to avoid the overuse of sump pumps and frequent flooding of the basement.
3. No detention facility or other water storage area, permanent or temporary, shall be constructed under or within twenty (20) feet of any pole or high voltage electric line. Likewise, poles or high voltage electric lines shall not be placed within twenty (20) feet of any detention facility or other water storage area.
4. Detention facilities shall be separated from parking lots and roadways by an appropriately-selected and designed method of safety barrier, such as guard rails, bollards, or other physical barriers capable of deterring the passage of a vehicle into the pond.
5. Slopes no steeper than 3 horizontal to 1 vertical (3:1) for safety, erosion control, stability, and ease of maintenance shall be permitted.
6. Safety screens having a maximum opening of six (6) inches shall be provided for any pipe or opening end sections 12-inch in diameter or larger. Storm drain pipes outletting into the pond shall not be submerged.
7. Use of fences around all retention/detention ponds is strongly encouraged to assure safety.

Unless specifically required by the Hendricks County Drainage Board and/or Hendricks County Surveyor, the decision to use fencing around retention/detention ponds are left to the owner or the

developer. Recommendations contained within this document do not relieve the applicant and owner/developer from the responsibility of taking all necessary steps to ensure public safety with regards to such facilities.

8. Outlet control structures shall be designed to operate as simply as possible and shall require little or no maintenance and/or attention for proper operation. For maintenance purposes, the outlet from the pond (if any) shall be a minimum of 0.5 foot above the normal water level of the receiving water body. They shall limit discharges into existing or planned downstream channels or conduits so as not to exceed the predetermined maximum authorized peak flow rate. For above ground facilities, if an outlet control structure includes an orifice to restrict the flow rate, such orifice shall be no less than 4 inches in diameter, even if the 4-inch diameter orifice results in a discharge that exceeds the predetermined maximum authorized peak flow release rates. However, note that the sizing of the pond must still be based on the more restrictive maximum allowable release rate.
9. Emergency overflow facilities such as a weir or spillway shall be provided for the release of exceptional storm runoff or in emergency conditions should the normal discharge devices become totally or partially inoperative. The overflow facility shall be of such design that its operation is automatic and does not require manual attention.

Emergency overflow facilities shall be designed to convey, without overtopping the detention facility banks, one and one-quarter (1.25) times the peak inflow discharge resulting from the 100-year design storm event runoff from the entire contributing watershed draining to the detention/retention facility, assuming post-development condition on-site and existing condition off-site. The length of the weir is to be determined using the weir equation, with the overflow weir control elevation at the Pond's 100-year elevation (pond is assumed full to the overflow weir control elevation), discharge equal to 1.25 times the peak 100-year inflow, and the maximum head being the difference between the weir control elevation and the top of the bank.

The emergency overflow routing from the emergency overflow facility to an adequate receiving system must be positive (by gravity) and shown on the construction plans. It must be sized to accommodate the design flow of the pond's emergency overflow weir. Thirty (30) feet along the centerline of this emergency overflow route shall be designated as permanent drainage easement. This emergency overflow path/easement area shall be shown on the plans as hatched

area or another distinctive symbol. No fences or landscaping can be constructed within the easement areas. The Lowest Adjacent Grade of all residential, commercial, or industrial buildings along this emergency overflow route shall be set a minimum of 2 feet above the flood elevation along the route, calculated based on the pond's emergency overflow weir design discharge.

10. Grass or other suitable vegetative cover shall be provided along the banks of the retention/detention storage basin. Vegetative cover around detention facilities should be maintained as appropriate.
11. Debris and trash removal and other necessary maintenance shall be performed on a regular basis to assure continued operation in conformance to design.
12. No residential lots or any part thereof shall be used for any part of a detention basin assumed full to the 100-year water surface elevation or the emergency overflow weir elevation, whichever is higher. Detention basins, assumed full to the 100-year water surface elevation or the emergency overflow weir elevation, whichever is higher, shall be placed within a common area either platted or legally described and recorded as a perpetual stormwater easement. A minimum of twenty (20) feet horizontally from the top of bank of the facility, or the 100-year pool if no defined top of bank is present, shall be dedicated as permanent stormwater easement if the above-noted boundary of the common area does not extend that far.
13. Anti-Clog & Frost Protection Features: All detention outlet structures (if any) shall include anti-clog devices acceptable to the Hendricks County Drainage Board and/or Hendricks County Surveyor. The structure shall also include frost depth protection located a minimum of 42 inches below grade.

D. Additional Requirements for Wet-Bottom Facility Design

Where part of a detention facility will contain a permanent pool of water, all the items required for detention storage shall apply. Also, a controlled positive outlet will be required to maintain the design water level in the wet bottom facility and provide required detention storage above the design water level. However, the following additional conditions shall apply:

1. Facilities designed with permanent pools or containing permanent lakes shall have a water area of at least one-half (0.5) acre with a minimum depth of eight (8) feet over the majority of pond area. If fish are to be used to keep the pond clean, a minimum depth of

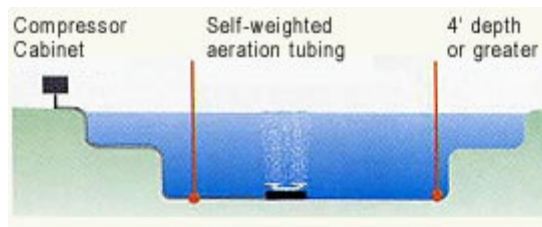
approximately ten (10) feet shall be maintained over at least 25 percent of the pond area. The remaining pond area shall have no extensive shallow areas, except as required to install the safety ramp, safety ledge, and BMPs as required below. Construction trash or debris shall not be placed within the permanent pool.

2. All wet detention/retention ponds must be constructed in as natural a shape (footprint) as possible, and have a vegetated safety ledge (approximately 6 inches below normal pool) and/or have native vegetation planted on the pond banks to create a riparian buffer (minimum 10 feet wide). Native vegetation can be installed as container grown plants or as seed at the time of construction. If native vegetation is planted on the pond banks, signage must be provided indicating that it is a natural "Do Not Mow" area. All pond slopes shall be 3:1 (horizontal to vertical) or flatter.
3. For wet-bottom facilities without a security fence, a maintenance ledge ten (10) feet in width is required and shall be installed approximately 12 inches above the permanent water level and a safety ledge ten (10) feet in width is required and shall be installed approximately 6 inches below the permanent water level. If a non-vegetated safety ledge is installed, the depth of the safety ledge shall be approximately 18 inches below normal pool. The slope between the two ledges shall be stable and protected from erosion with hard armoring or bioengineered techniques.

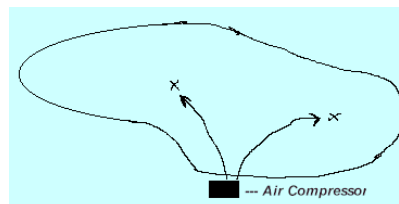
For wet-bottom facilities with a security fence, a maintenance ledge six (6) feet in width is required and shall be installed approximately 12 inches above the permanent water level and a safety ledge six (6) feet in width is required and shall be installed approximately 6 inches below the permanent water level. If a non-vegetated safety ledge is installed, the depth of the safety ledge shall be approximately 18 inches below normal pool. The slope between the two ledges shall be stable and protected from erosion with hard armoring or bioengineered techniques.

4. Prior to final acceptance of construction and release of bonds, danger signs warning of deep water, possible flood conditions during storm periods, or other dangers, shall be installed at an interval of 400 feet around the perimeter of wet-bottom facilities without a vegetated safety ledge, riparian buffer, or a security fence. Rescue equipment stations shall be posted at the same locations as the warning signs. Maintenance of the warning signs and rescue equipment stations shall be the responsibility of the owner or the homeowners association.

5. If a retaining wall is used below the normal pool of wet detention pond, the wall shall have either steps or a ladder incorporated into the construction at the center of the wall span.
6. A safety ramp exit from the lake shall be required in all cases and shall have a minimum width of twenty (20) feet and exit slope of 6 horizontal to 1 vertical (6:1). The safety ramp shall be constructed of suitable material to prevent structural instability due to vehicles or wave action. Adequate access to the safety ramp shall be provided by locating it adjacent to public right-of-way or by providing a clear route recorded within an access easement.
7. Periodic maintenance is required in lakes to control weed and larval growth. The facility shall also be designed to provide for the easy removal of sediment that will accumulate during periods of reservoir operation. A means of maintaining the designed water level of the lake during prolonged periods of dry weather may also be required.
8. For maintenance purposes, the outlet of storm sewers entering the pond shall be a minimum of 0.5 foot above the normal pool level.
9. Methods to prevent pond stagnation, including but not limited to surface or sub-surface aeration or destratification facilities that can, at the minimum, achieve one complete pond volume turnover per day should be considered. Figure below shows a typical diffuser aeration system that consists of a quiet air compressor at the shore, aeration tubing, and one or more sets of diffuser head(s).



Irregularly shaped ponds should be treated as two or three separate ponds. Likewise, larger ponds will also need multiple aeration units.



Design calculations to substantiate the effectiveness of proposed aeration facilities shall be submitted with final engineering plans. Design calculations should, at a minimum, indicate that the device and/or series of devices are providing a minimum volume turnover of once per 24 hours over the majority of the pond volume (i.e. pump radius of influence calculations, etc.). Agreements for the perpetual operation and maintenance of aeration facilities shall be prepared to the satisfaction of the Hendricks County Drainage Board and/or Hendricks County Surveyor.

If the detention pond is also proposed to be used as a post-construction stormwater BMP, alternative means of aeration (such as diffuser aeration systems) shall be used that would not result in re-suspension of sediment particles and would not prevent the efficient settling of sediment particles.

E. Additional Requirements for Dry-Bottom Facility Design

In addition to general design requirements, retention/detention facilities that will not contain a permanent pool of water shall comply with the following requirements:

1. Provisions shall be incorporated into facilities for complete interior drainage of dry bottom facilities, including the provisions of natural grades to outlet structures (if any), longitudinal and transverse grades to perimeter drainage facility. Unless designed as a retention facility, a 6-inch underdrain with a minimum of 1.5 feet of cover shall be provided within all dry-bottom ponds.
2. For residential developments, unless the facility is fully fenced in and gated, the maximum planned depth of stormwater stored shall not exceed four (4) feet.
3. In excavated retention/detention facilities, a minimum side slope of 3:1 shall be provided for stability. In the case of valley storage, natural slopes may be considered to be stable.

F. Detention Facilities in Floodplains

No detention facilities are allowed within FEMA regulatory floodplains.

G. Joint Development of Control Systems

Stormwater control systems may be planned and constructed jointly by two or more developers as long as compliance with this Ordinance is maintained.

H. Diffused Outlets

When the allowable runoff is released in an area that is susceptible to flooding or erosion, the developer may be required to construct appropriate storm drains through such area to avert increased flood hazard caused by the concentration of allowable runoff at one point instead of the natural overland distribution. The requirement of diffused outlet drains shall be at the discretion of the Hendricks County Drainage Board and/or Hendricks County Surveyor.

I. IDNR Requirements

Any construction in the floodway of a stream with a drainage area of one square mile or more must satisfy IDNR permit requirements.

J. Allowance for Sedimentation

Retention/detention basins shall be designed with an additional ten (10) percent of available capacity to allow for sediment accumulation resulting from development and to permit the pond to function for reasonable periods between cleanings. Basins should be designed to collect sediment and debris in specific locations, such as a forebay, so that removal costs are kept to a minimum. For wet-bottom ponds, the sediment allowance may be provided below the permanent pool elevation. No construction trash or debris shall be allowed to be placed within the permanent pool. If the pond is used as a sediment control measure during active construction, the performance sureties will not be released until sediment has been cleaned out of the pond and elevations and grades have been reestablished as noted in the accepted plans.

K. Maintenance

The routine maintenance of stormwater detention facilities (i.e. trash pickup, aeration, weed control, sediment removal, etc.) is the responsibility of the Homeowners' Association. In the event the Association fails to exercise its obligation, the Hendricks County Drainage Board may perform the required

maintenance and shall have the right to assess each lot in the subdivision a proportionate amount of the associated costs. If necessary, a Notice of Lien shall be filed against the affected lots. The lien shall be enforced in the same manner as a mortgage lien under Indiana law and, therefore, shall include reimbursement of attorney's fees, title expenses, interest, and costs of collection.



Chapter Seven

CONSTRUCTION SITES STORMWATER POLLUTION PREVENTION STANDARDS

The requirements contained in this chapter are intended to prevent stormwater pollution resulting from soil erosion and sedimentation or from mishandling of solid and hazardous waste. Practices and measures included herein should assure that no foreign substance, (e.g. sediment, construction debris, chemicals) be transported from a site and allowed to enter any drainageway, whether intentionally or accidentally, by machinery, wind, rain, runoff, or other means.

A. POLLUTANTS OF CONCERN DURING CONSTRUCTION

The major pollutant of concern during construction is sediment. Natural erosion processes are accelerated at a project site by the construction process for a number of reasons, including the loss of surface vegetation and compaction damage to the soil structure itself, resulting in reduced infiltration and increased surface runoff. Clearing and grading operations also expose subsoils which are often poorly suited to re-establish vegetation, leading to longer-term erosion problems.

Problems associated with construction site erosion include: transport of pollutants attached to transported sediment; increased turbidity (reduced light) in receiving waters; recreational use impairment. The deposited sediment may pose direct toxicity to wildlife, or smother existing spawning areas and habitat. This siltation also reduces the capacity of waterways, resulting in increased flood hazards to the public.

Other pollutants of concern during the construction process are hazardous wastes or hydrocarbons associated with the construction equipment or processes. Examples include concrete washout, paints, solvents, and hydrocarbons from refueling operations. Poor control and handling of toxic construction materials pose an acute (short-term) or chronic (long-term) risk of death to aquatic life, wildlife, and the general public.

B. EROSION AND SEDIMENT CONTROL REQUIREMENTS

General and Implementation Requirements - The following general and implementation requirements apply to all land-disturbing activities and shall be considered in the preparation of a SWPPP within the corporate boundaries of Hendricks County.

1. Certified professionals must be utilized for activities associated with the development and design of the SWPPP, stormwater measure implementation, and stormwater project management.
2. Minimize the potential for soil erosion by designing a development that fits the topography and soils of the site. Unless needed to meet requirements and goals of the development, steep slopes should be avoided, and natural contours should be followed.
3. All activities on a site should be conducted in a logical sequence and in accordance with the site's construction phasing plan so that the smallest practical area of land will be exposed for the shortest practical period of time during development.
4. The length and steepness of designed slopes should be minimized to reduce erosion potential. Drainage channels and swales must be designed and adequately protected so that their final gradients and resultant velocities will not cause erosion in the receiving channel or at the outlet. Methods for determining acceptable velocities are included in this Stormwater Technical Standards Manual as well as in the IDEM Storm Water Quality Manual.
5. Sediment-laden water which otherwise would flow from the project site shall be managed by appropriate erosion and sediment control measures to minimize sedimentation to receiving waters and adjacent properties as discussed in the IDEM Storm Water Quality Manual and other authoritative sources.
6. Public roadways and roadways not exclusive to construction traffic shall be kept cleared of accumulated sediment that is a result of runoff or tracking. The following minimum conditions are applicable:
 - a. Clearing of sediment must not include the utilization of mechanical methods that will result in mobilization of dust off the project site or flushing the area with water unless the flushed water is directed to an appropriate sediment control measure.
 - b. Cleared sediment must be redistributed or disposed of in a manner that is in accordance with all applicable statutes and regulations.
 - c. Sediment discharged or tracked onto roadways that are open to traffic must be removed as directed by a regulatory authority or at a minimum, removed by the end of the same day.
7. Phasing of construction activities must be used, when feasible, to minimize the footprint of disturbed unstable areas.
8. Collected runoff leaving a project site must be either discharged directly into a well-defined, stable receiving channel, or diffused and released to adjacent property without causing an erosion or pollutant problem to the adjacent property owner.

9. Natural features, including wetlands and sinkholes (karst features), shall be protected from pollutants associated with stormwater runoff, through appropriate stormwater management and/or treatment measures.
10. Soil compaction is to be minimized, especially in areas where permanent vegetation will be re-established and/or areas that are designated to infiltrate stormwater for the post-construction phase.
11. Topsoil must be preserved, unless infeasible.
12. Existing natural buffers that are adjacent to waters of the state must be preserved to promote infiltration and provide protection of the water resource, unless infeasible. Activities performed by a county drainage board under IC 36-9-27 are excluded.
 - a. Natural buffers must be preserved, including the entire buffer bordering and/or surrounding the water resource. Existing buffers:
 - i. 50 feet or more in width must be preserved to a minimum of 50 feet.
 - ii. less than 50 feet in width must be preserved in their entirety. May be enhanced with vegetation that is native and promotes ecological improvement and sustainability.
 - b. Runoff directed to the natural buffer must be:
 - i. treated with appropriate erosion and sediment control measures prior to discharging to the buffer.
 - ii. managed with appropriate runoff control measures to prevent erosion from occurring within the buffer area.
 - c. Further information regarding buffer requirements is contained in IDEM's "Implementation of Buffers" guidance document.
13. Minimize the generation of dust through dust suppression techniques to prevent deposition into waters of the state and areas located beyond the permitted boundaries of the site as discussed in the IDEM Storm Water Quality Manual and other authoritative sources.
14. A stable construction site access measure must be provided at all points of construction traffic ingress and egress to the project site. Where the selected measure is not effective, an alternative measure or additional controls must be utilized to minimize tracking. Alternative measures may include, but are not limited to, wheel wash systems and rumble strips.

15. During the period of construction activities, all stormwater management measures necessary to meet the requirements of this permit must be maintained. Alternative measures must be selected and implemented, as necessary.
16. Discharge water from dewatering of ground water from excavations, trenches, foundations, etc. must not be discharged when:
- a. Sediment-laden water is not first directed to an appropriate sediment control measure or a series of control measures, as per IDEM Storm Water Quality Manual and other authoritative sources, that minimizes the discharge of the sediment.
 - b. A visible sheen and/or pollutants are present at a level that requires additional treatment and/or an alternate permit.
17. Appropriate measures must be implemented to eliminate wastes or unused building materials including, but not limited to garbage, debris, cleaning wastes, wastewater, concrete washout, mortar/masonry products, soil stabilizers, lime stabilization materials, and other substances from being carried from a project site by runoff or wind. Wastes and unused building materials must be managed and disposed of in accordance with all applicable statutes and regulations.
18. Construction and domestic waste must be managed to prevent the discharge of pollutants and windblown debris. Surplus plastic or hardened concrete/cementitious materials are not required to be placed in trash receptacles and are considered clean fill that may be reused, disposed of on-site, or recycled in accordance with applicable state and federal regulations. Management of waste materials may include, but are not limited to:
- a. Waste containers (trash receptacles), when selected to manage waste, must be managed to reduce the discharge of pollutants and blowing of debris. Receptacles that are not appropriately managed will require alternatives that include but are not limited to:
 - i. A cover (e.g., lid, tarp, plastic sheeting, temporary roof) to minimize exposure of wastes to precipitation or
 - ii. A similarly effective method designed to minimize the discharge of pollutants.
 - b. Waste that is not disposed of in trash receptacles must be protected from exposure to the weather and/or removed at the end of the day from the site and disposed of properly.
19. Concrete and cementitious wash water areas, where cementitious fluids are permissible, must be identified for the site and the locations clearly posted. Wash water must be directed into leak-proof containers or leak-proof containment areas which are located and designed to divert runoff away from the measure and sized

to prevent the discharge and/or overflow of the cementitious wash water. If not evaporated, wash water must be removed (pumped) for appropriate off-site disposal.

20. Fertilizer applications associated with the stabilization plan for the project must meet the following requirements:

- a. Apply fertilizer at a rate and amount as determined by a soil analysis or in accordance with the Indiana Stormwater Quality Manual or similar guidance documents.
- b. Apply fertilizer at an appropriate time of year for the project location, taking into consideration proximity to a waterbody, and preferably timed to coincide with the period of maximum vegetative uptake and growth.
- c. Avoid applying fertilizer immediately prior to precipitation events that are anticipated to result in stormwater runoff from the application area.

21. Proper storage and handling of materials, such as fuels or hazardous wastes, and spill prevention and clean-up measures must be implemented to minimize the potential for pollutants to contaminate surface or ground water or degrade soil quality. To meet this requirement:

- a. A spill prevention and response plan, meeting the requirements in 327 IAC 2-6.1, must be completed.
- b. Proper project management and the utilization of appropriate measures including, but not limited to, eliminating a source or the exposure of materials must be completed.
- c. Manage the following activities:
- d. Fueling and maintenance of equipment.
- e. Washing of equipment and vehicles.
- f. Storage, handling, and disposal of construction materials, products, and wastes.
- g. Application of pesticides, herbicides, insecticides, and fertilizers
- h. Dispensing and utilization of diesel fuel, oil, hydraulic fluids, other petroleum products, and other chemicals.
- i. Handling and disposal of hazardous wastes, including, but not limited to paints, solvents, petroleum-based products, wood preservatives, additives, curing compounds, and acids.
- j. Washing of applicators and containers used for paint, grout, or other materials.

22. Personnel associated with the project must be informed of the terms and conditions of this permit and the requirements within the SWPPP. The permittee is required to document this process. Information must be provided through written notification, contracts, or other means (i.e., pre-construction meetings) that effectively communicates the provisions and requirements of the permit and SWPPP. Personnel may include, but are not limited to:

- a. General contractors, construction management firms, grading or excavating contractors, and trade industry representatives (i.e. concrete industry) associated with the overall project.
 - b. Contractors or individual lot operators that have primary oversight on individual building lots.
 - c. Those responsible for the implementation of the SWPPP, and the installation, repair, and maintenance of stormwater measures.
 - d. Those responsible for the application and storage of treatment chemicals.
 - e. Those responsible for administering the self-monitoring program (SMP).
23. A notice must be posted near the main entrance of the project site or at a publicly accessible location. For linear project sites, such as a pipeline or highway, the notice must be placed in a publicly accessible location near the project field office.
- a. The notice must be maintained in a legible condition and include:
 - b. A copy of the completed IDEM NOI or a document, such as the Permit Summary Report & Notice of Sufficiency letter produced by IDEM's online ePortal system, that at a minimum contains the name and address of the owner, name and location address of the construction project, and where would the runoff from project directed to (stream(s) receiving the discharge(s).
 - c. The NPDES permit number(s), upon receipt.
 - d. The location of the construction plan/SWPPP if the project site does not have an on-site location to store the plan.
24. The use of anionic polymers (cationic polymers are not authorized for use) on the project site are authorized for sediment control provided their use is in conformance with current State of Indiana standards and specifications and the use is identified in the stormwater pollution prevention plan (SWPPP). If use of a polymer is not in the SWPPP and is selected at a later date, notification to IDEM and the Hendricks County Surveyor is required. An email notification prior to the use of the polymer to the IDEM Stormwater Program is acceptable. For projects regulated by a MS4 notification must follow the local process for the use of polymers.
25. Restoration and/or clean-up may be required for those areas impacted by sediment or other pollutant discharges. These activities will be performed as directed by the inspecting authority and may require:
26. Development and submittal of a removal and restoration plan to ensure the methodology chosen will not result in further degradation of the resource.
27. Permission by a property owner when the restoration activity requires access to a property owned by another entity or individual.

28. Additional permits prior to initiation of the work.

Stabilization Requirements - The following stabilization requirements apply to all land-disturbing activities:

1. Un-vegetated areas that are left idle or scheduled to be left inactive must be temporarily or permanently stabilized with measures appropriate for the season to minimize erosion potential. To meet this requirement, the following apply:
 - a. Stabilization must be initiated by the end of the seventh day the area is left idle. The stabilization activity must be completed within fourteen (14) days after initiation. Initiation of stabilization includes, but is not limited to, the seeding and/or planting of the exposed area and applying mulch or other temporary surface stabilization methods where appropriate. Areas that are not accessible due to an unexpected and disruptive event that prevents construction activities are not considered idle.
 - b. Areas that have been compacted may be excluded from the stabilization requirement when the areas are intended to be impervious surfaces associated with the final land use, provided runoff from the area is directed to appropriate sediment control measures.
2. Final stabilization of a project site is achieved when:
 - a. All land-disturbing activities have been completed and a uniform (evenly distributed, without large bare areas) perennial vegetative cover with a density of seventy percent (70%) has been established on all unpaved disturbed areas, and areas not covered by permanent structures, or equivalent permanent stabilization measures have been employed. This requirement does not apply to:
 - i. Landscaping that is part of the final project plan is considered stable when the plan has been fully implemented and areas not being vegetated are stable with a non-erosive material and/or product.
 - ii. Projects or specific stormwater measures that utilize native vegetation and/or special vegetative plantings that are either required by a water quality permit/authorization or part of the design and functionality of a stormwater measure provided the activity does not pose a threat that will result in off-site sedimentation.
 - iii. Projects on land used for agricultural purposes when:
 - a) Stabilization is completed in accordance with the above Stabilization Requirements (in 1. a. and b.) as land-disturbance progresses. Land that is returned to agricultural production must be temporarily or permanently seeded upon completing land-disturbing activities. Stabilization

requirements may be waived by the inspecting authority if the project site does not pose a threat of discharging sediment.

- b) Disturbed areas, not previously used for agricultural production, such as filter strips, must be returned to their pre land disturbance use.
3. Specific projects, due to function and/or operation may necessitate that an area remain disturbed. Only the minimum operational area is allowed to remain disturbed. This option primarily applies to off-road recreational commercial operations but may apply to other land use types upon determination by the regulating entity.

Design Requirements - The following design requirements apply to all land-disturbing activities and shall be considered in the selection, design, and implementation of all stormwater quality and management measures contained in the SWPPP:

1. Sound engineering, agronomic, and scientific principles must be utilized for measures contained in the SWPPP.
2. Appropriate measures must be planned, designed, and installed as part of an erosion and sediment control system and in accordance with the site's construction phasing plan.
3. Stormwater runoff leaving the project site must be discharged in a manner that is consistent with this ordinance, state, or federal law.
4. Collected runoff leaving the project site must be directed to an established vegetated area, when feasible and applicable, to increase pollutant removal and maximize stormwater infiltration and then either discharged directly into a well-defined, stable receiving conveyance or diffused and released without causing erosion at the point of discharge.
5. Conveyance systems must be designed taking into consideration both peak flow and total volume and must be adequately protected so that their final gradients and resultant velocities are unlikely to cause erosion at the outlet or in the receiving channel, based on known conditions of the discharge at the time of design to accommodate post-construction conditions.
6. Sediment basins, where feasible, must withdraw water from the surface of the water column unless equivalent sediment reduction can be achieved by use of alternative measures. Alternative measures include but are not limited to increasing the basin length to width ratio to 4:1 or greater, implementation of porous baffles, use of flocculants/polymers, and/or phasing of project land disturbance that also incorporates a rapid stabilization program. During freezing conditions, the implementation of alternative withdrawal methods may be utilized.

Monitoring and Management Requirements - A trained individual, acceptable to the Hendricks County Drainage Board, shall monitor project construction and stormwater activities. These shall include:

1. A written evaluation of the entire project site, with the exception of those areas that are considered unsafe. The evaluation must be performed by a trained individual and completed:
 - a. Twenty-four (24) hours prior to a qualifying precipitation event or by the end of the next business day following each measurable storm event (excludes accumulated snow events); which is defined as a precipitation accumulation equal to, or greater than, one-half (0.50) inch of rainfall within a 24-hour period. If no rain event occurs within the work week a minimum of one inspection must occur. In the event of multiple qualifying events during the work week, no more than three (3) inspections would be required to meet the self-monitoring commitment.
 - b. At a minimum of one (1) time per month for specific areas within the project which are stabilized with permanent vegetative cover at seventy (70) percent density and/or erosion resistant armoring is installed. A reduction to once per month is also applicable for the entire project site for stabilized common areas, basins, conveyances, outfalls, and inactive building sites. Prior to reducing the monitoring to monthly, records must identify the area and the date the area became eligible for monthly monitoring. Weekly monitoring as identified in (a) above must resume if one or more of the following occurs:
 - i. The vegetative cover fails or there is evidence of erosion in the identified area.
 - ii. The Hendricks County Surveyor requires monitoring to resume.
2. A complete written evaluation report which must include:
 - a. Name of the individual performing the evaluation, including printed name, title, and signature (electronic signatures are acceptable).
 - b. Date of the evaluation.
 - c. Amount of precipitation, when the evaluation is conducted after a measurable storm event. Recorded rainfall may be documented utilizing an on-site rain gauge or storm event information from a weather station that is representative of the project location.
 - d. Observations of project performance in relation to:
 - i. Implementation of the stormwater pollution prevention plan.

- ii. Assessment of existing stormwater measures based on industry standards and maintenance standards as identified in Section 5 of the Stormwater Permit Application Form (found in Appendix B1 of this document) to ensure each measure is operational and functioning properly.
 - iii. Additional measures necessary in the event an existing measure fails or is not present in the landscape
 - iv. Impacts including, but not limited to, sediment discharges, erosion, discharges that results in bank erosion, and operational activities that have the potential to generate pollutants and unauthorized discharges.
- e. Documentation of an actual discharge that is visible during the assessment, the location of the discharge and a visual description of the discharge. The visual description includes, but is not limited to, color (turbidity reading is an option), odor, floatables, settled/suspended solids, foam, oil sheen, and any other visible sign that may be attributed to operations occurring on the project site.
- f. Detail of corrective action recommended and/or completed. Corrective action includes, but is not limited to:
 - i. Repairing, modifying, or replacing any stormwater management measure.
 - ii. Clean-up and proper disposal of spills, releases, or other deposits.
 - iii. Remedying a permit violation.
 - iv. Taking reasonable steps to remediate, minimize or prevent the discharge of pollutants associated with the construction activity until a permanent corrective solution is initiated.
 - v. Restoring an impacted area and/or removing accumulated sediment, provided appropriate permission and permits are obtained to conduct the activity.
- g. A timeline for which corrective action will occur to remediate the discharge of pollutants. The established corrective action, at a minimum, must be initiated:
 - i. On the day the deficiency was discovered or when it is not practical to initiate on the discovery date, no later than forty- eight (48) hours for the repair of a measure or installation of a temporary measure until a new and/or replacement measure is installed as specified in item ii) below.
 - ii. Within seven (7) days of discovery for the installation of a new (alternative) measure or replacement of an existing measure unless a shorter timeframe is required as part of a regulatory inspection. The inspecting authority may also allow additional time to take corrective action.
 - iii. If corrective action cannot be achieved within the timelines outlined in i) or ii) above, a reason for incompleteness must be provided and documented, including the anticipated completion date.

- h. Documentation of corrective action taken from the previous self-monitoring report.
- 3. Maintaining the SMP reports at the site or at an easily accessible location (refer to Project Documentation Requirements below).
- 4. Providing all reports for the project site to the Hendricks County Surveyor within forty-eight (48) hours of a request. Electronic copies are acceptable, provided they are in a format consistent with the paper record.

Project Documentation Requirements – The following project documentation shall be developed and maintained:

- 1. Maintain a project management log that contains:
 - a. Information related to all off-site borrow sites, disposal areas, and staging areas, including the location of each activity as it is identified and/or selected.
 - b. Information related to all project activities including, but not limited to:
 - i. SMP reports.
 - ii. Regulatory inspections.
 - iii. Responses to a compliance action or enforcement action.
 - iv. Records showing the dates of all SWPPP modifications. The records must include the name of the person authorizing each change and a summary of all changes.
- 2. Ensure the SWPPP and supporting documentation associated with the SMP and project management log are accessible at the project site office or in the possession of on-site individuals with responsibility for the overall project management or associated with the management and operations of construction activities. This information must be provided to *the* Hendricks County Surveyor within forty-eight (48) hours of a request.

C. COMMON CONTROL PRACTICES

All erosion control and stormwater pollution prevention measures required to comply with the Ordinance or these Technical Standards shall meet the design criteria, standards, and specifications similar to or the same as those outlined in the “Indiana Drainage Handbook” and “Indiana Storm Water Quality Manual” (ISWQM), or other comparable and reputable references. Table 7-1 lists some of the more common and effective practices for preventing stormwater pollution from construction sites. Details of each practice can be found in the Indiana Drainage Handbook, ISWQM, or in Appendix C.

These practices should be used to protect **every** potential pollution pathway to stormwater conveyances.

**Table 7-1
Common Stormwater Pollution Control Practices for Construction Sites**

Practice No.	BMP Description	Applicability	Fact Sheet
1	Site Assessment	All sites	ISWQM (Ch.2)
2	Development Of A Construction Sequence Schedule	All sites	ISWQM (Ch. 5)
3	Tree Preservation and Protection	Nearly all sites	ISWQM
4	Temporary Construction Ingress/Egress Pad	All sites	ISWQM
5	Wheel Wash	All sites	CN - 101
6	Silt Fence	Small drainage areas	ISWQM
7	Surface Roughening	Sites with slopes that are stabilized with vegetation	ISWQM
8	Temporary Seeding	Areas of bare soil where additional work is not scheduled to be performed for a minimum of 15 days	ISWQM
9	Mulching	Temporary surface stabilization	ISWQM
10	Erosion Control Blanket (Surface)	Temporary surface stabilization, anchor for mulch	ISWQM
11	Temporary Diversion	Up-slope and down-slope sides of construction site, above disturbed slopes within site	ISWQM
12	Rock Check Dam	2 acres maximum contributing drainage area	ISWQM
13	Temporary Slope Drain	Sites with cut or fill slopes	ISWQM
14	Geotextile Fabric Drop Inlet Protection	1 acre maximum contributing drainage area	ISWQM
15	Insert (Basket) Curb Inlet Protection	1 acre maximum contributing drainage area	ISWQM
16	Temporary Sediment Trap	5 acre maximum contributing drainage area	ISWQM
17	Temporary Dry Sediment Basin	30 acre maximum contributing drainage area	ISWQM
18	Dewatering Structures	Sites requiring dewatering	CN-102
19	Dust Control	All sites	ISWQM
20	Spill Prevention and Control	All sites	CN - 103
21	Solid Waste Management	All sites	CN - 104
22	Hazardous Waste Management	All sites	CN - 105

* See ISWQM Chapter 7 (2007 or latest version), unless otherwise noted.
(<http://www.in.gov/idem/stormwater/>)

D. INDIVIDUAL LOT OR PARCEL CONTROLS

Although individual lots within a larger development may not appear to contribute as much sediment as the overall development, the cumulative effect of lot development is of concern. The same is true for individual parcels of land of any size that are not associated with a larger development. From the time construction on an individual lot begins, until the individual lot is stabilized, the builder must take steps to:

- protect adjacent properties from sedimentation

- prevent mud/sediment from depositing on the street
- protect drainageways from erosion and sedimentation
- prevent sediment laden water from entering storm sewer inlets.

This can be accomplished using numerous erosion and sediment control measures. Individual lot drainage permit and detailed requirements, including a standard erosion control plan for individual lots, are provided in Appendix B. The standard plan includes perimeter silt fence, stabilized construction entrance, curb inlet protection, drop inlet protection, stockpile containment, stabilized drainage swales, downspout extensions, temporary seeding and mulching, and permanent vegetation. Every relevant measure should be installed at each individual lot site.

Construction sequence on individual lots and parcels should be as follows:

1. Clearly delineate areas of trees, shrubs, and vegetation that are to be undisturbed. To prevent root damage, the areas delineated for tree protection should be at least the same diameter as the crown.
2. Install perimeter silt fence at construction limits. Position the fence to intercept runoff prior to entering drainage swales.
3. Avoid disturbing drainage swales if vegetation is established. If drainage swales are bare, install erosion control blankets or sod to immediately stabilize.
4. Install drop inlet protection for all inlets on the property.
5. Install curb inlet protection, on both sides of the road, for all inlets along property frontage and the along the frontage of adjacent lots.
6. Install gravel construction entrance that extends from the street to the building pad.
7. Perform primary grading operations.
8. Contain erosion from any soil stockpiles created on-site with silt fence around the base.
9. Establish temporary seeding and straw mulch on disturbed areas.
10. Construct the home and install utilities.
11. Install downspout extenders once the roof and gutters have been constructed. Extenders should outlet to a stabilized area.
12. Re-seed any areas disturbed by construction and utilities installation with temporary seed mix within 3 days of completion of disturbance.
13. Grade the site to final elevations.
14. Install permanent seeding or sod.

The following criteria is used by the Hendricks County Surveyor, or a designee for approval of the individual plot plans:

1. 1' Contours and how they were derived.
2. All Easements shown and labeled correctly.
3. Sump pumps labeled near where it will be during construction. If no sump pump is being installed, then it will need to be annotated on the plan as such.
4. Sub-surface drains (SSD) labeled (Including the sump pump outlets).

5. Sump pump outlets (connection or day lighted to open ditch or surface outlet) shall be shown.
6. Perimeter drain for septic system, if required, shall be shown.
7. Outlet for all perimeter drains with proper outlet protection.
8. All invert elevations of pipe outlets shall be labeled.
9. Swales annotated with arrows showing the direction of surface flow.
10. First floor elevations (FFE or Slab Height) shall be 2 feet or greater above the emergency over-flow at the house.
11. First floor elevations (FFE or Slab Height) shall be no greater than 2 feet higher, or lower, than any adjoining house elevation in a platted subdivision unless the proposed house is located in a subdivision and has been approved to be greater than 2 feet higher than an adjoining lot at the approval process of said subdivision plat.

Note: Every site is unique and may require information and criteria specific to the site. The Hendricks County Surveyor has the authority to modify, add to or amend any of these requirements based on the individual site of the proposed plot plan.

All erosion and sediment control measures must be properly maintained throughout construction. Temporary and permanent seeding should be watered as needed until established. For further information on individual lot and parcel erosion and sediment control, please see the "Individual Lot Erosion and Sediment Control Plan and Certification" form in Appendix B as well as the latest information posted on IDEM's website.



Chapter Eight

POST-CONSTRUCTION STORMWATER QUALITY MANAGEMENT STANDARDS

A. INTRODUCTION

Requirements of the Ordinance and this Technical Standards Manual with regards to the channel protection and water quality protection can be satisfied through a variety of methods that can be broadly categorized under two general approaches:

1. Conventional Approach
2. Low Impact Development (LID) Approach

This Chapter establishes minimum standards for the selection and design of post-construction water quality and channel protection BMPs. The information provided in this Chapter establishes performance criteria for stormwater quality management and procedures to be followed when preparing a BMP plan for compliance. Post-construction BMPs must be sized to treat the channel protection volume (CPv), water quality volume (WQv), and for flow-through BMPs the water quality discharge rate (Qwq). For Conventional approach, the methodology for calculating the CPv, WQv, and Qwq values is provided in Chapter 9. For LID approach, alternative methods of calculating these values are provided in Section F of this Chapter. Note that the provision of this Chapter applies to all unincorporated areas within the jurisdiction of Hendricks County as well as areas within incorporated towns and cities that are located in the watershed of a Hendricks County regulated drain.

B. POST-CONSTRUCTION BMPs PERFORMANCE CRITERIA

Channel protection is typically achieved by matching the post-construction runoff volume and rate to the pre-conversion (prior to any historical land conversion by man) condition for all runoff events up to the bankfull flow. The bankfull flow in most Indiana streams correlates with the 1.5- to 2-year flood event flow. However, due to difficulties in determining the pre-conversion conditions, the net control of runoff resulting from a 1-year, 24-hour storm in proposed conditions (rather than the alternative method of determining increase in 2-year, 24-hour storm over pre-conversion conditions) is established as the Hendricks County standard for channel protection.

Hendricks County has also established a minimum standard that the measurement of the effectiveness of the control of post-construction stormwater runoff quality will be based on removal of floatables in stormwater runoff and treatment, to the maximum extent practicable, of all major pollutants of concern expected for the proposed land use and/or

those identified in the Storm Water Pollution Prevention Plan (SWPPP) for the site (including, if applicable, those pollutants found to be the cause of the receiving stream to be listed in IDEM 303(d) list) for the first inch of rainfall at the site. The above-noted “maximum extent practicable” criterion is subject to a minimum of 80% removal of Total Suspended Solids (TSS). These requirements are adopted as the basis of the Hendricks County stormwater quality management program for all areas of the jurisdiction.

For the purpose of these Standards, the control of post-construction stormwater runoff quality is assumed satisfactory when the appropriate number of pre-approved structural BMPs, tiered in accordance to the total site disturbed area as shown below, are designed, installed, and operated in accordance with fact sheets provided in Appendix D1.

Total Property/Development Area	Post-Construction BMP Requirement*
0 to less than ½ acre	No BMP
At least ½ acre to less than 3 acres	At least 1 BMP
At least 3 acres	2 BMPs in series**

* These BMPs are in addition to any pre-treatment that may be required for hot spots.

** If the Channel Protection Volume is provided in the form of retention that is pretreated for sedimentation by a settling basin (see Infiltration Basin Fact Sheet), then no additional BMPs are required.

As noted above, unless the Channel Protection Volume or Water Quality Volume can be fully retained and infiltrated, a combination of at least two BMPs in series (each sized to handle water quality volume) is required for sites with a disturbed area of at least 3 acres, with the first BMP acting as a pretreatment measure to reduce pollutant concentrations within the downstream, or secondary, BMP. A dual BMP provision provides a failsafe benefit should adverse conditions result in undue clogging or other potential BMP impairment. Only one of the required BMPs can be a proprietary Water Quality Device.

C. POLLUTANTS OF CONCERN AFTER CONSTRUCTION STABILIZATION

There are three major sources of pollutants for a stabilized construction site:

- Deposition of atmospheric material (including wind-eroded material and dust)
- General urban pollution (thermal pollution, litter)
- Pollutants associated with specific land uses

It should be noted that some pollutants accumulate on impervious surfaces. This accumulated material is then subject to being washed into watercourses during storm events. It is for this reason that fish kills often occur during a rain event with a substantial prior rainless period. This is also the reason that the most hazardous driving conditions

are realized after the initial onset of a storm event, when deposited oil has not yet washed into adjacent conveyance systems.

pollutants of concern include:

- **Sediment** is the major pollutant of concern during active construction. Natural erosion processes are accelerated at a project site by the construction process for a number of reasons, including the loss of surface vegetation and compaction damage to the soil structure itself, resulting in reduced infiltration and increased surface runoff. After the construction is completed, other chemicals that are released to surface waters from industrial and municipal discharges and polluted runoff from urban and agricultural areas continue to accumulate to harmful levels in sediments.
- **Toxic chemicals** from illegal dumping and poor storage and handling of materials. Industrial sites pose the most highly variable source of this pollution due to the dependency of the specific process to the resulting pollution amounts and constituents. As during construction, these chemicals can pose acute (short-term) or chronic (long-term) risk to aquatic life, wildlife and the general public.
- **Bacteria** from illicit sanitary connections to storm sewer systems, combined sewers, leaking septic systems, wildlife and domestic animal waste. Bacteria pathogens pose a direct health risk to humans and aquatic life.
- **Nutrients** can be released from leaking septic systems or applied in the form of fertilizers. Golf courses, manicured landscapes and agricultural sources are the primary land uses associated with excess fertilization. Excessive nutrients in the local ecosystem are the source of algal blooms in ponds and lakes. These excessive nutrients also lead to acceleration of the eutrophication process, reducing the usable lifespan of these water bodies. Nitrogen and phosphorous are the primary nutrients of concern.
- **Oxygen demand** can be impacted by chemicals transported on sediment, by nutrients, and other pollutants (such as toxic chemicals). Reduced levels of oxygen impair or destroy aquatic life.
- **Oils and hydrocarbons** accumulate in streets from vehicles. They can also be associated with fueling stations and illicit dumping activities. Oils and hydrocarbons pose health risk to both aquatic and human health.
- **Litter, including floatables**, can result in a threat to aquatic life. The aesthetic impact can also reduce the quality of recreational use.
- **Metals** can be associated with vehicular activity (including certain brake dusts), buildings, construction material storage, and industrial activities. Metals are often toxic to aquatic life and threaten human health.

- **Chlorides** (salts) are historically associated with deicing activities. Chlorides are toxic to native aquatic life (verses saltwater aquatic life). Communities should consider a combination of cinders or sand to replace or supplement their deicing activities with chlorides. In addition, chloride stockpiles should remain covered.
- **Thermal effects** can be introduced by the removal of shade provided by riparian trees, as well as impervious channel linings, such as concrete, which release stored heat to water passing over them. Other sources of elevated temperature include effluent from power plant and industrial activities. Thermal pollution can threaten aquatic habitat, including fish species and beneficial water insects. Of particular concern are salmonid streams, due to the effect of thermal pollution on spawning for this particular species.

D. WATER QUALITY CHARACTERISTICS BY LAND USE

Direct water quality sampling is not generally required at this time under the Phase II provisions. However, water quality characteristics are strongly tied to land use. For the purpose of these standards, all proposed developments and re-developments shall be assumed to involve increased levels of floatables, TSS, TP, TN, and metals. Additional pollutants may also be expected at certain types of developments and specific sites, as identified in the Storm Water Pollution Prevention Plan for the site (including, if applicable, those pollutants found to be the cause of the receiving stream to be listed in IDEM 303(d) list).

E. CONVENTIONAL APPROACH PROCEDURES

The following procedures shall be followed according to the Conventional approach:

Step 1: Provide BMPs to address Channel Protection Volume

In a conventional approach, the receiving channel is protected through retaining (when possible) or the extended detention (if infiltration methods are considered ineffective/inappropriate for the site) of the 1-year, 24-hour storm event on entire site (disturbed and undisturbed) tributary to each outlet. The methodology for calculating the Channel Protection Volume (CPv) is according to that discussed in Chapter 9 of this Standards Manual. Both retention or wet/dry extended detention may be used so long as only 10% of the maximum stored volume is left in the basin after 36 hours from maximum storage time (or 48 hours from the start of storm) and no more than 40% of the maximum stored volume is released within the first 12 hours. To ensure that adequate retention/detention volume is available within the facility over the years, the facility should be designed for long-term sediment accumulation. If long-term sediment accumulation cannot be adequately provided for in the pond, or if the pond is intended to provide sediment control during the construction phase of the project, forebays near inlets can be included to help manage sediment accumulation.

Forebays do not require a hard maintenance surface and shall not be visibly disconnected from the pond by rip rap or other berm structures.

Since, by design, 90% of the original volume will be available within 48 hours of start of each storm event (assumed to be about 36 hours from when the Channel Protection pool is full), the volume in the pond associated with the channel protection (CPv) may be assumed empty for the purpose of peak flow retention/detention analysis discussed in Chapter 6. In addition, the volume provided for channel protection would also satisfy the water quality volume (WQv) requirement provided that the facility meets the design criteria in the fact sheet and additional pre-treatment and/or wetland fringe can be provided to assure the performance criteria noted in Section B of this Chapter are met.

Step 2: Provide BMPs to address Water Quality Management

When the channel protection volume is controlled with BMPs that also meet the stormwater quality performance criteria in Section B, often no additional calculation or BMP implementation is necessary. If the channel protection volume is not controlled through practices that also meet the stormwater quality performance criteria in Section B, additional BMPs will be required. Hendricks County has designated a number of pre-approved structural BMP methods (listed in **Table 8-1** for Conventional Approach and Tables 8-4 through 8-6 for LID Approach) to be used alone or in combination to achieve the stormwater quality performance criteria noted in Section B of this Chapter for runoff generated from up to first inch of rainfall on the entire site (disturbed and undisturbed) tributary to each outlet. Details regarding the applicability and design of these pre-approved BMPs, including the effectiveness of these BMPs in treating pollutants of concern (including, if applicable, those pollutants found to be the cause of the receiving stream to be listed in IDEM 303(d) list), are contained within fact sheets presented in **Appendix D1**. Additional information on recommended plant lists and recommended materials used for construction of stormwater BMPs are provided in **Appendix D2** and **Appendix D3**, respectively.

Innovative BMPs, including but not limited to, BMPs not previously accepted by Hendricks County must be certified by a Professional Engineer licensed in State of Indiana and approved through Hendricks County. ASTM standard methods must be followed when verifying performance of new measures. New BMPs, individually or in combination, must meet the performance criteria noted in Section B of this Chapter, including the capture and removal of floatables. All innovative BMPs must have a low to medium maintenance requirement to be considered by Hendricks County. Testing to establish the pollutant removal rate must be conducted by an independent testing facility, not the BMP manufacturer. The accepted design flow rate for a Water Quality Device shall be the flow value at which the claimed removal rate for TSS is equaled or exceeded based on the unit's efficiency curve (flow rate versus removal rate graph).

Note that a single BMP measure may not be adequate to achieve the water quality requirements (as noted above) for a project. It is for this reason that a "treatment train", a number of BMPs in series, is often required for a project. The pollutant

removal efficiency of a number of BMPs in series may be determined from the following formula:

$$E_{\text{series}} = 1 - (1-E_1)(1-E_2)(1-E_3)\dots$$

where,

E_{series} = Removal Efficiency of the BMP series combined (in decimal form)

E_1, E_2, E_3, \dots = Removal Efficiency of Units 1, 2, 3, ..., respectively (in decimal form)

TABLE 8-1
Pre-approved Post-Construction BMPs for Conventional Approach

BMP ^A	Typical % Removal Efficiency ^B	Maintenance Easement Requirements
	TSS	
Bioretention	90 ^C	25 feet wide along the perimeter
Constructed Wetland	67 ^C	25 feet wide along the outer perimeter of forebay & 30 feet wide along centerline of outlet
Underground Detention	70	20 feet wide strip from access easement to tank's access shaft & 30 feet wide along centerline of inlet and outlet
Extended Detention/Dry Pond	72	25 feet wide along the outer perimeter of forebay & 30 feet wide along centerline of outlet
Infiltration Basin (including retention ponds with pretreatment)	90 ^C	25 feet wide along the perimeter
Infiltration Trench	90 ^C	25 feet wide along the perimeter
Constructed (Sand) Filter	70 ^C	25 feet wide along the perimeter
Water Quality Device	VARIES ^D	20 feet wide strip from access easement to chamber's access shaft
Vegetated Filter Strip	78 ^C	25 feet wide along the length on the pavement side
Vegetated Swale	81 ^C	25 feet wide along the top of bank on one side
Wet Ponds/Retention Basin	80	25 feet wide along the outer perimeter of forebay & 30 feet wide along centerline of outlet

Notes:

- A. Detailed specifications for these BMPs are provided in the fact sheets contained in Appendix D1.
- B. Removal rates shown are based on typical results. Unless otherwise shown, data extracted by CBBEL from various data sources. These rates are also dependent on proper installation and maintenance. The ultimate responsibility for determining whether additional measures must be taken to meet the Ordinance requirements for site-specific conditions rests with the applicant.
- C. IDEM Stormwater Quality Manual, 2007.
- D. The removal rate for this category varies widely between various models and manufacturers. The acceptable treatment rate for these devices shall be based on that currently certified by the New Jersey Department of Environmental Protection (NJDEP). Further details on acceptable Water Quality Devices and their treatment rates are provided in Chapter 9.

F. LOW IMPACT DEVELOPMENT (LID) APPROACH PROCEDURES

Low Impact Development (LID) stormwater management design approaches are fundamentally different from conventional design approaches and challenge traditional thinking regarding development standards, watershed protection, and public participation. LID combines fundamental hydrologic concepts with many of today's common stormwater strategies, practices and techniques to reshape development patterns in a way that maintains natural watershed hydrologic functions. When a county or community has a stormwater user fee system based on imperviousness, the utilization of LID approach will often result in reduced stormwater user fee for non-residential lots, because LID reduces overall imperviousness of the lot. The five principles of LID are:

- a) Conservation of existing natural and topographic features;
- b) Minimization of land clearing and impervious surfaces;
- c) Maintain or lengthen the pre-developed time of concentration;
- d) Installation of integrated structural best management practices; and
- e) Use of pollution prevention measures and practices.

Several methods for achieving the above principals are outlined below. In addition to methods described in this Standards Manual, several readily available references provide details on incorporating LID practices into site development. One of the most recent, comprehensive resources for incorporating LID practices into site development design is "Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers" available online at www.semcog.org/LowImpactDevelopment.aspx. The noted resource was used extensively for the development of LID section in this Standards Manual.

The following steps shall be followed for the LID approach:

Step 1: Minimize Disturbed Areas and Protect Sensitive Areas

- Map sensitive areas such as waterbodies, floodplains, and natural flow paths. Identify hydrologic soil types on the maps. Show elevations and identify critical slopes of 15 percent to 25 percent and above 25 percent. Show areas of known contamination. Also show existing structures and infrastructure.
- Determine the total area of impervious surface existing prior to development.
- Note the seasonal high groundwater level.
- Designate sensitive areas that are proposed to be protected as part of the proposed layout.
- Lay out the proposed development, minimizing disturbance and avoiding the sensitive areas, utilizing existing soils.

- Utilize the non-structural BMPs listed in **Table 8-2** to properly protect sensitive areas so they maintain their pre-development state and runoff characteristics. Fact Sheets for these BMPs are provided in **Appendix D1**.

Table 8-2
Pre-approved BMPs with Treatment Area Reduction Recognitions for LID Approach

BMP ^A	Runoff Reduction Recognition ^B
Protect Sensitive Areas	Area (acres complying with the requirements of this BMP) can be subtracted from site development area for Channel Protection Volume and Water Quality Volume/Rate calculations.
Protect Riparian Buffers	Area (acres complying with the requirements of this BMP) can be subtracted from site development area for Channel Protection Volume and Water Quality Volume/Rate calculations.
Minimize Total Disturbed Area	Area (acres complying with the requirements of this BMP) can be subtracted from site development area for Channel Protection Volume and Water Quality Volume/Rate calculations.
Reduce Impervious Surfaces	Area (acres complying with the requirements of this BMP) can be subtracted from site development area for Channel Protection Volume and Water Quality Volume/Rate calculations.
Protect Natural Flow Pathways	Area (acres complying with the requirements of this BMP) can be subtracted from site development area for Channel Protection Volume and Water Quality Volume/Rate calculations.
Cluster-Type Development	Area (undisturbed acres complying with the requirements of this BMP) can be subtracted from site development area for Channel Protection Volume and Water Quality Volume/Rate calculations.

Notes:

- A. In using and crediting these BMPs, applicants must meet the review criteria located within the discussion of each BMP provided in Appendix D1.
 - B. If the LID track is pursued, reduced CNs (associated with pre-developed underlying soil types instead of the normal requirement of assigning the post-development CN according to the next lower infiltration soil group) for areas protected by these BMPs may be used for determining the post-developed runoff rates and volumes for larger events (up to and including the 100-year event). See **Table 8-8**.
- As shown in Table 8-2, when using the LID Approach, any area that is set aside and protected as described in those BMPs may be subtracted from site development area for purposes of determining Channel Protection Volume calculations and water quality volume/rate calculations.
 - Since the LID track is being used, for determining the 10-year and 100-year runoff and peak discharges, the CN associated with the original, pre-development soil groups (instead of the normal requirement of assigning the

post-development CN according to the next lower infiltration soil group) may be used for these areas (see **Table 8-8**).

- The runoff reduction recognition only works with designs based on the Curve Number or CN method of analysis utilizing non-composite CN determination methods.

Step 2: Restore Disturbed Areas

- For the LID Approach, runoff reduction recognitions are used in the design process to emphasize the use of BMPs that, when applied, restore/alter the disturbed area in a way that reduces the volume of runoff from that area.
- Runoff reduction recognition is provided for the five BMPs listed in **Table 8-3** because they enhance the response of a piece of land to a storm event rather than treat the runoff that is generated. These BMPs are encouraged because they are relatively easy to implement over structural controls, require little if any maintenance, and the land they are applied to remains open to other uses.
- Runoff reduction recognition is applied by reducing the default CN value so that the amount of runoff generated from an event is reduced.
- The runoff reduction recognition only works with designs based on the CN method of analysis utilizing non-composite CN determination methods.
- Fact sheets for these BMPs are provided in Appendix D1.

Table 8-3
Pre-approved BMPs with Runoff Reduction Recognitions for Restoring Disturbed
Areas as Part of LID Approach

BMP ^A	Runoff Reduction Recognition ^B
Minimize Soil Compaction	Area (acres complying with the requirements of this BMP) can be assigned a CN based on the Pre-developed soil group conditions instead of the normal requirement of assigning the post-development CN according to the next lower infiltration soil group.
Protection of Existing Trees within disturbed areas (part of Protect Sensitive Areas)	Trees protected under the requirements of this BMP can be assigned a CN based on the Pre-developed soil group conditions at a rate of 800 square feet per tree instead of the normal requirement of assigning Post-developed CN according to the next lower infiltration soil group for the acres covered by the tree area.
Soil Amendment and Restoration	Area (acres complying with the requirements of this BMP) can be assigned a CN based on the Pre-developed soil group conditions instead of the normal requirement of assigning the post-development CN according to the next lower infiltration soil group.
Native Revegetation	Proposed trees and shrubs to be planted under the requirements of this BMP can be assigned a CN based on the Pre-developed soil group conditions at a rate of 200 square feet per tree and 25 square feet per shrub instead of the normal requirement of assigning Post-developed CN according to the next lower infiltration soil group for the acres covered by the existing land use area.
Riparian Buffer Restoration	Proposed trees and shrubs to be planted under the requirements of this BMP can be assigned a CN based on the Pre-developed soil group conditions at a rate of 200 square feet per tree and 25 square feet per shrub instead of the normal requirement of assigning Post-developed CN according to the next lower infiltration soil group for the acres covered by the existing land use area.

Notes:

- A. In using and crediting these BMPs, applicants must meet the review criteria located within the discussion of each BMP provided in Appendix D1.
- B. If the LID track is pursued, reduced CNs (associated with pre-developed underlying soil types instead of the normal requirement of assigning the post-development CN according to the next lower infiltration soil group) for areas covered by these BMPs may be used for determining the post-developed runoff rates and volumes for larger events (up to and including the 100-year event). See **Table 8-8**.

Step 3: Minimize Imperviousness

- The BMPs listed in **Table 8-4** are designed to reduce the volume of runoff from hard surfaces such as roads, sidewalks, parking areas, roofs, etc. Runoff reduction recognition is used to encourage these practices and recognize their runoff reduction impacts when LID Approach is being pursued. Fact Sheets for these BMPs are provided in Appendix D1.

Table 8-4
Pre-approved BMPs with Runoff Reduction Credits for Reducing Imperviousness
as Part of LID Approach

BMP ^A	Runoff Reduction Recognition ^B
Porous Pavement	Area covered by Porous Pavement with a minimum of 8 inch washed aggregate base may be assigned a weighted CN value of 87 (instead of CN of 98 normally used for impervious surfaces) for the purpose of Channel Protection Volume calculations. Use a weighted CN of 74 for the purpose of Water Quality Volume calculations, if needed. Note: If this BMP is specifically designed to provide permanent volume reduction through infiltration or through providing detention storage within the aggregate void, the volume reduction recognition discussed in Step 5 should be pursued instead of the CN reduction recognition, assuming CN of 98.
Vegetated Roof	Vegetated roofs are designed to reduce runoff volumes. However, the volume reduction is highly dependent on the media and planting used, with the calculation methods very complex at times. In lieu of calculating the volume reduction benefits, the roof area with vegetated roof with a minimum media depth of 4 inches and a void ratio of 0.3 (as described in the fact sheet) may be assigned a weighted CN of 87 (instead of CN of 98 normally used for impervious surfaces) for the purpose of Channel Protection Volume calculations. Use a weighted CN of 74 for the purpose of Water Quality Volume calculations, if needed.

Notes:

- A. In using and crediting these BMPs, applicants must meet the review criteria located within the discussion of each BMP provided in Appendix D1.
 - B. If the LID track is pursued, reduced CNs for areas covered by these BMPs may be used for determining the post-developed runoff rates and volumes for larger events (up to and including the 100-year event). See **Table 8-8** for weighted CN values used for such larger events.
- Although imperviousness reduction BMPs are encouraged throughout any new development or re-development, the runoff reduction recognition may only be considered where the following conditions are met:

- The BMP must be in the common areas and covered by an easement or other agreement that assigns responsibility for its maintenance.
- The BMP must be covered by a maintenance plan and agreement with assurances for the long-term availability of maintenance funds (such as funds held in a permanent escrow account) in a form acceptable to Hendricks County.

Step 4: Calculate the amount of volume control needed for channel protection

- Determine the 1-year 24-hour rainfall from Table 2-5,
- Delineate subbasins in a manner that, at a minimum and to the extent possible, the pervious and impervious surfaces are in different subbasins
- Determine the disturbed drainage area for each subbasin by subtracting the protected area determined in Step 1 from total contributing drainage area.
- Assign CN to each cover type and land use, assigning “credited CN” for areas treated in Steps 2 and 3 instead of normal post-development CN that is determined based on the proposed land use and the next less infiltrating underlying soil group, when applicable. Published pre-determined weighted CN values shall not be utilized for LID Approach. This applies regardless of whether manual methods or computer modeling techniques are used.
- Determine the total post-development 1-year, 24-hour runoff volume for the entire site’s disturbed areas through the use of acceptable computer models or manually as specified below. This is the net Channel Protection volume needing to be permanently removed by appropriate structural BMPs.
 - Computer Model: Use acceptable computer models (listed in Chapter 2) to determine the total runoff volume for the site, utilizing 1-year, 24 hour rainfall depth with Soil Conservation Service (SCS) type 2 storm distribution, drainage area, and CN determined above, according to the Soil Conservation Service (SCS) CN loss method along with SCS unitless hydrograph methodology.
 - Manual Calculation: If calculating manually, use the following formula:
 - **Runoff Volume (ft³) for each cover type = $Q_v \times 1/12 \times A$**
Where
 - A = disturbed area of the particular cover type (ft²)
 - $Q_v = \text{Runoff Depth (in)} = (P - 0.2S)^2 / (P + 0.8S)$
 - P = 1-Year, 24 Hr Rainfall (in)
 - $S = (1000/CN) - 10$

- Sum the individual volumes to obtain the total post-development runoff volume for area to be managed.

Step 5: Provide Distributed Volume Reduction/Infiltration Practices

- **Table 8-5** includes a list of the structural BMPs from potential BMPs that provide volume removal/retention. Select and design structural BMPs that provide volume control to meet, when combined, the total net channel protection volume determined in Step 4. Fact Sheets for these and other relevant post-construction structural BMPs are provided in Appendix D1.

Table 8-5
Pre-approved Structural BMPs with Permanent Volume Reduction
Recognitions for Channel Protection as Part of LID Approach

BMP ^A	Channel Protection Volume Runoff Reduction Recognition ^B
Infiltration Practices (Infiltration Basin, Subsurface Infiltration Bed, Infiltration Trench, and Dry Well)	Volume reduction is achieved by surface storage volume (if included in the design), subsurface volume (if included in the design), and infiltration volume as described in the fact sheet. If an underdrain has to be used due to soil conditions, no recognition is granted for the “infiltration volume” portion.
Bioretention	Volume reduction is achieved by surface storage volume, soil storage volume, and infiltration bed volume as described in the fact sheet.
Vegetated Swale	Volume reduction is achieved by surface storage volume (if included in the design through inclusion of check dams) and active infiltration volume during the storm (when infiltration is expressly designed for as a purpose) as described in the fact sheet.

Notes:

- A. In using and crediting these BMPs, applicants must meet the review criteria located within the discussion of each BMP provided in Appendix D1.
 - B. If the LID track is pursued, the volume reduction provided by these BMPs may be recognized towards determining the post-developed runoff rates and volumes for larger events (up to and including the 100-year event). See **Table 8-8** for extent of runoff reduction recognition allowed for such larger events.
- The volume reduction BMPs work well when they are placed in an appropriate setting. Please see “Applicability and Limitation” discussions in each Fact Sheet for best suited placement of BMP. In order to qualify for recognition, the BMPs must also meet all the following:
 - Be in the common areas and covered by an easement or other agreement that assigns responsibility for its maintenance.

- Be covered by a maintenance plan and agreement with assurances for the long-term availability of maintenance funds (such as funds held in a permanent escrow account) in a form acceptable to Hendricks County.
- Be constructed on undisturbed A or well-drained B soils (B/D soils do not qualify) or amended soil with underdrains, as needed. If underdrains are used, the bottom elevations of the underdrains should be above the seasonal high water table. Soil infiltration testing protocol, provided in **Appendix D4**, must be followed to determine if infiltration BMPs are suitable at a site and to obtain the required data (such as soil conditions and depth of seasonal high water table) for infiltration design.
- Be constructed in an area where the depth of seasonal high water table and any bedrock is more than a minimum of 2 feet (4 feet is desirable) from BMP bottom elevation.
- Be constructed in a manner that any infiltration practices are adequately separated from basement foundations (50 feet up gradient, 10 feet down gradient), on-site septic systems/drainfields (100 feet), wells (50 feet), and other building elements that could be affected by infiltration systems.
- Be constructed outside of any 1-year (Zone 1) or 5-year (Zone 2) time of travel areas to public water supply wells, as defined by a modeled wellfield delineation performed in compliance with 327 IAC 8-4.1. When such delineation is not available, said practice must be at least 3,000 feet from the nearest public water supply well (unless applicant can demonstrate that the proposed practice will have no impacts on the water quality of the water supply well).
- Final construction should be completed after the contributing drainage area has been stabilized.
- Must contain erosion-protection features at the inflow to prevent scouring
- Must contain a maintenance area near the inlet to collect large debris. Examples include small concrete aprons, catch basin inserts, or similar durable maintenance point.
- When the LID Approach is being pursued in all other aspects of the design but site limitations would not allow permanent volume reduction practices/infiltration, channel protection volume should, at a minimum and as site limitations would allow, be accommodated through distributed storage solutions noted in Table 8-5 that also include underdrains as described in the

appropriate Fact Sheets so that at a minimum they can act as both extended detention and filtration practices.

- **Calculation Methods for Recognizing Impacts of Distributed Storage on Overall Site's Peak Flow Detention Requirements:** when all the stated conditions above are met for volume-reduction distributed storage practices noted in Table 8-5, total volume provided for channel protection within distributed storage units (not to exceed the required channel protection volume calculated in Step 4) may be applied towards the site's overall detention requirements for peak (10-year and 100-year) flow control (see **Table 8-8**). Several methods are available to account for the noted runoff reduction recognition. A few common methods are listed below (other methods not noted below may also be used as appropriate):
 - Method 1: Assume that the provided CPv in the distributed storage units (not to exceed the required CPv calculated in Step 4) will be stored below the detention pond's normal pool (below the lowest outlet). To simulate this condition, all the volumes in the elevation-storage table are increased by the provided CPv, an additional table entry is made as the first row with an artificial lower elevation and with zero for storage, and the reservoir's starting elevation is set at the noted artificial elevation.
 - Method 2: Utilize the "Divert" option of the hydrologic model used to compute the inflow to the pond to simulate the diversion (abstraction) of the provided CPv (not to exceed the required CPv calculated in Step 4) from the detention pond inflow before the remaining flood hydrograph is routed through the detention system. To accomplish this, the model should have capability to simulate diversion with a volume cap option.
 - Method 3: Explicitly model the distributed storage features as a network of storage and conveyance units through the use of computer programs that can correctly model interconnected storage.

Step 6: Provide Additional (as-needed) Extended Detention Practices

- When the LID Approach is being pursued in all other aspects of the design but site limitations would not allow adequate distributed volume reduction/infiltration practices noted in Step 5 (with or without underdrain), then a constructed wetland or a wet-bottom extended detention facility along with incorporation of an appropriate wetland fringe should be utilized as listed in **Table 8-6**. If designed properly, such a facility can be incorporated into a multi-purpose facility to control channel protection volume, water quality volume, and 100-year peak flow rate. Note that since by design conditions of an extended detention facility, 90% of the original volume will be available within 48 hours of each storm event (i.e., a maximum of 36 hours from when the channel protection pool is full), the volume in the pond associated with the channel

protection may be assumed empty for the purpose of peak flow detention analysis discussed in Chapter 6 of these Standards (see **Table 8-8**).

Table 8-6
Pre-approved BMPs with Additional, As-needed Extended Detention Runoff Reduction Recognitions for Channel Protection as Part of LID Approach

BMP ^A	Runoff Reduction Recognition ^B
Constructed Wetland	The volume of the supplementary extended detention, in lieu of permanent volume reduction, is applied towards meeting Channel Protection Volume requirements so long as only 10% of the maximum stored volume is left in the basin after 36 hours from maximum storage time and no more than 40% from the maximum stored volume is released within the first 12 hours.
Extended Detention Wet/Dry Pond	The volume of the supplementary extended detention, in lieu of permanent volume reduction, is applied towards meeting Channel Protection Volume requirements so long as only 10% of the maximum stored volume is left in the basin after 36 hours from maximum storage time and no more than 40% from the maximum stored volume is released within the first 12 hours.

Notes:

- A. In using and crediting these BMPs, applicants must meet the review criteria located within the discussion of each BMP provided in Appendix D1.
- B. If the LID track is pursued, the volume reduction provided by these BMPs may be applied towards determining the post-developed runoff rates and volumes for larger events (up to and including the 100-year event). See **Table 8-8** for extent of volume reduction allowed for such larger events.

Step 7: Determine Water Quality Volume and Provide, As-needed, Additional Water Quality BMPs

- The expected treatment of many BMPs applied to LID designs is based on removing solids. Many pollutants are attached to solids or are removed by similar treatment mechanisms. Therefore, removing solids can act as a surrogate for the expected removal of other particulate pollutants. Often multiple BMPs will be necessary to remove successively smaller particle sizes to achieve the highest level of treatment.
- When the CPv is controlled with BMPs that also meet the stormwater quality performance criteria in Section B, often no additional calculation or BMP implementation is necessary. If the channel protection volume is not controlled through practices that also meet the stormwater quality performance criteria in Section B, calculate the water quality volume that

provides for the treatment of the first inch of rainfall on the site's disturbed areas as discussed below.

- The methodology for determining the design water quality volume or rate for the LID Approach is the same as that described for CPv calculation described in Step 4, except the rainfall depth for Water Quality will be 1 inch instead of the 1-year, 24-hour rainfall depth used for calculating the CPv. A few considerations specific to Water Quality Volume/Rate calculations are as follows:
 - Time of Concentration in the case of LID design is the time it takes a drop of water to move from the furthest point in the disturbed area to its discharge from the disturbed area.
 - Computer Model: If using acceptable computer models, perform the same procedure as that performed for calculating CPv in Step 4, but for 1 inch of rainfall depth.
 - Manual Calculation: If calculating manually, use the following formula:
 - **Runoff Volume (ft³) for each cover type = $Q_v \times 1/12 \times A$**
 Where
 A = disturbed area of the particular cover type (ft²)
 Q_v = Runoff Depth (in) = $(P - 0.2S)^2 / (P + 0.8S)$
 P = 1 inch
 S = $(1000/CN) - 10$
 - **Peak Runoff Rate (ft³/sec) = $q_u \times A \times Q_v \times 1/43,560$**
 Where
 A = disturbed area of the particular cover type (ft²)
 Q_v = Runoff Depth (in) calculated in previous step
 q_u = Unit Peak Discharge (cfs/mi²/in), determined from TR-55 Exhibit 4-II
 - Sum the individual volumes and peak runoff rates to obtain the total design post-development water quality runoff volume and rate.
 - Determine the total post-development water quality runoff volume and rate for the entire site's disturbed areas. These are the design post-development water quality runoff volume and rate needing to be treated.
- Select BMPs from the list provided in Table 8-1 that will meet the performance criteria noted in Section B of this Chapter. Often, multiple types of BMPs used in series will be required to provide adequate treatment. Design the BMPs in

conjunction with any detention control that is needed for peak rate control of larger floods (100-year), if possible.

Step 8: Complete the LID Approach Utilization Summary Form

- As the final step of the LID Approach, a summary of non-structural and structural BMPs utilized, as part of the LID Approach, in the site design of a particular development site is provided in **Table 8-7** and submitted as part of the permit request package.
- The presence of Table 8-7 in the submittal package and the information contained in the form would alert the plan reviewer that the LID Approach is being used to meet the post-construction stormwater quality requirements of the site and that the overall site design as well as peak discharge and detention calculations should be reviewed with the impacts of LID Approach in mind.

Table 8-7
LID Approach Summary Checklist

This checklist is a tool to allow both the regulatory agency and the Developer to reference various LID measures implemented within the development in order to meet the development's Post Construction Stormwater Management requirements.					
Project Name:		Engineer:		Developer:	
Total Site Area: _____ sf Proposed Earth Disturbance Area: _____ sf Existing Impervious Area: _____ sf					
LID Approach Step	Potential BMPs	√	Total Surface Area (sf) of LID Measure/BMP	Plan Pg # of LID Measure	Pg # of Calculations for LID Measure
1. Minimize Disturbed Areas	Protect Sensitive Areas				
	Protect Riparian Buffers				
	Protect Natural Flow Pathways				
	Minimize Total Disturbed Area				
	Reduce Impervious Surfaces				
	Cluster-Type Development				
2. Restore Disturbed Areas	Minimize Soil Compaction				
	Protect Trees in Disturbed Areas				
	Soil Amendment and/or Restoration				
	Native Revegetation				
	Riparian Buffer Restoration				
3. Minimize Imperviousness	Porous Pavement				
	Vegetated Roof				
4. Determine Volume Control Needed for Channel Protection	N/A (calculation step only)		N/A		
5. Provide Distributed Retention/Infiltration Practices	Infiltration Practices*				
	Bio-retention				
	Vegetated Swale				
6. Additional (as-needed) Extended Detention Practices	Constructed Wetland		N/A		
	Extended Detention Wet/Dry Pond		N/A		
7. Additional (as-needed) Water Quality BMPs	Pre-approved BMPs noted in Table 8-1 for conventional method		N/A		
Additional Flood Peak Control (2yr-100yr)	Detention Pond (wet/dry/underground)		N/A		
Total Surface Area of LID Measures			_____ sf		
Proposed Final Impervious Surface Area			_____ sf		
Percent of Total Site Area Covered by LID			_____ %		
Note: Not all LID measures are necessary or appropriate for every site. It is imperative that proper site assessments and due diligence is completed by the Developer and/or Engineer prior to design.					

*: Infiltration Practices include: Infiltration Basins, Subsurface Infiltration Beds or Trenches, and Dry Wells

Summary of Runoff Reduction Recognitions for Water Quality Volume, Channel Protection, and Peak Flow Control Detention Volume for LID approach

As discussed throughout this Section, to encourage LID approach for stormwater management, runoff reduction recognitions towards all three major stormwater management requirements, i.e., Water Quality, Channel Protection, and Peak Runoff Detention, are associated with various BMPS as noted through the above 8-step process. These runoff reduction recognitions are summarized in **Table 8-8**.

Table 8-8
Summary of Runoff Reduction Recognitions for Pre-approved BMPs Used in the LID Approach

Implementation Order	DESCRIPTION	POTENTIAL BMPs	RECOGNITION/CREDIT FOR POST-CONSTRUCTION WATER QUALITY CALCULATIONS		RECOGNITION/CREDIT FOR WATER QUANTITY (DETENTION AND STORM DRAIN) CALCULATIONS
			WATER QUALITY VOLUME	CHANNEL PROTECTION VOLUME	
1	Minimize Disturbed Areas	<ul style="list-style-type: none"> Protect Sensitive Areas Protect Riparian Buffers Minimize Total Disturbed Area Protect Natural Flow Pathways Reduce Impervious Surfaces Cluster-Type Development 	Full recognition through allowing to use "disturbed surface area" only for all calculations	Full recognition through allowing to use "disturbed surface area" only for all calculations	Full recognition through allowing CN for the undisturbed, protected area to be calculated based on pre-developed underlying soil types
2	Restore Disturbed Areas	<ul style="list-style-type: none"> Minimize Soil Compaction Protection of Existing Trees within disturbed areas (part of Minimize Total Disturbed Area) Soil Amendment and Restoration Native Revegetation Riparian Buffer Restoration 	Full recognition through allowing CN for the restored/protected area to be calculated based on pre-developed underlying soil types	Full recognition through allowing CN for the restored/protected area to be calculated based on pre-developed underlying soil types	Full recognition through allowing CN for the restored/protected area to be calculated based on pre-developed underlying soil types
3	Minimize Imperviousness	<ul style="list-style-type: none"> Porous Pavement 	Full recognition of perviousness through allowing CN for the application area to be calculated based on a pre-set value (74 instead of 98) AND full recognition of the stored volume (if provided for in the design) and WQ treatment, if designed as a true infiltration practice (no underdrain/ or extended 24-48 hrs release)	Partial (weighted) recognition of perviousness through allowing CN for the application area to be calculated based on a pre-set value (87 instead of 98) AND full recognition of the stored volume (if provided for in the design), if designed as a true infiltration practice (no underdrain/ or extended 24-48 hrs release)	Partial (weighted) recognition of perviousness through allowing CN for the application area to be calculated based on pre-set values (89 for 10-year and 90 for 100-year calculations instead of using 98) and limited recognition of the stored volume (if provided for in the design) up to Channel Protection Volume, on a case by case basis, treated as an underground detention
		<ul style="list-style-type: none"> Vegetated Roof 	Full recognition of perviousness through allowing CN for the application area to be calculated based on a pre-set value (74 instead of 98) AND full recognition of the stored volume (if provided for in the design) and/or WQ treatment if designed for	Partial (weighted) recognition of perviousness through allowing CN for the application area to be calculated based on a pre-set value (87 instead of 98)	Partial (weighted) recognition of perviousness through allowing CN for the application area to be calculated based on a pre-set value 89 for 10-year and 90 for 100-year calculations instead of using 98)
4	Provide Distributed Volume Reduction/Infiltration Practices (or Filtration Practices, if underdrains have to be provided) in Common Areas	<ul style="list-style-type: none"> Infiltration Practices (Infiltration Basin, Subsurface Infiltration Bed, Infiltration Trench, and Dry Well) Bioretention Vegetated Swale 	Full recognition of perviousness through allowing CN for the application area to be calculated based on cover type and underlying soil AND full recognition of the retained volume (if provided for in the design) and/or WQ treatment if designed for	Full recognition of retained volume if designed as true infiltration practice (on appropriate soil and no underdrain/ or extended 24-48 hrs release)	Limited recognition of retained volume (up to the Channel Protection Volume) if designed as true infiltration practice (on appropriate soil and no underdrain/ or extended 24-48 hrs release). Credit for retained volume up to 100-year peak flow rate volume may be granted on a case by case basis for sites with unusually high infiltration rates.
5	Provide, As-needed, Additional Extended Detention Practices in Common Areas	<ul style="list-style-type: none"> Constructed Wetland Extended Detention Wet/Dry Pond 	full recognition of the stored volume (with extended 24-48 hrs release) and/or WQ treatment if designed for	Full Recognition of stored volume (with extended 24-48 hrs release)	Full Recognition of stored volume (with extended 24-48 hrs release)
6	Provide, As needed, Additional Water Quality BMPs	<ul style="list-style-type: none"> Pre-approved BMPs noted in Table 8-1 for conventional method 	Full recognition of WQ treatment	N/A	N/A

G. SPECIAL PROVISIONS FOR “HOT SPOT” LAND USES

For all those projects involving land uses considered to be high pollutant producers or “hot spots” (see **Table 8-9** e.g., vehicle service and maintenance facilities, vehicle salvage yards and recycling facilities, vehicle and equipment cleaning facilities, fleet storage areas for buses, trucks, etc., industrial/commercial or any hazardous waste storage areas or areas that generate such wastes, industrial sites, restaurants and convenience stores, any activity involving chemical mixing or loading/unloading, outdoor liquid container storage, public works storage areas, commercial container nurseries, and some high traffic retail uses characterized by frequent vehicle turnover), additional water quality requirements may be imposed by Hendricks County in addition to those included in water quality criteria in order to remove potential pollutant loadings from entering either groundwater or surface water systems. These pre-treatment options are included in **Table 8-9** and **Table 8-10**.

Table 8-9
Pre-Treatment options for Stormwater Hot Spots

Stormwater Hot Spots	Minimum Pre-Treatment Options
Vehicle Maintenance and Repair Facilities	A, E, F, G
Vehicle Fueling Stations	A, D, G
Drive-through Restaurants, Pharmacies, Convenience Stores	B, C, D, I, K
Outdoor Chemical Mixing or Handling	G, H
Outdoor Storage of Liquids	G
Commercial Nursery Operations	I, J, L
Other Uses or Activities Designated by Appropriate Authority	As Required

Table 8-10
Minimum Pre-Treatment Options

Minimum Pre-Treatment Options	
A	Oil/Water Separators / Hydrodynamic Separators
B	Sediment Traps/Catch Basin Sumps
C	Trash/Debris Collectors in Catch Basins
D	Water Quality Inserts for Inlets (inspected and cleaned after every significant rainfall event)
E	Use of Drip Pans and/or Dry Sweep Material under Vehicles/Equipment
F	Use of Absorbent Devices to Reduce Liquid Releases
G	Spill Prevention and Response Program
H	Diversion of Stormwater away from Potential Contamination Areas
I	Vegetated Swales/Filter Strips
J	Constructed Wetlands
K	Stormwater Filters (Sand, Peat, Compost, etc.)
L	Stormwater Collection and Reuse (especially for irrigation)
M	BMPs that are a part of a Stormwater Pollution Prevention Plan (SWPPP) under a NPDES Permit

H. CONSTRUCTION SEQUENCING CONSIDERATIONS

BMPs noted in this chapter refer to post-construction BMPs, which continue to treat stormwater after construction has been completed and the site has been stabilized. Installing certain BMPs, such as bioretention areas and sand filters, prior to stabilization can cause failure of the measure due to clogging from sediment. If such BMPs are installed prior to site stabilization, they should be protected by traditional erosion control measures.

In those instances, the construction sequence must require that the pond is cleaned out with pertinent elevations and storage and treatment capacities reestablished as noted in the accepted stormwater management plan.

I. INSPECTION AND MAINTENANCE REQUIREMENTS

Subsequent to successful installation of Post-construction BMPs, they need to be inspected and maintained regularly in accordance with the Operation and Maintenance Manual required to be prepared for each BMP. An operations and maintenance (O&M) manual for all private infrastructure, including but not limited to pipes, ponds, ditches, and BMPs (when required), shall be submitted for the final plan approval and permit process. The manual will become a maintenance guide for the drainage infrastructure once development is complete. The final O&M manual will be provided to the County in both hard copy and digital formats. The O&M manual maintenance agreement along with a site map showing the BMP locations shall be recorded with the final plat. The O&M manual will include the following:

1. name, address, business phone number, home phone number, email address, cellular phone number, pager number;
2. Site drawings (8½" by 11" or 11" by 17"), showing both plan and cross-section views, showing the infrastructure and applicable features, including dimensions, easements, outlet works, forebays, signage, etc., as well as an overall site map of the development showing all structures;
3. Guidance on owner-required periodic inspections;
4. Requirement of owner to perform maintenance specified by County inspection, if any;
5. Guidance on routine maintenance, including mowing, litter removal, woody growth removal, signage, etc.;
6. Guidance on remedial maintenance; such as inlet replacement, outlet works maintenance, etc.;
7. Guidance on sediment and trash removal, both narrative and graphical, describing when sediment removal should occur in order to insure that BMPs and other infrastructure remain effective as water quality and/or quantity control devices;
8. A statement that the County's representatives have the right to enter the property to inspect the infrastructure;
9. A tabular schedule showing inspection and maintenance requirements; and

10. Identification of the property owner as the party responsible for all maintenance, including cost.

Inspection checklists for various types of BMPs are provided in **Appendix D5**. A sample Stormwater Management Maintenance Agreement is provided in **Appendix D6**. This agreement will need to be customized, signed, notarized, and recorded so that it can be a part of the property's deed.

Installation and maintenance of appropriate signage of all green infrastructure BMP sites shall also be required both to alert the maintenance crew and to educate the public.



Chapter Nine

METHODOLOGY FOR DETERMINATION OF REQUIRED SIZING OF BMPs

A. INTRODUCTION

This Chapter describes the acceptable methods for calculating Channel Protection Volume, Water Quality Volume, and Flow-Through BMP Flow Rate associated with Conventional Stormwater Management Approach (acceptable methods associated with the LID Stormwater Management Approach are discussed in Chapter 8). Channel Protection is achieved through retention or extended detention of runoff volume for 1-year, 24-hour storm event. Structural Water Quality treatment is achieved by treating the first inch of rainfall, either through retention/detention BMPs or by Flow-through BMPs. Detention/Retention BMPs impound (pond) the runoff to be treated, while flow-through BMPs treat the runoff through some form of filtration process.

B. RETENTION/DETENTION BMP SIZING

1. Channel Protection Volume

Channel Protection Detention/Retention BMPs must be designed to store the channel protection volume. The channel protection volume, CPv, is the storage needed to retain or detain the runoff to the receiving stream from the 1-year, 24-hour rainfall.

The methodology for calculating the Channel Protection Volume (CPv) for each of site's final outlets using computer models or manual calculation is as follows:

- Computer Model: Use acceptable computer models (listed in Chapter 2) to determine the total runoff volume for the site contributing to each site's outlet, utilizing 1-year, 24 hour rainfall depth with Soil Conservation Service (SCS) type 2 storm distribution, drainage area, and the composite CN calculated for the site, according to the Soil Conservation Service (SCS) CN loss method along with SCS unitless hydrograph methodology.
- Manual Calculation: If calculating manually, use the following formula:

$$CPv \text{ (ft}^3\text{)} = Qv \times 1/12 \times A$$

Where

A = total post-construction site area contributory to each outlet (ft²)

Qv = Runoff Depth (in) = $(P - 0.2S)^2 / (P + 0.8S)$

P = 1-Year, 24 Hr Rainfall (in)

S = $(1000/CN) - 10$

2. Water Quality Volume

Water Quality Detention BMPs must be designed to store the water quality volume for treatment. The water quality volume, WQv, is the storage needed to capture and treat the runoff from the first one inch of rainfall. The water quality volume is equivalent to one inch of rainfall multiplied by the volumetric runoff coefficient (Rv) multiplied by the site area.

A calculation methodology similar to that described for the channel protection volume may be utilized, except that the rainfall depth (P) will be equal to 1, instead of the 1-year, 24-hour depth.

Alternatively, a simpler methodology may be used for calculation of WQv as follows:

$$WQv = (P) (Rv) (A) / 12$$

where:

WQv = water quality volume for each site's outlet (acre-feet)

P = 1 inch

Rv = volumetric runoff coefficient

A = area in acres

The volumetric runoff coefficient is a measure of imperviousness for the contributing area, and is calculated as:

$$Rv = 0.05 + 0.009(I)$$

Where:

I is the percent impervious cover

For example, a proposed commercial site will be designed to drain to three different outlets, with the following drainage areas and impervious percentages:

Subarea ID	On-site Contributing Area (acres)	Impervious Area %	Off-Site Contributing Area (acres)
A	7.5	80	0.0
B	4.3	75	0.0
C	6.0	77	0.0

Calculating the volumetric runoff coefficient for subareas A, B and C yields:

$$R_v (\text{subarea A}) = 0.05 + 0.009(80) = 0.77$$

$$R_v (\text{subarea B}) = 0.05 + 0.009(75) = 0.73$$

$$R_v (\text{subarea C}) = 0.05 + 0.009(77) = 0.74$$

The water quality volumes for these three areas are then calculated as:

$$WQ_v (\text{subarea A}) = (1'')(R_v)(A)/12 = 0.77(7.5)/12 = 0.47 \text{ acre-feet}$$

$$WQ_v (\text{subarea B}) = 0.73(4.3)/12 = 0.26 \text{ acre-feet}$$

$$WQ_v (\text{subarea C}) = 0.74(6.0)/12 = 0.37 \text{ acre-feet}$$

Note that this example assumed no offsite sources of discharge through the water quality BMPs. If there were significant sources of off-site runoff (sometimes called runoff for upstream areas draining to the site), the designer would have the option of bypassing off-site runoff around the on-site systems, or the detention BMP should be sized to treat the on-site channel protection volume plus the water quality volume for the off-site sources.

C. FLOW THROUGH BMP SIZING

Flow-through BMPs are designed to treat runoff at a calculated water quality treatment flow rate through the system. Examples of flow through BMPs include catch basin inserts, sand filters, and grassed channels. Another flow through BMP is a hydrodynamic separator or other similar type of device discussed in the Water Quality Devices Fact Sheet (Appendix D1).

1. Requirements for Manufactured Treatment Devices

Stormwater Manufactured Treatment Devices (MTD), also known as Hydrodynamic separators are proprietary, and usually include a pollutant-water separation component. The MTD must be sized to treat flows up to, and including, the Water Quality Treatment Rate (Q_{wq}) calculated for each project site outlet. To be acceptable, the MTD must meet the following criteria:

- The MTD must provide complete and unobstructed access to the entire bottom of the system from grade level for ease of maintenance.

- The MTD must be offline and located upstream of detention facilities (if any).
- The MTD, or the treatment train (if applicable) that includes the MTD as one of its components, must have the ability to capture or skim pollutants including but not limited to: floating oils / immiscible materials.
- The MTD, or the treatment train (if applicable) that includes the MTD as one of its components, must have the ability to capture both floating and suspended solid material (trash, organic material, etc.) and other pollutants.
- The MTD must be provided with a well-defined access roadway located in common areas and contained in an easement.
- The MTD shall be a manufactured system currently certified by the New Jersey Department of Environmental Protection (NJDEP). A list of NJDEP- MTDs certified for 50% and 80% TSS removal are provided in a table located at <http://www.nj.gov/dep/stormwater/treatment.html>.

To obtain the maximum flow rate for various models of a MTD that is listed in the NJDEP-certified list, the latest verification report from NJCAT Verification Database must be used. A link to the database is provided right above the NJDEP-certified list table.

In summary, the following steps should be used to determine whether a proposed MTD unit is NJDEP-certified and to determine the accepted maximum flow rate for that unit.

Step 1: Determine if the MTD is NJDEP-certified for 50% treatment rate (when the MTD will be used in a treatment train) or 80% treatment rate (when the MTD will be used alone):

- a) Go to <http://www.nj.gov/dep/stormwater/treatment.html>
- b) Look up the name of the MTD in the first column of the table (see below a screen capture of a portion of the table at the time of this writing)
- c) Look up the Certified TSS Removal Rate of that MTD in the fourth column

The table below includes the listing of MTDs that are NJCAT verified and NJDEP certified under the updated procedures and protocols dated January 25, 2013.

[Click here](#) to link to NJCAT Verification Database

Stormwater Management Manufactured Treatment Devices Certified by NJDEP	MTD Laboratory Test Certifications	Superseded Certifications	Certified TSS Removal Rate	Maintenance Plan
Aqua-Swirl By AquaShield, Inc.	Certification	Superseded	50%	Plan
BayFilter by BaySaver Technologies, LLC	Certification		80%	Plan
Continuous Deflective Separator (CDS) Unit by CONTECH Stormwater Solutions, Inc.	Certification	Superseded	50%	Plan
Downstream Defender by Hydro International, Inc.	Certification	Superseded	50%	Plan
Dual Vortex Separator by Oldcastle Stormwater Solutions	Certification		50%	Plan
Filterra Bioretention System by Contech	Certification	Superseded	80%	Plan

Step 2: Determine the maximum accepted flow rate:

- Click the link "Certification" in the second column of the NJDEP-certified list table (above). In some cases, a table of MTD model versus the NJDEP-certified maximum flow rate is included in the certification letter. In that case, skip to sub-step "g)" (below). If not continue to the sub-step "b)" (below)
- Click the "Click here" link above the NJDEP-certified list table to access NJCAT Verification Database
- Find the name of the MTD manufacturer of interest in first column (see below a screen capture of a portion of the table at the time of this writing)
- Find the latest entry (one with the latest verification date shown in third column) for that particular MTD
- Click the report download link in the fourth column

Stormwater Technologies: Laboratory Verified			
Company	Product	Verification Date	Link to Report
AquaShield Inc.	Aqua-Filter	Sept. 2005, Updated December 2005, Addendum 2007	Download
AquaShield Inc.	Aqua-Swirl	Sept. 2005, Updated December 2005	Download
AquaShield, Inc.	Aqua-Swirl Stormwater Treatment System	November, 2016	Download
BaySaver Technologies	BayFilter	June 2008	Download
BaySaver technologies	Bay Separator	December 2004	Download
BaySaver Technologies, LLC	BayFilter Enhanced Media Cartridge	November, 2016	Download
Bio Clean Environmental Services	Kraken Membrane Filtration System	April 2016	Download
Contech Engineered Solutions LLC	Stormwater Management StormFilter with Perlite Media	November 2016	Download
CONTECH Stormwater Solutions	Continuous Deflective Separator (CDS)	September 2014, Updated January 2017	Download
CONTECH Stormwater Solutions	VortSentry	December 2005	Download
CONTECH Stormwater Solutions.	Filterra Bioretention System	May 2014	Download
Environment 21 LLC	StormPro Stormwater Treatment Device	October 2014, Updated January 2017	Download

- f) Find the Table in the report (typically towards the end of the report) that lists various MTD model sizes along with the NJDEP 50% (or 80%, if appropriate) TSS Maximum Treatment Flow Rate (see below a screen capture of a portion of the table for a sample MTD)
- g) The selected model should have a maximum flow rate that is equal or larger than the site's required

Model	Manhole Diameter (ft)	NJDEP 50% TSS Maximum Treatment Flow Rate (cfs)	Treatment Area (ft ²)	Hydraulic Loading Rate (gpm/ft ²)	50% Max Sediment Storage Volume (ft ³)	Required Sediment Removal Interval ¹ (Months)
4-ft	4-ft	1.12	12.6	40.0	9.45	60
6-ft	6-ft	2.52	28.3	40.0	28.35	80
8-ft	8-ft	4.49	50.3	40.0	62.78	99
10-ft	10-ft	7.00	78.5	40.0	117.45	119

Note that the NJDEP-certified manufactured system treatment rates for units not equipped with special filters reflect a standard certified 50% TSS reduction at the listed certified treatment flow rate. Therefore, to achieve the 80% TSS removal requirement, either a treatment train with a conventional listed in Table 8-1 (except for another MTD or a sand filter) must be used or a filtration system must be used instead in accordance to NJDEP methodology.

Also, note that the overall treatment system that includes the MTD unit as a component must also include components to capture a substantial amount of oil and floatable debris up to, and including, the Qwp calculated for each project site outlet.

2. Calculating the Required Treatment Flow Rate (Qwq)

The following procedure should be used to estimate peak discharges for flow through BMPs (adopted from Maryland, 2000). It relies on the volume of runoff computed using the Small Storm Hydrology Method (Pitt, 1994) and utilizes the NRCS, TR-55 Method.

Using the WQv methodology, a corresponding Curve Number (CNwq) is computed utilizing the following equation:

$$CN_{wq} = \frac{1000}{\left[10 + 5P + 10Qa - 10\sqrt{Qa^2 + 1.25QaP}\right]}$$

where:

CNwq = curve number for water quality storm event

P = 1" (rainfall for water quality storm event)

Qa = runoff volume, in inches = 1"×Rv = Rv (inches)

Rv=volumetric runoff coefficient (see previous section)

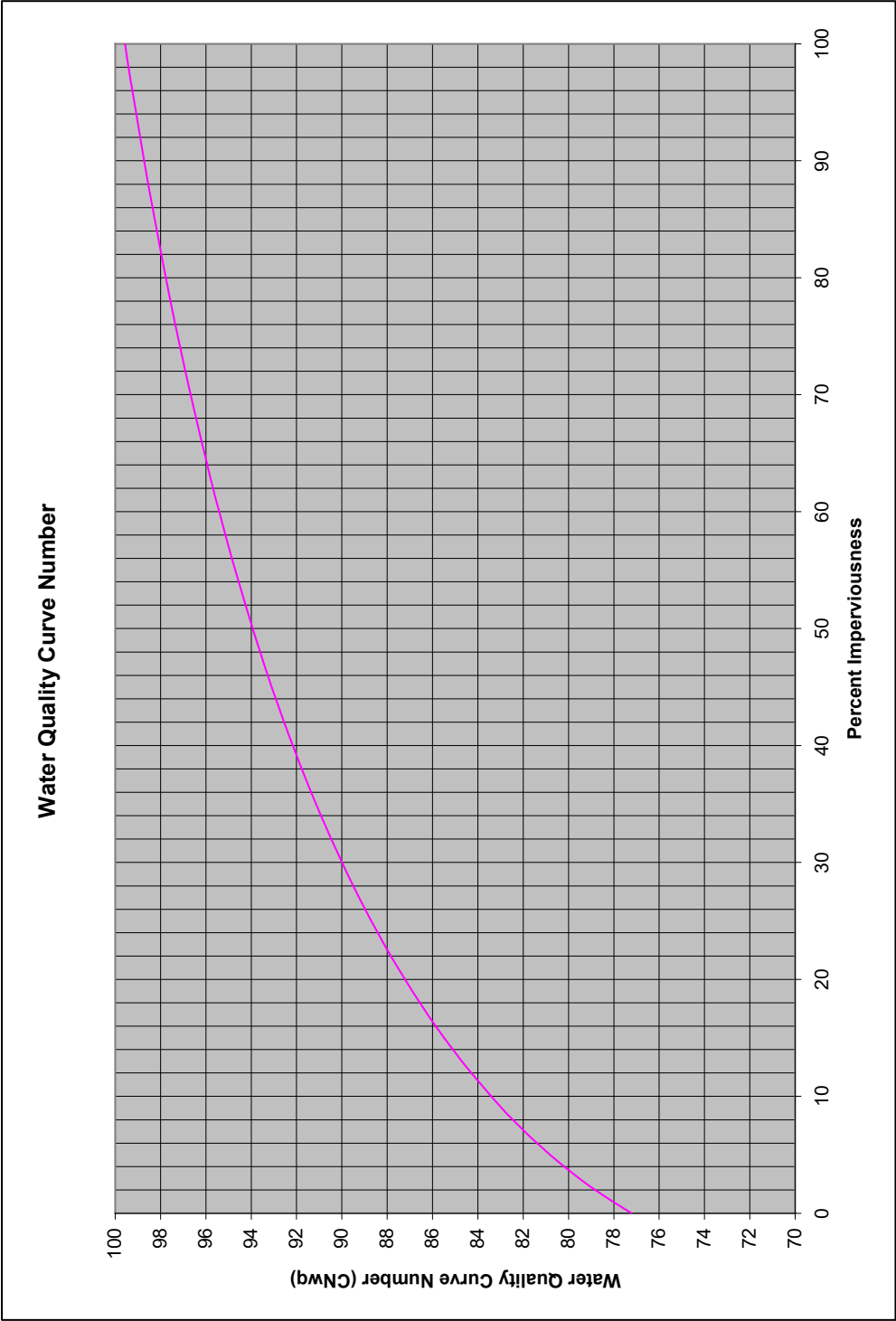
Due to the complexity of the above equation, the water quality curve number is represented as a function of percent imperviousness in **Figure 9-1**.

The water quality curve number, CNwq, is then used in conjunction with the standard calculated time-of-concentration, tc, and drainage area as the basis input for TR-55 calculations. Using the SCS Type II distribution for 1 inch of rainfall in 24-hours, the water quality treatment rate, Qwq, can then be calculated.

REFERENCES

1. Maryland Stormwater Design Manual, Volume II, Appendix D.10, 2000
2. Pitt, R., 1994, Small Storm Hydrology. University of Alabama - Birmingham. Unpublished manuscript. Presented at design of stormwater quality management practices. Madison, WI, May 17-19 1994.
3. Schueler, T.R. and R.A. Claytor, 1996, Design of Stormwater Filter Systems. Center for Watershed Protection, Silver Spring, MD.
4. United States Department of Agriculture (USDA), 1986. Urban Hydrology for Small Watersheds. Soil Conservation Service, Engineering Division. Technical Release 55 (TR-55).

Figure 9-1
Curve Number Calculation for Water Quality Storm Event





Chapter Ten

MISCELLANEOUS REQUIREMENTS

A. GRADING AND BUILDING PAD ELEVATIONS

Minimum Federal and State Requirements

For all structures located in the Special Flood Hazards Area (SFHA) as shown on the FEMA maps and/or that mapped by the IDNR based on Best Available Data, the Lowest Floor elevation, including basement, shall be at or above the flood protection grade (FPG) and therefore have a minimum of 2 feet of freeboard above the 100-year flood elevation. Additional requirements for buildings within SFHA are contained in the Hendricks County Floodplain Management Ordinance.

Additional Local Requirements

FPG for all buildings located within or adjacent to SFHA or an IDNR designated floodplain shall be shown on the secondary plat.

For all structures located outside SFHA or an IDNR designated floodplains that are subject to flooding from a detention/retention pond, the lowest adjacent grade (LAG) of all residential, commercial, or industrial buildings shall have a minimum of 2 feet of freeboard above the 100-year flood elevation or the emergency overflow weir elevation, whichever is higher.

For all structures located outside SFHA or an IDNR designated floodplains that are subject to flooding from a stream or an open ditch (an area along a stream with no floodplain designation or an area adjacent to a designated floodplain with ground elevation below 100-year flood elevation plus 2 feet), the LAG of all residential, commercial, or industrial buildings shall have a minimum of 2 feet of freeboard above the 100-year flood elevation.

For all structures fronting a flooding source other than a swale or an emergency flood route, the floor of any basements or crawl spaces (if provided) shall be a minimum of 1 foot above the normal pool level (if pond) or the 2-year flood level (if a stream or an open ditch). In addition, special considerations, based on detailed geotechnical analysis, should be made prior to considering placement of any basement below the 100-year flood elevation of an adjacent flooding source or pond.

For all structures adjacent to an emergency flood route (also referred to as overflow path/ponding areas), the minimum adjacent grade of the portion of the structure (the ground elevation next to the building after construction is completed that sits adjacent to the emergency flood route or may be subject to flooding by the emergency flood route) shall be a minimum of 1 foot above the estimated 100-year

elevation of the emergency flood route assuming that all stormwater inlets and pipes are fully clogged, with no discharge into the storm sewer system. The building adjacent grade requirements (including default elevations above the overflow route bottom) for buildings adjacent to overflow path/ponding areas are further discussed in Chapters 4 of this Manual.

For all structures adjacent to a road, the building's lowest entry elevation that is adjacent to and facing a road shall be a minimum of 1 foot above the road elevation (elevation of the gutter at the center of the lot) so that the road drainage is not directed against the building.

There shall be a positive slope drainage away from the building with maximum yard slopes that are 3:1 where soil has been disturbed during construction processes. Finished floor elevation or the lowest building entry elevation must be no less than 6 inches above finished grade around the building.

In addition to any other provisions in the Ordinance or these Standards, no buildings shall be placed within 25 feet from the top of the bank of any existing or proposed stream, drain, or watercourse, regardless of the contributing drainage area or the bank height.

B. LOT DRAINAGE

All lots shall be laid out so as to provide drainage away from all buildings, and individual lot drainage shall be coordinated with the general stormwater drainage pattern for the subdivision. Drainage shall be designed so as to avoid the concentration of stormwater runoff from a lot onto adjacent lots. Each lot owner shall maintain the lot grade, as it relates to stormwater drainage, in compliance with the approved construction plans.

No part of the lot area of any lot may contain land that is utilized as retention or detention facility or drainage pond, contains a watercourse, or is within a floodway. Where a watercourse separates the buildable area of the lot from the street by which it has access, provisions shall be made for the installation of a culvert or other appropriate structure, as approved by the Hendricks County Drainage Board and/or Hendricks County Surveyor or designee. If a subdivision contains an existing or to be developed waterbody, watercourse, or portion thereof, appropriate documentary assurances acceptable to the Hendricks County Drainage Board and/or Hendricks County Surveyor shall be provided for the maintenance of such waterbody or watercourse.

It shall be the property owners' responsibility to maintain the natural features on their lots and to take preventive measures against any and all erosion and/or deterioration of natural or manmade features on their lots.

C. ACCEPTABLE OUTLET AND ADJOINING PROPERTY IMPACTS POLICIES

Design and construction of the stormwater facility shall provide for the discharge of the stormwater runoff from off-site land areas as well as the stormwater from the area being developed (on-site land areas) to an acceptable outlet(s) (as determined by the Hendricks County Drainage Board and/or Hendricks County Surveyor) having capacity to receive upstream (off-site) and on-site drainage. A Roadside Ditch is generally not considered an adequate outlet. The flow path from the development outfall(s) to a regulated drain, a Hendricks County storm drain, or natural watercourse (as determined or approved by the Hendricks County Drainage Board and/or Hendricks County Surveyor) shall be provided on an exhibit that includes topographic information. Any existing field tile encountered during the construction shall also be incorporated into the proposed stormwater drainage system or tied to an acceptable outlet.

Where the outfall from the stormwater drainage system of any development flows through real estate owned by others prior to reaching a regulated drain or watercourse, no approval shall be granted for such drainage system until all owners of real estate and/or tenants crossed by the outfall either consent in writing to the use of their real estate or are notified of a hearing relevant to the proposed use. Notification of the time and place of the hearing shall be made in person or by certified mail at least ten (10) days prior to the hearing. Proof of notice to each landowner shall be filed by affidavit with the Hendricks County Drainage Board and/or Hendricks County Surveyor prior to the hearing. In addition, no activities conducted as part of the development shall be allowed to obstruct the free flow of floodwaters from an upstream property.

If an adequate outlet is not located on site, then off-site drainage improvements may be required. Those improvements may include, but are not limited to, extending storm sewers, clearing, dredging and/or removal of obstructions to open drains or natural water courses, and the removal or replacement of undersized culvert pipes as required by the Hendricks County Drainage Board and/or Hendricks County Surveyor.

D. Development within Floodways and Fluvial Erosion Hazard Corridors

Regulatory Floodway and Fluvial Erosion Hazard (FEH) Corridor along regulated drains or any natural stream watercourse are considered Impact Drainage Areas and must be preserved to the extent possible to minimize flooding and erosion impacts within the stream system.

Basis for Establishing Floodways

The regulatory floodway along Hendricks County streams are established as detailed in the latest edition of the Hendricks County Floodplain Management Ordinance.

Basis for Establishing Fluvial Erosion Hazard (FEH) Corridors

The Indiana Silver Jackets Hazard Mitigation Task Force has initiated a multi-agency program to identify, study and provide mitigation planning resources for communities who would like to adopt Fluvial Erosion Hazard (FEH) avoidance strategies. The resources provided by this project enable individuals and communities to better recognize areas prone to natural stream-erosion processes and adopt strategies to avoid FEH-related risks. The FEH resources define approximate setbacks for communities to better manage river corridors. The setbacks vary based on the stream's recent migration history (actively migrating or relatively stationary).

For actively migrating and relatively stationary streams, a GIS analysis algorithm generated bankfull width values for each stream segment using regional curves that are based on drainage area within each physiographic region in Indiana. For relatively stationary streams, the analysis used these values to create buffer zones of at least one bankfull width on each side (a total corridor width of 3 times bankfull width) or 100 feet on each side of the bankfull bank, whichever is greater. For actively migrating streams, GIS generated a total corridor width of 8 times bankfull width, which was manually edited and refined to reflect the digital elevation model and stream meander evidence.

It should be noted that the FEH corridors were created at a map scale of approximately 1:10,000 to 1:15,000. The depicted areas were not meant to be accurate beyond providing an approximate boundary of potential stream migration. A data layer containing FEH Corridors along Indiana streams is currently hosted by IDNR-Division of Water on their mapping portal currently at: <https://indnr.maps.arcgis.com/apps/webappviewer/index.html?id=43e7b307a0184c7c851b5068941e2e23>. The IDNR website notes that, due to its level of detail, this data is not intended for use in project design or parcel level site analysis and that a more detailed analysis of the localized geology and fluvial mechanics is necessary for the proper evaluation of the fluvial erosion hazard.

Despite its inherent level of accuracy, the FEH corridor map created by the Indiana Silver Jackets constitutes the best available data in Hendricks County and is the basis for regulating development within these corridors by Hendricks County Drainage Board. A scaled version of the Hendricks County FEH corridor map is available from the Hendricks County GIS website. More detailed mapping than that used as part of the Indiana Silver Jackets erosion hazard mapping program may be provided by the applicant if it is based on detailed field assessment acceptable to Hendricks County.

Special Requirements within Floodways and FEH Corridors

No disturbance (fill or excavation) associated with a new development or redevelopment is permitted within FEH corridors or regulatory floodways, unless such modifications are part of a stream-wide restoration plan or a watershed master plan. Any streambank stabilization effort within an FEH corridor shall require prior review by the Hendricks County Drainage Board and/or the Hendricks County Surveyor to safeguard against potential negative impacts on other properties or on the stream morphological system.

Should excavation within a floodway be allowed in special circumstances, there shall be no reduction in floodway surface area as a result of a floodway modification, unless such modification is part of a stream-wide plan or necessary to reduce flooding at an existing structure.

E. ADDITIONAL CONSIDERATION FOR DEVELOPMENT WITHIN OR ADJACENT TO BLUFF ZONES AND STEEP SLOPES

In addition to riverine erosion hazards that exist due to lateral migration of streams as discussed in Section D (above), there are hazardous areas along many bluffs and steep slopes existing in Hendricks County. For the purpose of these Standards, Bluff is defined as a natural topographic feature having:

- a. A slope that rises at least 25 feet and the grade of the slope averages 30 percent or greater, measured over a horizontal distance of 25 feet, from the toe of the slope to the top of the slope. Where the slope begins below the ordinary high water level, the ordinary high water level is the toe of the slope. See **Figure 10-1**; or
- b. A natural escarpment or cliff with a slope that rises at least ten feet above the ordinary high water level or toe of the slope, whichever is applicable, to the top of the slope, with a slope of 75 degrees or greater. See **Figure 10-2**.

These bluffs exist in many places and do not have to be necessarily along a permanent stream. They may be along the rivers (but sometimes outside the floodway and FEH zones) or along many headcut channels and developing ravines in Hendricks County that may be tributary to various streams. To prevent buildings from damage due to natural slope adjustment next to bluffs, a minimum of 40 feet of landward setback shall be required from top of the bluff as illustrated in Figures 10-1 and 10-2. If a floodway or FEH is also present on the site, the most landward limit shall govern.

The definition of other terms shown in Figures 10-1 and 10-2 are as follows:

- Bluff impact zone: A bluff and land located within 20 feet of the bluff.

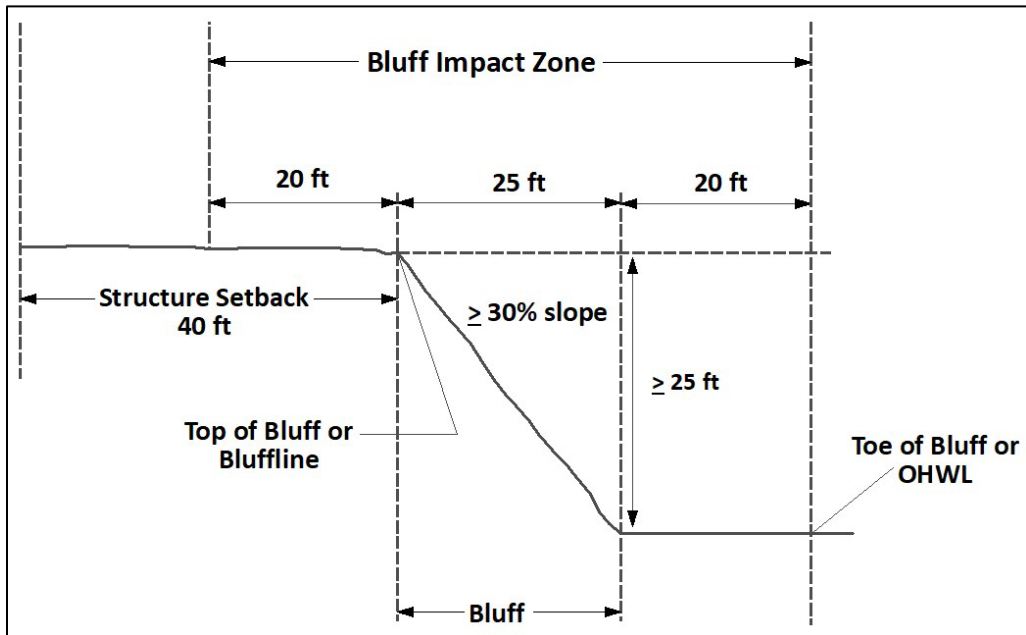
- Bluffline: A line delineating the top of the bluff. More than one bluffline may be encountered proceeding landward from the river.
- Toe of Bluff: A line along the bottom of a bluff, requiring field verification, such that the slope above the line exceeds 30 percent and the slope below the line is 30 percent or less, measured over a horizontal distance of 25 feet.
- Top of Bluff: A line along the top of a bluff, requiring field verification, such that the slope below the line exceeds 30 percent and the slope above the line is 30 percent or less, measured over a horizontal distance of 25 feet.

Where principal structures exist on the adjoining lots on both sides of a proposed building site, the minimum setback may be altered to conform to the average of the adjoining setbacks.

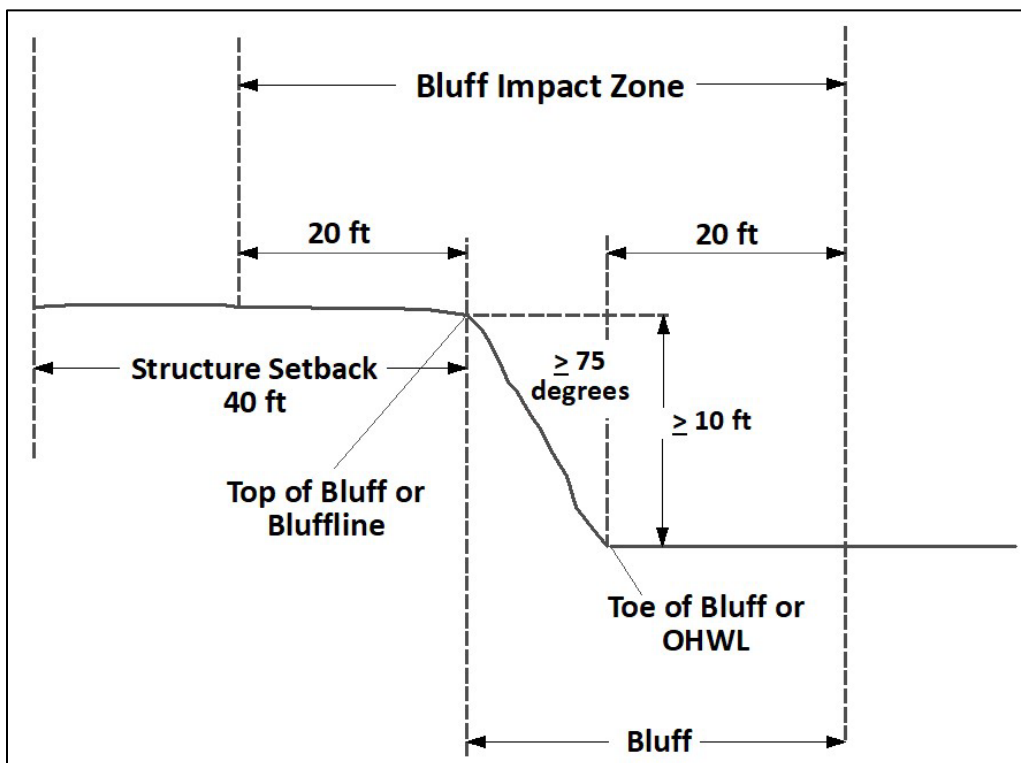
In addition to structure setback noted above, with the exception of erosion control practices sanctioned by or approved by the Hendricks County, no land disturbance (fill or excavation) shall be allowed within a Bluff Impact Zone.

Also note that the minimum setback required in these standards is just that: a minimum, which is based on national experience. When buildings or other infrastructure is proposed near bluffs or steep slopes, the applicant is encouraged to seek a detailed geotechnical evaluation that may result in needing to have a larger setback or have special provisions even when the slopes are gentler than that regulated in these Standards.

**Figure 10-1
Bluff and Bluff Impact Zone**



**Figure 10-2
Natural Escarpment Bluff and Bluff Impact Zone**



F. FLOODPLAIN STORAGE PRESERVATION STANDARDS

Floodplains exist adjacent to all natural and man-made streams, regardless of contributing drainage area or whether they have been previously identified or mapped. Due to potential impacts of floodplain loss on peak flows in streams and on the environment, floodplains are considered Impact Drainage Areas and disturbance to these areas should be avoided. When the avoidance of floodplain disturbance is not practical, the natural functions of the floodplain should be preserved to the extent possible.

In an attempt to strike a balance between the legitimate need for economic development within the Hendricks County jurisdictional area and the ever-increasing importance of and the need to preserve the natural functions of floodplains to the extent possible (especially given the ongoing and projected climate change impacts), compensatory excavation equivalent to the floodplain storage lost shall be required for all activities within area inundated by the 100-year flood elevation plus 2 feet along floodplain of streams located in Hendricks County where drainage area of the stream is equal to or larger than one square mile. The Hendricks County Drainage Board and/or Hendricks County Surveyor may alter the compensation ratio, based on extenuating circumstances, for a specific project.

General Requirements

Note that by definition, compensatory storage is the replacement of the existing floodplain and, in rare exceptions, the floodway storage lost due to fill. Compensatory storage is required when a portion of the floodplain is filled, occupied by a structure, or when as a result of a project a change in the channel hydraulics occurs that reduces the existing available floodplain storage. Compensatory storage must:

- Be provided regardless of whether the flooding source is mapped or whether flood elevations are published or not. When flood elevations are not available for a flooding source that has a drainage area equal to or larger than one (1) square miles (640 acres), the applicant is to determine the 10-year and 100-year flood elevations at the site and get them approved by the IDNR prior to use for floodplain compensation calculations.
- Equal at least 1 times the volume of flood storage lost below the 10-year and 100-year plus 2 feet flood elevations;
- Be operational prior to placement of fill, structures, or other materials temporarily or permanently placed in the regulatory floodplain;
- Be provided in the immediate vicinity of the flood storage lost, where practical;
- Be provided in such a way to mimic as close as possible the function provided by the lost floodplain storage. If the floodplain storage is to be lost outside the active flow conveyance path, then it must be

compensated for outside the flow conveyance path (e.g., a flood conveyance shelf/2-stage ditch, while improving conveyance and erosion, is not an appropriate compensation for floodplain storage lost in the floodway fringe area).

- Be provided in addition to the site retention/detention volume; and
- Drain freely and openly to the waterway.

Compensatory storage is also required to be provided incrementally such that:

- All floodplain storage/conveyance capacity lost within the floodway shall be compensated for within the floodway;
- All floodplain storage lost within the floodway fringe shall be compensated for within the floodway fringe;
- All floodplain storage lost below the existing 10-year flood elevation shall be compensated for below the proposed 10-year flood elevation; and
- All floodplain storage lost above the existing 10-year flood elevation shall be compensated for above the proposed 10-year flood elevation.

Note that compensatory storage is required for activities in the regulatory floodplain. There is no threshold to compensatory storage; any volume of fill requires compensatory storage be provided. However, the compensatory storage requirement does not apply to specific activities in the regulatory floodplain, such as the floodproofing of an existing building, where the floodproofing measures such as berms or floodwalls are within 10 feet of the building, or crossing improvements, where artificially created storage is lost due to a reduction in head loss.

Computing Compensatory Storage

Computations must show 1 times compensation for floodplain storage volume lost for 10-year and 100-year storm plus 2 feet events. Storage lost between the existing ground and the existing 10-year flood elevation must be compensated by providing 1 time the amount lost and be placed between the existing ground elevation and the proposed 10-year floodplain elevation. Storage lost between the existing 10-year and the existing 100-year plus 2 feet elevation must be compensated by providing 1 times the amount lost and be placed between the proposed 10-year elevation and proposed 100-year plus 2 feet elevation.

When preparing a grading plan, thought should be given to how compensatory storage will be quantified. The most common methodology is the use of cross sections and the “average end area method”. The following requirements should be followed when preparing cross sections:

1. Prepare a detailed topographic survey tied to North American Vertical Datum of 1988 and the Hendricks County Survey Control Network benchmarks.

2. Locate cross sections parallel to each other and perpendicular to a reference line, often times a property line or fence line. Cross sections used in a hydraulic model are always perpendicular to flood flows, and not always parallel to each other. Therefore, these are often not suitable for computing flood fringe compensatory storage volumes.
3. Plot cross sections at a standard engineering scale so as to allow the reviewer to verify areas. Horizontal scale should be a maximum of 1"=50' and vertical scale should be a maximum of 1"=5', or as approved by the County.
4. Show existing grades, proposed grades, existing and proposed 10-year flood elevations, existing and proposed 100-year flood elevations, normal water level, a reference line, and floodway limits on the cross sections on the plans.
5. Locate cross sections no more than 150 feet apart, with a minimum of three cross sections per cut/fill area, or as necessary to accurately quantify cuts and fills.
6. Locate cross sections to pick up critical features such as berms, ditches, and existing and proposed structures.
7. Each cross section should be numbered or lettered and referenced on the plans.

This information is then utilized to compute the areas of cut and fill. A sample grading plan, a typical cross section, and associated compensatory storage calculations for the 10-year flood are provided on **Figures 10-3, Figure 10-4, and Table 10-1**, respectively.

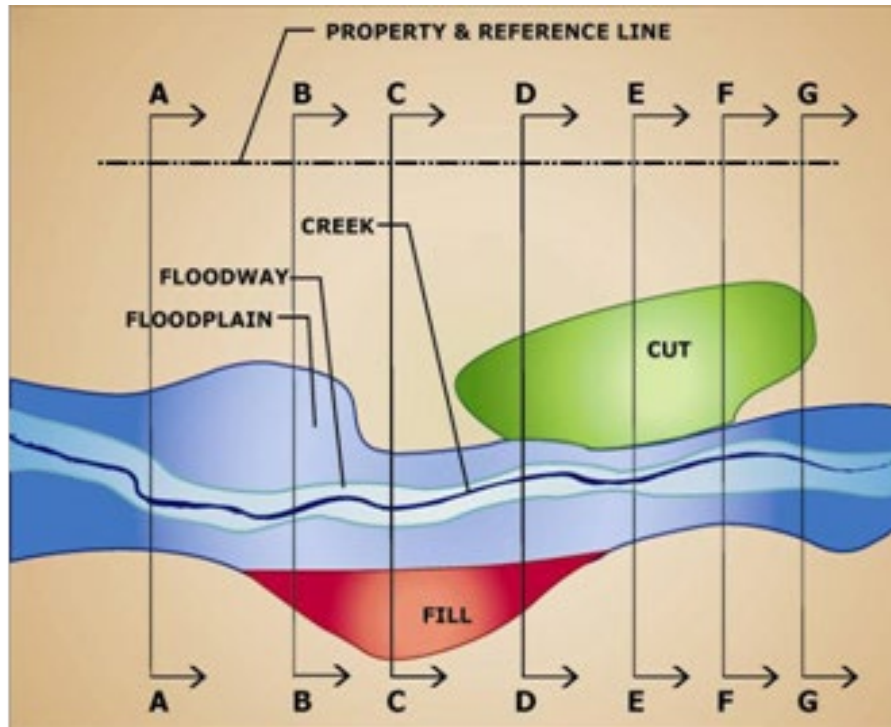
Volume of Fill between cross sections are calculated by finding the average fill cross sectional area and multiplying it by the distance between the two cross sections. For example, the fill volume between cross sections A and B is calculated as follows:

$$\begin{aligned}\text{Average Fill Area} &= (\text{Fill Area "A"} + \text{Fill Area "B"})/2 = (0 \text{ ft}^2 + 100 \text{ ft}^2)/2 = 50 \text{ ft}^2 \\ \text{Volume of Fill} &= (\text{Average Fill Area}) \times (\text{Distance}) = (50 \text{ ft}^2) \times (150 \text{ ft}) = 7,500 \text{ ft}^3\end{aligned}$$

Once the total volume of fill placed, for this example, between the 0-and 10-yr flood elevations is determined, the total required compensatory storage can be calculated and compared against the total compensatory storage volume provided by the design as shown in the table. For this example:

$$\begin{aligned}\text{Required Compensatory Storage} &= (1) \times (\text{Total Volume of Fill}) = (1) \times (36,250 \text{ ft}^3) \\ &= 36,250 \text{ ft}^3\end{aligned}$$

Figure 10-3 - Example Compensatory Storage Grading Plan



* Not to Scale & Topography not shown for clarity.

Figure 10-4 – Example Cross Section D-D

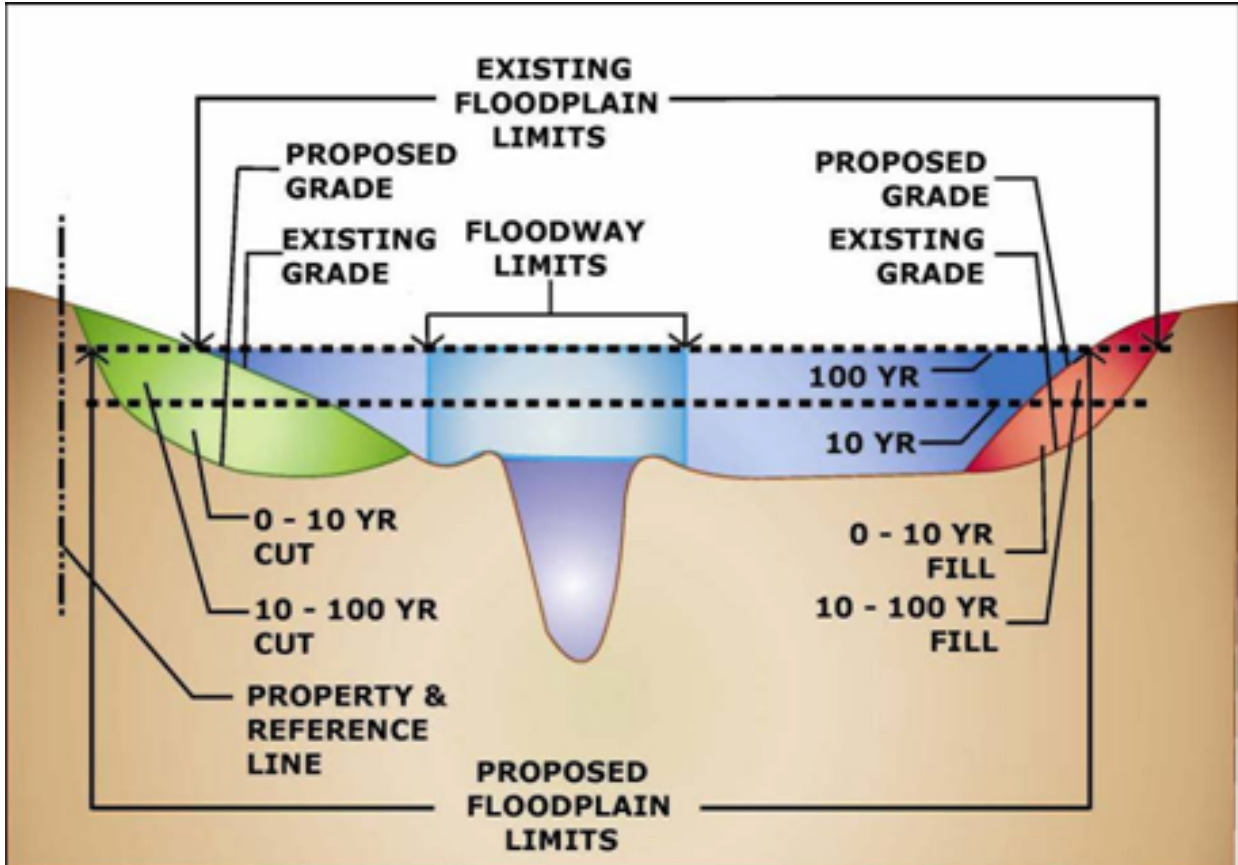


Table 1 - Example Compensatory Storage Calculations for 0-10 year event

Cross Section	Distance Between Sections (ft.)	Fill Area (sq. ft.)	Average Fill Area (sq. ft.)	Volume of Fill (cu. Ft.)	Cut Area (sq. ft.)	Average Cut (sq. ft.)	Volume of Cut (cu. Ft.)
A		0			0		
	150		50	7,500	0	0	
B		100			0		
	90		125	11,250		20	1,800
C		150			40		
	100		125	12,500		65	6,500
D		100			90		
	100		50	5,000		100	10,000
E		0			110		
	100		0	0		120	12,000
F		0			130		
	85		0	0		85	7,225
G		0			40		
Total Fill				36,250	Total Cut		37,525

Since the total amount of cut provided (37,525 ft^3 as shown in the table) is larger than that required (36,250 ft^3), the design meets the compensatory storage requirement for the 10-year flood. An additional table and calculation should be completed for the flood storage between the 10-year and 100-year plus 2 feet flood elevation in a similar manner to determine whether the design meets the compensatory storage requirement for the 100-year flood.

Location of Compensatory Storage

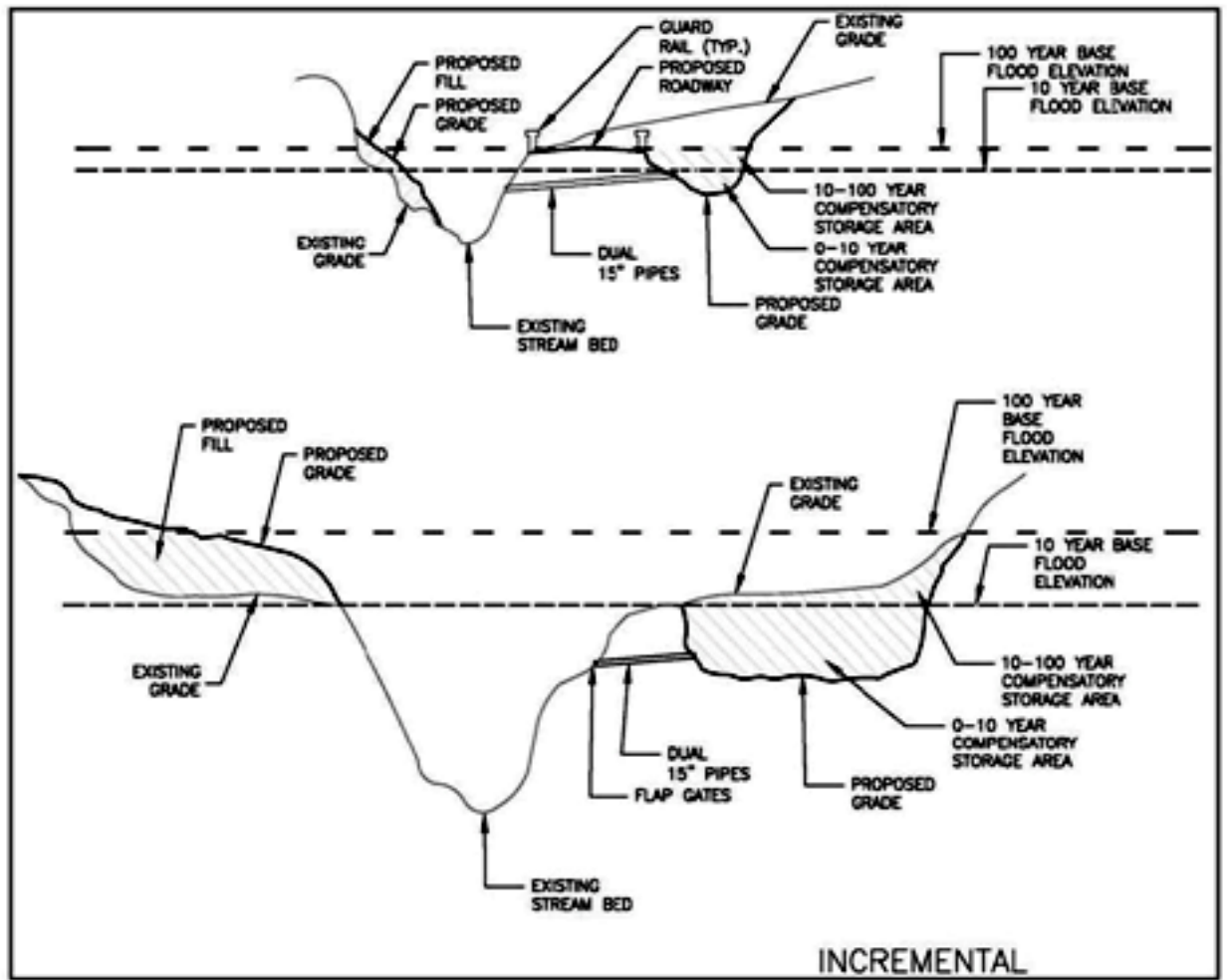
Compensatory storage must be located on-site and adjacent to or opposite the areas filled or occupied by a structure. In those rare instances when compensatory storage cannot be located adjacent to or opposite to the areas filled or occupied, engineering computations demonstrating that hydraulically equivalent compensatory storage has been provided is required. These computations must show that no increase in flood flows or flood depths will result as a result of the location of the proposed compensatory storage.

Compensatory storage must be constructed to drain freely and openly to watercourses. In some rare cases it may be necessary to install pipes to construct and/or operate a compensatory storage basin. This may occur when site constraints, such as a roadway or sidewalk, separate the waterway from the compensatory storage area. This is illustrated in the top half of **Figure 10-5**.

Another scenario may occur when a site cannot meet the incremental storage requirements discussed in this document. If incremental storage requirements from the 10-year to 100-year plus 2 feet elevations cannot be met, pipes could be installed with a flap gate to prevent the water from entering from the stream bed at lower elevations. The berm could then be set at the elevation of the 10-year flood elevation, thus allowing the storage to only become effective above the 10-year flood elevation. This is illustrated in the bottom half of the illustration in Figure 10-5.

The use of pipes in compensatory storage will require approval by the County. If approved, two pipes will be required to reduce the risk of clogging. Pipes must be a minimum of 15 inches in diameter so as to allow water to enter and exit freely with a minimum head differential. If compensatory storage is proposed to be combined with detention, it must be demonstrated the compensatory storage and detention do not interfere with one another.

Figure 10-5 – Example of Compensatory Storage Connection to Stream through Pipe



Compensatory Storage in the Regulatory Floodway

Only fill associated with appropriate uses of the regulatory floodway may be allowed to be placed within the limits of the floodway. When in rare circumstances, fill is allowed, all provisions discussed above relating to compensatory storage must be met in addition to the items discussed below.

- Any fill placed within the existing floodway must be compensated for within the proposed floodway.
- All floodway storage lost below the existing 10-year base flood elevation shall be replaced below the proposed 10-year base flood elevation.
- All floodway storage lost between the existing 10-year flood elevation and the existing 100-year flood plus 2 feet elevation shall be replaced between the proposed 10-year and proposed 100-year flood plus 2 feet elevation.

G. STANDARDS ASSOCIATED WITH DAMS AND LEVEES

Dams and levees have the potential for significant, sometimes catastrophic consequences should they fail. In order to minimize the potential for loss of life and public safety, decrease the potential for increased flood damage and disaster costs, and safeguard the downstream property rights, the following shall be required by the Hendricks County Drainage Board and/or Hendricks County Surveyor for any proposed new or improvements to any existing dam or levee. These requirements are in addition to what is normally required for other development subject to this Ordinance and/or that required by State or Federal agencies.

- i. Design of new dams and improvements to existing dams shall follow the requirements of the latest edition of IDNR-Division of Water "General Guidelines for New Dams and Improvements to Existing Dams in Indiana" as well as principles provided in the latest edition of "Indiana Dam Safety Inspection Manual". The design parameters shall be appropriate for the actual hazard potential of the dam based on an up-to-date breach inundation map discussed in Item iii (below).
- ii. Design of levee/floodwalls shall follow the FEMA requirements and guidelines provided in 44 CFR Section 65.10 and USACE Engineer Manual 1110-2-193, Design and Construction of Levees.
- iii. An Incident and Emergency Action Plan (IEAP), including a detailed dam breach inundation map, shall be developed in accordance with the template provided in the latest edition of "Indiana Dam Safety Inspection Manual" and submitted to the Hendricks County Drainage Board and/or Hendricks County Surveyor. The detailed dam breach inundation map referenced in this paragraph shall be developed for both "Sunny Day Breach" Scenario (breach during normal loading conditions) and for maximum loading condition with breach assumed to occur as the spillway system is passing the Spillway Design Flood associated with the dam ("SDF + Breach" Scenario).
- iv. For proposed new dams or dam improvements involving an increase in the dam height: Unless the "Sunny Day Breach Inundation Area" is entirely contained within the applicant's property and/ or contained within the existing 100-year floodplain, a copy of recorded flood/inundation easement or a recorded written consent for every property within the potential "Sunny Day Breach Inundation Area" shall be submitted to the Hendricks County Drainage Board and/or Hendricks County Surveyor. In addition, all the affected property owners whose properties are located within the "SDF + Breach Inundation Area" must be notified of a hearing relevant to the proposed added flooding risk, should such a man-made structure suffer a catastrophic failure. Notification of the time and place of the hearing shall

be made in person or by certified mail at least five (5) to ten (10) days prior to the hearing. Proof of notice to each landowner shall be filed by affidavit with the Hendricks County Drainage Board and/or Hendricks County Surveyor prior to the hearing.

- v. A copy of a Management and Maintenance Plan for the proposed dam or levee developed in accordance with the latest edition of "Indiana Dam Safety Inspection Manual" shall be submitted to the Hendricks County Drainage Board and/or Hendricks County Surveyor.
- vi. Unless the dam is subject to and regulated by IDNR, following the permitting and construction of the dam or levee, a copy of a formal periodic inspection report prepared in accordance with the recommendations contained in the latest edition of "Indiana Dam Safety Inspection Manual" shall be submitted to the Hendricks County Drainage Board and/or Hendricks County Surveyor along with evidence that the identified maintenance deficiencies have been corrected. The inspection report has to be submitted as it gets completed in accordance with the inspection frequency recommended in the latest edition of "Indiana Dam Safety Inspection Manual".

H. STANDARDS ASSOCIATED WITH PROPOSED DEVELOPMENTS DOWNSTREAM OF DAMS

As indicated in the previous section, dams have the potential for significant, sometimes catastrophic consequences should they fail. Placing new development downstream of an existing dam does not only expose the future residents or users of the newly developed areas to a potential new significant risk, but could also have an impact on the hazard rating of the dam itself, which can in turn make the dam non-compliant with the state and federal standards. In order to minimize the potential for loss of life and public safety, decrease the potential for increased flood damage and disaster costs, and safeguard the upstream dam owner's rights, the following shall be required by the Hendricks County Drainage Board and/or Hendricks County Surveyor for any proposed new development or redevelopment downstream of an existing dam. These requirements are in addition to what is normally required for new development or redevelopment subject to these Standards.

- i. Dam breach inundation maps have been created for several existing dams within the State of Indiana by the dam owners, IDNR, or others as part of development of individual IEAPs for these dams. When the development location is suspected by the applicant or the Hendricks County Drainage Board and/or Hendricks County Surveyor to be within an existing dam's breach inundation zone, the applicant is required to include a copy of the breach inundation mapping associated with that dam as part of its stormwater management permit application. To locate such a mapping, the

- applicant should contact the dam owner, IDNR- Division of Water, Hendricks County Drainage Board and/or Hendricks County Surveyor, or other agencies to obtain the breach inundation map for the dam, if available. If no dam breach inundation map can be located for the dam, it will be the applicant's responsibility to produce an Hendricks County Drainage Board and/or Hendricks County Surveyor-acceptable dam breach mapping either through directly contracting with a qualified engineer or through funding the production of such a map by the Hendricks County Drainage Board and/or Hendricks County Surveyor review consultant in accordance with standards and guidelines established by the IDNR-Division of Water.
- ii. If the location of the proposed development falls within the dam breach inundation zone on the map discussed under Item i (above), additional requirements as determined by Hendricks County Drainage Board and/or Hendricks County Surveyor may be imposed before a permit is issued and the development is allowed to occur. The noted additional requirements depend on several variables and are expected to vary case by case. Typical requirements could include relocating a portion or all of the proposed development to areas outside of the dam breach inundation zone, cost-sharing with the dam owner in necessary upgrades to the dam as a result of a potential hazard classification increase, addition of structural protection measures (such as flood protection levees), additional freeboard requirements, development and periodic exercise of warning and evacuation plans, and other measures considered necessary by Hendricks County Drainage Board and/or Hendricks County Surveyor to minimize the potential for loss of life and public safety, decrease the potential for increased flood damage and disaster costs, and safeguard the upstream dam owner's rights.

I. SPECIAL STANDARDS FOR PROPOSED SOLAR FARMS

Solar development has expanded over the last several years as Indiana and other states have invested in this important resource to further greenhouse gas emission reductions. The large amount of impervious surface inherent in the construction of a large-scale solar array entails challenges not encountered in traditional development projects. If not properly managed through appropriate design and mitigation measures, stormwater discharged during and after the construction of solar arrays can be a significant source of pollution resulting from increased runoff, erosion, and sedimentation, which can adversely impact adjoining properties, streams, wetlands, or other natural resources. Solar installations must be properly designed to assure soil stabilization, minimize soil disturbance and soil compaction, and address ineffective controls to manage the total runoff volume and velocity that can lead to the loss of topsoil, erosion and sediment discharges from disturbed areas and stormwater outlets, and erosion along downstream channels and streambanks. The ability to address such significant environmental

problems during construction and post-construction becomes more difficult as site imperviousness increases.

Solar projects that use traditional elevated solar panels are unique because they contain an impervious surface (elevated solar panel) that often has a pervious surface (vegetation) underneath the panel. Stormwater runoff from solar projects is generated primarily from rain that falls on access roads, inverter pads, and solar panels. Water that falls off solar panels runs across the panel to the dripline, and eventually falls to the underlying surface. Some of this water will infiltrate and some will run off downslope and eventually off site.

One of the most notable impacts that solar sites have on water quality is the potential for erosion and/or scour at the dripline. To minimize the erosion and/or scour at the dripline, the lowest vertical clearance of any solar array shall be no greater than 10 feet. Also, erosion prevention and sediment control Best Management Practices (BMPs) as detailed in Chapter 7 of these Standards must be utilized during construction.

In addition to providing construction BMPs, Solar projects must adhere to the post-construction stormwater management requirements, including providing the required Water Quality Volume (WQv) and Channel Protection Volume (CPv) described in Chapter 8 of these Standards, as well as peak flow control (detention) requirements described in Chapter 6. However, because solar farms—particularly the panels—have unique characteristics, not like constructing a building or road, they often inherently include stormwater disconnection features that qualifies them for recognition/credit afforded to the Stormwater Disconnection BMP, which similar to typical solar panel farms rely on maintaining sheet flow and infiltration in adequately-sized, vegetative areas receiving runoff. The Stormwater Disconnection BMP is detailed in Appendix D1. Per recommendations from the Center for Watershed Protection, the following Stormwater Disconnection recognitions/credits are established as part of these standards for solar farms that meet the conditions stated in these standards:

- i. WQv: Up to 100% of the required Water Quality Volume, proportionate to the percentage of total disconnected area to total site impervious area, may be subtracted from the required WQv.
- ii. CPv: For determining the Channel Protection Volume (CPv), the post-construction CN for the impervious area treated by the stormwater disconnection BMP may be determined assuming the treated area is “Meadow” according to the NRCS TR-55 CN guidance table (for the next less infiltrating hydrologic soil group than the pre-construction hydrologic soil group, since the area underneath panels is assumed disturbed/compacted during construction).

- iii. Qp (2, 10, 100): For determining the peak flow controls (detention), the post-construction CN for the area treated by the stormwater disconnection BMP, needed for determining post-construction peak flows (Qp) for 2, 10, and 100-year storms, may be determined assuming the treated area is “Meadow” according to the NRCS TR-55 CN guidance table (for the next less infiltrating hydrologic soil group than the pre-construction hydrologic soil group, since the area underneath panels is assumed disturbed/compacted during construction).

In order for the solar farm developments to be eligible for Stormwater Disconnection BMP recognitions/credits, the following design and construction guidelines must be met (Items d and g are required for all proposed solar farms regardless of whether Stormwater Disconnection recognition/credit is being sought):

- i. Roadways, gravel surfaces, transformer pads, and level spreaders within the solar field are considered effective impervious cover for the purposes of calculating Water Quality Volume (WQv), Channel Protection Volume (CPv), and post-construction peak flows.
- ii. All solar panels in the array should also be considered additional effective impervious cover for the purposes of calculating the WQv, CPv, and post-construction peak flow unless ALL the following conditions are met:
 - a) The vegetated area receiving runoff between rows of solar panels (see **Figures 10-6** and **10-7**, below) is equal to or greater than the average width of the row of solar panels draining to the vegetated area.
 - b) Overall site conditions and solar panel configuration within the array are designed and constructed such that the runoff remains as sheet flow across the entire site. Design array to ensure a perpendicular layout of drip edge to slope direction or install devices such as a Level Spreader to ensure sheet flow from the drip edge. Level Spreaders shall be designed in accordance with the Level Spreader fact sheet contained in Appendix D1.
 - c) The following conditions are satisfied regarding the design of the post-construction slope of the site:
 - For slopes less than or equal to 5%, appropriate vegetation shall be established as indicated in **Figure 10-6**, below.

- For slopes greater than 5%, but less than 10%, practices including, but not limited to, the use of level spreaders, infiltration trenches, or similar energy dissipating practices as described in **Figure 10-7**, below, shall be used to ensure long term sheet flow conditions.
 - For slopes equal to or greater than 10% and less than 15%, the Plan includes specific engineered stormwater control measures, such as level spreaders, infiltration trenches, or similar energy dissipating practices, with detailed specifications that are designed to provide permanent stabilization and non-erosive conveyance of runoff to the property line of the site or downgradient from the site.
 - Slopes greater than 15% are not qualified for a stormwater disconnection recognition/credit.
- d) The lowest vertical clearance of the solar panels above the ground should not be greater than ten (10) feet. The panels should, however, be at an adequate height to support vegetative growth and maintenance beneath and between the panels. If the lowest vertical clearance of the solar panels above the ground is greater than ten (10) feet, non-vegetative control measures will be necessary to prevent/control erosion and scour along the drip line or otherwise provide energy dissipation from water running off the panels.
- e) Disconnecting impervious surfaces works best in undisturbed soils. To minimize disturbance and compaction, construction vehicles and equipment should avoid areas used for disconnection during installation of the solar panels. Hydrologic Soil Group D soils or soils that are compacted by construction equipment may need to be tilled to a depth of four to six inches and/or amended to increase permeability.
- f) Groundcover vegetation must be maintained in good condition in those areas receiving disconnected runoff. Areas receiving runoff should be protected (e.g., planting shrubs or trees along the perimeter) from future compaction. Vegetated areas shall not be subject to chemical fertilization or herbicides/pesticides except for those applications that are necessary to get vegetation established and which follow an approved Erosion and Sediment Pollution Control Plan.

To maximize the potential for infiltration and reduce maintenance, the use of native deep-rooted vegetative cover under the panels and between the panel rows is highly encouraged. To achieve a native

deep-rooted vegetative cover, a mixture of perennial grasses and wildflowers is recommended with a diversity of forbs or flowering plants that bloom throughout the growing season. Blooming shrubs may also be used in buffer areas as appropriate for visual screening. Perennial vegetation (grasses and forbs) should be native to Indiana, but where appropriate to the vegetative management plan goals, may also include other naturalized and non-invasive species which provide habitat for pollinators and wildlife and/or other ecosystem services.

- g) A fifty (50) foot buffer should be maintained between any part of the solar array and any “watercourse” or “waterbody” as that term is defined in Appendix A of these standards. The buffer shall consist of undisturbed existing vegetation or native shrub plantings.
- h) Similar to other post-construction BMPs, the vegetated area underneath the panels, the vegetated area receiving runoff, and any buffer areas will need to be mapped, maintained in accordance with the stormwater Management operation and maintenance manual, and covered by the recorded maintenance agreement described in Chapter 8 of these standards.

Depending on the layout and number of panels installed, the stormwater disconnection BMP may address some or all of the stormwater management requirements (WQv) for an individual project. Where the imperviousness is high or there is other infrastructure (e.g., access roads, transformers), additional runoff may need to be treated. Further reduction in the remaining required Water Quality, Channel Protection, and Peak flow control volumes is possible through utilizing the BMPs described as part of the LID track in Chapter 8 of these standards.

A solar panel project should ideally be installed and placed outside of the floodplain or detention facilities. If proposed to be placed within a floodplain or in a dry detention facility, panels (all tilt positions) must be installed at or above the flood protection grade (2 feet above the BFE) or at or above the 100-year emergency overflow of the detention facility plus one foot. This includes all electrical systems associated with the panels. If the solar array project is proposed within floodway portion of the floodplain, the project shall also require a Construction in Floodway Permit from the IDNR.

Figure 10-6
Typical Solar Panel Installation with Slopes $\leq 5\%$

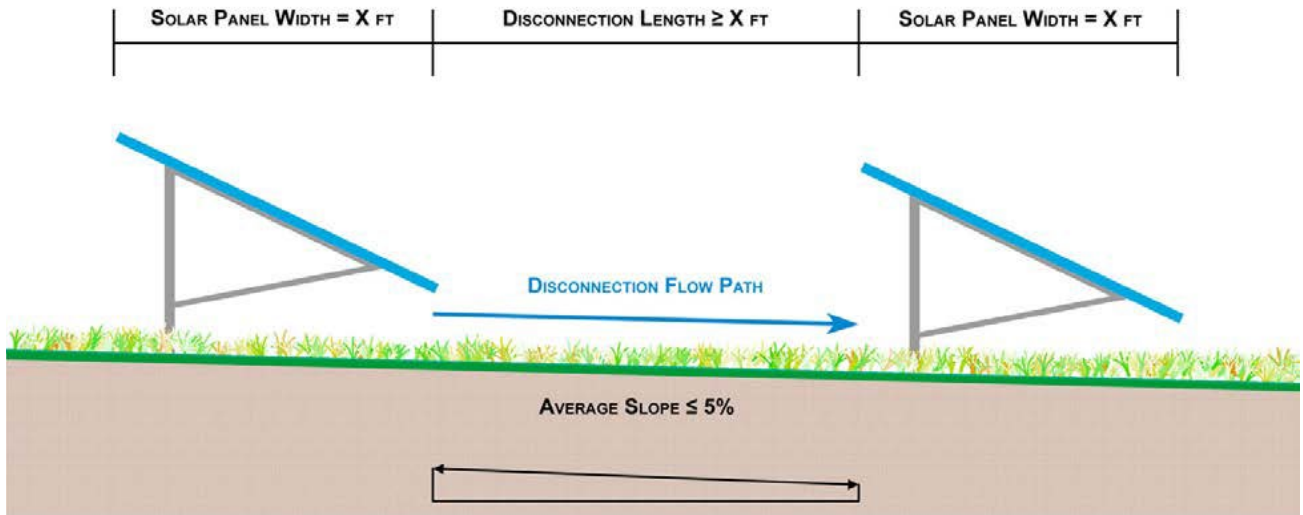
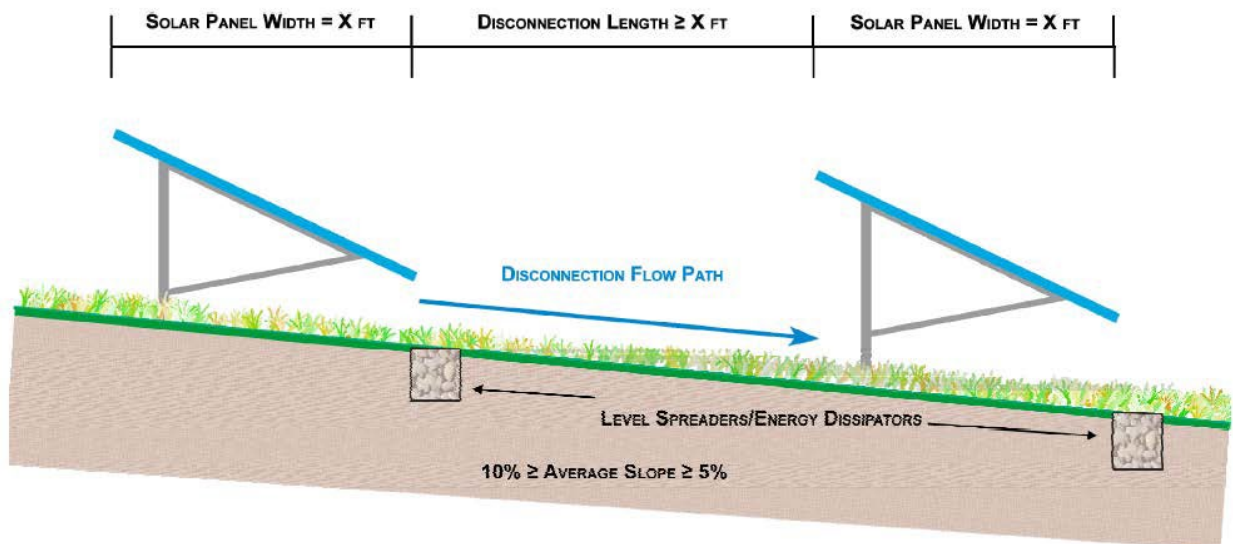


Figure 10-7
Typical Solar Panel Installation with Slopes $> 5\%$ and $\leq 10\%$



Source: Maryland Department of the Environment: Stormwater Design Guidance
 – Solar Panel Installations

APPENDIX A

ABBREVIATIONS AND DEFINITIONS



APPENDIX A

ABBREVIATIONS AND DEFINITIONS

ABBREVIATIONS

BFE	Base Flood Elevation
BMP	Best Management Practice
CFS	Cubic Feet Per Second
CLOMR	Conditional Letter of Map Revision (from FEMA)
CLOMR-F	Conditional Letter of Map Revision Based on Fill (from FEMA)
CN	Curve Number
COE	United States Army Corps of Engineers
CSMP	Comprehensive Stormwater Management Program
CSO	Combined Sewer Overflow
CWA	Clean Water Act
ERM	Elevation Reference Mark
E&SC	Erosion and Sediment Control
EPA	Environmental Protection Agency
ETJ	Extraterritorial Jurisdiction
FBFM	Flood Boundary and Floodway Map
FEH	Fluvial Erosion Hazard
FEMA	Federal Emergency Management Agency
FHBM	Flood Hazard Boundary Map
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FPG	Flood Protection Grade
FPS	Feet Per Second
GIS	Geographical Information System
GPS	Global Positioning System
HGL	Hydraulic Grade Line

HHW	Household Hazardous Waste
HUC	Hydrologic Unit Code
IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
INDOT	Indiana Department of Transportation.
LAG	Lowest Adjacent Grade
LID	Low Impact Development
LOMA	Letter of Map Amendment (from FEMA)
LOMR	Letter of Map Revision (from FEMA)
LOMR-F	Letter of Map Revision Based on Fill (from FEMA)
MCM	Minimum Control Measure
MS4	Municipal Separate Storm Sewer System
NAVD	North American Vertical Datum of 1988
NFIP	National Flood Insurance Program
NGVD 1929	National Geodetic Vertical Datum of 1929
NRCS	USDA-Natural Resources Conservation Service
NPDES	National Pollution Discharge Elimination System
NPS	Non-point source
POTW	Publicly Owned Treatment Works
SFHA	Special Flood Hazard Area
SWCD	Soil and Water Conservation District
SWPPP	Stormwater Pollution Prevention Plan
SWQMP	Stormwater Quality Management Plan
Tc	Time of Concentration
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids

USCS	Unified Soil Classification System
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service

DEFINITIONS

Acre-Foot (AF). A measure of water volume equal to the inundation of a flat one-acre area to a depth of one foot (43,560 cubic feet).

Administering authority. The designated unit of government given the authority to issue permits.

Agricultural land disturbing activity. Tillage, planting, cultivation, or harvesting operations for the production of agricultural or nursery vegetative crops. The term also includes pasture renovation and establishment, the construction of agricultural conservation practices, and the installation and maintenance of agricultural drainage tile. For purposes of this Technical Standards, the term does not include land disturbing activities for the construction of agricultural related facilities, such as barns, buildings to house livestock, roads associated with infrastructure, agricultural waste lagoons and facilities, lakes and ponds, wetlands; and other infrastructure.

Agricultural land use conservation practices. Use of land for the production of animal or plant life, including forestry, pasturing or yarding of livestock, and planting, growing, cultivating, and harvesting crops for human or livestock consumption. Practices that are constructed on agricultural land for the purposes of controlling soil erosion and sedimentation. These practices include grass waterways, sediment basins, terraces, and grade stabilization structures.

Amortization Period. The length of time used to repay a debt or mortgage or to depreciate an initial cost.

Antecedent Runoff Condition. The index of runoff potential before a storm event. The index, developed by the Soil Conservation Service (SCS), is an attempt to account for the variation of the SCS runoff curve number (CN) from storm to storm.

Backflow Preventer. Device that allows liquids to flow in only one direction in a pipe. Backflow preventers are used on sewer pipes to prevent a reverse flow during flooding situations.

Backwater. The rise in water surface elevation caused by some obstruction such as a narrow bridge opening, buildings or fill material that limits the area through which the water shall flow.

Base Flood Elevation. The water surface elevation corresponding to a flood having a one percent probability of being equaled or exceeded in a given year.

Base Flood. See "Regulatory Flood".

Base Flow. Stream discharge derived from groundwater sources as differentiated from surface runoff. Sometimes considered to include flows from regulated lakes or reservoirs.

Basement. A building story that is all or partly underground but having at least one-half of its height below the average level of the adjoining ground. A basement shall not be counted as a story for the purpose of height regulations.

Benchmark. A marked point of known elevation from which other elevations may be established.

Best Management Practices. Design, construction, and maintenance practices and criteria for stormwater facilities that minimize the impact of stormwater runoff rates and volumes, prevent erosion, and capture pollutants.

Buffer Strip. An existing, variable width strip of vegetated land intended to protect water quality and habitat.

Building. See “structure”.

Capacity of a Storm Drainage Facility. The maximum flow that can be conveyed or stored by a storm drainage facility without causing damage to public or private property.

Catch Basin. A chamber usually built at the curb line of a street for the admission of surface water to a storm drain or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.

Centerline of Channel. The thalweg of a channel.

Channel Improvement. Alteration, maintenance, or reconstruction of the channel area for the purpose of improving the channel capacity or overall drainage efficiency. The noted “improvement” does not necessarily imply water quality or habitat improvement within the channel or its adjacent area.

Channel Modification. Alteration of a channel by changing the physical dimensions or materials of its bed or banks. Channel modification includes damming, rip-rapping or other armoring, widening, deepening, straightening, relocating, lining, and significant removal of bottom or woody vegetation. Channel modification does not include the clearing of dead or dying vegetation, debris, or trash from the channel. Channelization is a severe form of channel modification typically involving relocation of the existing channel (e.g., straightening).

Channel Stabilization. Protecting the sides and bed of a channel from erosion by controlling flow velocities and flow directions using jetties, drops, or other structures and/or by fining the channel with vegetation, riprap, concrete, or other suitable lining material.

Channel. A portion of a natural or artificial watercourse which periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. It has a defined bed and banks which serve to confine the water.

Class V injection well. A type of well, which typically has a depth greater than its largest surface dimension, emplaces fluids into the subsurface, and does not meet the definitions of Class I through Class IV wells as defined under 40 CFR 146.5. While the term includes the specific examples described in 40 CFR 144.81, septic systems that serve more than one (1) single-family dwelling or provide service for non-domestic waste, dug wells, bored wells, improved sinkholes, french drains, infiltration sumps, and infiltration galleries, it does not include surface impoundments, trenches, or ditches that are wider than they are deep.

Closed Conduit. A pipe, tube, or tile used for transmitting water.

Combined Sewer Overflow. A system designed and used to receive and transport combined sewage so that during dry periods the wastewater is carried to a treatment facility. During storm events, the excess water is discharged directly into a river, stream, or lake without treatment.

Compensatory Storage. An artificial volume of storage within a floodplain used to balance the loss of natural flood storage capacity when artificial fill or substructures are placed within the floodplain.

Compost. Organic residue (or a mixture of organic residue and soil) that has undergone biological decomposition until it has become relatively stable humus.

Comprehensive Stormwater Management Program. A comprehensive stormwater program for effective management of stormwater quantity and quality throughout the community.

Constructed Wetland. A manmade shallow pool that creates growing conditions suitable for wetland vegetation and is designed to maximize pollutant removal.

Construction activity. Land disturbing activities, and land disturbing activities associated with the construction of infrastructure and structures. This term does not include routine ditch or road maintenance or minor landscaping projects.

Construction plan. A representation of a project site and all activities associated with the project. The plan includes the location of the project site, buildings and other infrastructure, grading activities, schedules for implementation and other pertinent information related to the project site. A storm water pollution prevention plan is a part of the construction plan.

Construction site access. A stabilized stone surface at all points of ingress or egress to a project site, for the purpose of capturing and detaining sediment carried by tires of vehicles or other equipment entering or exiting the project site.

Contiguous. Adjoining or in actual contact with.

Contour Line. Line on a map which represents a contour or points of equal elevation.

Contour. An imaginary line on the surface of the earth connecting points of the same elevation.

Contractor or subcontractor. An individual or company hired by the project site or individual lot owner, their agent, or the individual lot operator to perform services on the project site.

Control Structure. A structure designed to control the rate of flow that passes through the structure, given a specific upstream and downstream water surface elevation.

Conveyance. Any structural method for transferring stormwater between at least two points. The term includes piping, ditches, swales, curbs, gutters, catch basins, channels, storm drains, and roadways.

Convolution. The process of translating precipitation excess into a runoff hydrograph.

Crawl Space. Low space below first floor of a house where there has not been excavation deep enough for a basement, usually less than seven (7) feet in depth, but where there is access for pipes, ducts, utilities and similar equipment.

Critical Duration Analysis. The process of testing different rainfall durations to find that “critical duration”, which produces the highest peak runoff or the highest storage volume.

Cross-Section. A graph or plot of ground elevation across a stream valley or a portion of it, usually along a line perpendicular to the stream or direction of flow.

Crown of Pipe. The elevation of top of pipe.

Cubic Feet Per Second (CFS). Used to describe the amount of flow passing a given point in a stream channel. One cubic foot per second is equivalent to approximately 7.5 gallons per second.

Culvert. A closed conduit used for the conveyance of surface drainage water under a roadway, railroad, canal or other impediment.

Curve Number (CN). The Soil Conservation Service index that represents the combined hydrologic effect of soil, land use, land cover, hydrologic condition and antecedent runoff condition.

Dam. A barrier to confine or impound water for storage or diversion, to prevent gully erosion, or to retain soil, sediment, or other debris.

Damage. Measurable rise in flood heights on buildings currently subject to flooding, flooding of buildings currently not subject to flooding and increases in volume or velocity to the point where the rate of land lost to erosion and scour is substantially increased.

Datum. Any level surface to which elevations are referred, usually Mean Sea Level.

Dechlorinated swimming pool discharge. Chlorinated water that has either sat idle for seven (7) days following chlorination prior to discharge to the MS4 conveyance, or, by analysis, does not contain detectable concentrations (less than five-hundredths (0.05) milligram per liter) of chlorinated residual.

Depressional Storage Areas. Non-riverine depressions in the earth where stormwater collects. The volumes are often referred to in units of acre-feet.

Design Storm. A selected storm event, described in terms of the probability of occurring once within a given number of years, for which drainage or flood control improvements are designed and built.

Detention Basin. A facility constructed or modified to restrict the flow of storm water to a prescribed maximum rate, and to detain concurrently the excess waters that accumulate behind the outlet.

Detention Facility. A facility designed to detain a specified amount of stormwater runoff assuming a specified release rate. The volumes are often referred to in units of acre-feet.

Detention Storage. The temporary detaining of storage of stormwater in storage facilities, on rooftops, in streets, parking lots, school yards, parks, open spaces or other areas under predetermined and controlled conditions, with the rate of release regulated by appropriately installed devices.

Detention Time. The theoretical time required to displace the contents of a tank or unit at a given rate of discharge (volume divided by rate of discharge).

Detention. Managing stormwater runoff by temporary holding and controlled release.

Detritus. Dead or decaying organic matter; generally contributed to stormwater as fallen leaves and sticks or as dead aquatic organisms.

Developer. Any person financially responsible for construction activity, or an owner of property who sells or leases, or offers for sale or lease, any lots in a subdivision.

Development. Any man-made change to improved or unimproved real estate including but not limited to:

1. Construction, reconstruction, or placement of a building or any addition to a building;
2. Construction of flood control structures such as levees, dikes, dams or channel improvements;
3. Construction or reconstruction of bridges or culverts;
4. Installing a manufactured home on a site, preparing a site for a manufactured home, or installing a recreational vehicle on a site for more than hundred eight (180) days;
5. Installing utilities, erection of walls, construction of roads, or similar projects;

6. Mining, dredging, filling, grading, excavation, or drilling operations;
7. Storage of materials; or
8. Any other activity that might change the direction, height, or velocity of flood or surface waters.

“Development” does not include activities such as the maintenance of existing buildings and facilities such as painting, re-roofing, resurfacing roads, or gardening, plowing and similar agricultural practices that do not involve filling, grading, excavation, or the construction of permanent buildings.

Direct Release. A method of stormwater management where runoff from a part or the entire development is released directly to the receiving stream without providing detention.

Discharge In the context of water quantity provisions, usually the rate of water flow, i.e., a volume of fluid passing a point per unit time commonly expressed as cubic feet per second, cubic meters per second, gallons per minute, or millions of gallons per day. In the context of water quality provisions, the discharge means any addition of liquids or solids to a water body or a flow conveyance facility.

Disposal. The discharge, deposit, injection, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land/or water so that the solid waste or hazardous waste, or any constituent of the waste, may enter the environment, be emitted into the air, or be discharged into any waters, including

Ditch. A man-made, open drainageway in or into which excess surface water or groundwater drained from land, stormwater runoff, or floodwaters flow either continuously or intermittently.

Drain. A buried slotted or perforated pipe or other conduit (subsurface drain) or a ditch (open drain) for carrying off surplus groundwater or surface water.

Drainage Area. The area draining into a stream at a given point. It may be of different sizes for surface runoff, subsurface flow and base flow, but generally the surface runoff area is considered as the drainage area.

Drainage Classification (soil). As a natural condition of the soil, drainage refers to both the frequency and duration of periods when the soil is free of saturation. Soil drainage conditions are defined as:

- *Well-drained*--Excess water drains away rapidly, and no mottling occurs within 36 in. of the surface.
- *Moderately well drained*--Water is removed from the soil somewhat slowly resulting in small but significant periods of wetness, and mottling occurs between 18 and 36 in.
- *Poorly drained*--Water is removed so slowly that it is wet for a large part of the time, and mottling occurs between 0 and 8 in.
- *Somewhat poorly drained*--Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time, and mottling occurs between 8 to 18 in. *Very poorly drained*--Water is removed so slowly that the water table remains at or near the surface for the greater part of the time; there may also be periods of surface ponding; the soil has a black to gray surface layer with mottles up to the surface.

Drainage. The removal of excess surface water or groundwater from land by means of ditches or subsurface drains. Also see Natural drainage.

Drop Manhole. Manhole having a vertical drop pipe connecting the inlet pipe to the outlet pipe. The vertical drop pipe shall be located immediately outside the manhole.

Dry Well. A type of infiltration practice that allows stormwater runoff to flow directly into the ground via a bored or otherwise excavated opening in the ground surface.

Dry-Bottom Detention Basin. A basin designed to be completely dewatered after having provided its planned detention of runoff during a storm event.

Duration. The time period of a rainfall event.

Earth Embankment. A man-made deposit of soil, rock, or other material often used to form an impoundment.

Elevation Certificate. A form published by the Federal Emergency Management Agency that is used to certify the 100-year or base flood elevation and the lowest elevation of usable space to which a building has been constructed.

Elevation Reference Mark (ERM). Elevation benchmark tied to the National Geodetic Vertical Datum of 1929 and identified during the preparation of a Flood Insurance Study prepared for the Federal Emergency Management Agency.

Emergency Spillway. Usually a vegetated earth channel used to safely convey flood discharges around an impoundment structure.

Energy Dissipater. A device to reduce the energy of flowing water.

Environment. The sum total of all the external conditions that may act upon a living organism or community to influence its development or existence.

Erosion and sediment control measure. A practice, or a combination of practices, to control erosion and resulting sedimentation. and/or off-site damages.

Erosion and sediment control system. The use of appropriate erosion and sediment control measures to minimize sedimentation by first reducing or eliminating erosion at the source and then as necessary, trapping sediment to prevent it from being discharged from or within a project site.

Erosion control plan. A written description and site plan of pertinent information concerning erosion control measures designed to meet the requirements of the Ordinance or these Standards.

Erosion. The wearing away of the land surface by water, wind, ice, gravity, or other geological agents. The following terms are used to describe different types of water erosion:

- *Accelerated erosion* -- Erosion much more rapid than normal or geologic erosion, primarily as a result of the activities of man.
- *Channel erosion* -- An erosion process whereby the volume and velocity of flow wears away the bed and/or banks of a well-defined channel.
- *Gully erosion* --An erosion process whereby runoff water accumulates in narrow channels and, over relatively short periods, removes the soil to considerable depths, ranging from 1-2 ft. to as much as 75-100 ft.
- *Rill erosion*--An erosion process in which numerous small channels only several inches deep are formed; occurs mainly on recently disturbed and exposed soils (see Rill).

- **Splash erosion**--The spattering of small soil particles caused by the impact of raindrops on wet soils; the loosened and spattered particles may or may not be subsequently removed by surface runoff.
- **Sheet erosion**--The gradual removal of a fairly uniform layer of soil from the land surface by runoff water.

Extraterritorial Jurisdiction (ETJ). Areas located outside the corporate limits of a community over which the community has statutory development authority.

Farm or Field Tile. A pipe installed in an agricultural area to allow subsurface drainage of farmland for the purpose of agricultural production.

FEMA. The Federal Emergency Management Agency.

Filter Strip. Usually a long, relatively narrow area (usually, 20-75 feet wide) of undisturbed or planted vegetation used near disturbed or impervious surfaces to filter stormwater pollutants for the protection of watercourses, reservoirs, or adjacent properties.

Final stabilization. The establishment of permanent vegetative cover or the application of a permanent non-erosive material to areas where all land disturbing activities have been completed and no additional land disturbing activities are planned under the current permit.

Floatable. Any solid waste that will float on the surface of the water.

Flood (or Flood Waters). A general and temporary condition of partial or complete inundation of normally dry land areas from the overflow, the unusual and rapid accumulation, or the runoff of surface waters from any source.

Flood Boundary and Floodway Map (FBFM). A map prepared by the Federal Emergency Management Agency that depicts the FEMA designated floodways within a community. This map also includes delineation of the 100-year and 500-year floodplain boundaries and the location of the Flood Insurance Study cross-sections.

Flood Crest. The maximum stage or elevation reached or expected to be reached by the waters of a specific flood at a given time.

Flood Duration. The length of time a stream is above flood stage or overflowing its banks.

Flood Easement. Easement granted to identify areas inundated by the 100-year flood and prohibit or severely restrict development activities.

Flood Elevation. The elevation at all locations delineating the maximum level of high waters for a flood of given return period.

Flood Fighting. Actions taken immediately before or during a flood to protect human life and to reduce flood damages such as evacuation, emergency sandbagging and diking.

Flood Forecasting. The process of predicting the occurrence, magnitude and duration of an imminent flood through meteorological and hydrological observations and analysis.

Flood Frequency. A statistical expression of the average time period between floods equaling or exceeding a given magnitude. For example, a 100-year flood has a magnitude expected to be equaled or exceeded on the average of once every hundred years; such a flood has a one-percent chance of being equaled or exceeded in any given year. Often used interchangeably with "recurrence interval".

Flood Hazard Area. Any floodplain, floodway, floodway fringe, or any combination thereof which is subject to inundation by the regulatory flood; or any flood plain as delineated by Zone X on a Flood Hazard Boundary Map.

Flood Hazard Boundary Map (FHBM). A map prepared by the Federal Emergency Management Agency that depicts Special Flood Hazard Areas as a Zone A within a community. There are no study text, base flood elevations, or floodways associated with this map.

Flood Insurance Rate Map (FIRM). A map prepared by the Federal Emergency Management Agency that depicts Special Flood Hazard Areas within a community. This map also includes the 100-year or Base Flood Elevation at various locations along the watercourses. More recent versions of the FIRM may also show the FEMA designated floodway boundaries and the location of the Flood Insurance Study cross-sections.

Flood Insurance Study (FIS). A study prepared by the Federal Emergency Management Agency to assist a community participating in the National Flood Insurance Program in its application of the program regulations. The study consists of a text which contains community background information with respect to flooding, a floodway data table, summary of flood discharges, flood profiles, a Flood Insurance Rate Map, and a Flood Boundary and Floodway Map.

Flood Profile. A graph showing the relationship of water surface elevation to a specific location, the latter generally expressed as distance above the mouth of a stream of water flowing in a channel. It is generally drawn to show surface elevation for the crest or a specific magnitude of flooding, but may be prepared for conditions at any given time or stage.

Flood Protection Grade (FPG). The elevation of the regulatory or 100-year flood plus two (2) feet of freeboard if the flooding source is a lake, pond, stream, or an open channel/ditch (or 1 foot of freeboard if the flooding source is an overflow path/ponding area provided that the elevation of the overflow path/ponding area is calculated based on the assumption of fully plugged storm pipe system).

Flood Resistant Construction (Flood Proofing). Additions, changes or adjustments to structures or property that are designed to reduce or eliminate the potential for flood damage.

Flood Storage Areas. Depressions, basins, or other areas that normally stand empty or partially empty, but fill with rainfall runoff during storms to hold the runoff and reduce downstream flow rates. The volumes are often referred to in units or acre-feet.

Floodplain Management. The operation of a program of corrective and preventive measures for reducing flood damage, including but not limited to flood control projects, floodplain land use regulations, flood proofing of buildings, and emergency preparedness plans.

Floodplain Regulations. General term applied to the full range of codes, ordinances and other regulations relating to the use of land and construction within floodplain limits. The term encompasses zoning ordinances, subdivision regulations, building and housing codes, encroachment laws and open area (space) regulations.

Floodplain. The channel proper and the areas adjoining the channel which have been or hereafter may be covered by the regulatory or 100-year flood. Any normally dry land area that is susceptible to being inundated by water from any natural source. The floodplain includes both the floodway and the floodway fringe districts.

Floodway Fringe. That portion of the flood plain lying outside the floodway, which is inundated by the regulatory flood.

Floodway. The channel of a river or stream and those portions of the floodplains adjoining the channel which are reasonably required to efficiently carry and discharge the peak flow of the regulatory flood of any river or stream.

Fluvial Erosion Hazard (FEH) Corridor. Fluvial (riverine) Erosion Hazard corridors represent the areas along the streams (including the channel and immediate overbanks areas) that are believed to be subject to stream movement or streambank erosion. These corridors have been delineated for most actively migrating and relatively stationary streams in Indiana through an Indiana Silver Jackets initiative, with data for Hendricks County currently contained on the Hendricks County GIS website. More detailed mapping than that used as part of the Indiana Silver Jackets erosion hazard mapping program may be provided by the applicant if it is based on detailed field assessment acceptable to the Hendricks County.

Footing Drain. A drain pipe installed around the exterior of a basement wall foundation to relieve water pressure caused by high groundwater elevation.

Forebay (or Sediment Forebay). A small pond placed in front of a larger retention/detention structure such as a wet pond, dry pond, or wetland to intercept and concentrate a majority of sediment that is coming into the system before it reaches the larger structure.

Freeboard. An increment of height added to the base flood elevation to provide a factor of safety for uncertainties in calculations, unknown local conditions, wave actions and unpredictable effects such as those caused by ice or debris jams. (See Flood Protection Grade).

French Drain. A drainage trench backfilled with a coarse, water-transmitting material; may contain a perforated pipe.

Gabion. An erosion control structure consisting of a wire cage or cages filled with rocks.

Garbage. All putrescible animal solid, vegetable solid, and semisolid wastes resulting from the processing, handling, preparation, cooking, serving, or consumption of food or food materials.

Geographical Information System. A computer system capable of assembling, storing, manipulation, and displaying geographically referenced information. This technology can be used for resource management and development planning.

Geotextile Fabric. A woven or non-woven, water-permeable synthetic material used to trap sediment particles, prevent the clogging of aggregates with fine grained soil particles, or as a separator under road aggregate.

Geotextile Liner. A synthetic, impermeable fabric used to seal impoundments against leaks.

Global Positioning System. A system that provides specially coded satellite signals that is processed by a receiver, which determines position, velocity, and time. The system is funded and controlled by the U.S. Department of Defense.

Grade. (1) The inclination or slope of a channel, canal, conduit, etc., or natural ground surface usually expressed in terms of the percentage the vertical rise (or fall) bears to the corresponding horizontal distance. (2) The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared to a design elevation for the support of construction, such as paving or the laying of a conduit. (3) To finish the surface of a canal bed, roadbed, top of embankment, or bottom of excavation, or other land area to a smooth, even condition.

Grading. The cutting and filling of the land surface to a desired slope or elevation.

Grass. A member of the botanical family Graminae, characterized by blade-like leaves that originate as a sheath wrapped around the stem.

Grassed swale. A type of vegetative practice used to filter stormwater runoff via a vegetated, shallow-channel conveyance.

Grassed Waterway. A natural or constructed waterway, usually broad and shallow, covered with erosion-resistant grasses and used to conduct surface water from an area.

Ground Cover (horticulture). Low-growing, spreading plants useful for low-maintenance landscape areas.

Groundwater Recharge. The infiltration of water into the earth. It may increase the total amount of water stored underground or only replenish supplies depleted through pumping or natural discharge.

Groundwater. Accumulation of underground water, natural or artificial. The term does not include

Habitat. The environment in which the life needs of a plant or animal are supplied.

Hard Surface. See “Impervious Surface.”

High Water. Maximum designed permitted, or regulated water level for an impoundment.

Household Hazardous Waste. Solid waste generated by households that is ignitable, toxic, reactive, corrosive, or otherwise poses a threat to human health or the environment.

Hydraulic Grade Line (HGL). For Channel flow, the HGL is equal to the water surface whereas for pressure flow it is the piezometric surface.

Hydraulics. A branch of science that deals with the practical application of the mechanics of water movement. A typical hydraulic study is undertaken to calculate water surface elevations.

Hydrodynamic Loads. Forces imposed on structures by floodwaters due to the impact of moving water on the upstream side of the structure, drag along its sides, and eddies or negative pressures on its downstream side.

Hydrograph. For a given point on a stream, drainage basin, or a lake, a graph showing either the discharge, stage (depth), velocity, or volume of water with respect to time.

Hydrologic Unit Code. A numeric United States Geologic Survey code that corresponds to a watershed area. Each area also has a text description associated with the numeric code.

Hydrology. The science of the behavior of water in the atmosphere, on the surface of the earth, and underground. A typical hydrologic study is undertaken to compute flow rates associated with specified flood events.

Hydrometeorologic. Water-related meteorologic data such as rainfall or runoff.

Hydrostatic Loads. Those loads or pressures resulting from the static mass of water at any point of floodwater contact with a structure. They are equal in all direction and always act perpendicular to the surface on which they are applied. Hydrostatic loads can act vertically on structural members such as floors, decks and roofs, and can act laterally on upright structural members such as walls, piers, and foundations.

IDNR. Indiana Department of Natural Resources.

Illicit Discharge. Any discharge to a conveyance that is not composed entirely of stormwater except naturally occurring floatables, such as leaves or tree limbs. Illicit discharges include polluted flows from direct and indirect connections to the MS4 conveyance, illegal dumping, and contaminated runoff.

Impact Areas. Areas defined or mapped that are unlikely to be easily drained because of one or more factors including but not limited to any of the following: soil type, topography, land where there is not adequate outlet, a floodway or floodplain, land within 75 feet of each bank of any regulated drain or within 75 feet from the centerline of any regulated tile ditch.

Impaired Waters. Waters that do not or are not expected to meet applicable water quality standards, as included on IDEM's CWA Section 303(d) List of Impaired Waters.

Impervious surface. Surfaces, such as pavement and rooftops, which prevent the infiltration of stormwater into the soil.

Individual building lot. A single parcel of land within a multi-parcel development.

Individual lot operator. A contractor or subcontractor working on an individual lot.

Individual lot owner. A person who has financial control of construction activities for an individual lot.

INDOT. Indiana Department of Transportation. Generally used here to refer to specifications contained in the publication "INDOT Standard Specifications."

Infiltration practices. Any structural BMP designed to facilitate the percolation of run-off through the soil to ground water. Examples include infiltration basins or trenches, dry wells, and porous pavement.

Infiltration. Passage or movement of water into the soil.

Infiltration Swales. A depressed earthen area that is designed to promote infiltration.

Inlet. An opening into a storm drain system for the entrance of surface storm water runoff, more completely described as a storm drain inlet.

Intermittent Stream. A stream which carries water a considerable portion of the time, but which ceases to flow occasionally or seasonally because bed seepage and evapotranspiration exceed the available water supply.

Invert. The inside bottom of a culvert or other conduit.

Junction Chamber. A converging section of conduit, usually large enough for a person to enter, used to facilitate the flow from one or more conduits into a main conduit.

Land Surveyor. A person licensed under the laws of the State of Indiana to practice land surveying.

Land-disturbing Activity. Any man-made change of the land surface, including removing vegetative cover that exposes the underlying soil, excavating, filling, transporting and grading.

Larger common plan of development or sale. A plan, undertaken by a single project site owner or a group of project site owners acting in concert, to offer lots for sale or lease; where such land is contiguous, or is known, designated, purchased or advertised as a common unit or by a common name, such land shall be presumed as being offered for sale or lease as part of a larger common plan. The term also includes phased or other construction activity by a single entity for its own use.

Lateral Storm Sewer. A drain that has inlets connected to it but has no other storm drain connected.

Life Cycle Cost. Cost based on the total cost incurred over the system life including research, development, testing, production, construction, operation, and maintenance. Costs are normally determined on present worth or equivalent annual cost basis.

Low Entry Elevation. The elevation in a structure where overbank flooding can enter the structure.

Lowest Adjacent Grade. The elevation of the lowest grade adjacent to a structure, where the soil meets the foundation around the outside of the structure (including structural members such as basement walkout, patios, decks, porches, support posts or piers, and rim of the window well).

Lowest Floor. Refers to the lowest of the following:

1. The top of the basement floor;
2. The top of the garage floor, if the garage is the lowest level of the building;
3. The top of the first floor of buildings constructed on a slab or of buildings elevated on pilings or constructed on a crawl space with permanent openings; or
4. The top of the floor level of any enclosure below an elevated building where the walls of the enclosure provide any resistance to the flow of flood waters unless:
 - a] The walls are designed to automatically equalize the hydrostatic flood forces on the walls by allowing for the entry and exit of flood waters, by providing a minimum of two opening (in addition to doorways and windows) having a total area of one (1) square foot for every two (2) square feet of enclosed area subject to flooding. The bottom of all such openings shall be no higher than one (1) foot above grade.
 - b] Such enclosed space shall be usable only for the parking of vehicles or building access.

Low Impact Development. LID is a land planning and engineering design approach with a goal of replicating the pre-development hydrologic regime of urban and developing watersheds. The primary goal of LID is to mimic a site's predevelopment hydrology by reducing the impervious surface, infiltrating, filtering, storing, evaporating, and detaining runoff close to its source.

Major Drainage System. Drainage system carrying runoff from an area of one or more square miles.

Manhole. Storm drain structure through which a person may enter to gain access to an underground storm drain or enclosed structure.

Manning Roughness Coefficient or Manning's "n" Value. A dimensionless coefficient ("n") used in the Manning's equation to account for channel wall frictional losses in steady uniform flow.

Measurable storm event. A precipitation event that results in a total measured precipitation accumulation equal to, or greater than, one-half (0.5) inch of rainfall.

Minimum Control Measure. Minimum measures required by the NPDES Phase II program. The six (6) MCMs are: Public education and outreach, Public participation and involvement, Illicit discharge detection and elimination, Construction site runoff control, Post-construction runoff control, and Pollution prevention and good housekeeping.

Minor Drainage Systems. Drainage system carrying runoff from an area of less than one square mile.

Minor Subdivision. See Subdivision, Minor.

Mulch. A natural or artificial layer of plant residue or other materials covering the land surface which conserves moisture, holds soil in place, aids in establishing plant cover, and minimizes temperature fluctuations.

Multi-Family. Any structure which contains three or more dwelling units. A dwelling unit is any structure, or part of a structure, which is constructed to a house a family.

Municipal Separate Storm Sewers. An MS4 meets all the following criteria: (1) is a conveyance or system of conveyances owned by the state, county, City, or other public entity; (2) discharges to waters of the U.S.; (3) is designed or used for collecting or conveying stormwater; (4) is not a combined sewer; and, (5) is not part of a Publicly Owned Treatment Works (POTW).

Municipal, state, federal, or institutional refueling area. An operating gasoline or diesel fueling area whose primary function is to provide fuel to either municipal, state, federal, or institutional equipment or vehicles.

Mutual Drain. A drain that: (1) Is located on two or more tracts of land that are under different ownership; (2) was established by the mutual consent of all the owners; and (3) was not established under or made subject to any drainage statute.

National Flood Insurance Program (NFIP). The NFIP is a Federal program enabling property owners to purchase flood insurance. The Federal Emergency Management Agency administers the NFIP in communities throughout the United States. The NFIP is based on an agreement between local communities and the Federal government which states that if a community will implement floodplain management measures to reduce future flood risks to new construction and substantially improved structures in flood hazard areas, the Federal government will make flood insurance available within the community as a financial protection against flood losses that do occur.

National Geodetic Vertical Datum of 1929. The nationwide, Federal Elevation datum used to reference topographic elevations to a known value.

National Pollution Discharge Elimination System (NPDES). A permit developed by the U.S. EPA through the Clean Water Act. In Indiana, the permitting process has been delegated to IDEM. This permit covers aspects of municipal stormwater quality.

Natural Drainage. The flow patterns of stormwater run-off over the land in its pre-development state.

Nonagricultural land use. Commercial use of land for the manufacturing and wholesale or retail sale of goods or services, residential or institutional use of land intended primarily to shelter people, highway use of land including lanes, alleys, and streets, and other land uses not included in agricultural land use.

Nonpoint Source Pollution. Pollution that enters a water body from diffuse origins on the watershed and does not result from discernable, confined, or discrete conveyances.

Normal Depth. Depth of flow in an open conduit during uniform flow for the given conditions.

North American Vertical Datum of 1988 (NAVD 1988). The nationwide, Federal Elevation datum used to reference topographic elevations to a known value.

Nutrient(s). (1) A substance necessary for the growth and reproduction of organisms. (2) In water, those substances (chiefly nitrates and phosphates) that promote growth of algae and bacteria.

Off-site. Everything not located at or within a particular site.

Off-site Land Areas. Those areas that by virtue of existing topography naturally shed surface water onto or through the developing property.

100-Year Frequency Flood. See “regulatory flood”.

On-Site. Located within the controlled or urbanized area where runoff originates.

Open Drain. A natural watercourse or constructed open channel that conveys drainage water.

Open Space. Any land area devoid of any disturbed or impervious surfaces created by industrial, commercial, residential, agricultural, or other manmade activities.

Orifice. A device which controls the rate of flow from a detention basin.

Outfall scouring. The deterioration of a streambed or lakebed from an outfall discharge to an extent that the excessive settling of solid material results and suitable aquatic habitat is diminished.

Outfall. The point, location, or structure where a pipe or open drain discharges to a receiving body of water.

Outlet. The point of water disposal from a stream, river, lake, tidewater, or artificial drain.

Overland Flow. Consists of sheet flow, shallow concentrated flow and channel flow.

Peak Discharge (or Peak Flow). The maximum instantaneous flow from a given storm condition at a specific location.

Percolation. The movement of water through soil.

Perennial Stream. A stream that maintains water in its channel throughout the year.

Permanent stabilization. The establishment, at a uniform density of seventy percent (70%) across the disturbed area, of vegetative cover or permanent non-erosive material that will ensure the resistance of the soil to erosion, sliding, or other movement.

Permeability (soil). The quality of a soil that enables water or air to move through it. Usually expressed in inches per hour or inches per day.

Pervious. Allowing movement of water.

Pesticides. Chemical compounds used for the control of undesirable plants, animals, or insects. The term includes insecticides, herbicides, algicides, rodenticides, nematocides, fungicides, and growth regulators.

pH. A numerical measure of hydrogen ion activity, the neutral point being 7.0. All pH values below 7.0 are acid, and all above 7.0 are alkaline.

Phasing of construction. Sequential development of smaller portions of a large project site, stabilizing each portion before beginning land disturbance on subsequent portions, to minimize exposure of disturbed land to erosion.

Phosphorus (available). Inorganic phosphorus that is readily available for plant growth.

Piping. The formation of "pipes" by underground erosion. Water in the soil carries the fine soil particles away, and a series of eroded tubes or tunnels develop. These openings will grow progressively larger and can cause a dam failure.

Planimetric Data. Horizontal measurements involving distances or dimensions on a diagram, map, Plat of Survey or topographic map. Normally in units of feet.

Plat of Survey. A scaled diagram showing boundaries of a tract of land/or subdivision. This may constitute a legal description of the land and be used in lieu of a written description.

Point Source. Any discernible, confined, and discrete conveyance including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, or container from which pollutants are or maybe discharged (P.L. 92-500, Section 502[14]).

Pollutant of concern. Any pollutant that has been documented via analytical data as a cause of impairment in any waterbody.

Porosity. The volume of pore space in soil or rock.

Porous pavement. A type of infiltration practice to improve the quality and reduce the quantity of storm water run-off via the use of manmade, pervious pavement which allows run-off to percolate through the pavement and into underlying soils

Private Drain. A drain that: (1) Is located on land owned by one person or by two or more persons jointly; and (2) was not established under or made subject to any drainage statute.

Professional Engineer. A person licensed under the laws of the State of Indiana to practice professional engineering.

Programmatic Indicator. Any data collected by an MS4 entity that is used to indicate implementation of one (1) or more minimum control measures.

Project site owner. The person required to submit a stormwater permit application, and required to comply with the terms of the ordinance or these Technical Standards, including a developer or a person who has financial and operational control of construction activities, and project plans and specifications, including the ability to make modifications to those plans and specifications.

Project site. The entire area on which construction activity is to be performed.

Probable Maximum Flood. The most severe flood that may be expected from a combination of the most critical meteorological and hydrological conditions that are reasonably possible in the drainage basin. It is used in designing high-risk flood protection works and citing of structures and facilities that shall be subject to almost no risk of flooding. The probable maximum flood is usually much larger than the 100-year flood.

Publically Owned Treatment Works (POTW). A municipal operation that breaks down and removes contaminants in the wastewater prior to discharging to a stream through primary and/or secondary treatment systems.

Qualified professional. An individual who is trained and experienced in storm water treatment techniques and related fields as may be demonstrated by state registration, professional certification, experience, or completion of coursework that enable the individual to make sound, professional judgments regarding storm water control or treatment and monitoring, pollutant fate and transport, and drainage planning.

Radius of Curvature. Length of radius of a circle used to define a curve.

Rain garden. A vegetative practice used to alter impervious surfaces, such as roofs, into pervious surfaces for absorption and treatment of rainfall.

Rainfall Intensity. The rate at which rain is falling at any given instant, usually expressed in inches per hour.

Reach. Any length of river, channel or storm drain.

Receiving Stream or Receiving Water. The body of water into which runoff or effluent is discharged. The term does not include private drains, unnamed conveyances, retention and detention basins, or constructed wetlands used as treatment.

Recharge. Replenishment of groundwater reservoirs by infiltration and transmission from the outcrop of an aquifer or from permeable soils.

Recurrence Interval. A statistical expression of the average time between floods equaling or exceeding a given magnitude.

Redevelopment. Alterations of a property that change a site or building in such a way that there is disturbances of one (1) acre or more of land. The term does not include such activities as exterior remodeling.

Regional Pond. A detention/retention basin sized to detain/retain the runoff from the entire watershed, on-site and off-site, tributary to the pond's outlet.

Regulated Area. The following areas within Hendricks County:

1. All territory of the County except for a territory of a municipality located within the County unless the municipality has entered into an agreement to adopt the Hendricks County Stormwater Management Ordinance.
2. All areas, within a municipality, that directly drain to a Regulated Drain.

Regulated Drain. A drain subject to the provisions of the Indiana Drainage Code, I.C.-36-9-27.

Regulatory or 100-Year Flood. The discharge or elevation associated with the 100-year flood as calculated by a method and procedure which is acceptable to and approved by the Indiana Department of Natural Resources and the Federal Emergency Management Agency. The "regulatory flood" is also known as the "base flood".

Regulatory Floodway. See Floodway.

Release Rate - The amount of storm water release from a storm water control facility per unit of time.

Reservoir. A natural or artificially created pond, lake or other space used for storage, regulation or control of water. May be either permanent or temporary. The term is also used in the hydrologic modeling of storage facilities.

Retail gasoline outlet. An operating gasoline or diesel fueling facility whose primary function is the resale of fuels. The term applies to facilities that create five thousand (5,000) or more square feet of impervious surfaces, or generate an average daily traffic count of one hundred (100) vehicles per one thousand (1,000) square feet of land area.

Retention basin. A type of storage practice, that has no positive outlet, used to retain storm water run-off for an indefinite amount of time. Runoff from this type of basin is removed only by infiltration through a porous bottom or by evaporation.

Retention. The storage of stormwater to prevent it from leaving the development site. May be temporary or permanent.

Retention Facility. A facility designed to completely retain a specified amount of stormwater runoff without release except by means of evaporation, infiltration or pumping. The volumes are often referred to in units of acre-feet.

Return Period - The average interval of time within which a given rainfall event will be equaled or exceeded once. A flood having a return period of 100 years has a one percent probability of being equaled or exceeded in any one year.

Revetment. Facing of stone or other material, either permanent or temporary, placed along the edge of a stream to stabilize the bank and protect it from the erosive action of the stream. Also see Revetment riprap.

Right-of-Way for a County Drain. The statutory right of way as defined by Indiana Code for a regulated drain.

Riparian habitat. A land area adjacent to a waterbody that supports animal and plant life associated with that waterbody.

Riparian zone. Of, on, or pertaining to the banks of a stream, river, or pond.

Riprap. Broken rock, cobble, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves). Revetment riprap is material graded such that: (1) no individual piece weighs more than 120 lbs. and (2) 90-100% will pass through a 12-inch sieve, 20-60% through a 6-inch sieve, and not more than 10% through a 12-inch sieve.

River Restoration. Restoring the channel of a stream or ditch to its perceived original, non-obstructed capacity by means of clearing & snagging, obstruction removal, and inexpensive streambank protection measures. The term "restoration", as noted, does not necessarily imply restoration or improvement of water quality or habitat within the channel or its adjacent area.

Riverine. Relating to, formed by, or resembling a stream (including creeks and rivers).

Runoff Coefficient - A decimal fraction relating the amount of rain which appears as runoff and reaches the storm drain system to the total amount of rain falling. A coefficient of 0.5 implies that 50 percent of the rain falling on a given surface appears as storm water runoff.

Runoff. That portion of precipitation that flows from a drainage area on the land surface, in open channels, or in stormwater conveyance systems.

Sand. (1) Soil particles between 0.05 and 2.0 mm in diameter. (2) A soil textural class inclusive of all soils that are at least 70% sand and 15% or less clay.

Sanitary Backup. The condition where a sanitary sewer reaches capacity and surcharges into the lowest area.

Scour. The clearing and digging action of flowing water.

Sediment. Solid material (both mineral and organic) that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface.

Sediment Forebay. See "Forebay".

Sedimentation. The process that deposits soils, debris and other unconsolidated materials either on the ground surfaces or in bodies of water or watercourses.

Seepage. The passage of water or other fluid through a porous medium, such as the passage of water through an earth embankment or masonry wall.

Sensitive Water. A water body in need of priority protection or remediation based on its:

- providing habitat for threatened or endangered species,
- usage as a public water supply intake,
- relevant community value,
- usage for full body contact recreation,
- exceptional use classification as found in 327 IAC 2-1-11(b), outstanding state resource water classification as found in 327 IAC 2-1-2(3) and 327 IAC 2-1.5-19(b).

Settling Basin. An enlargement in the channel of a stream to permit the settling of debris carried in suspension.

Silt Fence. A fence constructed of wood or steel supports and either natural (e.g. burlap) or synthetic fabric stretched across area of non-concentrated flow during site development to trap and retain on-site sediment due to rainfall runoff.

Silt. (1) Soil fraction consisting of particles between 0.002 and 0.05 mm in diameter. (2) A soil textural class indicating more than 80% silt.

Siphon - A closed conduit or portion of which lies above the hydraulic grade line, resulting in a pressure less than atmospheric and requiring a vacuum within the conduit to start flow. A siphon utilizes atmospheric pressure to effect or increase the flow of water through a conduit. An inverted siphon is used to carry storm water flow under an obstruction such as a sanitary sewer.

Site. The entire area included in the legal description of the land on which land disturbing activity is to be performed.

Slope. Degree of deviation of a surface from the horizontal, measured as a numerical ratio or percent. Expressed as a ratio, the first number is commonly the horizontal distance (run) and the second is the vertical distance (rise)--e.g., 2:1. However, the preferred method for designation of slopes is to clearly identify the horizontal (H) and vertical (V) components (length (L) and Width (W) components for horizontal angles). Also note that according to international standards (Metric), the slopes are presented as the vertical or width component shown on the numerator--e.g., 1V:2H. Slope expressions in the Ordinance or these Technical Standards follow the common presentation of slopes--e.g., 2:1 with the metric presentation shown in parenthesis--e.g., (1V:2H). Slopes can also be expressed in "percent". Slopes given in percent are always expressed as (100*V/H) --e.g., a 2:1 (1V:2H) slope is a 50% slope.

Soil and Water Conservation District. A public organization created under state law as a special-purpose district to develop and carry out a program of soil, water, and related resource conservation, use, and development within its boundaries. A subdivision of state government with a local governing body, established under IC 14-32.

Soil. The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants.

Solid Waste. Any garbage, refuse, debris, or other discarded material.

Special Flood Hazard Area. An area that is inundated during the 100-Year flood.

Spill. The unexpected, unintended, abnormal, or unapproved dumping, leakage, drainage, seepage, discharge, or other loss of petroleum, hazardous substances, extremely hazardous substances, or objectionable substances. The term does not include releases to impervious surfaces when the substance does not migrate off the surface or penetrate the surface and enter the soil.

Spillway - A waterway in or about a hydraulic structure, for the escape of excess water.

Standard Project Flood. A term used by the U.S. Army Corps of Engineers to designate a flood that may be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonable characteristics of the geographical area in which the drainage basin is located, excluding extremely rare combinations. The peak flow for a standard project flood is generally 40 – 60 percent of the probable maximum flood for the same location.

Stilling Basin - A basin used to slow water down or dissipate its energy.

Storage practices. Any structural BMP intended to store or detain stormwater and slowly release it to receiving waters or drainage systems. The term includes detention and retention basins.

Storm drain signing. Any marking procedure that identifies a storm sewer inlet as draining directly to a receiving waterbody so as to avoid dumping pollutants. The procedures can include painted or cast messages and adhesive decals.

Storm Duration. The length of time that water may be stored in any stormwater control facility, computed from the time water first begins to be stored.

Storm Event. An estimate of the expected amount of precipitation within a given period of time. For example, a 10-yr. frequency, 24-hr. duration storm event is a storm that has a 10% probability of occurring in any one year. Precipitation is measured over a 24-hr. period.

Storm Frequency. The time interval between major storms of predetermined intensity and volumes of runoff--e.g., a 5-yr., 10-yr. or 20-yr. storm.

Storm Sewer. A closed conduit for conveying collected storm water, while excluding sewage and industrial wastes. Also called a storm drain. **Stormwater Drainage System** - All means, natural or man-made, used for conducting storm water to, through or from a drainage area to any of the following: conduits and appurtenant features, canals, channels, ditches, storage facilities, swales, streams, culverts, streets and pumping stations.

Stormwater Facility. All ditches, channels, conduits, levees, ponds, natural and manmade impoundments, wetlands, tiles, swales, sewers and other natural or artificial means of draining surface and subsurface water from land.

Stormwater Pollution Prevention Plan. A plan developed to minimize the impact of storm water pollutants resulting from construction activities.

Stormwater Quality Management Plan. A comprehensive written document that addresses stormwater runoff quality.

Stormwater Quality Measure. A practice, or a combination of practices, to control or minimize pollutants associated with storm water runoff.

Stormwater runoff. The water derived from rains falling within a tributary basin, flowing over the surface of the ground or collected in channels or conduits.

Stormwater. Water resulting from rain, melting or melted snow, hail, or sleet.

Stream Gauging. The quantitative determination of streamflow using gauges, current meters, weirs, or other measuring instruments at selected locations (see Gauging station').

Stream Length. The length of a stream or ditch, expressed in miles, from the confluence of the stream or ditch with the receiving stream to the upstream extremity of the stream or ditch, as indicated by the solid or dashed, blue or purple line depicting the stream or ditch on the most current edition of the seven and one-half (7.5) minute topographic quadrangle map published by the United States Geological Survey, measured along the meanders of the stream or ditch as depicted on the map.

Stream. See intermittent stream, Perennial stream, Receiving stream.

Streambanks. The usual boundaries (not the flood boundaries) of a stream channel. Right and left banks are named facing downstream.

Strip development. A multi-lot project where building lots front on an existing road.

Structure. Refers to a structure that is principally above ground and is enclosed by walls and a roof. The term includes but is not limited to, a gas or liquid storage tank, a manufactured home or a prefabricated building, and recreational vehicles to be installed on a site for more than 180 days.

Structural Engineer. A person licensed under the laws of the State of Indiana to engage in the designing or supervising of construction, enlargement or alteration of structures or any part thereof.

Structural Floodplain. Management Measures. Those physical or engineering measures employed to modify the way floods behave, (e.g., dams, dikes, levees, channel enlargements and diversions).

Subarea/Sub-basin. Portion of a watershed divided into homogenous drainage units which can be modeled for purposes of determining runoff rates. The subareas/sub-basins have distinct boundaries, as defined by the topography of the area.

Subdivision. Any land that is divided or proposed to be divided into lots, whether contiguous or subject to zoning requirements, for the purpose of sale or lease as part of a larger common plan of development or sale.

Subdivision, Minor. The subdivision of a parent parcel into any combination of not more than three (3) contiguous or non-contiguous new residential, commercial, or industrial building sites. The parcel shall front upon an existing street which is an improved right-of-way maintained by the County or other governmental entity and not involve any new street.

Subsoil. The B horizons of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below which roots do not normally grow.

Subsurface Drain. A pervious backfield trench, usually containing stone and perforated pipe, for intercepting groundwater or seepage.

Subwatershed. A watershed subdivision of unspecified size that forms a convenient natural unit. See also Subarea.

Sump Failure. A failure of the sump pump that results in inundation of crawl space or basement.

Sump Pump. A pump that discharges seepage from foundation footing drains.

Surcharge. Backup of water in a sanitary or storm sewer system in excess of the design capacity of the system.

Surface Runoff. Precipitation that flows onto the surfaces of roofs, streets, the ground, etc., and is not absorbed or retained by that surface but collects and runs off.

Suspended Solids. Solids either floating or suspended in water.

Swale. An elongated depression in the land surface that is at least seasonally wet, is usually heavily vegetated, and is normally without flowing water. Swales conduct stormwater into primary drainage channels and may provide some groundwater recharge.

Tailwater. The water surface elevation at the downstream side of a hydraulic structure (i.e. culvert, bridge, weir, dam, etc.).

Temporary Stabilization. The covering of soil to ensure its resistance to erosion, sliding, or other movement. The term includes vegetative cover, anchored mulch, or other non-erosive material applied at a uniform density of seventy percent (70%) across the disturbed area.

Thalweg. The deepest point (or centerline) of a channel.

Tile Drain. Pipe made of perforated plastic, burned clay, concrete, or similar material, laid to a designed grade and depth, to collect and carry excess water from the soil.

Tile Drainage. Land drainage by means of a series of tile lines laid at a specified depth, grade, and spacing.

Time of Concentration (tc). The travel time of a particle of water from the most hydraulically remote point in the contributing area to the point under study. This can be considered the sum of an overland flow time and times of travel in street gutters, storm sewers, drainage channels, and all other drainage ways.

Topographic Map. Graphical portrayal of the topographic features of a land area, showing both the horizontal distances between the features and their elevations above a given datum.

Topography. The representation of a portion of the earth's surface showing natural and man-made features of a give locality such as rivers, streams, ditches, lakes, roads, buildings and most importantly, variations in ground elevations for the terrain of the area.

Topsoil. (1) The dark-colored surface layer, or a horizon, of a soil; when present it ranges in depth from a fraction of an inch to 2-3 ft. (2) Equivalent to the plow layer of cultivated soils. (3) Commonly used to refer to the surface layer(s), enriched in organic matter and having textural and structural characteristics favorable for plant growth.

Total Maximum Daily Load. Method used to establish allowable loadings for specified pollutants in a surface water resource to meet established water quality standards.

Toxicity. The characteristic of being poisonous or harmful to plant or animal life. The relative degree or severity of this characteristic.

TP-40 Rainfall. Design storm rainfall depth data for various durations published by the National Weather Service in their Technical Paper 40 dated 1961.

Trained individual. An individual who is trained and experienced in the principles of storm water quality, including erosion and sediment control as may be demonstrated by state registration, professional certification (such as CESSWI and/or CPESC certification), or other documented and applicable experience or coursework as deemed sufficient by the County that enable the individual to make judgments regarding storm water control or treatment and monitoring.

Transition Section. Reaches of the stream of floodway where water flows from a narrow cross-section to a wide cross-section or vice-versa.

Tributary. Based on the size of the contributing drainage area, a smaller watercourse which flows into a larger watercourse.

Turbidity. (1) Cloudiness of a liquid, caused by suspended solids. (2) A measure of the suspended solids in a liquid.

Underdrain. A small diameter perforated pipe that allows the bottom of a detention basin, channel or swale to drain.

Unified Soil Classification System. A system of classifying soils that is based on their identification according to particle size, gradation, plasticity index, and liquid limit.

Uniform Flow. A state of steady flow when the mean velocity and cross-sectional area remain constant in all sections of a reach.

Unit Hydrograph. A unit hydrograph is the hydrograph that results from one inch of precipitation excess generated uniformly over the watershed at a uniform rate during a specified period of time.

Urban Drain. A drain defined as “Urban Drain” in Indiana Drainage Code.

Urbanization The development, change or improvement of any parcel of land consisting of one or more lots for residential, commercial, industrial, institutional, recreational or public utility purposes.

Vegetative practices. Any nonstructural or structural BMP that, with optimal design and good soil conditions, utilizes various forms of vegetation to enhance pollutant removal, maintain and improve natural site hydrology, promote healthier habitats, and increase aesthetic appeal. Examples include grass swales, filter strips, buffer strips, constructed wetlands, and rain gardens.

Vegetative Stabilization. Protection of erodible or sediment producing areas with: permanent seeding (producing long-term vegetative cover), short-term seeding (producing temporary vegetative cover), or sodding (producing areas covered with a turf of perennial sod-forming grass).

Water Course. Any river, stream, creek, brook, branch, natural or man-made drainage way in or into which stormwater runoff or floodwaters flow either regularly or intermittently.

Water Quality. A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Water Resources. The supply of groundwater and surface water in a given area.

Water Table. (1) The free surface of the groundwater. (2) That surface subject to atmospheric pressure under the ground, generally rising and failing with the season or from other conditions such as water withdrawal.

Waterbody. Any accumulation of water, surface, or underground, natural or artificial.

Watercourse. Any river, stream, creek, brook, branch, natural or man-made drainageway in or into which stormwater runoff or floodwaters flow either continuously or intermittently.

Watershed Area. All land and water within the confines of a drainage divide. See also Watershed.

Watershed. The region drained by or contributing water to a specific point that could be along a stream, lake or other stormwater facilities. Watersheds are often broken down into subareas for the purpose of hydrologic modeling.

Waterway. A naturally existing or manmade open conduit or channel utilized for the conveyance of water.

Weir. A channel-spanning structure for measuring or regulating the flow of water.

Wellhead protection area. Has the meaning set forth at 327 IAC 8-4.1-1(27).

Wet-Bottom Detention Basin (Retention Basin) - A basin designed to retain a permanent pool of water after having provided its planned detention of runoff during a storm event.

Wetlands. Areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions.

APPENDIX B

APPLICATIONS, FORMS AND MISCELLANEOUS SHEETS REQUIRED TO COMPLY WITH THE HENDRICKS COUNTY STORMWATER MANAGEMENT ORDINANCE AND TECHNICAL STANDARDS

B1 – Primary Drainage Plan Approval Forms

Primary Petition to Hendricks County Drainage Board
Statement of Financial Responsibility
Primary Project Check-In Checklist

B2 – Secondary Stormwater Permit Forms

Secondary Stormwater Permit Application Form
Required Information List
Construction/SWPPP Technical Review
Secondary Petition to Hendricks County Drainage Board
Statement of Financial Responsibility
Construction/SWPPP Technical Review
BMP Maintenance Agreement
Secondary Project Check-In Checklist

B3 – Construction Inspection/Completion Forms

Construction Self-Monitoring Report
Certification of Completion & Compliance
Termination Inspection Checklist and Compliance Assessment

B4 – Individual Lot/Parcel Permit Forms

Instructions for Individual Lot Clean Water Permit Request
Individual Lot Clean Water Permit Request Application
Individual Lot Typical Erosion & Sediment Control Plan and Certification
Individual Lot Stormwater Pollution Prevention Requirements

B1 – Primary Drainage Plan Approval Forms

Primary Petition to Hendricks County Drainage Board
Statement of Financial Responsibility
Primary Project Check-In Checklist

**PRIMARY PETITION
TO
HENDRICKS COUNTY DRAINAGE BOARD**

IN THE MATTER OF A PROPOSED SUBDIVISION TO BE CALLED:

PROPOSED NUMBER OF LOTS: _____

COMES now the undersigned as owner(s) in fee simple, contract buyer(s), or optionee(s) of the following described real estate, to-wit:

(ATTACH LEGAL DESCRIPTION OF PROPERTY)

and state that the undersigned propose(s) to lay out and subdivide said land into lots, in accordance with the primary plat attached hereto and made a part hereof. Said primary plat suggests a way said subdivision may be drained. It is hereby requested that said drainage plan be reviewed and be given tentative approval by the Drainage Board in order that the Hendricks County Plan Commission may be induced to accept an application for the Plan Commission approval of said primary plat. This request is made with the understanding that if the County Plan Commission approves said primary plat, the undersigned will file with the County Surveyor a Secondary Petition requesting that said drainage system and the easements thereof be accepted into the County's Regulated Drainage System so that a fund may be established for the maintenance of the drainage system of said subdivision.

Dated this _____ day of _____, 20____.

Owner(s) – Contract Buyers – Optionee(s)
(strike out inappropriate nouns)

Statement of Financial Responsibility

The undersigned of the proposed project to be known as

do hereby agree to take full responsibility of financial payment of review fees incurred on the above project. I am aware that the review fees will begin as soon as primary and/or secondary application is filed and continues until the project is approved and/or withdrawn. I understand that if the project is withdrawn the review fees are still due and payable from the application date to the date on the letter of withdrawal. No project will receive an approval letter nor will the plat be approved for recording until all fees are paid. All review fees are made payable to the Hendricks County Drainage Board.

The undersigned, having duly sworn upon oath, that the above information has been read and fully understood to be true and correct and is (undersigned) voluntary act and deed. The undersigned assumes responsibility for the aforementioned fees.

Signature

Mailing Address

Signature Printed

City, State, Zip Code

STATE OF INDIANA)

COUNTY OF _____)

Subscribed and sworn before me, a Notary Public, within and for said County and State, this _____ day of _____, 20_____.

My Commission Expires _____

Notary Public _____

(Notary Stamp or Seal)

Primary Project Check-In Checklist

Project Name: _____

Engineer: _____ Contact Person: _____

Address: _____

Phone Number: _____ Fax Number: _____

Developer/Owner: _____ Contact Person: _____

Address: _____

Phone Number: _____ Fax Number: _____

Project Information:

Section: _____ Township: _____ Range: _____

Township: _____ City: _____

Number of Lots: _____ Acres: _____

Parcel Number: _____ Reg. Drain: _____

Checklist:

1 Copy of Primary Petition: _____ 1 CD (with complete project submittal): _____

2 Copy of Legal Description: _____ 2 Sets of Plans: _____

1 Copy of Drainage Calculations: _____ 1 Check for Application Fee: _____

1 Copy of Primary Drainage Plan Approval Application: _____

Original Letter and 1 copy of Financial Responsibility: _____

1 Copy of Primary Project Check-In Checklist (this sheet): _____

Is this project within the MS4 area? Yes or No

Office Use Only

Continued: _____ **Primary Approval:** _____

B2 – Secondary Stormwater Permit Forms

Secondary Stormwater Permit Application Form
Required Information List

Construction/SWPPP Technical Review

Secondary Petition to Hendricks County Drainage Board

Statement of Financial Responsibility

BMP Maintenance Agreement

Secondary Project Check-In Checklist

Hendricks County
Application Form for Stormwater Permit
(To Be Completed by Applicant)

Project Name:

General Location:

Form Completed By (Name):

Date Completed:

Total Site Acreage:

Proposed Land Disturbance Acreage:

1. Application Fee

Check Attached

Amt. \$

2. Owner/Applicant Information

Owner Name:

Phone #:

E-Mail:

Engineer Company Name:

Engineer Name:

Phone #:

E-Mail:

Brief Project Purpose and Description:

Hendricks County
Required Information List for Stormwater Permit
(For use by the Applicant and the Reviewer)

1. Construction Plans – General Requirements

1.1	Title sheet which includes location map, vicinity map, operating authority, design company name, developer name, and index of plan sheets.												
1.2	A copy of a legal boundary survey for the site, performed in accordance with Rule 12 of Title 865 of the Indiana Administrative Code or any applicable and subsequently adopted rule or regulation for the subdivision limits, including all drainage easements and wetlands.												
1.3	A reduced plat or project site map showing the parcel identification numbers, the lot numbers, lot boundaries, easements, and road layout and names. The reduced map must be legible and submitted on a sheet or sheets no larger than eleven (11) inches by seventeen (17) inches for all phases or sections of the project site.												
1.4	An existing project site layout that must include the following information: <table> <tr> <td>1.4a</td><td>A topographic map of the land to be developed and such adjoining land whose topography may affect the layout or drainage of the development. The contour intervals shall be one (1) foot when slopes are less than or equal to two percent (<2%) and shall be two (2) feet when slopes exceed two percent (>2%). All elevations shall be given in either National Geodetic Vertical Datum of 1929 (NGVD) or North American Vertical Datum of 1988 (NAVD). The horizontal datum of topographic map shall be based on Indiana State Plane Coordinates, NAD83. The map will contain a notation indicating these datum information. <ul style="list-style-type: none"> i. If the project site is less than or equal to two (2) acres in total land area, the topographic map shall include all topography of land surrounding the site to a distance of at least one hundred (100) feet. ii. If the project site is greater than two (2) acres in total land area, the topographic map shall include all topography of land surrounding the site to a distance of at least two hundred (200) feet. </td></tr> <tr> <td>1.4b</td><td>Location, name, and normal water level of all wetlands, lakes, ponds, and water courses on or adjacent to the project site.</td></tr> <tr> <td>1.4c</td><td>Location of storm, sanitary, combined sewer, and septic tank systems and outfalls.</td></tr> <tr> <td>1.4d</td><td>The location of regulated drains, farm drains, inlets and outfalls, if any of record.</td></tr> <tr> <td>1.4e</td><td>Location of all existing cornerstones within the proposed development and a plan to protect and preserve them.</td></tr> </table>	1.4a	A topographic map of the land to be developed and such adjoining land whose topography may affect the layout or drainage of the development. The contour intervals shall be one (1) foot when slopes are less than or equal to two percent (<2%) and shall be two (2) feet when slopes exceed two percent (>2%). All elevations shall be given in either National Geodetic Vertical Datum of 1929 (NGVD) or North American Vertical Datum of 1988 (NAVD). The horizontal datum of topographic map shall be based on Indiana State Plane Coordinates, NAD83. The map will contain a notation indicating these datum information. <ul style="list-style-type: none"> i. If the project site is less than or equal to two (2) acres in total land area, the topographic map shall include all topography of land surrounding the site to a distance of at least one hundred (100) feet. ii. If the project site is greater than two (2) acres in total land area, the topographic map shall include all topography of land surrounding the site to a distance of at least two hundred (200) feet. 	1.4b	Location, name, and normal water level of all wetlands, lakes, ponds, and water courses on or adjacent to the project site.	1.4c	Location of storm, sanitary, combined sewer, and septic tank systems and outfalls.	1.4d	The location of regulated drains, farm drains, inlets and outfalls, if any of record.	1.4e	Location of all existing cornerstones within the proposed development and a plan to protect and preserve them.		
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1.4d	The location of regulated drains, farm drains, inlets and outfalls, if any of record.												
1.4e	Location of all existing cornerstones within the proposed development and a plan to protect and preserve them.												
1.5	A grading and drainage plan, including the following information: <table> <tr> <td>1.5a</td><td>Location of all proposed site improvements, including roads, utilities, lot delineation and identification, proposed structures, and common areas.</td></tr> <tr> <td>1.5b</td><td>Delineation of all proposed land disturbing activities, including off-site activities that will provide services to the project site.</td></tr> <tr> <td>1.5c</td><td>Information regarding any off-site borrow, stockpile, or disposal areas that are associated with a project site, regardless of who owns or controls those areas. Off-site disposal areas may need to have their own permits.</td></tr> <tr> <td>1.5d</td><td>Location, size, and dimensions of all existing streams to be maintained, and new drainage systems such as culverts, bridges, storm sewers, conveyance channels, and 100-year overflow paths/ponding areas shown as hatched areas, along with the associated easements.</td></tr> <tr> <td>1.5e</td><td>Location, size, and dimensions of features such as permanent retention or detention facilities, including existing or manmade wetlands, used for the purpose of stormwater management. Include existing retention or detention facilities that will be maintained, enlarged, or otherwise altered and new ponds or basins to be built.</td></tr> <tr> <td>1.5f</td><td>One or more typical cross sections of all existing and proposed channels or other open drainage facilities carried to a point above the 100-year high water and showing the elevation of the existing land and the proposed changes, together with the high water elevations expected from the 100 year storm under the controlled conditions called for by this ordinance, and the relationship of structures, streets, and other facilities.</td></tr> </table>	1.5a	Location of all proposed site improvements, including roads, utilities, lot delineation and identification, proposed structures, and common areas.	1.5b	Delineation of all proposed land disturbing activities, including off-site activities that will provide services to the project site.	1.5c	Information regarding any off-site borrow, stockpile, or disposal areas that are associated with a project site, regardless of who owns or controls those areas. Off-site disposal areas may need to have their own permits.	1.5d	Location, size, and dimensions of all existing streams to be maintained, and new drainage systems such as culverts, bridges, storm sewers, conveyance channels, and 100-year overflow paths/ponding areas shown as hatched areas, along with the associated easements.	1.5e	Location, size, and dimensions of features such as permanent retention or detention facilities, including existing or manmade wetlands, used for the purpose of stormwater management. Include existing retention or detention facilities that will be maintained, enlarged, or otherwise altered and new ponds or basins to be built.	1.5f	One or more typical cross sections of all existing and proposed channels or other open drainage facilities carried to a point above the 100-year high water and showing the elevation of the existing land and the proposed changes, together with the high water elevations expected from the 100 year storm under the controlled conditions called for by this ordinance, and the relationship of structures, streets, and other facilities.
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1.5e	Location, size, and dimensions of features such as permanent retention or detention facilities, including existing or manmade wetlands, used for the purpose of stormwater management. Include existing retention or detention facilities that will be maintained, enlarged, or otherwise altered and new ponds or basins to be built.												
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1.6	Utility plan sheet(s) showing the location of all proposed utility lines for the project	
1.7	Storm sewer plan/profile sheet(s) showing the elevation, size, length, location of al proposed storm sewers. Existing and proposed ground grades, storm sewer structures elevations, and utility crossings also must be included.	
1.8	A 24-inch by 36-inch plat, including the following information:	
	1.8a	Legal description.
	1.8b	Cross reference to Rule 12.
	1.8c	Regulated drain statement and table.
1.9	Any other information required by Hendricks County to thoroughly evaluate the submitted material.	
2. Storm Water Drainage Technical Report		
2.1	A summary report, including the following information:	
	4.1a	Description of the nature and purpose of the project.
	4.1b	The significant drainage problems associated with the project.
	4.1c	The analysis procedure used to evaluate these problems and to propose solutions.
	4.1d	Any assumptions or special conditions associated with the use of these procedures, especially the hydrologic or hydraulic methods.
	4.1e	The proposed design of the drainage control system.
	4.1f	The results of the analysis of the proposed drainage control system showing that it does solve the project’s drainage problems. Any hydrologic or hydraulic calculations or modeling results must be adequately cited and described in the summary description. If hydrologic or hydraulic models are used, the input and output files for all necessary runs must be included in the appendices. A map showing any drainage area subdivisions used in the analysis must accompany the report.
	4.1g	Proof of Errors and Omissions Insurance for the registered professional engineer or licensed surveyor showing a minimum amount of \$1,000,000 in coverage.
2.2	A Hydrologic/Hydraulic Analysis, consistent with the methodologies and calculation included in the technical standards, and including the following information:	
	2.2a	A hydraulic report detailing existing and proposed drainage patterns on the subject site. The report should include a description of present land use and proposed land use. Any off-site drainage entering the site should be addressed as well. This report should be comprehensive and detail all of the steps the engineer took during the design process.
	2.2b	All hydrologic and hydraulic computations should be included in the submittal. These calculations should include, but are not limited to: runoff curve numbers and runoff coefficients, runoff calculations, stage-discharge relationships, times-of-concentration and storage volumes.
	2.2c	Copies of all computer runs. These computer runs should include both the input and the outputs. Electronic copies of the computer runs with input files will expedite the review process and is required to be submitted.
	2.2d	A set of exhibits should be included showing the drainage sub-areas and a schematic detailing of how the computer models were set up.
	2.2e	A conclusion which summarizes the hydraulic design and details how this design satisfies this Ordinance.
3. Stormwater Pollution Prevention Plan for Construction Sites		
3.1	Construction Plan Elements (Section A in IDEM Form)	
	A1	Index of the location of required plan elements in the construction plan
	A2	A vicinity map depicting the project site location in relationship to recognizable local landmarks, towns, and major roads
	A3	Narrative of the nature and purpose of the project
	A4	Latitude and longitude to the nearest fifteen (15) seconds

A5	Legal description of the project site
A6	11 X 17-inch plat showing building lot numbers/boundaries and road layout/names
A7	Boundaries of the one hundred (100) year floodplains, floodway fringes, and floodways
A8	Land use of all adjacent properties
A9	Identification of a U.S. EPA approved or established TMDL
A10	Name(s) of the receiving water(s)
A11	Identification of discharges to a water on the current 303d list of impaired waters and the pollutant(s) for which it is impaired
A12	Soil map of the predominant soil types
A13	Identification and location of all known wetlands, lakes and water courses on or adjacent to the project site (construction plan, existing site layout)
A14	Identification of any other state or federal water quality permits or authorizations that are required for construction activities
A15	Identification and delineation of existing cover, including natural buffers
A16	Existing topography at a contour interval appropriate to indicate drainage patterns
A17	Location(s) of where run-off enters the project site
A18	Location(s) of where run-off discharges from the project site prior to land disturbance
A19	Location of all existing structures on the project site
A20	Existing permanent retention or detention facilities, including manmade wetlands, designed for the purpose of stormwater management
A21	Locations where stormwater may be directly discharged into ground water, such as abandoned wells, sinkholes, or karst features
A22	Size of the project area expressed in acres
A23	Total expected land disturbance expressed in acres
A24	Proposed final topography
A25	Locations and approximate boundaries of all disturbed areas
A26	Location, size, and dimensions of all stormwater drainage systems, such as culverts, storm sewers, and conveyance channels
A27	Locations of specific points where stormwater and non-stormwater discharges will leave the project site
A28	Location of all proposed site improvements, including roads, utilities, lot delineation and identification, proposed structures, and common areas
A29	Location of all on-site soil stockpiles and borrow areas
A30	Construction support activities that are expected to be part of the project
A31	Location of any in-stream activities that are planned for the project including, but not limited to stream crossings and pump arounds

3.2	Erosion and Sediment Control/Project Site Management (Section B in IDEM Form)	
	B1	Description of the potential pollutant generating sources and pollutants, including all potential non-stormwater discharges
	Where applicable, Items in B2 through B10 below will be evaluated for location, dimensions, detailed specifications, and construction details	
	B2	Stable construction entrance locations and specifications
	B3	Specifications for temporary and permanent stabilization
	B4	Sediment control measures for concentrated flow areas
	B5	Sediment control measures for sheet flow areas
	B6	Run-off control measures
	B7	Stormwater outlet protection locations and specifications
	B8	Grade stabilization structure locations and specifications
	B9	Dewatering applications and management methods
	B10	Measures utilized for work within waterbodies
	B11	Maintenance guidelines for each proposed temporary stormwater quality measure
	B12	Planned construction sequence describing the relationship between implementation of stormwater quality measures in relation to land disturbance
	B13	Provisions for erosion and sediment control on individual building lots regulated under the proposed project
	B14	Material handling, spill prevention and spill response plan meeting requirements in 327 IAC 2-6.1
B15	Material handling and storage procedures associated with construction activity	
4. Post-Construction Stormwater Pollution Prevention Plan		
4.1	SWPPP – Post-Construction (Section C in IDEM Form)	
	C1	Description of pollutants and their sources associated with the proposed land use
	C2	Description of proposed post-construction stormwater measures
	C3	Plan details for each stormwater measure
	C4	Sequence describing stormwater measure implementation
	C5	Maintenance guidelines for proposed post-construction stormwater measures
	C6	Entity that will be responsible for operation and maintenance of the post-construction stormwater measures

Hendricks County, Indiana Surveyor's Office	Construction/ Stormwater Pollution Prevention Plan Technical Review Hendricks County Stormwater Technical Standards IDEM Construction Stormwater General Permit: https://www.in.gov/idem/stormwater/construction-land-disturbance-permitting/ (INRA00000 effective 12/18/2021)
--	---

Construction/Stormwater Pollution Prevention Plan Technical Review and Comment

Project Name: Scope of Project: County(ies): Latitude: Longitude:	Plan Submittal Date: Click here to enter a date. Plan Review Date: Click here to enter a date.
---	---

Plan Preparer: Address: City: State: Zip: Phone: Cell Phone: Email:	Affiliation:
--	---------------------

Project Site Owner: Address: City: State: Zip: Phone: Cell Phone: Email:	Company Name (if applicable):
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Plan Reviewer: Address: City: State: Zip: Phone: Cell Phone: Email:	Affiliation: On behalf of:
--	---

Plan Review Status:

<input type="checkbox"/>	Plan is Adequate	A comprehensive plan review has been completed and it has been determined that the plan satisfies the minimum requirements of the Hendricks County Stormwater Ordinance and Technical Standards and the Construction Stormwater General Permit INRA00000 (Effective 12-18-2021).
<input type="checkbox"/>	Preliminary Review	A comprehensive review will not be completed at this time. The plan review authority reserves the right to perform a comprehensive review at a later date, and revisions may be required at that time.
<input type="checkbox"/>	Conditional Acceptance	Acceptance of the plan is conditional. The conditional acceptance is contingent upon addressing the issues identified in the comment sections.
<input type="checkbox"/>	Plan is Deficient	Significant deficiencies were identified and must be addressed. Refer to the comment sections.

Action:

<input type="checkbox"/>	Submit a Notice of Intent: • Submit the Notice of Intent (NOI) online through the IDEM Regulatory ePortal. It is required to upload a copy of this review form when submitting the NOI through the IDEM Regulatory ePortal: https://stormwater.idem.in.gov/ncore/external/home
<input type="checkbox"/>	Do not file a Notice of Intent or commence land-disturbing activities: Deficiencies must be adequately addressed and an acceptable plan review completed.
<input type="checkbox"/>	Comments: Refer to Plan Review Comments Sections of this document.
<input type="checkbox"/>	Revisions: Update and submit the revised Construction/Stormwater Pollution Prevention Plan as indicated below.
<input type="checkbox"/>	Update and submit a complete plan set that addresses plan deficiencies.
<input type="checkbox"/>	Update and submit a document (narrative and/or plan sheets) that address plan deficiencies.
<input type="checkbox"/>	Update and submit a complete plan set that addresses plan deficiencies. A comprehensive plan review will not be completed.

Plan Review Information

- The technical review and comment is intended to evaluate the completeness of the Construction/Stormwater Pollution Prevention Plan for the project. The Plan submitted was not reviewed for the adequacy of engineering design. All measures included in the plan, as well as those recommended in the comments should be evaluated as to their feasibility by a qualified individual with structural measures designed by a qualified engineer. The Plan has not been reviewed for other local, state, or federal permits that may be required to proceed with this project.
- Additional information, including design calculations may be requested to further evaluate the plan.
- All proposed stormwater pollution prevention measures and those referenced in this review must meet the design criteria and standards set forth in the "Indiana Stormwater Quality Manual" from the Indiana Department of Environmental Management or similar Guidance Documents.
- Construction activities and unforeseen weather conditions may affect the performance of the erosion and sediment control system, individual measures, or the effectiveness of the plan. The plan must be a flexible document, with provisions to modify or substitute measures as necessary to ensure compliance.

Section A: Construction Plan Elements

Adequate	Deficient	NA	A	The construction plan elements include general information associated with the project site that are critical for the evaluation of the stormwater pollution prevention plan component. This information includes, but is not limited to an index, resource information, reference maps, grading information, project layout and design, and drainage plan
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	Index of the location of required plan elements in the construction plan
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	A vicinity map depicting the project site location in relationship to recognizable local landmarks, towns, and major roads
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	3	Narrative of the nature and purpose of the project
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	4	Latitude and longitude to the nearest fifteen (15) seconds
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	5	Legal description of the project site
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	6	11 X 17-inch plat showing building lot numbers/boundaries and road layout/names
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	7	Boundaries of the one hundred (100) year floodplains, floodway fringes, and floodways
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	8	Land use of all adjacent properties
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	9	Identification of a U.S. EPA approved or established TMDL
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	10	Name(s) of the receiving water(s)
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	11	Identification of discharges to a water on the current 303d list of impaired waters and the pollutant(s) for which it is impaired
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	12	Soil map of the predominant soil types
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	13	Identification and location of all known wetlands, lakes and water courses on or adjacent to the project site (construction plan, existing site layout)
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	14	Identification of any other state or federal water quality permits or authorizations that are required for construction activities
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	15	Identification and delineation of existing cover, including natural buffers
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	16	Existing topography at a contour interval appropriate to indicate drainage patterns
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	17	Location(s) of where run-off enters the project site
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	18	Location(s) of where run-off discharges from the project site prior to land disturbance
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	19	Location of all existing structures on the project site
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	20	Existing permanent retention or detention facilities, including manmade wetlands, designed for the purpose of stormwater management

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	21	Locations where stormwater may be directly discharged into ground water, such as abandoned wells, sinkholes, or karst features
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	22	Size of the project area expressed in acres
Adequate	Deficient	NA	A	<i>The construction plan elements include general information associated with the project site that are critical for the evaluation of the stormwater pollution prevention plan component. This information includes, but is not limited to an index, resource information, reference maps, grading information, project layout and design, and drainage plan</i>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	23	Total expected land disturbance expressed in acres
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	24	Proposed final topography
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	25	Locations and approximate boundaries of all disturbed areas
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	26	Location, size, and dimensions of all stormwater drainage systems, such as culverts, storm sewers, and conveyance channels
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	27	Locations of specific points where stormwater and non-stormwater discharges will leave the project site
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	28	Location of all proposed site improvements, including roads, utilities, lot delineation and identification, proposed structures, and common areas
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	29	Location of all on-site soil stockpiles and borrow areas
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	30	Construction support activities that are expected to be part of the project
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	31	Location of any in-stream activities that are planned for the project including, but not limited to stream crossings and pump arounds

Section A – Comments:

- Evaluate areas with potential waters of the state and, where required, verify if permits/authorizations are required prior to any impacts to waters of the state. These potential resources include areas with hydric soil, hydrophytic vegetation, pooling water, or evidence of flowing water such as swales, ditches, drains, or natural conveyances. Evaluation of hydric soil, hydrophytic vegetation, or pooling water should conform to the US Army Corps of Engineers Wetlands Delineation Manual," Technical Report Y-87-1, and the applicable regional supplement https://www.usace.army.mil/Missions/Civil-Works/Regulatory-Program-and-Permits/reg_supp/. Avoidance and minimization of impacts to waters of the state should be prioritized.

Section B: Stormwater Pollution Prevention Plan – Erosion and Sediment Control/Project Site Management

Adequate	Deficient	NA	B	
			1	<p><i>The construction component of the Stormwater Pollution Prevention Plan includes stormwater quality measures to address erosion, sedimentation, and other pollutants associated with land disturbance and construction activities. Proper implementation of the plan, maintenance of measures, and administering a self-monitoring program is required to manage the project site to minimize the discharge of sediment and other pollutants. Construction activities and unforeseen weather conditions may affect the performance of the erosion and sediment control system, individual measures, or the effectiveness of the plan. The plan must be a flexible document, with provisions to modify or substitute measures as necessary to ensure compliance.</i></p> <p>Description of the potential pollutant generating sources and pollutants, including all potential non-stormwater discharges</p>
Where applicable, Items in 2 through 10 below will be evaluated for Location, dimensions, detailed specifications, and construction details				
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	Stable construction entrance locations and specifications
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	3	Specifications for temporary and permanent stabilization
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	4	Sediment control measures for concentrated flow areas
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	5	Sediment control measures for sheet flow areas
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	6	Run-off control measures
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	7	Stormwater outlet protection locations and specifications
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	8	Grade stabilization structure locations and specifications
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	9	Dewatering applications and management methods
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	10	Measures utilized for work within waterbodies
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	11	Maintenance guidelines for each proposed temporary stormwater quality measure
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	12	Planned construction sequence describing the relationship between implementation of stormwater quality measures in relation to land disturbance
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	13	Provisions for erosion and sediment control on individual building lots regulated under the proposed project
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	14	Material handling and spill prevention and spill response plan meeting the requirements in 327 IAC 2-6.1
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	15	Material handling and storage procedures associated with construction activity

Section B – Comments:

- Stormwater quality measures for the reduction of sediment have not been evaluated for adequacy of design. The proposed measures included in this SWPPP are being accepted based on the design engineer's submittal.

Section C: Stormwater Pollution Prevention Plan – Post-Construction

Adequate	Deficient	NA	C	<i>The post-construction component of the Stormwater Pollution Prevention Plan includes the implementation of stormwater quality measures to address pollutants that will be associated with the final project land use. Post-construction stormwater measures should be functional upon completion of the project. Long term functionality of the measures is critical to their performance and should be monitored and maintained.</i>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	Description of pollutants and their sources associated with the proposed land use
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	Description of proposed post-construction stormwater measures
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	3	Plan details for each stormwater measure
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	4	Sequence describing stormwater measure implementation
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	5	Maintenance guidelines for proposed post-construction stormwater measures
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	6	Entity that will be responsible for operation and maintenance of the post-construction stormwater measures

Section C – Comments:

- Post-construction stormwater quality and quantity measures have not been evaluated for adequacy of design. The proposed measures included in this SWPPP are being accepted based on the design engineer's submittal.
- The rate of stormwater run-off and/or volume from the project site must meet local requirements to address stormwater quantity as established by ordinance or other regulatory mechanism. When a local requirement does not exist, the post-development run-off discharge from the project site must not exceed the pre-development discharge based on the two-year, ten-year, and one-hundred-year peak storm events.

**SECONDARY PETITION
TO
HENDRICKS COUNTY DRAINAGE BOARD**

THE UNDERSIGNED, as owner(s) of the proposed subdivision to be known as:

final number of lots: _____, situated in Section _____,

Township _____, Range _____, _____ Township,

Hendricks County, Indiana, and more particularly described as follows:

(ATTACH LEGAL DESCRIPTION OF PROPERTY)

do(es) hereby petition the Hendricks County Drainage Board to accept the drainage system and the easements therefore in and for said proposed Subdivision into the County Regulated Drainage System, and to establish a maintenance fund therefore.

STATE OF INDIANA)
)
COUNTY OF _____)

The undersigned, having been duly sworn upon oath, say(s) that the above information is true and correct and is (their) (his) (her) voluntary act and deed.

Owner Signature

Owner Signature

Owner Printed

Owner Printed

Address

Address

Subscribed and sworn to before me, a Notary Public, within and for said County and

State, this _____ day of _____, 20_____.

Notary Public

(Notary Stamp or Seal)

My Commission Expires

ENGINEER'S STATEMENT

I hereby certify to the best of my knowledge and belief:

1. That the plans and specifications which are attached to and made a part of this petition have been prepared by me or under my direct supervision.
2. That these plans and specifications have been prepared in accordance with all applicable Codes and Ordinances.
3. That I will perform reasonable and regular inspections of this project during construction as required to enable me to certify, upon completion, that the work was done in accordance with approved construction plans and specifications.

DATE: _____ SIGNATURE: _____

Telephone: _____ Typed Name: _____

Indiana Registration Number: _____

Address: _____

This petition given primary approval this ____ day of _____, 20____.

* * * * *

This petition given secondary approval and the above-mentioned drains accepted/not accepted into the Hendricks County Regulated Drainage System this _____ day of _____, 20____.

HENDRICKS COUNTY DRAINAGE BOARD

Statement of Financial Responsibility

The undersigned of the proposed project to be known as

do hereby agree to take full responsibility of financial payment of review fees incurred on the above project. I am aware that the review fees will begin as soon as primary and/or secondary application is filed and continues until the project is approved and/or withdrawn. I understand that if the project is withdrawn the review fees are still due and payable from the application date to the date on the letter of withdrawal. No project will receive an approval letter nor will the plat be approved for recording until all fees are paid. All review fees are made payable to the Hendricks County Drainage Board.

The undersigned, having duly sworn upon oath, that the above information has been read and fully understood to be true and correct and is (undersigned) voluntary act and deed. The undersigned assumes responsibility for the aforementioned fees.

Signature

Mailing Address

Signature Printed

City, State, Zip Code

STATE OF INDIANA)
)
COUNTY OF _____)

Subscribed and sworn before me, a Notary Public, within and for said County and State, this _____ day of _____, 20_____.

My Commission Expires _____

Notary Public _____

(Notary Stamp or Seal)

Stormwater Management BMPs Maintenance Agreement

THIS AGREEMENT is made this _____ day of _____, 20____, by
[Owner Name] of _____
[Company Name] with principal offices located _____
[Owner/Company Address], hereinafter "Owner".

In accordance with Hendricks County Stormwater Ordinance and Technical Standards, the Owner agrees to install and maintain stormwater management practice(s) (also known as BMPs) on the subject property, known as _____ [Property's Common Name] located at _____ [Property's Address], hereinafter "Property" in accordance with Exhibit A. The Owner further agrees to the terms stated in this document to ensure that the stormwater management practice(s) continues serving the intended function in perpetuity. This Agreement includes the following exhibit:

Exhibit A: BMP Operation and Maintenance Manual ("Manual").

Note: This agreement and all Exhibits shall be recorded with the deed of property by the Owner at the Hendricks County Recorder's Office and two (2) copies of the recorded document provided to Hendricks County Surveyor's Office, hereinafter "Community".

Through this Agreement, the Owner hereby subjects the Property to the following covenants, conditions, and restrictions:

1. The Owner shall be solely responsible for the installation, maintenance, and repair of the stormwater management practices, drainage easements, and associated landscaping identified in the Manual.
2. No alterations or changes to the stormwater management practice(s) identified in the Manual shall be permitted unless they are deemed to comply with this Agreement and are approved in writing by the Community.
3. The Owner shall retain the services of a qualified individual or company to operate and ensure the maintenance of the stormwater management practice(s) identified in the Manual.
4. The Owner shall annually, by December 30th, provide to the Community records of inspections, maintenance, and repair of the stormwater management practices in accordance with the Manual.
5. The Community or its designee is authorized to access the property as necessary to conduct inspections of the stormwater management practices or drainage easements to ascertain compliance with the intent of this Agreement and the activities prescribed in the Manual. Upon written notification by the Community or its designee of required maintenance or repairs, the Owner shall complete the specified maintenance or repairs within a reasonable time frame determined by the Community. The Owner(s) shall be liable for the failure to undertake any maintenance or repairs so that the public health, safety and welfare shall not be endangered nor the road improvement damaged.
6. If the Owner fails to properly maintain the stormwater management practice(s) in accordance with the Manual and this Agreement, the Community is authorized, but not required, to perform the specified inspections, maintenance, or repairs in order to preserve the intended functions of the practice(s) and prevent the practice(s) from becoming a threat to public health, safety, general

welfare or the environment. In the case of an emergency, as determined by the Community, no notice shall be required prior to the Community performing emergency maintenance or repairs. The Community may levy the costs and expenses of such inspections, maintenance, or repairs plus a ten percent (10%) administrative fee against the Owner. The Community at the time of entering upon said stormwater management practice for the purpose of maintenance or repair may file a notice of lien in the office of the Register of Deeds of Hendricks County upon the property affected by the lien. If said costs and expenses are not paid by the Owner, the Community may pursue the collection of same through appropriate court actions and in such a case, the Owner shall pay in addition to said costs and expenses all costs of litigation, including attorney fees.

7. The Owner hereby conveys to the Community an easement over, on, and in the Property or otherwise grants perpetual access rights for the purpose of access to the stormwater management practice for the inspection, maintenance, and repair thereof, should the Owner fail to properly inspect, maintain, and repair the practice(s).
8. The Owner agrees that this Agreement shall be recorded and that the Property shall be subject to the covenants and obligations contained herein, and this Agreement shall bind all current and future owners of the property.
9. The Owner agrees in the event that the Property is sold, transferred, or leased to provide information to the new owner, operator, or lessee regarding proper inspection, maintenance, and repair of the stormwater management practice(s). The information shall accompany the first deed transfer and include this Agreement and all Exhibits. The transfer of this information shall also be required with any subsequent sale, transfer, or lease of the Property.
10. The Owner agrees that the rights, obligations, and responsibilities hereunder shall commence upon execution of the Agreement.
11. The Owner whose signatures appear below hereby represent and warrant that they have the authority and capacity to sign this agreement and bind the respective parties hereto.
12. The Owner, its agents, representatives, successors, and assigns shall defend, indemnify and hold the Community harmless from and against any claims, demands, actions, damages, injuries, costs or expenses of any nature whatsoever, hereinafter "Claims", fixed or contingent, known or unknown, arising out of or in any way connected with the design, construction, use, maintenance, repair or operation (or omissions in such regard) of the stormwater management practice(s) referred to in Exhibit A which are the subject of this Agreement. This indemnity and hold harmless shall include any costs, expenses, and attorney fees incurred by the Community in connection with such Claims or the enforcement of this Agreement.

IN WITNESS WHEREOF, the Owner has executed this Agreement on the day and year first above written.

Owner Signature

Date

Printed Name

Company

Title

STATE OF INDIANA)
)
COUNTY OF HENDRICKS) SS:

BEFORE ME, the undersigned, a Notary Public in and for said County and State, personally appeared _____ Owner subscribed and sworn before this _____ day of _____, 20 ____.

Commission Expiration Date

County of Residence

Signature

Printed Name

WHEN RECORDED, RETURN FILE STAMPED COPY TO:

**Hendricks County Surveyor's Office
355 South Washington St.
Danville, IN 46122**

.....

Accepted by Hendricks County Surveyor's Office:

Signature: _____

Date: _____

Printed Name: _____

Title: _____

Secondary Project Check-In Checklist

Project Name: _____

Engineer: _____ Contact Person: _____

Address: _____

Phone Number: _____ Fax Number: _____

Developer/Owner: _____ Contact Person: _____

Address: _____

Phone Number: _____ Fax Number: _____

Project Information:

Section: _____ Township: _____ Range: _____

Township: _____ City: _____

Number of Lots: _____ Acres: _____

Parcel Number: _____ Reg. Drain: _____

Accepted Drainage Footage:

Open: _____ Tile: _____

Checklist:

1 Copy of Secondary Petition Signed & Notarized by Owner: _____

1 Copy of Legal Description: _____ 2 Sets of Plans: _____

1 Copy of Engineer Statement: _____ 1 CD (with complete project submittal): _____

1 Copy of NOI (only if in County): _____ 1 Check for Application Fee: _____

1 Copy of Secondary Stormwater Permit Application: _____

1 Copy of Regulated Drain Exhibit: _____

1 Copy of Stormwater Drainage Technical Report: _____

1 Copy of Stormwater Pollution Prevention Plan for Construction Sites: _____

1 Copy of Post-Construction Stormwater Pollution Prevention Plan: _____

Original Letter and 1 copy of Financial Responsibility: _____

1 Copy of Secondary Project Check-In Checklist (this sheet): _____

OFFICE USE ONLY

Assessment: _____

Revisions: _____

Approval: _____

Denial: _____

B3 – Construction Inspection/Completion Forms

Construction Self-Monitoring Report
Certification of Completion & Compliance
Termination Inspection Checklist and Compliance Assessment

Self-Monitoring Report (To Be Completed by Permittee's Trained Individual)

PART A: INSPECTION INFORMATION

Project Name: CSGP Project # Number: Permit # Assigned by MS4: Name of MS4: County: Name of Evaluator: Title of Evaluator: Affiliation: Email/Phone Number:	Inspection Type	Inspection Date and Time	
	<input type="checkbox"/> 24 hr (after >.5" rain) <input type="checkbox"/> 24 hr (before >.5" rain) <input type="checkbox"/> Weekly <input type="checkbox"/> Monthly <i>(only applies to areas permanently stabilized)</i>	Click here to enter a date.	
		Date of Last or Forecasted (circle one) Precipitation:	
		Click here to enter a date.	
		Amount of Last or Forecasted (circle one) Precipitation:	
		Click here to enter a date.	

PART B: SITE CONDITIONS

Current Site Information (check all that apply): ☐ Clearing ☐ Grubbing ☐ Grading ☐ Building Construction
☐ Installation of Infrastructure ☐ Utility Work ☐ Vegetative Establishment ☐ Other:

Soil Conditions: ☐ Dry ☐ Moist ☐ Wet ☐ Muddy ☐ Partial Snow Cover ☐ Snow Cover ☐ Frozen ☐ Freeze/Thaw
☐ Other:

PART C: PROJECT MANAGEMENT

(1) Was the SWP3 accessible at the time of the inspection?	<input type="checkbox"/> Yes <input type="checkbox"/> No
(2) Is the SWP3 current and/or updated to reflect the current stage of development?	<input type="checkbox"/> Yes <input type="checkbox"/> No
(3) Have all action items identified on the preceding reports been resolved? (a) If not identify which items require repair and provide a resolution timeline:	<input type="checkbox"/> Yes <input type="checkbox"/> No
(4) Is the project posting information posted in accordance with the CSGP Section 3.7?	<input type="checkbox"/> Yes <input type="checkbox"/> No

PART D: GUIDANCE FOR COMPLETION OF FORM

- Identify all areas of the site that currently have an erosion/sediment control measure in place. Using Part E, evaluate the current condition of the measure and using the middle column, determine what action needs to be taken.
- Identify all areas of the site where stormwater run-off leaves site or where any discharge occurs. In each location where run-off leave the site, evaluate:
 - If an erosion/sediment control measure is in place: evaluate each action step required in Part E
 - If no erosion/sediment control measure is in place or a measure is required, use Part E to include specifics about the location and type of measure to be implemented.
- For any area of the site where there is run-off, or a discharge provide a description and location using Part F.
 - If any sedimentation is occurring note where it is discharging: Off site, to a waterbody (on or off-site) or other sensitive area
- For Part H in the Evaluation of sheet flow and concentrated run-off:
 - Identify location of discharge/run-off and check any visual descriptions that apply to the discharge. If the discharge/run-off will resolve with the repair of a sediment or erosion control measure or good housekeeping practices, you do not need to list an action in the observations/notes section. If the discharge/run-off will not be solved with repair/replacement of a sediment control measure or good housekeeping practices, you will need to list the action taken to resolve the run-off and any additional pollutants visible in the discharge.
 - Print out additional pages for Parts E and F.

PART E: SEDIMENT CONTROL AND RUN-OFF MANAGEMENT

Measure: Location(s):	<input type="checkbox"/> No Action Required <input type="checkbox"/> Maintenance Required <input type="checkbox"/> Repair Measure <input type="checkbox"/> Temporary Measure <input type="checkbox"/> Replace Measure <input type="checkbox"/> Alternative Measure <input type="checkbox"/> Additional Measure	Observations/Notes:
Action Initiated Date: Click here to enter a date. Initials:		Action Completed Date: Click here to enter a date. Initials
Measure: Location(s):	<input type="checkbox"/> No Action Required <input type="checkbox"/> Maintenance Required <input type="checkbox"/> Repair Measure <input type="checkbox"/> Temporary Measure <input type="checkbox"/> Replace Measure <input type="checkbox"/> Alternative Measure <input type="checkbox"/> Additional Measure	Observations/Notes:
Action Initiated Date: Click here to enter a date. Initials:		Action Completed Date: Click here to enter a date. Initials
Measure: Location(s):	<input type="checkbox"/> No Action Required <input type="checkbox"/> Maintenance Required <input type="checkbox"/> Repair Measure <input type="checkbox"/> Temporary Measure <input type="checkbox"/> Replace Measure <input type="checkbox"/> Alternative Measure <input type="checkbox"/> Additional Measure	Observations/Notes:
Action Initiated Date: Click here to enter a date. Initials:		Action Completed Date: Click here to enter a date. Initials
Measure: Location(s):	<input type="checkbox"/> No Action Required <input type="checkbox"/> Maintenance Required <input type="checkbox"/> Repair Measure <input type="checkbox"/> Temporary Measure <input type="checkbox"/> Replace Measure <input type="checkbox"/> Alternative Measure <input type="checkbox"/> Additional Measure	Observations/Notes:
Action Initiated Date: Click here to enter a date. Initials:		Action Completed Date: Click here to enter a date. Initials
Measure: Location(s):	<input type="checkbox"/> No Action Required <input type="checkbox"/> Maintenance Required <input type="checkbox"/> Repair Measure <input type="checkbox"/> Temporary Measure <input type="checkbox"/> Replace Measure <input type="checkbox"/> Alternative Measure <input type="checkbox"/> Additional Measure	Observations/Notes:
Action Initiated Date: Click here to enter a date. Initials:		Action Completed Date: Click here to enter a date. Initials

PART F: SURFACE STABILIZATION

Location(s):	<input type="checkbox"/> Permanent Vegetative Cover: <input type="checkbox"/> Continue to Monitor <input type="checkbox"/> 70 Percent Density Achieved <input type="checkbox"/> Perform Seeding/Reseed <input type="checkbox"/> Temporary <input type="checkbox"/> Permanent <input type="checkbox"/> Apply straw mulch and anchor <input type="checkbox"/> Install Erosion Control Blanket <input type="checkbox"/> Repair Erosion <input type="checkbox"/> Utilize Alternative Stabilization Method	Observations/Notes:
Action Initiated Date: Click here to enter a date. Initials:		Action Completed Date: Click here to enter a date. Initials
Location(s):	<input type="checkbox"/> Permanent Vegetative Cover: <input type="checkbox"/> Continue to Monitor <input type="checkbox"/> 70 Percent Density Achieved <input type="checkbox"/> Perform Seeding/Reseed <input type="checkbox"/> Temporary <input type="checkbox"/> Permanent <input type="checkbox"/> Apply straw mulch and anchor <input type="checkbox"/> Install Erosion Control Blanket <input type="checkbox"/> Repair Erosion <input type="checkbox"/> Utilize Alternative Stabilization Method	Observations/Notes:
Action Initiated Date: Click here to enter a date. Initials:		Action Completed Date: Click here to enter a date. Initials
Location(s):	<input type="checkbox"/> Permanent Vegetative Cover: <input type="checkbox"/> Continue to Monitor <input type="checkbox"/> 70 Percent Density Achieved <input type="checkbox"/> Perform Seeding/Reseed <input type="checkbox"/> Temporary <input type="checkbox"/> Permanent <input type="checkbox"/> Apply straw mulch and anchor <input type="checkbox"/> Install Erosion Control Blanket <input type="checkbox"/> Repair Erosion <input type="checkbox"/> Utilize Alternative Stabilization Method	Observations/Notes:
Action Initiated Date: Click here to enter a date. Initials:		Action Completed Date: Click here to enter a date. Initials
Location(s):	<input type="checkbox"/> Permanent Vegetative Cover: <input type="checkbox"/> Continue to Monitor <input type="checkbox"/> 70 Percent Density Achieved <input type="checkbox"/> Perform Seeding/Reseed <input type="checkbox"/> Temporary <input type="checkbox"/> Permanent <input type="checkbox"/> Apply straw mulch and anchor <input type="checkbox"/> Install Erosion Control Blanket <input type="checkbox"/> Repair Erosion <input type="checkbox"/> Utilize Alternative Stabilization Method	Observations/Notes:
Action Initiated Date: Click here to enter a date. Initials:		Action Completed Date: Click here to enter a date. Initials

PART G: GOOD HOUSEKEEPING

Site Ingress/Egress Location(s):	<input type="checkbox"/> Maintain Construction Entrance <input type="checkbox"/> Remove Tracked Sediment (do not flush sediment) <input type="checkbox"/> Install Additional Measures	Observations/Notes:
Action Initiated Date: Click here to enter a date. Initials:		Action Completed Date: Click here to enter a date. Initials
Trash Location(s):	<input type="checkbox"/> Continue to Monitor and Manage <input type="checkbox"/> Cover Trash Receptacles <input type="checkbox"/> Clean Up Wind-blown Trash <input type="checkbox"/> Other	Observations/Notes:
Action Initiated Date: Click here to enter a date. Initials:		Action Completed Date: Click here to enter a date. Initials
Spills or Leaks Location(s):	Type of Leak/Spill <input type="checkbox"/> Concrete and/or Cementitious Washout <input type="checkbox"/> Fuel <input type="checkbox"/> Other	Observations/Notes/Action Taken:
Action Initiated Date: Click here to enter a date. Initials:		Action Completed Date: Click here to enter a date. Initials

PART H: EVALUATION OF SHEET FLOW AND CONCENTRATED RUN-OFF (DISCHARGES)

Location(s):	<input type="checkbox"/> Sediment <input type="checkbox"/> Oil Sheen <input type="checkbox"/> Odor <input type="checkbox"/> Floatables/Trash <input type="checkbox"/> Foam <input type="checkbox"/> Color/Turbid Discharge <input type="checkbox"/> Other	Observations/Notes:
Action Initiated Date: Click here to enter a date. Initials:		Action Completed Date: Click here to enter a date. Initials
Location(s):	<input type="checkbox"/> Sediment <input type="checkbox"/> Oil Sheen <input type="checkbox"/> Odor <input type="checkbox"/> Floatables/Trash <input type="checkbox"/> Foam <input type="checkbox"/> Color/Turbid Discharge <input type="checkbox"/> Other	Observations/Notes:
Action Initiated Date: Click here to enter a date. Initials:		Action Completed Date: Click here to enter a date. Initials

PART I: CHANGES TO SWPPP

Does the corrective action based on this inspection require modification to the SWPPP? <input type="checkbox"/> Yes <input type="checkbox"/> No	
Date of SWPPP update:	
Brief description of the changes:	
Action Initiated Date: Click here to enter a date. Initials:	Action Completed Date: Click here to enter a date. Initials

PART J: TRAINED INDIVIDUAL CERTIFICATION
I certify that Part A-I of this evaluation were evaluated by me as a trained individual. To the best of my knowledge and belief, the information documented in the report is true, accurate, and complete.
Evaluator Name and Title:
Signature and Date: _____

CERTIFICATE OF COMPLETION & COMPLIANCE

Name of project: _____

Address of premises on which land alteration was accomplished: _____

Inspection Date(s): _____ Stormwater Permit Number: _____

Relative to plans prepared by: _____ on _____
(date)

I hereby certify that:

1. I am familiar with drainage requirements applicable to such land alteration (as set forth in the Stormwater Management Ordinance of Hendricks County); and
2. I (or a person under my direct supervision) have personally inspected the completed work and examined the drainage permit and its conditions, as-built plans, and final drainage calculations consistent with as-built conditions performed pursuant to the above referenced drainage permit; and
3. To the best of my knowledge, information, and belief, such land alteration has been performed and completed in conformity with all such drainage requirements, except _____

Signature: _____

Date: _____

Typed or Printed Name: _____

Phone: (____) _____

(SEAL)

Business Address: _____

SURVEYOR

(circle one)

ENGINEER

Indiana Registration No. _____

TERMINATION INSPECTION CHECKLIST AND COMPLIANCE ASSESSMENT

(To Be Completed by Hendricks County)

1. Compliance Requirements

All construction sites shall undergo a final inspection by the Hendricks County prior to submittal of a Notice of Termination (NOT) to IDEM by the project owner to document the site is stabilized, temporary BMPs have been removed and no future land disturbance will occur within the permitted boundaries. A completed copy of this form confirming compliance with project termination requirements, signed by the Hendricks County representative, is required to be sent by the applicant to IDEM along with the NOT.

2. Inspection Details

Project Name:	
Address/Lot #:	
IDEM Permit No. ("INR" followed by 6 digits):	
Inspection Performed By:	Date:

3. Notice of Termination (NOT) Verification Inspection Items

ITEM	YES	NO	N/A
A. Have all earth disturbing activities been completed?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
B. Are all soils stabilized as appropriate?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
C. Are all drainageways stabilized with either vegetation, rip rap, or other armament?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
D. Have all temporary erosion and sediment control measures been removed?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
E. Has all construction waste, trash, and debris been removed from the site?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
F. Has all construction equipment and material been removed from the site?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
G. Are all the permanent BMPs free of sediment accumulation resulting from construction activities?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

4. Corrective Actions Required (If Applicable)

If you answered "no" to any of the above questions, describe any corrective action which must be taken to remedy the problem and when the corrective actions are to be completed.

Attach additional sheet(s) if needed

5. Compliance Assessment

<input type="checkbox"/> DEFICIENT – Applicant must schedule a re-inspection by Hendricks County after deficiencies are addressed.
<input type="checkbox"/> COMPLIANT – Applicant must upload a signed copy to IDEM along with the IDEM NOT online submittal.

6. Certification and Signature

Inspector Name and Title:	Phone:
Inspector Signature:	Date:

B4 - Individual Lot/Parcel Permit Forms

Instructions for Individual Lot Clean Water Permit Request
Individual Lot Clean Water Permit Request Application
Typical Erosion & Sediment Control Plan and Certification
Individual Lot Stormwater Pollution Prevention Requirements

INSTRUCTIONS FOR INDIVIDUAL LOT CLEAN WATER PERMIT REQUEST

Request shall be made to the Hendricks County Surveyor's Office.

1. Request shall be made on standard form only, supplied by the Surveyor's Office.
2. The form shall be completely filled out, including the following information:
 - a. Name of subdivision/minor plat and lot number.
 - b. Section/Township/Range
 - c. Parcel number of property involved.
 - d. Project name (if none then put individual's name).
 - e. Contact person(s).
 - f. Type of residential lot and/or improvement. This office may require more details depending on the type of improvements being proposed.
3. A certified Plot Plan, including site layout (per Chapter 6, Section 5 of the Stormwater Management Ordinance), is required to be submitted with each permit application.
4. An erosion and sediment control plan is required to be submitted with each permit application. This plan must conform to the minimum requirements in Chapter 6, Section 5 of the Stormwater Management Ordinance and Chapter 7, Section D of these Standards.
5. Need to provide the name, address telephone number, and list of qualifications of the trained individual in charge of the mandatory stormwater pollution prevention self-monitoring program for the project site.
6. Need to abide by any additional requirements set forth in Chapter 6, Section 5 of the Hendricks County Stormwater Management Ordinance.
7. The applicant or an agent of the applicant must sign the form.
8. Check or money order is to be made payable to the Hendricks County Drainage Board. The correct amount of fee, based on the Fee Ordinance, must be included with the application package.

INDIVIDUAL LOT CLEAN WATER PERMIT REQUEST

Name of Subdivision/Minor Plat & Lot #: _____ Project Name: _____
Parcel Number: _____ Section/Township/Range _____
Township Name: _____

Applicant's Name: _____ Property Owner: _____
Address: _____ Property Address: _____
Phone: (____) _____ Phone: (____) _____
Fax: (____) _____ Fax: (____) _____

Contractor/Builder: _____
Address: _____
Phone: (____) _____ Fax: (____) _____
Contact Person: _____ Cell Phone: _____

Type of Residential Lot or Improvement: _____

Trained Individual in Charge of the Mandatory Stormwater Pollution Prevention

Program Name: _____ Address: _____ Phone #: _____

List of Qualifications): _____









The individual lot operator is responsible for installation and maintenance of all erosion and sediment control measures until the site is stabilized.

Signature _____ Date _____

Check Title: Owner _____ Contractor _____ Engineer _____ Agent _____ Other _____

*** For Office Use Only ***	Engineering Firm: _____
Permit # _____	Plan Project # _____ Check # _____

Legend and Check List

	Silt Fence	<input type="checkbox"/>
	Gravel Construction Entrance	<input type="checkbox"/>
	Drop Inlet Protection	<input type="checkbox"/>
	Curb Inlet Protection	<input type="checkbox"/>
	Temporary Seeding	<input type="checkbox"/>
	Property Lines / Drainage Swale	<input type="checkbox"/>
	Constructed Building Pad	<input type="checkbox"/>
	Soil Stockpile Protection	<input type="checkbox"/>

Notes:

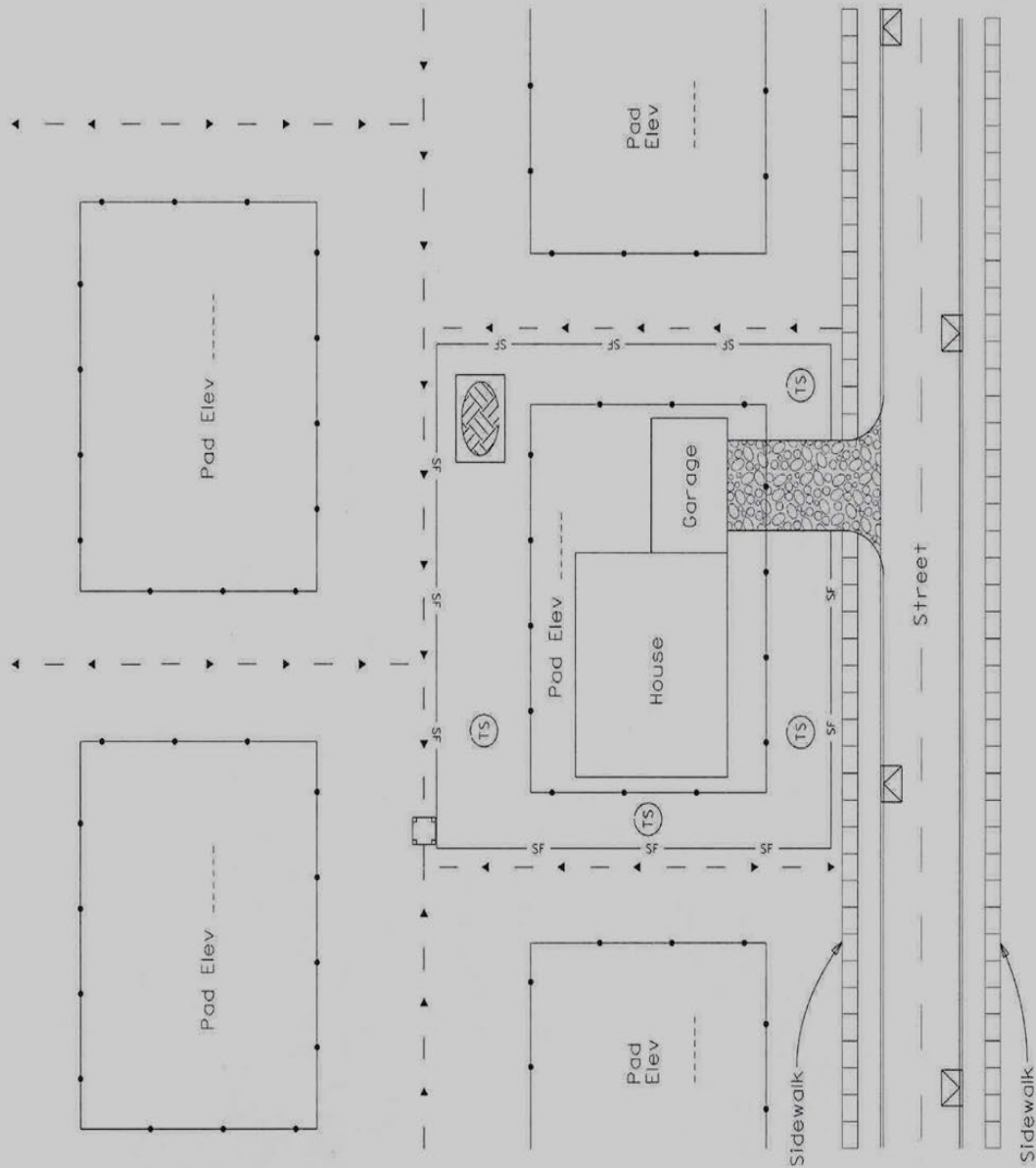
- Draw in any "Do Not Disturb" areas.
- Provide pad elevations for subject property and adjacent properties.
- Erosion Control Measures must be functional and maintained throughout construction.

I hereby certify that the drainage ways, pad elevations, and erosion and sediment control measures are consistent with the overall development plans.

Signature _____

Date _____

Individual Lot Erosion and Sediment Control Plan and Certification



Individual Lot/Parcel Stormwater Pollution Prevention Requirements

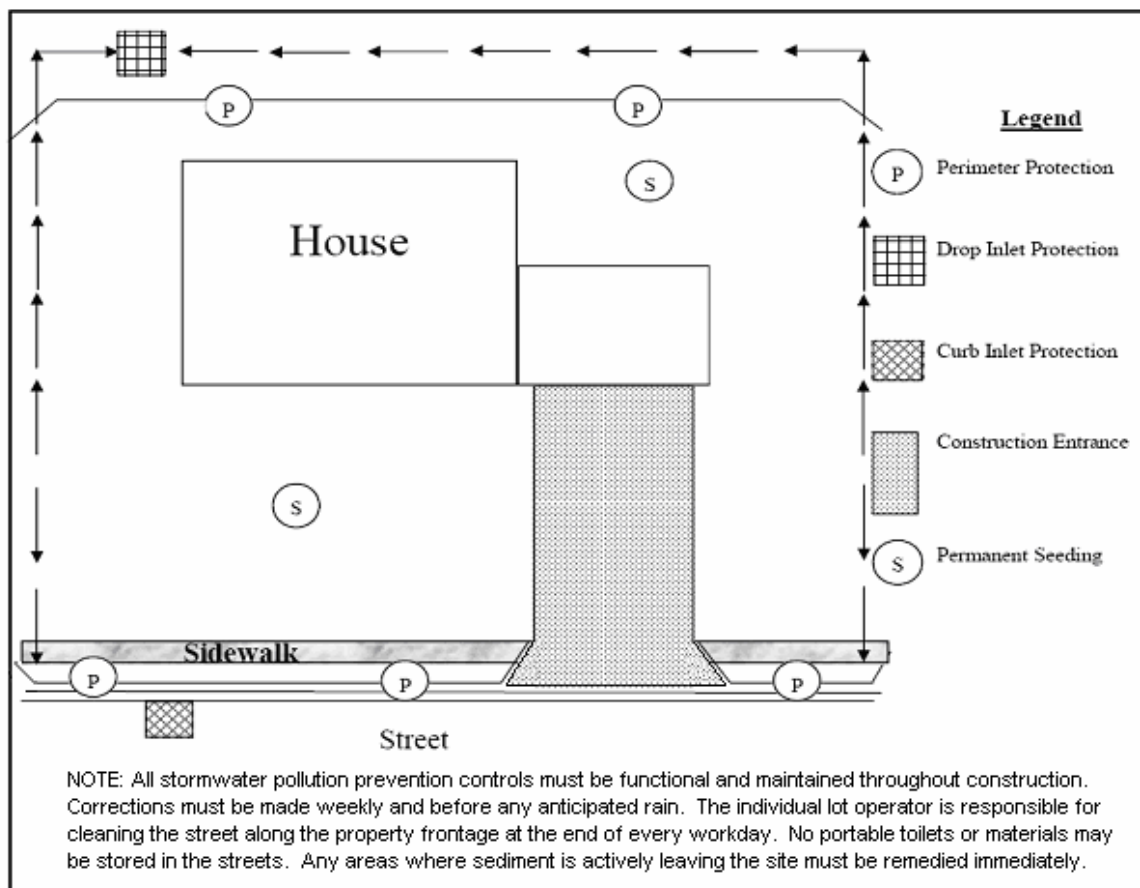
FOR COMPLIANCE WITH HENDRICKS COUNTY STORMWATER CODE

THE INDIVIDUAL LOT OWNER OR OPERATOR IS RESPONSIBLE FOR THE INSTALLATION AND MAINTENANCE OF STORMWATER POLLUTION PREVENTION CONTROLS UNTIL THE ENTIRE LOT IS COMPLETE AND 100% STABILIZED.

- Initial Stormwater controls such as construction entrances, curbside and rear of lot storm inlet protection (geo-textile wrapped under grate is prohibited), and perimeter controls (typically silt fence) must be in place BEFORE ANY LOT DISTURBANCE begins.
- All construction materials must be staged off of the street and on the lot behind perimeter controls.
- Portable toilets must be kept off of the street and should be placed on even ground on the lot behind perimeter controls.
- All lots must provide and utilize appropriate trash containment for site waste.
- Contractors must use appropriate practices for concrete, mortar, and paint washout. These materials must be properly contained and NOT enter the storm drains or other conveyances.
- Any off site tracking of sediment into the street, or off site sedimentation into swales or drains MUST be cleaned as soon as possible and by no later than the end of the day.
- Lot frontage should be cleaned and acceptable in appearance at the end of every business day.
- Areas where operations have impacted adjacent lots or rear yard swales MUST be repaired to design condition and 100% stabilized.

PLEASE NOTE: ANY INSPECTION WILL FAIL IF THE CORRECT STORMWATER POLLUTION PREVENTION CONTROLS ARE NOT IN PLACE AND PROPERLY MAINTAINED.

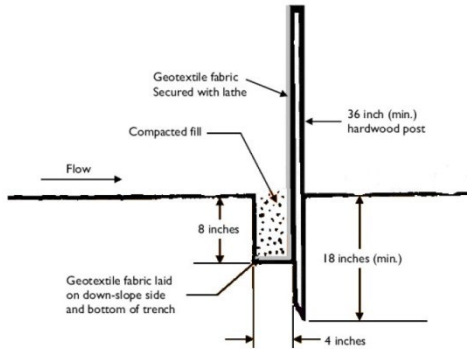
Stormwater Pollution Prevention Controls on Individual Lots



Construction Sequence

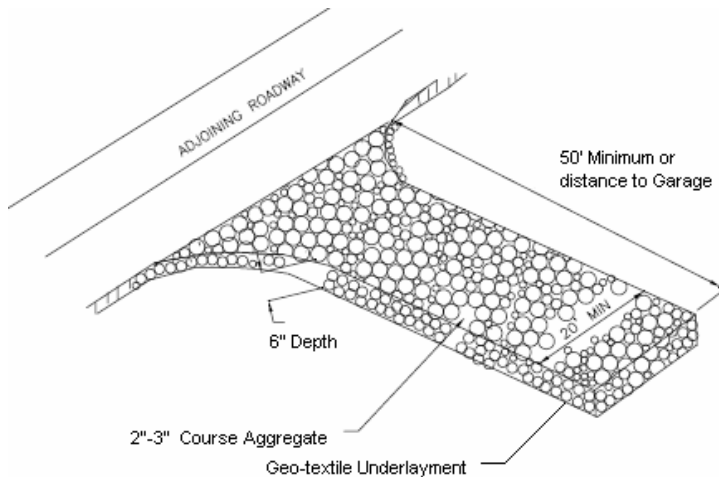
1. Install construction entrance.
 - a. Use #2 stone. Flare entrance at street so it can handle vehicle turn radius. See Detail.
2. Install perimeter protection.
 - a. Protection along the sides of the lot is only necessary if the adjacent lot is built out or if stormwater runoff will drain in that direction.
 - b. Make sure perimeter protections are turned into the lot where they terminate to create a ponding area. See above diagram.
 - c. Rear of lot perimeter protection should be installed to protect the rear yard swale.
3. Install protections on storm inlets at curbside and at rear of lot.
 - a. Geo-textile or "fabric" wrapped underneath the grate is **PROHIBITED**.
 - b. Make sure curbside inlet protection leaves the top 3-4 inches of the storm grate exposed to allow for overflow to enter the storm inlet, preventing ponding.
4. Lot disturbance may begin once the controls listed above are in place.
5. Maintain lot controls at all times and repair as soon as possible when a correction is needed.
 - a. If sediment is actively leaving the site due to a failing control such as tracking or an operation such as dewatering, it must be corrected **IMMEDIATELY**.
6. Stabilize all exposed soils with vegetation, mulch, or stone when construction is complete.
 - a. Lot is considered stabilized once vegetation has reached 100% coverage and 70 % density.
7. Remove temporary stormwater pollution prevention controls.
 - a. These may be removed when exposed soils have been stabilized with vegetation, sod, or mulch.
 - b. Seed alone is not a stabilization measure until it germinates and achieves proper coverage.

BMP DETAILS



Silt Fence

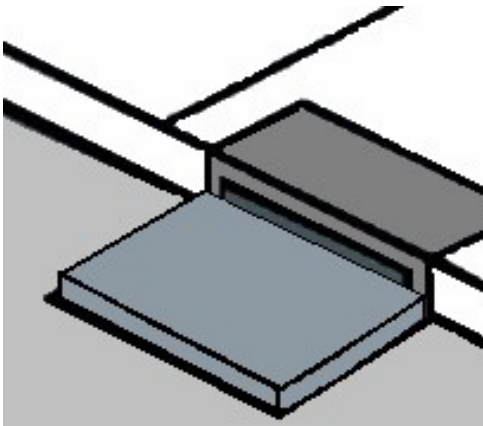
1. Install silt fence parallel to the contour of the land.
2. Extend ends of silt fence upslope 3-4 feet to allow for ponding areas behind the fence.
3. Excavate trench 8 inches deep and 4 inches wide.
4. Install with stakes on the down slope side of fence.
5. Bury 12 inches of fabric in the trench, extending the bottom 4 inches toward the upslope side.
6. Backfill trench on both sides of fence and compact.
7. Join silt fence sections by wrapping two posts and driving them in together. Do not use any other method of joining.
8. Inspect weekly and within 24 hrs of a ½" of rain. Silt fence should be cleaned out when the sediment has reached 1/3 the height of the exposed fencing. Repair silt fence where torn or damaged. Complete repairs before the next anticipated rain and by no later than one week from the date they are noticed.



Construction Entrance

1. Install construction entrance from street to face of proposed building or at a 50' minimum length. Use #2 stone at a 6" minimum depth.
2. A geo-textile is required underneath the entrance to extend its functionality.
3. Flare out entrance where it meets the street so that vehicle turn radiuses do not travel over disturbed ground.
4. Perimeter Controls (silt fence) should be turned into the lot for a few feet where they meet the construction entrance.
5. Inspect weekly and within 24 hrs of a ½"

of rain. Freshen or replace stone as needed to prevent off site tracking. If offsite tracking is occurring, clean up immediately, and correct the reason why the drive is failing as soon as possible. Complete repairs before the next anticipated rain and by no later than one week from the date they are noted.



Inlet Protection

1. Install inlet protection on all curbside and rear of lot storm inlets within the flow line of the active lot.
2. Curbside inlet protection should be installed so that 3 – 4 inches of the top of the casting is exposed to allow for overflow, preventing excessive ponding.
3. Wrapping geo-textile underneath the grate for protection or straw bale barriers are PROHIBITED practices.
4. Make sure inlet protection is securely fastened to the storm grate and installed per the manufacturer's recommendations.

5. Inspect weekly and within 24 hrs of a $\frac{1}{2}$ " of rain. Sediment accumulation or standing water around the inlet can indicate the need for maintenance. Clean protection when clogged with sediment or when it reaches $\frac{1}{2}$ of the storage capacity or height of the control. Replace protection if torn or worn. Clean sediment from street around the storm inlet and place back onto lot behind perimeter controls. Complete repairs before the next anticipated rain and by no later than one week from the day they are noted.

APPENDIX C

CONSTRUCTION BMPs

BMP CN – 101 WHEEL WASH

DESCRIPTION

When a stabilized construction entrance is not preventing sediment from being tracked onto pavement, a wheel wash may be installed. Wheel washing is generally an effective BMP when installed with careful attention to topography. For example, a wheel wash can be detrimental if installed at the top of a slope abutting a right-of-way where the water from the dripping truck can run unimpeded into the street. Pressure washing combined with an adequately sized and surfaced pad with direct drainage to a large 10-foot x 10-foot sump can be very effective.

ADVANTAGES

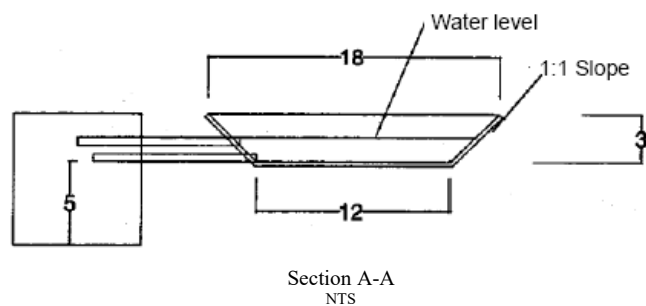
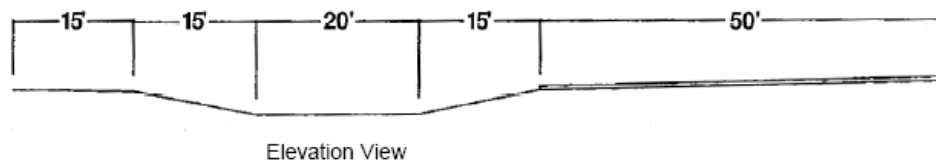
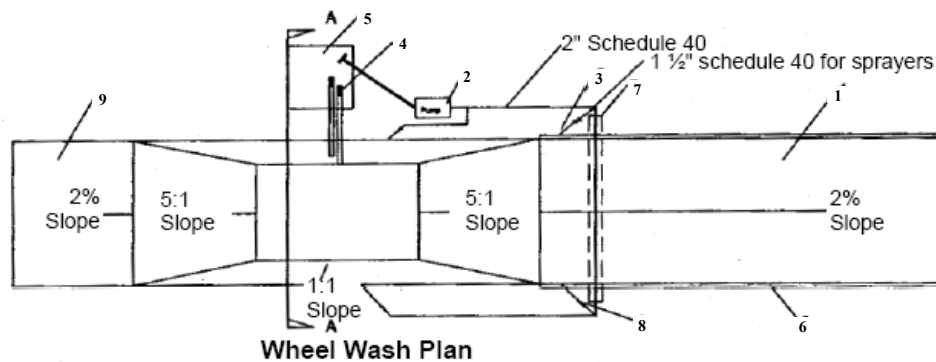
1. Wheel washes reduce the amount of sediment transported onto paved roads by motor vehicles.

DESIGN CRITERIA

1. Suggested details are shown in Figure CN-101-A. Hendricks County may allow other designs.
2. A minimum of 6 inches of asphalt treated base (ATB) over crushed base material or 8 inches over a good subgrade is recommended to pave the wheel wash.
3. Use a low clearance truck to test the wheel wash before paving. Either a belly dump or lowboy will work well to test clearance.
4. Keep the water level from 12 to 14 inches deep to avoid damage to truck hubs and filling the truck tongues with water.
5. Midpoint spray nozzles are only needed in extremely muddy conditions.
6. Wheel wash systems should be designed with a small grade change, 6 to 12 inches for a 10-foot-wide pond, to allow sediment to flow to the low side of pond to help prevent re-suspension of sediment.
7. A drainpipe with a 2- to 3-foot riser should be installed on the low side of the pond to allow for easy cleaning and refilling.
8. Polymers may be used to promote coagulation and flocculation in a closed-loop system. Polyacrylamide (PAM) added to the wheel wash water at a rate of 0.25 - 0.5 pounds per 1,000 gallons of water increases effectiveness and reduces cleanup time.
9. If PAM is already being used for dust or erosion control and is being applied by a water truck, the same truck can be used to change the wash water.
10. The wheel wash should start out the day with fresh water. The wash water should be changed a minimum of once per day.
11. On large earthwork jobs where more than 10-20 trucks per hour are expected, the wash water will need to be changed more often.
12. Wheel wash or tire bath wastewater shall be discharged to a separate on-site treatment system, such as closed-loop recirculation or land application, or to the sanitary sewer with proper local sewer utility approval.

REFERENCE

City of Tacoma, Surface Water Management Manual, 2003 or later



Notes:

1. Asphalt construction entrance 6 in. asphalt treated base (ATB).
2. 3-inch trash pump with floats on the suction hose.
3. Midpoint spray nozzles, if needed.
4. 6-inch sewer pipe with butterfly valves. Bottom one is a drain. Locate top pipe's invert 1 foot above bottom of wheel wash.
5. 8 foot x 8 foot sump with 5 feet of catch. Build so can be cleaned with trackhoe.
6. Asphalt curb on the low road side to direct water back to pond.
7. 6-inch sleeve under road.
8. Ball valves.
9. 15 foot. ATB apron to protect ground from splashing water.

Figure CN-101-A

BMP CN – 102 DEWATERING STRUCTURE

DESCRIPTION

Water which is pumped from a construction site usually contains a large amount of sediment. A dewatering structure is designed to remove the sediment before water is released off-site.

This practice includes several types of dewatering structures which have different applications dependent upon site conditions and types of operation. Other innovative techniques for accomplishing the same purpose are encouraged, but only after specific plans and details are submitted to and approved by Hendricks County .

DESIGN CRITERIA

1. A dewatering structure must be sized (and operated) to allow pumped water to flow through the filtering device without overtopping the structure.
2. Material from any required excavation shall be stored in an area and protected in a manner that will prevent sediments from eroding and moving off-site.
3. An excavated basin (applicable to "Straw Bale/Silt Fence Pit") may be lined with filter fabric to help reduce scour and to prevent the inclusion of soil from within the structure.
4. Design criteria more specific to each particular dewatering device can be found in Figures CN-102-A through CN-102-C.
5. A dewatering structure may not be needed if there is a well-stabilized, vegetated area onsite to which water may be discharged. The area must be stabilized so that it can filter sediment and at the same time withstand the velocity of the discharged water without eroding. A minimum filtering length of 75 feet must be available in order for such a method to be feasible.
6. The filtering devices must be inspected frequently and repaired or replaced once the sediment build-up prevents the structure from functioning as designed.
7. The accumulated sediment which is removed from a dewatering device must be spread on-site and stabilized or disposed of at an approved disposal site as per approved plan.

Portable Sediment Tank (see Figure CN102-A)

- The structure may be constructed with steel drums, sturdy wood or other material suitable for handling the pressure exerted by the volume of water.
- Sediment tanks will have a minimum depth of 2 ft.
- The sediment tank shall be located for easy clean-out and disposal of the trapped sediment and to minimize the interference with construction activities.
- The following formula shall be used to determine the storage volume of the sediment tank:

$$\text{Pump discharge (gallons/min.)} \times 16 = \text{cubic feet of storage required}$$

- Once the water level nears the top of the tank, the pump must be shut off while the tank drains and additional capacity is made available.
- The tank shall be designed to allow for emergency flow over top of the tank. Clean-out of the tank is required once one-third of the original capacity is depleted due to sediment accumulation. The tank shall be clearly marked showing the clean-out point.

Filter Box (see Figure CN-102-B)

- The box selected should be made of steel, sturdy wood or other materials suitable to handle the pressure requirements imposed by the volume of water. Normally readily available 55 gallon drums welded top to bottom will suffice in most cases.
- Bottom of the box shall be made porous by drilling holes (or some other method).
- Coarse aggregate shall be placed over the holes at a minimum depth of 12 inches, metal "hardware" cloth may need to be placed between the aggregate and the holes if holes are drilled larger than the majority of the stone.
- As a result of the fast rate of flow of sediment-laden water through the aggregate, the effluent must be directed over a well-vegetated strip of at least 50 feet after leaving the base of the filter box.
- The box shall be sized as follows:

$$\text{Pump discharge (gallons/min.)} \times 16 = \text{cubic feet of storage required}$$

- Once the water level nears the top of the box, the pump must be shut off while the box drains and additional capacity is made available.
- The box shall be designed/constructed to allow for emergency flow over the top of this box.
- Clean-out of the box is required once one-third of the original capacity is depleted due to sediment accumulation. The tank shall be clearly marked showing the clean-out point.
- If the stone filter does become clogged with sediment so that it no longer adequately performs its function, the stones must be pulled away from the inlet, cleaned and replaced.
- Using a filter box only allows for minimal settling time for sediment particles; therefore, it should only be used when site conditions restrict the use of the other methods.

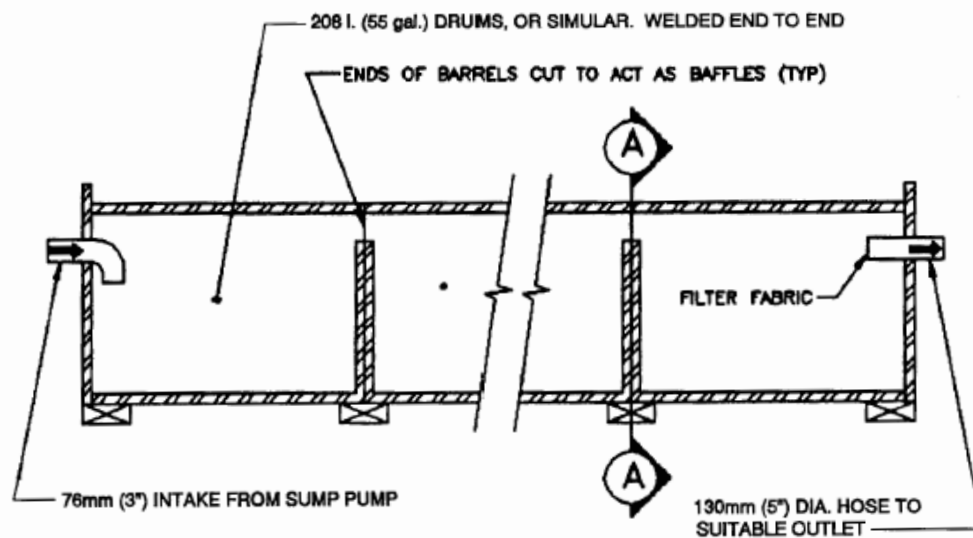
Straw Bale/Silt Fence Pit (see Figure CN-102-C)

- Measure shall consist of straw bales, silt fence, a stone outlet (a combination of riprap and aggregate) and a wet storage pit oriented as shown in Figure CN-102-C.
- The structure must have a capacity which is dictated by the following formula:
$$\text{Pump discharge (gallons/min.)} \times 16 = \text{cubic feet of storage required}$$
- In calculating the capacity, one should include the volume available from the floor of the excavation to the crest of the stone weir.
- In any case, the excavated area should be a minimum of 3 feet below the base of the perimeter measures (straw bales or silt fence).
- The perimeter measures must be installed as per the guidelines found in BMP-4, STRAW BALE BARRIER and BMP-5, SILT FENCE.
- Once the water level nears the crest of the stone weir (emergency overflow), the pump must be shut off while the structure drains down to the elevation of the wet storage.
- The wet storage pit may be dewatered only after a minimum of 6 hours of sediment settling time. This effluent should be pumped across a well vegetated area or through a silt fence prior to entering a watercourse.
- Once the wet storage area becomes filled to one-half of the, excavated depth, accumulated sediment shall be removed and properly disposed of.

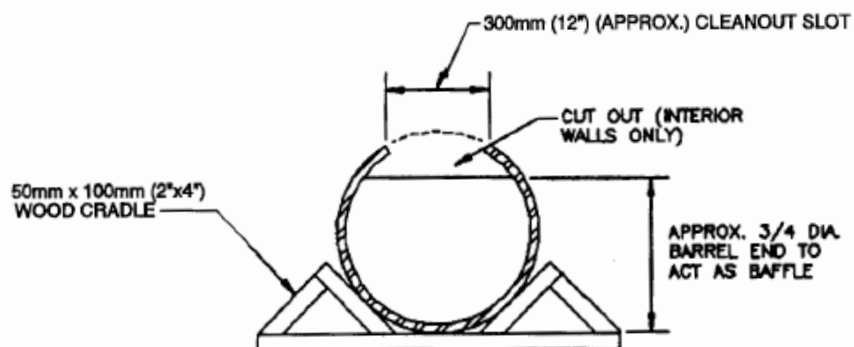
- Once the device has been removed, ground contours will be returned to original condition.

REFERENCE

United States Army Corps of Engineers, Handbook for the Preparation of Storm Water Pollution Prevention Plans for Construction Activities, 1997 or later

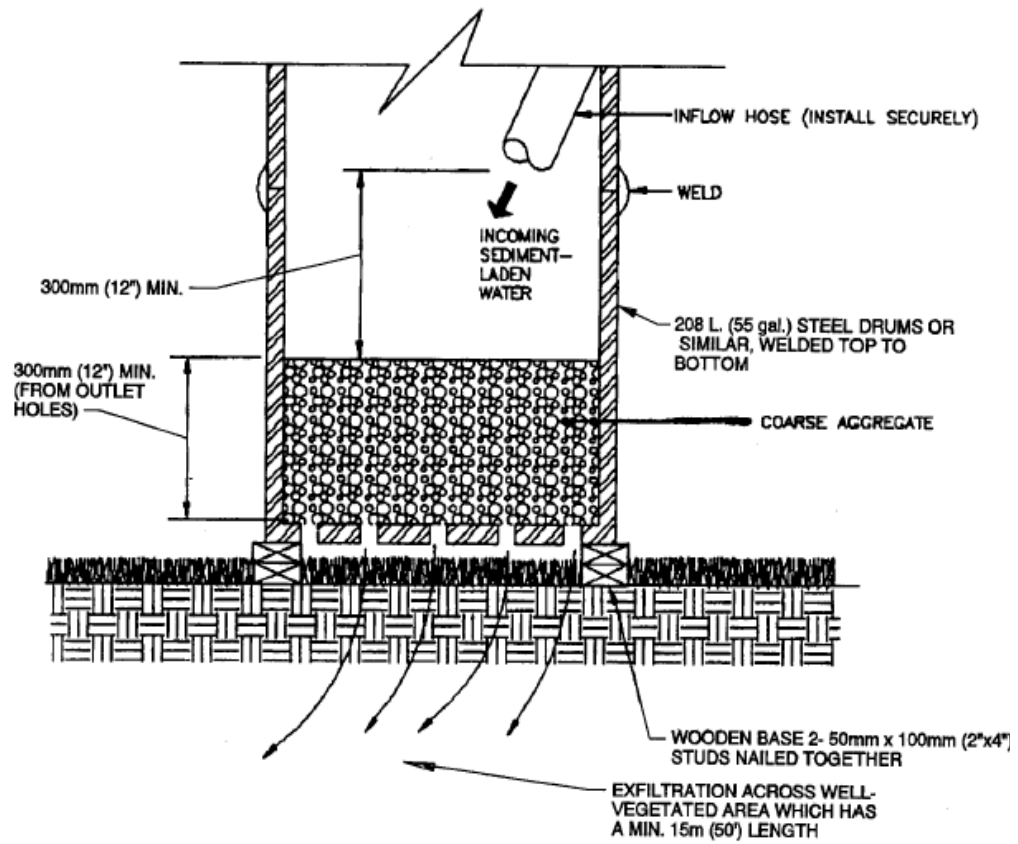


ELEVATION



CROSS-SECTION A-A

Figure CN-102-A
Portable Sediment Tank



ELEVATION VIEW

**Figure CN-102-B
Filter Box**



BMP CN – 103

SPILL PREVENTION AND CONTROL

DESCRIPTION

These procedures and practices are implemented to prevent and control spills in a manner that minimizes or prevents the discharge of spilled material to the drainage system or watercourses.

This best management practice (BMP) applies to all construction projects. Spill control procedures are implemented anytime chemicals and/or hazardous substances are stored. Substances may include, but are not limited to:

- Soil stabilizers/binders
- Dust Palliatives
- Herbicides
- Growth inhibitors
- Fertilizers
- Deicing/anti-icing chemicals
- Fuels
- Lubricants
- Other petroleum distillates

To the extent that the work can be accomplished safely, spills of oil, petroleum products, sanitary and septic wastes, and substances listed under 40 Code of Federal Regulations (CFR) parts 110, 117, and 302 shall be contained and cleaned up immediately.

LIMITATIONS

1. This BMP only applies to spills caused by the contractor.
2. Procedures and practices presented in this BMP are general. Contractor shall identify appropriate practices for the specific materials used or stored on-site in advance of their arrival at the site.

DESIGN CRITERIA

1. To the extent that it doesn't compromise cleanup activities, spills shall be covered and protected from stormwater runoff during rainfall.
2. Spills shall not be buried or washed with water.
3. Used clean up materials, contaminated materials, and recovered spill material that is no longer suitable for the intended purpose shall be stored and disposed of in conformance with BMP CN-105: Hazardous Waste Management.
4. Water used for cleaning and decontamination shall not be allowed to enter storm drains or watercourses and shall be collected and disposed of in accordance with BMP CN-105: Hazardous Waste Management.
5. Water overflow or minor water spillage shall be contained and shall not be allowed to discharge into drainage facilities or watercourses.

6. Proper storage, clean-up and spill reporting instruction for hazardous materials stored or used on the project site shall be posted at all times in an open, conspicuous and accessible location.
7. Waste storage areas shall be kept clean, well organized and equipped with ample clean-up supplies as appropriate for the materials being stored. Perimeter controls, containment structures, covers and liners shall be repaired or replaced as needed to maintain proper function.
8. Verify weekly that spill control and clean up materials are located near material storage, unloading, and use areas.
9. Update spill prevention and control plans and stock appropriate clean-up materials whenever changes occur in the types of chemicals used or stored onsite.

Cleanup and Storage Procedures for Minor Spills

- Minor spills typically involve small quantities of oil, gasoline, paint, etc., which can be controlled by the first responder at the discovery of the spill.
- Use absorbent materials on small spills rather than hosing down or burying the spill.
- Remove the absorbent materials promptly and dispose of properly.
- The practice commonly followed for a minor spill is:
 - Contain the spread of the spill.
 - Recover spilled materials.
 - Clean the contaminated area and/or properly dispose of contaminated materials.

Cleanup and Storage Procedures for Semi-Significant Spills

- Semi-significant spills still can be controlled by the first responder along with the aid of other personnel such as laborers and the foreman, etc. This response may require the cessation of all other activities.
- Clean up spills immediately:
- Notify the project foreman immediately. The foreman shall notify the jurisdiction's Emergency Management Agency's Hazardous Materials Response Team.
- Contain spread of the spill.
- If the spill occurs on paved or impermeable surfaces, clean up using "dry" methods (absorbent materials, cat litter and/or rags). Contain the spill by encircling with absorbent materials and do not let the spill spread widely.
- If the spill occurs in dirt areas, immediately contain the spill by constructing an earthen dike. Dig up and properly dispose of contaminated soil.
- If the spill occurs during rain, cover spill with tarps or other material to prevent contaminating runoff.

Cleanup and Storage Procedures for Significant/Hazardous Spills

- For significant or hazardous spills that cannot be controlled by personnel in the immediate vicinity, notify the local emergency response by dialing 911. In addition to 911, the contractor will notify the proper jurisdiction's officials. It is the contractor's responsibility to have all emergency phone numbers at the construction site.

- For spills of federal reportable quantities, in conformance with the requirements in 40 CFR parts 110,119, and 302, the contractor shall notify the National Response Center at (800) 424-8802.
- Notification shall first be made by telephone and followed up with a written report.
- The services of a spills contractor or a Haz-Mat team shall be obtained immediately. Construction personnel shall not attempt to clean up the spill until the appropriate and qualified personnel have arrived at the job site.

REFERENCE

California Department of Transportation, Construction Site BMP Manual, 2000 or later

BMP CN – 104

SOLID WASTE MANAGEMENT

DESCRIPTION

Solid waste management procedures and practices are designed to minimize or eliminate the discharge of pollutants to the drainage system or to watercourses as a result of the creation, stockpiling, or removal of construction site wastes.

Solid waste management procedures and practices are implemented on all construction projects that generate solid wastes.

Solid wastes include but are not limited to:

1. Construction wastes including brick, mortar, timber, steel and metal scraps, sawdust, pipe and electrical cuttings, non-hazardous equipment parts, styrofoam and other materials used to transport and package construction materials.
2. Landscaping wastes, including vegetative material, plant containers, and packaging materials.
3. Litter, including food containers, beverage cans, coffee cups, paper bags, plastic wrappers, and smoking materials, including litter generated by the public.

LIMITATIONS

1. Temporary stockpiling of certain construction wastes may not necessitate stringent drainage related controls during the non-rainy season.

DESIGN CRITERIA

1. Dumpsters of sufficient size and number shall be provided to contain the solid waste generated by the project and properly serviced.
2. Littering on the project site shall be prohibited.
3. To prevent clogging of the storm drainage system, litter and debris removal from drainage grates, trash racks, and ditch lines shall be a priority.
4. Trash receptacles with lids shall be provided in the contractor's yard, field trailer areas, and at locations where workers congregate for lunch and break periods.
5. Construction debris and litter from work areas within the construction limits of the project site shall be collected and placed in watertight dumpsters at least weekly regardless of whether the litter was generated by the contractor, the public, or others. Collected litter and debris shall not be placed in or next to drain inlets, storm water drainage systems or watercourses.
6. Full dumpsters shall be removed from the project site and the contents shall be disposed of, off-site, in an appropriate manner.;
7. Litter stored in collection areas and containers shall be handled and disposed of by trash hauling contractors.
8. Construction debris and waste shall be removed from the site every two weeks.
9. Stormwater run-off shall be prevented from contacting stored solid waste through the use of berms, dikes, or other temporary diversion structures or through the use of measures to elevate waste from site surfaces.
10. Solid waste storage areas shall be located at least 50 ft from drainage facilities and watercourses and shall not be located in areas prone to flooding or ponding.

11. Except during fair weather, construction and landscaping waste not stored in watertight dumpsters shall be securely covered from wind and rain by covering the waste with tarps, plastic sheeting, or equivalent.
12. Dumpster washout on the project site is not allowed.
13. Notify trash hauling contractors that only watertight dumpsters are acceptable for use on-site.
14. Plan for additional containers during the demolition phase of construction.
15. Plan for more frequent pickup during the demolition phase of construction.
16. Construction waste shall be stored in a designated area. Access to the designated area shall either be well vegetated ground, a concrete or asphalt road or drive, or a gravel construction entrance, to avoid mud tracking by trash hauling contractors.
17. Segregate potentially hazardous waste from non-hazardous construction site waste.
18. Keep the site clean of litter debris.
19. Make sure that toxic liquid wastes (e.g., used oils, solvents, and paints) and chemicals (e.g., acids, pesticides, additives, curing compounds) are not disposed of in dumpsters designated for construction debris.
20. For disposal of hazardous waste, see BMP CN-105: Hazardous Waste Management. Have hazardous waste hauled to an appropriate disposal and/or recycling facility.
21. Salvage or recycle useful vegetation debris, packaging and/or surplus building materials when practical. For example, trees and shrubs from land clearing can be converted into wood chips, then used as mulch on graded areas. Wood pallets, cardboard boxes, and construction scraps can also be recycled.
22. Prohibit littering by employees, subcontractors, and visitors.
23. Wherever possible, minimize production of solid waste materials.

REFERENCE

California Department of Transportation, Construction Site BMP Manual, 2000 or later

BMP CN – 105

HAZARDOUS WASTE MANAGEMENT

DESCRIPTION

These are procedures and practices to minimize or eliminate the discharge of pollutants from construction site hazardous waste to the storm drain systems or to watercourses.

This best management practice (BMP) applies to all construction projects.

Hazardous waste management practices are implemented on construction projects that generate waste from the use of:

- Petroleum Products,
- Asphalt Products,
- Concrete Curing Compounds,
- Pesticides,
- Acids,
- Paints,
- Stains,
- Solvents,
- Wood Preservatives,
- Roofing Tar, or
- Any materials deemed a hazardous waste in 40 CFR Parts 110, 117, 261, or 302.

DESIGN CRITERIA

Storage Procedures

1. Wastes shall be stored in sealed containers constructed of a suitable material and shall be labeled as required by 49 CFR Parts 172, 173, 178, and 179.
2. All hazardous waste shall be stored, transported, and disposed as required in 49 CFR 261-263.
3. Waste containers shall be stored in temporary containment facilities that shall comply with the following requirements:
 - Temporary containment facility shall provide for a spill containment volume able to contain precipitation from a 24-hour, 25 year storm event, plus the greater of 10% of the aggregate volume of all containers or 100% of the capacity of the largest tank within its boundary, whichever is greater.
 - Temporary containment facility shall be impervious to the materials stored there for a minimum contact time of 72 hours.
 - Temporary containment facilities shall be maintained free of accumulated rainwater and spills. In the event of spills or leaks accumulated rainwater and spills shall be placed into drums after each rainfall. These liquids shall be handled as a hazardous waste unless testing determines them to be non-hazardous. Non-hazardous liquids shall be sent to an approved disposal site.
 - Sufficient separation shall be provided between stored containers to allow for spill cleanup and emergency response access.
 - Incompatible materials, such as chlorine and ammonia, shall not be stored in the same temporary containment facility.

- Throughout the rainy season, temporary containment facilities shall be covered during non-working days, and prior to rain events. Covered facilities may include use of plastic tarps for small facilities or constructed roofs with overhangs. A storage facility having a solid cover and sides is preferred to a temporary tarp. Storage facilities shall be equipped with adequate ventilation.
- 4. Drums shall not be overfilled and wastes shall not be mixed.
- 5. Unless watertight, containers of dry waste shall be stored on pallets.
- 6. Paint brushes and equipment for water and oil based paints shall be cleaned within a contained area and shall not be allowed to contaminate site soils, watercourses or drainage systems. Waste paints, thinners, solvents, residues, and sludge that cannot be recycled or reused shall be disposed of as hazardous waste. When thoroughly dry, latex paint and paint cans, used brushes, rags, absorbent materials, and drop cloths shall be disposed of as solid waste.
- 7. Ensure that adequate hazardous waste storage volume is available.
- 8. Ensure that hazardous waste collection containers are conveniently located.
- 9. Designate hazardous waste storage areas on site away from storm drains or watercourses and away from moving vehicles and equipment to prevent accidental spills.
- 10. Minimize production or generation of hazardous materials and hazardous waste on the job site.
- 11. Use containment berms in fueling and maintenance areas and where the potential for spills is high.
- 12. Segregate potentially hazardous waste from non-hazardous construction site debris.
- 13. Keep liquid or semi-liquid hazardous waste in appropriate containers (closed drums or similar) and under cover.
- 14. Clearly label all hazardous waste containers with the waste being stored and the date of accumulation.
- 15. Place hazardous waste containers in secondary containment.
- 16. Do not allow potentially hazardous waste materials to accumulate on the ground.
- 17. Do not mix wastes.

Disposal Procedures

1. Waste shall be removed from the site within 90 days of being generated.
2. Waste shall be disposed of by a licensed hazardous waste transporter at an authorized and licensed disposal facility or recycling facility utilizing properly completed Uniform Hazardous Waste Manifest forms.
3. A certified laboratory shall sample waste and classify it to determine the appropriate disposal facility.
4. Make sure that toxic liquid wastes (e.g., used oils, solvents, and paints) and chemicals (e.g., acids, pesticides, additives, curing compounds) are not disposed of in dumpsters designated for solid waste construction debris.
5. Properly dispose of rainwater in secondary containment that may have mixed with hazardous waste.
6. Recycle any useful material such as used oil or water-based paint when practical.

Maintenance and Inspection

1. A foreman and/or construction supervisor shall monitor on-site hazardous waste storage and disposal procedures.
2. Waste storage areas shall be kept clean, well organized, and equipped with ample clean-up supplies as appropriate for the materials being stored. Storage areas shall be inspected in conformance with the provisions in the contract documents.

3. Perimeter controls, containment structures, covers, and liners shall be repaired or replaced as needed to maintain proper function.
4. Hazardous spills shall be cleaned up and reported in conformance with the applicable Material Safety Data Sheet (MSDS) and the instructions posted at the project site.
5. The National Response Center, at (800) 424-8802, shall be notified of spills of Federal reportable quantities in conformance with the requirements in 40 CFR parts 110, 117, and 302.
6. Copy of the hazardous waste manifests shall be provided to the owner.

REFERENCE

California Department of Transportation, Construction Site BMP Manual, 2000 or later

APPENDIX D

POST-CONSTRUCTION APPENDICES

(Separate Document)

List of Post-Construction BMP Appendices

- **Stormwater BMP Fact Sheets (Appendix D1)**
 - **Part 1: Nonstructural BMPs for LID Approach**
 - **Part 2: Structural BMPs for LID and Conventional Approaches**
- **Recommended Plant Lists for Best Management Practices (Appendix D2)**
- **Recommended Materials (Appendix D3)**
- **Soil Infiltration Testing Protocol (Appendix D4)**
- **Maintenance Inspection Checklists (Appendix D5)**
- **Stormwater Management Practices Maintenance Agreement (Appendix D6)**

Stormwater BMP Fact Sheets

Appendix D1

Part 1

Nonstructural BMPs for LID Approach

- **Introduction**
- **Cluster-Type Development**
- **Minimize Soil Compaction**
- **Minimize Total Disturbed Area**
- **Protect Natural Flow Pathways**
- **Protect Riparian Buffer Areas**
- **Protect Sensitive Areas**
- **Reduce Impervious Surfaces**
- **Stormwater Disconnection**

INTRODUCTION TO LID NONSTRUCTURAL BEST MANAGEMENT PRACTICES

A core concept of LID is preventing stormwater runoff by integrating site design and planning techniques that preserve natural systems and hydrologic functions, protect open spaces, as well as conserve wetlands and stream corridors on a site. This introductory segment provides detailed technical information on integrating nonstructural Best Management Practices (BMPs) early into the site design process.

The nonstructural BMPs are:

- Cluster-Type development,
- Minimize soil compaction,
- Minimize total disturbed area,
- Protect natural flow pathways,
- Protect riparian buffers,
- Protect sensitive areas,
- Reduce impervious surfaces, and
- Stormwater disconnection.

Specifically, this introductory segment discusses:

- The benefits of using nonstructural BMPs,
- The process for selecting nonstructural BMPs, and
- An overview of the format and contents of BMP fact sheets.

Green Development Standards

The primary LID characteristic of nonstructural BMPs is preventing stormwater runoff from the site. This differs from the goal of structural BMPs which is to help mitigate stormwater-related impacts after they have occurred.

More specifically, nonstructural BMPs take broader planning and design approaches, which are less “structural” in their form. Many nonstructural BMPs apply to an entire site and often to an entire community, such as wetland protection through a community wetland ordinance. They are not fixed or specific to one location. Structural BMPs, on the other hand, are decidedly more location specific and explicit in their physical form.

Benefits of using nonstructural BMPs

There are numerous benefits of incorporating nonstructural BMPs into a site. While individual benefits are discussed in detail under each BMP, there are many benefits that apply to most, if not all, of the nonstructural BMPs. These include:

- Reduced land clearing costs,
- Reduced costs for total infrastructure,
- Reduced total stormwater management costs,
- Enhanced community and individual lot aesthetics, and
- Improved overall marketability and property values.

The following steps are used to integrate LID into the site design process:

Step 1 - Property acquisition and use analysis

Step 2 - Inventory and evaluate the site

Step 3 - Integrate municipal, county, state, and federal requirements

Step 4 - Develop initial concept design using nonstructural BMPs

Step 5 - Organize pre-submission meeting and site visit with local decision makers

Step 6 - Incorporate revisions to development concept

Step 7 - Apply structural BMP selection process

Step 8 - Apply the LID calculation methodology

Step 9 - Develop the preliminary site plan

BMP Selection Process

This introductory segment and the nonstructural BMP fact sheets that follow focus on Step 4 in the site design process for LID to develop the initial concept design using nonstructural BMPs. Selection of nonstructural BMPs should focus on information gathered in Steps 1-3 of the site design process. Following are specific questions and issues to provide guidance in the selection process.

- How is the property being used? A residential development may have more applicability for certain nonstructural BMPs than other land uses. For example, cluster development is an applicable BMP for residential development, but may be less used in more urban situations.
- What natural features are on site? A thorough site inventory will provide the necessary information to assess the ability to implement many of the BMPs, including preserving sensitive and riparian areas.
- What local, county, state, and other regulations need to be met? A review of local, county, state, and other regulations can also provide guidance on selecting the right mix of nonstructural BMPs.

Overview of the Format of the BMP Fact Sheets

Each BMP fact sheet begins with a summary sheet that provides a quick overview of the BMP. The ratings contained in the summary sheet have been condensed to general categories (High, Medium, and Low) with these summary ratings often discussed in more detail in the detailed information segment of the fact sheet. Stormwater Quality Functions are based on a compilation of recent national/international studies rating pollutant removal performance.

Following the summary sheet, a series of detailed information on the BMP is provided which includes:

Variations

Discusses the variations to the BMP, if applicable. Examples include alternatives in design that can increase storage capacity or infiltration rates.

Applications

Indicates land use types for which the BMP is applicable or feasible.

Design Considerations

This section includes a list of technical procedures to be considered when designing for the individual BMP. This specific design criteria is presented, which can assist planners in incorporating LID techniques into a site design, as well as provide a basis for reviewers to evaluate submitted LID techniques.

Stormwater Calculations and Functions

Provides specific guidance on achieving sizing criteria, volume reduction, and peak rate mitigation, as applicable. This section also references the Post-Construction Stormwater Quality Management Chapter of the Technical Standards which discusses in detail how to achieve a specific standard or implement measures that contribute to managing water onsite in a more qualitative manner.

Construction Guidelines

Provides a typical construction sequence for implementing the BMP. However, it does not specifically address soil erosion and sedimentation control procedures. Erosion and sediment control methods need to adhere to the construction BMP requirements contained in the Technical Standards document and the latest requirements of IDEM's Soil Erosion and Sedimentation Control (Rule 5) Program.

Maintenance

Provides guidance on recommended maintenance procedures for the BMP.

Winter Considerations

Discusses how well the BMP performs in Indiana's cold climate.

Cost

Provides general cost information for comparison purposes. If specific dates of costs are not referenced in this section, the costs reflect 2007 conditions.

Designer/Reviewer's Checklist

Developed to assist a designer and or reviewer in evaluating the critical components of a BMP that is

being designed. It references not only individual design considerations, but also suggests review of additional pertinent sections of the Technical Standards that may need to be considered for implementation of that BMP.

References

Provides a list of sources of information utilized in the creation of this section of the manual. This list also provides additional sources that can be used for additional information.

Each fact sheet includes a summary sheet and additional detailed information regarding the BMP:

BMP Fact Sheet

TITLE

Short definition of BMP

Applications – Indicates in what type of land use BMP is applicable or feasible (**Yes**, **No**, or **Limited**).

Stormwater Quantity Functions – Indicates how well the BMP functions in mitigating stormwater management criteria (**High**, **Medium**, or **Low**).

Stormwater Quality Functions – Indicates how well the BMP performs in terms of pollutant removal (**High**, **Medium**, or **Low**).

Applications		Stormwater Quantity Functions	
Residential		Volume	
Commercial		Groundwater Recharge	
Ultra Urban		Peak Rate	
Industrial		Stormwater Quality Functions	
Retrofit		TSS – Total Suspended Solids	
Highway/Road		TP – Total Phosphorus	
Recreational		TN or NO ₃ – Total Nitrogen/Nitrate	
		Temperature	

Additional Considerations

Cost – Indicates whether cost is high, medium or low by the following categories

- **High** – adds more than 5% to total project cost
- **Medium** – adds 1–5% to total project cost
- **Low** – adds less than 1% to total project cost

Maintenance – Indicates level of maintenance required to maintain BMP (**High**, **Medium**, or **Low**).

- **High** – Maintenance intensive (i.e., year-round maintenance)
- **Medium** – Several times per year
- **Low** – One time per year

Winter Performance – Indicates if BMP provides equivalent performance throughout the winter (**High**, **Medium**, or **Low**)

- **High** – BMP performs very well in winter conditions
- **Medium** – BMP has reduced performance in winter conditions
- **Low** – BMP still performs in winter conditions, but performance is significantly reduced.

Variations (optional)

Lists of variations to the BMP if applicable

Key Design Features

Bulleted list of information that is key to the design of BMP

Site Factors (optional)

List of specific factors that relate to BMP performance

- Water table/bedrock separation distance
- Soil type
- Feasibility on steeper slopes
- Applicability on potential hotspots (e.g., brownfields)

Benefits

List of benefits directly related to implementing the BMP

Limitations

List of site constraints associated with implementation

Detailed Information - As indicated earlier, more detailed information regarding each BMP, including Description and Function, Variations, Applications, Design Considerations, Stormwater Calculations and Functions, Construction Guidelines, Maintenance, Winter Considerations, Cost, Designer/Reviewer Checklist, References, and Credits and Acknowledgments will follow the summary sheet.

Credits and Acknowledgments

This introductory segment and the fact sheets that follow have been developed by Christopher B. Burke Engineering, LLC, and are primarily based upon similar segments contained in “Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers” published in 2009 by the Southeast Michigan Council of Governments (SEMCOG). A selection of material contained in the noted SEMCOG publication has been modified to reflect conditions in Indiana and used, with permission, for development of this introductory segment and the fact sheets that follow. The valuable contribution of SEMCOG through sharing of this material for use in this introductory segment and the fact sheets that follow are hereby acknowledged.

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BMP Fact Sheet

CLUSTER-TYPE DEVELOPMENT

Cluster-type development (also known as open space development) concentrates development on smaller lots on a portion of a larger site. Clustering allows the site planner to avoid resource sensitive and constrained areas at a site, such as steep slopes and water-sensitive areas including riparian buffers, wetlands, and floodplains without sacrificing the level of development. Clustering reduces the amount of required infrastructure and various development-related costs. Clustering lends itself to residential development, with greatest potential in municipalities where large-lot residential development is typical. Clustering can reduce total impervious area and total disturbed areas at development sites, thereby reducing stormwater peak rates of runoff, reducing total volume of runoff, and reducing nonpoint source pollutant loads.



Figure 1 Pinehills Development, Plymouth, MA (MA Office of Energy and Environmental Affairs)

Potential Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	High
Commercial	Yes*	Groundwater Recharge	High
Ultra Urban	Limited	Peak Rate	High
Industrial	Limited	Stormwater Quality Functions	
Retrofit	No	TSS	High
Highway/Road	No	TP	High
Recreational	Limited	NO ₃	High
		Temperature	High

*Depending upon site size, constraints, and other factors.

Additional Considerations	
Cost	Low
Maintenance	Low/Med
Winter Performance	High

Variations

- Clustering as an option
- Clustering mandated by the municipality
- Clustering with incentives such as density bonuses

Key Design Features

- Develop inventory
- Map sensitive areas
- Reduce total site disturbance and develop cluster plan
- Increase undisturbed open space

Benefits

- Reduces required infrastructure
- Increases open space
- Protects environmentally sensitive natural resources

Limitations

- Site specific based on land topography and individual conditions

Description and Function

Cluster-type development is driven by reducing minimum lot size, though not necessarily changing the total number of lots or amount of development occurring. As lot sizes decrease, the portion of the site which remains as undisturbed open space increases. If clustering is done carefully, this remaining open space can and should include those areas which are most sensitive environmentally and/or which offer special value functions not otherwise protected from development (e.g., high-quality woodlands areas).

Variations

One variation to a typical cluster-type development allows for a density bonus to incentivize use of this technique. A density bonus allows for additional lots to be added to the site beyond what the yield plan would show with a conventional subdivision. Proponents of this method state that allowing an additional lot or two may be the incentive needed to increase implementation of this technique. Opponents of this variation state that a density bonus is not needed since the development already costs less due to less stormwater and transportation infrastructure.

A second clustering variation for municipalities to consider, subject to legal review, is establishing clustering as the baseline requirement, at least in some zoning categories. Conventional non-clustered development would still be an option (variance, conditional use, etc.), but only if a variety of performance standards are satisfied.

A third variation for consideration relates to the nature and extent of development types subject to clustering provisions. As discussed above, single-family residential development at lower densities/on larger lots is ready-made for clustering. However, clustering concepts can provide LID benefits in larger corporate office parks, in retail centers, and other uses. Often this clustering concept takes on its own nomenclature e.g., New Urbanist, Smart Growth, Planned Integrated Development, and others. In these cases, not only are individual lots reduced in size, but the physical form of the development typically undergoes

change (i.e., 50,000 square feet of retail can move from a one-story box to stacked development with a much different New Urbanist configuration). Depending upon the nature and extent of the uses involved, “clustering” of nonresidential uses (e.g., daytime offices with evening/ weekend retail), if carefully planned can offer potential for reduced parking requirements.

Applications

Residential Clustering

The most common clustering option is residential clustering on new development. **Figure 2** illustrates a more traditional development scenario where lots are placed across the entire site. In this example, the lot and house placement does avoid major natural features such as floodplain and wetlands, but still substantially encroaches into woodlands and riparian buffer features. Such a development layout (“yield plan”) provides an estimate of a site’s capacity to accommodate lots and houses at the base density hypothetically allowed under a local zoning ordinance.



Figure 2 Conventional Development

Source: Growing Greener: Putting Conservation into Local Codes Natural Lands Trust, Inc., 1997

Figure 3 illustrates a “density-neutral” approach to clustering, where the number of lots and houses is held constant at 18 lots; however, the lot size has been reduced significantly allowing for 50 percent of open space area.

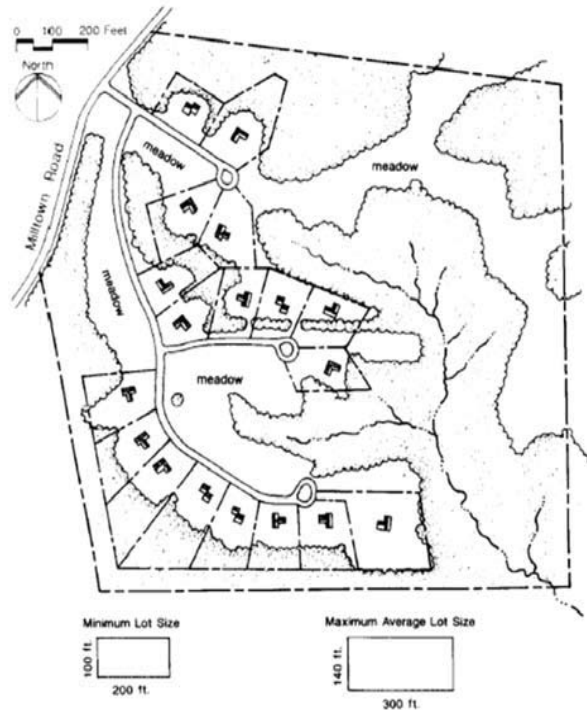


Figure 3 Clustered Development
Source: *Growing Greener: Putting Conservation into Local Codes*. Natural Lands Trust, Inc., 1997

Nonresidential Clustering

Conventional nonresidential development (e.g., retail commercial development) can also be configured in the form of low-rise (one story), relatively low-density strip or “big box” centers.

Design Considerations

The design process for implementing clustering at a proposed development site can occur in a variety of ways. Randall Arendt’s *Growing Greener: Putting Conservation into Local Codes* (1997) provides clustering guidance in several straightforward steps. The process typically begins with the applicant applying existing conventional code to the site with any necessary net outs to develop a “yield plan.” The purpose is to determine how many units can be developed conventionally:

- Step 1: Identify land to be protected: Primary conservation areas,
 - Identify land to be protected: Secondary conservation areas, and
 - Delineate potential development area.

- Step 2: Locate house sites on potential development area
- Step 3: Connect with streets and trails
- Step 4: Draw in lot lines

A major issue to address is the extent to which a clustering process is consistent with local ordinance requirements. How many house sites, and with what lot size, are going to be located in the potential development area?

If the existing local code is fully flexible, applicants can comprehensively “zone out” primary and secondary conservation areas and be confident that the baseline “yield plan” unit count can be loaded into the potential development area at whatever lot size is necessary (some applicants/developers believe that smaller lots translate into less valuable and marketable units and are reluctant to make considerable reductions in lot sizes). Often, however, such reduced lot sizes are less than the local ordinance allows. In such cases, the applicant is motivated to reduce primary and secondary conservation areas, so that the potential development area can be enlarged.

Stormwater Functions and Calculations

Volume and peak rate

Cluster-type development is a technique that results in increased open space, which reduces stormwater peak rate and volume. These open spaces are often associated with other BMPs from this manual, including preserving sensitive areas and protecting riparian corridors. These BMPs are not to be included in the disturbed stormwater management area when calculating runoff volume (See the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards).

Any portion of the open space that is mitigated or revegetated/reforested should be included in the disturbed stormwater management area, but may be granted runoff reduction recognition in accordance with the applicable BMP for native revegetation,

soil restoration, minimize soil compaction, riparian buffer restoration, or minimize total disturbed area.

Water quality improvement

Clustering minimizes impervious areas and their associated pollutant loads, resulting in improved water quality. In addition, clustering preserves open space and other natural features, such as riparian corridors, which allow for increased infiltration of stormwater and removal of pollutant loads. (See the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards).

Maintenance

Preserving open space creates concerns regarding responsibility for maintenance activities. Legally, the designated open space may be conveyed to the municipality. More likely, ownership of these natural areas will be assumed by homeowners' associations or the specific individual property owners where these resources are located. Specific maintenance activities will depend on the type of vegetation present in the preserved natural area. For example, woodlands require little to no maintenance and open lawns require higher maintenance. An objective of cluster-type development is to conserve the existing natural systems with minimal, if any, intervention and disturbance.

Cost

Clustering is beneficial from a cost perspective. Costs to build 100 clustered single-family residential homes is less due to less land clearing and grading, less road and sidewalk construction (including curbing), less lighting and street landscaping, potentially less sewer and water line construction, potentially less stormwater collection system construction, and other economies of scale.

Post-construction, clustering also reduces costs. A variety of studies from Rutgers University's landmark *Costs of Sprawl* studies and later updates show that delivery of a variety of municipal services such as street maintenance, sewer and water services, and trash collection are more economical on a per person or per house basis when development is clustered. Furthermore, services such as police protection are made more efficient when residential development is clustered.

Additionally, clustering has been shown to positively affect land values. Analyses of market prices of conventional development over time in contrast with comparable clustered residential developments (where size, type, and quality of the house itself is held constant) indicate that clustered development increases in value at a more rapid rate than conventionally designed developments. This is partly due to the proximity to permanently protected open space.

Designer/Reviewer Checklist for Cluster-Type Development

ITEM	Page No.	YES	NO	N/A	NOTES
Has nonstructural BMP Protect Sensitive Resources been applied? If not, complete this BMP.	2, 3				
Has a baseline “yield plan” been developed by applicant?	2, 3				
What local ordinance provisions - obstacles and opportunities - exist for clustering?	3				
Has a Potential Development Area, or comparable, which avoids Sensitive Resources, been delineated?	3				
Has “yield plan” house/unit count been loaded into Potential Development Area?	3				
What clustered lot size assumptions are being used? Compatible with local ordinance?	3				
Compare disturbed area/developed area of “yield plan” with clustered plan?	3				

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BMP Fact Sheet

MINIMIZE SOIL COMPACTION

Minimizing soil compaction is the practice of protecting and minimizing damage to existing soil quality caused by the land development process. Enhancing soil composition with soil amendments and mechanical restoration after it has been damaged is addressed in a separate structural BMP.



Figure 1 Areas where heavy equipment is not allowed are fenced off to avoid compaction of soils and damages to vegetation (MD Custom Homes, WI)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Med/High
Commercial	Yes	Groundwater Recharge	Med/High
Ultra Urban	Limited	Peak Rate	Low/Med
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Limited	TSS	Med/High
Highway/Road	Limited	TP	Med/High
Recreational	Yes	NO ₃	Low
		Temperature	Med/High

Additional Considerations	
Cost	Low/Med
Maintenance	Low
Winter Performance	Low/Med

Key Design Features

- Reduce disturbance through design and construction practices
- Limit areas of heavy equipment
- Avoid extensive and unnecessary clearing and stockpiling of topsoil
- Use top quality topsoil; maintain topsoil quality during construction

Benefits

- Increases infiltration capacity
- Provides a healthy environment for vegetation
- Preserves low areas, which offer added benefit when runoff is directed there from impervious areas

Limitations

- Difficult to implement on small development sites

Description and Function

Minimizing soil compaction relates directly to reducing total site disturbance, site clearing, site earthwork, the need for soil restoration, and the size and extent of costly, engineered stormwater management systems. Ensuring soil quality can significantly reduce the cost of landscaping vegetation (higher survival rate, less replanting) and landscaping maintenance. Fencing off an area can help minimize unnecessary soil compaction.

Soil is a physical matrix of weathered rock particles and organic matter that supports a complex biological community. This matrix has developed over a long time period and varies greatly within the state. Healthy soils, which have not been compacted, perform numerous valuable stormwater functions, including:

- Effectively cycling nutrients,
- Minimizing runoff and erosion,
- Maximizing water-holding capacity,
- Reducing storm runoff surges,
- Absorbing and filtering excess nutrients, sediments, and pollutants to protect surface and groundwater,
- Providing a healthy root environment,
- Creating habitat for microbes, plants, and animals, and
- Reducing the resources needed to care for turf and landscape plantings.

Undisturbed soil consists of pores that have water-carrying and holding capacity. When soils are overly compacted, the soil pores are destroyed and permeability is drastically reduced. In fact, the runoff response of vegetated areas with highly compacted soils closely resembles that of impervious areas, especially during large storm events (Schueler, 2000). Recent research studies indicate that compacted soils from development practices end up as dense as concrete.

Applications

Minimizing soil compaction can be performed at any land development site during the design phase. It is especially suited for developments where significant “pervious” areas (i.e., post-development

lawns and other maintained landscapes) are being proposed. If existing soils have already been excessively compacted, soil restoration is applicable (see Soil Restoration BMP Fact Sheet).

Design Considerations

Early in a project’s design phase, the designer should develop a soil management plan based on soil types and existing level of disturbance (if any), how runoff will flow off existing and proposed impervious areas, trees and natural vegetation that can be preserved, and tests indicating soil depth and quality. The plan should clearly show the following:

1. **No disturbance areas.** Soil and vegetation disturbance is not allowed in designated no disturbance areas. Protecting healthy, natural soils is the most effective strategy for preserving soil functions. Not only can the functions be maintained, but protected soil organisms are also available to colonize neighboring disturbed areas after construction.
2. **Minimal disturbance areas.** Limited construction disturbance occurs, but soil restoration may be necessary for such areas to be considered fully pervious after development. In addition, areas to be vegetated after development should be designated minimal disturbance areas. These areas may allow some clearing, but no grading due to unavoidable cutting and/or filing. They should be immediately stabilized, revegetated, and avoided in terms of construction traffic and related activity. Minimal disturbance areas do not include construction traffic areas.
3. **Construction traffic areas.** Construction traffic is allowed in these areas. If these areas are to be considered fully pervious following development, a soil restoration program will be required.
4. **Topsoil stockpiling and storage areas.** If these areas are needed, they should be protected and maintained. They are subject to soil restoration (including compost and other amendments) following development.

5. **Topsoil quality and placement.** Soil tests are necessary to determine if it meets minimum parameters. Critical parameters include: adequate depth (four inches minimum for turf, more for other vegetation), organic content (five percent minimum), and reduced compaction (1,400 kPa maximum) (Hanks and Lewandowski, 2003). To allow water to pass from one layer to the other, topsoil must be “bonded” (See Construction Guidelines #4 below) to the subsoil when it is reapplied to disturbed areas.

Construction Guidelines

1. At the start of construction, no disturbance and minimal disturbance areas must be identified with signage and fenced as shown on the construction drawings.
2. No disturbance and minimal disturbance areas should be strictly enforced.
3. No disturbance and minimal disturbance areas should be protected from excessive sediment and stormwater loads while adjacent areas remain in a disturbed state.
4. Topsoil stockpiling and storage areas should be maintained and protected at all times. When topsoil is reapplied to disturbed areas it should be “bonded” with the subsoil. This can be done by spreading a thin layer of topsoil (2-3 inches), tilling it into the subsoil, and then applying the remaining topsoil. Topsoil should meet locally available specifications/requirements.

Stormwater Functions and Calculations

Volume and peak rate reduction

Minimizing soil compaction can reduce the volume of runoff by maintaining soil functions related to stormwater infiltration and evapotranspiration. Designers that use this BMP can select a lower runoff curve number for calculating runoff volume and peak rate from the area of minimized soil compaction. See the discussion under LID Approach in Post-Construction Stormwater Quality

Management Chapter of the Technical Standards on how to calculate the runoff reduction recognition for this BMP.

Where no disturbance areas are specified, which are also sensitive areas maintained in their presettlement state, there will be no net increase in stormwater runoff from that area. Calculation methodology to account for the protection of sensitive areas is provided under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards.

Water quality improvement

Minimizing soil compaction improves water quality through infiltration, filtration, chemical and biological processes in the soil, and a reduced need for fertilizers and pesticides after development. See the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards for information on how to calculate the volume of runoff that needs water quality treatment.

Maintenance

Sites that have minimized soil compaction properly during the development process should require considerably less maintenance than sites that have not. Landscape vegetation, either retained or replanted, will likely be healthier, have a higher survival rate, require less irrigation and fertilizer, and have better aesthetics.

Some maintenance activities, such as frequent lawn mowing, can cause considerable soil compaction after construction and should be avoided whenever possible. Planting low-maintenance native vegetation is the best way to avoid damage due to maintenance. No disturbance areas on private property should have an easement, deed restriction, or other legal measure imposed to prevent future disturbance or neglect.

Cost

Minimizing soil compaction generally results in significant construction cost savings. Design costs may increase slightly due to a more time intensive design.

Criteria to Receive Runoff Reduction Recognition for Minimize Soil Compaction BMP

To receive runoff reduction recognition under the local regulation, areas of no disturbance and minimal disturbance must meet the following criteria:

- ☐ No disturbance and minimal disturbance areas are protected by having the limits of disturbance and access clearly shown on the Stormwater Plan, all construction drawings, and delineated/flagged/fenced in the field.
- ☐ No disturbance and minimal disturbance areas are not be stripped of existing topsoil.
- ☐ No disturbance and minimal disturbance areas are not be stripped of existing vegetation.
- ☐ No disturbance and minimal disturbance areas are not be subject to excessive equipment movement. Vehicle movement, storage, or equipment/material lay-down is not be permitted in these areas.
- ☐ Use of soil amendments and additional topsoil is permitted in other areas being disturbed, as described above. Light grading may be done with tracked vehicles that prevent compaction.
- ☐ Lawn and turf grass are acceptable uses. Planted meadow is an encouraged use.
- ☐ Areas receiving runoff reduction recognition are located on the development project.

Designer/Reviewer Checklist for Minimize Soil Compaction References

ITEM	Page No.	YES	NO	N/A	NOTES
Have no disturbance areas been defined on plans (see minimize total disturbed area BMP)?	2				
Have no disturbance areas been fenced/flagged in field?	3, 4				
Have minimal disturbance areas been defined on plans?	2				
Have construction traffic areas been defined on plans?	2				
Is soil restoration BMP committed to construction traffic areas, post-construction phase?	2				
Are soil stockpiling and storage areas defined on plan?	3				
Have proper topsoil quality and placement specifications been committed in the plans?	3				

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BMP Fact Sheet

MINIMIZE TOTAL DISTURBED AREA

A key component of LID is to reduce the impacts during development activities such as site grading, removal of existing vegetation, and soil mantle disturbance. This can be achieved through developing a plan to contain disturbed areas.



Figure 1 Undisturbed areas are protected during construction (Lake County, OH Stormwater Management Department)

Key Design Features

- Identify and avoid special value and environmentally sensitive areas (See Protect Sensitive Areas BMP)
- Maximize undisturbed open space
- Minimize disturbance lot-by-lot
- Maximize soil restoration and restore soil permeability
- Minimize and control construction traffic areas
- Minimize and control construction stockpiling and storage areas

Benefits

- Reduced runoff volume
- Reduced peak rates
- High water quality benefits
- Increased infiltration capacity
- Provides healthy environment for vegetation

Limitations

- Difficult to achieve on small development sites

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	High
Commercial	Yes	Groundwater Recharge	High
Ultra Urban	Limited	Peak Rate	High
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Limited	TSS	High
Highway/Road	Limited	TP	High
Recreational	Yes	NO ₃	High
		Temperature	High

Additional Considerations	
Cost	Low
Maintenance	Low
Winter Performance	High

Description and Function

Disturbance at a development site can occur through normal construction practices, such as grading, cutting, or filling. Minimizing the total disturbed area of the site requires the consideration of multiple BMPs, such as cluster development and identifying and protecting sensitive areas. These BMPs serve to protect area resources by reducing site grading and maintenance required for long-term operation of the site.

Minimizing the total disturbed area of a site specifically focuses on how to minimize the grading and overall site disturbance, maximizing conservation of existing native plant communities and the existing soil mantle of a site. If invasive plant species are present in the existing vegetation, proper management of these areas may be required in order for the vegetation to achieve its greatest hydrological potential.

Minimize grading

Reduction in grading can be accomplished in several ways, including the conformation of the site design with existing topography and land surface, where road alignments strive to follow existing contours as much as possible, varying the grade and alignment criteria as necessary to comply with safety limits.

Minimize overall site disturbance

Site design criteria have evolved in local jurisdictions to ensure that developments meet safety standards (i.e. sight distance and winter icing) as well as certain quality or appearance standards. Roadway design criteria should be flexible in order to optimize the fit for a given parcel and achieve optimal roadway alignment. The avoidance of environmentally sensitive resources, such as important woodlands, may be facilitated through flexible roadway layout.

From the single lot perspective, the conventional lot layout can impose added earthwork and grading. Although the intent of these local requirements is to provide privacy and spacing between units, the end result is often a cleared and graded lot, which reduces stormwater benefits. And although configuring lots in a rectilinear shape may optimize

the number of units, local jurisdictions should consider requiring that the total site be made to fit the natural landscape as much as possible.

Local criteria that impose road geometry are usually contained within the subdivision and land development ordinance. Densities, lot and yard setbacks, and minimum frontages are usually contained in the zoning ordinance. Flexibility in the following land development standards will help to minimize site disturbance on an individual lot basis, thereby achieving area-wide stormwater quality and quantity results:

- Road vertical alignment criteria (maximum grade or slope)
- Road horizontal alignment criteria (maximum curvature)
- Road frontage criteria (lot dimensions)
- Building setback criteria (yards dimensions)

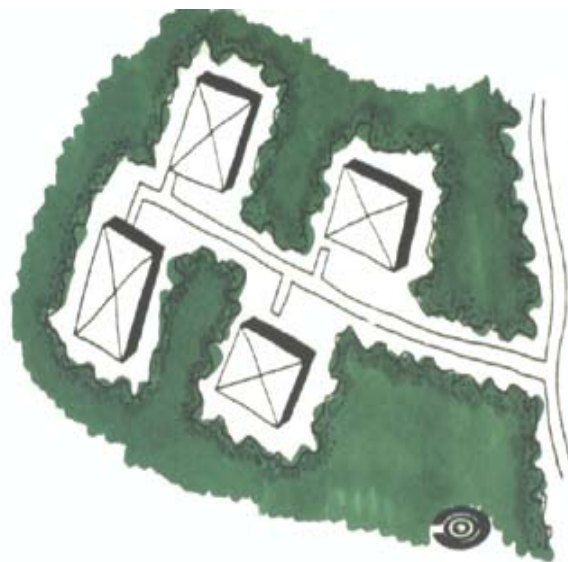


Figure 2 Minimally Disturbed Development
Source: Metropolitan Washington Council of Governments

Applications

Minimizing the total disturbed area of a site is best applied in lower density single-family developments, but can also be applied in residential developments of all types including commercial, office park, retail center, and institutional developments. Larger industrial park developments

can also benefit from this BMP. However, as site size decreases and density and intensity of development increases, this BMP is uniformly more difficult to apply successfully. At some larger sites where Ultra Urban, Retrofit, or Highway/Road development is occurring, limited application may be feasible.

Design Considerations

During the initial conceptual design phase of a land development project, the applicant's design engineer should provide the following information, ideally through development of a Minimum Disturbance/Minimum Maintenance Plan:

1. **Identify and Avoid Special Value/Sensitive Areas**

Delineate and avoid environmentally sensitive resources using existing data from appropriate agencies, as applicable.

2. **Minimize Disturbance at Site** Modify road alignments (grades, curvatures, etc.), lots, and building locations to minimize grading, and earthwork as necessary to maintain safety standards and local code requirements. Minimal disturbance design should allow the layout to best fit the land form without significant earthwork, such as locating development in areas of the site that has been previously cleared, if possible. If cut/fill is required, the use of retaining walls is preferable to earthwork. Limits of grading and disturbance should be designated on plan documentation submitted to the local jurisdiction for review/approval and should be physically designated at the site during construction via flagging, fencing, etc.

In addition, utilizing natural drainage features generally results in less disturbance and requires less revegetation.

3. **Minimize Disturbance at Lot**

To decrease disturbance, grading should be limited to roadways and building footprints. Local jurisdictions should establish maximum setbacks from structures, drives, and walks. These setbacks should be designed to be rigorous but reasonable in terms of current

feasible site construction practices. These standards may need to vary with the type of development being proposed and the context of that development (the required disturbance zone around a low density single-family home can be expected to be less than the disturbance necessary for a large commercial structure), given necessity for use of different types of construction equipment and the realities of different site conditions. For example, the U.S. Green Building Council's Leadership in Energy & Environmental Design Reference Guide (Version 2.0 June 2001) specifies:

"...limit site disturbance including earthwork and clearing of vegetation to 40 feet beyond the building perimeter, 5 feet beyond the primary roadway curbs, walkways, and main utility branch trenches, and 25 feet beyond pervious paving areas that require additional staging areas in order to limit compaction in the paved area... "

Stormwater Functions and Calculations

Volume

Any portion of a site that can be maintained in its predevelopment state by using this BMP will not contribute increased stormwater runoff and will reduce the amount of treatment necessary for Channel Protection Volume and Water Quality Volume requirements. In addition, isolated trees within disturbed areas that are protected in accordance to this BMP or the "Protect Sensitive Areas" BMP requirements can get "runoff reduction recognition" by receiving a curve number reflecting a woodlot in "good" condition for the pre-developed underlying soil conditions. Calculation methodology to account for this BMP is provided in the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards.

Peak rate

Runoff from the minimized disturbed area may be excluded from peak rate calculations for rate control, provided that the runoff from the area is not conveyed to and/or through stormwater

management control structures. If necessary, runoff from the minimized disturbed area should be directed around BMPs and stormwater pipes and inlets by means of vegetated swales or low berms that direct flow to natural drainageways.

Water quality improvement

Water quality is benefited substantially by minimizing the disturbed area.

Maintenance

Minimizing site disturbance will result in a reduction of required maintenance of a site in both the short and long terms. Areas of the site left as intact native plant communities do not typically require replacement with hard surfaces or additional vegetation to retain function. On the other hand, artificial surfaces such as pavement or turf grass require varying levels of maintenance throughout the life of a development. Higher levels of disturbance will also typically require significant maintenance of erosion control measures during the active development of a parcel, thus adding to short-term development costs.

While intact natural areas may require small amounts of occasional maintenance to maintain function (typically through invasive species control), levels of maintenance required for hard surfaces or turf grass will remain static or, in most cases, increase over time. Avoiding disturbance to natural areas benefits the short-term developer and the long-term owner by minimizing time and money needed to maintain artificial surfaces.

Cost

The reduced costs of minimized grading and earthwork should benefit the developer. Cost issues include reduced grading and related earthwork as well as costs involved with site preparation, fine grading, and seeding.

Calculation of reduced costs is difficult due to the extreme variation in site factors, (amount of grading, cutting/filling, and haul distances for required trucking,). Some relevant costs factors are as follows (as based on R.S. Means, Site Work & Landscape Cost Data, 2007):

Site Clearing

- Cut & chip light trees to diameter \$3,475/acre
- Grub stumps and remove \$1,600/acre
- Cut & chip light trees to 24-inch diameter \$11,600/acre
- Grub stumps and remove \$6,425/acre

Strip Topsoil and Stockpile

- Ranges from \$0.52- \$1.78/yd³ because of Dozer horse power, and ranges from ideal to adverse conditions
- Assuming six inches of topsoil, 500-ft haul: \$2.75-9.86/yd³
- Assuming six inches of topsoil, 500-ft haul: \$9,922 -16,746 / acre

Site Preparation, Fine Grading, Seeding

- Fine grading w/ seeding: \$2.91 /yd²
- Fine grading w/ seeding: \$14,084 /acre

In sum, total costs usually range from \$29,000 - \$49,000 per acre and could substantially exceed that figure at more challenging sites.

Criteria to Receive Runoff Reduction Recognition for Minimizing Total Disturbed Area

To receive runoff reduction recognition for protection of existing trees under a local regulation, the following criteria must be met:

- ☐ Area has not been subject to grading or movement of existing soils.
- ☐ Existing native vegetation are in a healthy condition as determined through a plant inventory and may not be removed.
- ☐ Invasive vegetation may be removed.
- ☐ Pruning or other required maintenance of vegetation is permitted. Additional planting with native plants is permitted.
- ☐ Area is protected by having the limits of disturbance clearly shown on all construction drawings and delineated in the field.
- ☐ Area is located on the development project.

Designer/Reviewer Checklist for Minimizing Total Disturbed Area

ITEM	Page No.	YES	NO	N/A	NOTES
Do local jurisdiction requirements for open space and related resource protection exist? Applied here?	2				
Have related BMPs (Protect Sensitive Areas, Natural Flow Pathways, Riparian Buffers, Clustering) been applied?	2				
Has Potential Development Area been defined?	3				
Have infrastructure connections/constraints been analyzed?	2				
On site, have roads been aligned to fit topography, to parallel contours and minimize cut/fill? On areas previously cleared? With terracing? Compatible with natural flow pathways?	3				
On lots, have buildings been located to reduce disturbance?	3				
On lots, have maximum disturbance radii been established and applied?	2				
No disturbance areas shall be clearly delineated on construction plans and flagged/fenced in field	3				
Have no disturbance zones been assessed qualitatively for invasive management needs?	2				

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BMP Fact Sheet

PROTECT NATURAL FLOW PATHWAYS

A main component of LID is to identify, protect, and use natural drainage features, such as swales, depressions, and watercourses to help protect water quality. Designers can use natural drainage features to reduce or eliminate the need for structural drainage systems.



Figure 1 Long swales utilized in areas of natural drainage pathways, Lenexa, KS (USEPA, picasaweb)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low/Med
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	No	Peak Rate	Med/High
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Yes	TSS	Low/Med
Highway/Road	Yes	TP	Low/Med
Recreational	Yes	NO ₃	Low
		Temperature	Low

Additional Considerations	
Cost	Low
Maintenance	Low/Med
Winter Performance	Low/Med

Variations

- Check dams to slow velocity
- Earthen berms for additional storage
- Additional native vegetation for increased infiltration

Key Design Features

- Identifies and maps natural drainage features (e.g., swales, channels, ephemeral streams, depressions, etc.)
- Uses natural drainage features to guide site design
- Distributes non-erosive surface flow to natural drainage features
- Keeps non-erosive channel flow within drainage pathways
- Uses native vegetative buffers

Benefits

- Maximizes natural hydrological functions
- Reduces structural management practices
- Reduces management costs

Limitations

- Minimal water quality benefits

Description and Function

Many natural undeveloped sites have identifiable drainage features such as swales, depressions, and watercourses which effectively manage the stormwater that is generated on the site. By identifying, protecting, and using these features, a development can minimize its stormwater impacts. Instead of ignoring or replacing natural drainage features with engineered systems that rapidly convey runoff downstream, designers can use these features to reduce or eliminate the need for structural drainage systems.

Naturally vegetated drainage features tend to slow runoff and thereby reduce peak discharges, improve water quality through filtration, and allow some infiltration and evapotranspiration to occur. Protecting natural drainage features can provide for significant open space and wildlife habitat, improve site aesthetics and property values, and reduce the generation of stormwater runoff itself. If protected and used properly, natural drainage features generally require very little maintenance and can function effectively for many years.

Site designs should use and/or improve natural drainage pathways whenever possible to reduce or eliminate the need for stormwater pipe networks. This can reduce costs, maintenance burdens, and site disturbance related to pipe installation. Natural drainage pathways should be protected from significantly increased runoff volumes and rates due to development. The design should prevent the erosion and degradation of natural drainage pathways through the use of upstream volume and rate control BMPs, if necessary. Level spreaders, erosion control matting, revegetation, outlet stabilization, and check dams can also be used to protect natural drainage features.

Variations

Natural drainage features can also be made more effective through the design process. Examples include constructing slight earthen berms around natural depressions or other features to create additional storage, installing check dams within drainage pathways to slow runoff and promote

infiltration, and planting additional native vegetation within swales and depressions.

Applications

As density and overall land disturbance decreases, this BMP can be used with a greater variety of land uses and development types. It is best used in residential development, particularly lower density single-family residential development. Where local jurisdiction ordinances already require a certain percentage of the undeveloped site to remain as undeveloped open space, this open space requirement can be overlain onto natural flow pathways/drainage features, as well as floodplains, wetlands, and related riparian areas. After minimizing runoff as much as possible, reduced runoff quantities can then be distributed into this natural flow pathway system, on a broadly distributed basis, lot by lot.

Other land uses such as commercial and industrial developments tend to be associated with higher density development. This results in higher



Figure 2 Schematic of a site design protecting natural drainage features.

Source: Georgia Stormwater Management Manual, Volume 2: Technical Handbook, First Edition. August, 2001

impervious coverage and maximum site disturbance allowances, making protecting and conserving natural flow pathways/drainage areas more difficult.

Applications for both retrofit and highway/road are limited. In terms of retrofitting, some developed

sites may have elements of natural flow pathways/drainage features intact, although many presettlement site features may have been altered and/or eliminated. Developed sites of lower densities may offer limited retrofit potential. Similarly, highway/road projects are likely to be characterized by both limited site area, given the difficulties of right-of-way acquisition, as well as substantial disturbance of this limited site area.

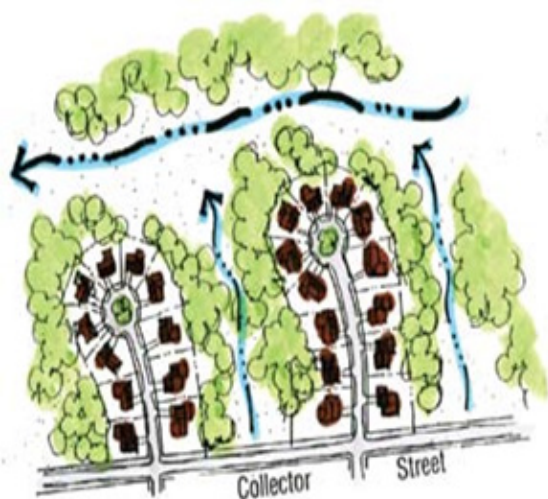


Figure 3 Natural drainage features can guide the design
Source: Delaware Department of Natural Resources and Environmental Control - Conservation Design for Stormwater Management

Design Considerations

1. **Identify natural drainage features.** Identifying and mapping natural drainage features is generally done as part of a comprehensive site analysis. This process is an integral first step of site design (**Figure 3**). Subtle site features such as swales, drainage pathways, and natural depressions should be delineated in addition to commonly mapped hydrologic elements such as wetlands, perennial and intermittent streams, and waterbodies.
2. **Use natural drainage features to guide site design.** Instead of imposing a two-dimensional paper design on a particular site, designers can use natural drainage features to steer the site layout. Drainage features define contiguous open space and other undisturbed

areas as well as road alignment and building placement. The design should minimize disturbance to natural drainage features. Drainage features that are to be protected should be clearly shown on all construction plans. Methods for protection, such as signage and fencing, should also be noted on applicable plans.

3. **Use native vegetation.** Natural drainage pathways should be planted with native vegetative buffers and the features themselves should include native vegetation where applicable. If drainage features have been previously disturbed, they can be restored with native vegetation and buffers.
4. **County Regulated Drain Considerations:** Special attention needs to be paid regarding the type and density of vegetation used if the natural drainage pathway is or will be a part of the County Regulated Drain system. The County may require that at least one side of the regulated drain is clear of woody vegetation, with continuous access provided for reconstruction and maintenance. Pre-coordination with the County Surveyor's Office is highly recommended.

Stormwater Function and Calculations

Volume reduction

Protecting natural flow pathways can reduce the volume of runoff in several ways. Reducing disturbance and maintaining a natural cover reduces the volume of runoff through infiltration and evapotranspiration. Using natural flow pathways further reduces runoff volumes through allowing increased infiltration to occur, especially during smaller storm events. Encouraging infiltration in natural depressions also reduces stormwater volumes. Employing strategies that direct non-erosive sheet flow onto naturally vegetated areas also promotes infiltration – even in areas with relatively impermeable soils. (See the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards.)

Peak rate mitigation

Protecting natural flow pathways can reduce the peak rate of runoff in several ways. Reducing disturbance and maintaining a natural cover reduces the runoff rate. Using natural flow pathways can lower discharge rates by slowing runoff and increasing onsite storage.

Water quality improvement

Protecting natural flow pathways improves water quality through filtration, infiltration, sedimentation, and thermal mitigation. (See the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards.)

Maintenance

Natural drainage features that are properly protected and used as part of site development should require very little maintenance. However, periodic inspections are important. Inspections should assess erosion, bank stability, sediment/debris accumulation, and vegetative conditions, including the presence of invasive species. Problems should be corrected in a timely manner.

Protected drainage features on private property should have an easement, deed restriction, or other legal measure to prevent future disturbance or neglect.

Cost

Protecting natural flow pathways generally results in significant construction cost savings. Protecting these features results in less disturbance, clearing, and earthwork and requires less revegetation. Using natural flow pathways reduces the need and size of costly, engineered stormwater conveyance systems. Together, protecting and using natural flow pathways reduces and even eliminates the need for stormwater management facilities (structural BMPs), lowering costs even more.

Designer/Reviewer Checklist for Protect Natural Flow Pathways

ITEM	Page No.	YES	NO	N/A	NOTES
Identify in plan all natural flow pathways before proposed development?	2				
Identify in plan natural flow pathways protected post-development?	2				
Highlight in plan natural flow pathways which are integrated into stormwater management?	2, 3				
Have measures been taken to guarantee that natural pathways won't be negatively impacted by stormwater flows?	2				
Has runoff reduction recognition been calculated for natural flow pathways being protected?	3				

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BMP Fact Sheet

PROTECT RIPARIAN BUFFER AREAS

Riparian buffer areas are important elements of local communities' green infrastructure and/or LID tool box. These areas are critical to the biological, chemical, and physical integrity of our waterways. Riparian buffer areas protect water quality by cooling water, stabilizing banks, mitigating flow rates, and providing for pollution and sediment removal by filtering overland sheet runoff before it enters the water. The Environmental Protection Agency defines buffer areas as, "areas of planted or preserved vegetation between developed land and surface water, [which] are effective at reducing sediment and nutrient loads."

Physical restoration of riparian buffer areas is discussed in a separate structural BMP. A detailed description of the characteristics of riparian buffer areas is combined with a discussion of their stormwater functions in the Riparian Buffer Restoration BMP.

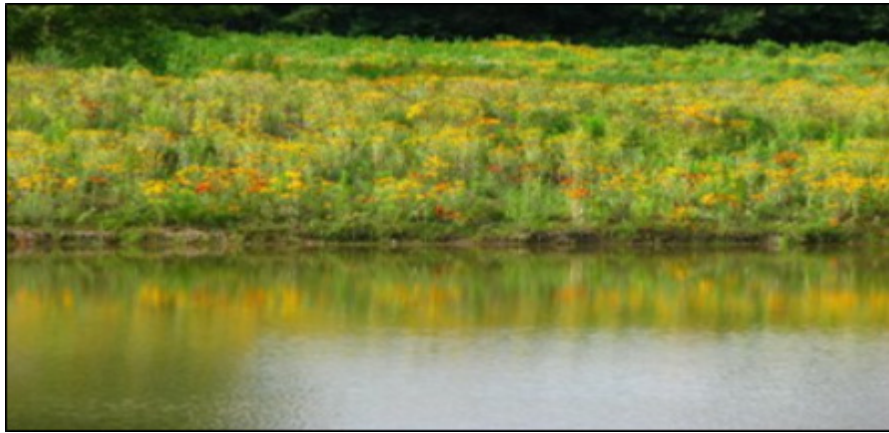


Figure 1 Urban riparian buffer (Hamilton County, IN Urban Conservation Association)

Key Design Features

- Physical protection
- Protection through planning tools

Benefits

- Improves water quality
- Reduces runoff velocities
- Reduces flow
- Enhances site aesthetics, habitat
- Reduces shoreline and bank erosion
- Improves flood control
- Reduces water temperature

Limitations

- Limited in reducing total runoff volumes
- Size of lot and/or development site may reduce ability to protect riparian buffers

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low/Med
Commercial	Yes	Groundwater Recharge	Low/Med
Ultra Urban	Limited	Peak Rate	Low/Med
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Yes	TSS	High
Highway/Road	Limited	TP	High
Recreational	Yes	NO ₃	Medium
		Temperature	High

Additional Considerations	
Cost	Low/Med
Maintenance	Low
Winter Performance	High

Applications

As with the Protect Sensitive Areas nonstructural BMP, protecting riparian buffer areas has great value and utility for virtually all types of development proposals and land uses. This BMP works best on larger sites. Therefore, although riparian buffer programs should be advocated in the densest of settings, their application is likely to be limited in high density contexts. Creative design can maximize the potential of riparian buffers. Clustering and density bonuses are design methods available to increase the amount and connectedness of open space areas such as riparian buffers.

Design Considerations

Physical Design

Consider the following when protecting the proper riparian buffer area width and related specifications:

- Existing or potential value of the resource to be protected,
- Site, watershed, and buffer characteristics,
- Intensity of adjacent land use, and
- Specific water quality and/or habitat functions desired.

Riparian buffers can be divided into different zones (**Figure 2**) that include vegetation to enhance the quality of the body of water.

Zone 1: Also termed the “streamside zone,” Zone 1 begins at the edge of the stream bank of the active channel and extends a minimum distance of 25 feet, measured horizontally on a line perpendicular to the water body. Undisturbed vegetated area aims to protect the physical and ecological integrity of the stream ecosystem. The vegetative target for the streamside zone is undisturbed native woody species with native plants forming canopy, understory, and duff layer. Where such forest does not grow naturally, the native vegetative cover appropriate for the area (such as grasses, forbs, or shrubs) is the vegetative target.

Zone 2: Also termed the “middle zone,” Zone 2 extends immediately from the outer edge of Zone 1 for a minimum distance of 55 feet. This managed area of native vegetation protects key components of the stream ecosystem and provides distance between upland development and the streamside zone. The vegetative target for the middle zone is either undisturbed or managed native woody species or, in its absence, native vegetative cover of shrubs, grasses, or forbs. Undisturbed forest, as in Zone 1, is encouraged strongly to protect future water quality and the stream ecosystem.

Zone 3: Also termed the “outer zone,” Zone 3 extends a minimum of 20 feet immediately from the outer edge of Zone 2. This zone prevents encroachment into the riparian buffer area, filters

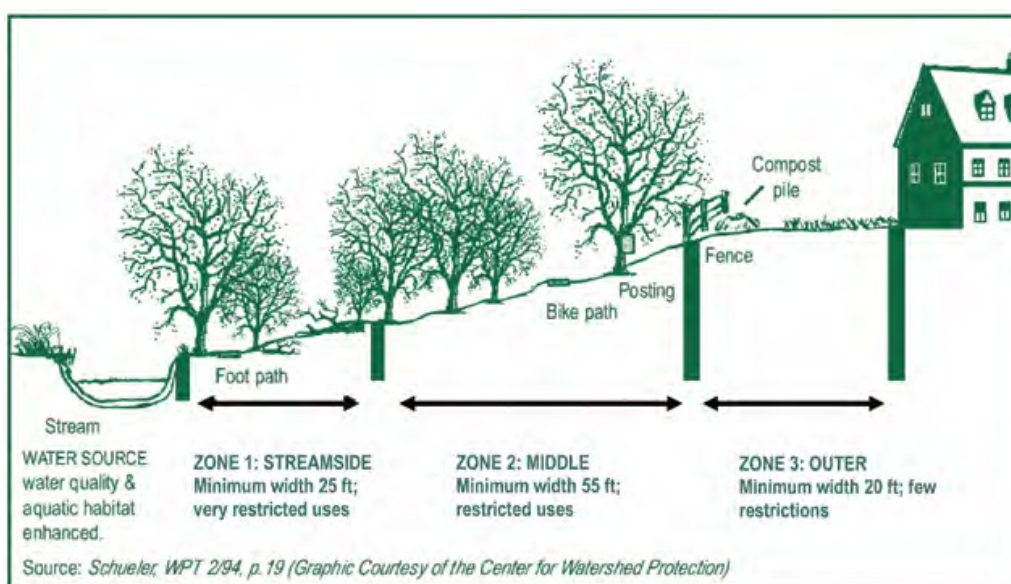


Figure 2 Buffer Width Recommendations

Source: Schueler, Watershed Protection Techniques, 1994

runoff from adjacent land, and encourages sheet flow of runoff into the buffer. The vegetative target for the outer zone is native woody and herbaceous vegetation to increase the total width of the buffer; native grasses and forbs are acceptable.

County Regulated Drain Considerations: Special attention needs to be paid regarding the type and density of vegetation used if the natural drainage pathway or stream is or will be a part of the County Regulated Drain system. The County may require that at least one side of the regulated drain is clear of woody vegetation, with continuous access provided for reconstruction and maintenance. Pre-coordination with the County Surveyor's Office is highly recommended.

Local Planning and Riparian Buffers
Numerous tools exist at the community level to protect riparian buffers, including ordinances, integrating buffers into plans, and public education.

Local buffer regulations

To effectively manage riparian buffer areas, a community must properly plan for these resources. Some Indiana communities have riparian buffer ordinances that explicitly regulate these areas. Typical components of a riparian ordinance include:

- Exemptions,
- Width requirements,
- Permitted and prohibited uses within the riparian buffer,
- Maintenance requirements,
- Waivers and variances, and
- Maintenance and construction of utilities and public roads along the stream corridor.

Natural features setback standards establish a minimum setback (buffer width) from natural features to prevent physical harm or destruction of the feature. These standards recognize the relationship between terrestrial and aquatic ecosystems and should be applied to both lakes and rivers. Each community establishes buffer width standards at their discretion.

In general, the wider the buffer, the greater the number of ecological functions the riparian zone will provide. Communities may choose to establish

fixed or variable width buffers or a combination of the two (Oakland County Planning & Economic Development Services).

Key planning elements of a local riparian protection program*

- Provide ample setbacks for sanitary facilities on buffer areas
- The wider the riparian buffer, the greater the water quality protection and habitat value of the area
- Establish setbacks from rivers and streams
- Regulate road placement adjacent to the riparian buffer area
- Restrict clearing, construction, and development within the 100-year floodplain
- Zone areas adjacent to riparian buffer areas for low intensity development
- Establish minimum lot size, frontage, and width requirements
- Include reference to floodplain, soil, and sedimentation controls administered by other agencies in riparian regulations
- Screen new structures with native vegetation
- Limit industrial use along riparian corridors and regulate through special use permits subject to pre-designated standards
- Limit the amount of impervious surfaces allowed adjacent to the buffer area
- Clearly outline appropriate and inappropriate uses of riparian buffer areas
- Promote intergovernmental coordination of regulations among communities along the river corridor

* - Adapted from *Michigan Wetlands – Yours to Protect*

Integrating buffer protection into plans

In addition to implementing a riparian buffer ordinance, communities can include riparian buffer area protection in the following planning tools:

- Local master plans,
- Park and recreation plans, and
- Subdivision and land development ordinances.

Park and recreation plans can adopt the goals, policies, and objectives for riparian protection that are listed in the community master plan, or include its own park and recreation-specific recommendations for riparian buffer management. Content may focus on defining appropriate and inappropriate recreational uses for riparian areas located within parks. Park and recreation plans may also provide guidelines for proper construction and maintenance of river access points, and rules and regulations for public access as these topics relate to potential impacts on riparian buffers (Oakland County Planning & Economic Development Services).

Riparian buffer education

Educational opportunities for the general public are an important component in community planning. Informing riparian owners of the importance of buffer areas will help to ensure these areas are understood and maintained over time. Public education activities include hosting public meetings, direct mailings to riparian homeowners, and educational workshops. These activities can be developed to meet the specific needs of your community through partnerships with local watershed groups.

Design Measures

The following elements represent a menu of design measures for riparian and natural resource protection that communities may choose to encourage or require developers to incorporate during the site plan review process.

Conservation subdivision or open space regulations:

- Prepare natural features inventory on proposed project sites.
- Require certain percentage of total parcel acreage to be retained as open space.
- Reference minimum buffer widths for riparian buffer areas and identify upland areas adjacent to riparian buffer areas as preferred green space designated for low-impact residential recreation activities.
- Advocate cluster development that concentrates construction on land with less conservation value, and allows owners of house lots in the development to share undivided ownership of the portion of property remaining in a scenic and natural condition.
- Advocate lot averaging standards for retaining riparian resources and natural features on smaller sites.

Lot size and density regulations:

- Provide flexible lot size and density standards to guide development away from a stream buffer or other sensitive land.
- Provide developers with density bonuses for land-conserving design and density disincentives to actively discourage land-consuming layouts.

Minimum frontage and road setback regulations:

- Provide flexibility in frontage and road setback standards to minimize development intrusion on riparian buffer areas.

Stormwater management guidelines:

- Regulate erosion control before, during, and after construction.
- Encourage developers to retain natural vegetation already protecting waterways.
- Create a variable-width, naturally vegetated buffer system along lakes and streams that also encompasses critical environmental

features such as the 100-year floodplain, steep slopes, and wetlands.

- Limit clearing and grading of forests and native vegetation at a site to the minimum amount needed to build lots, allow access, and provide fire protection.
- Promote riparian buffer areas as part of stormwater management planning.

Source: Planning for Green River Corridors, Oakland County Planning & Economic Development Services.

Stormwater Functions and Calculations

Any portion of a site that can be maintained in its presettlement state by using this BMP will not contribute increased stormwater runoff and will reduce the amount of treatment necessary. Calculation methodology to account for this BMP is provided in the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards.

Volume

Protected riparian buffers are not to be included in the disturbed stormwater management area when calculating runoff volume (See the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards.)

Any portion of a riparian buffer area that is mitigated or revegetated/reforested should be included in the disturbed stormwater management area, but may be granted runoff reduction recognition in accordance with the applicable BMP for native revegetation, soil restoration, minimize soil compaction, riparian buffer restoration, or minimize total disturbed area.

Peak rate

Runoff from the riparian buffers may be excluded from peak rate calculations for rate control, provided that runoff from the riparian buffers is not conveyed to and/or through stormwater management control structures. If necessary, runoff from riparian buffers should be directed around BMPs and stormwater pipes and inlets by means of

vegetated swales or low berms that direct flow to natural drainageways.

Water quality improvement

Water quality is benefited substantially by avoiding negative impacts which otherwise would have resulted from impacts to riparian buffers (e.g., loss of water quality functions from riparian buffers, from wetland reduction, etc.).

Cost

The costs of protecting riparian areas relate to a reduction in land available for development. However, most riparian areas are located in wetlands or floodplains, restricting the amount of buildable area.

Designer/Reviewer Checklist for Protect Riparian Buffer Areas

ITEM	Page No.	YES	NO	N/A	NOTES
Define municipal programs requirements or resources for riparian buffer protection, if any.	3-4				
Based on above and relevant sources, establish riparian buffer protection standards for development site.	3-4				
Map riparian resources at the site which need buffer protection.	3				
Apply Zone1/Zone2/Zone3 determinations; adjust for steep slopes and/or other natural/made factors.	2				
Overlay development program onto site, avoiding/minimizing Riparian Buffer Zone impacts.	3				
Contacted the County Surveyor's Office if the drainage pathway or stream is a County Regulated Drain?	3				
Provide for Riparian Buffer Zone maintenance?	4				
Provide for Riparian Buffer Zone protection in perpetuity (deed restrictions? covenants? easements?)?	--				

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BMP Fact Sheet

PROTECT SENSITIVE AREAS

Protecting sensitive and special value features is the process of identifying and avoiding certain natural features during development. This allows these features to be used for various benefits, including reducing stormwater runoff.

Protecting sensitive areas can be implemented both at the site level and throughout the community. For prioritization purposes, natural resources and their functions may be weighted according to their functional value. Sensitive areas should be preserved in their natural state to the greatest extent possible and are not the appropriate place to locate stormwater infrastructure.



Figure 1 Tree Preservation during construction, Seattle, WA (USEPA, picasaweb)

Key Design Features

- Identify and map the following: floodplains, riparian areas, wetlands, woodlands, prairies, natural flow pathways, steep slopes, and other sensitive areas
- Identify and map potential development areas

Benefits

- Improved water quality
- Mitigation of runoff volume and peak rates

Limitations

- Difficult to implement on smaller sites

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	High
Commercial	Yes	Groundwater Recharge	High
Ultra Urban	Limited	Peak Rate	High
Industrial	Yes	Stormwater Quality Functions	
Retrofit	No	TSS	High
Highway/Road	Limited	TP	High
Recreational	Yes	NO ₃	Low
		Temperature	High

Additional Considerations	
Cost	Low/Med
Maintenance	Low/Med
Winter Performance	High

Description and Function

Protecting sensitive areas challenges the site planner to inventory and then, to the greatest extent possible, avoid resource sensitive areas at a site, including riparian buffers, wetlands, hydric soils, floodplains, steep slopes, woodlands, valuable habitat zones, and other sensitive resource areas. Development, directed away from sensitive areas, can be held constant, if BMPs such as cluster development are also applied.

A major objective of LID is to accommodate development with fewer impacts to the site. If development avoids encroachment upon, disturbance of, and impact to those natural resources which are especially sensitive to land development impacts and/or have special functional value, then low impact development can be achieved.

The first step in protecting sensitive areas is for the site planner to define, inventory, and map which resources are especially sensitive and/or have special value at a site proposed for development. Although many sensitive areas are common to all areas within Indiana, they can vary by region. The most detailed inventories are often compiled at the municipal or county level. For those areas without municipal or county-level data, state-level data can be used.

Preserving open space in multiple development areas throughout a community can ultimately evolve to form a unified open space system, integrating important conservation areas throughout the community and beyond. Many communities within Indiana are undertaking “green infrastructure” planning initiatives to proactively map these systems in order to restore or protect them as development occurs. The objective of these plans is to avoid impacting sensitive areas by: 1) carefully identifying and mapping these resources (resource areas, primary and secondary) from the start of the site planning process, and 2) striving to protect resource areas by defining other portions of the site free of these resources (potential development areas).

At the community level, local governments can implement community-wide regulations that protect

sensitive areas such as wetlands, woodlands, riparian areas, and floodplains.

Potential Applications

Regardless of land use type, protecting sensitive areas is applicable across all types of land development projects, whether residential of varying densities or office park, retail center or industrial and institutional uses. As density and intensity of uses increases, ease of application of this BMP decreases. In such limited cases, it is especially important that sensitive areas be prioritized.

Design Considerations

1. **Identify, map, and inventory sensitive areas.** Mapping a site’s sensitive areas is an important step in preserving them. These features often include wetlands, steep slopes, woodlands, floodplains, and riparian areas. These data may give the community a general idea of the sensitive resources that could be on the site. In addition, the mapping will help the site designer define a potential development area which avoids encroachment upon and disturbance of defined and mapped sensitive areas.

The inventory of sensitive areas should also include an assessment of the *quality* of the existing natural communities. Because plant communities will exist in a variety of states based on historic disturbance and degradation, the quality of the given community needs to be considered in comparison to other similar communities.

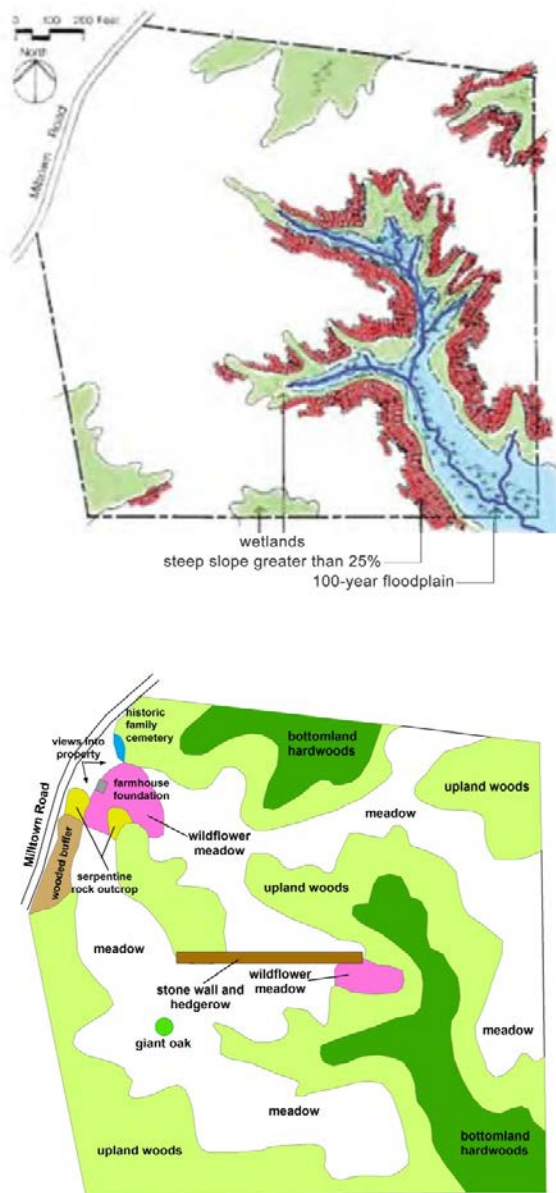


Figure 2 Map of Sensitive Areas (top) and Secondary Resources (bottom)
Source: Arendt, Randall. 1997

2. **Combine mapped natural features into a sensitive resource areas map, prioritizing areas to avoid development.** All sensitive resource mapping should be overlain to produce a sensitive areas map. In *Growing Greener*, Randall Arendt acknowledges prioritizing or weighting of sensitive areas by defining them as either Primary Conservation Areas (the most critical – avoid at all costs) or Secondary Conservation Areas (important

resources which should be avoided when possible). Mapping the secondary resources of the site is an important step; the community can provide input to determine which features are important for preservation. Additionally, Primary and Secondary Conservation Areas can be defined in different ways, possibly varying with watershed context, (e.g., woodlands in some contexts may be classified as Primary Conservation Areas, rather than secondary).

3. **Map potential development areas; prioritize/ weight as necessary.** The potential development area should be delineated on the basis of protecting the primary and secondary resources on a site. Like the sensitive areas map, priorities and weightings may be reflected in the potential development area map. If sensitive areas have been prioritized, then weightings of potential development also may be established, varying with lack of degree of sensitivity measured by the resources themselves or overlapping of



Figure 3 Map of Potential Development Areas
Source: Arendt, Randall. 1997

resources.

4. **Local regulation.** The level of regulation imposed on resource areas (primary and secondary) will likely vary by local jurisdiction. A local ordinance may prohibit and/or otherwise restrict development in primary and secondary resource areas, provided certain legal tests (such as a takings determination) are passed. Additional

activities include:

- a. Conservation easement – Given to land conservancy or maintained by homeowners association.
- b. Requirements in the master deed and bylaws for protection and preservation.
- c. Boundary markers at edges of lots to minimize encroachment.
- d. Cooperative agreements for stewardship of sensitive areas between homeowners' associations and local conservation organizations.

Stormwater Functions and Calculations

Any portion of a site that can be maintained in its predevelopment state by using this BMP will not contribute increased stormwater runoff and will reduce the amount of treatment necessary. Calculation methodology to account for this BMP is provided in the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards.

Volume

Protected sensitive areas are not to be included in the disturbed stormwater management area when calculating runoff volume (see the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards).

Any portion of a sensitive area that is mitigated or revegetated/reforested should be included in the disturbed stormwater management area, but may be granted runoff reduction recognition in accordance with the applicable BMP for native revegetation, soil restoration, minimize soil compaction, riparian buffer restoration, or minimize total disturbed area.

Peak Rate

Runoff from the protected sensitive area may be excluded from peak rate calculations for rate control, provided that the runoff is not conveyed to and/or through stormwater management control structures. If necessary, runoff from protected sensitive areas should be directed around BMPs and stormwater pipes and inlets by means of vegetated

swales or low berms that direct flow to natural drainageways.

Water Quality Improvement

Water quality is benefited substantially by avoiding negative impacts which otherwise would have resulted from impacts to sensitive areas (e.g., loss of water quality functions from riparian buffers, from wetland reduction, etc.)

Construction Guidelines

Although protecting sensitive areas happens early in the site plan process, it is equally important that the developer and builder protect these areas during construction.

The following guidelines describe good planning practices that will help ensure protection of a few common environmentally sensitive resources during construction.

Water Resources

- If vegetation needs to be reestablished, plant native species, or use hydroseed and mulch blankets immediately after site disturbance.
- Use bioengineering techniques, where possible, to stabilize stream banks.
- Block or protect storm drains in areas where construction debris, sediment, or runoff could pollute waterways.
- During and after construction activities, sweep the streets to reduce sediment from entering the storm drain system.
- Avoid hosing down construction equipment at the site unless the water is contained and does not get into the stormwater conveyance system.
- Implement spill control and clean-up practices for leaks and spills from fueling, oil, or use of hazardous materials. Use dry clean-up methods (e.g., absorbents) if possible. Never allow a spill to enter the stormwater conveyance system.
- Avoid mobile fueling of equipment. If mobile fueling is necessary, keep a spill kit on the fueling truck.

- Properly dispose of solid waste and trash to prevent it from ending up in our lakes and streams.
- When protecting riparian buffer areas, consider the three buffer zones in protection criteria:

Zone 1: Also termed the “streamside zone,” Zone 1 begins at the edge of the stream bank of the active channel and extends a minimum distance of 25 feet, measured horizontally on a line perpendicular to the water body. Undisturbed vegetated area aims to protect the physical and ecological integrity of the stream ecosystem. The vegetative target for the streamside zone is undisturbed native woody species with native plants forming canopy, understory, and duff layer; where such forest does not grow naturally, then native vegetative cover appropriate for the area (such as grasses, forbs, or shrubs) is the vegetative target.

Zone 2: Also termed the “middle zone,” Zone 2 extends immediately from the outer edge of Zone 1 for a minimum distance of 55 feet. This managed area of native vegetation protects key components of the stream ecosystem and provides distance between upland development and the streamside zone. The vegetative target for the middle zone is either undisturbed or managed native woody species or, in its absence, native vegetative cover of shrubs, grasses, or forbs. Undisturbed forest, as in Zone 1, is strongly encouraged to protect further water quality and the stream ecosystem.

Zone 3: Also termed the “outer zone,” Zone 3 extends a minimum of 20 feet immediately from the outer edge of Zone 2. This zone prevents encroachment into the riparian buffer area, filters runoff from adjacent land, and encourages sheet flow of runoff into the buffer. The vegetative target for the outer zone is native woody and herbaceous vegetation to increase the total width of the buffer; native grasses and forbs are acceptable.

County Regulated Drain Considerations: Special attention needs to be paid regarding the type and density of vegetation used if the natural drainage pathway or stream is or will be a part of the County Regulated Drain system. The County may require that at least one side of the regulated drain is clear of woody vegetation, with continuous access

provided for reconstruction and maintenance. Pre-coordination with the County Surveyor’s Office is highly recommended.

Wetlands

- Avoid impacts to wetlands whenever possible. If impractical, determine if a wetland permit is needed from the state or local government. (If any permit requirements or wetland regulations conflict with these guidelines, comply with the permit or regulation).
- Excavate only what is absolutely necessary to meet engineering requirements. Do not put excavated material in the wetland. (Excavated material could be used in other areas of the site to improve seeding success).
- If construction activities need to occur within a wetland, activities should be timed, whenever possible, when the ground is firm and dry. Avoid early spring and fish-spawning periods.
- Install flagging or fencing around wetlands to prevent encroachment.
- Travel in wetlands should be avoided. Access roads should avoid wetlands whenever possible. Crossing a wetland should be at a single location and at the edge of the wetland, if possible.
- Never allow a spill to enter area wetlands.

Floodplains

- Design the project to maintain natural drainage patterns and runoff rates if possible.
- Maintain as much riparian vegetation as possible. If riparian vegetation is damaged or removed during construction, replace with native species.
- Use bioengineering techniques to stabilize stream banks.
- Keep construction activity away from wildlife crossings and corridors.
- Stockpile materials outside of the floodplain and use erosion control techniques

Woodlands and Isolated Trees in Disturbed Areas

- Protect trees on sites with severe design limitations, such as steep slopes and highly erodible soils.
- Preserve trees along watercourses to prevent bank erosion, decreased stream temperatures, and to protect aquatic life.
- Protect the critical root zone of trees during construction. This is the area directly beneath a tree's entire canopy. For every inch of diameter of the trunk, protect 1.5 feet of area away from the trunk.

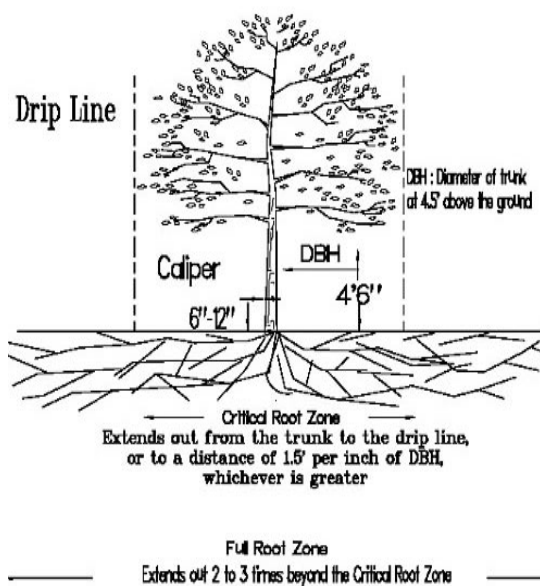


Figure 4 Critical Root Zone of a Tree

Source: www.ncufc.org/

- Avoid trenching utilities through the tree's critical root zone.
- Avoid piling excavated soil around any tree.
- Replace trees removed during construction with native trees.
- Conduct post-construction monitoring to ensure trees impacted by construction receive appropriate care.

General Construction Considerations

- Conduct a pre-construction meeting with local jurisdiction officials, contractors, and subcontractors to discuss natural resource protection. Communicate agreed-upon goals to everyone working on the project.

- Insert special requirements addressing sensitive natural areas into plans, specifications, and estimates provided to construction contractors. Note the kinds of activities that are not allowed in sensitive areas.
- Confine construction and staging areas to the smallest necessary and clearly mark area boundaries. Confine all construction activity and storage of materials to designated areas.
- Install construction flagging or fencing around sensitive areas to prevent encroachment.
- Excavate only what is absolutely necessary to meet engineering requirements. Do not put excavated material in sensitive areas. (Excavated material could be used in other areas of the site to improve seeding success.)
- Conduct onsite monitoring during construction to ensure sensitive areas are protected as planned. Conduct post-construction monitoring to ensure sensitive areas that were impacted by construction receive appropriate care.

Maintenance

The preservation of open space creates maintenance concerns related to who is required to perform the maintenance activities. Legally, the designated open space may be conveyed to the local government. More likely, ownership of these natural areas will be assumed by homeowners' associations or simply the specific individual property homeowners where these resources are located. Specific maintenance activities will depend upon the type of vegetation present in the preserved natural area where woodlands require little to no maintenance and open lawn require higher maintenance.



Figure 5 Protecting Woodlands

Cost

When development encroaches into sensitive areas, dealing with their special challenges invariably adds to development and construction costs. Sometimes these added costs are substantial, as in the case of working with wetlands or steep slopes.

Sometimes costs emerge only in longer-term operation, like encroachment in floodplains. This can translate into added risk of building damage for future owners, as well as health and safety impacts, insurance costs, and downstream flooding. If all short- and long-term costs of impacting sensitive areas were quantified and tallied, total real costs of sensitive area encroachment would increase substantially. Conversely, protecting sensitive areas results not only in cost savings, but also in water quality benefits.

At the same time, reduction in potential development areas resulting from protecting and conserving sensitive areas can have the effect of altering — even reducing — a proposed development program, thereby reducing development yield and profit. To address this, this BMP can be applied in tandem with the cluster development BMP.

Designer/Reviewer Checklist for Protect Sensitive Areas

ITEM	Page No.	YES	NO	N/A	NOTES
Define sensitive resources at proposed development site (see Key Design Features for list of sensitive resources)	1, 2				
Map sensitive resources at proposed development site	1, 2				
Prioritize/weight sensitive areas, as necessary and appropriate	3				
Develop potential development area map, or comparable, defined as converse/negative of sensitive areas, with priorities/weightings as necessary and appropriate.	3				
Determine baseline development plan, compatible with municipal ordinance.	2				
Iteratively fit baseline development plan to potential development area, minimizing sensitive area encroachment?	2				
Is this BMP process required by municipality? Yes or no, has applicant followed these steps, or comparable?	3, 4				

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BMP Fact Sheet

REDUCE IMPERVIOUS SURFACES

Reducing impervious surfaces includes minimizing areas such as streets, parking lots, and driveways. By reducing the amount of paved surfaces, stormwater runoff is decreased while infiltration and evapotranspiration opportunities are increased.



Figure 1 Grassed overflow parking areas (NEMO, University of Connecticut)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	High
Commercial	Yes	Groundwater Recharge	High
Ultra Urban	Limited	Peak Rate	High
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Limited	TSS	Medium
Highway/Road	Yes	TP	Low
Recreational	Yes	NO ₃	Low
		Temperature	Medium

Additional Considerations	
Cost	Low
Maintenance	Low
Winter Performance	High

Key Design Features

Streets

- Evaluate traffic volumes and street parking requirements
- Consult with local fire department and road agencies
- If available, consider a private road ordinance, as necessary, to minimize width
- Minimize pavement widths and lengths by using alternative roadway layouts, restricting on-street parking, minimizing cul-de-sac radii, and using permeable pavers

Parking Lots

- Evaluate parking requirements considering average demand as well as peak demand
- Consider smaller parking stalls and/or compact parking spaces
- Analyze parking lot layout to evaluate the applicability of narrowed traffic lanes and slanted parking stalls
- If appropriate, minimize impervious parking area by using overflow parking areas constructed of pervious paving materials

Lot Level

- Use maximum lot coverage requirements to manage the amount of impervious surfaces
- Reduce front yard setbacks to allow for shorter driveways
- Use alternative materials for patios, sidewalks, driveways, as appropriate

Benefits

- Directly reduces runoff volumes and peak rates
- Reduces development and maintenance costs
- Enhances aesthetics and habitat

Limitations

- Must comply with local private road ordinances
- Must comply with vehicular safety standards

Description and Function

Reducing street imperviousness performs valuable stormwater functions in contrast to conventional development in the following ways:

- Increases infiltration,
- Decreases runoff volumes,
- Increases stormwater time of concentration,
- Improves water quality by decreasing nonpoint source pollutant loading, and
- Decreases the concentration and energy of stormwater.

Design Considerations

Street Width

Streets usually are the largest single component of imperviousness in residential development. Universal application of high-volume, high-speed traffic design criteria results in excessively wide streets. Coupled with the perceived need to provide both on-street parking and emergency vehicle access, the end result is residential streets that may be 36 feet or greater in width.

The American Society of Civil Engineers (ASCE) and the American Association of State Highway

Jurisdiction	Residential Street Pavement Width	Maximum Daily Traffic (trips/day)
State of New Jersey	20 ft. (no parking)	0-3,500
	28 ft. (parking on one side)	0-3,500
State of Delaware	12 ft. (alley)	--
	21 ft. (parking on one side)	--
Howard County, Maryland	24 ft. (parking not regulated)	1,000
Charles County, Maryland	24 ft. (parking not regulated)	---
Morgantown, West Virginia	22 ft. (parking on one side)	--
Boulder, Colorado	20 ft.	150
	20 ft. (no parking)	350-1,000
	22 ft. (parking on one side)	350
	26 ft. (parking on both sides)	350
	26 ft. (parking on one side)	500-1,000
Bucks County, Pennsylvania	12 ft (alley)	--
	16-18 ft. (no parking)	200
	20-22 ft. (no parking)	200-1,000
	26 ft. (parking on one side)	200
	28 ft. (parking on one side)	200-1,000

Table 1 Narrow Residential Street Widths

Source: Cohen, 1992; Bucks County Planning Commission, 1980; Center for Watershed Protection, 1998

Imperviousness greatly influences stormwater runoff volume and quality by increasing the rapid transport of stormwater and collecting pollutants from atmospheric deposition, automobile leaks, and additional sources.

Stream degradation has been observed at impervious levels as low as 10-20 percent watershed-wide when these areas are managed conventionally. Recent findings indicate that degradation is observed even at much lower levels of imperviousness. Reducing imperviousness improves an area's hydrology, habitat structure, and water quality.

and Transportation Officials (AASHTO) recommend that low-traffic-volume roads (less than 50 homes or 500 daily trips) be as narrow as 22 feet. Some municipalities have reduced their lowest trafficable residential roads to 18 feet or less. Higher-volume roads are recommended to be wider. **Table 1** provides sample road widths from different jurisdictions.

Need for adequate emergency vehicle access, notably fire trucks, also leads to wider streets. While it is perceived that very wide streets are required for fire trucks, some local fire codes permit roadway widths as narrow as 18 feet (**Table 2**). Concerns also exist relating to other vehicles and maintenance activities on narrow streets. School buses are typically nine feet wide, mirror to mirror.

Source	Residential Street Width
U.S. Fire Administration	18-20 ft.
Baltimore County, Maryland Fire Department	16 ft. (no on-street parking)
	24 ft. (on-street parking)
Virginia State Fire Marshall	18 ft. minimum
	24 ft. (no parking)
Prince George's County, Maryland Department of	30 ft. (parking on one side)
Environmental Resources	36 ft. (parking on both sides)
	20 ft. (fire truck access)
Portland, Oregon Office of Transportation	18 ft. (parking on one side)

Table 2 Fire Vehicle Street Requirements

Source: Adapted from Center for Watershed Protection, 1998

Prince George's and Montgomery Counties in Maryland require only a 12-foot driving lane for buses (Center for Watershed Protection, 1998).

Similarly, trash trucks require only a 10.5-foot driving lane. Trash trucks have a standard width of nine feet (Waste Management, 1997; BFI, 1997). In some cases, road width for emergency vehicles may be added through use of permeable pavers for roadway shoulders.

Snow removal on narrower streets is readily accomplished with narrow, eight-foot snowplows. Restricting parking to one side of the street allows accumulated snow to be piled on the other side of the street. Safety concerns are also cited as a justification for wider streets, but increased vehicle-pedestrian accidents on narrower streets are not supported by research. In fact, wider streets have been shown to promote increased speeds and accidents. The Federal Highway Administration states that narrower streets reduce vehicle travel speeds, lessening the incidence and severity of accidents.

Higher density developments require wider streets, but alternative layouts can minimize street widths. For example, in instances where on-street parking is desired, impervious pavement is used for the travel lanes, with permeable pavers placed on the road apron for the parking lanes. The width of permeable pavers is often the width of a standard parking lane (six to eight feet). This design approach minimizes impervious area while also providing an infiltration and recharge area for the impervious roadway stormwater.

Street Length

Numerous factors influence street length, including

clustering techniques. As with street width, street length greatly impacts the overall imperviousness of a developed site. While no one prescriptive technique exists for reducing street length, alternative street layouts should be investigated for options to minimize impervious cover. Successful clustering design consistently has shown to reduce required street lengths, holding development programs constant (i.e., 100 homes successfully clustered on a 100-acre property results in a significant reduction in street length and total imperviousness than 100 homes conventionally gridded in large-lot development format).

Cul-de-sacs

The use of cul-de-sacs introduces large areas of imperviousness into residential developments. Some communities require the cul-de-sac radius to be as large as 50 to 60 feet. Simply reducing the radius from 40 feet to 30 feet can reduce the imperviousness by 50 percent (Schueler, 1995).

When cul-de-sacs are necessary, three primary alternatives can reduce their imperviousness; reduce the required radius, incorporate a landscaped island into the center of the cul-de-sac, or create a T-shaped (or hammerhead) turnaround (**Figure 2**). To reduce the radius, many jurisdictions have identified required turnaround radii (**Table 3**).

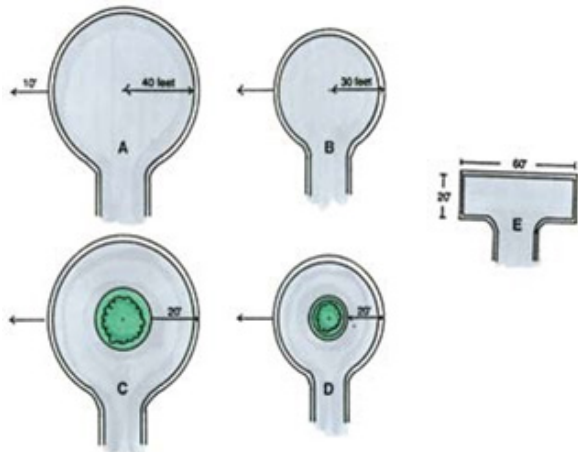


Figure 2 Five Cul-de-Sac Options
Source: Center for Watershed Protection, 1998

A landscaped island in the center of a cul-de-sac can provide the necessary turning radius, minimizing impervious cover. This island can be designed as a depression to accept stormwater runoff from the surrounding pavement, thus furthering infiltration. A flat apron curb will stabilize roadway pavement and allow for runoff to flow into the cul-de-sac's open center.

A T-shaped turnaround reduces impervious surface even further – yielding a paved area less than half that of a 30-foot radius turnaround. Since vehicles need to make a three-point turn to drive out, T-

Source	Radius
Portland, Oregon Office of Transportation	35 ft (with fire dept. approval)
Buck County, Pennsylvania Planning Commission	38 ft (outside turning radius)
Fairfax County, Virginia Fire and Rescue	45 ft
Baltimore County, Maryland Fire Department	35 ft (with fire dept. approval)
Montgomery County, Maryland Fire Department	45 ft
Prince George's County, Maryland Fire Department	43 ft

Table 3 Cul-de-sac Turning Radii
Source: Adapted from Center for Watershed Protection, 1998

shaped turnarounds are most appropriate on streets with 10 or fewer homes.

Parking

Parking lots often comprise the largest percentage of impervious area. Parking lot size is dictated by lot layout, stall geometry, and parking ratios. Modifying any or all of these three aspects can serve to minimize the total impervious areas associated with parking lots. Parking ratio requirements and accommodating peak parking demand often provide parking capacity substantially in excess of average parking needs. This results in vast quantities of unused impervious surface. A design alternative to this scenario is to provide designated overflow parking areas.

The primary parking area, sized to meet average demand, might still be constructed on impervious pavement to meet local construction codes and American with Disabilities Act requirements. However, the overflow parking area, designed to accommodate increased parking requirements associated with peak demand, could be constructed on pervious materials (e.g., permeable pavers, grass pavers, gravel. See Porous Pavement BMP Fact Sheet). This design approach, focused on average parking demand, will still meet peak parking demand requirements while reducing impervious pavement.

Parking Ratios

Parking ratios express the specified parking requirements provided for a given land use. These specified ratios are often set as minimum requirements. Many developers seeking to ensure adequate parking provide parking in excess of the minimum parking ratios. Additionally, commercial parking is often provided to meet the highest hourly demand of a given site, which may only occur a few times per year. However, average parking demand is generally less than the typical required parking ratios (**Table 4**).

Parking spaces are comprised of five impervious components (Center for Watershed Protection, 1998):

1. The parking stall,
2. The overhang at the stall's edge,
3. A narrow curb or wheel stop,
4. The parking aisle that provides stall access, and

5. A share of the common impervious areas (e.g., fire lanes, traffic lanes).

imperviousness achieved through reduced street widths and lengths and reduced paved parking areas

Land Use	Parking Ratio	Average Parking Demand
Single Family Home	2 spaces per dwelling unit	1.1 spaces per dwelling unit
Shopping Center	5 spaces per 1,000 ft ² of GFA	3.97 spaces per 1,000 ft ² of GFA
Convenience Store	3.3 spaces per 1,000 ft ² of GFA	Not available
Industrial	1 space per 1,000 ft ² of GFA	1.48 spaces per 1,000 ft ² of GFA
Medical/Dental Office	5.7 spaces per 1,000 ft ² of GFA	4.11 spaces per 1,000 ft ² of GFA

(GFA – Gross Floor Area, excluding storage and utility space)

Table 4 Example Minimum Parking Ratios

Source: Institute of Transportation Engineers, 1987; Smith, 1984; Wells, 1994

Of these, the parking space itself accounts for approximately 50 percent of the impervious area, with stall sizes ranging from 160 to 190 square feet.

Several measures can be taken to limit parking space size. First, jurisdictions can review standard parking stall sizes to determine their appropriateness. A typical stall dimension may be 10 feet by 18 feet, much larger than needed for many vehicles. The great majority of SUVs and vehicles are less than seven feet in width, providing opportunity for making stalls slightly narrower and shorter. In addition, a typical parking lot layout includes parking aisles that accommodate two-way traffic and perpendicularly oriented stalls. The use of one-way aisles and angled parking stalls can reduce impervious area.

Municipalities can also stipulate that parking lots designate a percentage of stalls as compact parking spaces. Smaller cars comprise a significant percentage of vehicles and compact parking stalls create 30 percent less impervious cover than average-sized stalls (Center for Watershed Protection, 1998).

Stormwater Functions and Calculations

Quantifying impervious areas at a proposed development site, pre- to post-development continues to dominate stormwater calculations. Stormwater calculations, as discussed in the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards, are sensitive to pervious areas and their contribution to total volume of runoff, increased peak rate of runoff, and increased generation of nonpoint source pollutants. A reduction in

automatically reduces the volume and peak rate of runoff. To the extent that water quality is linked to runoff volume, reduction in imperviousness translates into a reduction in water quality management requirements as compared with standard design.

Maintenance

A reduction in impervious area results in decreased maintenance. For example, whether publicly or privately maintained, reducing roadway or parking lot imperviousness typically translates into reduction in all forms of maintenance required, from basic roadway repair to winter maintenance and snow removal.

Cost

Street Width

Costs for paving are estimated to be approximately \$15 per square yard (Center for Watershed Protection, 1998), which would be considerably higher in current dollars. At this cost, for each one-foot reduction in street width, estimated savings are \$1.67 per linear foot of paved street. For example, reducing the width of a 500-foot road by five feet would result in a savings of over \$4,100, which would be considerably higher in current dollars. This cost is exclusive of other construction costs including grading and infrastructure.

Street Length

Factoring in pavement costs at \$15 per square yard (as above), a 100-foot length reduction in a 25-foot-wide road would produce a savings in excess of \$4,000 (much higher in current dollars).

In addition to pavement costs, costs for street lengths, including traditional curb and gutter and stormwater management controls, are approximately \$150 per linear foot of road (Center for Watershed Protection, 1998), which would be considerably higher in current dollars. Decreasing road length by 100 feet would save an additional \$15,000, for a combined total of \$19,100.

Parking

Estimates for parking construction range from \$1,200 to \$1,500 per space (Center for Watershed Protection, 1998), which would be significantly higher in current dollars. For example, assuming a cost of \$1,200 per parking space, reducing the required parking ratio for a modest 20,000 square foot shopping strip from five spaces per 1,000 square feet to four spaces per 1,000 square feet would represent a savings of \$24,000.

Designer/Reviewer Checklist for Reducing Impervious Surfaces

ITEM	Page No.	YES	NO	N/A	NOTES
Check municipal ordinances for requirements/specifications for roads, drives, parking, walkways, other (problems vs. opportunities?), including safety requirements.	1				
Have both macro (e.g., clustering) and micro site planning (e.g., reduced setbacks) activities been applied fully?	1, 3				
Have LID impervious reduction standards for roads, drives, parking, and other impervious areas been consulted and applied? ➤ <i>Street Width: See Tables 1 and 2 on Pages 2-3</i> ➤ <i>Cul-de-sac: See Table 3 on Page 4</i>	2-4				
Have roads and drives been reduced or narrowed as much as possible?	1-3				
Have macro parking ratios, lot layout, sharing strategies, and micro strategies (sizes/dimensions) been applied fully? ➤ <i>Parking Ratios: See Table 4 on Page 5</i>	4, 5				
Have pervious surfaces been applied for roads, drives, walks, parking, patios, and other hard surfaces, with maintenance been provided?	5				

➤ *Denotes Minimum Design Considerations*

References

American Association of State Highway and Transportation Officials. *A Policy on Geometric Design of Highways and Streets*. Washington, DC, 2001.

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BMP Fact Sheet

STORMWATER DISCONNECTION

Minimize stormwater volume by disconnecting roof leaders, impervious roads, and driveways and direct runoff to other BMPs including vegetated areas that infiltrate at the site.



Figure 1 Curb cuts and vegetated areas along a Portland, OR street (USEPA, picasaweb)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	High
Commercial	Yes	Groundwater Recharge	High
Ultra Urban	Limited	Peak Rate	High
Industrial	Limited	Stormwater Quality Functions	
Retrofit	Limited	TSS	High
Highway/Road	Limited	TP	High
Recreational	Yes	NO ₃	Low/Med
		Temperature	High

Additional Considerations	
Cost	Low
Maintenance	Low
Winter Performance	Low

Variations

- Rooftop disconnection
- Driveway/walkway/small parking areas/patio disconnection
- Minor roads
- Distribute to existing vegetated services
- Distribute to existing depressions, re-graded areas
- Distribute via curb cuts/curb removal

Key Design Features

- Encourages shallow sheet flow through vegetated areas
- Directs flows into stabilized vegetated areas, including on-lot swales and bioretention areas
- Limits the contributing rooftop area to a maximum of 500 ft² per downspout
- Maximizes overland flows
- Minimizes use of curb and gutter systems and piped drainage systems

Site Factors

- Water table to bedrock depth: two-foot minimum
- Soils: A, B
- Slope: maximum 5 percent
- Potential hotspots: No
- Max. drainage area: rooftop area of 1,000 ft²

Benefits

- Reduces runoff volume and peak rate
- Increases water quality benefits

Limitations

- Requires area for infiltration

Description and Function

Roofs, roads, and driveways account for a large percentage of post-development imperviousness. These surfaces influence stormwater quality and runoff volume by facilitating the rapid transport of stormwater and collecting pollutants from rainfall, automobile leaks, and additional sources.

Disconnecting roof leaders and routing road and driveway runoff from conventional stormwater conveyance systems allows runoff to be collected and managed onsite. Runoff can be directed to designed vegetated areas for onsite storage, treatment, and volume control. This is a distributed, low-cost method for reducing runoff volume and improving stormwater quality through:

- Increasing infiltration and evapotranspiration,
- Decreasing stormwater runoff volume, and
- Increasing stormwater time of concentration.

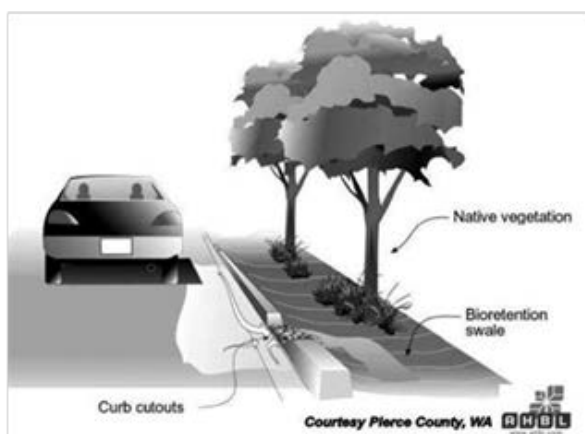


Figure 2 Curb cut-outs allow stormwater runoff from a parking lot to flow into a bioretention swale

The suitability of vegetated swales to receive runoff depends on land use, soil type, imperviousness of the contributing watershed, and dimensions and slope of the vegetated swale system. Use of natural low-lying areas is encouraged; natural drainage courses should be used and preserved.

Some ponding of water in areas receiving runoff may occur. It is important to take into account site usage when applying this BMP so that ponding does not unnecessarily interfere with expected site use (including backyard play areas). These areas should be shown on plan documents and protected with easements and deed restrictions.

Although this BMP can be applied in a variety of development settings, it will likely be more successful as lot size increases and density decreases. In situations where clustering has not been fully exercised and lots remain relatively large, these lots and the large areas of perviousness make perfect candidates for stormwater disconnection.

Variations

Disconnecting stormwater can be achieved through identifying the source of runoff and how it will be managed once disconnection occurs.

Source

Stormwater can flow from rooftop areas or from impervious areas such as driveways, walkways, small parking areas, minor roadways, and ancillary outdoor areas such as patios. (Note: Roads and highways, because of their greater runoff generation require Structural BMPs.)

Management practices

A common and successful management practice is to direct stormwater runoff to areas of existing vegetation. Vegetation can be of varying types, from established meadow to immature to mature woodland. A particular variation to consider is grading (crowning) of drives and minor roadways and

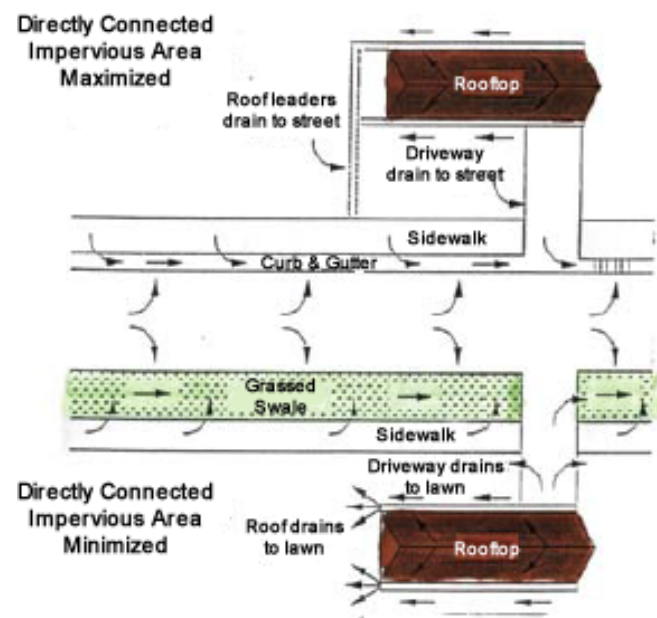


Figure 3 Difference between maximizing and minimizing runoff

eliminating curbing (or provision of curb cuts) so that runoff is allowed to flow in an even and non-concentrated manner onto adjacent vegetated areas.

In addition to directing runoff to vegetated areas, runoff may also be discharged to non-vegetated BMPs, such as dry wells, rain barrels, and cisterns for stormwater retention and volume reduction.

Another management practice includes routing runoff to existing grades and depressions that can be used to capture, store, and treat runoff. An important caveat is that applying this BMP should not prompt grading and disturbing areas which otherwise would not have been disturbed. However, assuming that grading and disturbance cannot be avoided, then subtle adjustments to grading may create additional management/storage opportunities for disconnected runoff.

An ideal coupling of BMPs is to minimize the total disturbed area of a site in coordination with stormwater disconnection. This not only reduces runoff volumes, peak rates, and pollutant loadings, but also provides multiple decentralized opportunities to receive disconnected flows.

Applications

Disconnection is ideal for most single-family developments, but can also be applied to many development sites, including larger office parks and retail centers. Industrial developments, with their larger impervious covers and greater runoff volumes, make stormwater disconnection a challenge. Even so, there are isolated applications which are beneficial and promote LID objectives. Similarly, Ultra Urban and Highway/Road developments with large flows would be more limited in application.

If downspout disconnection is applied as a retrofit, downspouts should be extended away from the basement as many footing drains are attached to the sanitary sewer system.

Design Considerations

Careful consideration should be given to the design of vegetated collection areas. Concerns pertaining to basement seepage and water-soaked yards are warranted, with the potential arising for saturated depressed areas and eroded water channels. Proper

design and use of bioretention areas, infiltration

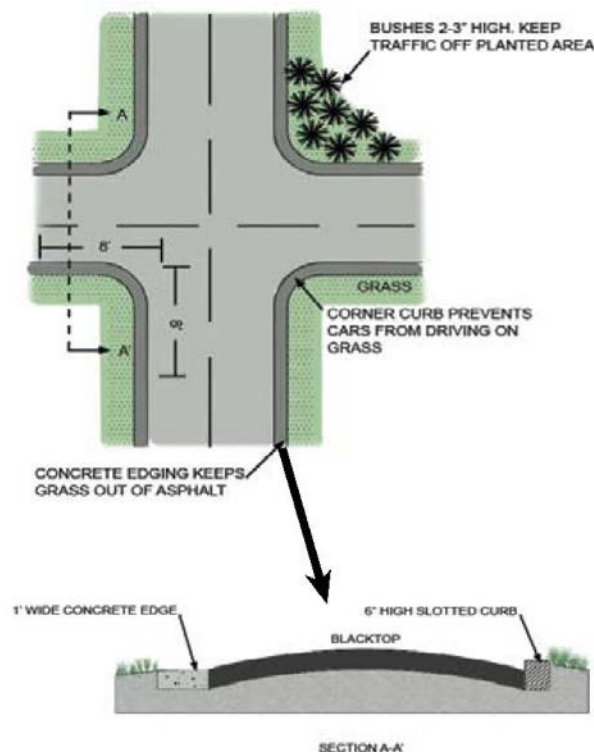


Figure 4 Curb cuts as a method of stormwater disconnection

trenches, and/or dry wells reduces or eliminates the potential for surface ponding and facilitates functioning during cold weather months. Where basements exist, consider the direction of groundwater flow and proximity.

Disconnection of small runoff flows can be accomplished in a variety of ways (Prince George's County Department of Environmental Protection, 1997; Maryland Department of the Environment, 1997; Cahill, 2008).

1. Encourage shallow sheet flow through vegetated areas.
2. Direct roof leader flow into BMPs designed specifically to receive and convey rooftop runoff.
3. Direct flows into stabilized vegetated areas, including on-lot swales and bioretention areas.
4. Rooftop runoff may also be directed to onsite depression storage areas.

5. The entire vegetated “disconnection” area should have a maximum slope of five percent.
6. Runoff should not be directed to vegetated areas if there is reason to believe that pollutant loadings will be elevated.
7. Roof downspouts or curb cuts should be at least 10 feet away from the nearest connected impervious surface to discourage “re-connections.”
 - a. Limit the contributing impervious area to a maximum of 1,000 sq. ft. per discharge point.
 - b. Limit the contributing rooftop area to a maximum of 1,000 sq. ft. per downspout, where pervious area receiving runoff must be at least twice this size.
 - c. For contributing areas greater than 1,000 sq. ft., leveling devices are recommended.
8. The maximum contributing impervious flow path length should be 75 feet.
9. For impervious areas, the length of the disconnection area must be at least the length of the contributing area (a minimum 75 feet for discharges which are concentrated; 25 feet for discharges which are not concentrated).
10. In all cases, flows from roof leaders should not contribute to basement seepage.

Stormwater runoff from disconnection needs to be monitored to ensure that flows do not become channelized that can result in erosion. Attention must be given to safe overflowing of larger storms, though clearly the more frequent smaller storms are of greatest interest and concern for successful design (use two-year storm for erosion analysis). Make sure flow of water and temporary ponding of water in management areas will not become a problem.

Stormwater Functions and Calculations

Peak rate and volume

This BMP reduces total volume and peak rates of runoff, as runoff is minimized from centralized stormwater management systems at the development

site. Disconnection directly reduces volume and peak rates, which reduces the need for structural BMPs.

Water quality improvement

In terms of rooftop disconnection, this BMP has limited water quality benefit because rooftops typically have minimal pollution. In terms of other impervious area runoff sources being disconnected (driveways, walkways, ancillary areas, minor roads), water quality benefits can be significant given their greater pollutant loadings.

Maintenance

When disconnecting stormwater from rooftops or other impervious surfaces, maintaining the vegetated areas is required, but is limited.

If using structural BMPs, such as bioretention or vegetated swales, follow their specific maintenance activities. Typical maintenance of vegetation includes a biannual health evaluation of the vegetation and subsequent removal of any dead or diseased vegetation plus mulch replenishment, if included in the design. This can be incorporated into regular maintenance of the site landscaping. In some cases, if leaders are directing stormwater to lawn depressions, maintenance may be as simple as mowing.

Cost

Stormwater disconnection reduces both construction and maintenance costs due to less reliance on traditional stormwater management infrastructure. In addition, using existing or planned bioretention areas within a site creates a double usage of these BMPs.

Designer/Reviewer Checklist for Disconnection

ITEM	Page No.	YES	NO	N/A	NOTES
Are site factors conducive to disconnection (infiltration- related factors? slope? other?)	2, 3				
Is proposed development type (e.g., residential, commercial) conducive to disconnection? Free of hot spots?	3				
Have potential disconnection runoff sources been adequately reviewed/utilized in terms of proposed plan? <ul style="list-style-type: none"> ➤ <i>Max. slope for entire vegetated "disconnection" area: 5%</i> ➤ <i>Minimum distance of roof downspouts or curb cuts from nearest connected impervious surface to discourage "re-connections": 10 feet</i> ➤ <i>Max. contributing impervious area: 1000 ft² per discharge point</i> ➤ <i>Max. contributing rooftop area (receiving pervious area must be twice this size): 1000 ft² per downspout</i> ➤ <i>If contributing area > 1000 ft², leveling device is recommended</i> ➤ <i>Max. length of contributing impervious flow path: 75 feet</i> ➤ <i>Minimum length of disconnection area to contributing impervious area: 75 feet for concentrated discharges; 25 feet for non-concentrated discharges</i> 	3, 4				
Have potential disconnection management measures been used/exploited for all potential sources?	2, 3				
Have Criteria and Runoff Reduction Recognitions specifications for both rooftop and non-rooftop sources of disconnection been satisfied?	3				
Have disconnection calculation Runoff Reduction Recognitions been properly entered, as specified in Criteria and Runoff Reduction Recognitions?	3				

➤ *Denotes Minimum Design Consideration*

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Part 2

Structural BMPs for LID and Conventional Approaches

- **Introduction**
- **Bioretention (Raingardens)**
- **Capture Reuse**
- **Constructed Filter**
- **Detention Basins – Constructed Wetlands**
- **Detention Basins – Dry Pond**
- **Detention Basins – Underground Detention**
- **Detention Basins – Wet Pond**
- **Infiltration Practices**
- **Level Spreaders**
- **Native Revegetation**
- **Pervious Pavement with Infiltration**
- **Planter Boxes**
- **Riparian Buffer Restoration**
- **Soil Restoration**
- **Vegetated Filter Strip**
- **Vegetated Roof**
- **Vegetated Swale**
- **Water Quality Devices**

INTRODUCTION TO STRUCTURAL BEST MANAGEMENT PRACTICES FOR LID AND CONVENTIONAL APPROACHES

This introductory segment focuses on structural Best Management Practices (BMPs), and provides guidance on selecting the proper BMPs for a site. Specifically, this introductory segment discusses the following:

- The BMP selection process, including a matrix that compares the key applications and functions of each BMP,
- Cold climate considerations, and
- An overview of format and contents of the structural BMP fact sheets

The structural BMPs, for which fact sheets are provided includes an array of practices that are used both for LID and conventional approaches to post-construction stormwater quality management.

BMP Selection Process

Selecting BMPs which accomplish as many stormwater functions as possible is important. At the same time, meeting a certain function or level of pollution control can require multiple BMPs integrated at the site, thus creating a “treatment train.” Such treatment trains direct stormwater to or through multiple BMPs in order to achieve quantity and/or quality stormwater management objectives. In addition, implementing BMPs as part of a treatment train can also provide a level of backup and needed redundancy, which provides additional assurance if one BMP does not work as designed (e.g., maintenance problems, large storm event).

Some BMPs are more readily linked to other BMPs, better lending themselves to treatment train configurations. For example, water quality devices and constructed filters are often used in treatment trains to pre-treat runoff before entering different types of infiltration-driven BMPs. In addition, vegetated swales and vegetated filter strips link well with infiltration systems, rain gardens, wet ponds, and constructed wetlands in treatment trains.

How many of what BMPs should go where? Not all structural BMPs are appropriate for each land development at each site. The selection process of the large

array of structural BMPs can be complex, as multiple factors are juggled. The successful design process requires balancing technical and nontechnical factors, and is summarized in **Figure 1**. In order to assist a quick comparison of the BMPs, **Table 1** provides summary information on potential applications, stormwater quality and quantity functions, cost, maintenance, and winter performance for each BMP.

Site design plan developers should look for performance data that cites total volume into the BMP and out of the BMP, with pollutant concentration or load information for each. One of the most useful databases for deriving performance information for structural stormwater facilities is the *International Stormwater BMP Database*, which includes information on more than 300 BMP studies, performance analysis results, tools for use in BMP performance studies, monitoring guidance, and other study-related publications (www.bmpdatabase.org/). Information in the database aids in estimating the total pollutant load removed by a BMP; i.e., input load minus output load. The total load can be calculated using the volume of water entering into or discharged from the BMP over a given period, multiplied by the mean or average concentration of the pollutant. Another tool that summarizes BMP performance information is EPA’s Urban BMP Performance Tool (www.bmpdatabase.org/). The post-construction stormwater quality management Chapter of the Technical Standards lists accepted, default levels of treatment rate for 4 major pollutants for pre-approved water quality control BMPs used in conventional or LID approaches.

The factors in Figure 1 help guide comprehensive stormwater planning and LID site design. Selecting BMPs requires balancing numerous factors, including the following:

Runoff quantity and runoff quality needs
BMP selection is often based on the pollutant loadings and amount of stormwater runoff. For example, in areas with high phosphorus runoff, infiltrations BMPs are excellent choices for removing phosphorus as long as other selection criteria (e.g., site factors) allow for these techniques. BMP fact sheets provide guidance relating

to BMP performance in terms of runoff volume, groundwater recharge, peak rate, and water quality (total suspended solids, total phosphorous, nitrogen, and temperature).

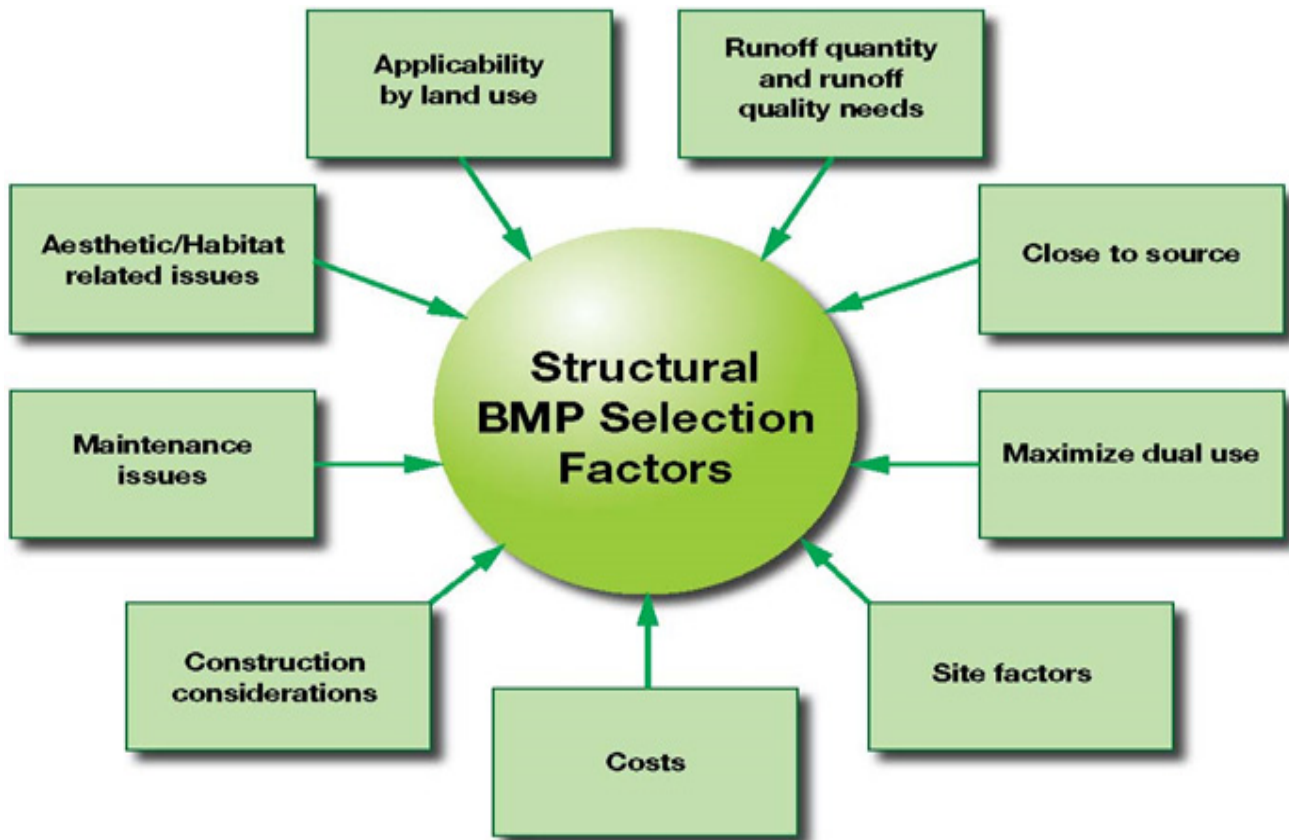


Figure 1 Factors to consider when selecting Structural BMPs

		Potential Applications							Stormwater Quantity Functions			Stormwater Quality Functions				Cost	Maintenance	Winter Perform.
		Residential	Commercial	Ultra Urban	Industrial	Retro	Road	Rec	Volume	GW Recharge	Peak Rate	TSS	TP	NITROGEN ¹	Temp			
Runoff Volume/ Infiltration	Bioretention	YES	YES	LIMITED	LIMITED	YES	YES	YES	MED/HIGH	MED/HIGH	MEDIUM	HIGH	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	MEDIUM
	Vegetated Filter Strip	YES	YES	LIMITED ²	LIMITED	YES	YES	YES	LOW	LOW	LOW	MED/HIGH	MED/HIGH	MED/HIGH (NO ₃)	MED/HIGH	LOW	LOW/MED	HIGH
	Vegetated Swale	YES	YES	LIMITED ²	YES	LIMITED	YES	YES	LOW/MED	LOW/MED	LOW/MED	MED/HIGH	LOW/HIGH	MEDIUM	MEDIUM	LOW/MED\	LOW/MED	MEDIUM
	Pervious Pavement	YES ³	YES	YES	YES ³	YES ³	LIMITED ³	YES	HIGH	HIGH	MED/HIGH	HIGH ⁴	MED/HIGH	LOW	HIGH	MEDIUM	HIGH	MEDIUM
	Infiltration Basin	YES	YES	LIMITED ²	YES	LIMITED	LIMITED	NO	HIGH	HIGH	HIGH	HIGH ⁴	MED/HIGH	MED (NO ₃)	HIGH	LOW/MED	LOW/MED	MED/HIGH
	Subsurface Infiltration Bed	YES	YES	YES	YES	YES	LIMITED	NO	HIGH	HIGH	HIGH	HIGH ⁴	MED/HIGH	LOW	HIGH	HIGH	MEDIUM	HIGH
	Infiltration Trench	YES	YES	YES	YES	YES	YES	NO	MEDIUM	HIGH	LOW/MED	HIGH ⁴	MED/HIGH	LOW/MED	HIGH	MEDIUM	LOW/MED	HIGH
	Dry Well	YES	YES	YES	LIMITED	YES	NO	NO	MEDIUM	HIGH	MEDIUM	HIGH ⁴	MED/HIGH	LOW/MED	HIGH	MEDIUM	LOW/MED	HIGH
	Level Spreaders	YES	YES	NO	YES	YES	YES	YES	LOW	LOW	LOW	LOW	LOW	LOW (NO ₃)	LOW	LOW	LOW	HIGH
	Berming	YES	YES	LIMITED ²	YES	YES	YES	NO	LOW/MED	LOW/MED	MEDIUM	MED/HIGH	MEDIUM	MEDIUM	MEDIUM	LOW/MED	LOW/MED	MED/HIGH
	Planter Box	YES	YES	YES	LIMITED	YES	NO	LIMITED	LOW/MED	MED ⁵	MEDIUM	MEDIUM	LOW/MED	LOW/MED	HIGH	MEDIUM	MEDIUM	MEDIUM
Runoff Volume/ Non-Infiltration	Vegetated Roof	LIMITED	YES	YES	YES	YES	N/A	YES	MED/HIGH	LOW ⁶	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	MEDIUM
	Capture Reuse	YES	YES	YES	YES	YES	NO	YES	HIGH	LOW	LOW ³	MED ⁴	MEDIUM	MED (NO ₃)	MEDIUM	Rain Barrel-LOW-Cistern-MED	MEDIUM	MEDIUM
Runoff Quality/ Non-infiltration	Constructed Wetland	YES	YES	YES	YES	YES	YES	YES	LOW	LOW	HIGH	HIGH	MEDIUM	MEDIUM	LOW/MED	HIGH	LOW/MED	MED/HIGH
	Wet Ponds/Retention Basin	YES	YES	YES	YES	YES	YES	YES	LOW	LOW	HIGH	HIGH	MEDIUM	MEDIUM	LOW/MED	HIGH	LOW/MED	MED/HIGH
	Constructed Filters	LIMITED	YES	YES	YES	YES	YES	YES	LOW ⁸	LOW ⁸	LOW ⁸	HIGH ⁷	MEDIUM ⁷	MEDIUM ⁷	LOW	MED/HIGH	HIGH	MEDIUM
	Water Quality Devices	YES	YES	YES	YES	YES	YES	YES	N/A	N/A	N/A	VARIES	VARIES	VARIES (NO ₃)	NONE	VARIES	VARIES	HIGH
	Underground Detention	YES	YES	YES	YES	YES	YES	YES	LOW	LOW	HIGH	N/A	N/A	N/A	N/A	HIGH	MED/HIGH	MED/HIGH
	Extended Detention/ Dry Pond	YES	YES	YES	YES	YES	YES	YES	LOW	LOW	HIGH	MEDIUM	MEDIUM	LOW	LOW	HIGH	Sediment-LOW, Vegetation-High	MED/HIGH
Restoration	Riparian Buffer Restoration	YES	YES	YES	YES	YES	LIMITED	YES	LOW/MED	LOW/MED	LOW/MED	MED/HIGH	MED/HIGH	MED/HIGH (NO ₃)	MED/HIGH	LOW/MED	LOW	HIGH
	Native Revegetation	YES	YES	LIMITED	YES	YES	LIMITED	YES	LOW/MED/HIGH	LOW/MED/HIGH	LOW/MED	HIGH	HIGH	MED/HIGH	MEDIUM	LOW/MED	LOW	MEDIUM
	Soil Restoration	YES	YES	YES	YES	LIMITED	YES	YES	MED	LOW	MEDIUM	HIGH	HIGH	MED/(NO ₃)	MEDIUM	MEDIUM	LOW	HIGH

Table 1 BMP Summary Matrix

Notes:

- 1 – Reported as TN except as noted as (NO₃)
- 2 – Difficult to apply due to space limitations typically associated with these land uses.
- 3 – Applicable with special design considerations
- 4 – This assumes TSS loads and their debris have been managed properly before entering the BMP to prevent clogging
- 5 – Requires infiltration planter box.
- 6 – Although vegetated roofs can be used very successfully in combination with infiltration systems.
- 7 – Sand filters only (For filters with infiltration, see Subsurface Infiltration Bed section, or other infiltration BMP sections. For manufactured systems, see manufacturer's information, as well as results from independent verification.
- 8 – Increases with infiltration

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Close to source

Manage stormwater runoff as close to the source, or origin, as possible. Implementing this factor will vary by site and by the proposed development. For example, vegetated swales may work well in new development, but would unlikely be used as part of a retrofit.

Maximize dual use

Consider integrating stormwater management into already disturbed areas (e.g., stormwater recharge beds beneath parking areas, play fields on infiltration basins). This can minimize total disturbed area and, in some cases, provide recreational opportunities for residents or employees. For example, Blue Cross Blue Shield of Michigan located in Detroit, built a green roof on their parking structure that incorporated a running track for their employees.

Site factors

Each site should be inventoried for certain characteristics (e.g., soil type, depth to water table, slopes) which should be incorporated into the BMP selection process. For example, some sites in Indiana might be characterized by a high water table, surface bedrock, or extremely slow-draining soils, which would make using infiltration BMPs challenging. BMP fact sheets highlight these site factors which are discussed in more detail in each BMP Design Considerations section. In addition, each BMP has a Designer/Reviewer's Checklist that allows for quick review of the consideration of each key site factor in the design process.

Costs

BMP costs include both construction and long-term maintenance activities. Costs are often related to the size and nature of the development. The BMP fact sheets, as well as the more detailed discussions, provide approximate cost information, although construction and maintenance costs tend to be site and development-specific.

Construction considerations

Many BMPs have construction guidelines to provide additional guidance. For example, locating and properly using excavation equipment is critical during construction of infiltration BMPs to avoid soil compaction. In addition, recommended construction materials specific

to individual BMPs are listed in the Recommended Materials Appendix.

Maintenance issues

Ease of maintenance and needed repairs are critical issues to consider in selecting a BMP. Some BMPs require greater maintenance to function properly. However, they may also achieve greater stormwater quantity and quality goals specific to the objectives of the site. Vegetated BMPs require various types of landscape care. Structural BMPs such as pervious pavement require periodic vacuuming, while infiltration basins, trenches, and dry wells are likely to require little maintenance. Some BMPs, especially those with plantings, may naturally improve in performance over time as vegetation grows and matures. In any case, general maintenance requirements are discussed for each BMP. The Maintenance Inspection Checklists Appendix includes example Inspection Checklists for maintenance activities that should be considered. In addition, the Stormwater Management Practices Maintenance Agreement Appendix includes Model Maintenance Agreements between property owners and the jurisdiction entity for maintenance of BMPs.

Aesthetic/Habitat related issues

Landscape enhancement is becoming an ever-greater goal in most communities and developments. In some cases, developers are willing to pay for BMPs which serve to make their developments more attractive and improve value and marketability. For example, rain gardens make yard areas more attractive. Wet ponds and constructed wetlands, naturally planted swales and filter strips, vegetated roofs, and many other BMPs can be integrated into landscape design while creating value and solving stormwater problems. In addition, many of these BMPs add habitat values and provide other environmental benefits. BMP fact sheets and the detailed BMP discussions provide additional information on aesthetics.

Applicability by land use

Some land uses lend themselves to certain BMPs. Low density residential development lacks large congregate parking areas conducive to pervious pavement with infiltration. Conversely, rain barrels are especially good for residential use, but vegetated roofs are unlikely to be used on single-family homes. Successful LID programs strive to match the BMP with the land use and user type,

as listed on BMP fact sheets (applications) and detailed in each BMP discussion.

Cold Climate Considerations

Another important design consideration is how the BMP will function in our cold climate. The detailed design considerations in each BMP are written to address typical cold climate issues. In addition, cold climate is discussed throughout each BMP's various recommendations including a specific section dedicated to winter considerations.

In general, the techniques described in this manual can be used very effectively in cold climate settings such as Indiana (when the appropriate recommendations are followed). In addition, LID encourages stormwater management systems and treatment trains that can offer increased resiliency for cold climate issues.

Critical aspects of winter conditions are extremely cold temperatures, sustained cold periods, polluted snow-melt, and a short growing season (**Table 2**). Extreme cold can cause rapid freezing and burst pipes. Sustained cold can result in development of thick ice or

snowpack all winter, as well as material it picks up as it flows over the land's surface.

Chloride is the cause of many problems associated with snowmelt runoff. Chloride is a very soluble chemical that migrates easily through treatment systems and soil. Avoiding over-application of chloride, and routing runoff properly are effective ways to reduce damage to LID BMPs.

General considerations

Avoid pipe freezing by laying pipes and installing underground systems below the typical frost line. Pipe freezing for standpipes is not likely to be an issue, but conveyance pipes laid nearly horizontal should be below the freezing line. In Indiana, most communities plant at least a foot or two of groundcover over stormwater pipes to minimize the risk of pipe freezing. Over-excavation and filling with sand and gravel around stormwater pipes will also help with frost penetration and frost heave.

Research in the Saginaw River valley in Michigan has shown (for the winter of 1996-1997) that soils in cultivated areas with little to no snow cover froze to

Climactic Condition	BMP Design Challenge
Cold Temperatures	<ul style="list-style-type: none"> • Pipe Freezing • Permanent pool ice cover • Reduced biological activity • Reduced oxygen levels during ice cover • Reduced settling velocities
Deep Frost Line	<ul style="list-style-type: none"> • Frost heaving • Reduced soil infiltration • Pipe freezing
Short Growing Season	<ul style="list-style-type: none"> • Short time period to establish vegetation • Different plant species appropriate to cold climates than moderate climates
Significant Snowfall	<ul style="list-style-type: none"> • High runoff volumes during snowmelt and rain-on snow • High pollutant loads during spring melt • Other impacts of road salt/deicers • Snow management may affect BMP storage

Table 2 Cold Climate Design Challenges

frozen soil layers in some BMPs. On the other hand, the deeper and more persistent the snow layer, the less severe the soil freezing. Water quality problems associated with snow melt occur because of the large volume of water released during rain and snow events. This runoff carries material that has accumulated in the

depths of up to eight inches, while in areas with forest cover, leaf litter, and thin but persistent snow cover, frost depths only reached about an inch (Schaetzl and Tomczak, 2002). One conclusion that can be drawn from this is that plant material should be left in applicable stormwater BMPs to provide insulation through the winter. The ability of persistent snow cover

to act as insulation also suggests that some BMPs such as bioretention areas, infiltration basins, and vegetated swales can be used for snow storage (as long as it does not cause physical damage to the vegetation or other BMP components). However, large amounts of sand or salt should be kept out of vegetated and infiltration BMPs. Sand and salt can smother and/ or kill plants and reduce infiltration/storage capacity. Sand should also never be used on or adjacent to porous pavement systems (see detailed BMP section).

In addition, some BMPs, such as bioretention areas should be installed with a mulch layer that is two to three inches thick. For maximum insulation effectiveness, the mulch should be spread evenly and consistently throughout the BMP (for details on mulch see the individual BMP sections).

All biological activity is mediated by temperature. Cold winter temperatures significantly decrease nutrient uptake and pollutant conversion processes by plants and microbes; however, soil microbes still live and consume nutrients even in the dead of winter. Accumulation of chloride is generally not a problem in shallow biological systems, as long as very highly concentrated levels are not directly routed to them.

Winter Pollution Prevention Tips

- Choose proper de-icing materials
- Consider pre-wetting brine treatments to salt for better application
- Load salt trucks on covered, impervious pads
- Calibrate salting vehicles often
- Properly manage salt storage piles
- Identify and avoid salt-sensitive areas prior to plowing or salting

Infiltration considerations

As water cools its viscosity increases, reducing particle-settling velocities and infiltration rates into the soil. The problem with infiltration in cold weather is that ice that forms both over the tops of infiltration practices and in the soil pore spaces. To avoid these problems to the extent possible, the BMP must be actively managed to keep it dry before it freezes in the fall. This can be done by various methods including limiting inflow, under-drainage, and surface disking. Routing the first highly soluble portions of snowmelt to an infiltration BMP provides the opportunity for soil infiltration and treatment.

Infiltration practices are prohibited in proximity to public water supply wells as discussed in the Post-Construction Stormwater Quality Chapter, Section F, Step 5 of the Technical Standards.

Snow Storage Tip

Commercial and industrial areas that plow their parking and paved areas into big piles on top of pavement could greatly improve runoff management if instead, they dedicated a pervious area within their property for the snow. Even pushing the plowed snow up and over a curb onto a pervious grassed area will provide more treatment than allowing snow to melt on a paved surface and run into a storm sewer.

Detention considerations

For BMPs with a permanent pool, winter conditions can create ice layers and reduce biological activity, oxygen levels, and settling velocities. Ice layers can reduce the permanent pool volume, act as an impervious surface during rainfall, and potentially force incoming water under ice layers and scour bottom sediments. Ice layers can also reduce the oxygen exchange between the air-water interface. If low oxygen levels extend to the sediment-water interface, they can cause some adsorbed pollutants, such as phosphorus and some metals, to be released back into the water column. Reduced settling velocities will potentially result in lower pollutant removal rates.

Minimizing the effect of ice cover can help address these issues and can be accomplished by maintaining design storage volumes. Installing a control

mechanism, such as a valve, weir, or stop-log, can reduce or eliminate outflow for the normal water quality volume. This volume is then made available for meltwater, which can be held and slowly released.

It is important to recognize the potential for detention facilities to incur a buildup of pollutants (mostly chloride applied to impervious surfaces) throughout the winter. A balance needs to be considered in deciding whether to adjust the detention level to pass pollutant-laden runoff downstream or retain as much as possible for later release when flows are higher. Retaining polluted water all winter long only to discharge it all at once in the spring is not in the best interest of receiving waters; however, this is what can happen in a detention BMP that is not being managed for seasonal conditions. In no case should detention BMPs be drained in the spring after a winter-long accumulation of under-ice contaminants. If lowering is done, it should occur in late fall prior to freeze-up.

Chloride-laden runoff can be denser than water already in a basin, so it often pools at the bottom of the basin. Without some level of mixing in the basin, the pool can increase in chloride concentration over time. This is especially important to consider during dewatering, or if the pond will be used for irrigation and a pump is placed in the bottom of the pond. Altering pump placement or testing the bottom water before pumping are two methods to avoid discharge or use of salty water.

Overview of the Format of the Structural BMP Fact Sheets

As with the nonstructural chapter, each BMP starts with a summary sheet. This summary sheet provides a quick overview of the BMP. Following each summary sheet is detailed information on the BMP which includes:

Variations

Discusses the variations to the BMP, if they are applicable. Examples include alternatives in design that can increase storage capacity or infiltration rates.

Applications

Indicates in what type of land use the BMP is applicable or feasible.

BMP Family	BMP	Considerations
Runoff Volume Minimization	Natural area conservation	Preserving pervious areas for meltwater to infiltrate is effective to control volume
	Soil amendments	Enhancing soil permeability will increase infiltration of meltwater
	Reducing impervious surface	Preserving pervious areas for meltwater to infiltrate is effective to control volume and minimize pollutants
	Grass drainage channel	Routing meltwater over a pervious surface will yield some reduction in flow and improved water quality
	Rain barrel/cistern	Capturing meltwater from a building will reduce volume but ice build-up could be a problem unless collection occurs below frost line
	Permeable pavement	Recent research has shown this approach to be successful in cold climates when properly installed and maintained, and when sanding is kept to a minimum
	Dry well	Effective as long as system is installed below the frost line to avoid ice build-up
	Planter box	These are designed more for the growing season, but they do provide a sump area for runoff to collect and will infiltrate some volume
	Vegetated roof	Recent research shows that slow melting in the spring reduces the volume running off of roof surfaces
Bioretention	Rain gardens	By definition, these are growing-season practices, but they do provide a sump area for storage and some infiltration during a melt
Filtration	Constructed filter	Surface systems need to be fully dry before freeze-up for these to work properly; subgrade systems can be very effective for meltwater treatment
	Vegetated filter	Vegetative filtering is reduced once vegetation dies back in fall; some physical filtering will occur if vegetation density and depth are sufficient
Infiltration	Trench	Effective when designed, installed, and maintained properly; caution applies to limitations on source area to avoid high concentrations of chloride and toxics
	Basin	See above comment
Detention Facilities	Forebay	Effective if designed with enough available volume to accommodate spring meltwater
	Storage components	Adaptations must be made to allow meltwater runoff to achieve appropriate amount of treatment; treatment effectiveness usually lower in warm weather
	Outlet	Proper design of the outlet structure can be the key to ponding effectiveness
Constructed Wetlands	Forebay	See comment for forebay above
	Storage components	Volume will be less than typical pond, but provide location for storage, some infiltration, filtration, and some microbial activity; biological activity at a minimum

Table 3 Additional BMP considerations for cold climate use

Design Considerations

This section includes a list of technical procedures to be considered when designing for the individual BMP. This specific design criteria is presented, which can assist planners in incorporating conventional or LID techniques into a site design, as well as provide a basis for reviewers to evaluate submitted conventional or LID techniques.

Stormwater Calculations

Provides specific guidance on achieving sizing criteria, volume reduction, and peak rate mitigation, as applicable. This section also references the Post-Construction Stormwater Quality Management Chapter of the Technical Standards which discusses in detail how to achieve a specific standard or implement measures that contribute to managing water onsite in a more qualitative manner.

Construction Guidelines

Provides a typical construction sequence for implementing the BMP. However, it does not specifically address soil erosion and sedimentation control procedures. Erosion and sediment control methods need to adhere to the the Post-Construction Stormwater Quality Management Chapter of the Technical Standards construction BMP requirements contained in the Technical Standards document and the latest requirements of IDEM's Soil Erosion and Sedimentation Control (Rule 5) Program.

Maintenance

Provides guidance on recommended maintenance procedures for the BMP.

Winter Considerations

Discusses how well the BMP performs in Indiana's cold climate.

Cost

Provides general cost information for comparison purposes. If specific dates of costs are not referenced in this section, the costs reflect 2007 conditions.

Designer/Reviewer's Checklist

Developed to assist a designer and or reviewer in evaluating the critical components of a BMP that is being designed. It references not only individual design considerations, but also suggests review of additional pertinent sections of the Technical Standards that may need to be considered for implementation of that BMP.

References

Provides a list of sources of information utilized in the creation of this section of the manual. This list also provides sources that can be used for additional information.

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Credits and Acknowledgments

This introductory segment and the fact sheets that follow have been developed by Christopher B. Burke Engineering, LLC, and are primarily based upon similar segments contained in "Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers" published in 2009 by the Southeast Michigan Council of Governments (SEMCOG). A selection of material contained in the noted SEMCOG publication has been modified to reflect conditions in Indiana and used, with permission, for development of this introductory segment and the fact sheets that follow. The valuable contribution of SEMCOG through sharing of this material for use in this introductory segment and the fact sheets that follow are hereby acknowledged.

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BMP Fact Sheet

BIORETENTION (RAIN GARDENS)

Bioretention areas (often called rain gardens) are shallow surface depressions planted with specially selected native vegetation to capture and treat stormwater runoff from rooftops, streets, and parking lots.



Figure 1 Residential rain garden, Lenexa KS (USEPA, picasaweb)

Stormwater Quantity Functions			
Residential	Yes	Volume	Med/High
Commercial	Yes	Groundwater Recharge	Med/High
Ultra Urban	Limited	Peak Rate	Medium
Stormwater Quality Functions			
Industrial	Yes	TSS	High
Retrofit	Yes	TP	Medium
Highway/Road	Yes	TN	Medium
Recreational	Yes	Temperature	High

Additional Considerations	
Cost	Medium
Maintenance	Medium
Winter Performance	Medium

Variations

- Subsurface storage/infiltration bed
- Use of underdrain
- Use of impervious liner

Key Design Features

- Flexible in size and infiltration
- Ponding depths 6-18 inches for drawdown within 48 hours
- Native plants
- Amend soil as needed
- Provide positive overflow for extreme storm events

Site Factors

- Water table/bedrock separation: two-foot minimum, four foot recommended
- Soils: HSG A and B preferred; C & D may require an underdrain (see Infiltration BMP)
- Feasibility on steeper slopes
- Potential hotspots: Yes with pretreatment and/or impervious liner
- Maximum drainage area: 5:1, not more than 1 acre to one area

Benefits

- Volume control and groundwater recharge, moderate peak rate control, filtration
- Versatile with broad applicability
- Enhance site aesthetics, habitat
- Potential air quality and climate benefits

Limitations

- Higher maintenance until vegetation is established
- Limited impervious drainage area
- Requires careful selection and establishment of plants

Description and Function

Bioretention is a method of managing stormwater by pooling water within a planting area and allowing the water to infiltrate the garden. In addition to managing runoff volume and reducing peak discharge rates, this process filters suspended solids and related pollutants from stormwater runoff. Bioretention can be implemented in small, residential applications or as part of a management strategy in larger applications.

Bioretention is designed into a landscape as a typical garden feature, to improve water quality while reducing runoff quantity. Rain gardens can be integrated into a site with a high degree of flexibility and can integrate nicely with other structural management systems including porous pavement parking lots, infiltration trenches, and other non-structural stormwater BMPs.

Bioretention vegetation serves to filter (water quality) and transpire (water quantity) runoff, and enhance infiltration. Plants absorb pollutants while microbes associated with the plant roots and soil break them down. The soil medium filters out pollutants and allows storage and infiltration of stormwater runoff, providing volume control. In addition, engineered soil media may serve as a bonding surface for nutrients to enhance pollutant removal.

Properly designed bioretention techniques provide a layer of compost that acts like a sponge to absorb and hold runoff. Vegetation in the rain garden can be diverse, through the use of many plant species and types, resulting in a system tolerant to insects, diseases, pollution, and climatic stresses.

The term "rain garden" is used to refer to smaller-scale bioretention facilities typically found on residential properties

Bioretention can accomplish the following:

- Reduce runoff volume
- Filter pollutants, through both soil particles (which trap pollutants) and plant material (which take up pollutants)
- Provide habitat
- Recharge groundwater (if no underdrain is placed underneath)
- Reduce stormwater temperature impacts
- Enhance site aesthetics
- Higher maintenance until vegetation is established
- Limited impervious drainage area
- Requires careful selection and establishment of plants

Figure 2 illustrates a schematic of a relatively simple bioretention area (or rain garden). **Figure 3** illustrates a schematic of a bioretention area that is a more technically engineered structure, designed to complete specific stormwater management goals. Pond depth, soil mixture, infiltration bed, perforated underdrains, domed risers, and positive overflow structures may be designed according to the specific, required stormwater management functions.

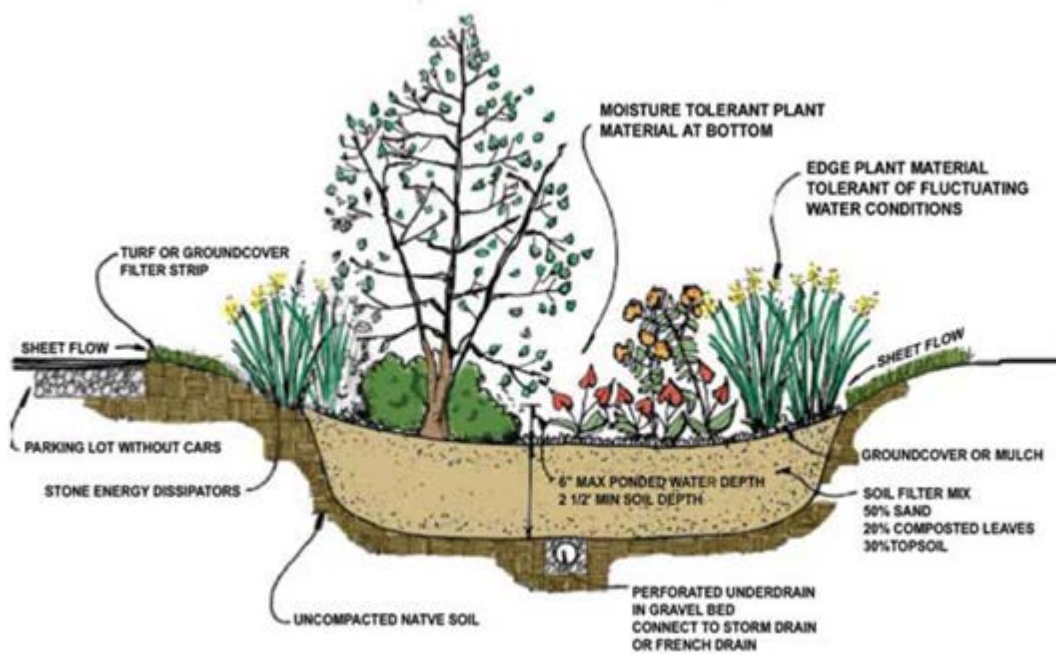


Figure 2 Schematic of a small residential rain garden

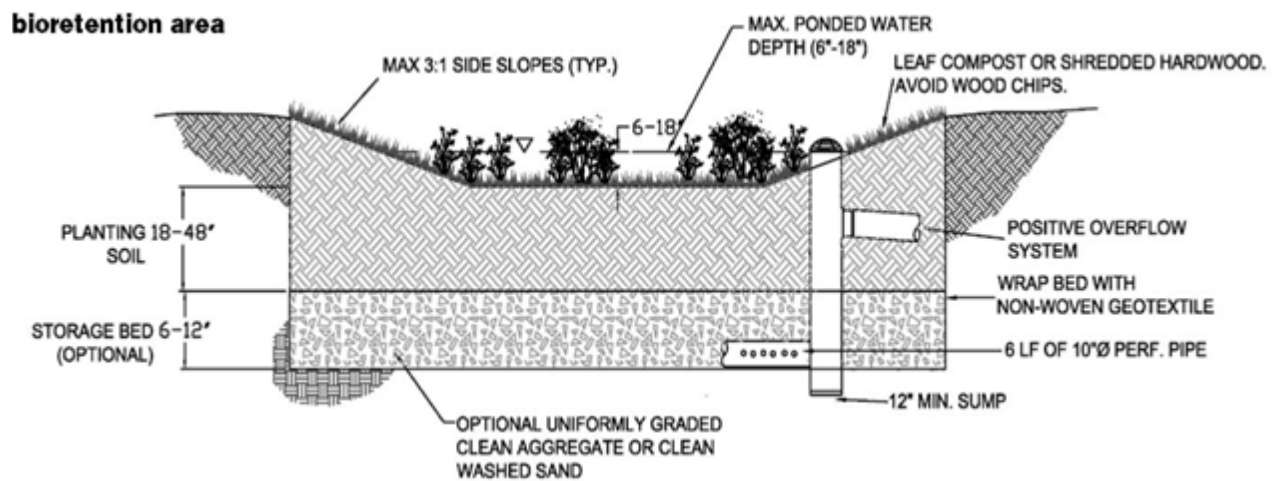


Figure 3 Schematic of a technically engineered bioretention area

Variations

A bioretention system is a depression in the ground planted like a garden that provides for the storage and infiltration of relatively small volumes of stormwater runoff, often managing stormwater on a lot-by-lot basis. This use of many small stormwater controls versus one large detention area promotes the low impact development goal of decentralized treatment of stormwater. But, if greater volumes of runoff must be managed or stored, a bioretention system can be designed with an expanded subsurface infiltration bed, or can be increased in size. Typically, the ratio of impervious area draining to the bioretention area should not exceed five-to-one, and the total impervious area draining to a single system should not be more than one acre. Variations noted relate to performance types, flow entrance, and positive overflow.

Performance types

Depending on varying site conditions, bioretention can be designed to allow for 1) complete infiltration, 2) infiltration/filtration, or 3) filtration. These variations will often determine the need for such design features as the gravel bed, double-walled underdrains, and impervious liners.

Bioretention using complete infiltration occurs in areas where groundwater recharge is beneficial and the soils have the permeability necessary to accommodate the inflow. This type of BMP is often less expensive to construct because there is no underdrain and the soils on site are often used.

The most common variation to this type of bioretention includes a gravel or sand bed underneath the planting bed and often accompanied by the use of a double-walled underdrain. This allows for additional storage or for areas with low permeability to use bioretention as infiltration, as well as, filtration (Figure 3). Some volume reduction will occur through infiltration, as well as evaporation and transpiration.

Another variation is to use bioretention primarily for filtration. This is often used in contaminated soils or hot spot locations using an impervious liner to prevent infiltration and groundwater

contamination. The primary stormwater function then becomes filtration with some volume reduction through evaporation and transpiration.

For areas with low permeability, bioretention may achieve some infiltration while acting as detention with peak rate control for all storms up to the design storm.

Flow inlet

Pretreatment of runoff should be provided where sediment or pollutants entering the rain garden may cause concern or decreased BMP functionality. Soil erosion control mats, blankets, or rock must be used where runoff flows from impervious areas enter the rain garden.

Flow inlet: Trench drain

Trench drains can accept runoff from impervious surfaces and convey it to a rain garden. The trench drain may discharge to the surface of the rain garden or may connect directly to an aggregate infiltration bed beneath.

Educational Signage

Once a bioretention area is established, installing signage will help the general public and maintenance crews recognize LID practices, which can help promote sustainable stormwater management. Educational signs can incorporate LID goals and maintenance objectives, in addition to the type of LID project being employed.

Flow inlet: Curbs and curb cuts

Curbs can be used to direct runoff from an impervious surface along a gutter to a low point where it flows into the rain garden through a curb cut. Curb cuts may be depressed curbs, or may be full height curbs with openings cast or cut into them.

Positive overflow

A positive overflow, via the surface or subsurface, is recommended to safely convey excessive runoff from extreme storm events.

Positive overflow: Domed riser

A domed riser may be installed to ensure positive, controlled overflow from the system. Once water ponds to a specified depth, it will begin to flow into the riser through a grate, which is typically domed to prevent clogging by debris.

Positive overflow: Inlet structure

An inlet structure may also be installed to ensure positive, controlled overflow from the system. Once water ponds to a specified depth, it will begin to flow into the inlet.

Applications

Bioretention areas can be used in a variety of applications, from small areas in residential lawns to extensive systems in commercial parking lots (incorporated into parking islands or perimeter areas). Industrial, retrofit, highway/road, and recreational areas can also readily incorporate bioretention. One key constraint in using bioretention in ultra-urban settings is space.

Residential

The residential property owner that wants to design and build a rain garden at home does not need to go through the engineering calculations listed under stormwater calculations and functions. Assistance with simple rain gardens is available from several sources listed under the Plant Selection portion of this BMP. **Figure 4** shows a typical rain garden configuration on a residential property.

Another source of water for a small rain garden is connecting the roof leader from adjacent buildings. The stormwater may discharge to the surface of the bioretention area or may connect directly to an aggregate infiltration bed beneath.

Tree and shrub pits

Tree and shrub pits intercept runoff and provide shallow ponding in mulched areas around the tree or shrub (**Figure 5**). Mulched areas should typically extend to the tree's drip line. Plant material should be selected based on tolerance to standing water as identified in Recommended Plant List for BMPs Appendix.

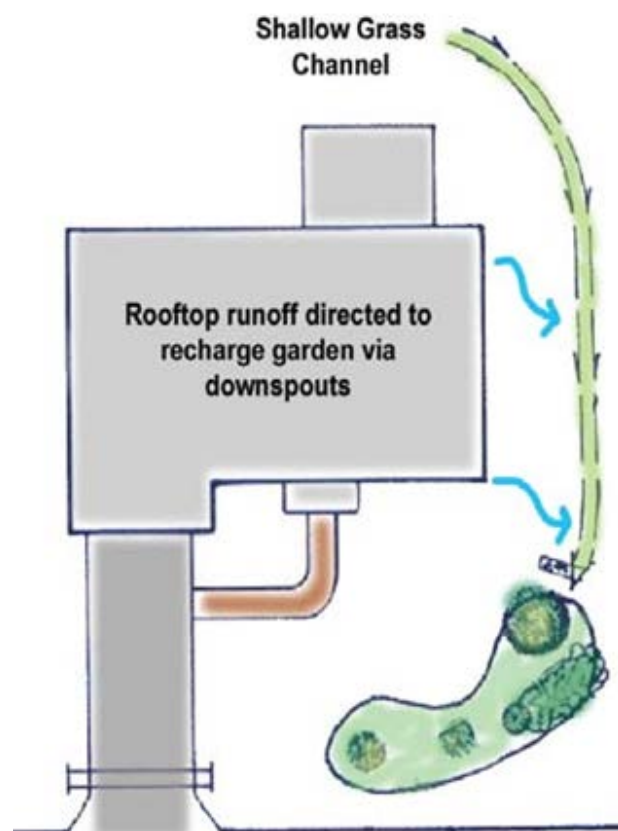


Figure 4 Single-family residential lot drainage schematic
Source: Claytor and Schueler, 1995 with modifications by Cahill

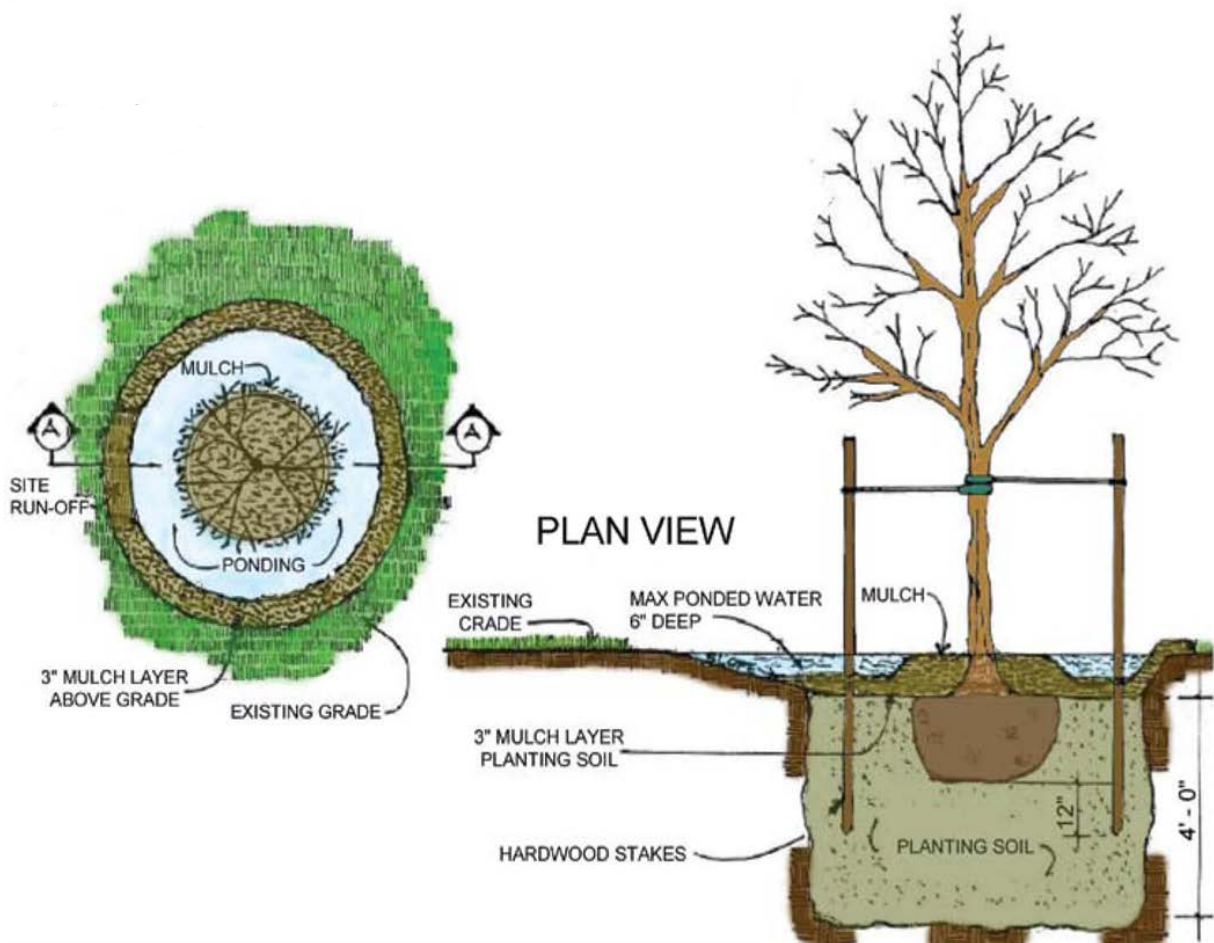


Figure 5 Tree planting detail

Roads and highways

Linear bioretention area feature may be used along a highway. Runoff is conveyed along the concrete curb until it reaches the end of the gutter, where it spills into the vegetated area.

Parking lot island bioretention

In parking lots for commercial, industrial, institutional, and other uses, stormwater management and green space areas are limited. In these situations, bioretention areas for stormwater management and landscaping may provide multiple benefits.

A bioretention area in a parking lot can occur in parking lots with no curbs and with curbs. The no-curb alternative allows stormwater to sheet flow over the parking lot directly into the bioretention area.

In a curbed parking lot, runoff enters the bioretention area through a curb cut. If the runoff volume exceeds the ponding depth available, water overflows the bioretention area and enters a standard inlet.

A variation on this design is a direct underground connection to the standard inlet from the underground aggregate infiltration bed via an overflow pipe.

Primary Components of a Bioretention System

1. Pretreatment (may be necessary to help prevent clogging)
 - Sediment removal through a vegetated buffer strip, cleanout, stabilized inlet, water quality inlet, or sediment trap prior to runoff entry into the bioretention area
2. Flow inlet
 - Varies with site use (e.g., parking island versus residential lot applications)
 - Entering velocities must be non-erosive – use erosion control mats, blankets, or rock where concentrated runoff enters the bioretention area
3. Ponding area
 - Provides temporary surface storage of runoff and allows sediment to settle
 - Provides evaporation for a portion of runoff
 - Depth no more than 6-18 inches for aesthetics, functionality, and safety
4. Plant material (see the Recommended Plant Lists Appendix)
 - Absorbs stormwater through transpiration
 - Root development creates pathways for infiltration
 - Bacteria community resides in the root system creating healthy soil structure with water quality benefits
 - Can improve aesthetics for site
 - Provides habitat for animals and insects
 - Reinforces long-term performance of subsurface infiltration
 - Ensures plants are salt tolerant if in a location that would receive snowmelt chemicals
 - Should be native plant species and placed according to drought and water tolerance
 - Should be selected based on tolerance to standing water as identified in Recommended Plant List for BMPs Appendix
5. Organic layer or mulch
 - Acts as a filter for pollutants in runoff
 - Protects underlying soil from drying and eroding. Simulates leaf litter by providing environment for microorganisms to degrade organic material
 - Provides a medium for biological growth, decomposition of organic material, adsorption and bonding of heavy metals
 - Wood mulch should be shredded – compost or leaf mulch is preferred
6. Planting soil/volume storage bed
 - Provides water/nutrients to plants
 - Enhances biological activity and encourages root growth
 - Provides storage of stormwater by the voids within the soil particles
 - Provides surface for adsorption of nutrients
7. Positive overflow
 - Provides for the direct discharge of runoff during large storm events when the subsurface/surface storage capacity is exceeded
 - Examples of outlet controls include domed risers, inlet structures, and weirs

Design Considerations

Bioretention is flexible in design and can vary in complexity according to site conditions and runoff volume requirements. Design and installation procedures may vary from very simple for “backyard” rain gardens to highly engineered bioretention areas in ultra-urban areas.

Infiltration BMPs should be sited so that they minimize risk to groundwater quality and present no threat to subsurface structures. **Table 1** provides recommended setback distances of bioretention areas to various lot elements.

The distance from the bottom of the infiltration

Setback from	Minimum distance (feet)
Property line	10
Building foundation*	10
Private well	50
Public water supply well**	50
Septic system drainfield***	100
* minimum with slopes directed away from building ** At least 200 feet from Type I or IIa wells, 75 feet from Type IIb and III wells *** 50 feet for septic systems with a design flow of less than 1,000 gallons per day	

Table 1 Recommended Setback Distances

BMP to the seasonal high groundwater level or bedrock is recommended to be four feet. Two feet is allowable, but may reduce the performance of the BMP.

Bioretention is best suited for areas with at least moderate infiltration rates (more than 0.25 inches per hour) – see Infiltration BMP. In extreme situations where permeability is less than 0.25 inches per hour, special variations may apply, such as using amended subsoils or double-walled underdrains (or using constructed wetlands instead). The following procedures should be considered when designing bioretention areas:

1. The **flow entrance** must be designed to prevent erosion in the bioretention area. Some alternatives include flared end sections, erosion control mats, sheet flow into the facility over grassed areas, rock at entrance to

bioretention area, curb cuts with grading for sheet flow, and roof leaders with direct surface connection.

2. A **positive overflow system** should be designed to safely convey away excess runoff. The overflow can be routed to the surface in a non-erosive manner or to another stormwater system. Some alternatives include domed risers, inlet structures, weirs, and berms.
3. Sizing criteria
 - a. **Surface area** is dependent upon storage volume requirements, but should generally not exceed a maximum loading ratio of 5:1 impervious drainage area to bioretention area and no more than one acre drainage area to one bioretention cell. However, for design purposes, the total volume of water generated from the contributing drainage area must be used, not just the impervious portion. See Infiltration BMP for additional guidance on loading ratios.

The required bioretention surface area is determined by taking the volume of runoff to be controlled according to LID criteria, and maintaining the maximum ponding depth, loading rate, and emptying time. Infiltration and evapotranspiration are increased by increasing the surface area of the bioretention area. The total surface area needed may be divided into multiple cells. This configuration may be useful to collect runoff from both the front and back of a building.

- b. Surface side slopes should be gradual. For most areas, a maximum of 3:1 side slopes are recommended.
- c. The recommended surface ponding depth is six inches. Up to 18 inches may be used if plant selection is adjusted to tolerate water depth. Drain within 24-48 hours.
- d. **Ponding area** should provide sufficient surface area to meet required storage volume without exceeding the design ponding depth. The subsurface infiltration

bed is used to supplement surface storage where appropriate.

4. **Planting soil depth** should generally be between 18 and 48 inches where only herbaceous plant species will be used. 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 to be suitable on many sites. Small, backyard rain gardens can generally use existing soils without a specialized depth. Planting soil should be approximately four inches deeper than the bottom of the largest root ball.
5. **Planting soil** should be capable of supporting a healthy vegetative cover. Soils should be amended with a composted organic material. A recommended range of a soil mixture is 20-40 percent organic material (compost), 30-50 percent sand, and 20-30 percent topsoil, although any soil with sufficient drainage may be used for bioretention.

Soils should also have a pH of between 5.5 and 6.5 (better pollutant adsorption and microbial activity), a clay content less than 10 percent (a small amount of clay is beneficial to adsorb pollutants and retain water although no clay is necessary if pollutant loadings are not an issue), be free of toxic substances and unwanted plant material, and have a 5-10 percent organic matter content. Additional organic matter can be added to the soil to increase water holding capacity.

If brought from off site, **sand** should be clean, coarse, and conform to ASTM C-33 or AASHTO M-6 (Standard Specification for Concrete Aggregates).

If the void space within an amended soil mix will be used in calculating runoff volume capacity in the system, tests should be conducted on the soil's porosity to determine the available storage capacity.

6. 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 area. Suggested species may include Cardinal Flower (*Lobelia cardinalis*), Blue Lobelia (*Lobelia siphilitica*), New England Aster (*Aster novae-angliae*), and Brown Fox Sedge (*Carex vulpinoidea*) (See Recommended Plant Lists Appendix for a detailed list).

In most cases, seed is not the preferred method for establishing plants in a bioretention area. The fluctuating water levels make it difficult for the seed to readily establish, while the random nature of seeding produces a look which previous experience indicates is unacceptably "wild." Therefore, it is strongly recommended that live plant material in plug or gallon-potted form be used, and installed on 1-2 foot centers for a more formal appearance. Shrubs and trees are also recommended to be included in a bioretention area. Plant material should be selected based on tolerance to standing water as identified in Recommended Plant List for BMPs Appendix.

7. **Planting periods** will vary but, in general, trees and shrubs should be planted from mid-April through early June, or mid-September through mid-November. Native seed should be installed between October 1 and June 1. Live plant material (plugs or gallon pots) should be installed between May 1 and June 15. Planting dates may be lengthened if a regular water source can be provided. Likewise, planting should be ceased at an earlier date in the event of a drought year.
8. A maximum of 2-3 inches of shredded hardwood **mulch**, aged at least six months to one year, or leaf compost (or other comparable product) should be uniformly applied immediately after shrubs and trees are planted to prevent erosion, enhance metal removals, and simulate leaf litter in a natural forest system. Wood chips should be avoided as they tend to float during inundation periods. In order to maintain oxygen flow, mulch or compost should not exceed three

inches in depth or be placed directly against the stems or trunks of plants.

9. When working in areas with **steeper slopes**, bioretention areas should be terraced laterally along slope contours to minimize earthwork and provide level areas for infiltration.
10. A subsurface **storage/infiltration bed**, if used, should be at least six inches deep and constructed of clean gravel with a significant void space for runoff storage (typically 40 percent) and wrapped in geotextile fabric.
11. **Underdrains** are often not needed unless in-situ soils are expected to cause ponding lasting longer than 48 hours. If used, underdrains are typically small diameter (6-12 inches) perforated pipes in a clean gravel trench wrapped in geotextile fabric (or in the storage/infiltration bed). Underdrains should have a flow capacity greater than the total planting soil infiltration rate and should have at least 18 inches of soil/gravel cover. They can daylight to the surface or connect to another stormwater system. A method to inspect and clean underdrains should be provided (via cleanouts, inlet, overflow structure, etc.)

Stormwater Functions and Calculations

When designing a bioretention area, it is recommended to follow a two-step process:

1. Initial sizing of the bioretention area based on the principles of Darcy's Law.
2. Verify that the loading ratio and the necessary volume reductions are being met.

Initial sizing of the bioretention area
Bioretention areas can be sized based on the principles of Darcy's Law, as follows:

With an underdrain:

$$A_f = V * d_f / [k * (h_f + d_f) * t_f]$$

Without an underdrain:

$$A_f = V * d_f / [i * (h_f + d_f) * t_f]$$

Where:

A_f = surface area of filter bed (ft²)

V = required storage volume (ft³)

d_f = filter bed depth (ft)

k = coefficient of permeability of filter media (ft/day)

i = infiltration rate of underlying soils (ft/day)

h_f = average height of water above filter bed (ft)

t_f = design filter bed drain time (days)

A "quick check" for sizing the bioretention area is to ignore the infiltration rate and calculate the storage volume capacity of the bioretention area as follows:

A_{inf} = (Area of bioretention area at ponding depth + Bottom area of bioretention area) divided by two = Infiltration area (average area)

The size of the infiltration area is determined by the volume of water necessary to remove as determined by LID criteria, depth of the ponded area (not to exceed 18 inches), infiltration rate of the soil, loading ratio, and, if applicable, any subsurface storage in the amended soil or gravel.

This volume can be considered removed if the bioretention is not underdrained. If the bioretention cell is underdrained, consider the bioretention cell as a detention device with the volume calculated above discharged to a surface water over time t_f .

Verification of meeting volume reduction requirements

The bioretention facility should be sized to accommodate the desired volume reductions towards the required Channel Protection Volume or the required Water Quality Volume, as appropriate (see the Post-Construction Stormwater Quality Management Chapter of the Technical Standards).

The volume of a bioretention area can have three components: surface storage volume, soil storage volume, and infiltration bed volume. These three components should be calculated separately and added together. The goal is that this total volume is larger than the required Channel Protection Volume or the Water Quality Volume, as appropriate. If the total volume is less than the required volume,

another adjustment may be needed to the bioretention area (e.g., increased filter bed depth).

Total volume calculation:

1. Surface storage volume (ft³) = Average bed area (ft²) * Maximum design water depth (ft)
2. Soil storage volume (ft³) = Infiltration area (ft²) * Depth of amended soil (ft) * Void ratio of amended soil.
3. Subsurface storage/Infiltration bed volume (ft³) = Infiltration area (ft²) * Depth of underdrain material (ft) * Void ratio of storage material

Total bioretention volume = Surface storage volume + Soil storage volume (if applicable) + Infiltration bed volume (if applicable).

Peak rate mitigation

The discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards provides information on methodology to account for the provided distributed storage for the purpose of calculating the required detention pond size for peak rate control. If an underdrain is required, the bioretention also acts as a detention practice with a discharge rate roughly equal to the infiltration rate of the soil multiplied by the average bed area. The discharge rate should be counted towards the site's allowable release rate (if not leading to the site's detention pond) or as inflow to the site's detention pond (if an underdrain would eventually empty into the site's detention pond).

Water Quality Improvement

The reported water quality benefits of bioretention can be expected to remove a high amount of total suspended solids (typically 70-90 percent), a medium amount of total phosphorus (approximately 60 percent), and a medium amount of total nitrogen (often 40-50 percent). In areas with high sediment loading, pretreatment of runoff can significantly reduce the amount of bioretention maintenance required (See discussion in the Post-Construction Stormwater Quality Management Chapter of the Technical Standards for water quality calculation procedures).

Construction Guidelines

The following is a typical construction sequence (Note for all construction steps: Erosion and sediment control methods need to adhere to the construction BMP requirements contained in the Technical Standards document and the latest requirements of IDEM's Soil Erosion and Sedimentation Control (Rule 5) Program).

1. Complete site grading, minimizing compaction as much as possible. If applicable, construct curb cuts or other inflow entrance, but provide protection so that drainage is prohibited from entering the bioretention construction area. Construct pre-treatment devices (filter strips, swales, etc.) if applicable.
2. Subgrade preparation
 - a. Existing subgrade in rain gardens should not be compacted or subject to excessive construction equipment traffic. Loads on the subgrade should not exceed four pounds per square inch.
 - b. Initial excavation can be performed during rough site grading, but should not be carried to within one foot of the final bottom elevation. Final excavation should not take place until all disturbed areas in the drainage area have been stabilized.
 - c. Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding in the graded bottom, this material should be removed with light equipment and the underlying soils scarified to a minimum depth of six inches with a york rake or equivalent by light tractor.
 - d. Bring subgrade of bioretention area to line, grade, and elevations indicated. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction. All bioretention areas should be level grade on the bottom.
3. Stabilize grading except within the bioretention area. Bioretention areas may be used as temporary sediment traps, provided the proposed finish elevation of the bed is at

least 12 inches lower than the bottom elevation of the sediment trap (if used as such, all accumulated material and at least 12 inches of soil should be removed).

4. Excavate bioretention area to proposed invert depth and scarify the existing soil surfaces. Do not compact soils.
5. Backfill bioretention area with amended soil as shown on plans and specifications. Overfilling is recommended to account for settling. Light hand tamping is acceptable if necessary.
6. Complete final grading to achieve proposed design elevations, leaving space for upper layer of compost, mulch, or topsoil as specified on plans.
7. Bioretention area/rain garden installation
 - a. Upon completing subgrade work, notify the engineer to inspect at his/her discretion before proceeding with bioretention installation.
 - b. For the subsurface storage/infiltration bed installation, amended soils should be placed on the bottom to the specified depth.
 - c. Planting soil should be placed immediately after approval of subgrade preparation/bed installation. Any accumulation of debris or sediment that takes place after approval of subgrade should be removed prior to installation of planting soil at no extra cost to the owner.
 - d. If called for in the design, install approved planting soil in 18-inch maximum lifts and lightly compact (tamp with backhoe bucket or by hand). Keep equipment movement over planting soil to a minimum – **do not over-compact**. Install planting soil to grades indicated on the drawings. Loads on the soil should not exceed four pounds per square inch.
 - e. Presoak the planting soil at least 24 hours prior to planting vegetation to aid in settlement.
 - f. Plant trees and shrubs according to supplier's recommendations and only from

mid-March through the end of June or from mid-September through mid-November.

- g. Install two or three inches of shredded hardwood mulch (minimum age six months) or compost mulch evenly as shown on plans. Do not apply mulch in areas where ground cover is to be grass or where cover will be established by seeding.
 - h. Protect rain gardens from sediment at all times during construction. Compost socks, diversion berms, and/or other appropriate measures should be used at the toe of slopes that are adjacent to rain gardens to prevent sediment from washing into these areas during site development.
 - i. When the site is fully vegetated and the soil mantle stabilized, notify the plan designer to inspect the rain garden drainage area at his/her discretion before the area is brought online and sediment control devices removed.
8. Mulch and install erosion protection at surface flow entrances where necessary.

Maintenance

Properly designed and installed bioretention areas require some regular maintenance, most within the first year or two of establishment. Less maintenance is required when the native perennial vegetation becomes established.

1. Water vegetation at the end of each day for two weeks after planting is completed. Newly established plants should continue to receive approximately one inch of water per week throughout the first season, or as determined by the landscape architect.
2. While vegetation is being established, pruning and weeding may be required. Weeds should be removed by hand.
3. Organic material may also need to be removed approximately twice per year (typically by hand).
4. Perennial plantings may be cut down at the end of the growing season to enhance root establishment.

5. Mulch should be re-spread when erosion is evident and replenished once every one to two years or until the plants begin to fill in the area and the space between plants is minimized.
6. Bioretention area should be inspected at least two times per year for sediment buildup, erosion, and to evaluate the health of the vegetation. If sediment buildup reaches 25 percent of the ponding depth, it should be removed. If erosion is noticed within the bioretention area, additional soil stabilization measures should be applied. If vegetation appears to be in poor health with no obvious cause, a landscape specialist should be consulted.
7. Bioretention vegetation may require watering, especially during the first year of planting. Ensure the maintenance plan includes a watering schedule for the first year, and in times of extreme drought after plants have been established.
8. Bioretention areas should not be mowed on a regular basis. Trim vegetation as necessary to maintain healthy plant growth.

Planting Tip

When planting your bioretention area, it is usually helpful to mark the different planting areas. An effective method is using spray paint and flags to mark designated areas. This is especially helpful when utilizing volunteers.

Winter Considerations

Use salt-tolerant vegetation where significant snow-melt containing deicing chemicals is expected. The use of sand, cinders, and other winter abrasives should be minimized. If abrasives are used, additional maintenance may be required to remove them in the spring. Bioretention soils can be expected to resist freezing and remain functioning for most of the year (although biological pollutant

removal processes will be reduced during winter). Bioretention areas can even be used for snow storage assuming this will not harm the vegetation. Pipes, inlets, overflow devices, and other stormwater structures associated with bioretention should be designed according to general guidance on cold climate construction.

Cost

Bioretention areas often replace areas that were intensively landscaped and require high maintenance. In addition, bioretention areas can decrease the cost for stormwater conveyance systems on a site. Bioretention areas cost approximately \$5-7 per cubic foot of storage to construct.

Designer/Reviewer Checklist for Rain Gardens/Bioretention

Item	Page No.	Yes	No	N/A	Notes
Was Soil infiltration Testing Protocol Appendix followed?*					
Appropriate areas of the site evaluated?	--				
Infiltration rates measured? <i>Moderate infiltration rates: > 0.25 inches/hour. If < 0.25 inches/hour, special variations may apply – such as using amended subsoils or underdrains.</i>	8				
Were the bioretention design guidelines followed?					
Minimum 2-foot separation between the bed bottom and bedrock/ SHWT?	8				
Soil permeability acceptable?	8				
If not, appropriate underdrain provided? <i>6-12 inches in diameter; perforated pipes</i>	10				
Natural, uncompacted soils?	11				
Level infiltration area (bed bottom)?	11				
Excavation in rain garden areas minimized?	--				
Hotspots/pretreatment considered?	1				
➤ Loading ratio below 5:1 (described in infiltration BMP)?	8				
Ponding depth limited to 18 inches?	1,7,8				
Drawdown time less than 48 hours?	1				
Positive overflow from system?	7,8				
Erosion and Sedimentation control?	12				
Feasible construction process and sequence?	11,12				
Entering flow velocities non-erosive or erosion control devices?	7,8				
Acceptable planting soil specified? ➤ 20-40% organic material (compost), 30-50% sand, 20-30% topsoil)	9				
➤ Appropriate native plants selected?	9				
Maintenance accounted for and plan provided? Review of treatment volume? Review of calculations?	10-13				

* In general, the protocol should be followed as much as possible.

➤ Denotes Minimum Design Considerations

References

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BMP Fact Sheet

CAPTURE REUSE

Structures designed to intercept and store runoff from rooftops allow for its reuse, reducing volume and overall water quality impairment. Stormwater is contained in the structures and typically reused for irrigation or other water needs.



Figure 1 Above ground cistern, Chicago, IL (USEPA, picasaweb)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	High
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	Yes	Peak Rate	Low*
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Yes	TSS	Med
Highway/Road	No	TP	Med
Recreational	Yes	NO ₃	Med
		Temperature	Med

* Depends on site design

Additional Considerations	
Cost	
• Rain Barrel	Low
• Cistern	Med
• Manufactured product	Varies
Maintenance	Med
Winter Performance	Med

Variations

- Rain barrels
- Cisterns, both underground and above ground
- Tanks
- Storage beneath a surface (using manufactured products)

Key Design Features

- Small storm events are captured with most structures
- Provide overflow for large storm events
- Discharge water before next storm event
- Consider site topography, placing structure up-gradient in order to eliminate pumping needs

Site Factors

- Water table to bedrock depth: N/A (although must be considered for subsurface systems)
- Soils: N/A
- Slope: N/A
- Potential hotspots: Yes, with treatment
- Maximum drainage area: N/A

Benefits

- Provides supplemental water supply
- Wide applicability
- Reduces potable water use
- Related cost savings and environmental benefits

Limitations

- Manages only relatively small storm events which requires additional management and use for the stored water

Description and Function

Capture reuse is the practice of collecting rainwater in a container and reusing it in the future. Other terms for this BMP include *storage/reuse*, *rainwater harvesting*, and *rainwater catchment system*.

This structural BMP reduces potable water needs while simultaneously reducing stormwater discharges. When rain barrels or cisterns are full, rooftop runoff should be directed to drywells, planters, or bioretention areas where it will be infiltrated.

Variations

Rain Barrels

Commonly, rooftop downspouts are connected to a rain barrel 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 areas. Other uses include commercial and institutional facilities where the capacity of stormwater can be captured in smaller volume rain barrels.

Cisterns

A cistern is a container or tank that has a greater storage capacity than a rain barrel. Typically, cisterns are used to supplement greywater needs (i.e., toilet flushing, or some other sanitary sewer use), though they can also be used for irrigation. Cisterns may be comprised of fiberglass, concrete, plastic, brick, or other materials and can be located either above or below ground. The storage capacity of cisterns can range from 200 gallons to 10,000 gallons. Very large cisterns, essentially constructed like an underground parking level, can also be used. **Figure 2** highlights the typical components of a cistern.

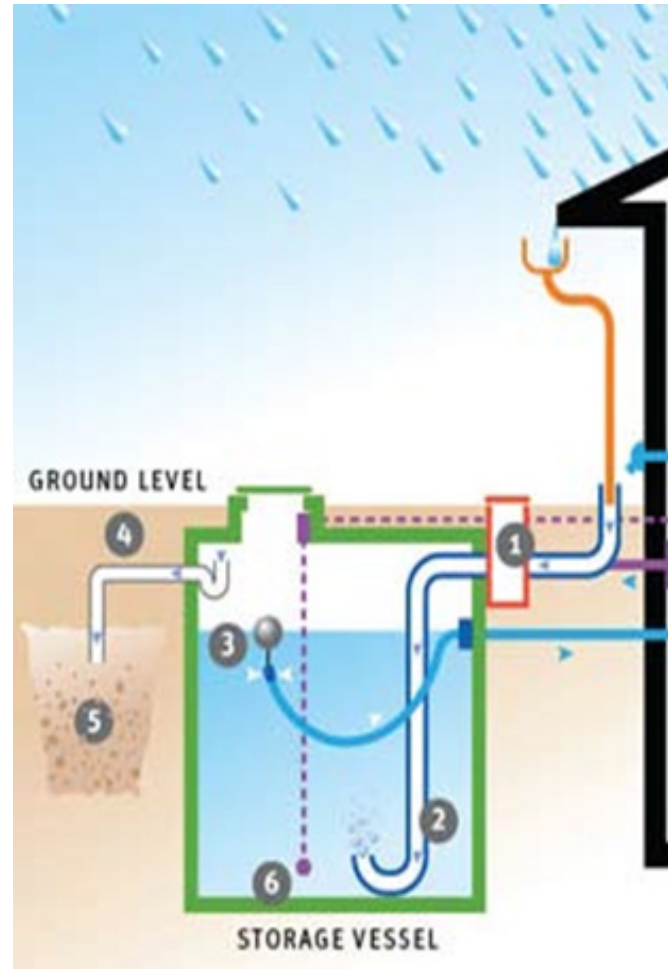


Figure 2 Typical cistern components

Source: This image generously provided by www.rainkeeper.us

Figure Description:

1. Filter/screening mechanism to filter runoff
2. Inflow into cistern
3. Intake for water use
4. Cistern overflow
5. Subsequent stormwater system (infiltration system in this case) for cistern overflow
6. Optional level gauge

Vertical storage

A vertical storage container is a structure designed to hold a large volume of stormwater drained from a large impervious area and is the largest of the capture reuse containers. The use of these structures is a function of drainage area and water needs. Vertical structures are best used for intensive irrigation needs or even fire suppression requirements, and should be designed by a licensed professional. These storage systems can be integrated into commercial sites where water needs may be high.

Storage beneath structure

Stormwater runoff can be stored below ground under pavement and landscaped surfaces through the use of structural plastic storage units and can supplement onsite irrigation needs. These structures can provide large storage volumes without the need for additional structural support from the building.

Designing a capture reuse system in which the storage unit is underground is best used in institutional or commercial settings. This type of subsurface storage is larger, more elaborate, typically designed by a licensed professional, and requires pumps to connect to the irrigation system.

Applications

Capture reuse containers can be used in urbanized areas where the need for supplemental onsite irrigation or other high water use exists. Areas that would benefit from using a capture reuse container include:

- Parking garage,
- Office building,
- Residential home or building, and
- Other building use (commercial, light industrial, institutional, etc.).

Design Considerations

Design and installation procedures for capture reuse containers can vary from simple residential rain barrels to highly engineered

underground systems in ultra-urban areas. **Table 1** provides general information on cistern holding capacity. The following procedures should be considered when designing sites with capture reuse containers.

Height (feet)	6-foot Diameter	12-foot Diameter	18-foot Diameter
6	1,269	5,076	11,421
8	1,692	6,768	15,227
10	2,115	8,460	19,034
12	2,538	10,152	22,841
14	2,961	11,844	26,648
16	3,384	13,535	30,455
18	3,807	15,227	34,262
20	4,230	16,919	38,069

Table 1 Round Cistern Capacity (Gallons)

Source: The Texas Manual on Rainwater Harvesting

1. Identify opportunities where water can be reused for irrigation or indoor greywater reuse and then calculate the water need for the intended uses. For example, if a 2,000 square foot landscaped area requires irrigation for four months in the summer at a rate of one inch per week, the designer must determine how much water will be needed to achieve this goal (1,250 gallons per week, approximately 22,000 gallons for the season), and how often the storage unit will be refilled with precipitation. The usage requirements and the expected rainfall volume and frequency must be determined.
2. Rain barrels and cisterns should be positioned to receive rooftop runoff.
3. If cisterns are used to supplement greywater needs, a parallel conveyance system must be installed to separate greywater from other potable water piping systems. Do not connect to domestic or commercial potable water system.
4. Consider household water demands (**Table 2**) when sizing a system to supplement residential greywater use.

Fixture	Use	Flow Rate
Toilet	# flushes per person per day	1.6 gallons per flush (new toilet)
Shower	# minutes per person per day (5 minutes suggested max.)	2.75 gallons per minute (restricted flow head)
Bath	# baths per person per day	50 gallons per bath (average)
Faucets	Bathroom and kitchen sinks	10 gallons per day
Washing Machine	# loads per day	50 gallons per load (average)
Dishwasher	# loads per day	9.5 gallons per load

Table 2 Household Water Demand Chart
Source: Philadelphia Stormwater Manual

5. Discharge points and storage units should be clearly marked "Caution: Untreated Rainwater, Do Not Drink."
6. Screens should be used to filter debris from runoff flowing into the storage units. Screens should be made of a durable, non-corrodible material and be easily maintainable.
7. Protect storage elements from direct sunlight by positioning and landscaping. Limit light into devices to minimize algae growth.
8. The proximity to building foundations should be considered for overflow conditions. The minimum setback distance for capture and reuse systems is 10 feet.
9. If the capture and reuse system or any elements of the system are exposed to freezing temperatures, then it should be emptied during the winter months to prevent ice damage.
10. Cisterns should be watertight (joints sealed with nontoxic waterproof material) with a smooth interior surface.
11. Covers and lids should have a tight fit to keep out surface water, insects (mosquitoes), animals, dust, and light.

12. Release stored water between storm events for the necessary storage volume to be available.
13. Positive outlet for overflow should be provided a few inches from the top of the cistern and sized to safely discharge the appropriate design storms when the cistern is full.
14. 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.
15. Observation risers should be at least six inches above grade for buried cisterns.
16. Reuse may require pressurization. Water stored has a pressure of 0.43 psi per foot of water elevation. A 10-foot tank when full would have a pressure of 4.3 psi (0.43*10). Most irrigation systems require at least 15 psi. To add pressure, a pump, pressure tank, and fine mesh filter can be used. While this adds to the cost of the system, it makes the system more versatile and therefore practical.
17. Capture/reuse can also be achieved using a subsurface storage reservoir which provides temporary storage of stormwater runoff for reuse. The stormwater storage reservoir may consist of clean uniformly graded aggregate and a waterproof liner or pre-manufactured structural stormwater storage units.

Stormwater Functions and Calculations

Volume reduction

In order to keep storage costs to a minimum, it makes sense to size the storage tank so that it does not greatly exceed the water need. Where this is done, especially where a high-volume demand greatly exceeds runoff (e.g., irrigation or industrial makeup water), runoff volume

reduction for a particular storm can be assumed to equal the total volume of storage.

Where the captured water is the sole source for a particular operation (e.g., flushing toilets), the user does not want the stored water to be depleted before the next runoff event that replenishes it. In that case, the appropriate volume to store will be relatively easy to calculate based on the daily water need. After water need is determined, choose which structure will be large enough to contain the

Additional Volume Reduction Considerations

For storage vessels that are not drained down completely before the next runoff event, the volume available to be filled by a particular storm may be difficult to calculate. Typical LID sizing criteria is based on the volume that goes to storage during a particular storm. That volume can be subtracted from the runoff volume, and the designer/developer can size the storage unit to achieve the targeted volume reduction. But sizing criteria under these capture and reuse circumstances may become need based. The designer/builder may estimate the volume removal for a particular storm, but estimates should be realistic given the use rate and storm runoff frequency. The estimate can be based on an average available storage capacity or preferably on a water balance analysis based on actual rainfall statistics.

amount of water needed. The amount replenished by a particular storm is equal to the volume reduction.

Available Volume for Capture (gallons) =
Runoff Coefficient (unitless) * Precipitation
(inches) * Area (ft²) * 1 foot/12 inches *
7.4805 gallons/ft³

OR

$$V = 0.62 * C * P * A$$

Where:

V = available volume for capture (gallons)

0.62 = unit conversion (gal/in./ft²)

C = volumetric runoff coefficient (unitless),
typically 0.9 to 0.95 for impervious areas

P = precipitation amount (inches)

A = drainage area to cistern (ft²)

Sizing the tank is a mathematical exercise that balances the available collection (roof) area, annual rainfall, intended use of rainwater and cost. In other words, balance what can be collected against how the rainwater will be used and the financial and spatial costs of storing it. In most areas of the country, it's possible to collect 80 percent of the rain that falls on the available roof area. The 20 percent reduction accounts for loss due to mist and heavy storms that release more rain than the tank can accommodate. That level of capture would yield approximately 500 gallons per inch of rain per 1000 SF of capture area. **Table 3** includes available capture volumes based on drainage area and annual rainfall.

Note: Although utilization of Capture Reuse BMP is beneficial and encouraged, no runoff reduction recognition is considered for this practice towards the required Channel Protection Volume or Water Quality Volume discussed under LID Approach in Post-Construction Stormwater Quality Management Chapter of Technical Standards.

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 improvement

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 will depend on the area below the outlet that is designed for sediment accumulation, time in

Annual Rainfall Yield in Gallons for Various Impervious Surface Sizes and Rainfall Amounts								
Impervious Surface Area (ft ²)	Rainfall (inches)							
	26	28	30	32	34	36	38	40
200	3,079	3,316	3,553	3,790	4,027	4,264	4,501	4,738
400	6,159	6,633	7,106	7,580	8,054	8,528	9,002	9,475
600	9,238	9,949	10,660	11,370	12,081	12,792	13,502	14,213
800	12,318	13,265	14,213	15,160	16,108	17,056	18,003	18,951
1,000	15,397	16,582	17,766	18,951	20,135	21,319	22,504	23,688
1,200	18,477	19,898	21,319	22,741	24,162	25,583	27,005	28,426
1,400	21,556	23,214	24,873	26,531	28,189	29,847	31,505	33,164
1,600	24,636	26,531	28,426	30,321	32,216	34,111	36,006	37,901
1,800	27,715	29,847	31,979	34,111	36,243	38,375	40,507	42,639
2,000	30,795	33,164	35,532	37,901	40,270	42,639	45,008	47,377
2,200	33,874	36,480	39,086	41,691	44,297	46,903	49,508	52,114
2,400	36,954	39,796	42,639	45,481	48,324	51,167	54,009	56,852
2,600	40,033	43,113	46,192	49,272	52,351	55,431	58,510	61,589
2,800	43,113	46,429	49,745	53,062	56,378	59,694	63,011	66,327
3,000	46,192	49,745	53,299	56,852	60,405	63,958	67,512	71,065
3,200	49,272	53,062	56,852	60,642	64,432	68,222	72,012	75,802
3,400	52,351	56,378	60,405	64,432	68,459	72,486	76,513	80,540
3,600	55,431	59,694	63,958	68,222	72,486	76,750	81,014	85,278
3,800	58,510	63,011	67,512	72,012	76,513	81,014	85,515	90,015

Table 3 Annual Rainfall yield (in gallons) for impervious surfaces

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.).

Maintenance

Rain Barrels

- Inspect rain barrels four times per year, and after major storm events.
- Remove debris from screen as needed.
- Replace screens, spigots, downspouts, and leaders as needed.
- To avoid damage, drain container prior to winter, so that water is not allowed to freeze in devices.

Cisterns

- Flush cisterns annually to remove sediment.
- Brush the inside surfaces and thoroughly disinfect twice per year.
- To avoid damage, drain container prior to winter, so that water is not allowed to freeze in devices.

Cost

Both rain barrels and cisterns are assumed to have a life span of 25 years. **Table 4** shows typical costs for rain barrels and cisterns.

	Capacity	Cost Range
Rain barrel	40-75 gal.	\$100-\$250
Cistern	200-10,000 gal.	Varies by manufacturer and material
Vertical storage	64-12,000 gal	\$100-\$11,000

Table 4 Capacities and Costs

Designer/Reviewer Checklist for Capture Reuse

Type and size (gallons) of storage system provided: _____

ITEM*	Page No.	YES	NO	N/A	NOTES
Capture area defined and calculations performed?	5,6				
Pretreatment provided to prevent debris/sediment from entering storage system?	4				
Water use identified and calculations performed?	3,4				
If the use is seasonal, has off-season operation been considered?	--				
Draw-down time considered?	--				
Is storage system located optimally for the use?	--				
Is a pump required?	--				
If so, has an adequate pump system been developed?	4				
Acceptable overflow provided?	4				
Winter operation (protection from freezing) considered?	4,6				
Observation/clean-out port provided?	4				
Maintenance accounted for and plan provided?	6				

* These items primarily relate to larger systems, not residential rain barrels

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BMP Fact Sheet

CONSTRUCTED FILTER

Constructed filters are structures or excavated areas containing a layer of sand, compost, organic material, peat, or other media that reduce pollutant levels in stormwater runoff by filtering sediments, metals, hydrocarbons, and other pollutants. Constructed filters are suitable for sites without sufficient surface area available for bioretention.



Figure 1 Constructed filter, Portland, OR (City of Portland 2004 Stormwater Management Manual)

Applications		Stormwater Quantity Functions	
Residential	Limited	Volume	Low/High*
Commercial	Yes	Groundwater Recharge	Low/High*
Ultra Urban	Yes	Peak Rate	Low/High*
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Yes	TSS	High**
Highway/Road	Yes	TP	Medium**
Recreational	Yes	TN	Medium**
		Temperature	Low

Additional Considerations	
Cost	Med/High
Maintenance	High
Winter Performance	Medium

* Function is low without infiltration and increases when infiltration is provided

** Sand filters only (For filters with infiltration, see Subsurface Infiltration Bed section, or other infiltration BMP sections. For manufactured systems, see manufacturer's information, as well as results from independent verification.)

Variations

- Surface non-vegetated
- Vegetated
- Infiltration
- Contained
- Linear perimeter
- Small subsurface
- Large subsurface
- Manufactured filtration systems

Key Design Features

- Depth of filtering medium 18-30"
- Surface ponding should drain down within 72 hours (3-6" ponding depth)
- May be designed to infiltrate
- May require pretreatment for debris and sediment
- Some systems require sufficient head (2-6 feet)
- Flow splitter or positive overflow required to bypass large storms
- Requires minimum permeability of filtration medium
- Underdrains may be needed if infiltration is infeasible

Site Factors

- Water table to bedrock depth: N/A
- Soils: N/A
- Slope: N/A
- Potential hotspots: Yes
- Maximum drainage area: N/A

Benefits

- Good water quality performance
- Lots of variations for a variety of applications
- Can be used effectively as pretreatment for other BMPs

Limitations

- Limited water quantity benefits
- Relatively high cost
- High maintenance needs

Description and Function

A constructed filter is a structure or excavation filled with material that filters stormwater runoff to remove particulate matter and the pollutants attached to it. The filter media may be comprised of materials such as sand, peat, compost, granular activated carbon (GAC), perlite, or inorganic materials. In some applications, the stormwater runoff flows through an unfilled “pretreatment” chamber to allow the large particles and debris to settle out. Surface vegetation is another good option for pretreatment, as long as it is extensive enough to protect the filter from sediment during large storm events. The runoff then passes through the filter media where additional pollutants are filtered out, and is collected in an underdrain and returned to the conveyance system, receiving waters, or infiltrated into the soil. In general, constructed filters are best applied at sites without sufficient surface area available for bioretention.

Variations

There are a wide variety of constructed filter applications, including surface and subsurface, vegetated, and with or without infiltration. There are also a variety of manufactured filter products that may be purchased (see water quality devices BMP). In general, constructed filters consist of some, if not all, of the following components: excavation or container for media, pretreatment, flow entrance/inlet, surface storage (ponding area), filter media, underdrain (if necessary), and positive overflow. Examples of these variations include:

- Surface non-vegetated filter,
- Surface vegetated filter,
- Surface contained filter,
- Surface linear “perimeter” filter,
- Small subsurface filter, and
- Large subsurface filter.

Surface Infiltration Filter

Filters may be designed to allow some or all of the treated water to infiltrate. Infiltration design criteria apply for all filters designed (**Figure 2**) with infiltration. In all cases, a positive overflow system is recommended.

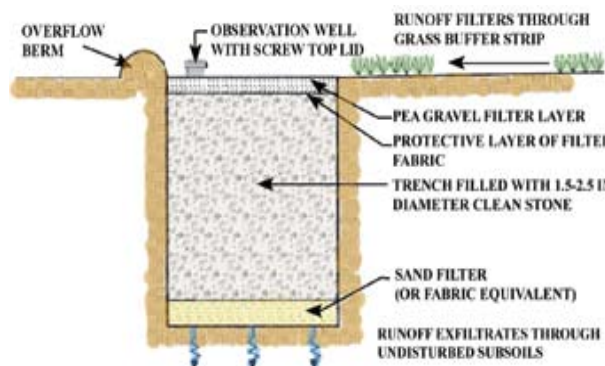


Figure 2 Filter with infiltration to subsoils

Surface non-vegetated filter

A surface non-vegetated filter is constructed by excavation or by use of a structural container. The surface may be covered in gravel, sand, peat, river stone, or similar material.

Surface vegetated filter

A layer of vegetation is planted on top of the filtering medium (**Figure 3**). Compost-amended soil may serve as a filter medium. (See soil restoration BMP for precautions about compost materials, to prevent exporting phosphorus from the filter.) For filters composed of filtering media such as sand (where topsoil is required for vegetation), a layer of nonwoven, permeable geotextile should separate the topsoil and vegetation from the filter media.

Surface contained filter

In contained filters, infiltration is not incorporated into the design. Contained filters may consist of a physical structure, such as a precast concrete box, or they may be excavated chambers or trenches. For excavated contained filters, an impermeable liner is added to the bottom of the excavation to convey the filtered runoff downstream.

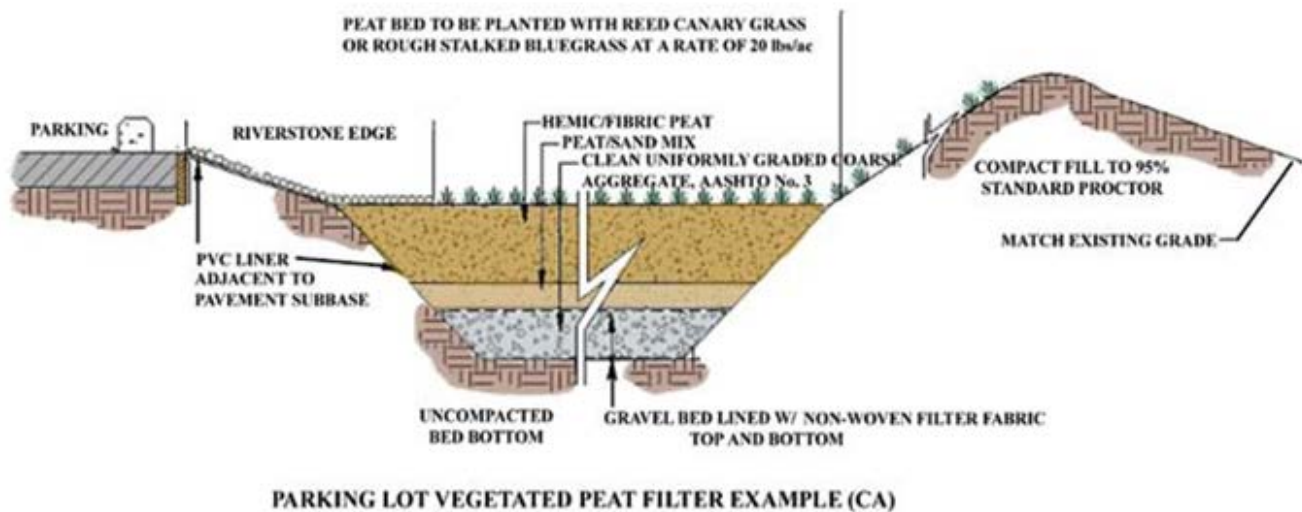


Figure 3 Vegetated peat filter adjacent to a parking lot

Surface linear “perimeter” filter

Perimeter filters may consist of enclosed chambers (such as trench drains) that run along the perimeter of an impervious surface. Perimeter filters may also be constructed by excavation, and be vegetated. All perimeter filters must be designed with the necessary filter medium and sized in accordance with the drainage area.

Small subsurface filter

A small subsurface filter (**Figure 4**) is an inlet designed to treat runoff at the collection source. Small subsurface filters are useful for hot spot pretreatment and are similar in function to water quality inlets/inserts. Small subsurface filters must be carefully designed and maintained so that runoff is directed through the filter media (see Design Considerations).

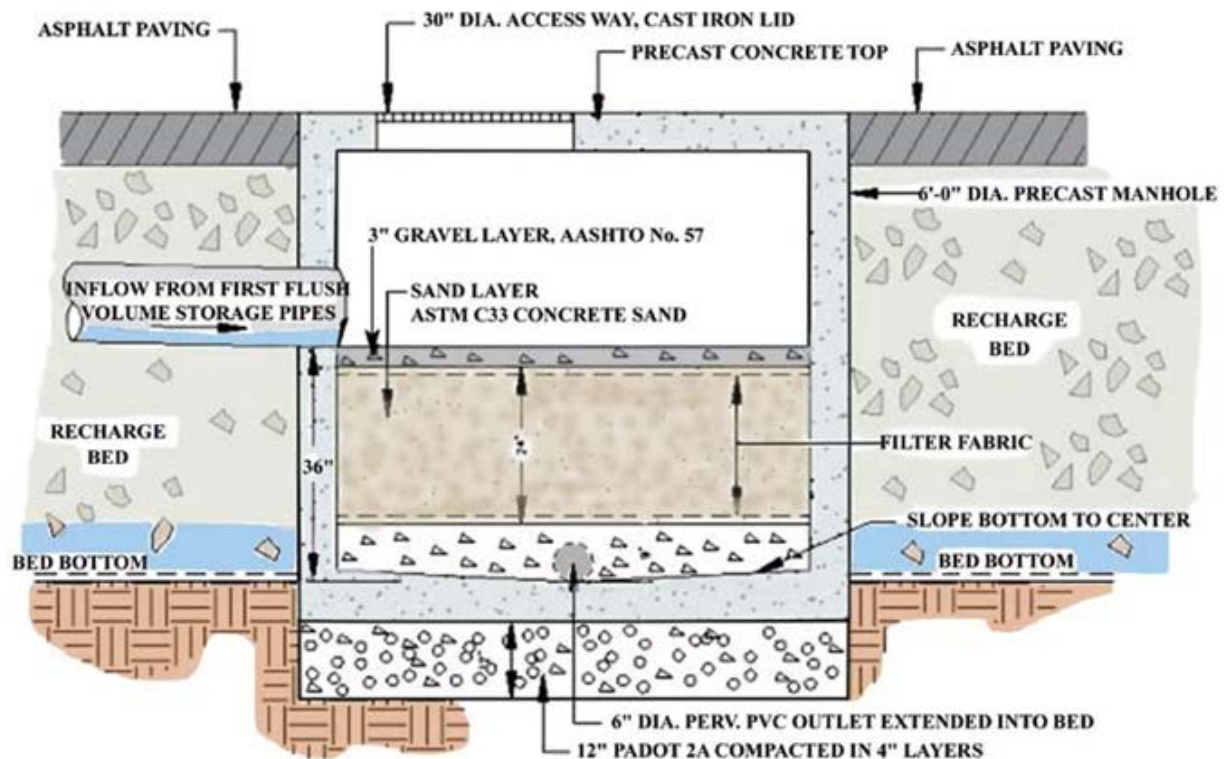


Figure 4 Small subsurface filter

Source: Pennsylvania Stormwater BMP Manual

Large subsurface filter

Large subsurface filters (**Figure 5**) receive relatively large amounts of flow directed into an underground box that has separate chambers. One chamber settles large particles, and the other chamber contains media to filter small particles. The water discharges through an outlet pipe and into the stormwater system.

residential projects (constructed filters are generally used for areas with high impervious cover).

Filters are applicable in urban areas of high pollutant loads and are especially applicable where there is limited area for constructing BMPs. Filters may be used as a pretreatment BMP for other BMPs such as wet ponds or infiltration systems, but input

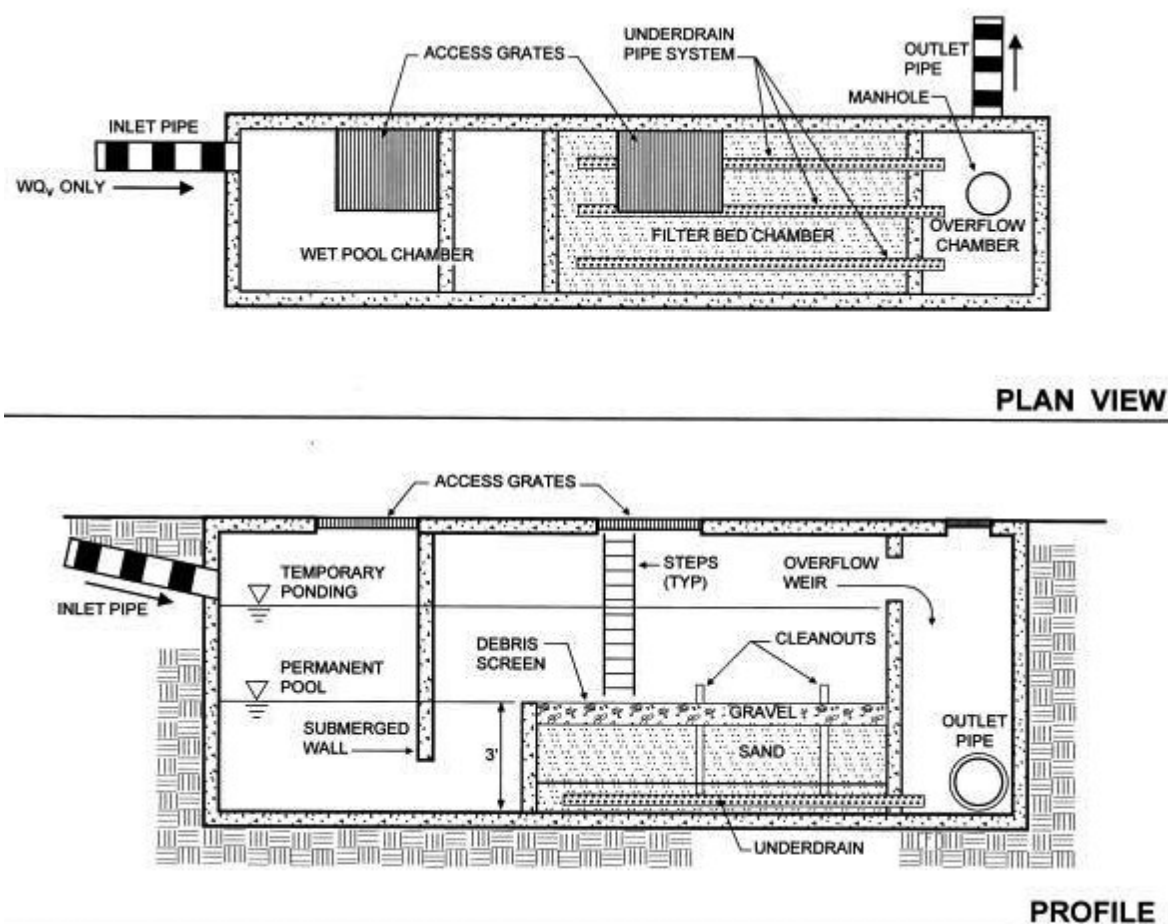


Figure 5 Large subsurface filter
Source: New York Stormwater BMP Manual

Applications

Constructed filters can be used in a wide variety of applications, from commercial/industrial developments to ultra-urban sites and even transportation projects. Their application in residential settings, especially low-density residential, can be limited because they require extensive maintenance. Moreover, other BMPs are more cost effective for stormwater management in

to many filters also requires pretreatment to reduce large settled particulates or debris.

Filters may be used in hot spot areas for water quality treatment, and spill containment capabilities may be incorporated into a filter. Examples of typical areas that benefit from the use of a constructed filter include:

- Parking lots,
- Roadways and highways,

- Light industrial sites,
- Marina areas,
- Transportation fueling and maintenance facilities,
- Fast food and shopping areas,
- Waste transfer stations, and
- Urban streetscapes.

Design Considerations

1. All constructed filters must be designed so that larger storms may safely overflow or bypass the filters. Flow splitters, multi-stage chambers, or other devices may be used. A flow splitter may be necessary to allow only a portion of the runoff to enter the filter. This would create an “off-line” filter, where the volume and velocity of runoff entering the filter is controlled. If the filter is “on-line”, excess flow should be designed to bypass the filter and continue to another water quality BMP.
2. **Entering velocity must be controlled.** A level spreader may be used to spread flow evenly across the filter surface during all storms without eroding the filter material. Level spreaders for this purpose should use a concrete lip or other non soil material to avoid clogging as a result of failure of the level spreader lip. Parking lots may be designed to sheet flow into filters. Small rip-rap or landscaped riverstone edges may be used to reduce velocity and distribute flows more evenly.
3. Contributing areas must be **stabilized** with vegetation or other permanent soil cover before runoff enters filters. Permanent filters should not be installed until the site is stabilized. Excessive sediment generated during construction can clog the filter and prevent or reduce the anticipated post-construction water quality benefits.
4. **Pretreatment** may be necessary in areas with especially high levels of debris, large settled particulates, etc. Pretreatment may include a forebay, oil/grit separators, vegetated filter strips, or grass swales. These measures will settle out the large particles and reduce

velocity of the runoff before it enters the filter. Regular maintenance of the pretreatment is critical to avoid wastes being flushed through and causing the filter to fail. Forebays must be in compliance with local Stormwater Management Ordinance and standard detailed drawing requirements.

5. There should be sufficient space (head) between the top of the filtering bed and the overflow of the filter to allow for the maximum head designed to be stored before filtration.
6. The **filter media** may be a variety of materials (sand, peat, GAC, leaf compost, pea gravel, etc) and in most cases should have a minimum depth of 18 inches and a maximum depth of 30 inches, although variations on these guidelines are acceptable if justified by the designer. Coarser materials allow for greater hydraulic conductivity, but finer media filter particles of a smaller size.

Sand has been found to provide a good balance between these two criteria, but different types of media remove different pollutants. While sand is a reliable material to remove total suspended solids, peat removes slightly more total phosphorous, copper, cadmium, and nickel than sand (Debusk and Langston, 1997).

The filter media should have a minimum hydraulic conductivity (k) as follows:

- Sand 3.5 feet/day
- Peat 2.5 feet/day
- Leaf compost 8.7 feet/day

Depending on the characteristics of the stormwater runoff, a combination of filter materials will provide the best quality results. In addition to determining the degree of filtration, media particle size determines the travel time in the filter and plays a role in meeting release rate requirements.

Sand filtration enhanced with steel wool, calcareous sand, or limestone provides a practical and cost-effective method for

reducing levels of dissolved phosphorus (Erickson et al, Journal of Environmental Engineering, 2007). Sand enhanced with steel wool fabric proved especially effective, removing between 25 percent and 99 percent of dissolved phosphorus and enhancing the quantity and duration of phosphorous retention as compared to sand alone. Sand enhanced with calcareous sand or limestone exhibited signs of clogging in the Erickson et al study. The study also found that enhancing sand filtration with steel wool fabric would modestly increase construction costs by approximately three to five percent. As with other sand filtration systems, steel-enhanced sand filters should be sized and installed according to local guidelines, with consideration given to proper pretreatment for influent solids, as necessary.

7. A **gravel layer** at least six inches deep is recommended beneath the filter media.
8. **Underdrain piping** should be double-walled with four-inch minimum (diameter) perforated pipes, with a lateral spacing of no more than 10 feet. A collector pipe can be used, (running perpendicular to laterals) with a slope of one percent. All underground pipes should have clean-outs accessible from the surface. Underdrain design must minimize the chance of clogging by including a pea gravel filter of at least three inches of gravel under the pipe and six inches above the pipe.
9. Infiltration filters should be underlain by a layer of permeable nonwoven geotextile.
10. A total **drawdown time** of no more than 72 hours is recommended for constructed filters, though the surface should drawdown between 24 and 48 hours. The drawdown time can be estimated using the filter surface area and the saturated vertical infiltration rate of the filter media. If the storage does not drawdown in the time allowed, adjust the pretreatment depth, the filter media depth, and the surface area. Adjust the design until the volume (if applicable) and drainage time constraints are met.

11. The filter **surface area** may be estimated initially using Darcy's Law, assuming the soil media is saturated:

$$A = V * d_f / [k * (h_f + d_f) * t_f]$$

A = Surface area of filter (ft²)

V = Water volume (ft³)

d_f = Depth of filter media (min 1.5 ft; max 2.5 ft)

t_f = Drawdown time (days), not to exceed 3 days

h_f = Head (average head in feet; typically ½ of the maximum head on the filter media, which is typically ≤ to 6 ft)

k = Hydraulic conductivity (ft/day)

12. For vegetated filters, a layer of nonwoven geotextile between non-organic filter media and planting media is recommended.
13. Filters, especially those that are subsurface, must be **designed with sufficient maintenance access** (clean-outs, room for surface cleaning, entry space, etc.). Filters that are visible and simple in design are more likely to be maintained correctly. For underground vault heights greater than four feet, ladder access is necessary.
14. In areas where infiltration is infeasible due to a hot spot or unstable fill that threatens an existing structure, specify an **impervious liner**.

Stormwater Functions and Calculations

Volume reduction

If a filter is designed to include infiltration, the infiltration BMP should be followed. There is minimal, if any, volume reduction for filters that are not designed to infiltrate.

Peak rate mitigation

Constructed filters generally provide little, if any, peak rate reduction. However, if the filter is designed to infiltrate, then medium to high levels of peak rate attenuation can be expected.

Water quality improvement

Constructed filters are considered an excellent stormwater treatment practice with the primary pollutant removal mechanism being filtration and settling. Less significant pollutant removal may result from evaporation, transpiration, biological and microbiological uptake, and soil adsorption.

Sand filters have been shown to have a high removal efficiency of Total Suspended Solids (TSS), and medium removal efficiencies for Total Nitrogen (TN) and Total Phosphorus (TP). Organic filter media also perform very well for TSS and standard for TP, but perform relatively poorly for TN (See **Table 1**).

For filters that are also designed to infiltrate, see the water quality summary in the subsurface infiltration bed section, or in the infiltration BMP. For manufactured, proprietary systems, see the manufacturer's information. Also see the Post-Construction Stormwater Quality Management Chapter of Technical Standards, which addresses pollutant removal effectiveness of this BMP.

Construction Guidelines

1. Follow the recommended materials for constructed filters listed in Recommended Materials Appendix.
2. Structures such as inlet boxes, reinforced concrete boxes, etc. should be installed in accordance with the guidance of the manufacturers or design engineer.
3. Excavated or structural filters that infiltrate should be excavated in such a manner as to avoid compaction of the subbase. Structures may be set on a layer of clean, lightly compacted gravel (such as AASHTO #57).
4. Place underlying gravel/stone in maximum six-inch lifts and lightly compact. Place underdrain pipes in gravel during placement.
5. Wrap and secure gravel/stone with nonwoven geotextile to prevent clogging with sediments.

6. Lay filtering material. Do not compact.
7. Saturate filter media with water and allow media to drain to properly settle and distribute.

Maintenance

Filters require a regular inspection and maintenance program to maintain the integrity of filtering systems and pollutant removal mechanisms. Studies have shown that filters are very effective upon installation, but quickly decrease in efficiency as sediment accumulates in the filter. Odor is also a concern for filters that are not maintained. Inspection of the filter is recommended at least four times a year.

When a filter has accumulated sediment in its pore space, its hydraulic conductivity is reduced, along with its ability to removal pollutants. Inspection and maintenance are essential for continued performance of a filter. Based upon inspection, some or all portions of the filter media may require replacement.

During the inspection the following conditions should be considered:

- **Standing water** – any water left in a surface filter after the design drain down time indicates the filter is not functioning according to design criteria.
- **Film or discoloration** of any surface filter material – this indicates organics or debris have clogged the filter surface.
- Remove trash and debris as necessary
- Scrape silt with rakes, if collected on top of the filter
- Till and aerate filter area
- Replenish filtering medium if scraping/removal has reduced depth of filtering media
- Repair leaks from the sedimentation chamber or deterioration of structural components
- Clean out accumulated sediment from filter bed chamber and/or sedimentation chamber
- Clean out accumulated sediment from underdrains

Studies	No. of studies	TSS % Removal		TN % Removal		TP % Removal	
		Range	Median	Range	Median	Range	Median
U.S.*	18	80 - 92	86	30-47	32	41-66	59
International**	38		75		44		45
Organic media*	N/A	85-100		poor		50-85	

Table 1 Pollutant Removal efficiencies for sand filters

**The Center for Watershed Protection, in its National Pollutant Removal Performance Database – Version 3 (September 2007)*

***The International Stormwater Best Management Practices (BMP) Database, October 2007*

In areas where the potential exists for the discharge and accumulation of toxic pollutants (such as metals), filter media removed from filters must be handled and disposed of in accordance with all state and federal regulations.

Winter Considerations

Indiana's winter temperatures can go below freezing for a few months out of every year and surface filtration does not work as well in the winter. Peat and compost may hold water freeze, and become relatively impervious on the surface. Design options that allow directly for subsurface discharge into the filter media during cold weather may overcome this condition. Otherwise, the reduced performance when the filter media may be temporarily frozen should be considered.

There are various filtration options available for treating snowmelt runoff. In some cases, installations are built below the frost line (trenches, subgrade proprietary chambers) and do not need further adaptation for the cold. However, some special consideration is highly recommended for surface systems.

The main problem with filtration in cold weather is the ice that forms both over the top of the facility and within the soil. To avoid these problems to the extent possible, it is recommended that the facility be actively managed to keep it dry before it freezes in the late fall. Additional modifications, such as increasing the size of underdrains to eight inches, increasing the slope of the underdrains to one percent, and increasing the thickness of the gravel layer to at least 12 inches can prevent freezing and are recommended by EPA.

Proprietary, subsurface filter systems provide an alternative to standard surface-based systems. Essentially, these systems provide an insulated (i.e., subsurface) location for pre-treated snowmelt to be

filtered. The insulating value of these systems adds to their appeal as land conserving alternatives to ponds and surface infiltration basins.

Cost

Filter costs vary according to the filtering media (sand, peat, compost), land clearing, excavation, grading, inlet and outlet structures, perforated pipes, encasing structure (if used), and maintenance cost. Underground structures may contribute significantly to the cost of a filter. In general, filters are one of the more costly and maintenance-intensive BMPs.

Underground sand filters are generally considered to be a high-cost option for water quality management. In 1994, the construction cost was estimated between \$10,000 to \$14,000 per impervious acre served, excluding real estate, design, and contingency costs (Schueler, 1994).

In ultra-urban areas where land costs are high, however, underground sand filters can represent significant cost savings in reduced land consumption. For small ultra-urban areas with no land available, underground sand filters may be the only practical option for stormwater quality treatment as they can be placed under roads or parking lots.

In recent years, various manufacturers have made available prefabricated units that include precast vaults and inlets delivered to the site either partially or fully assembled. These units have generally resulted in decreased construction costs. Typical significant cost variables include the location of subsurface utilities, type of lids and doors, customized casting of weirs, sections, or holes, and depth of the vault.

The surface sand filter design is a moderately expensive water quality option to employ (Claytor

and Schueler, 1996). However, the cost of installation is strongly correlated with the nature of the construction employed. If the filter is installed within an ultra-urban setting, it is likely that relatively expensive concrete walls will be used to create the various chambers. This type of installation will be significantly more expensive than an earthen-walled design, where relatively inexpensive excavation and compaction construction techniques lower the installation cost. However, earthen-wall designs require a greater land area commitment, which can offset the reduction in construction costs.

The construction cost of surface sand filters is also related to economies of scale: the cost per impervious acre served typically decreases with an increase in the service area. In 1994, the construction costs for surface sand or organic media filters were \$16,000 per impervious acre for facilities serving less than two acres (Schueler, 1994). Once again, these construction cost estimates exclude real estate, design, and contingency costs.

Designer/Reviewer Checklist for Constructed Filters

Type of constructed filter(s) proposed: _____

Type of filter media proposed: _____

ITEM	Page No.	YES	NO	N/A	NOTES
Adequate depth of filter media? ➤ <i>Minimum Depth: 18 inches; maximum depth: 36 inches</i>	1				
Acceptable drawdown time (72 hour max.)?	1,6				
Pretreatment provided?	2,5				
Adequate hydraulic head available for filter to operate?	1,5				
➤ Flow bypass and/or overflow provided?	1,4-5				
Permeability of filter media acceptable? <i>Minimum hydraulic conductivity (k); sand = 3.5 ft/day; peat = 2.5 ft/day; compost = 8.7 ft/day</i>	5				
Underdrain provided for non infiltration systems?	1				
Appropriate placement of nonwoven filter fabric?	2-3,6				
Gravel layer provided beneath filter media? <i>Minimum depth: 6 inches</i>	6				
➤ Non-erosive inflow condition?	5				
➤ Adequate surface area provided?	6				
Construction timing places installation after site stabilization?	5				
Erosion control provided during construction?	--				
Cleanouts included?	6				
Maintenance accounted for and plan provided?	7				

➤ *Denotes Minimum Design Considerations*

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BMP Fact Sheet

DETENTION BASINS - CONSTRUCTED WETLAND

A constructed wetland is a type of detention basin that is developed as shallow marsh system planted with emergent vegetation designed to treat stormwater runoff.



Figure 1 Photo Courtesy of USDA NRCS

Applications	
Residential	Yes
Commercial	Yes
Ultra Urban	No
Industrial	Yes
Retrofit	Yes
Highway/Road	Yes
Recreational	Yes

Stormwater Quality Functions

Varies by type as follows:

Type	TSS	TP	TN	Temperature
Constructed Wetland	High	Medium	Medium	Low/Medium

Variations

- Shallow Wetlands
- Extended Detention Shallow Wetlands
- Pocket Wetlands
- Pond/Wetland

Key Design Features

- Storage capacity highly dependent on available site area
- Outlet structure configuration determines peak rate reduction effectiveness
- Regular maintenance of vegetation and sediment removal required
- Natural high groundwater table required
- Relatively impermeable soils or impermeable liner
- Forebay for sediment collection and removal
- Dewatering mechanism required
- Stabilized emergency overflow and energy dissipation at all outlets

Stormwater Quantity Functions	
Volume	Low
Groundwater Recharge	None or Low
Peak Rate	High

Site Factors

Type	Basin Bottom Relative to Water Table	Soils	Slope	Potential Hotspots	Max. Drainage Area (acres)	Benefits	Limitations
Const. Wetland	Can be below WT	C or D*	Low	Yes w/ considerations	50	Good peak rate & water quality performance, wide applicability, potential aesthetic/habitat value	Limited volume/GW recharge benefits, high total cost, potentially thermal impact

*C or D soils typically work without modification. A and B soils may require modifications to reduce their permeability.

Additional Considerations

Cost

- High – Cost must include excavation of basin and enhanced vegetation.
- The cost of each basin is highly dependent on the size of the basin and site characteristics.

Maintenance

Type	Maintenance
Constructed Wetland	Low/Med

Winter Performance

- Med/High

Description and Function

Constructed wetlands are shallow marsh systems planted with emergent vegetation designed to treat stormwater runoff. While they are one of the best BMPs for pollutant removal, constructed wetlands can also mitigate peak rates and even reduce runoff volume to a certain degree. They also can provide considerable aesthetic and wildlife benefits. Constructed wetlands use a relatively large amount of space and may require an adequate source of inflow if a permanent water surface is maintained. (Not all constructed wetlands maintain a water surface year round).

Applications

Constructed wetlands can be used in a wide variety of applications when the necessary space is available. Their use is limited in ultra urban areas and some redevelopment projects simply due to a

lack of available space (in these cases underground and/or special detention may be used).

Variations

Constructed wetlands can be designed as either online (within the stormwater system) or offline facilities. They can be used effectively in series with other flow/ sediment reducing BMPs that reduce the sediment load and equalize incoming flows to the constructed wetland. They are a good option for retrofitting existing detention basins and are often organized into the following four groups:

- **Shallow wetlands** are large surface area constructed wetlands that primarily accomplish water quality improvement through displacement of the permanent pool.
- **Extended detention shallow wetlands** are similar to shallow wetlands but use extended detention as another mechanism for water quality and peak rate control.
- **Pocket wetlands** are smaller constructed wetlands that serve drainage areas between approximately 5 and 10 acres and are constructed near the water table.
- **Pond/wetland** systems are a combination of wet ponds and constructed wetlands.

Although discussion of constructed wetlands in this BMP focuses on surface flow as described above, subsurface flow constructed wetlands can also be used to treat stormwater runoff.

While typically used for wastewater treatment, subsurface flow constructed wetlands for

stormwater can offer some advantages over surface flow wetlands, such as improved reduction of total suspended solids and biological oxygen demand. They also can reduce the risk of disease vectors (especially mosquitoes) and safety risks associated with open water. However, nitrogen removal may be deficient (Campbell and Ogden, 1999) if most of the incoming nitrogen is in the form of ammonia. Subsurface flow wetlands are poor converters of ammonia to nitrate (nitrification) but are excellent converters of nitrate to nitrogen gas (denitrification). Perhaps the biggest concern regarding subsurface constructed wetlands is their relatively high cost. They can be two to three times more expensive to construct than surface flow constructed wetlands.

Design Considerations

Hydrology

- Constructed wetlands should be designed to mitigate peak runoff rates for the one-year through 100-year rainfall events.
- Inflow and discharge hydrographs should be calculated for each selected design storm. Hydrographs should be based on the 24-hour rainfall event or that required in the local Stormwater Ordinance. Typically, the NRCS 24-hour Type II rainfall distribution should be utilized to generate hydrographs.
- Constructed wetlands must be able to receive and retain enough flow from rain, runoff, and groundwater to ensure long-term viability. Hydrologic calculations (e.g., a water balance) must be performed to verify this. Shallow marsh areas can become dry at the surface but not for greater than one month, even in the most severe drought. A permanent water surface in the deeper areas of the constructed wetland should be maintained during all but the driest periods. The average target pool depth to maintain emergent wetland vegetation is six to 12 inches. Maximum water depths of three to four feet should not be exceeded for more than 12 hours at a time, for more than a few days out of the year. The deeper the water and the longer it sits, the greater the chances that a wetland vegetation monoculture, such as cattails, will develop. A relatively stable

normal water surface elevation reduces the stress on wetland vegetation. A constructed wetland must have a drainage area of at least 10 acres (five acres for “pocket” wetlands) or some means of sustaining constant inflow. Even with a large drainage area, a constant source of inflow can improve the biological health and effectiveness of a constructed wetland. Indiana’s precipitation is generally well distributed throughout the year and is therefore suited for constructed wetlands.

Storage volume, depth, and duration

- Constructed wetlands should be designed to treat the runoff volume produced by the water quality design storm unless additional upstream BMPs are provided.
- If high water table conditions are anticipated, then the design of a constructed wetland should be considered.
- Ponding depths should not exceed 3 – 4 feet for more than 12 hours.
- Detention time is defined as the time from when the maximum storage volume is reached until only 10 percent of that volume remains in the basin. In order to achieve an 80 percent total suspended solids removal rate, a 36-hour detention time is required within an extended detention basin, with no more than 40% of the maximum stored volume released within the first 12 hours.

Basin sizing and configuration

- Constructed wetlands should be shaped to maximize the hydraulic length of the stormwater flow pathway. A minimum length-to width ratio of 3:1 is recommended to maximize sedimentation. If the length-to-width ratio is lower, the flow pathway should be maximized. A wedge-shaped pond with the major inflows on the narrow end can prevent short-circuiting and stagnation.
- Irregularly shaped basins are acceptable and may even be encouraged to improve site aesthetics.
- Distances of flow paths from inflow points to outlets should be maximized.
- If site conditions inhibit construction of a long, narrow basin, baffles consisting of

earthen berms or other materials can be incorporated into the pond design to lengthen the stormwater flow path.

- Constructed wetlands must have one or more sediment forebays or equivalent upstream pretreatment to trap coarse sediment, prevent short circuiting and facilitate maintenance (i.e., sediment removal). The forebay should consist of a separate cell, formed by a structural barrier. The forebay will require periodic sediment removal.
- Permanent access must be provided to the forebay, outlet, and embankment areas. It should be at least nine feet wide, having a maximum slope of 15 percent, and be stabilized for vehicles.
- An emergency outlet or spillway capable of conveying the spillway design flood (SDF) must be included in the design. The SDF is usually equal to the 1.25 times the 100-year design flood.
- Constructed wetlands should be designed so that the 10-year water surface elevation does not exceed the normal water surface elevation by more than three feet. Slopes in and around constructed wetlands should be 4:1 to 5:1 (horizontal:vertical) whenever possible.
- All areas that are deeper than four feet should have two safety benches, each four to six feet wide. One should be situated about one to 1.5 feet above the normal water elevation and the other 2 to 2.5 feet below the water surface.

Embankments

- Vegetated embankments less than or equal to three feet in height are recommended. Embankments should have side slopes no steeper than 3:1 (horizontal to vertical).
- The constructed wetland should have a minimum freeboard of one foot above the SDF elevation to the top of the berm.
- Woody vegetation is generally discouraged in the embankment area because of the risk of compromising the integrity of the embankment.
- Embankments should incorporate measures, such as buried chain link fencing, to prevent or discourage damage caused by tunneling wildlife (e.g., muskrat).

Constructed wetland location

- Constructed wetlands should be located down gradient of disturbed or developed areas on the site. The constructed wetland should collect as much site runoff as possible, especially from the site's impervious surfaces (roads, parking, buildings, etc.), and where other BMPs are not proposed.
- Constructed wetlands should not be constructed on steep slopes, nor should slopes be significantly altered or modified to reduce the steepness of the existing slope, for the purpose of installing a basin.
- Constructed wetlands should not worsen the runoff potential of the existing site by removing trees for the purpose of installing a basin.
- Constructed wetlands should not be constructed within 10 feet of the property line or within 50 feet of a private well or septic system.
- Constructed wetlands should not be constructed in areas with high quality and/or well draining soils, which are adequate for installing BMPs capable of achieving stormwater infiltration and, hence, volume reduction.

Outlet design

- The low-flow orifice should typically be no smaller than 4 inches in diameter. However, the orifice diameter may be reduced to two inches if adequate protection from clogging is provided.
- The hydraulic design of all outlet structures must consider any significant tailwater effects of downstream waterways.
- The primary and low flow outlets should be protected from clogging by an external trash rack or other mechanism.
- Online facilities should have an emergency spillway that can safely pass 1.25 times the 100-year storm with one foot of freeboard. All outflows should be conveyed downstream in a safe and stable manner.
- Outlet control devices should be in open water areas, four to six feet deep, comprising about five percent of the total surface area to prevent clogging and allow the wetland to be drained for maintenance. Outlet devices are

generally multistage structures with pipes, orifices, or weirs for flow control. All outflows should be conveyed downstream in a safe and stable manner.

Inlet structures

- Erosion protection measures should be used to stabilize inflow structures and channels.

Sediment forebay

- Forebays must be in compliance with local Stormwater Management Ordinance and standard detailed drawing requirements.
- Forebays must be incorporated into the basin design. Forebays should be provided at all major inflow points to capture coarse sediment, prevent excessive sediment accumulation in the main basin, and minimize erosion by inflow.
- Forebays should be vegetated to improve filtering of runoff, to reduce runoff velocity, and to stabilize soils against erosion. Forebays should adhere to the following criteria:
 - A minimum length of 10 feet.
 - Storage should be provided to trap sediment over from storms with return periods between 1 and 10 years.
 - Forebays should be physically separated from the rest of the pond by a berm, gabion wall, etc.
 - Flows exiting the forebay must be non-erosive to the newly constructed basin.
 - Forebays should be installed with permanent vertical markers that indicate sediment depth.
 - Storage volume of 10 to 15 percent of the total permanent pool volume and is four to six feet deep.
 - All major inflow points to dry detention basins should include sediment forebays sized for 10 percent of the water quality volume.

Vegetation and soils protection

- Underlying soils must be identified and tested. Generally, hydrologic soil groups “C” and “D” are suitable without modification; “A” and “B” soils may require a clay or synthetic liner. Soil permeability must be

tested in the proposed constructed wetland location to ensure that excessive infiltration will not cause it to dry out. Field results for permeability should be used in the water balance calculations to confirm suitability. If necessary, constructed wetlands should have highly compacted subsoil or an impermeable liner to minimize infiltration.

- Organic soils should be used for constructed wetlands. Organic soils can serve as a sink for pollutants and generally have high water holding capacities. They will also facilitate plant growth and propagation and may hinder invasion of undesirable species. Care must be taken to ensure that soils used are free of invasive or nuisance plant seed.
- About half of the emergent vegetation zone should be high marsh (up to six inches deep) and half should be low marsh (6 to 18 inches deep). Varying depths throughout the constructed wetland can improve plant diversity and health.
- The open water zone (approximately 35 to 40 percent of the total surface area) should be between 18 inches and six feet deep. Allowing a limited five-foot deep area can prevent short-circuiting by encouraging mixing, enhance aeration of water, prevent resuspension, minimize thermal impacts, and limit mosquito growth. Alternating areas of emergent vegetation zone (up to 18 inches deep) and open water zone can also minimize short-circuiting and hinder mosquito propagation.

General Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

Excavation

- The area to be used for the constructed wetland should be excavated to the required depth below the desired bottom elevation to

accommodate any required impermeable liner, organic matter, and/or planting soil.

- The compaction of the subgrade and/or the installation of any impermeable liners will follow immediately.

Subsoil preparation

- Subsoil should be free from hard clods, stiff clay, hardpan, ashes, slag, construction debris, petroleum hydrocarbons, or other undesirable material. Subsoil must not be delivered in a frozen or muddy state.
- Scarify the subsoil to a depth of 8 to 10 inches with a disk, rototiller, or similar equipment.
- Roll the subsoil under optimum moisture conditions to a dense seal layer with four to six passes of a sheepsfoot roller or equivalent. The compacted seal layer should be at least eight inches thick.

Impermeable liner

- If necessary, install impermeable liner in accordance with manufacturer's guidelines.
- Place a minimum 12 inches of subsoil on top of impermeable liner in addition to planting soil.

Earth fill material & placement

- The fill material should be taken from approved designated excavation areas. It should be free of roots, stumps, wood, rubbish, stones greater than six inches, or other objectionable materials. Materials on the outer surface of the embankment must have the capability to support vegetation.
- Areas where fill is to be placed should be scarified prior to placement. Fill materials for the embankment should be placed in maximum eight-inch lifts. The principal spillway must be installed concurrently with fill placement and not excavated into the embankment.
- Control movement of the hauling and spreading equipment over the site.

Embankment core

- The core should be parallel to the centerline of the embankment as shown on the plans. The top width of the core should be at least four feet. The height should extend up to at least the 10-year water elevation or as shown on the plans. The side slopes should be 1:1 or flatter. The core should be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum permeability. The core should be placed concurrently with the outer shell of the embankment.
- Construction of the berm should follow specifications by the project's geotechnical engineer.

Structure backfill

- Backfill adjacent to pipes and structures should be of the type and quality conforming to that specified for the adjoining fill material. The fill should be placed in horizontal layers not to exceed eight inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material should fill completely all spaces under and adjacent to the pipe. At no time during the backfilling operation should driven equipment be allowed to operate closer than four feet to any part of the structure. Equipment should not be driven over any part of a concrete structure or pipe, unless there is a compacted fill of 24 inches or greater over the structure or pipe.
- Backfill content and placement should follow specifications by the project's geotechnical engineer.

Pipe conduits

Corrugated metal pipe – All of the following criteria should apply for corrugated metal pipe:

- Materials – Polymer coated steel pipe, aluminum coated steel pipe, aluminum pipe. This pipe and its appurtenances should conform to the requirements of AASHTO specifications with watertight coupling bands or flanges.

- Coupling bands, anti-seep collars, end sections, etc., must be composed of the same material and coatings as the pipe. Metals must be insulated from dissimilar materials with use of rubber or plastic insulating materials at least 24 mils in thickness.
- Connections – All connections with pipes must be completely watertight. The drain pipe or barrel connection to the riser should be welded all around when the pipe and riser are metal. Anti-seep collars should be connected to the pipe in such a manner as to be completely watertight. Dimple bands are not considered to be watertight.
- Bedding – The pipe should be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material should be removed and replaced with suitable earth compacted to provide adequate support.
- Backfilling should conform to “structure backfill.”
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Reinforced concrete pipe - All of the following criteria should apply for reinforced concrete pipe:

- Materials – Reinforced concrete pipe should have bell and spigot joints with rubber gaskets and should equal or exceed ASTM standards.
- Laying pipe – Bell and spigot pipe should be placed with the bell end upstream. Joints should be made in accordance with recommendations of the manufacturer of the material. After the joints are sealed for the entire line, the bedding should be placed so that all spaces under the pipe are filled. Take care to prevent any deviation from the original line and grade of the pipe.
- Backfilling should conform to “structure backfill.”
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Plastic pipe

- Materials – PVC pipe should be PVC-1120 or PVC-1220, conforming to ASTM standards. Corrugated High Density Polyethylene

(HDPE) pipe, couplings, and fittings should meet AASHTO specifications.

- Joints and connections to anti-seep collars should be completely watertight.
- Bedding – The pipe should be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material should be removed and replaced with suitable earth compacted to provide adequate support.
- Backfilling should conform to “structure backfill.”
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Drainage diaphragms – When a drainage diaphragm is used, a registered professional engineer must supervise the design and construction inspection.

Planting soil (topsoil)

- See local specifications for general planting soil requirements.
- Use a minimum of 12 inches of topsoil in the emergent vegetation zone (less than 18” inches deep) of the pond. If natural topsoil from the site is to be used it must have at least eight percent organic carbon content (by weight) in the A-horizon for sandy soils, and 12 percent for other soil types.
- If planting soil is imported, it should be made up of equivalent proportions of organic and mineral materials. All soils used should be free of invasive or nuisance seeds.
- Lime should not be added to planting soil unless absolutely necessary, as it may encourage the propagation of invasive species.
- The final elevations and hydrology of the vegetative zones should be evaluated prior to planting to determine if grading or planting changes are required.

Vegetation

- See Recommended Plant List for BMPs Appendix for plant lists for constructed wetlands. Substitutions of specified plants should be subject to prior approval of the designer. Planting locations should be based on the planting plan and directed in the field

by a qualified wetland ecologist. Plant material should be selected based on tolerance to standing water as identified in Recommended Plant List for BMPs Appendix.

- All wetland plant stock should exhibit live buds or shoots. All plant stock should be turgid, firm, and resilient. Internodes of rhizomes may be flexible and not necessarily rigid. Soft or mushy stock should be rejected. The stock should be free of deleterious insect infestation, disease, and defects such as knots, sun-scald, injuries, abrasions, or disfigurement that could adversely affect the survival or performance of the plants.
- All stock should be free from invasive or nuisance plants or seeds.
- During all phases of the work, including transport and onsite handling, the plant materials should be carefully handled and packed to prevent injuries and desiccation. During transit and onsite handling, the plant material should be kept from freezing and be covered, moist, cool, out of the weather, and out of the wind and sun. Plants should be watered to maintain moist soil and/or plant conditions until accepted.
- Plants not meeting these specifications or damaged during handling, loading, and unloading will be rejected.

Outlet control structure

- Outlet control structures should be constructed of non-corrodible material.
- Outlets should be resistant to clogging by debris, sediment, floatables, plant material, or ice.
- Materials should comply with applicable specifications (INDOT or AASHTO, latest edition).
- For maximum flexibility with wetland water levels (if actual depths are uncertain) adjustable water level control structures are recommended (see EPA, 2000 in reference section for design concepts).

Stormwater Functions and Calculations

Volume reduction

Although not typically considered a volume-reducing BMP, constructed wetlands can achieve some volume reduction through infiltration and evapotranspiration, especially during small storms and high temperature periods. The volume stored between the predicted water level (from the water balance calculations) and the lowest outlet elevation will be removed from the storm that occurs under those conditions.

Peak rate mitigation

Inflow and discharge hydrographs must be calculated for each design storm.

Peak rate is primarily controlled in detention facilities through the transient storage above any permanent water surface. The degree to which peak rate is controlled is a function of the transient storage volume provided (i.e., depth and area) and the configuration of the outlet control structure.

Water quality improvement

Constructed wetlands rely on physical, biological, and chemical processes to remove pollutants from influent stormwater runoff. The primary treatment mechanism is settling by gravity of particulates and their associated pollutants, while stormwater is retained in the pond. Another mechanism for the removal of pollutants, especially nutrients, is uptake by algae and aquatic vegetation. Typical pollutant removal efficiencies are provided in the Post-Construction Stormwater Quality Management Chapter of the Technical Standards.

The longer the runoff remains in a constructed wetland, the more settling (and associated pollutant removal) and other treatment can occur. After the particulates reach the bottom, the permanent pool protects them from resuspension when additional runoff enters.

Construction Guidelines

The following guidelines pertain to constructed wetlands:

- Install all temporary erosion and sedimentation controls.
- Separate pond area from contributing drainage area.
- All channels/pipes conveying flows to the pond must be routed away from the pond area until it is completed and stabilized.
- Prior to construction of the pond, the area immediately adjacent to the pond must be stabilized in accordance with the erosion and sediment control methods discussed in the Erosion and Sediment Control Requirements Chapter of the Technical Standards and the latest requirements of IDEM's Soil Erosion and Sedimentation Control (Rule 5) Program.
- Prepare site for excavation and/or embankment construction.
- All existing vegetation should remain, if feasible, and only be removed if necessary for construction.
- Care should be taken to prevent compaction of the basin bottom.
- If excavation is required, clear the area of all vegetation. Remove all tree roots, rocks, and boulders only in the excavation area.
 - Excavate bottom of basin to desired elevation (if necessary).
- Install surrounding embankments and inlet and outlet control structures.
- Grade and prepare subsoil in bottom of basin. Compact bottom of basin in constructed wetlands.
 - Apply and grade planting soil. Matching design grades is crucial especially in constructed wetlands because aquatic plants can be very sensitive to depth.
 - Apply geo-textiles and other erosion-control measures.
- Seed, plant, and mulch according to landscaping plan.
- Install any safety or anti-grazing measures, if necessary.
- Follow required maintenance and monitoring guidelines.

Maintenance

Constructed wetlands must have a maintenance plan and privately owned facilities should have an easement, deed restriction, or other legal measure to prevent neglect or removal.

A basin maintenance plan should be developed which includes the following measures:

- All basin structures should be inspected for clogging and excessive debris and sediment accumulation at least four times per year, as well as after every storm greater than one inch. Structures that should be inspected include basin bottoms, trash racks, outlets structures, riprap or gabion structures, and inlets.
- Sediment should be removed from the forebay before it occupies 50 percent of the forebay, typically every 3 to 10 years. Sediment removal should be conducted when the basin is completely dry.
- Constructed wetlands should be drained prior to sediment removal. Sediment should be disposed of properly and once sediment is removed, disturbed areas need to be immediately stabilized and re-vegetated. Proper disposal of removed material depends on the nature of the drainage area and the intent and function of the detention basin. Material removed from detention basins that treat hot spots such as fueling stations or areas with high pollutant concentrations should be disposed according to IDEM regulations for solid waste. Detention basins that primarily catch sediment from areas such as lawns may redistribute the waste on site.
- The wetland drain should be inspected and tested four times per year.
- The embankment should be inspected for evidence of tunneling or burrowing wildlife at least twice during the growing season. If damage is found, the damage should be repaired and the animals removed.
- Mowing and/or trimming of vegetation should be performed as necessary to sustain the system, but all detritus must be removed from the basin. Embankment should be mowed 1–2 times per year to prevent the establishment of woody vegetation.

- Inspections should assess the vegetation, erosion, flow channelization, bank stability, inlet/outlet conditions, embankment, and sediment/debris accumulation.
- Vegetated areas should be inspected annually for unwanted growth of invasive species.
- Vegetative cover should be maintained at a minimum of 85 percent.

Winter Considerations

One of the biggest problems associated with proper constructed wetland operation during cold weather is the freezing and clogging of inlet and outlet pipes. To avoid these problems, the Center for Watershed Protection (Caraco and Claytor, 1997) made some general design suggestions, which are adapted as follows:

- Inlet pipes should typically not be submerged, since this can result in freezing and upstream damage or flooding.
- Burying all pipes below the frost line can prevent frost heave and pipe freezing. Wind protection can also be an important consideration for pipes above the frost line. In these cases, designs modifications that have pipes “turn the corner” are helpful.
- Incorporate lower winter operating levels as part of the design to introduce available storage for melt events.
- Increase the slope of inlet pipes to a minimum of one percent to prevent standing water in the pipe, reducing the potential for ice formation. This design may be difficult to achieve at sites with flat local slopes.
- If perforated riser pipes are used, the minimum opening diameter should be ½-inch. In addition, the pipe should have a minimum 8-inch diameter.
- When a standard weir is used, the minimum slot width should be 3 inches, especially when the slot is tall.
- Baffle weirs can prevent ice reformation during the spring melt near the outlet by preventing surface ice from blocking the outlet structure.
- In cold climates, riser hoods should be oversized and reverse slope pipes should draw from at least 6 inches below the typical ice layer.

- Alternative outlet designs that have been successful include using a pipe encased in a gravel jacket set at the elevation of the aquatic bench as the control for water-quality events. This practice both avoids stream warming and serves as a non-freezing outlet.
- Trash racks should be installed at a shallow angle to prevent ice formation. Constructed wetland performance can be decreased in spring months when large volumes of runoff occur in a relatively short time carrying the accumulated pollutant load from the winter months. Since constructed wetlands are relatively shallow, freezing of the shallow pool can occur.

Cost

The cost of constructed wetlands varies greatly depending on the configuration, location, site specific conditions, etc. Typical construction costs in 2004 dollars range from approximately \$30,000 to \$65,000 per acre (USEPA Wetlands Fact Sheet, 1999). Costs are generally most dependent on the amount of earthwork and planting. Annual maintenance costs have been reported to be approximately two to five percent of the capital costs (USEPA, 2000).

Designer/Reviewer Checklist for Constructed Wetlands

ITEM	Page No.	YES	NO	N/A	NOTES
Used in conjunction with other BMPs for groundwater recharge and/or water quality?	1,3				
Adequate drainage area/water supply/groundwater table to maintain permanent water surface? ➤ <i>Min. drainage area: 10 acres, 5 acres for pocket wetland</i> ➤ <i>Max. drainage area: 50 acres</i>	2-4				
➤ Relatively impermeable soils and/or soil modification?	6				
Hydrologic calculations (e.g., water balance) performed?	3,4				
Stable inflow points provided?	6				
➤ Forebay and/or pretreatment provided for sediment removal? <i>Min. width of permanent access: 9 ft</i> <i>Max. slope: 15%</i>	4-6				
➤ Adequate length to width ratio?	4				
Appropriate and varying water depths for diverse vegetation? ➤ <i>Max. water depth: 3-4 feet, no longer than 12 hours for more than a few days annually</i>	4,6				
Sudden water level fluctuations minimized to reduce stress on vegetation?	4				
Acceptable side slopes?	5				
Safety benches provided?	5				
Properly designed outlet structure?	4,5				
Adjustable permanent pool and dewatering mechanism provided?	--				
Trash rack provided to prevent clogging?	5				
Stable emergency overflow and outflow points?	5				
➤ Adequate soils for plantings?	6,7				
➤ Appropriate native plants selected in and around wetland?	9				
25-foot buffer provided?	--				
Erosion and sedimentation control considered?	--				
Maintenance accounted for and plan provided? <i>Min. vegetative cover to be maintained: 85%</i> ➤ <i>Denotes Minimum Design Consideration</i>	10,1 1				

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BMP Fact Sheet

DETENTION BASINS - DRY POND

Also called Dry-bottom Detention Ponds, Dry Ponds are earthen structures that provide temporary storage of runoff and release the stored volume of water over time to help reduce flooding.



Figure 1 Photograph Courtesy of US Environmental Protection Agency

Key Design Features

- Storage capacity highly dependent on available site area
- Outlet structure configuration determines peak rate reduction effectiveness
- Regular maintenance of vegetation and sediment removal required
- Relatively impermeable soils or impermeable liner
- Forebay for sediment collection and removal
- Stabilized emergency overflow and energy dissipation at all outlets

Applications	
Residential	Yes
Commercial	Yes
Ultra Urban	No
Industrial	Yes
Retrofit	Yes
Highway/Road	Yes
Recreational	Yes

Stormwater Quantity Functions	
Volume	Low
Groundwater Recharge	None or Low
Peak Rate	High

Stormwater Quality Functions

Type	TSS	TP	TN	Temperature
Dry Pond	Medium	Medium	Low	Low

Site Factors

Type	Basin Bottom Relative to Water Table	Soils	Slope	Potential Hotspots	Max. Drainage Area (acres)	Benefits	Limitations
Dry Pond	Above	N/A	Low/ Med	Yes w/ considerations	50	Good peak rate performance, wide applicability, can be used as temporary sediment basin	Low volume/GW recharge and water quality benefits, must be combined with other BMPs, high total cost

**C or D soils typically work without modification. A and B soils may require modifications to reduce their permeability.*

Additional Considerations

Cost

- High – Cost for above ground basins must include excavation of basin, construction of berm, and installation of storm sewer conveyance system, including pipes and structures.
- The cost of each basin is highly dependent on the size of the basin and site characteristics.

Maintenance

Type	Maintenance
Dry Pond	High/Low - Year round maintenance for vegetation; one time per year sediment removal

Winter Performance

- Med/High

Description and Function

Dry ponds are earthen structures that provide temporary storage of runoff and release the stored volume of water over time to help reduce flooding. They are constructed either by impounding a natural depression or excavating existing soil, and are intended to enhance the settlement process in order to maximize water quality benefits, while achieving reduced runoff volume.

Applications

Dry ponds can be used in a wide variety of applications when the necessary space is available. Their

uses are limited in ultra urban areas and some redevelopment projects simply due to a lack of available space (in these cases underground and/or special detention may be used).

Design Considerations

Hydrology

- Dry ponds should be designed to mitigate peak runoff rates for the 1-year through 100-year rainfall events.
- Inflow and discharge hydrographs should be calculated for each selected design storm. Hydrographs should be based on the 24-hour rainfall event or that required in the Stormwater Ordinance. Typically, the local NRCS 24-hour Type II rainfall distribution should be utilized to generate hydrographs.

Storage volume, depth, and duration

- Dry ponds should be designed to treat the runoff volume produced by the water quality design storm unless additional upstream BMPs are provided.
- The lowest elevation within a dry detention basin should be at least two feet above the seasonal high water table. If high water table conditions are anticipated, then the design of a wet pond, constructed wetland, or bioretention facility should be considered.
- The maximum water depth of the basin should not exceed 4 feet.
- Detention time is defined as the time from when the maximum storage volume is reached until only 10 percent of that volume remains in the basin. In order to

achieve an 80 percent total suspended solids removal rate, a 36-hour detention time is required within an extended detention basin, with no more than 40% of the maximum stored volume released within the first 12 hours.

- The low flow orifice should be sized and positioned to detain the calculated water quality runoff volume for at least 24 hours, but no more than 36 hours. The low flow orifice may be allowed as small as 4 inches in diameter if adequate protection from clogging is provided.

Basin sizing and configuration

- Dry ponds should be shaped to maximize the hydraulic length of the stormwater flow pathway. A minimum length-to-width ratio of 3:1 is recommended to maximize sedimentation. If the length-to-width ratio is lower, the flow pathway should be maximized. A wedge-shaped pond with the major inflows on the narrow end can prevent short-circuiting and stagnation.
- Irregularly shaped basins are acceptable and may even be encouraged to improve site aesthetics.
- Distances of flow paths from inflow points to outlets should be maximized.
- If site conditions inhibit construction of a long, narrow basin, baffles consisting of earthen berms or other materials can be incorporated into the pond design to lengthen the stormwater flow path.
- Basins must have one or more sediment forebays or equivalent upstream pretreatment to trap coarse sediment, prevent short circuiting and facilitate maintenance (i.e., sediment removal). The forebay should consist of a separate cell, formed by a structural barrier. The forebay will require periodic sediment removal.
- Permanent access must be provided to the forebay, outlet, and embankment areas. It should be at least nine feet wide, having a maximum slope of 15 percent, and be stabilized for vehicles.
- An emergency outlet or spillway capable of conveying the spillway design flood (SDF) must be included in the design. The SDF is

usually equal to the 1.25 times the 100-year design flood.

Embankments

- Vegetated embankments less than or equal to three feet in height are recommended. Embankments should have side slopes no steeper than 3:1 (horizontal to vertical).
- The basin should have a minimum freeboard of one foot above the SDF elevation to the top of the berm.
- Woody vegetation is generally discouraged in the embankment area because of the risk of compromising the integrity of the embankment.
- Embankments should incorporate measures, such as buried chain link fencing, to prevent or discourage damage from tunneling wildlife (e.g., muskrat).



Figure 2 Dry Pond: Photo courtesy of Fairfax County VA Department of Public Works and Environmental Services.

Dry pond location

- Dry ponds should be located down gradient of disturbed or developed areas on the site. The pond should collect as much site runoff as possible, especially from the site's impervious surfaces (roads, parking, buildings, etc.), and where other BMPs are not proposed.
- Dry ponds should not be constructed on steep slopes, nor should slopes be significantly altered or modified to reduce the steepness of the existing slope, for the purpose of installing a pond.
- Dry ponds should not worsen the runoff potential of the existing site by removing trees for the purpose of installing a pond.

- Dry ponds should not be constructed within 10 feet of the property line or within 50 feet of a private well or septic system.
- Dry ponds should not be constructed in areas with high quality and/or well draining soils, which are adequate for installing BMPs capable of achieving stormwater infiltration and, hence, volume reduction.

Additional design considerations for extended detention basins (Figure 3)

- Dry detention basins should not be constructed within jurisdictional waters, including wetlands, or their regulated buffers.

Outlet design

- The low-flow orifice should typically be no

smaller than 4 inches in diameter. However, the orifice diameter may be reduced to two inches if adequate protection from clogging is provided.

- The hydraulic design of all outlet structures must consider any significant tailwater effects of downstream waterways.
- The primary and low flow outlets should be protected from clogging by an external trash rack or other mechanism.
- Online facilities should have an emergency spillway that can safely pass the 1.25 times the 100-year storm with one foot of freeboard. All outflows should be conveyed downstream in a safe and stable manner.
- When designed to meet discharge criteria for a range of storms, basins should incorporate a multistage outlet structure. Three elements are typically included in

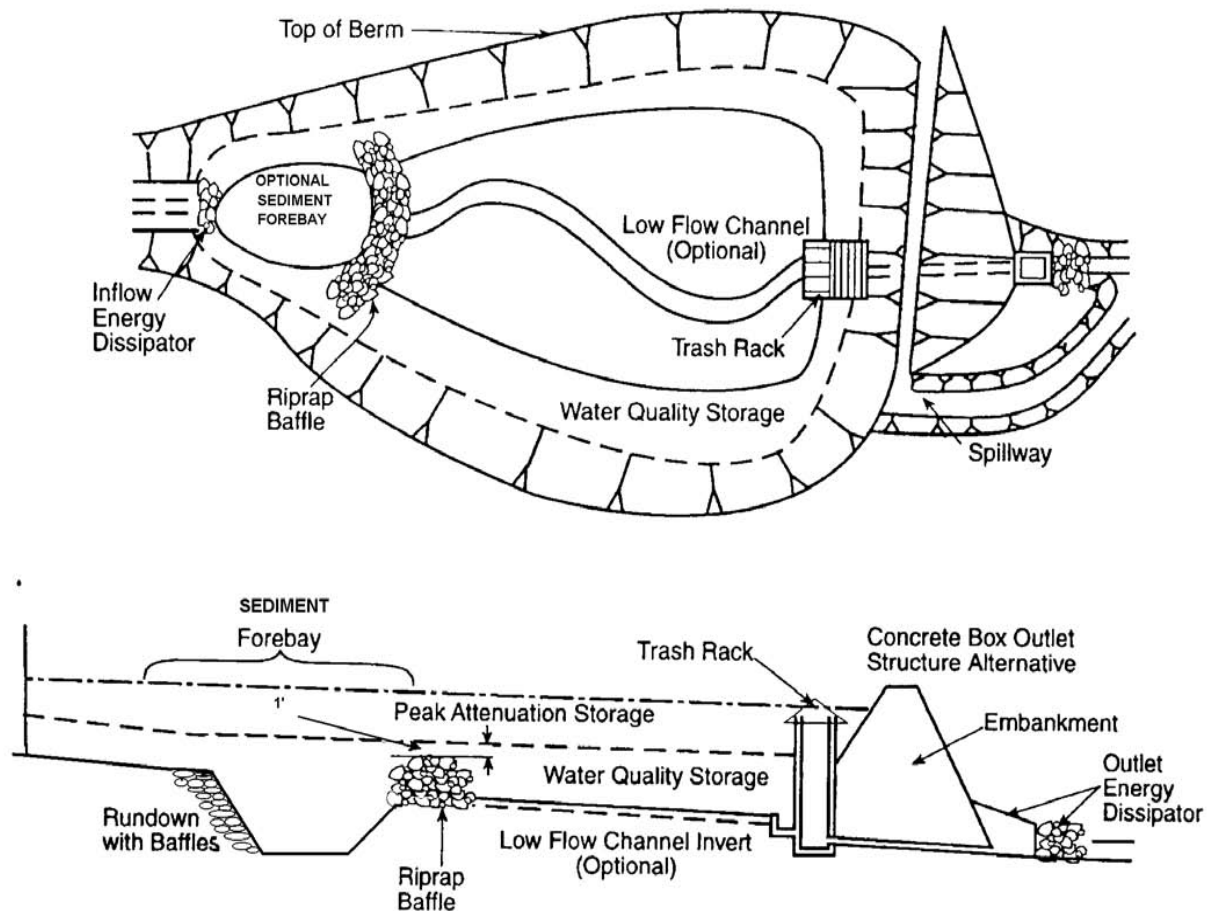


Figure 3 Extended Detention Basin
Source: New Jersey BMP Manual

this design:

- A low-flow outlet that controls the extended detention and functions to slowly release the water quality or channel protection design storm.
- A primary outlet that functions to attenuate the peak of larger design storms.
- An emergency overflow outlet/spillway. The emergency spillway should be at the top of the berm.
- The primary outlet structure should incorporate weirs, orifices, pipes, or a combination of these to control runoff peak rates for multiple design storms. Water quality storage should be provided below the invert of the primary outlet. When routing basins, the low-flow outlet should be included in the depth-discharge relationship.
- Energy dissipaters should be placed at the end of the primary outlet to prevent erosion. If the basin discharges to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone between the outlet and natural channel. Where feasible, a multiple orifice outlet system is preferred to a single pipe.

Inlet structures

- Erosion protection measures should be used to stabilize inflow structures and channels.

Sediment forebay

- [Must be in compliance with local Stormwater Management Ordinance and standard detailed drawing requirements.](#)
- Forebays must be incorporated into the basin design. Forebays should be provided at all major inflow points to capture coarse sediment, prevent excessive sediment accumulation in the main basin, and minimize erosion by inflow.
- Forebays should be vegetated to improve filtering of runoff, to reduce runoff velocity, and to stabilize soils against erosion. Forebays should adhere to the following criteria:

- A minimum length of 10 feet.
- Storage should be provided to trap sediment over from storms with return periods between 1 and 10 years.
- Forebays should be physically separated from the rest of the pond by a berm, gabion wall, etc.
- Flows exiting the forebay must be non-erosive to the newly constructed basin.
- Forebays should be installed with permanent vertical markers that indicate sediment depth.
- Storage volume of 10 to 15 percent of the total permanent pool volume and is four to six feet deep.
- All major inflow points to dry detention basins should include sediment forebays sized for 10 percent of the water quality volume.

Vegetation and soils protection

- Care should be taken to prevent compaction of soils in the bottom of the extended detention basin in order to promote healthy plant growth and encourage infiltration. If soils compaction is not prevented during construction, soils should be restored as discussed in the Soils Restoration BMP.
- Basin bottoms and side slopes should be vegetated with a diverse native planting mix to reduce maintenance needs, promote natural landscapes, and increase infiltration potential.
- Vegetation may include trees, woody shrubs, and meadow/wetland herbaceous plants.
- Woody vegetation is generally discouraged in the embankment.
- Meadow grasses or other deeply rooted herbaceous vegetation is recommended on the interior slope of embankments.
- Fertilizers and pesticides should not be used.

General Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

Site preparation

All excavation areas, embankments, and structure locations should be cleared and grubbed as necessary, but trees and existing vegetation should be retained and incorporated within the dry detention basin area where possible. Trees should not be removed unless absolutely necessary.

Where feasible, trees and other native vegetation should be protected, even in areas where temporary inundation is expected. A minimum 10-foot radius around the inlet and outlet structures can be cleared to allow room for construction.

Any cleared material should be used as mulch for erosion control or soil stabilization.

Care should be taken to prevent compaction of the bottom of the reservoir. If compaction should occur, soils should be restored and amended.

Earth fill material & placement

- The fill material should be taken from approved designated excavation areas. It should be free of roots, stumps, wood, rubbish, stones greater than six inches, or other objectionable materials. Materials on the outer surface of the embankment must have the capability to support vegetation.
- Areas where fill is to be placed should be scarified prior to placement. Fill materials for the embankment should be placed in maximum eight-inch lifts. The principal spillway must be installed concurrently with fill placement and not excavated into the embankment.

- Control movement of the hauling and spreading equipment over the site.

Embankment core

- The core should be parallel to the centerline of the embankment as shown on the plans. The top width of the core should be at least four feet. The height should extend up to at least the 10-year water elevation or as shown on the plans. The side slopes should be 1:1 or flatter. The core should be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum permeability. The core should be placed concurrently with the outer shell of the embankment.
- Construction of the berm should follow specifications by the project's geotechnical engineer.

Structure backfill

- Backfill adjacent to pipes and structures should be of the type and quality conforming to that specified for the adjoining fill material. The fill should be placed in horizontal layers not to exceed eight inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material should fill completely all spaces under and adjacent to the pipe. At no time during the backfilling operation should driven equipment be allowed to operate closer than four feet to any part of the structure. Equipment should not be driven over any part of a concrete structure or pipe, unless there is a compacted fill of 24 inches or greater over the structure or pipe.
- Backfill content and placement should follow specifications by the project's geotechnical engineer.

Pipe conduits

Corrugated metal pipe – All of the following criteria should apply for corrugated metal pipe:

- Materials – Polymer coated steel pipe, aluminum coated steel pipe, aluminum pipe. This pipe and its appurtenances should conform to the requirements of AASHTO specifications with watertight coupling bands or flanges.
- Coupling bands, anti-seep collars, end sections, etc., must be composed of the same material and coatings as the pipe. Metals must be insulated from dissimilar materials with use of rubber or plastic insulating materials at least 24 mils in thickness.
- Connections – All connections with pipes must be completely watertight. The drain pipe or barrel connection to the riser should be welded all around when the pipe and riser are metal. Anti-seep collars should be connected to the pipe in such a manner as to be completely watertight. Dimple bands are not considered to be watertight.
- Bedding – The pipe should be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material should be removed and replaced with suitable earth compacted to provide adequate support.
- Backfilling should conform to “structure backfill.”
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Reinforced concrete pipe - All of the following criteria should apply for reinforced concrete pipe:

- Materials – Reinforced concrete pipe should have bell and spigot joints with rubber gaskets and should equal or exceed ASTM standards.
- Laying pipe – Bell and spigot pipe should be placed with the bell end upstream. Joints should be made in accordance with recommendations of the manufacturer of the material. After the joints are sealed for the entire line, the bedding should be placed so that all spaces under the pipe are filled. Take care to prevent any deviation from the original line and grade of the pipe.
- Backfilling should conform to “structure backfill.”

- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Plastic pipe

- Materials – PVC pipe should be PVC-1120 or PVC-1220 conforming to ASTM standards. Corrugated High Density Polyethylene (HDPE) pipe, couplings, and fittings should meet AASHTO specifications.
- Joints and connections to anti-seep collars should be completely watertight.
- Bedding – The pipe should be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material should be removed and replaced with suitable earth compacted to provide adequate support.
- Backfilling should conform to “structure backfill.”
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Drainage diaphragms – When a drainage diaphragm is used, a registered professional engineer must supervise the design and construction inspection.

Rock riprap

Rock riprap should meet the Construction BMP requirements contained in the Technical Standards document and the latest requirements of IDEM’s Soil Erosion and Sedimentation Control Program (Rule 5).

Stabilization

All borrow areas should be graded to provide proper drainage and left in a stabilized condition. All exposed surfaces of the embankment, spillway, spoil and borrow areas, and berms should be stabilized by seeding, planting, and mulching in accordance with Construction BMP requirements contained in the Technical Standards document and the latest requirements of IDEM’s Soil Erosion and Sedimentation Control Program (Rule 5).

Operation and maintenance

An operation and maintenance plan in accordance with local or state regulations must be prepared for all basins. At a minimum, include a dam and inspection checklist as part of the operation and maintenance plan and perform at least annually.

Stormwater Functions and Calculations

Volume reduction

Dry ponds do not provide an appreciable amount of volume reduction.

Peak rate mitigation

Inflow and discharge hydrographs must be calculated for each design storm.

Peak rate is primarily controlled through the transient storage above the bottom elevation of the dry detention facility. The degree to which peak rate is controlled is a function of the transient storage volume provided (i.e., depth and area) and the configuration of the outlet control structure.

Water quality improvement

The primary treatment mechanism is settling by gravity of particulates and their associated pollutants while stormwater is retained in the pond.

Construction Guidelines

The following guidelines pertain to dry ponds:

- Install all temporary erosion and sedimentation controls.
- Separate pond area from contributing drainage area.
- All channels/pipes conveying flows to the pond must be routed away from the pond area until it is completed and stabilized.
- Prior to construction of the pond, the area immediately adjacent to the pond must be stabilized in accordance with the erosion and sediment control methods discussed in the Erosion and Sediment Control Requirements Chapter of the Technical Standards and the latest requirements of

IDEM's Soil Erosion and Sedimentation Control Program (Rule 5).

- Prepare site for excavation and/or embankment construction.
- All existing vegetation should remain, if feasible, and only be removed if necessary for construction.
- Care should be taken to prevent compaction of the basin bottom.
- If excavation is required, clear the area of all vegetation. Remove all tree roots, rocks, and boulders only in excavation area.
 - Excavate bottom of basin to desired elevation (if necessary).
- Install surrounding embankments and inlet and outlet control structures.
- Grade and prepare subsoil in bottom of basin while taking care to prevent compaction. Equipment that will apply pressure to the basin bottom of less than or equal to four pounds per square inch is recommended. Compact only the surrounding embankment areas and around inlet and outlet structures.
 - Apply and grade planting soil.
 - Apply geo-textiles and other erosion-control measures.
- Seed, plant, and mulch according to landscaping plan.
- Install any safety or anti-grazing measures, if necessary.
- Follow required maintenance and monitoring guidelines.

Maintenance

Dry ponds must have a maintenance plan and privately owned facilities should have an easement, deed restriction, or other legal measure to prevent neglect or removal.

A basin maintenance plan should be developed which includes the following measures:

- All basin structures should be inspected for clogging and excessive debris and sediment accumulation at least four times per year, as well as after every storm greater than one inch. Structures that should be inspected include basin bottoms, trash racks, outlets

structures, riprap or gabion structures, and inlets.

- Sediment should be removed from the forebay before it occupies 50 percent of the forebay, typically every three to 10 years. Sediment removal should be conducted when the basin is completely dry.
- Sediment should be disposed of properly and once sediment is removed, disturbed areas need to be immediately stabilized and re-vegetated. Proper disposal of removed material depends on the nature of the drainage area and the intent and function of the detention basin. Material removed from detention basins that treat hot spots, such as fueling stations or areas with high pollutant concentrations, should be disposed according to IDEM regulations for solid waste. Detention basins that primarily catch sediment from areas such as lawns may redistribute the waste on site.
- The pond drain should be inspected and tested four times per year.
- The embankment should be inspected for evidence of tunneling or burrowing wildlife at least twice during the growing season. If damage is found, the damage should be repaired and the animals removed.
- Mowing and/or trimming of vegetation should be performed as necessary to sustain the system, but all detritus must be removed from the basin. Embankment should be mowed 1–2 times per year to prevent the establishment of woody vegetation.
- Inspections should assess the vegetation, erosion, flow channelization, bank stability, inlet/outlet conditions, embankment, and sediment/debris accumulation.
- Vegetated areas should be inspected annually for unwanted growth of invasive species.

- Vegetative cover should be maintained at a minimum of 85 percent.

Winter Considerations

Dry ponds should be inspected and maintained during winter months. Application of sand, ash, cinders, or other anti-skid materials may cause sediment forebays to fill more quickly. Otherwise, dry ponds should function as intended in cold weather.

Cost

The construction costs associated with dry ponds can vary considerably. One study evaluated the cost of all pond systems (Brown and Schueler, 1997). Adjusting for inflation, the cost of dry extended detention ponds can be estimated with the equation:

$$C = 12.4V^{0.760}$$

Where:

C = Construction, design and permitting cost

V = Volume needed to control the 10-year storm (ft³)

Using this equation, typical construction costs are:

\$41,600 for a one acre-foot pond

\$239,000 for a 10 acre-foot pond

\$1,380,000 for a 100 acre-foot pond

Dry ponds using highly structural design features (riprap for erosion control, etc.) are more costly than natural basins. An installation cost savings is associated with a natural vegetated slope treatment, which is magnified by the additional environmental benefits provided. Long-term maintenance costs for processes such as mowing and fertilizing are reduced when more naturalized approaches are used, due to the ability of native vegetation to adapt to local weather conditions and a reduced need for maintenance.

Annual maintenance costs for dry ponds have been reported to be approximately three to five percent of the capital costs, though there is little data available to support this. Alternatively, a community can estimate the cost of the maintenance activities

outlined in the maintenance section. Ponds are long-lived facilities (typically longer than 20 years). Thus, the initial investment into pond systems may be spread over a relatively long time period.

Designer/Reviewer Checklist for Dry Extended Detention Ponds

ITEM	Page No.	YES	NO	N/A	NOTES
Used in conjunction with other BMPs for groundwater recharge and/or water quality?	1				
Adequate drainage area/water supply/groundwater table to maintain permanent water surface? <i>Max. drainage area: 50 acres</i>	2				
Relatively impermeable soils and/or soil modification?	--				
Stable inflow points provided?	6				
Forebay and/or pretreatment provided for sediment removal? <i>Min. width of permanent access: 9 ft</i> <i>Max. slope: 15%</i> <i>Min. length of forebay: 10 ft</i>	3,6				
Adequate length to width ratio? ➤ <i>Min. length-to-width ratio: 3:1</i>	3				
Appropriate and varying water depths? <i>Max. water depth: 4 feet</i> <i>Lowest elevation: at least 2 feet above seasonal high water table</i>	3				
Acceptable side slopes? <i>Max. side slopes: 3:1</i>	4				
Safety benches provided?	--				
Properly designed outlet structure?	5				
➤ Dewatering mechanism provided?	--				
Trash rack provided to prevent clogging?	5				
Stable emergency overflow and outflow points?	5				
Soil compaction minimized?	6,9				
Adequate soils for plantings?	--				
Appropriate native plants selected in and around pond?	6				
25-foot buffer provided?	--				
Erosion and sedimentation control considered?	8,9				
Maintenance accounted for and plan provided?	10				

➤ *Denotes Minimum Design Consideration*

References

- AMEC Earth and Environmental Center for Watershed Protection, et al. *Georgia Stormwater Management Manual*, 2001.
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U.S. Environmental Protection Agency. *Constructed Wetlands Treatment for Municipal Wastewaters Manual*. Cincinnati, OH: National Risk Management Research Laboratory, Office of Research and Development, 2000. EPA/625/R-99/010. www.epa.gov/owow/wetlands/pdf/Design_Manual2000.pdf

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BMP Fact Sheet

DETENTION BASINS - UNDERGROUND DETENTION

An Underground Detention system is a type of detention basin that is completely underground.



Figure 1 Photograph courtesy of Vertex Design Group

Variations

- Underground Detention Beds
- Underground Vaults

Key Design Features

- Storage capacity highly dependent on available site area
- Outlet structure configuration determines peak rate reduction effectiveness
- Regular maintenance of vegetation and sediment removal required
- Relatively impermeable soils or impermeable liner
- Forebay for sediment collection and removal
- Stabilized emergency overflow and energy dissipation at all outlets

Applications	
Residential	Yes
Commercial	Yes
Ultra Urban	Yes
Industrial	Yes
Retrofit	Yes
Highway/Road	Yes
Recreational	Yes

Stormwater Quantity Functions	
Volume	Low
Groundwater Recharge	None or Low
Peak Rate	High

Stormwater Quality Functions

Type	TSS	TP	TN	Temperature
Underground Detention	N/A	N/A	N/A	N/A

Site Factors

Type	Basin Bottom Relative to Water Table	Soils	Slope	Potential Hotspots	Max. Drainage Area (acres)	Benefits	Limitations
Under-ground Detention	Above	N/A	Low/Med	Yes w/ considerations	30	Dual use, good peak rate performance, wide applicability (including ultra-urban and redevelopment.)	Low volume/GW recharge and water quality benefits, must be combined with other BMPs, high cost, maintenance considerations

*C or D soils typically work without modification. A and B soils may require modifications to reduce their permeability.

Additional Considerations

Cost

- The cost of each basin is highly dependent on the size of the basin and site characteristics.

Maintenance

Type	Maintenance
Underground Detention	Med/High

Winter Performance

- Med/High

Description and Function

Underground systems can be provided in a variety of subsurface structural elements, such as underground aggregate-filled beds or vaults, tanks, large pipes, or other fabricated structures placed in aggregate-filled beds in the soil mantle. All such systems are designed to provide runoff peak rate attenuation as their primary function. Regular maintenance is required, because sediment must be removed from the structures within their respective design periods to ensure detention capacity for subsequent rainfall events.

Applications

Detention systems can be used in a wide variety of applications when the necessary space is available. Their use is limited in ultra-urban areas and some redevelopment projects simply due to a lack of available space (in these cases underground and/or special detention may be used).

Variations

Underground detention

These facilities are usually intended for applications on sites where space is limited and are not intended to provide significant water quality treatment. Examples include:

Underground detention beds

Underground detention beds can be constructed by excavating a broad area and filling it with uniformly graded aggregate. Runoff can be stored within the void spaces of the aggregate while the aggregate bed structurally supports overlying land uses.

- Storage design and routing methods are the same as for surface detention basins.
- Underground detention beds may be used where space is limited, but subsurface infiltration is not feasible due to high water table conditions, shallow soil mantle, or poorly draining soils.
- Underground detention beds provide minimal water quality treatment and should

be used in combination with a pretreatment BMP.

- Except where runoff is, or may become toxic and contamination of soil or the water table below the site is possible, underground detention beds should not be lined with an impervious geomembrane. By not installing a geomembrane, a minimal amount of infiltration may still occur. If infiltration is allowed, proper pretreatment is necessary to avoid polluting groundwater. See the infiltration practices BMP for more information.

Underground vaults

Underground vaults are stormwater storage facilities usually constructed of precast reinforced concrete or a structural high density polyethylene plastic system. Tanks are usually constructed of large diameter metal or plastic pipe. Concrete, metal, or plastic pipes may also be installed with no slope as part of a network designed for storage.

- Storage design and routing methods are the same as for surface detention basins.
- Underground detention beds may be used where space is limited but subsurface infiltration is not feasible due to high water table conditions, a shallow soil mantle, or poorly draining soils.
- Underground vaults provide minimal water quality treatment and should be used in combination with a pretreatment BMP.

Design Considerations

Hydrology

- Underground detention basins should be designed to mitigate peak runoff rates for the 1-year through 100-year rainfall events.
- Inflow and discharge hydrographs should be calculated for each selected design storm. Hydrographs should be based on the 24-hour rainfall event or that required in the local Stormwater Ordinance. Typically, the NRCS 24-hour Type II rainfall distribution should be utilized to generate hydrographs.

Storage volume, depth, and duration

- If water quality treatment is one of the objectives of the system, the underground detention basins should be designed to treat the runoff volume produced by the water quality design storm, unless additional upstream BMPs are provided.
- Detention time is defined as the time from when the maximum storage volume is reached until only 10 percent of that volume remains in the basin.

Detention basin location

- Underground detention basins should be located down gradient of disturbed or developed areas on the site. The basin should collect as much site runoff as possible, especially from the site's impervious surfaces (roads, parking, buildings, etc.), and where other BMPs are not proposed.
- Basins should not be constructed on steep slopes, nor should slopes be significantly altered or modified to reduce the steepness of the existing slope, for the purpose of installing a basin.
- Basins should not worsen the runoff potential of the existing site by removing trees for the purpose of installing a basin.
- Basins should not be constructed within 10 feet of the property line or within 50 feet of a private well or septic system.
- Detention basins should not be constructed in areas with high quality and/or well-draining soils, which are adequate for installing BMPs capable of achieving stormwater infiltration and, hence, volume reduction.

Outlet design

- The low-flow orifice should typically be no smaller than 4 inches in diameter. However, the orifice diameter may be reduced to 2 inches if adequate protection from clogging is provided.
- The hydraulic design of all outlet structures must consider any significant tailwater effects of downstream waterways.
- The primary and low flow outlets should be protected from clogging by an external trash rack or other mechanism.

Inlet structures

- Erosion protection measures should be used to stabilize inflow structures and channels.
- Cleanouts or inlets should be installed at a few locations within the system at appropriate intervals to allow access to the piping network and/or storage media and

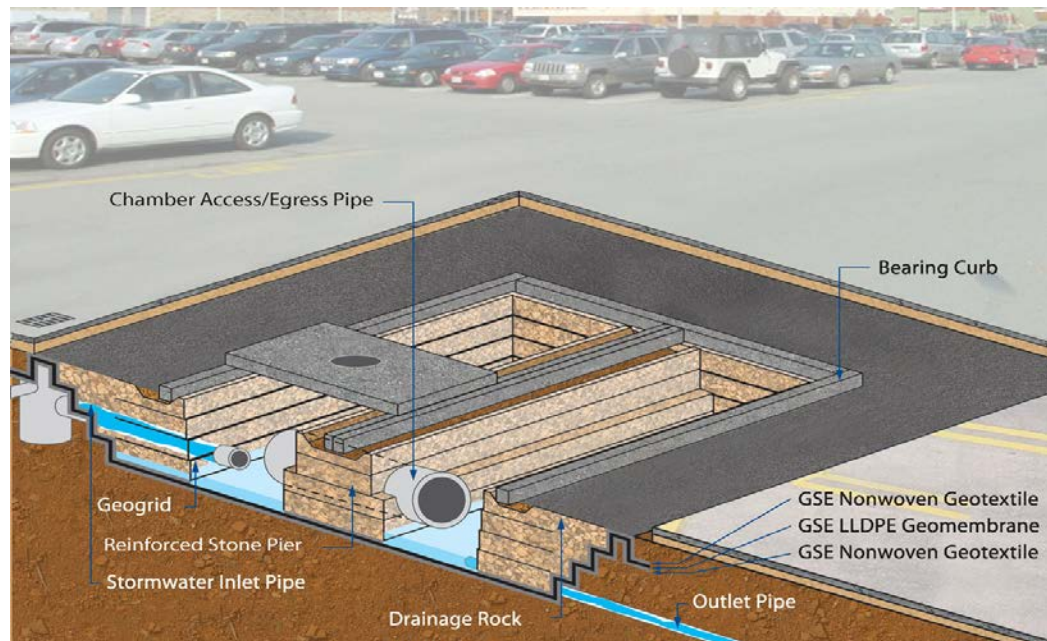


Figure 2 Schematic of underground detention facility, courtesy of CETCO Contracting Services

Vegetation and soils protection

- Underground systems that provide storage within the void space of a stone layer should be wrapped (bottom, top, and sides) in nonwoven geotextile filter fabric to prevent migration of the subsoils into the voids.
- Control of sediment is critical. Rigorous erosion and sediment control measures are required to prevent sediment deposition within the underground system. Nonwoven geotextile may be folded over the edge of the system until the site is stabilized. To minimize maintenance and prevent siltation of the system, pretreatment devices are strongly recommended.
- Aggregate, if used for storage, should be clean, durable and contain a high percentage of void space (typically 40 percent).
- Perforated pipes, if used to distribute runoff to/from the system, should connect structures (such as cleanouts and inlet boxes).

complete removal of accumulated sediment.

General Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

Underground structures

Site preparation

All excavation areas and structure locations should be cleared and grubbed as necessary.

Where feasible, trees and other native vegetation should be protected, even in areas where temporary inundation is expected. A minimum 10-foot radius around the inlet and outlet structures can be cleared to allow room for construction.

Any cleared material should be used as mulch for erosion control or soil stabilization.

Care should be taken to prevent compaction of the bottom of the reservoir. If compaction should occur, soils should be restored and amended.

Structure backfill

- Backfill adjacent to pipes and structures should be of the type and quality conforming to that specified for the adjoining fill material. The fill should be placed in horizontal layers not to exceed eight inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material should fill completely all spaces under and adjacent to the pipe. At no time during the backfilling operation should driving equipment be allowed to operate closer than four feet to any part of the structure. Equipment should not be driven over any part of a concrete structure or pipe, unless there is a compacted fill of 24 inches or greater over the structure or pipe.
- Backfill content and placement should follow specifications by the project's geotechnical engineer.

Pipe conduits

Corrugated metal pipe – All of the following criteria should apply for corrugated metal pipe:

- Materials – Polymer coated steel pipe, aluminum coated steel pipe, aluminum pipe. This pipe and its appurtenances should conform to the requirements of AASHTO specifications with watertight coupling bands or flanges.
- Coupling bands, anti-seep collars, end sections, etc., must be composed of the same material and coatings as the pipe. Metals must be insulated from dissimilar materials with use of rubber or plastic insulating materials at least 24 mils in thickness.
- Connections – All connections with pipes must be completely watertight. The drain

pipe or barrel connection to the riser should be welded all around when the pipe and riser are metal. Anti-seep collars should be connected to the pipe in such a manner as to be completely watertight. Dimple bands are not considered to be watertight.

- Bedding – The pipe should be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material should be removed and replaced with suitable earth compacted to provide adequate support.
- Backfilling should conform to “structure backfill.”
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Reinforced concrete pipe - All of the following criteria should apply for reinforced concrete pipe:

- Materials – Reinforced concrete pipe should have bell and spigot joints with rubber gaskets and should equal or exceed ASTM standards.
- Laying pipe – Bell and spigot pipe should be placed with the bell end upstream. Joints should be made in accordance with recommendations of the manufacturer of the material. After the joints are sealed for the entire line, the bedding should be placed so that all spaces under the pipe are filled. Take care to prevent any deviation from the original line and grade of the pipe.
- Backfilling should conform to “structure backfill.”
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Plastic pipe

- Materials – PVC pipe should be PVC-1120 or PVC-1220 conforming to ASTM standards. Corrugated High Density Polyethylene (HDPE) pipe, couplings, and fittings should meet AASHTO specifications.
- Joints and connections to anti-seep collars should be completely watertight.
- Bedding – The pipe should be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other

unstable soil is encountered, all such material should be removed and replaced with suitable earth compacted to provide adequate support.

- Backfilling should conform to “structure backfill.”
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Drainage diaphragms – When a drainage diaphragm is used, a registered professional engineer must supervise the design and construction inspection.

Operation and maintenance

An operation and maintenance plan in accordance with local or state regulations must be prepared for all underground detention basins. At a minimum, include a dam and inspection checklist as part of the operation and maintenance plan and perform at least annually.

Stormwater Functions and Calculations

Volume reduction

Underground detention systems do not provide an appreciable amount of volume reduction.

Peak rate mitigation

Inflow and discharge hydrographs must be calculated for each design storm.

Peak rate is primarily controlled in detention facilities through the transient storage above any permanent water surface. The degree to which peak rate is controlled is a function of the transient storage volume provided (i.e., depth and area) and the configuration of the outlet control structure.

Water quality improvement

Underground detention facilities are usually intended for applications on sites where space is limited and are not intended to provide significant water quality treatment. When appropriate, underground detention may incorporate infiltration practices. For limitations refer to Infiltration Considerations (Introduction to Structural BMPs).

Construction Guidelines

Underground detention systems should be installed per the manufacturer’s recommendations.

Maintenance

Underground detention facilities must have a maintenance plan and privately owned facilities should have an easement, deed restriction, or other legal measure to prevent neglect or removal.

Maintenance activities required for underground detention systems focus on regular sediment and debris removal. All catch basins, inlets, and pretreatment devices draining to the underground bed should be inspected and cleaned at least two times per year. The underground bed and its outlet should be inspected at least once per year and cleaned as needed. A basin maintenance plan should be developed which includes the following measures:

- All basin structures should be inspected for clogging and excessive debris and sediment accumulation at least four times per year, as well as after every storm greater than one inch. Structures that should be inspected include basin bottoms, trash racks, outlets structures, riprap or gabion structures, and inlets.
- Sediment should be disposed of properly and once sediment is removed, disturbed areas need to be immediately stabilized and re-vegetated. Proper disposal of removed material depends on the nature of the drainage area and the intent and function of the detention basin. Material removed from detention basins that treat hot spots, such as fueling stations or areas with high pollutant concentrations, should be disposed according to IDEM regulations for solid waste. Detention basins that primarily catch sediment from areas such as lawns may redistribute the waste on site.
- The underground detention drain should be inspected and tested four times per year.

- Inspections should assess the inlet/outlet conditions and sediment/debris accumulation.

Cost

The construction cost of underground detention can vary greatly depending on the design, configuration, location, storage volume and media, and site specific conditions, among other factors. Typical construction costs are approximately \$8 to \$10 per cubic foot for proprietary high capacity storage systems. Systems using uniformly graded aggregate as the primary storage media will typically be less expensive but require additional area and/or depth for an equivalent storage volume.

Designer/Reviewer Checklist for Underground Detention

ITEM	Page No.	YES	NO	N/A	NOTES
Used in conjunction with other BMPs for water quality and groundwater recharge?	1,4				
Stable inflow points provided?	4				
➤ Pretreatment provided for sediment removal?	5				
Properly designed outlet structure?	4				
Adequate cleanouts/maintenance access provided?	5				
Stable emergency overflow and outflow points?	--				
Drawdown time less than 36 hours for 90% of stored volume?	--				
Soil compaction minimized?	5				
Clean, washed, open-graded aggregate specified, if applicable?	5				
Geotextile specified?	5				
If proprietary storage media is used, were the manufacturer recommendations followed?	--				
Appropriate native plants selected, if applicable?	--				
Erosion and sedimentation control considered?	5				
Maintenance accounted for and plan provided?	7				

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AMEC Earth and Environmental Center for Watershed Protection, et al. *Georgia Stormwater Management Manual*, 2001.

Brown, W. and T. Schueler. *The Economics of Stormwater BMPs in the Mid-Atlantic Region*. Ellicott City, MD: Center for Watershed Protection, 1997.

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BMP Fact Sheet

DETENTION BASINS - WET POND

Wet Ponds, also called wet-bottom detention ponds, are earthen structures that provide temporary storage of runoff and release the stored volume of water over time to help reduce flooding while providing a permanent pool of water for aesthetics, recreation, and settlement of sediments.



Figure 1 Pond collecting runoff from rooftops, sidewalks, and yards, Wilsonville, Oregon (USEPA, picasaweb)

Applications	
Residential	Yes
Commercial	Yes
Ultra Urban	No
Industrial	Yes
Retrofit	Yes
Highway/Road	Yes
Recreational	Yes

Stormwater Quality Functions

Type	TSS	TP	TN	Temperature
Wet Pond	High	Medium	Medium	Low/Medium

Key Design Features

- Wet Ponds
- Wet Detention Ponds
- Pocket Wet Ponds

Key Design Features

- Storage capacity highly dependent on available site area
- Outlet structure configuration determines peak rate reduction effectiveness
- Regular maintenance of vegetation and sediment removal required
- Natural high groundwater table required
- Relatively impermeable soils or impermeable liner
- Optional forebay for sediment collection and removal
- Dewatering mechanism required
- Stabilized emergency overflow and energy dissipation at all outlets

Stormwater Quantity Functions	
Volume	Low
Groundwater Recharge	None or Low
Peak Rate	High

Site Factors

Type	Basin Bottom Relative to Water Table	Soils	Slope	Potential Hotspots	Max. Drainage Area (acres)	Benefits	Limitations
Wet Pond	Can be below WT	C or D*	Low	Yes w/ considerations	50	Good peak rate & TSS performance, wide applicability, potential aesthetic value; can be used as temporary sediment basin	Low volume/GW recharge benefits, high total cost, potentially thermal impact

*C or D soils typically work without modification. A and B soils may require modifications to reduce their permeability.

Additional Considerations

Cost

- High – Cost for above ground basins must include excavation of basin, construction of berm, and installation of storm sewer conveyance system, including pipes and structures. Additional cost may be added for enhanced vegetation.
- The cost of each basin is highly dependent on the size of the basin and site characteristics.

Maintenance

Type	Maintenance
Wet Pond	Low/Med

Winter Performance

- Med/High

Description and Function

Wet ponds are earthen structures that provide temporary storage of runoff and release the stored volume of water over time to help reduce flooding. They are constructed either by impounding a natural depression or excavating existing soil, and are intended to enhance the settlement process in order to maximize water quality benefits, while achieving reduced runoff volume.

Wet ponds include a permanent pool for water quality treatment and additional capacity above the permanent pool for temporary storage. The pond perimeter should generally be covered by a dense stand of emergent wetland vegetation. While they do not achieve significant groundwater recharge or volume reduction, wet ponds can be effective for pollutant removal and peak rate mitigation.

Wet ponds can also provide aesthetic and wildlife benefits. Wet ponds require an adequate source of inflow to maintain the permanent water surface. Due to the potential to discharge warm water, wet ponds should be used with caution near temperature-sensitive water bodies. Properly designed and maintained wet ponds generally do not support significant mosquito populations.

Applications

Wet ponds can be used in a wide variety of applications when the necessary space is available. Their use is limited in ultra urban areas and some redevelopment projects simply due to a lack of available space (in these cases underground and/or special detention may be used).

Variations

Wet ponds can be designed as either online or offline facilities. They can also be used effectively in series with other sediment-reducing BMPs, such as vegetated filter strips, swales, and filters. Wet ponds may be a good option for retrofitting existing

dry detention basins. Wet ponds are often organized into the following three groups:

- **Wet ponds** primarily accomplish water quality improvement through displacement of the permanent pool and are generally only effective for small inflow volumes (often they are placed offline to regulate inflow).
- **Wet detention ponds** are similar to wet ponds but use extended detention as another mechanism for water quality and peak rate control. (Discussion of wet ponds in this BMP section focuses on wet detention ponds as described above because this tends to be the most common and effective design.)
- **Pocket wet ponds** are smaller wet ponds that serve drainage areas between approximately 5 and 10 acres and are constructed near the water table to help maintain the permanent pool. They often include extended detention.

Design Considerations

Hydrology

- Wet ponds should be designed to mitigate peak runoff rates for the 1-year through 100-year rainfall events.
- Inflow and discharge hydrographs should be calculated for each selected design storm. Hydrographs should be based on the 24-hour rainfall event or that required in the local Stormwater Ordinance. Typically, the NRCS 24-hour Type II rainfall distribution should be utilized to generate hydrographs.
- Wet ponds must be able to receive and retain enough flow from rain, runoff, and groundwater to ensure long-term viability. A permanent water surface in the deeper areas of the wet pond should be maintained during all but the driest periods. A relatively stable permanent water surface elevation will reduce the stress on vegetation in an area adjacent to the pond. A wet pond should have a drainage area of at least 10 acres (5 acres for pocket wet ponds) or some means of sustaining constant inflow. Even with a large drainage area, a constant source of inflow can improve the biological health and effectiveness of a wet pond while discouraging mosquito growth.

Storage volume, depth, and duration

- Wet ponds should be designed to treat the runoff volume produced by the water quality design storm unless additional upstream BMPs are provided.
- Detention time is defined as the time from when the maximum storage volume is reached until only 10 percent of that volume remains in the basin. In order to achieve an 80 percent total suspended solids removal rate, a 36-hour detention time is required, with no more than 40% of the maximum stored volume released within the first 12 hours.

Additional design considerations for extended detention (Figure 2)

The low flow orifice should be sized and positioned to detain the calculated water quality runoff volume for at least 24 hours, but no more than 36 hours. The low flow orifice may be allowed as small as 4 inches in diameter if adequate protection from clogging is provided.

Basin sizing and configuration

- Wet ponds should be shaped to maximize the hydraulic length of the stormwater flow pathway. A minimum length-to width ratio of 3:1 is recommended to maximize sedimentation. If the length-to-width ratio is lower, the flow pathway should be maximized. A wedge-shaped pond with the major inflows on the narrow end can prevent short-circuiting and stagnation.
- Irregularly shaped basins are acceptable and may even be encouraged to improve site aesthetics.
- Distances of flow paths from inflow points to outlets should be maximized.
- If site conditions inhibit construction of a long, narrow basin, baffles consisting of earthen berms or other materials can be incorporated into the pond design to lengthen the stormwater flow path.
- Basins may have one or more sediment forebays or equivalent upstream pretreatment to trap coarse sediment, prevent short circuiting and facilitate maintenance (i.e., sediment removal). The forebay should

consist of a separate cell, formed by a structural barrier. The forebay will require periodic sediment removal.

- Permanent access must be provided to the forebay, outlet, and embankment areas. It should be at least nine feet wide, having a maximum slope of 15 percent, and be stabilized for vehicles.
- An emergency outlet or spillway capable of conveying the spillway design flood (SDF) must be included in the design. The SDF is usually equal to the 1.25 times the 100-year design flood.
- The area required for a wet pond is generally one to three percent of its drainage area. Wet ponds should be sized to treat the water

quality volume and to mitigate the peak rates for larger events.

- All areas that are deeper than four feet should have two safety benches, totaling 15 feet in width. One should start at the normal water surface and extend up to the pond side slopes at a maximum slope of 10 percent. The other should extend from the water surface into the pond to a maximum depth of 18 inches, also at slopes no greater than 10 percent.
- Slopes in and around wet ponds should be 4:1 to 5:1 (horizontal: vertical) or flatter whenever possible (10:1 max. for safety/aquatic benches).

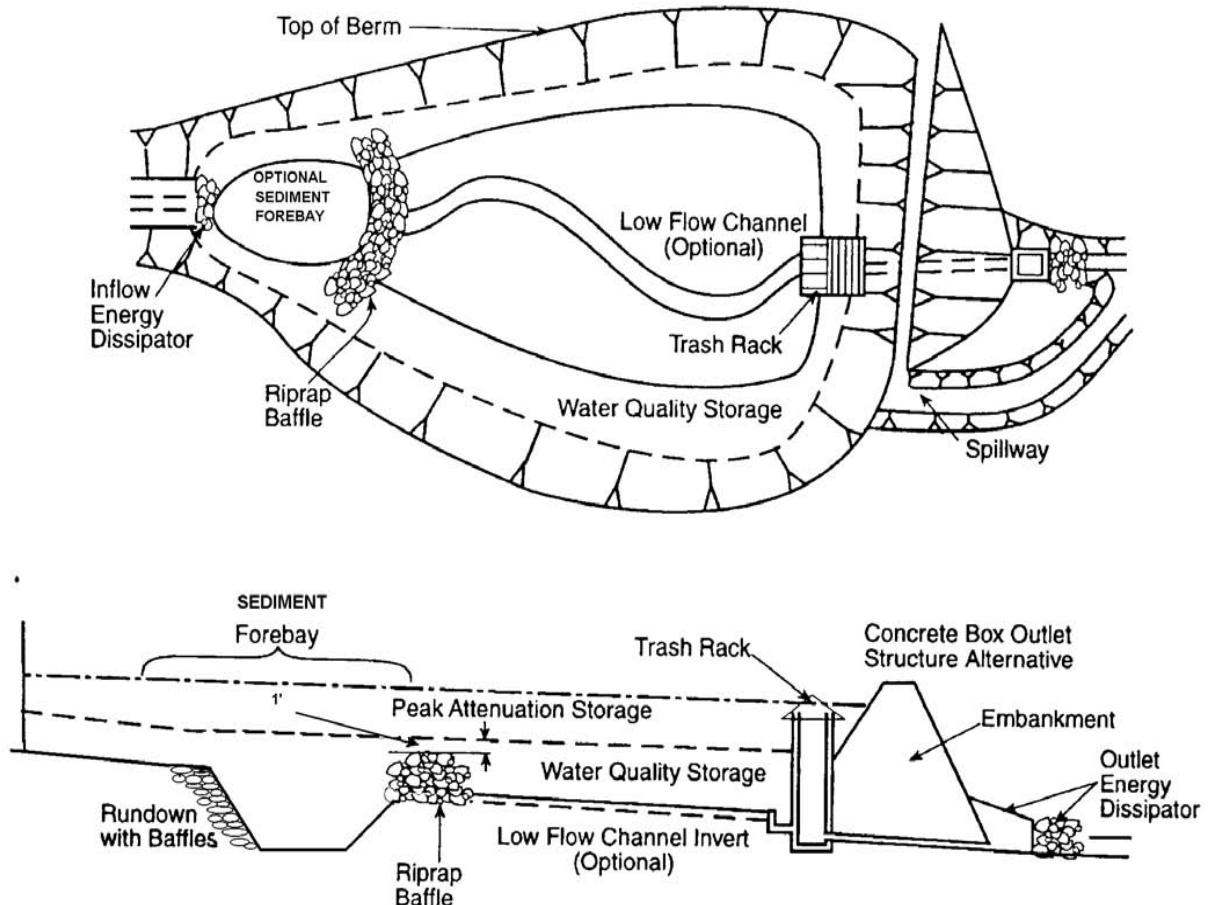


Figure 2 Extended detention basin
Source: New Jersey BMP Manual

Embankments

- Vegetated embankments less than or equal to three feet in height are recommended. Embankments should have side slopes no steeper than 3:1 (horizontal to vertical).
- The basin should have a minimum freeboard of one foot above the SDF elevation to the top of the berm.
- Woody vegetation is generally discouraged in the embankment area because of the risk of compromising the integrity of the embankment.
- Embankments should incorporate measures, such as buried chain link fencing, to prevent or discourage damage from tunneling wildlife (e.g., muskrat).

Wet pond location

- Wet ponds should be located down gradient of disturbed or developed areas on the site. The wet pond should collect as much site runoff as possible, especially from the site's impervious surfaces (roads, parking, buildings, etc.), and where other BMPs are not proposed.
- Wet ponds should not be constructed on steep slopes, nor should slopes be significantly altered or modified to reduce the steepness of the existing slope, for the purpose of installing a wet pond.
- Wet ponds should not worsen the runoff potential of the existing site by removing trees for the purpose of installing a wet pond.
- Wet ponds should not be constructed within 10 feet of the property line or within 50 feet of a private well or septic system.
- Wet ponds should not be constructed in areas with high quality and/or well draining soils, which are adequate for installing BMPs capable of achieving stormwater infiltration and, hence, volume reduction.

Additional design considerations for extended detention (Figure 2)

- Wet detention ponds should not be constructed within jurisdictional waters, including wetlands, or their regulated buffers.

Outlet design

- The low-flow orifice should typically be no smaller than 4 inches in diameter. However, the orifice diameter may be reduced to two inches if adequate protection from clogging is provided.
- The hydraulic design of all outlet structures must consider any significant tailwater effects of downstream waterways.
- The primary and low flow outlets should be protected from clogging by an external trash

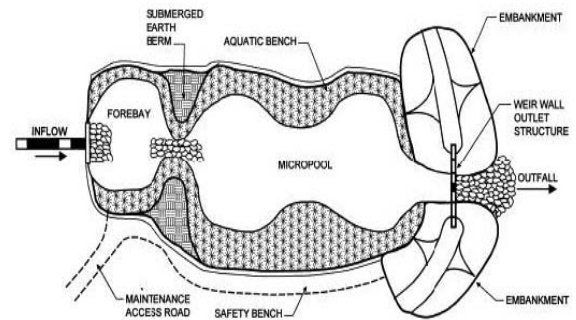


Figure 3 Pocket wet pond

Source: Maryland Stormwater Manual, 2000

- rack or other mechanism.
- Online facilities should have an emergency spillway that can safely pass the 1.25 times the 100-year storm with one foot of freeboard. All outflows should be conveyed downstream in a safe and stable manner.
- When designed to meet discharge criteria for a range of storms, basins should incorporate a multistage outlet structure. Three elements are typically included in this design:
 - An outlet that controls the extended detention and functions to slowly release the water quality or channel protection design storm.
 - A primary outlet that functions to attenuate the peak of larger design storms.
 - An emergency overflow outlet/spillway. The emergency spillway should be at the top of the berm.
- The primary outlet structure should incorporate weirs, orifices, pipes, or a combination of these to control runoff peak rates for multiple design storms. Water quality storage should be provided above the permanent pool elevation. When routing

basins, the water quality outlet should be included in the depth-discharge relationship.

- Energy dissipaters should be placed at the end of the primary outlet to prevent erosion. If the basin discharges to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone between the outlet and natural channel. Where feasible, a multiple orifice outlet system is preferred to a single pipe.

Inlet structures

- Erosion protection measures should be used to stabilize inflow structures and channels.

Sediment forebay

- Forebays must be in compliance with local Stormwater Management Ordinance and standard detailed drawing requirements.
- Forebays may be incorporated into the basin design, provided at all major inflow points to capture coarse sediment, prevent excessive sediment accumulation in the main basin, and minimize erosion by inflow.
- Forebays should be vegetated to improve filtering of runoff, to reduce runoff velocity, and to stabilize soils against erosion. Forebays should adhere to the following criteria:
 - A minimum length of 10 feet.
 - Storage should be provided to trap sediment over from storms with return periods between 1 and 10 years.
 - Forebays should be physically separated from the rest of the pond by a berm, gabion wall, etc.
 - Flows exiting the forebay must be non-erosive to the newly constructed basin.
 - Forebays should be installed with permanent vertical markers that indicate sediment depth.
 - Storage volume of 10 to 15 percent of the total permanent pool volume and is four to six feet deep.
 - All major inflow points to dry detention basins should include sediment forebays sized for 10 percent of the water quality volume.

Vegetation and soils protection

- Underlying soils must be identified and tested. Generally, hydrologic soil groups “C” and “D” are suitable without modification, though “A” and “B” soils may require modification to reduce their natural permeability. Soil permeability must be tested in the proposed wet pond location to ensure that excessive infiltration will not cause the wet pond to dry out.
- Organic soils should be used for shallow areas within wet ponds. Organic soils can serve as a sink for pollutants and generally have high water holding capacities. They will also facilitate plant growth and propagation and may hinder invasion of undesirable species. Care must be taken to ensure that soils used are free of invasive or nuisance plant seeds.
- To enhance habitat value, visual aesthetics, water temperature, and pond health, a 25-foot buffer should be provided, measured outward from the maximum water surface elevation. The buffer should be planted with trees, shrubs, and native ground covers. Except in maintenance access areas, turf grass should not be used. Existing trees within the buffer should be preserved. If soils in the buffer will become compacted during construction, soil restoration should take place to aid buffer vegetation.

General Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

Excavation

- The area to be used for the wet pond should be excavated to the required depth below the desired bottom elevation to accommodate any required impermeable liner, organic matter, and/or planting soil.

- The compaction of the subgrade and/or the installation of any impermeable liners will follow immediately.

Subsoil preparation

- Subsoil should be free from hard clods, stiff clay, hardpan, ashes, slag, construction debris, petroleum hydrocarbons, or other undesirable material. Subsoil must not be delivered in a frozen or muddy state.
- Scarify the subsoil to a depth of 8 to 10 inches with a disk, rototiller, or similar equipment.
- Roll the subsoil under optimum moisture conditions to a dense seal layer with four to six passes of a sheepsfoot roller or equivalent. The compacted seal layer should be at least eight inches thick.

Impermeable liner

- If necessary, install impermeable liner in accordance with manufacturer's guidelines.
- Place a minimum 12 inches of subsoil on top of impermeable liner in addition to planting soil.
- May be required when in proximity to a public water supply. See Infiltration Considerations (Introduction to Structural BMPs).

Earth fill material & placement

- The fill material should be taken from approved designated excavation areas. It should be free of roots, stumps, wood, rubbish, stones greater than six inches, or other objectionable materials. Materials on the outer surface of the embankment must have the capability to support vegetation.
- Areas where fill is to be placed should be scarified prior to placement. Fill materials for the embankment should be placed in maximum eight-inch lifts. The principal spillway must be installed concurrently with fill placement and not excavated into the embankment.
- Control movement of the hauling and spreading equipment over the site.

Embankment core

- The core should be parallel to the centerline of the embankment as shown on the plans. The top width of the core should be at least four feet. The height should extend up to at least the 10-year water elevation or as shown on the plans. The side slopes should be 1:1 or flatter. The core should be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum permeability. The core should be placed concurrently with the outer shell of the embankment.
- Construction of the berm should follow specifications by the project's geotechnical engineer.

Structure backfill

- Backfill adjacent to pipes and structures should be of the type and quality conforming to that specified for the adjoining fill material. The fill should be placed in horizontal layers not to exceed eight inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material should completely fill all spaces under and adjacent to the pipe. At no time during the backfilling operation should driving equipment be allowed to operate closer than four feet to any part of the structure. Equipment should not be driven over any part of a concrete structure or pipe, unless there is a compacted fill of 24 inches or greater over the structure or pipe.
- Backfill content and placement should follow specifications by the project's geotechnical engineer.

Pipe conduits

Corrugated metal pipe – All of the following criteria should apply for corrugated metal pipe:

- Materials – Polymer coated steel pipe, aluminum coated steel pipe, aluminum pipe. This pipe and its appurtenances should conform to the requirements of AASHTO specifications with watertight coupling bands or flanges.

- Coupling bands, anti-seep collars, end sections, etc., must be composed of the same material and coatings as the pipe. Metals must be insulated from dissimilar materials with use of rubber or plastic insulating materials at least 24 mils in thickness.
- Connections – All connections with pipes must be completely watertight. The drain pipe or barrel connection to the riser should be welded all around when the pipe and riser are metal. Anti-seep collars should be connected to the pipe in such a manner as to be completely watertight. Dimple bands are not considered to be watertight.
- Bedding – The pipe should be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material should be removed and replaced with suitable earth compacted to provide adequate support.
- Backfilling should conform to “structure backfill.”
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Reinforced concrete pipe - All of the following criteria should apply for reinforced concrete pipe:

- Materials – Reinforced concrete pipe should have bell and spigot joints with rubber gaskets and should equal or exceed ASTM standards.
- Laying pipe – Bell and spigot pipe should be placed with the bell end upstream. Joints should be made in accordance with recommendations of the manufacturer of the material. After the joints are sealed for the entire line, the bedding should be placed so that all spaces under the pipe are filled. Take care to prevent any deviation from the original line and grade of the pipe.
- Backfilling should conform to “structure backfill.”
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Plastic pipe

- Materials – PVC pipe should be PVC-1120 or PVC-1220 conforming to ASTM standards. Corrugated High Density Polyethylene (HDPE) pipe, couplings, and fittings should meet AASHTO specifications.

- Joints and connections to anti-seep collars should be completely watertight.
- Bedding – The pipe should be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material should be removed and replaced with suitable earth compacted to provide adequate support.
- Backfilling should conform to “structure backfill.”
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Drainage diaphragms – When a drainage diaphragm is used, a registered professional engineer must supervise the design and construction inspection.

Planting soil (topsoil)

- See local specifications for general planting soil requirements.
- Use a minimum of 12 inches of topsoil in the emergent vegetation zone (less than 18” deep) of the pond. If natural topsoil from the site is to be used it must have at least eight percent organic carbon content (by weight) in the A-horizon for sandy soils and 12 percent for other soil types.
- If planting soil is imported, it should be made up of equivalent proportions of organic and mineral materials. All soils used should be free of invasive or nuisance seeds.
- Lime should not be added to planting soil unless absolutely necessary as it may encourage the propagation of invasive species.
- The final elevations and hydrology of the vegetative zones should be evaluated prior to planting to determine if grading or planting changes are required.

Vegetation

- See Recommended Plant List for BMPs Appendix for plant lists for wet ponds. Substitutions of specified plants should be subject to prior approval of the designer. Planting locations should be based on the planting plan and directed in the field by a qualified wetland ecologist. Plant material should be selected based on tolerance to

standing water as identified in Recommended Plant List for BMPs Appendix.

- All wet pond plant stock should exhibit live buds or shoots. All plant stock should be turgid, firm, and resilient. Internodes of rhizomes may be flexible and not necessarily rigid. Soft or mushy stock should be rejected. The stock should be free of deleterious insect infestation, disease, and defects such as knots, sun-scald, injuries, abrasions, or disfigurement that could adversely affect the survival or performance of the plants.
- All stock should be free from invasive or nuisance plants or seeds.
- During all phases of the work, including transport and onsite handling, the plant materials should be carefully handled and packed to prevent injuries and desiccation. During transit and onsite handling, the plant material should be kept from freezing and be covered, moist, cool, out of the weather, and out of the wind and sun. Plants should be watered to maintain moist soil and/or plant conditions until accepted.
- Plants not meeting these specifications or damaged during handling, loading, and unloading will be rejected.

Outlet control structure

- Outlet control structures should be constructed of non-corrodible material.
- Outlets should be resistant to clogging by debris, sediment, floatables, plant material, or ice.
- Materials should comply with applicable specifications (INDOT or AASHTO, latest edition).

Stormwater Functions and Calculations

Volume reduction

Although not typically considered a volume-reducing BMP, wet ponds can achieve some volume reduction through infiltration and evapotranspiration, especially during small storms and high temperature periods.

According to the International Stormwater BMP Database, wet ponds have an average annual volume reduction of seven percent (Strecker et al., 2004). Hydrologic calculations should be performed to verify that the wet pond will have a viable amount of inflow and to predict the water surface elevation under varying conditions. The volume stored between the predicted water level and the lowest outlet elevation will be removed from the storm that occurs under those conditions.

Peak rate mitigation

Inflow and discharge hydrographs must be calculated for each design storm.

Peak rate is primarily controlled in detention facilities through the transient storage above any permanent water surface. The degree to which peak rate is controlled is a function of the transient storage volume provided (i.e., depth and area) and the configuration of the outlet control structure.

Water quality improvement

Wet ponds rely on physical, biological, and chemical processes to remove pollutants from influent stormwater runoff. The primary treatment mechanism is settling by gravity of particulates and their associated pollutants while stormwater is retained in the pond. Another mechanism for the removal of pollutants, especially nutrients, is uptake by algae and aquatic vegetation. Typical pollutant removal efficiencies are provided in the Post-Construction Stormwater Quality Management Chapter of the Technical Standards.

The longer the runoff remains in a wet pond, the more settling (and associated pollutant removal) and other treatment can occur. After the particulates reach the bottom, the permanent pool protects them from resuspension when additional runoff enters.

The long detention or retention time associated with wet ponds can be problematic in coldwater fisheries due to the potential increase in water temperature. In these situations, detention times should be limited to a maximum of 12 hours, or other treatment alternatives (e.g., infiltration) should be explored.

Construction Guidelines

The following guidelines pertain to wet ponds:

- Install all temporary erosion and sedimentation controls.
- Separate pond area from contributing drainage area.
- All channels/pipes conveying flows to the pond must be routed away from the pond area until it is completed and stabilized.
- The area immediately adjacent to the pond must be stabilized in accordance with the erosion and sediment control methods discussed in the Erosion and Sediment Control Requirements Chapter of the Technical Standards and the latest requirements of IDEM's Soil Erosion and Sedimentation Control Program prior to construction of the pond (Rule 5).
- Prepare site for excavation and/or embankment construction.
- All existing vegetation should remain if feasible and only be removed if necessary for construction.
- Care should be taken to prevent compaction of the basin bottom.
- If excavation is required, clear the area of all vegetation. Remove all tree roots, rocks, and boulders only in excavation area.
- Excavate bottom of basin to desired elevation (if necessary).
- Install surrounding embankments and inlet and outlet control structures.
- Grade and prepare subsoil in bottom of basin. Compact bottom of basin in wet ponds.
 - Apply and grade planting soil. Matching design grades is crucial in wet ponds because aquatic plants can be very sensitive to depth.
 - Apply geo-textiles and other erosion-control measures.
- Seed, plant, and mulch according to landscaping plan.
- Install any safety or anti-grazing measures, if necessary.
- Follow required maintenance and monitoring guidelines.

Maintenance

Wet ponds must have a maintenance plan and privately owned facilities should have an easement, deed restriction, or other legal measure to prevent neglect or removal.

A basin maintenance plan should be developed which includes the following measures:

- All basin structures should be inspected for clogging and excessive debris and sediment accumulation at least four times per year, as well as after every storm greater than one inch. Structures that should be inspected include basin bottoms, trash racks, outlets structures, riprap or gabion structures, and inlets.
- Sediment should be removed from the forebay before it occupies 50 percent of the forebay, typically every 3 to 10 years. Sediment removal should be conducted when the basin is completely dry.
- Wet ponds should be drained prior to sediment removal. Sediment should be disposed of properly and once sediment is removed, disturbed areas need to be immediately stabilized and re-vegetated. Proper disposal of removed material depends on the nature of the drainage area and the intent and function of the detention basin. Material removed from detention basins that treat hot spots, such as fueling stations or areas with high pollutant concentrations, should be disposed according to IDEM regulations for solid waste. Detention basins that primarily catch sediment from areas such as lawns may redistribute the waste on site.
- The pond drain should be inspected and tested four times per year.
- The embankment should be inspected for evidence of tunneling or burrowing wildlife at least twice during the growing season. If damage is found, the damage should be repaired and the animals removed.

- Mowing and/or trimming of vegetation should be performed as necessary to sustain the system, but all detritus must be removed from the basin. Embankment should be mowed 1–2 times per year to prevent the establishment of woody vegetation.
- Inspections should assess the vegetation, erosion, flow channelization, bank stability, inlet/outlet conditions, embankment, and sediment/debris accumulation.
- Vegetated areas should be inspected annually for unwanted growth of invasive species.
- Vegetative cover should be maintained at a minimum of 85 percent.

Winter Considerations

One of the biggest problems associated with proper wet pond operation during cold weather is the freezing and clogging of inlet and outlet pipes. To avoid these problems, the Center for Watershed Protection (Caraco and Claytor, 1997) made some general design suggestions, which are adapted as follows:

- Inlet pipes should typically not be submerged, since this can result in freezing and upstream damage or flooding.
- Burying all pipes below the frost line can prevent frost heave and pipe freezing. Wind protection can also be an important consideration for pipes above the frost line. In these cases, designs modifications that have pipes “turn the corner” are helpful.
- Incorporate lower winter operating levels as part of the design to introduce available storage for melt events.
- Increase the slope of inlet pipes to a minimum of one percent to prevent standing water in the pipe, reducing the potential for ice formation. This design may be difficult to achieve at sites with flat local slopes.
- If perforated riser pipes are used, the minimum opening diameter should be ½-

inch. In addition, the pipe should have a minimum eight-inch diameter.

- When a standard weir is used, the minimum slot width should be three inches, especially when the slot is tall.
- Baffle weirs can prevent ice reformation during the spring melt near the outlet by preventing surface ice from blocking the outlet structure.
- In cold climates, riser hoods should be oversized and reverse slope pipes should draw from at least six inches below the typical ice layer.
- Alternative outlet designs that have been successful include using a pipe encased in a gravel jacket set at the elevation of the aquatic bench as the control for water-quality events. This practice both avoids stream warming and serves as a non-freezing outlet.
- Trash racks should be installed at a shallow angle to prevent ice formation. Constructed wetland performance can be decreased in spring months when large volumes of runoff occur in a relatively short time carrying the accumulated pollutant load from the winter months. Since constructed wetlands are relatively shallow, freezing of the shallow pool can occur.

Cost

The construction cost of wet ponds varies greatly depending on the configuration, location, site specific conditions, etc. Typical construction costs in 2007 dollars range from approximately \$30,000 to \$60,000 per acre-foot of storage (based on USEPA, 1999). Alternately, the construction cost of a wet pond can be estimated as \$6,000 per acre of contributing drainage area. Costs are generally most dependent on the amount of earthwork and the planting.

In addition to the water resource protection benefits of wet ponds, there is some evidence to suggest that they may provide an economic benefit by increasing property values. The results of one study

suggest that “pond front” property can increase the selling price of new properties by about 10 percent (USEPA, 1995). Another study reported that the perceived value (i.e., the value estimated by residents of a community) of homes was increased by about 15 to 25 percent when located near a wet pond (Emmerling-Dinovo, 1995).

Annual maintenance costs for wet ponds have been reported to be approximately three to five percent of the capital costs, though there is little data available to support this. Alternatively, a community can estimate the cost of the maintenance activities outlined in the maintenance section. Ponds are long-lived facilities (typically longer than 20 years). Thus, the initial investment into pond systems may be spread over a relatively long time period.

Designer/Reviewer Checklist for Wet Detention Ponds

ITEM	Page No.	YES	NO	N/A	NOTES
Used in conjunction with other BMPs for water quality and groundwater recharge?	1				
Adequate drainage area/water supply/groundwater table to maintain permanent water surface? <i>Min. drainage area: 10 acres, 5 acres for pocket wet pond</i> <i>Max. drainage area: 50 acres</i>	2-4				
Stable inflow points provided?	6				
Forebay and/or pretreatment provided for sediment removal? <i>Min. width of permanent access: 9 ft</i> <i>Max. slope: 15%</i> <i>Min. length of forebay: 10 ft</i>	4,6,7				
Adequate length to width ratio? ➤ <i>Min. length-to-width ratio: 3:1</i>	4				
Total depth limited? <i>Max. depth: 10 ft</i>	8				
Acceptable side slopes? <i>Max. slope: 10%</i>	4,5				
Safety benches provided?	4				
Properly designed outlet structure?	6				
Trash rack provided to prevent clogging?	6				
Stable emergency overflow and outflow points?	6				
Drawdown time less than 36 hours for 90% of stored volume?	4				
Soil compaction minimized?	--				
Adequate underlying soils?	7,8				
Appropriate native plants selected?	7,8				
25-foot buffer provided?	7				
Erosion and sedimentation control considered?	11				
Maintenance accounted for and plan provided? <i>Min. vegetative cover to be maintained: 85%</i>	12				

➤ *Denotes Minimum Design Consideration*

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BMP Fact Sheet

INFILTRATION PRACTICES

Infiltration practices are natural or constructed land areas located in permeable soils that capture, store, and infiltrate the volume of stormwater runoff into surrounding soil.



Figure 1 Infiltration Bed, Seattle, WA (USEPA, picasaweb)

Variations

- **Dry Wells**, also referred to as seepage pits, French drains or Dutch drains, are a subsurface storage facility (structural chambers or excavated pits, backfilled with a coarse stone aggregate) that temporarily store and infiltrate stormwater runoff from rooftop structures. Due to their size, dry wells are typically designed to handle stormwater runoff from smaller drainage areas, less than one acre in size.
- **Infiltration basins** are shallow surface impoundments that temporarily store, capture, and infiltrate runoff over a period of several days on a level and uncompacted surface. Infiltration basins are typically used for drainage areas of 5 to 50 acres with land slopes that are less than 20 percent.
- **Infiltration berms** use a site's topography to manage stormwater and prevent erosion. Berms may function independently in grassy areas or may be incorporated into the design of other stormwater control facilities such as Bioretention and Constructed Wetlands. Berms may also serve various stormwater drainage functions including: creating a barrier to flow, retaining flow for volume control, and directing flows.
- **Infiltration trenches** are linear subsurface infiltration structures typically composed of a stone trench wrapped with geotextile which is designed for both stormwater infiltration and conveyance in drainage areas less than five acres in size.
- **Subsurface infiltration beds** generally consist of a rock storage (or alternative) bed below other surfaces such as parking lots, lawns, and playfields for temporary storage and infiltration of stormwater runoff with a maximum drainage area of 10 acres.
- **Bioretention** can be an infiltration practice and is discussed in the Bioretention BMP.
- **Level spreaders** can be an infiltration practice and are discussed in the Level Spreader BMP.

Key Design Features

- Depth to water table or bedrock
- Pretreatment is often needed to prevent clogging
- Often requires level infiltration surface
- Proximity to buildings, drinking water supplies, karst features, and other sensitive areas
- Soil types
- Provide positive overflow in most uses

Site Factors

- Maximum Site Slope: 20 percent
- Minimum depth to bedrock: Two feet
- Minimum depth to seasonally high water table: Two feet
- Potential Hotspots: Yes, with pretreatment and/or impervious liner
- NRCS Soil Type: A, B, C*, D*

* C & D soils have limited infiltration ability and may require an underdrain

Infiltration BMP	Max. Drainage Area
Berming	5 acres
Dry Well	1 acre
Infiltration Basin	10 acres
Infiltration Trench	2 acres
Subsurface Infiltration Bed	5 acres

Benefits

- Reduces volume of stormwater runoff
- Reduces peak rate runoff
- Increases groundwater recharge
- Provides thermal benefits

Limitations

- Pretreatment requirements to prevent clogging
- Not recommended for areas with steep slopes

Applications

	Residential	Commercial	Ultra Urban	Industrial	Retrofit	Highway/ Road	Recreational
Dry well	Yes	Yes	Yes	Limited	Yes	No	No
Infiltration basin	Yes	Yes	Limited	Yes	Limited	Limited	No
Infiltration berm	Yes	Yes	Limited	Yes	Yes	Yes	No
Infiltration trench	Yes	Yes	Yes	Yes	Yes	Yes	No
Subsurface infiltration bed	Yes	Yes	Yes	Yes	Yes	Limited	No

Stormwater Quantity Functions

	Volume	Groundwater Recharge	Peak Rate
Dry well	Medium	High	Medium
Infiltration basin	High	High	High
Infiltration berm	Low/Medium	Low/Medium	Medium
Infiltration trench	Medium	High	Low/Medium
Subsurface infiltration bed	High	High	High

Stormwater Quality Functions

	TSS	TP	NO3	Temperature
Dry well	High	High/Medium	Medium/Low	High
Infiltration basin	High	Medium/High	Medium	High
Infiltration berm	Medium/High	Medium	TN-Medium	Medium
Infiltration trench	High	High/Medium	Medium/Low	High
Subsurface infiltration bed	High	Medium/High	Low	High

Description and Function

Infiltration practices are designed to store, capture, and infiltrate stormwater runoff into the surrounding soils. During periods of rainfall, infiltration BMPs reduce the volume of runoff and help to mitigate potential flooding events, downstream erosion, and channel morphology changes. This recharged water serves to provide base-flow to streams and maintain stream water quality.

Infiltration BMPs provide excellent pollutant removal effectiveness because of the combination of a variety of natural functions occurring within the soil mantle, complemented by existing vegetation (where this vegetation is preserved). Soil functions include physical filtering, chemical interactions (e.g., ion exchange, adsorption), as well as a variety of forms of biological processing, conversion, and uptake. The inclusion of appropriate vegetation for some infiltration basins reinforces the work of the soil by reducing velocity and erosive forces, soil anchoring, and further uptake of nonpoint source pollutants. In many cases, even the more difficult-to-remove soluble nitrates can be reduced as well. It should be noted that infiltration BMPs tend to be excellent for removal of many pollutants, especially those that are in particulate form. However, there are limitations to the removal of highly soluble pollutants, such as nitrate, which can be transmitted through the soil.

In addition to the removal of chemical pollutants, infiltration can address thermal pollution. Maintaining natural temperatures in stream systems is recognized as an issue of increasing importance for protection of overall stream ecology. While detention facilities tend to discharge heated runoff flows, the return of runoff to the groundwater through use of infiltration BMPs guarantees that these waters will be returned at natural groundwater temperatures, considerably cooler than ambient air in summer and warmer in winter. As a result, seasonal extreme fluctuations in stream water temperature are minimized. Fish, macro-invertebrates, and a variety of other biota will benefit as the result.

Infiltration Limitations

The use of sediment pretreatment with infiltration BMPs is required for many infiltration BMPs to prevent clogging of the infiltration surface area. Sediment pretreatment can take the form of a water quality filtering device, a settling basin, filter strips, sediment trap, or a combination of these practices upstream of the infiltration practice. Pretreatment practices should be inspected and maintained at least once per year. Before entering an infiltration practice, stormwater should first enter a pretreatment practice sized to treat a minimum volume of 25% of the water quality volume (V_{wq}).

Sites that include hot spots, such as gasoline stations, vehicle maintenance areas, and high intensity commercial uses, may need additional pretreatment practices to prevent impairment of groundwater supplies. Infiltration may occur in areas of hot spots provided pretreatment is suitable to address concerns.

Pretreatment devices that operate effectively in conjunction with infiltration include grass swales, vegetated filter strips, bioretention, settling chambers, oil/grit separators, constructed wetlands, sediment sumps, and water quality inserts. Selection of pretreatment practices should be guided by the pollutants of greatest concern, and the extent of the land development under consideration.

Selection of pretreatment techniques will vary depending upon whether the pollutants are of a particulate (sediment, phosphorus, metals, etc.) versus a soluble (nitrogen and others) nature.

Applications

Infiltration systems can be used in a variety of applications, from small areas in residential properties to extensive systems under commercial parking lots or large basins in open space. Industrial, retrofit, highway/ road, and recreational areas can also readily incorporate

infiltration to varying degrees. The use of infiltration basins and berming in ultra-urban and redevelopment settings is limited primarily due to space constraints.

Dry wells have limited applicability in industrial settings as they are designed for runoff from relatively small roof areas (therefore they are also not applicable to transportation corridors). Infiltration basins, subsurface infiltration beds, and berming are also limited for transportation projects due to space constraints and grading requirements (however berming can be used to some degree – especially along the edge of the right of way – to capture runoff).

Variations

Subsurface infiltration

A subsurface infiltration bed generally consists of a rock storage (or alternative) bed below other surfaces such as parking lots, lawns and playfields for temporary storage and infiltration of stormwater runoff. Subsurface storage is enhanced with perforated or open bottom piping. Subsurface infiltration beds can be stepped or terraced down sloping terrain, provided that the base of the bed remains level. Stormwater runoff from nearby impervious areas is conveyed to the subsurface storage media, receives necessary pretreatment and is then distributed via a network of perforated piping.

The storage media for subsurface infiltration beds typically consists of clean-washed, uniformly graded aggregate. However, other storage media alternatives are available. These alternatives are generally variations on plastic cells that can more than double the storage capacity of aggregate beds. Storage media alternatives are ideally suited for sites where potential infiltration area is limited.

If designed, constructed, and maintained using the following guidelines, subsurface infiltration features can stand alone as significant stormwater runoff volume, rate, and quality control practices. These systems can also provide some aquifer recharge, while preserving or creating valuable open space and recreation areas. They have the

added benefit of functioning year-round, because the infiltration surface is typically below the frost line.

Various methods can be utilized to connect to subsurface infiltration areas:

Connection of roof leaders

Runoff from nearby roofs can be directly conveyed to subsurface beds via roof leader connections to perforated piping. Roof runoff generally has relatively low sediment levels, making it ideally suited for connection to an infiltration bed.

Connection of inlets

Catch basins, inlets, and area drains may be connected to subsurface infiltration beds. However, sediment, oil and grease, and debris removal must be provided. Storm structures should include sediment trap areas below the inverts of discharge pipes to trap solids and debris. Parking lots and roadways must provide for the removal of oil and grease and other similar constituents through appropriate treatment. In areas of high traffic or excessive generation of sediment, litter, and other similar materials, a water quality insert or other pretreatment device may be required.

Infiltration trench

An infiltration trench is a linear stormwater BMP consisting of a continuously perforated pipe within a sub-surface stone-filled trench wrapped with geotextile. Usually, an infiltration trench is part of a conveyance system and is designed so that large storm events are conveyed through the pipe with some runoff volume reduction. During small storm events, volume reduction may be significant and there may be little or no discharge.

All infiltration trenches should be designed with a positive overflow. Sediment pretreatment of runoff from impervious areas should be considered to prevent clogging within the trench, particularly when conveying runoff from roadways and parking areas.

An infiltration trench differs from an infiltration bed in that it may be constructed in more confined areas. The designer must still consider the impervious area to infiltration area loading rate. It can be located beneath or within roadways or

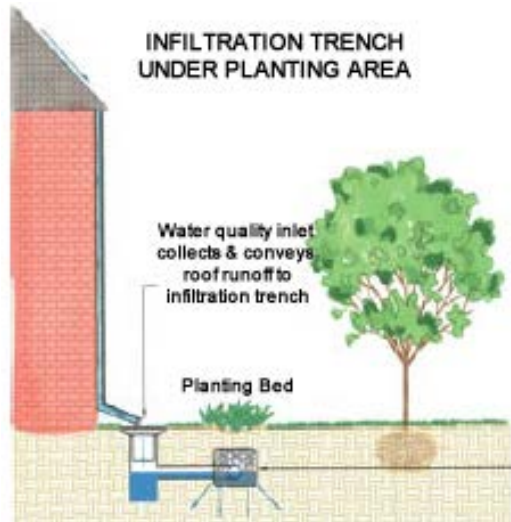


Figure 2 Infiltration trench with continuously perforated pipe for distribution with positive overflow

impervious areas (**Figure 2**) and can also be located down a mild slope by “stepping” the sections between control structures.

Infiltration basin

Infiltration basins (**Figure 3**) are shallow, impounded areas designed to temporarily store and infiltrate storm-water runoff. The size and

shape can vary from one large basin to multiple, smaller basins throughout a site.

Infiltration basins use the existing soil and native vegetation to reduce the volume of stormwater runoff by infiltration and evapotranspiration. Therefore, the use of sediment pretreatment is imperative to prevent clogging of the infiltration surface area within the basin. Sediment pretreatment can take the form of a water quality filtering device, vegetative filter strips, a settling basin, or a sediment trap. The key to promoting infiltration is to provide enough surface area for the volume of runoff to be absorbed within 72 hours.

An engineered overflow structure must be provided for the larger storms and can be designed for peak rate attenuation. With the use of a properly designed outlet structure, infiltration basins can be designed to mitigate volume and water quality for small frequent storms, while managing peak rates for large design storms.

Dry well

A dry well (**Figure 4**) is a subsurface storage facility that temporarily stores and infiltrates stormwater runoff from rooftops. Roof leaders usually connect directly into the dry well, which may be either an excavated pit filled with uniformly graded aggregate wrapped in geotextile or a prefabricated storage chamber or pipe segment. For structures without gutters or

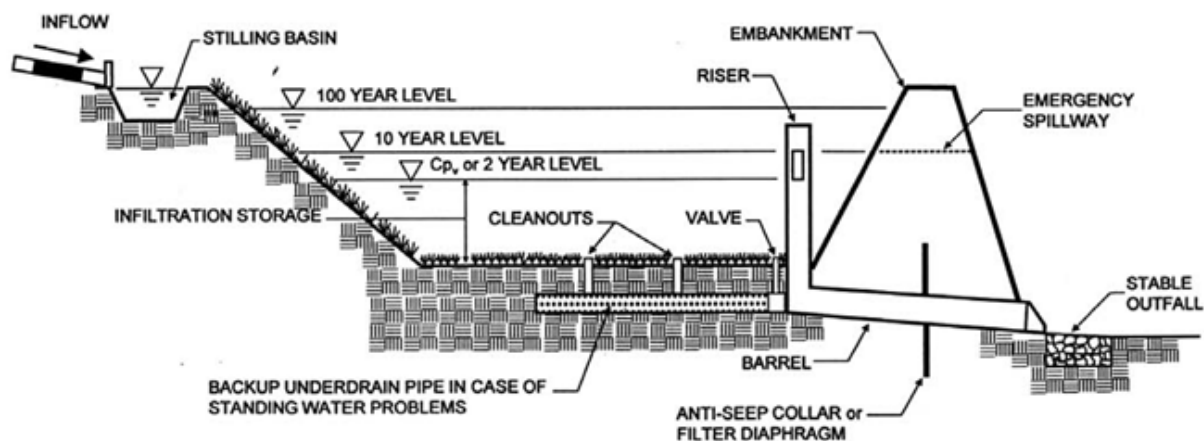


Figure 3 Residential Rain Garden with surface connection to subsurface infiltration bed under garden

downspouts, runoff can be designed to sheet flow off a pitched roof surface and onto a stabilized ground cover that is then directed toward a dry well via stormwater pipes or swales.

Dry wells discharge the stored runoff via infiltration into the surrounding soils. In the event that the dry well is overwhelmed in an intense storm event, an overflow mechanism (e.g., surcharge pipe, connection to larger infiltration area, etc.) will ensure that additional runoff is safely conveyed downstream.

Prefabricated Dry Wells

There are a variety of prefabricated, predominantly plastic subsurface storage chambers on the market today that can replace aggregate dry wells. Since these systems have significantly greater storage capacity than aggregate, space requirements are reduced and associated costs may be defrayed. If the following design guidelines are followed and infiltration is still encouraged, prefabricated chambers can prove just as effective as standard aggregate dry wells.

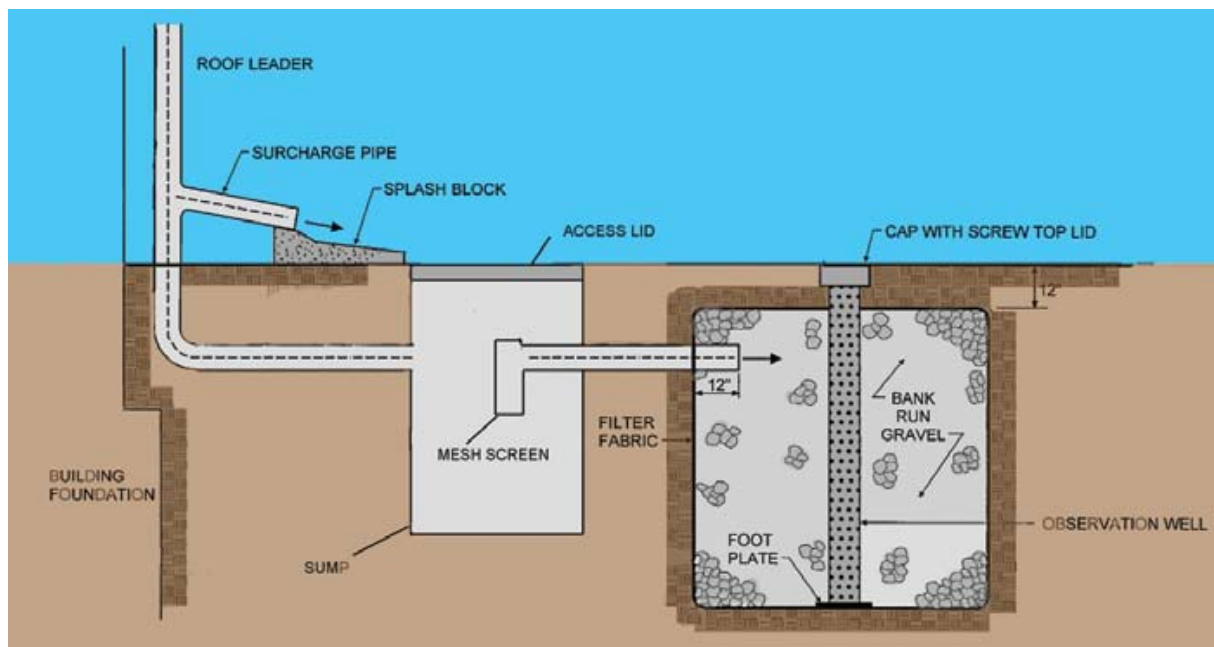


Figure 4 Cross Section of dry well with “sumped” catch basin for sediment pretreatment

Infiltration berm

Infiltration berms are linear vegetation features located along (i.e. parallel to) existing site contours in a moderately sloping area. They are built-up earthen embankments with sloping sides, which function to retain, slow down, or divert stormwater flows. Infiltration berms also have shallow depressions created by generally small earthen embankments that collect and temporarily store stormwater runoff, allowing it to infiltrate into the ground and recharge groundwater.

Infiltration berms can be constructed in various areas on the site, including:

Diversion berms

Diversion berms can be used to protect slopes from erosion and to slow runoff rate. Like swales, berms may divert concentrated discharge from a developed area away from the sloped area. Additionally, berms may be installed in series down the slope to retain flow and spread it out along multiple, level berms to discourage concentrated flow.

Diversion berms can also be used to direct stormwater flow in order to promote longer flow pathways, thus increasing the time of concentration. For example, berms can be installed such that vegetated stormwater flow pathways are allowed to “meander” so that stormwater travel time is increased.

Meadow/woodland infiltration berms

Woodland infiltration berms can be installed within existing wooded areas for additional stormwater management. Berms in wooded areas can even improve the health of existing vegetation, through enhanced groundwater recharge. Care should be taken during construction to ensure minimum disturbance to existing vegetation, especially tree roots.

Berms are also utilized for a variety of reasons independent of stormwater management, such as to add aesthetic value to a flat landscape, create a noise or wind barrier, separate land uses, screen undesirable views or to enhance or emphasize landscape designs. Berms are often used in conjunction with recreational features, such as pathways through woodlands. In summary, even when used for stormwater management, berms can be designed to serve multifunctional purposes and are easily incorporated into the landscape.

Design Considerations

The following general design considerations are for all BMPs utilizing infiltration. These include site conditions and constraints, as well as general design considerations. Specific design considerations for each BMP follow these same considerations.

Site conditions and constraints for all infiltration BMPs

- **Depth to seasonal high water table.** A four-foot clearance above the seasonally high water table is recommended. A two-foot clearance can be used, but may reduce the performance of the BMP. 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. In special circumstances, filter media may be employed to remove pollutants if adequate soil layers do not exist.

- **Depth to bedrock.** A four-foot minimum depth to bedrock is recommended to assure adequate pollutant removal and infiltration. A two-foot depth can be used, but may reduce the performance of the BMP. In special circumstances, filter media may be employed to remove pollutants if adequate soil mantle does not exist.
- **Soil infiltration.** Soils underlying infiltration devices should have infiltration rates between 0.1 and 10 inches per hour, which in most development programs 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 this range and cover most of the state. Type D soils may require the use of a double-walled underdrain.

Soils with rates in excess of six inches per hour may require an additional soil buffer (such as an organic layer over the bed bottom) if the Cation Exchange Capacity (CEC) is less than 10 and pollutant loading is expected to be significant. In carbonate soils, excessively rapid drainage may increase the risk of sinkhole formation, and some compaction or additional measures may be appropriate.

- **Setbacks.** Infiltration BMPs should be sited so that any risk to groundwater quality is minimized and they present no threat to sub-surface structures such as foundations and septic systems. (Table 1)

General design considerations for all infiltration BMPs

Setback from	Minimum Distance (feet)
Property Line	10
Building Foundation*	10
Private Well	50
Public Water Supply Well**	50
Septic System Drainfield***	100

Table 1 Setback Distances

* Minimum with slopes directed away from building. 100 feet up gradient from basement foundations.

** At least 200 feet from Type I or IIa wells, 75 feet from Type IIb and III wells

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

- Do not infiltrate in 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, often 18 inches or more. If site grading requires placement of an infiltration BMP on fill, compaction should be minimal to prevent excess settlement. The infiltration capacity of the compacted fill should be measured in the field to ensure the design values used are valid.
- A level infiltration area (one percent 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. The longitudinal slope may range only from the preferred zero percent up to one percent, and that lateral slopes are held at zero percent. It is highly recommended that the maximum side slopes for an infiltration practice be 1:3 (V: H).
- The soil mantle should be preserved for surface infiltration BMPs and excavation**
- Isolate hot spot areas.** Site plans that include infiltration in hot spots need to be reviewed carefully. 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.). Infiltration may occur in areas of hot spots provided pretreatment is suitable to address concerns.
- Utilize pretreatment.** Pretreatment should be utilized for most infiltration BMPs, 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 a particulate (sediment, phosphorus, metals, etc.) versus soluble (nitrogen and others) nature. Types of pretreatment (i.e., filters) should be matched with the nature of the pollutants expected to be generated.
- The loading ratio of impervious area to bed bottom area must be considered.**

should be minimized. Those soils that do not need to be disturbed for the building program should be left undisturbed. Macropores can provide a significant mechanism for water movement in surface 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.

One of the more common reasons 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 work best 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 5:1 relating impervious drainage area to infiltration area.
- Maximum total loading ratio of 8:1 relating total drainage area to infiltration area.
- **The hydraulic head or depth of water should be limited.** The total effective depth of water within the infiltration BMP should generally not be greater than two feet to avoid excessive pressure and potential sealing of the bed bottom. Typically, the water depth is limited by the loading ratio and drawdown time and is not an issue.
- **Drawdown time must be considered.** In general, infiltration BMPs should be designed so that they completely empty within a 72-hour period in most situations (a 48-hour period is preferred).
- **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 storm frequency situations.
- **Geotextiles should be incorporated into the design as necessary.** Infiltration BMPs that are subject to soil movement into the stone medium or excessive sediment

deposition must be constructed with suitably permeable non-woven geotextiles to prevent the 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 within the BMP structure.

- **Aggregates used in construction should be washed.** In general, bank run material will contain fines that will wash off and clog the infiltration surface.
- **Infiltration utilizing vegetation.** Adequate soil cover (generally 12 to 18 inches) must be maintained above the infiltration bed to allow for a healthy vegetative cover. Vegetation over infiltration beds can be native grasses, meadow mix, or other low-growing, dense species (see Recommended Plant List for BMPs Appendix). These plants have longer roots than traditional grass and will likely benefit from the moisture in the infiltration bed, improving the growth of these plantings and, potentially increasing evapotranspiration.
- **Using underdrains in poor draining soils.** Double-walled underdrains can be used in infiltration BMPs where in situ soils are expected to cause ponding lasting longer than 48 hours. If used, underdrains are typically small diameter (6 to 12 inches) perforated pipes in a clean gravel trench wrapped in geotextile fabric (or in the storage/infiltration bed). Underdrains should have a flow capacity greater than the total planting soil infiltration rate and should have at least 18 inches of soil/gravel cover. They can daylight to the surface or connect to another stormwater system. A method to inspect and clean underdrains should be provided (via cleanouts, inlet, overflow structure, etc.)

Infiltration practices are prohibited in proximity to public water supply wells as discussed in the Post-Construction Stormwater Quality Chapter, Section F Step 5 of the Technical Standards.

designed to flow adjacent to (parallel to),

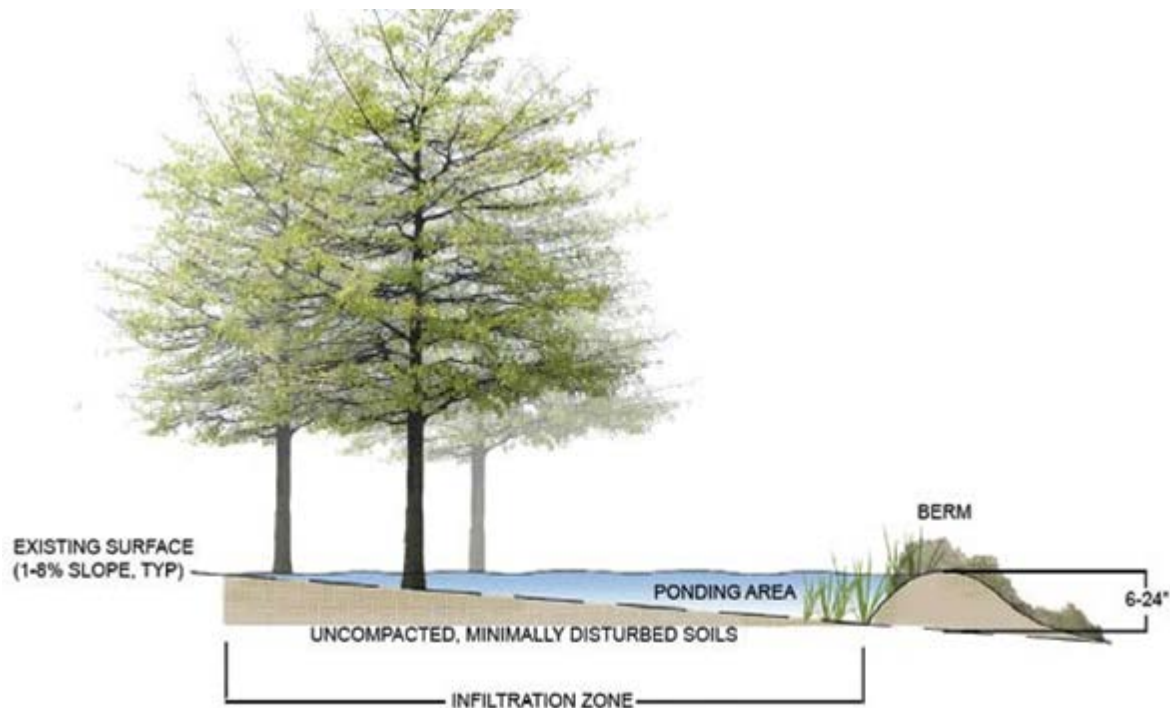


Figure 5 Typical Components of a Berm

- **Freeboard.** It is recommended that two feet of freeboard be provided from the 100-year flood elevation of the infiltration practice to the lowest basement floor elevation of residential, commercial, industrial, and institutional buildings located adjacent to the BMP, unless local requirements recommend or stipulate otherwise.

Additional design considerations for infiltration berms

- Sizing criteria (**Figure 5**) are dependent on berm function, location, and storage volume requirements.
 - Low **berm height** (less than or equal to 24 inches) is recommended to encourage maximum infiltration and to prevent excessive ponding behind the berm. Greater heights may be used where berms are being used to divert flow or to create “meandering” or lengthened flow pathways. In these cases, stormwater is

rather than over the crest of the berm. Generally, more berms of smaller size are preferable to fewer berms of larger size.

- **Berm length** is dependent on functional need and site size. Berms installed along the contours should be level and located across the slope. Maximum length will depend on width of the slope.
- Infiltration berms should be constructed along (parallel to) contours at a **constant level elevation**.
- **Soil.** The top one foot of a berm needs to consist of high quality topsoil, with well-drained, stable fill material making up the remainder of the berm. A berm may also consist entirely of high quality topsoil, but this is the more expensive option.

The use of gravel is not recommended in the layers directly underneath the topsoil because

of the tendency of the soil to wash through the gravel. In some cases, the use of clay may be required due to its cohesive qualities (especially where the berm height is high or relatively steeply sloped). However, well-compacted soil is usually sufficient provided that the angle of repose, the angle at which the soil will rest and not be subject to slope failure (discussed below), is adequate for the soil medium used.

- The **angle of repose** of any soil will vary with the texture, water content, compaction, and vegetative cover. Typical angles of repose are given below:
 - Non-compacted clay: 5 to 20 percent
 - Dry Sand: 33 percent
 - Loam: 35 to 40 percent
 - Compacted clay: 50 to 80 percent
- **Slope** The angle of repose for the soil used in the berm should determine the maximum slope of the berm with additional consideration being given to aesthetic, drainage, and maintenance needs. If a berm is to be mowed, the slope should not exceed a 4:1 ratio (horizontal to vertical) in order to avoid “scalping” by mower blades. If trees are to be planted on berms, the slope should not exceed a 5:1 to 7:1 ratio. Other herbaceous plants which do not require mowing can tolerate slopes of 3:1, though this slope ratio may promote increased runoff rate and erosive conditions. Berm side slopes should never exceed a 2:1 ratio.
- **Plant materials.** It is important to consider the function and form of the berm when selecting plant materials. When using native trees and shrubs, plant them in a pattern that appears natural and accentuates the form of the berm. Consider native species from a rolling prairie or upland forest habitat. If turf will be combined with woody and herbaceous plants, the turf should be placed to allow for easy maneuverability while mowing. Low maintenance native plantings, such as trees and meadow plants, rather than turf and formal landscaping, are encouraged and

can be found in Recommended Plant List for BMPs Appendix. Additionally, plant material should be selected based on tolerance to standing water as identified in Recommended Plant List for BMPs Appendix.

- **Infiltration trench option.** Soil testing is required for infiltration berms that will utilize a subsurface infiltration trench. Infiltration trenches are not recommended in existing woodland areas, because excavation and installation of subsurface trenches could damage tree root systems. See the infiltration trench section for information on infiltration trench design.
- **Aesthetics.** To the extent possible, berms should reflect the surrounding landscape. Berms should be graded so that the top of the berm is smoothly convex and the toes of the berms are smoothly concave. Natural, asymmetrical berms are usually more effective and attractive than symmetrical berms, which tend to look more artificial. The crest of the berm should be located near one end of the berm rather than in the middle.
- **Pretreatment.** The small depression created by an infiltration berm can act as a sediment forebay prior to stormwater entering a down slope BMP, such as a bioretention basin, a subsurface infiltration bed, or another such facility. Sediment forebays must be in compliance with local Stormwater Management Ordinance and standard detailed drawing requirements.

Additional design considerations for dry wells

- Dry wells typically consist of 18 to 48 inches of clean washed, uniformly graded aggregate with 40 percent void capacity (AASHTO No. 3, or similar). Dry well aggregate is wrapped in a nonwoven geotextile, which provides separation between the aggregate and the surrounding soil. Typically, dry wells will be covered in

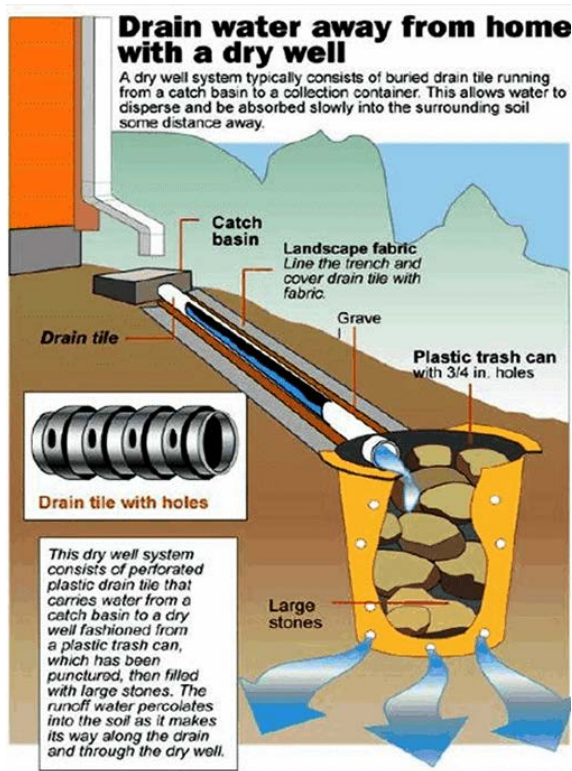


Figure 6 Residential dry well

Source - AP/Stan Kohler

at least 12 inches of soil or six inches of gravel or riverstone. An alternative form of dry well is a subsurface, prefabricated chamber, a number of which are currently available on the market.

- 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 from the dry well itself.
- The design depth of a dry well should take into account frost depth to prevent frost heave.
- A removable filter with a screened bottom should be installed in the roof leader below the surcharge pipe in order to screen out leaves and other debris.
- Inspection and maintenance access to the dry well should be provided. Observation

wells not only provide the necessary access to the dry well, but they also provide a conduit through which pumping of stored runoff can be accomplished in case of slowed infiltration.

- Though roofs are generally not a significant source of runoff pollution, they can still be a source of particulates and organic matter, as well as sediment and debris during construction. Measures such as roof gutter guards, roof leader clean-outs with sump, or an intermediate sump box can provide pretreatment for dry wells by minimizing the amount of sediment and other particulates that enter it.

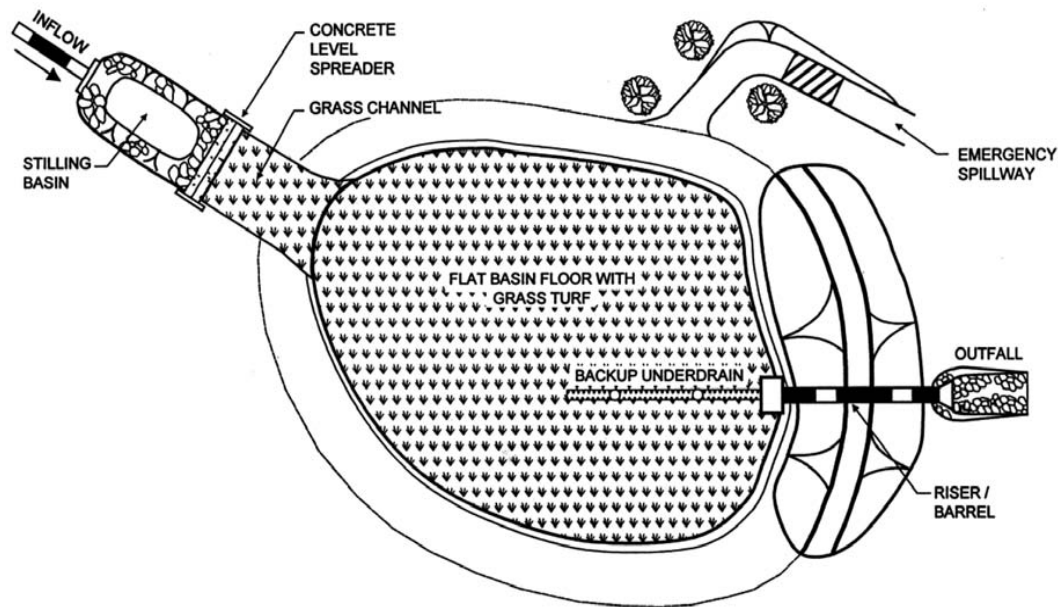


Figure 7 Infiltration Basin Sketch

Additional Design Considerations for Infiltration Basins

- Infiltration basins are typically used for drainage areas of 5 to 50 acres with land slopes that are less than 20 percent.
- A six-inch layer of sand must be placed on the bottom of an infiltration basin (**Figure 7**). This sand layer can intercept silt, sediment, and debris that could otherwise clog the top layer of the soil below the basin.
- An infiltration basin does not normally have a structural outlet to discharge runoff from the stormwater quality design storm. Instead, outflow from an infiltration basin is through the surrounding soil. An infiltration basin may also be combined with an extended detention basin to provide additional runoff storage for both stormwater quality and quantity management. A structural outlet or emergency spillway is provided for storms that exceed the design of the infiltration basin.
- The berms surrounding the basin should be compacted earth with a slope of not less than 3:1, and a top width of at least two feet.
- The overflow from the infiltration basin must be properly designed for anticipated flows. Large infiltration basins may require multiple outlet control devices to effectively allow for overflow water during the larger storms. Emergency overflow systems can be constructed to direct large storm overflows.
- The sediment pre-treatment structure should be designed to provide for access and maintenance.
- In some cases, basins may be constructed where impermeable soils on the surface are removed and where more permeable underlying soils are used for the basin bottom. Care should be taken in the excavation process to make sure that soil compaction does not occur.
- The inlets into the basin should have erosion protection.
- Use of a backup, double-walled underdrain or low-flow orifice may be considered in

the event that the water in the basin does not drain within 72 hours.

Additional design considerations for infiltration trenches

- The infiltration trench (**Figure 8**) is typically comprised of a section of uniformly graded aggregate, such as AASHTO No. 3, which ranges one to two inches in gradation. 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 at least 40 percent void space. The depth of the trench is a function of stormwater storage requirements, frost depth considerations, and site grading.

inlets capable of removing oil and grease and similar pollutants. Untreated parking lot and road runoff should never be directly discharged underground.

- Cleanouts, observation wells, or inlets must be installed at both ends of the infiltration trench and at appropriate intervals to allow access to the perforated pipe.
- When designed as part of a storm sewer system, a continuously perforated pipe that extends the length of the trench and has a positive flow connection may be included to allow high flows to be conveyed through the infiltration trench. Depending on size, these pipes may provide additional storage volume.
- Trees may be planted over the infiltration

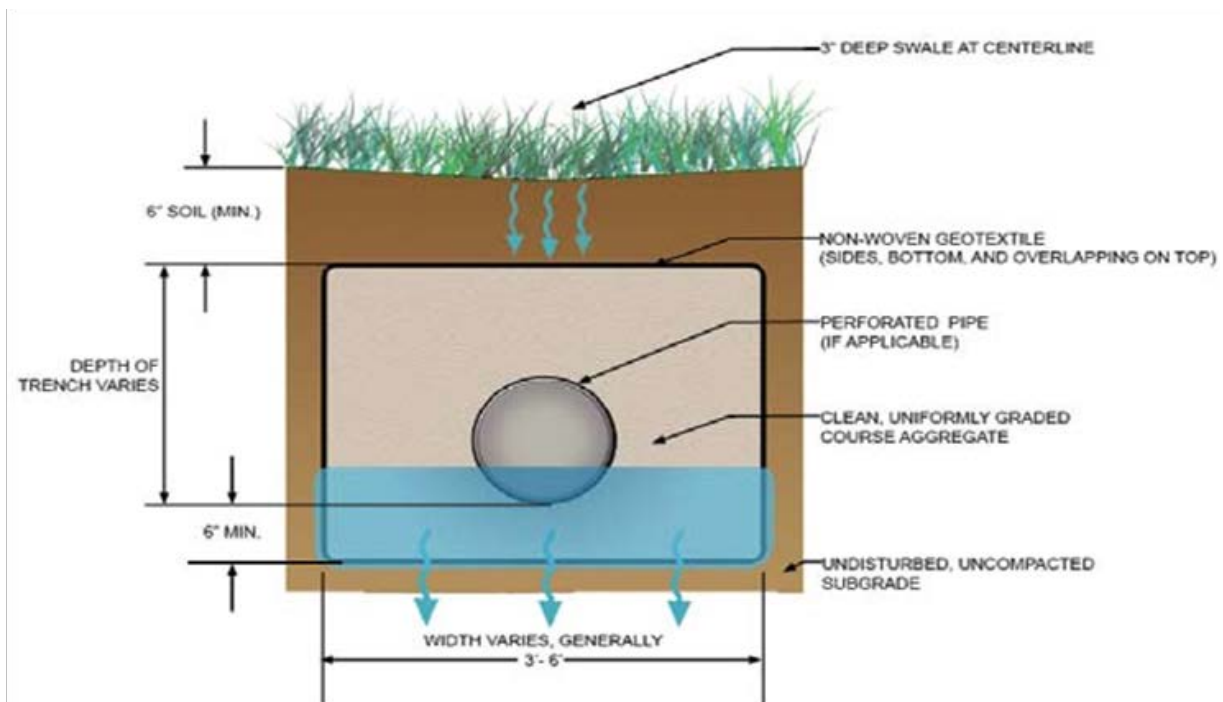


Figure 8 Infiltration trench cross section

- Water quality inlets or catch basins with sumps are required for all surface inlets to prevent clogging of the infiltration trench with sediment and debris. Parking lot and street runoff must be treated by vegetated filter strips, bioretention, or water quality

trench provided that adequate soil media is provided above the trench (a minimum of three feet).

- While most infiltration trenches areas consist of an aggregate storage bed, alternative subsurface storage products

may also be employed. These include a variety of proprietary, interlocking plastic units that contain much greater storage capacity than aggregate, though at an increased cost.

Additional design considerations for subsurface infiltration beds

- The infiltration bed must be wrapped in nonwoven geotextile filter fabric to prevent migration of the subsoils into the stone voids (bottom, top, and sides).

- A water quality inlet or catch basin with sump is required for all surface inlets to avoid standing water for periods greater than 72 hours.
- Perforated pipes along the bottom of the bed can be used to evenly distribute runoff over the entire bed bottom. Continuously perforated pipes should connect structures (such as cleanouts and inlet boxes). Pipes should lay flat along the bed bottom to

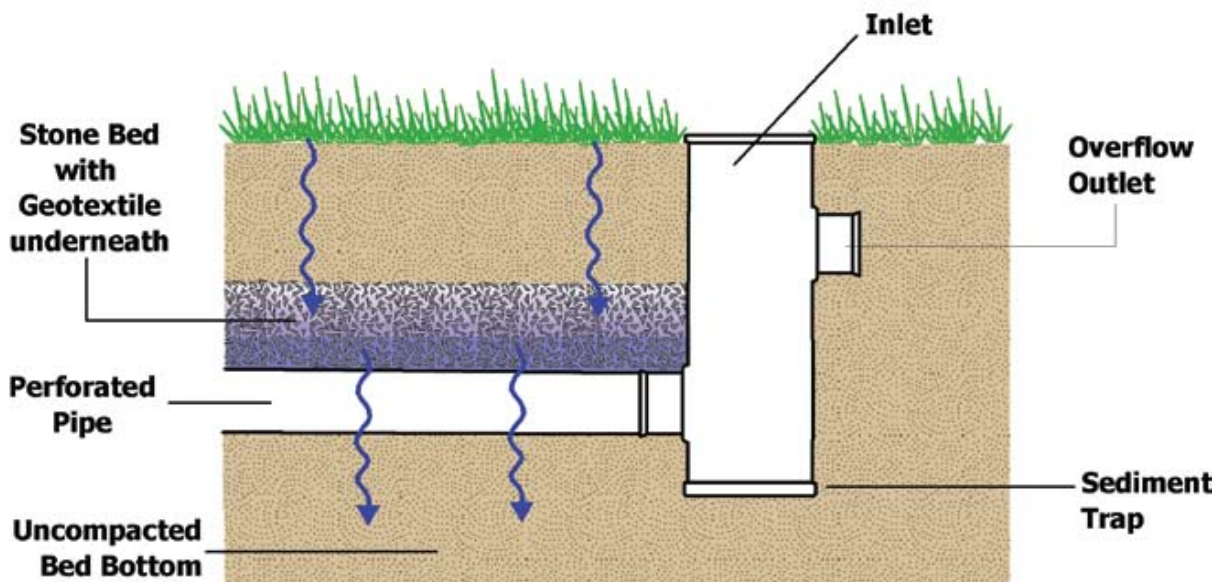


Figure 9 Schematic of subsurface infiltration bed cross section

- The subsurface infiltration bed (**Figure 9**) is typically comprised of a 12 to 36-inch section of aggregate, such as AASHTO No.3, which ranges from one to two inches in gradation. 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 at least 40 percent void space. The depth of the bed is a function of stormwater storage requirements, frost depth considerations, and site grading. Infiltration beds are typically sized to mitigate the increased runoff volume from a two-year design storm.

provide for uniform distribution of water. Depending on size, these pipes may provide additional storage volume.

- Cleanouts or inlets should be installed at a few locations within the bed at appropriate intervals to allow access to the perforated piping network and storage media.
- Grading of adjacent contributing areas should be mildly sloped between one percent and three percent to facilitate drainage.
- In areas with poorly-draining soils, subsurface infiltration areas may be

designed to slowly discharge to adjacent wetlands or bioretention areas.

- 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, detention basins may be eliminated or significantly reduced in size.
- During construction, the excavated bed may serve as a temporary sediment basin or trap, which can reduce overall site disturbance. The bed should be excavated to at least one foot above the final bed bottom elevation for use as a temporary sediment trap or basin. Following construction and site stabilization, sediment should be removed and final grades established.

Incorporating a Safety Factor into Infiltration BMP Design

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. Safety factors between 1 (no adjustment) and 10 have been used in the design of stormwater infiltration systems, with a factor of two being used in most cases. 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. See the Soil Infiltration Protocol Index in Appendix E for guidance on performing infiltration tests.

Modeling Infiltration Systems

As discussed in the Post-Construction Stormwater Management Chapter of Technical Standards, 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 sometimes useful to develop infiltration rates that vary (based on the infiltration area provided as the system fills with runoff) for inclusion in the stage-storage-discharge table.

	Volume	Peak Rate	Water Quality
Infiltration Berms	Can be used to reduce the volume of runoff and provide infiltration in accordance with LID stormwater goals. The volume reduction potential of berms is a function of the storage provided (surface and subsurface, if applicable) and the infiltration that will occur.	Can be used at mitigating peak rates for larger storms through two mechanisms: providing storage for detention (and on-going infiltration) behind them and, in some cases, elongating the flow path through a site, thereby extending the time of concentration.	Can be expected to achieve pollutant removals between 30% - 70% and in the upper ranges especially for smaller storms.
Infiltration Basins	Provides an excellent means of capturing and infiltrating runoff. Provides runoff volume storage during storm events, while the undisturbed vegetated surface allows infiltration of runoff into the underlying soil mantle. Can be sized to meet the entire channel protection volume recommended by LID criteria or sized smaller and used in conjunction with other LID practices.	Provides effective management of peak rates to meet the LID design criteria. The basin acts as a storage reservoir during large storm events, even while runoff infiltrates. Outlet structures can be designed to manage peak rates with the use of weir and orifice controls and systems can be designed to manage peak rates for storms up to and including the 100-year storm.	Effective in reducing total suspended solids, nutrients, metals, and oil and grease. Both the vegetative surface and the underlying soils allow pollutant filtration. When designed to capture and infiltrate runoff volumes from small storm events, they provide very high pollutant reductions.
Infiltration Trenches	Provides an excellent means of capturing and infiltrating runoff from small storms. The trench provides runoff volume storage and infiltration during small storm events, while the perforated pipe allows runoff conveyance during large design storms or more extreme events.	Provides limited management of peak rates. The trench may provide more peak rate benefit for small frequent storms, rather than large design storms. Because infiltration trenches help to provide a decentralized approach to stormwater management, they may benefit peak rate mitigation by contributing to increased stormwater travel time.	Effective in reducing total suspended solids, metals, and oil and grease. They provide very high pollutant reductions when designed to capture the volume from small storms because there is little, if any, discharge of runoff carrying the highest pollutant loads. Provide limited treatment of dissolved pollutants, such as nitrates.
Dry Wells	Dry wells are typically designed to capture and infiltrate runoff volumes from small storm events from roof area.	Provides limited management of peak rates. Provides some peak rate benefit by reducing direct connections of impervious area to storm sewer collection systems, and by contributing to increased stormwater travel time.	Effective at capturing and infiltrating the water quality volume or “first flush”. Provides very high pollutant reductions because there is little, if any, discharge of “first flush” runoff, which carries the highest pollutant loads.
Subsurface Infiltration	Provides effective management of volume. A well-designed system is capable of infiltrating the majority of small frequent storms on an annual basis.	Can be designed to manage peak rates by utilizing the stormwater storage bed, including simple rate controls such as weirs and orifices in the overflow control structure. Capable of infiltrating the majority of small frequent storms, while managing peak rates for design storms up to the 100-year frequency storm.	Very effective at reducing total suspended solids, phosphorus, metals, and oil and grease. Because many systems are designed to capture and infiltrate small, frequent storms, they provide effective water quality control by reducing pollutants associated with the “first-flush”.

Table 2 Stormwater Functions by Infiltration BMP Type

Stormwater Functions and Calculations

Infiltration practices can provide excellent benefits for managing volume and water quality protection. While some BMPs are better than others in managing peak rates, all infiltration BMPs provide some peak rate benefit by removing direct connections from impervious surfaces and increasing time of travel. **Table 2** provides a summary of the stormwater functions by BMP type.

Calculations for Infiltration BMPs

Infiltration area

The minimum infiltration area should be based on the following (according to the loading ratio):

$$\text{Minimum Surface Infiltration Area} = [\text{Contributing impervious area}] / 5^{\#}$$

- May be increased depending on soil infiltration capacity (e.g., where soils are Type A or rapidly draining). For carbonate, geologic areas may be decreased to three.

This actual infiltration area (**Table 3**) should be greater than the minimum infiltration area.

Protecting Groundwater Quality

The protection of groundwater quality is of utmost importance in any Indiana watershed. The potential to contaminate groundwater by infiltrating stormwater in properly designed and constructed BMPs with proper pretreatment is low.

Numerous studies have shown that stormwater infiltration BMPs have a minor risk of contaminating either groundwater or soil. The U.S. Environmental Protection Agency summarized in “Potential Groundwater Contamination from Intentional and Non-intentional Stormwater Infiltration” (Pitt et al., 1994) the potential of pollutants to contaminate groundwater as either low, low/moderate, moderate, or high. Of the 25 physical pollutants listed, one has a “high” potential (chloride), and two have “moderate” potential (fluoranthene and pyrene) for polluting groundwater through the use of shallow infiltration systems with some sediment pretreatment.

While chloride can be found in significant quantities due to winter salting, relatively high concentrations are generally safe for both humans and aquatic biota. Pentachlorophenol, cadmium, zinc, chromium, lead, and all the pesticides listed are classified as having a “low” contamination potential. Even nitrate, which is soluble and mobile, is only given a “low/moderate” potential.

BMP	Infiltration Area Definition
Infiltration Berms	Total Infiltration Area (Ponding Area) = Length of Berm * Average Width of ponding behind berm.
Infiltration Basin	The Infiltration Area is the bottom area of the basin. This is the area to be considered when evaluating the Loading Ratio to the Infiltration basin.
Infiltration Trench	The Infiltration Area is the bottom area of the trench. This is the area to be considered when evaluating the Loading Rate to the Infiltration basin. [Length of Trench] x [Width of Trench] = Infiltration Area (Bottom Area) Some runoff reduction recognition can be taken for the side area that is frequently inundated, as appropriate.
Dry Well	A dry well may consider both bottom and side (lateral) infiltration according to design.
Subsurface Infiltration	The Infiltration Area is the bottom area of the bed. Some runoff reduction recognition can be taken for the side area that is frequently inundated as appropriate.

Table 3 Definition of Infiltration Area for Infiltration BMPs

Volume reduction

Infiltration BMPs can be used to reduce the volume of runoff and provide infiltration in accordance with LID stormwater goals. The volume reduction potential is a function of the storage provided (surface and subsurface, if applicable) and the infiltration that will occur. If a perforated pipe or double-walled underdrain is used in the design that discharges directly to surface water, the volume of water discharged must be subtracted from the volume reduction calculation.

Total Volume Reduced = Surface Storage Volume (if applicable) + Subsurface Volume (if applicable) + Infiltration Volume

Where,

Surface storage volume (ft³) = Average bed area * (ft²) x maximum design water depth (ft)

Subsurface storage/Infiltration bed volume (ft³) = Infiltration area (ft²) * Depth of underdrain material (ft) * 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.*

Estimated Infiltration Volume (CF) = [Bed bottom area (ft²)] * [Infiltration design rate (in/hr)] * [Infiltration period[#] (hr)] / 12 inches/ft.

- Infiltration Period is the time during the storm event when bed is receiving runoff and capable of infiltration at the design rate (typically 6 to 12 hours).

Peak rate mitigation

The amount of peak rate control provided by infiltration practices is dependent on the cumulative runoff volume removed by all the infiltration practices applied to a site. Where sufficient infiltration is provided to control the runoff volume from any size storm, the corresponding peak runoff rate will also be restored and the peak runoff rate from larger, less frequent storms will be reduced. Where possible, reducing peak rate of runoff through volume

control is generally more effective than fixed rate controls.

Some infiltration BMPs (e.g., infiltration basins) can manage peak rates better than others (e.g., infiltration berms). However, all infiltration BMPs provide some peak rate benefit (e.g., by removing direct connections from impervious surfaces and increasing time of travel).

Water quality improvement

Infiltration practices are effective in reducing pollutants such as total suspended solids, nutrients, metals, oil and grease. The vegetative surface and the underlying soils allow pollutant filtration and studies have shown that pollutants typically are bound to the soils and do not migrate deeply below the surface (i.e. greater than 30-inches). Infiltration practices should be used as part of a treatment train when capturing runoff from storm-water hot spots, such as industrial parking lots, due to the increased level of pollutants. Typical ranges of pollutant reduction efficiencies for infiltration practices are based on available literature data and listed below:

TSS – 75 to 90 percent
TP – 60 to 75 percent
TN – 55 to 70 percent
NO₃ – 30 percent

Construction Guidelines

The following guidelines apply for all infiltration BMPs.

- **Do not compact soil infiltration beds during construction.** Prohibit all heavy equipment from the infiltration area and absolutely minimize all other traffic. Equipment should be limited to vehicles that will cause the least compaction, such as low ground pressure (maximum four pounds per square inch) tracked vehicles. Areas for Infiltration should be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.
- Protect the infiltration area from sediment by ensuring erosion and sediment control

practices are implemented until the surrounding site is completely stabilized. Methods to prevent sediment from washing into BMPs should be clearly shown on plans. Where geotextile is used as a bed bottom liner, this should be extended several feet beyond the bed and folded over the edge to protect from sediment wash into the bed during construction, and then trimmed.

- Runoff from construction areas should never be allowed to drain to infiltration BMPs. This can usually be accomplished by diversion berms and immediate vegetative stabilization. The infiltration area may be used as a temporary sediment trap or basin during earlier stages of construction. However, if an infiltration area is also to be utilized as a temporary sediment basin, excavation should be limited to within one foot of the final bottom invert of the infiltration BMP to prevent clogging and compacting the soil horizon, and final grade removed when the contributing site is fully stabilized.
- All infiltration BMPs should be finalized at the end of the construction process, when upstream soil areas have a dense vegetative cover. In addition, do not remove inlet protection or other erosion and sediment control measures until site is fully stabilized. Any sediment which enters inlets during construction is to be removed within 24 hours.
- Provide thorough construction oversight. Long-term performance of infiltration BMPs is dependent on the care taken during construction. Generally, plans and specifications must be followed precisely. The designer is encouraged to meet with the contractor to review the plans and construction sequence prior to construction, and to inspect the construction at regular intervals and prior to final acceptance of the BMP.
- Provide quality control of materials. As with all BMPs, the final product is only as

good as the materials and workmanship that went into it. The designer is encouraged to review and approve materials and workmanship, especially as related to aggregates, geotextiles, soil and topsoil, and vegetative materials.

Additional Construction Guidelines for Infiltration Berms

The following is a typical construction sequence for an infiltration berm without a subsurface infiltration trench, though alterations will be necessary depending on design variations.

- Lightly scarify (by hand) the soil in the area of the proposed berm before delivering soil to site (if required). Heavy equipment should not be used within the berm area.
- Bring in fill material to make up the major portion of the berm (as necessary) as soon as subgrade preparation is complete in order to avoid accumulation of debris. Soil should be added in eight-inch lifts and compacted after each addition according to design specifications. The slope and shape of the berm should be graded out as soil is added.
- Protect the surface ponding area at the base of the berm from compaction. If compaction of this area does occur, scarify soil to a depth of at least 8 inches.
- After allowing for settlement, complete final grading within two inches of proposed design elevations. Tamp soil down lightly and smooth sides of the berm. The crest and base of the berm should be level along the contour.
- Seed and plant berm with turf, meadow plants, shrubs or trees, as desired. Water vegetation at the end of each day for two weeks after planting is completed. (Recommended Plant List for BMPs Appendix).

- Mulch planted and disturbed areas with compost to prevent erosion while plants become established.

Additional Construction Guidelines for Subsurface Infiltration

- Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material should be removed with light equipment and the underlying soils scarified to a minimum depth of six inches with a York rake (or equivalent) and light tractor. All fine grading should be done by hand. All bed bottoms are to be at level grade.
- Earthen berms (if used) between infiltration beds should be left in place during excavation.
- Geotextile and bed aggregate should be placed immediately after approval of subgrade preparation and installation of structures. Adjacent strips of geotextile should overlap a minimum of 18 inches, and should also be secured at least four feet outside of the bed to prevent any runoff or sediment from entering the storage bed. This edge strip should remain in place until storage media is placed in the bed.
- Clean washed, uniformly graded aggregate should be placed in the bed in maximum eight-inch lifts. Each layer should be lightly compacted, with construction equipment kept off the bed bottom as much as possible.
- Once bed aggregate has been installed, geotextile can be folded over the top of the aggregate bed. Additional geotextile should be placed as needed to provide a minimum overlap of 18 inches between adjacent geotextile strips.
- Place approved engineered soil media over infiltration bed in maximum six-inch lifts.
- Seed and stabilize topsoil.

Additional Construction Guidelines for Infiltration Trenches

- Excavate infiltration trench bottom to a uniform, level uncompacted subgrade free from rocks and debris. Do NOT compact subgrade.
- Place nonwoven geotextile along bottom and sides of trench. Nonwoven geotextile rolls should overlap by a minimum of 16 inches within the trench. Fold back and secure excess geotextile during stone placement.
- Install upstream and downstream control structures, cleanouts, observation wells, etc.
- Place uniformly graded, clean-washed aggregate in 8-inch lifts, lightly compacting between lifts.
- Install continuously perforated pipe as indicated on plans. Backfill with uniformly graded, clean-washed aggregate in 8-inch lifts, lightly compacting between lifts.
- Fold and secure nonwoven geotextile over infiltration trench, with minimum overlap of 16 inches.
- If vegetated, place a minimum six-inch lift of approved topsoil over infiltration trench, as indicated on plans.
- Seed and stabilize topsoil.

Additional Construction Guidelines for Infiltration Basins

- If necessary, excavate infiltration basin bottom to provide a level and uncompacted subgrade free from rocks and debris. Never compact subgrade.
- Install outlet control structures.
- Seed and stabilize topsoil (Planting with native species is preferred).

Additional Construction Guidelines

Causes of Infiltration BMP Failure

With respect to stormwater infiltration BMPs, the result of “failure” is a reduction in the volume of runoff anticipated or the discharge of stormwater with excessive levels of some pollutants. Where the system includes built structures, such as porous pavements, failure may include loss of structural integrity for the wearing surface, whereas the infiltration function may continue uncompromised. For infiltration systems with vegetated surfaces, such as play fields or rain gardens, failure may include the inability to support surface vegetation, caused by too much or too little water.

The primary causes of reduced performances are:

- Poor construction techniques, especially soil compaction/smearing, which results in significantly reduced infiltration rates.
- A lack of site soil stabilization prior to the BMP receiving runoff, which greatly increases the potential for sediment clogging from contiguous land surfaces.
- Inadequate pretreatment, especially of sediment-laden runoff, which can cause a gradual reduction of infiltration rates.
- Lack of proper maintenance (erosion repair, re-vegetation, removal of detritus, catch basin cleaning, vacuuming of pervious pavement, etc.), which can reduce the longevity of infiltration BMPs.
- Inadequate design
- Inappropriate use of geotextile

Infiltration systems should always be designed such that failure of the infiltration component does not completely eliminate the peak rate attenuation capability of the BMP. Because infiltration BMPs are designed to infiltrate small, frequent storms, the loss or reduction of this capability may not significantly impact the storage and peak rate mitigation of the BMP during extreme events.

for Dry Wells

- 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.

- 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 should overlap by a minimum of 18-24 inches within the trench. Fold back and secure excess geotextile during stone placement.
- Install continuously perforated pipe, observation wells, and all other dry well structures. Connect roof leaders to structures as indicated on plans.
- Place uniformly graded, clean-washed aggregate in 6-inch lifts, between lifts.
- Fold and secure nonwoven geotextile over trench, with minimum overlap of 12 inches.
- Place 12-inch lift of approved topsoil over trench, as indicated on plans.
- Seed and stabilize topsoil.
- Connect surcharge pipe to roof leader and position over splashboard.

Maintenance

There are a few general maintenance practices that should be followed for all infiltration BMPs. These include:

- All catch basins and inlets should be inspected and cleaned at least twice per year.
- The overlying vegetation of subsurface infiltration features should be maintained in good condition, and any bare spots re-vegetated as soon as possible.

- Vehicular access on subsurface infiltration areas should be prohibited (unless designed to allow vehicles), and care should be taken to avoid excessive compaction by mowers.

Additional Maintenance Information for Infiltration Berms

Infiltration berms have low to moderate maintenance requirements, depending on the design. Unless otherwise noted, the following maintenance actions are recommended on an as-needed basis.

Infiltration berms

- Regularly inspect to ensure they are infiltrating; monitor drawdown time after major storm events (total drawdown of the system should not exceed 72 hours; surface drawdown should not exceed 48 hours).
- Inspect any structural components, such as inlet structures, to ensure proper functionality
- If planted in turf grass, maintain by mowing (maintain two to four-inch height); other vegetation will require less maintenance; trees and shrubs may require annual mulching, while meadow planting requires annual mowing and clippings removal
- Avoid running heavy equipment over the infiltration area at the base of the berms; the crest of the berm may be used as access for heavy equipment when necessary to limit disturbance.
- Do not apply pesticides or fertilizers in and around infiltration structures
- Routinely remove accumulated trash and debris
- Remove invasive plants as needed
- Inspect for signs of flow channelization and/or erosion; restore level spreading

immediately after deficiencies are observed (monthly)

Diversion berms

- Regularly inspect for erosion or other failures (monthly)
- Regularly inspect structural components to ensure functionality
- Maintain turf grass and other vegetation by mowing and re-mulching
- Do not apply pesticides or fertilizers where stormwater will be conveyed
- Remove invasive plants as needed
- Routinely remove accumulated trash and debris

Additional Maintenance Information for Infiltration Basins

- Inspect the basin after major storm events and make sure that runoff drains down within 72 hours. Mosquitoes should not be a problem if the water drains in 72 hours. Mosquitoes require a considerably long breeding period with relatively static water levels.
- Inspect for accumulation of sediment, damage to outlet control structures, erosion control measures, signs of water contamination/spills, and slope stability in the berms.
- Mow only as appropriate for vegetative cover species.
- Remove accumulated sediment from the sediment pretreatment device/forebay as needed. Inspect pretreatment forebay at least one time per year.
- If the infiltration basin bottom becomes clogged, scrape bottom and remove sediment and restore original cross section. Properly dispose of sediment.

Additional Maintenance Information for Dry Wells

- Inspect dry wells at least four times a year, as well as after every storm exceeding one inch.
- Remove sediment, debris/trash, and any other waste material from the dry well and dispose of at a suitable disposal/recycling site and in compliance with local, state, and federal waste regulations.
- Evaluate the drain-down time of the dry well to ensure the maximum time of 72 hours is not being exceeded. If drain down time exceeds the maximum, drain the dry well via pumping and clean out perforated piping, if included. If slow drainage persists, the system may need replacing.
- Regularly clean out gutters and ensure proper connections which will facilitate the effectiveness of the dry well.
- Replace filter screen that intercepts roof runoff as necessary.
- If an intermediate sump box exists, clean it out at least once per year.

summary of both construction and maintenance costs. This information should be strictly as guidance. More detailed cost information should be discerned for the specific site before assessing the applicability of the BMP.

	Construction Costs	Maintenance Costs
Dry well*	\$4-9/ft ³	5-10% of capital costs
Infiltration basin	Varies depending on excavation, plantings, and pipe configuration.	Disposal costs
Infiltration trench**	\$20-30/ ft ³	5-10% of capital costs
Subsurface infiltration bed	\$13/ ft ³	

Table 4 Summary of construction and maintenance costs for infiltration BMPs

**2003 dollars.*

***City of Portland. 2006 dollars.*

Winter Considerations

Most infiltration practices are typically located below the frost line and continue to function effectively throughout the winter. It is imperative to prevent salt, sand, cinder, and any other deicers from clogging the surface area of infiltration practices by avoiding piling snow in these areas. Sand and cinder deicers could clog infiltration devices and soluble deicers, such as salt, can damage the health of vegetation.

Cost

The construction cost of many infiltration BMPs can vary greatly depending on the configuration, location, site conditions, etc. Following is a

Designer/Reviewer Checklist for Infiltration Berms

ITEM	Page No.	YES	NO	N/A	NOTES
➤ Was the Soil Infiltration Testing Protocol followed?*	--				
Appropriate areas of the site evaluated?	--				
Infiltration rates measured? <i>Min. infiltration rate: 0.1 in/hr</i> <i>Max. infiltration rate: 10in/hr</i>	8				
Was the Infiltration BMP followed?	--				
➤ Two-foot separation from bedrock/SHWT?	2,8				
Soil permeability acceptable?	8				
Natural, uncompacted soils?	9				
Excavation in berm areas minimized?	9				
Loading ratio considered? ➤ <i>Max. impervious drainage area loading ratio – 5:1</i> ➤ <i>Max. total drainage area loading ratio – 8:1</i> ➤ <i>Max. drainage area: 5 acres</i>	10				
Drawdown time less than 72 hours?	10				
Erosion and Sedimentation control?	--				
Feasible construction process and sequence?	20				
Entering flow velocities non-erosive?	--				
Berm height 6 to 24 inches?	11				
Berm designed for stability (temporary and permanent)?	--				
Acceptable berm side slopes? <i>Max. side slopes: 2:1 (H:V)</i>	12				
Are berm materials resistant to erosion?	--				
Located level, along contour?	11				
Acceptable soil for plants specified?	11				
Appropriate plants selected?	10				
Maintenance accounted for and plan provided?	23				

➤ *Denotes Minimum Design Considerations*

* *In general, the protocol should be followed as much as possible (although there is more flexibility for berms than for other BMPs such as pervious pavement and subsurface infiltration that rely almost entirely on infiltration).*

Designer/Reviewer Checklist for Infiltration Trenches, Infiltration Basins, Dry Wells, and Subsurface Infiltration Beds

ITEM	Page No.	YES	NO	N/A	NOTES
➤ Was the Soil Infiltration Testing Protocol followed?	--				
Appropriate areas of the site evaluated?	--				
Infiltration rates measured? <i>Min. infiltration rate: 0.1 in/hr</i> <i>Max. infiltration rate: 10in/hr</i>	8				
Was the Infiltration BMP followed?	--				
➤ Two-foot separation between the bed bottom and bedrock/ SHWT?	2,8				
Soil permeability acceptable?	8				
If not, appropriate underdrain provided?	--				
Adequate separations from wells, structures, etc.? ➤ <i>Minimum Setback Distances:</i> <ul style="list-style-type: none"> ○ <i>Property Line – 10 feet</i> ○ <i>Building Foundation – 10 feet</i> ○ <i>Private Well – 50 feet</i> ○ <i>Public Water Supply Well – 50 feet</i> ○ <i>Septic System Drainfield – 100 feet</i> 	9				
Natural, uncompacted soils?	9				
➤ Level infiltration area (e.g., trench bottom, bed bottom)?	9				
Excavation in infiltration area minimized?	9				
➤ Hotspots/pretreatment considered?	9				
Loading ratio below 5:1? ➤ <i>Max. impervious drainage area loading ratio – 5:1</i> ➤ <i>Max. total drainage area loading ratio – 8:1</i> ➤ <i>Max. drainage area:</i> <ul style="list-style-type: none"> ○ <i>Dry Well – 1 acre</i> ○ <i>Infiltration Basin – 10 acres</i> ○ <i>Infiltration Trench – 2 acres</i> ○ <i>Subsurface Infiltration Bed – 5 acres</i> 	10				
➤ Storage depth limited to two feet?	10				
Drawdown time less than 72 hours?	10,24				
Positive overflow from system?	2,7, 10,12				
Erosion and sedimentation control?	14,19, 20				
Feasible construction process and sequence?	21,22				
Geotextile specified?	10,12				

ITEM	Page No.	YES	NO	N/A	NOTES
Pretreatment provided?	4,9				
Clean, washed, open-graded aggregate specified?	10,12, 15				
Stable inflows provided (infiltration basin)?	--				
Appropriate perforated pipe, if applicable?	--				
Appropriate plants selected, if applicable?	10				
Observation well/clean out provided, if applicable?	13,15				
Maintenance accounted for and plan provided?	22-24				
Additional Design Considerations <i>Infiltration Basins</i> <ul style="list-style-type: none"> ○ Berms – Min. 3:1 slope; Min. top width – 2 feet <i>Infiltration Trenches</i> <ul style="list-style-type: none"> ○ Soil media for tree planting – Min. of 3 feet 	--				

➤ Denotes Minimum Design Considerations

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BMP Fact Sheet

LEVEL SPREADERS

Level spreaders promote infiltration and improve water quality by evenly distributing flows over a stabilized, vegetated surface. This allows for better infiltration and treatment. There are several different types of level spreaders. Examples include concrete sills, earthen berms, and level perforated pipes.



Figure 1 Level spreader, Charlotte, NC (NC State University)

Applications			Stormwater Quantity Functions
Residential	Yes	Volume	Low
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	No	Peak Rate	Low
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Yes	TSS	Low
Highway/Road	Yes	TP	Low
Recreational	Yes	NO ₃	Low
		Temperature	Low

Additional Considerations	
Cost	Low
Maintenance	Low
Winter Performance	High

Variations (optional)

- Inflow
- Outflow

Key Design Features

- Ultimate outlet from structural BMPs
- Roof downspout connections (roof area > 500 ft²)
- Inlet connections (impervious area > 500 ft²)
- Inflow to structural BMP, such as a filter strip, infiltration basin, or vegetated swale

Site Factors

- Water table to bedrock depth: N/A
- Soils: Permeability not critical but should be considered for erodibility
- Slope: 1 to 8 percent max
- Potential hotspots: Yes
- Maximum drainage area: Varies (five acres maximum)

Benefits

- Low Cost
- Wide applicability
- Ability to work with other BMPs in a treatment train
- Avoids concentrated dischargers and their associated potential erosion

Limitations

- Low stormwater benefits by itself
- Careful design and construction required to function properly

Description and Function

Level spreaders are designed to disperse concentrated stormwater flows and are often used with other BMPs over a wide enough area to prevent erosion. Erosion can undermine a BMP, and can be a significant source of sediment pollution to streams and other natural water bodies. By dispersing flows, level spreaders assist vegetated BMPs in pollutant removal via filtration, infiltration, absorption, adsorption, and volatilization. Level spreaders also reduce the impact of a stormwater outlet to a receiving water body.

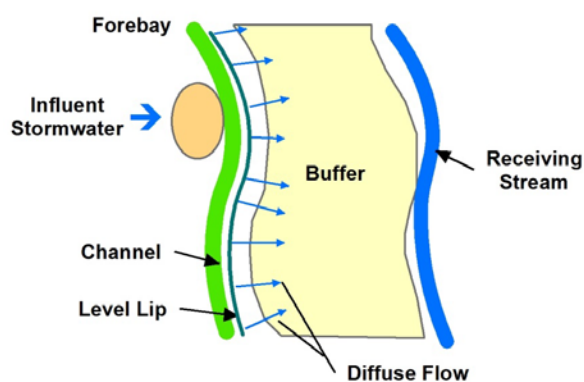


Figure 2 Level spreader located between a sediment forebay and a buffer
Source: NCSU-BAE

Variations

Inflow

Inflow level spreaders are meant to evenly distribute flow entering into another structural BMP, such as a filter strip, infiltration basin, or vegetated swale. Examples of this type of level spreader include concrete sills and earthen berms.

Outflow

Outflow level spreaders are intended to reduce the erosive force of high flows while at the same time enhancing natural infiltration opportunities. Examples of this second type include earthen berms and a level, perforated pipe in a shallow aggregate trench (Figure 3). In this example, the flow is from the left (from an outlet control device from another BMP) and flow reaches the spreader via the solid pipe.

Applications

Level spreaders can be used in a variety of applications, from residential areas to highway/road projects. The primary requirement is that there must be adequate area with an acceptable slope to receive the outflow from the spreader. In ultra-urban settings, there is typically not adequate space for level spreaders.

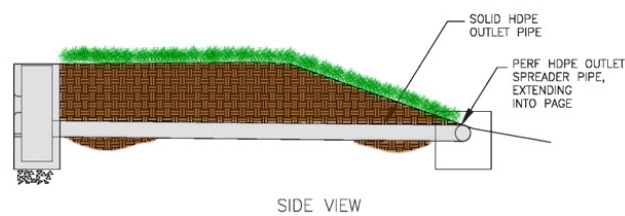


Figure 3 A level spreader with a perforated pipe

Figure 4, a close-up of Figure 3, shows an outlet pipe from an upstream BMP that serves as an inflow to the level spreader.

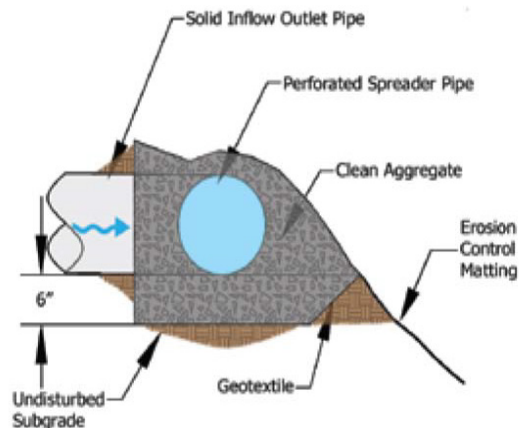


Figure 4 Level spreader with inflow pipe

Design Considerations

Level spreaders are considered a permanent part of a site's stormwater management system. Therefore, uphill development should be stabilized before any dispersing flow techniques are installed. If the level spreader is used as an erosion and sedimentation control measure, it must be reconfigured (flush perforated pipe, clean out all sediment) to its

original state before use as a permanent stormwater feature.

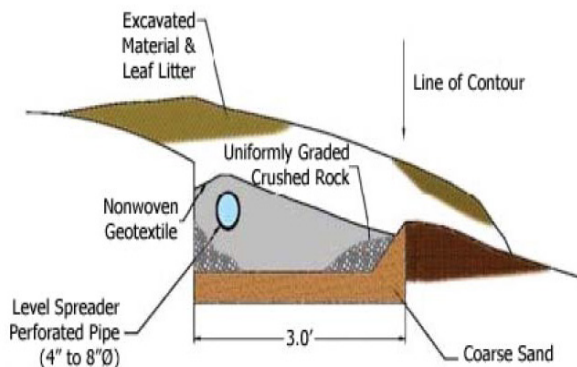


Figure 5 Level spreader with geotextile surrounding the aggregate helping to create a sloped area

All contributing stormwater elements (infiltration beds, inlets, outlet control structures, pipes, etc) should be installed first.

1. Provide as many outfalls as possible and avoid concentrating stormwater. This can reduce or even eliminate the need for engineered devices to provide even distribution of flow.
2. Level spreaders are not applicable in areas with easily erodible soils and/or little vegetation. The slope below the level spreader should be at a maximum eight percent in the direction of flow to discourage channelization. More gentle slopes (e.g., as low as one percent) are also acceptable.
3. The minimum length of flow after the level spreader (of the receiving area) should be 15 feet.
4. For design considerations of earthen berm level spreaders, refer to the Infiltration BMP.
5. Level spreaders should not be constructed in uncompacted fill. Undisturbed virgin soil and compacted fill is much more resistant to erosion and settlement than uncompacted fill.
6. Most variations of level spreaders should not be used alone for sediment removal. Significant sediment deposits in a level

spreader will render it ineffective. A level spreader may be protected by adding a forebay to remove sediment from the influent. This can also make sediment cleanout easier.

7. Perforated pipe used in a level spreader may range in size from 4-12 inches in diameter. The pipe is typically laid in an aggregate envelope, the thickness of which is left to the discretion of the engineer. A deeper trench will provide additional volume reduction and should be included in such calculations (see Infiltration BMP). A layer of nonwoven geotextile filter fabric separates the aggregate from the adjacent soil layers, preventing migration of fines into the trench.
8. The length of level spreaders is primarily a function of the calculated influent flow rate. The level spreader should be long enough to freely discharge the desired flow rate. At a minimum, the desired flow rate should be that resulting from a 10-year design storm. This flow rate should be safely diffused without the threat of failure (i.e., creation of erosion, gullies, or rills). Diffusion of the storms greater than the 10-year storm is possible only if space permits. Generally, level spreaders should have a minimum length of 10 feet and a maximum length of 200 feet.
9. Conventional level spreaders designed to diffuse all flow rates should be sized based on the following:
 - For grass or thick ground cover vegetation:
 - 13 linear feet of level spreader for every one cubic feet per second (cfs) of flow
 - Slopes of eight percent or less from level spreader to toe of slope
 - For forested areas with little or no ground cover vegetation:
 - 100 linear feet of level spreader for every one cfs of flow
 - Slopes of six percent or less from level spreader to toe of slope

For slopes up to 15 percent for forested areas and grass or thick ground cover, level spreaders may be installed in series. The above recommended lengths should be followed.

10. The length of a perforated pipe level spreader may be further refined by determining the discharge per linear foot of pipe. A level spreader pipe should safely discharge in a distributed manner at the same rate of inflow, or less. If the number of perforations per linear foot (based on pipe diameter) and average head above the perforations are known, then the flow can be determined by the following equation:

$$L = Q_P / Q_L$$

Where:

L = length of level spreader pipe (ft.)
 Q_P = design inflow for level spreader (cfs)
 Q_L = level spreader discharge per length (cfs/ft)

AND

$$Q_L = Q_O * N$$

Where:

Q_L = level spreader discharge per length (cfs/ft)
 Q_O = perforation discharge rate (cfs)
 N = number of perforations per length of pipe, provided by manufacturer based on pipe diameter (Number/ft)

AND

$$Q_O = C_d * A * \sqrt{2gH}$$

Where:

Q_O = perforation discharge rate (cfs)
 C_d = Coefficient of discharge (typically 0.60)
 A = Cross sectional area of one perforation (ft²)
 g = acceleration due to gravity, 32.2 ft./sec²
 H = head, average height of water above perforation (ft.) (provided by manufacturer)

11. Flows may bypass a level spreader in a variety of ways, including an overflow

structure or upturned ends of pipe. Cleanouts/overflow structures with open grates can also be installed along longer lengths of perforated pipe. Bypass may be used to protect the level spreader from flows above a particular design storm.

12. Erosion control matting, compost blanketing, or riprap on top of filter fabric are recommended immediately downhill and along the entire length of the level spreader, particularly in areas that are unstable or have been recently disturbed by construction activities. Generally, low flows that are diffused by a level spreader do not require additional stabilization on an already stabilized and vegetated slope.

Stormwater Functions and Calculations

Volume reduction

In general, level spreaders do not substantially reduce runoff volume. However, if level spreaders are designed similarly to infiltration trenches, a volume reduction can be achieved. Furthermore, for outflow level spreaders, the amount of volume reduction will depend on the length of level spreader, the density of receiving vegetation, the downhill length and slope, the soil type of the receiving area, and the design runoff. Large areas with heavy, dense vegetation will absorb most flows, while barren or compacted areas will absorb limited runoff.

Peak rate mitigation

Level spreaders will not substantially decrease the overall discharge rate from a site.

Water quality improvement

While level spreaders are low in water quality pollutant removal, they are often an important BMP used in concert with other BMPs. For example, level spreaders can work effectively (and improve performance) with related BMPs such as filter strips and buffers. In addition, level spreaders can avoid erosion problems associated with concentrated discharges.

Construction Guidelines

The condition of the area downhill of a level spreader must be considered prior to installation. For instance, the slope, density and condition of vegetation, natural topography, and length (in the direction of flow) will all impact the effectiveness of a distributed flow measure. Areas immediately downhill from a level spreader may need to be stabilized, especially if they have been recently disturbed. Erosion control matting, compost blanketing, and/or riprap are the recommended measures for temporary and permanent downhill stabilization. Manufacturer's specifications should be followed for the chosen stabilization measure.

Maintenance

Compared with other BMPs, level spreaders require only minimal maintenance efforts, many of which may overlap with standard landscaping demands. The following recommendations represent the minimum routine inspection maintenance effort for level spreaders:

Once a month and after every heavy rainfall (greater than two inches):

1. Inspect the diverter box and clean and make repairs. Look for clogged inlet or outlet pipes and trash or debris in the box.
2. Inspect the forebay and level spreader. Clean and make repairs. Look for:
 - Sediment in forebay and along level spreader lip,
 - Trash and/or leaf buildup,
 - Scour, undercutting of level spreader,
 - Settlement of level spreader structure (no longer level; you see silt downhill below level spreader),
 - Fallen trees on level spreader, and
 - Stone from below the level spreader lip washing downhill.
3. Inspect the filter strip and the bypass swale and make repairs as needed. Look for:

- Damaged turf reinforcement or riprap rolling downhill,
- Erosion within the buffer or swale, and
- Gullies or sediment flows from concentrated flows downhill of level spreader,

Once a year:

1. Remove any weeds or shrubs growing on level spreader or in swale.

Cost

Level spreaders are relatively inexpensive and easy to construct. There are various types of level spreaders, so costs will vary. Per foot material and equipment cost will range from \$5 to \$20 depending on the type of level spreader desired. Concrete level spreaders may cost significantly more than perforated pipes or berms, but they provide a more sure level surface, are easier to maintain, and more reliable.

Designer/Reviewer Checklist for Level Spreaders

ITEM	Page No.	YES	NO	N/A	NOTES
Avoidance of stormwater concentration as much as practical?	--				
Soil erodibility considered?	--				
Slope considered and appropriate? ➤ <i>Max Slope: 8%</i>	1,3				
Receiving vegetation considered?	4,5				
Located in undisturbed virgin soil?	3				
If not, will soil be properly compacted and stabilized?	--				
Acceptable minimum flow path length below level spreader?	--				
Level spreader length calculations performed? ➤ <i>Min length: 10 feet; Max length: 200 feet</i>	3				
Erosion control matting, compost blankets, etc. provided?	4,5				
Appropriate vegetation selected for stabilization?	--				
Feasible construction process and sequence?	--				
Erosion and sedimentation control provided to protect spreader?	4,5				
Maintenance accounted for and plan provided?	5				
Soils stable or vegetation established before flows are directed to the level spreader?	3				
If used during construction, are accumulated soils removed?	3				

➤ *Denotes Minimum Design Considerations*

References

Hathaway, Jon and Hunt, William. *Evaluation of Level Spreaders in the Piedmont of North Carolina- Final Report*. North Carolina State University: Department of Biological and Agricultural Engineering, 2006.

North Carolina Department of Environmental and Natural Resources. *Stormwater Best Management Practices Manual*, 2007.

Pennsylvania Department of Environmental Protection. *Pennsylvania Stormwater Best Management Practices Manual*, 2006.

Rocco, Domenic. *Level Spreaders and Off-Site Discharges of Stormwater to Non-Surface Waters*, Proceedings from the Villanova Urban Stormwater Partnership Conference, October 2007.

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BMP Fact Sheet

NATIVE REVEGETATION

Native revegetation includes the restoration of forest savanna (scattered trees among prairie plants), and/or prairie. Revegetation should primarily use native vegetation due to the numerous benefits, including reduced maintenance needs.



Figure 1 Native vegetation utilized in a wetland, Philadelphia, PA (USEPA, picasaweb)

Potential Applications			Stormwater Quantity Functions
Residential	Yes	Volume	Low/Med/High
Commercial	Yes	Groundwater Recharge	Low/Med/High
Ultra Urban	Limited	Peak Rate	Low/Med
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Yes	TSS	High
Highway/Road	Limited	TP	High
Recreational	Yes	TN	Med/High
		Temperature	Med

Additional Considerations	
Cost	Low/Med
Maintenance	Low
Winter Performance	Medium

Variations

- Prairie
- No-mow lawn area
- Woodland
- Constructed wetlands
- Buffer areas
- Replacement lawn areas

Key Design Features

- Minimize traditional turf lawn area
- Develop landscape plan using native materials, determining the most appropriate
- Protect areas during construction
- Use integrated pest management (IPM) approach

Site Factors

- Water table to bedrock depth: N/A
- Soils: Vegetation should match soil types
- Slope: Applicable on most slopes (up to 1H:1V)
- Potential hotspots: No
- Maximum drainage area: Optimal is five times (maximum 20 times) the revegetated area

Benefits

- Low long-term maintenance needs
- Improves water quality
- Reduces volume

Limitations

- Establishment period requires more intensive maintenance, such as weeding and watering

Description and Function

Using native plants to vegetate an area is an effective method of improving the quality and reducing the volume of site runoff. Native plants significantly change the soil medium by adding carbon, decreasing bulk density, and increasing infiltration rates by as much as a factor of 10 or more even in clay soils (see Bharati, et.al, 2002 and Fuentes, et.al, 2004).

Native species are generally described as those existing in a given geographic area prior to European settlement. Over time, native vegetation does not typically require significant chemical maintenance by fertilizers and pesticides. This results in additional water quality benefits. Native species are typically more tolerant and resistant to pest, drought, and other local conditions than non-native species. Landscape architects and ecologists specializing in native plant species are usually able to identify a wide variety of plants that meet these criteria anywhere in the state. Recommended Plan List for BMPs Appendix provides lists of commercially available native species. Additional information relating to native species and their use in landscaping is available from the Indiana Native Plant and Wildflower Society at www.inpaws.org.

In addition to chemical applications, minimum maintenance also means minimal mowing and irrigation in established areas. Native grasses and other herbaceous materials that do not require mowing or intensive maintenance are preferred. Because selecting such materials begins at the concept design stage, this BMP can generally result in a site with reduced runoff volume and rate, as well as significant nonpoint source load reduction/prevention.

A complete elimination of traditional lawns as a site design element can be a difficult BMP to implement, given the extent to which the lawn as an essential landscape design feature is embedded in current national culture. Instead, the landscape design should strategically incorporate areas of native plantings – surrounding limited turf grass areas – to act as buffers that will capture and filter stormwater flowing off of turf grasses or pavements.

Native species, being strong growers with denser root and stem systems than turf grass (**Figure 2**), result in:

- A greater volume of water uptake (evapotranspiration)
- Improved soil conditions through organic material and macropore formation
- Carbon sequestration
- Enhanced infiltration

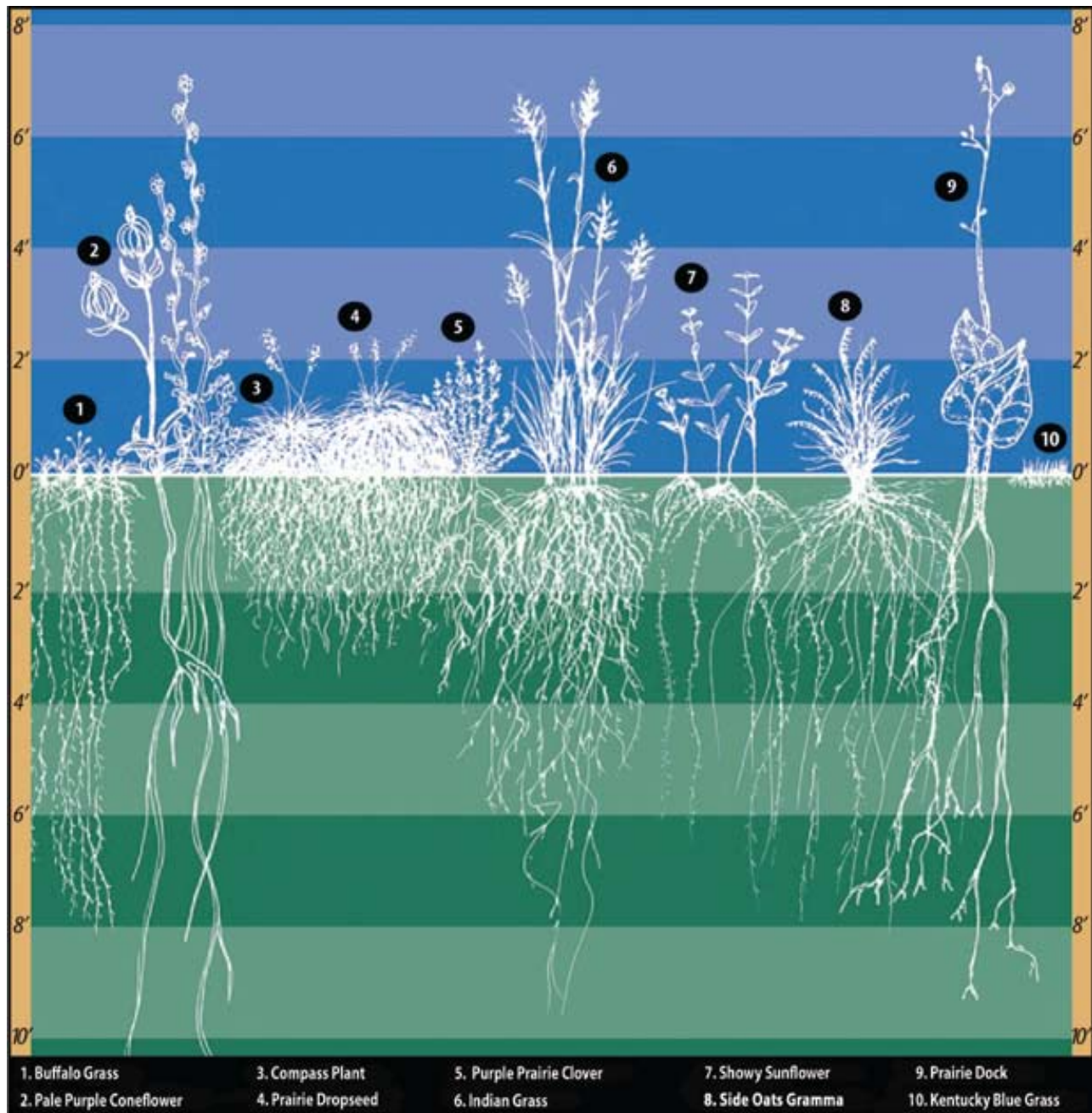


Figure 2 Native meadow species compared to turf grass

Source: JF New

If the objective is to revegetate an area with woodland species, the longer-term effect is a significant reduction in runoff volumes when contrasted with a conventional lawn planting. This decrease in runoff is caused by increases in interception, infiltration, evapotranspiration, and recharge. Peak runoff rate reduction also is achieved. Similarly, prairie reestablishment is also more beneficial than a conventional lawn planting. Again, these benefits are long term in nature and will not be apparent until the species have an

opportunity to grow and mature (one advantage of the prairie planting is that this maturation process requires considerably less time than a woodland area).

In general, seeded prairie plantings grow roots in the first two years of planting, and by the third year, start to show substantial top growth. Therefore, a prairie planting may not be aesthetically pleasing during the first several years. Aesthetic expectations should therefore be adjusted accordingly. Posting

signs explaining this fact to passersby can increase understanding and alleviate concerns about the look of the new planting. The signs can also explain the environmental benefits of planting native grasses.

Variations

Most newly-created native landscapes in Indiana fall under the category of either woodlands or prairies. Woodlands will provide shade, vertical structure, and a high level of rainfall interception in the long term. However, woodlands typically require a significant amount of time to mature. Prairies, on the other hand, have a tendency to establish and regain function rather quickly (3-10 years), and can provide lower-growing vegetation with highly attractive native grasses and wildflowers.

Species selection for any native landscape should be based on function, availability, and level of appropriateness for site conditions. Native species plantings can achieve variation in landscape across a variety of characteristics, such as texture, color, and habitat potential. Plant material should be selected based on tolerance to standing water as identified in Recommended Plant List for BMPs Appendix.

Properly selected mixes of flowering prairie species can provide seasonal color; native grasses offer seasonal variation in texture. Seed production is a food source for wildlife and reinforces habitat. In all cases, selection of native species should strive to achieve species variety and balance, avoiding creation of single-species or limited species “monocultures” which pose multiple problems. In sum, many different aspects of native species planting reinforce the value of native landscape restoration, typically increasing in their functional value as species grow and mature over time. Examples include:

- Prairie – Install forb/grass matrix that bears similarities to historic Indiana prairies and savannas
- No-mow lawn area – Install low-growing native grasses that are used as a substitute for lawn or cool-season grass plantings.

- Woodland – Install a balance of native trees, shrubs, forbs, grasses, and sedges that would historically be represented in Indiana woodlands.
- Constructed wetlands – Historic drained wetlands or existing artificial low areas may be planted with wetland species that will thrive in standing water or saturated conditions.
- Buffer areas – Bands of re-established native vegetation occurring between impermeable surfaces, lawns, or other non-native land uses and existing natural areas.
- Replacement lawn areas – Existing turf lawns may be converted to native prairies, wetlands, or woodlands to minimize maintenance while increasing stormwater benefits and wildlife habitat.

Applications

- Residential – Native landscapes can be incorporated into common areas of residential developments. Additionally, individual homeowners may incorporate native landscapes into their own properties. Native revegetation should also be used to provide buffers around any existing natural areas that are undisturbed within the residential development.
- Commercial – Common areas and open spaces within commercial developments may be planted with native species, as well as any created detention/retention basins or artificial waterways. Native revegetation should also be used to provide buffers around any existing natural areas that are undisturbed within the commercial development.
- Ultra Urban – Use of native revegetation in limited in ultra-urban settings because of the lack of available green space. Wherever possible, however, native species should be incorporated.

- Industrial – Use of native revegetation in industrial settings is very similar to that in commercial settings.
- Retrofit – Established turf grass may be converted into prairie, woodland, or wetland.
- Highway/Road – Native plants may be established in rights-of-way to minimize long-term maintenance while establishing linear habitat corridors.

Design Considerations

The basis for native revegetation design scheme begins with assessing the site for:

- Existing native vegetation,
- Soil,
- Hydrologic regimes,
- Sun exposure, and
- Aesthetics

Existing native vegetation is a good starting point for determining what can thrive on a given site. However, the designer must also consider and balance various factors in developing a successful plant list. The hydrologic patterns set the stage for where the moisture continuum plants will be most successful (easily found in native plant resource guides). The amount of sun and shade that a given species tolerates is also critical in successful plant selection (and is easy to find as well). Soil texture and pH (less often found in resources guides) will further narrow the plant choices. If soils are strongly acidic or basic, the pH will greatly influence and reduce plant choices. Once the potential plant list has run through the sieves of moisture, sun/shade, and soil characteristics, the designer will hopefully have a suite of loosely associated native plants that grow in similar conditions.

Besides the plants' physical requirements, there is the cultural issue of aesthetics to consider. Common issues that people have with native landscapes are the potential height and lack of cultivated

appearance (tall and thin, smaller flowers, looser look, etc.). If the designed areas are highly visible, then these aesthetic issues can be addressed with good design principles and a solid understanding of native plants.

1. Analyze site's physical conditions

The most important physical condition of the site is the topography, hydrology, and soil, each of which will guide protection activities and plant selection. Evaluate the soil using the USDA soil survey to determine important soil characteristics such as flooding potential, seasonal high water table, soil pH, soil moisture, and other characteristics. Evaluate the topography based on USGS maps or a topographical survey of the site.

2. Analyze site's vegetative features

Existing vegetation present at the site should be examined to determine the overall strategy for vegetation restoration and establishment. Strategies will differ whether pre-existing conditions are pasture, overgrown abandoned field, mid-succession forest, or another type of setting. An effort to inventory existing vegetation for protection and to determine type of pre-settlement vegetation should be made to guide efforts.

- Identify desirable species:* Use native tree and shrub species that thrive in local habitat. These species should be identified in the restoration site and protected. Several native vines and shrubs can provide an effective ground cover during establishment of the area, though they should be controlled to prevent herbaceous competition.
- Identify undesirable species:* Control invasive plants prior to planting new vegetation.
- Identify sensitive species:* Because many areas are rich in wildlife habitat and could potentially harbor wetland plant species, be aware of any rare, threatened, or endangered plant or animal species. Take

care to protect sensitive species during restoration activities.

3. *Map the site:* Prepare an existing conditions sketch of the site that denotes important features, including stream width, length, stream bank condition, adjacent land uses, stream activities, desired width of buffer, discharge pipes, obstructions, etc.
4. *Create a design that meets multiple stakeholder objectives*
 - a. *Landowner objectives:* Consider the current use of the existing vegetation, especially if the area will be protected by the landowner in perpetuity. Determine how the revegetated area will complement or conflict with existing and probable future uses of the property.
 - b. *Local objectives:* Consider linking the revegetated area to an existing or planned green infrastructure system, which may include trails, parks, preserves, and wildlife habitat corridors. Evaluate how the new vegetation could help achieve local outdoor recreation goals.
 - c. *Watershed objectives:* Examine the local watershed plan to identify goals related to establishing native plants. Have goals related to water quality been emphasized, or is wildlife habitat of primary concern? If no watershed plan has been prepared, examine other regional resource or recreation plans for reference to native plantings.
5. *Amend soil:* In those sites where soils have been disturbed, restore compromised soils by subsoiling and/or adding a soil amendment, such as compost. This will help in reestablishing its long-term capacity for infiltration and pollution removal.
6. Limit the development footprint as much as possible, preserving natural site features, such as vegetation and topography. In contrast to turf, “natural forest soils with similar overall slopes can store up to 50 times more

precipitation than neatly graded turf.” (Arendt, *Growing Greener*, pg. 81) If lawns are desired in certain areas of a site, they should be confined to those areas with slopes less than six percent.

7. Prairie restoration can reduce turf or create a buffer between turf and forest. Meadow buffers along forests help reduce off-trail trampling and direct pedestrian traffic in order to avoid “desire-lines” which can further concentrate stormwater.

Prepare the site for a prairie planting by weeding well before planting and during the first year. Perennial weeds may require year-long smothering, repeated sprayings with herbicides, or repeated tillage with equipment that can uproot and kill perennial weeds.

The site should be sunny, open, and well-ventilated, as prairie plants require at least a half a day of full sun.

Erosion prone sites should be planted with a nurse crop (such as annual rye or seed oats) for quick vegetation establishment to prevent seed and soil loss. Steep slopes (25 percent or steeper) and areas subject to water flow should be stabilized with erosion blankets, selected to mitigate expected runoff volumes and velocities. Hydro-seeding is generally not recommended for native species. There is tremendous variation among seed suppliers; choose seeds with a minimum percent of non-seed plant parts. Native seed should also be PLS (Pure Live Seed) tested by a third party to gauge seed viability.

8. Converting turf grass areas to prairie requires that all turf be killed or removed before planting, and care taken to control weeds prior to planting.
9. Forest restoration includes planting of tree species, 12-18 inches in height, and shrubs at 18-24 inches, with quick establishment of an appropriate ground cover to stabilize the soil and prevent colonization of invasive species. Trees and shrubs should be planted on eight-

foot centers, with a total of approximately 430 trees per acre.

Reforestation can be combined with other volume control BMPs such as retentive berming, vegetated filter strips and swales. Plant selection should mimic the surrounding native vegetation and expand on the native species already found on the site. A mixture of native trees and shrubs is recommended and should be planted once a ground cover is established.

10. Ensure adequate stabilization, since native grasses, meadow flowers, and woodlands establish more slowly than turf. Stabilization can be achieved for forest restoration by establishing a ground cover before planting of trees and shrubs. When creating meadows, it may be necessary to plant a fast growing nurse crop with meadow seeds for quick stabilization. Annual rye can be planted in the fall or spring with meadow seeds and will establish quickly and usually will not present a competitive problem. Erosion prone sites should be planted with a nurse crop and covered with weed-free straw mulch, while steep slopes and areas subject to runoff should be stabilized with erosion control blankets suitable for the expected volume and velocity of runoff.
11. Prepare a landscape maintenance plan that identifies weeding plans, mowing goals, irrigation needs, and trimming of herbaceous perennials or key tree specimens, as needed.

Maintenance

Local land conservancies are excellent resources when considering the long-term stewardship of the area. If a site has critical value, a local conservancy may be interested in holding a conservation easement on the area, or may be able to provide stewardship services and assistance. Wild Ones (www.for-wild.org/) is a national organization with local chapters which may also provide stewardship resources.

Applying a carefully selected herbicide (Roundup® or similar glyphosate herbicide) around the protective tree shelters/tubes may be necessary,

reinforced by selective cutting/manual removal, if necessary. This initial maintenance routine is often necessary for the first two to three years of growth and may be needed for up to five years until tree growth and tree canopy form, naturally inhibiting weed growth. Once shading is adequate, growth of invasive species and other weeds will be naturally prevented, and the woodland becomes self-maintaining. Survey the new woodland intermittently to determine if replacement trees should be provided. Keep in mind that some modest rate of planting failure is usual.

Prairie management is somewhat more straightforward. A seasonal mowing or burning may be required, although care must be taken to make sure that any management is coordinated with essential reseeding and other important aspects of meadow reestablishment. In addition, burning needs to be coordinated with the local fire department and follow local regulations. In the first year, weeds must be carefully controlled and consistently mowed back to four to six inches tall when they reach 12-18 inches in height.

In the second year, continue to monitor and mow weeds and hand-treat perennial or rhizomatous weeds with herbicide. Weeds should not be sprayed with herbicide if the drift from the spray may kill large patches of desirable plants; weeds will most likely move in to these new open areas. If necessary, controlled spot herbicide applications may be used to treat invasive plants if the treatments can be completed without damage to off-target vegetation.

A prescribed burn should be conducted at the end of the second or beginning of the third growing season. If burning is not possible, the prairie should be mowed very closely to the ground instead. If possible or practical, the mowed material should be removed from the site to expose the soil to the sun. This helps encourage rapid soil warming which favors the establishment of “warm season” plants over “cool season” weeds. Long-term maintenance should incorporate burning or mowing on a two to five year cycle to minimize woody species growth while encouraging development of the native prairie species.

Stormwater Functions and Calculations

Volume and peak rate

Native revegetation will lower runoff volume and peak rates by lowering the runoff coefficient (i.e., curve number). Designers can receive runoff reduction recognition based on the square feet of trees or shrubs being added. Proposed trees and shrubs to be planted under the requirements of these BMPs can be assigned a curve number (CN) reflecting a woodlot in “good” condition associated with the pre-development underlying soil layer for an area of 200 square feet per tree or the estimated tree canopy, whichever is greater. For shrubs, the area should be 25 square feet per shrub. Calculation methodology to account for this BMP is provided under LID Approach in Post-Construction Water Quality Management Chapter of Technical Standards.

Water quality improvement

Landscape restoration using native species (which includes minimizing disturbance and maintenance), improves water quality preventively by minimizing the application of fertilizers and pesticides. Avoiding this nonpoint pollutant source is an important water quality objective.

Cost

Cost estimates for various aspects of native landscaping, including material and installation costs, are the following:

- \$1,000-\$2,500/acre for prairie installation or woodland understory installation
- \$1,800-\$2,600/acre for bare-root tree installation (10-foot spacing)
- \$10-\$20/plant for gallon-potted native perennial
- \$2.50-\$3.50/plant for plug-sized native perennial
- \$250-\$400/tree for balled-and-burlap tree installation

Costs for meadow re-establishment are lower than those for woodland, largely due to the need for tree installation. Again, such costs can be expected to be

greater than installing a conventional lawn (seeding and mulching), although installation cost differences diminish when conventional lawn seeding is redefined in terms of conventional planting beds.

Cost differentials grow greater when longer term operating and maintenance costs are taken into consideration. If lawn mowing can be eliminated, or even reduced significantly to a once per year requirement, substantial maintenance cost savings result, often in excess of \$2,000-\$3,000 per acre per year.

If chemical application (fertilization, pesticides, etc.) can be eliminated, substantial additional savings result with use of native species. These reductions in annual maintenance costs resulting from a native landscape re-establishment quickly outweigh any increased installation costs that are required at project initiation. The aesthetic, water quality, and environmental protection benefits of native landscaping are clear. Nonetheless, implementation is often hindered because parties paying the higher up-front costs (usually the developer) are different than the parties reaping the benefits of reduced maintenance costs. Overcoming this impediment involves recognizing that native landscaping is another part of the “infrastructure” that communities must build into design in order to achieve the desired outcome of appearance and water quality protection.

Criteria to receive runoff reduction recognition for Native Revegetation

To receive runoff reduction recognition for native revegetation under a location regulation, the following criteria must be met:

- ☐ Area is protected by clearly showing the limits of disturbance on all construction drawings and delineated in the field.
- ☐ Area to receive runoff reduction recognition for trees is 200 square feet per tree or the estimated tree canopy, whichever is greater.
- ☐ Area to receive runoff reduction recognition for shrubs is 25 square feet per shrub.
- ☐ Area is located on the development project.
- ☐ Area has a maintenance plan that includes weeding and watering requirements from initial installation through ongoing maintenance.

Designer/Reviewer Checklist for Native Revegetation

ITEM	Page No.	YES	NO	N/A	NOTES
Avoidance of stormwater concentration as much as practical?	--				
Soil erodibility considered?	6				
Slope considered and appropriate?	6				
Existing and surrounding vegetation assessed, including desirable, sensitive, and non-native species?	5				
Site mapped?	5				
Does the design meet all stakeholder objectives, including storm-water, habitat, aesthetics, and timeframe for establishment?	5				
Does the soil require amendment?	6				
Erosion control matting, compost blankets, etc. provided as needed?	6				
Feasible construction process and sequence?	--				
Short and long-term maintenance accounted for and plan provided?	7				

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BMP Fact Sheet

PERVIOUS PAVEMENT WITH INFILTRATION

Pervious pavement is an infiltration technique that combines stormwater infiltration, storage, and structural pavement consisting of a permeable surface underlain by a storage reservoir. Pervious pavement is well suited for parking lots, walking paths, sidewalks, playgrounds, plazas, tennis courts, and other similar uses.

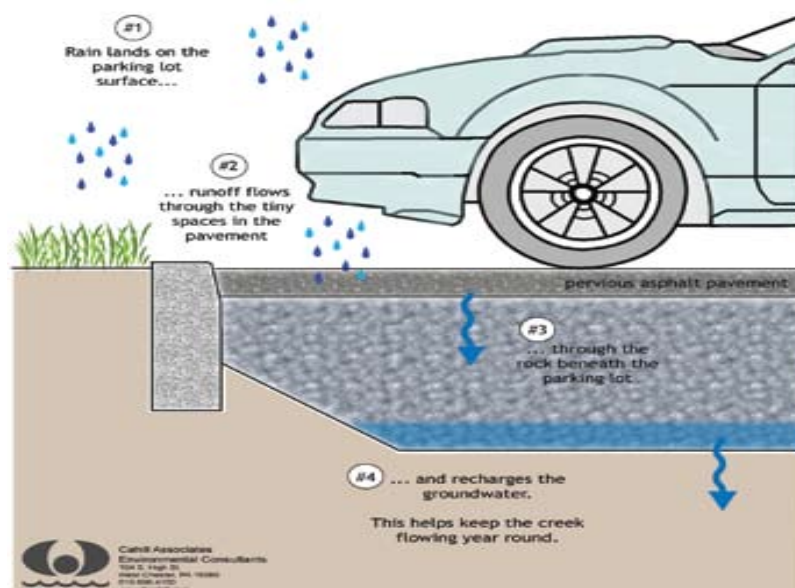


Figure 1 Pervious Pavement with infiltration schematic

Applications		Stormwater Quantity Functions	
Residential	Yes*	Volume	High
Commercial	Yes	Groundwater Recharge	High
Ultra Urban	Yes	Peak Rate	Med/High
Industrial	Yes*	Stormwater Quality Functions	
Retrofit	Yes*	TSS	High**
Highway/Road	Limited	TP	Med/High
Recreational	Yes	TN	Medium
		Temperature	High

Additional Considerations	
Cost	Medium
Maintenance	High
Winter Performance	Medium

*Applicable with special design considerations.

**Pretreatment for TSS is recommended.

Variations

- Porous asphalt
- Pervious concrete
- Permeable paver blocks
- Reinforced turf/gravel

Key Design Features

- Follow soil infiltration testing protocol (Appendix D4) and infiltration BMP guidelines
- Do not infiltrate on compacted soil
- Level storage bed bottoms
- Provide positive stormwater overflow from bed
- Surface permeability > 20"/hour

Site Factors

- Water table/Bedrock separation: two-foot minimum***
- Feasibility on steeper slopes: Low
- Potential hotspots: Not without design of pretreatment system

Benefits

- Volume control and groundwater recharge, moderate peak rate control
- Dual use for pavement structure and stormwater management

Limitations

- Pervious pavement not suitable for all uses
- High maintenance needs

*** Four feet recommended, if possible

Description and Function

A pervious pavement system consists of a porous surface course underlain by a storage reservoir placed on uncompacted subgrade to facilitate stormwater infiltration (**Figure 2**). The storage reservoir may consist of a stone bed of uniformly graded, clean, and washed coarse aggregate with a void space of approximately 40 percent or other pre-manufactured structural storage units (see Infiltration BMP for detailed information on the use of structural storage units). The pervious pavement may consist of porous asphalt, pervious concrete, permeable paver blocks, or reinforced turf/gravel.

Stormwater drains through the surface course where it is temporarily held in the voids of the stone bed, and then slowly infiltrates into the underlying, uncompacted soil mantle (in some extreme cases, minimal compaction of the soil may be required). The stone bed can be designed with an overflow control structure so that during large storm events peak rates are controlled. At no time does the water level rise to the pavement level.

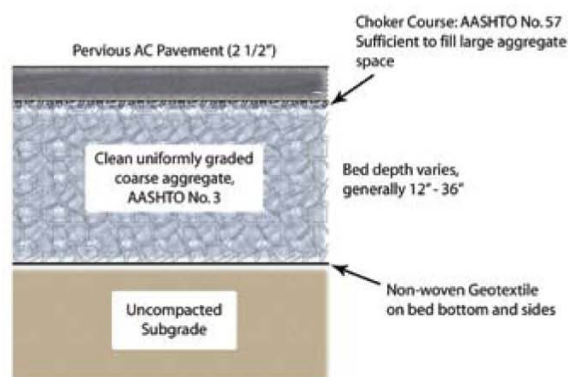


Figure 2 Example cross-section of porous asphalt system

A layer of nonwoven geotextile filter fabric separates the aggregate from the underlying soil, preventing the migration of fines into the bed. The bed bottoms should be level and uncompacted to allow for even and distributed stormwater infiltration.

If new fill is required, it should consist of additional stone and not compacted soil. It is recommended that a failsafe be built into the system in the event that the pervious surface is adversely affected and suffers reduced performance. Many designs incorporate a riverstone/rock edge treatment or

inlets which are directly tied to the bed so that the stormwater system will continue to function despite the performance of the pervious pavement surface.

Pervious pavement is well suited for parking lots, walking paths, sidewalks, playgrounds, plazas, tennis courts, and other similar uses. Pervious pavement can be used in driveways if the homeowner is aware of the stormwater functions of the pavement. Pervious pavement roadways have seen wider application in Europe and Japan than in the U.S., although at least one U.S. system has been constructed successfully. (In Japan and the U.S., applying an open-graded asphalt pavement of one inch or less on roadways has been used to provide lateral surface drainage and prevent hydroplaning, but these are applied over impervious pavement on compacted subgrade. This application is not considered a stormwater BMP.)

Properly installed and maintained pervious pavement has a significant life span. For example, existing systems that are more than 20 years old continue to function successfully. Because water drains through the surface course and into the subsurface bed, freeze-thaw cycles do not tend to adversely affect pervious pavement.

Pervious pavement is most susceptible to failure difficulties during construction and, therefore, it is important that construction be undertaken in such a way as to prevent:

- Compacted underlying soil (except in certain limited conditions),
- Contaminated stone subbase with sediment and fines,
- Tracking of sediment or any temporary storage of soil on the pavement surface, and
- Drainage of sediment-laden waters onto pervious surface or into constructed bed.

Staging, construction practices, and erosion and sediment control must all be considered when using pervious pavements.

When properly designed, pervious pavement systems provide effective management of stormwater volume and peak rates. The storage reservoir below the pavement surface can be sized

to manage both direct runoff and runoff generated by adjacent areas, such as rooftops. Because the stone bed provides storage, outlet structures can be designed to manage peak rates with the use of weir and orifice controls. A well-designed system can infiltrate the majority of frequent small storms on an annual basis while providing peak rate control for storms up to and including the 100-year frequency storm event.

Studies have shown that pervious systems have been very effective in reducing contaminants such as total suspended solids, metals, and oil and grease. Because pervious pavement systems often have zero net discharge of stormwater for small frequent storms, they provide effective water quality control. The pervious surface and underlying soils below the storage bed allow filtration of most pollutants.

However, care must be taken to prevent infiltration in areas where toxic/contaminated materials are present in the underlying soils or within the stormwater itself. When designed, constructed, and maintained according to the following guidelines, pervious pavement with underlying infiltration systems can dramatically reduce both the rate and volume of runoff, recharge the groundwater, and improve water quality.

In northern climates, pervious pavements have less of a tendency to form black ice and often require less plowing. Sand and other abrasives should never be used on pervious pavements, although salt may be used on pervious asphalt as long as it does not contain significant non-soluble particles. Commercial deicers may be used on pervious concrete. Pervious pavement surfaces often provide better traction for walking paths in rain or snow conditions.

Variations

Porous asphalt

Early work on porous asphalt pavement was conducted in the early 1970s by the Franklin Institute in Philadelphia. It consists of standard bituminous asphalt in which the fines have been screened and reduced, allowing water to pass through small voids. Pervious asphalt is typically

placed directly on the stone subbase in a single 3½ to 4-inch lift that is lightly rolled to a finished thickness of 2½ to 3 inches.

Because porous asphalt is standard asphalt with reduced fines, it is similar in appearance to standard asphalt. Newer open-graded mixes for highway application give improved performance through the use of additives and higher-grade binders. Porous asphalt is suitable for use in any climate where standard asphalt is appropriate.

Pervious concrete

Pervious Portland Cement Concrete, or pervious concrete, was developed by the Florida Concrete Association. Like pervious asphalt, pervious concrete is produced by substantially reducing the number of fines in the mix in order to establish voids for drainage. In northern and mid-Atlantic climates such as Indiana, pervious concrete should always be underlain by a stone subbase designed for stormwater management and should never be placed directly onto a soil subbase.

While porous asphalt is very similar in appearance to standard asphalt, pervious concrete has a coarser appearance than conventional concrete. A clean, swept finish cannot be achieved. Care must be taken during placement to avoid working the surface and creating an impervious layer. Placement should be done by a contractor experienced with pervious concrete. Appropriately installed pervious concrete has proven to be an effective stormwater management BMP. Additional information pertaining to pervious concrete, including specifications, is available from the Indiana Ready Mixed Concrete Association (www.irmca.com).

Permeable paver blocks

Permeable paver blocks consist of interlocking units (often concrete) that provide some portion of surface area that may be filled with a pervious material such as gravel. These units are often very attractive and are especially well suited to plazas, patios, parking areas, and low-speed streets. As new products are always being developed, the designer is encouraged to evaluate the benefits of various products with respect to the specific application.

Reinforced turf/gravel

Reinforced turf consists of interlocking structural units that contain voids or areas for turf grass growth or gravel and suitable for traffic loads and parking. Reinforced turf units may consist of concrete or plastic and are underlain by a stone and/or sand drainage system for stormwater management.

Reinforced turf/gravel applications are excellent for fire access lanes, overflow parking, and occasional-use parking (such as at religious and athletic facilities). Reinforced turf is also an excellent application to reduce the required standard pavement width of paths and driveways that must occasionally provide for emergency vehicle access.

Other

There are other proprietary products similar to pervious asphalt and concrete, but they use clear binders so that the beauty of the natural stone is visible. Material strength varies, so some of these products are not suitable for vehicular traffic. Typical applications include tree pits, walkways, plazas, and playgrounds. There are also pervious pavements made using recycled tires.

Applications

Pervious pavements have been widely applied in retrofit situations when existing standard pavements are being replaced. Care must be taken when using pervious pavements in industrial and commercial applications where pavement areas are used for material storage or the potential for surface clogging is high due to pavement use. They have also been used extensively for parking areas, walkways, playgrounds, basketball courts, tennis courts, streets, and alleys.

Pervious pavement systems are often used to provide total site stormwater management where rooftops and other impervious surfaces are tied into the infiltration bed below the pavement surface. This can be an effective means to manage stormwater for a development site, while reducing land disturbance for stormwater BMPs.

If pervious pavement systems receive runoff from adjacent areas, proper sediment pretreatment for that runoff must be considered to prevent clogging of the storage bed. Typical pretreatment can be achieved by the use of properly maintained cleanouts, inlet sediment traps, and water quality inserts or filter devices.

It is recommended that direct surface sheet flow conveyance of large impervious areas to the pervious pavement surface be avoided. High sheet flow loading to pervious pavement surfaces can lead to premature clogging of the pavement surface. To avoid this, it is recommended that adjacent impervious areas be drained and conveyed to the infiltration bed via inlets and trench drains with proper sediment pretreatment.

Design Considerations

While evaluating the following design considerations, there are also several additional resources to consider when implementing pervious pavement. These include the Soil Infiltration Testing Protocol (Soil Infiltration Testing Protocol Appendix), the Recommendations for Materials are specific to porous asphalt and porous concrete (Recommended Materials Appendix), and additional steps set forth in the Introduction to Structural BMPs segment of this Appendix.

Siting

1. The overall site should be evaluated for potential pervious pavement/infiltration areas *early* in the design process because effective pervious pavement design requires consideration of grading.
2. A four foot clearance above the seasonally high water table and bedrock is recommended. A two foot clearance can be used but may reduce the performance of the infiltration BMP used.
3. Orientation of the parking bays along the existing contours will significantly reduce the need for cut and fill.

4. Pervious pavement and infiltration beds **should not be placed on areas of recent fill** or compacted fill. If fill is unavoidable, permeable stone subbase material should be used wherever possible (and applicable infiltration rates should be used in the design). Areas of historical fill (>5 years) may also be considered for pervious pavement.
5. In those areas where the threat of spills and groundwater contamination is likely, pretreatment systems, such as filters and wetlands, may be required before any infiltration occurs. In hot spot areas, 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.
6. The use of pervious pavement must be carefully considered in areas where the pavement may be seal-coated or paved over due to lack of awareness, such as individual home driveways. In those situations, a system that is not easily altered by the property owner may be more appropriate. An example would include an infiltration system constructed under a conventional driveway. Educational signage at pervious pavement installations can encourage proper maintenance and is recommended.
7. In areas with poorly draining soils, infiltration beds below pervious pavement may be designed to slowly discharge to adjacent swales, wetlands, or bioretention areas. Only in extreme cases (e.g., industrial sites with contaminated soils) will the aggregate bed need to be lined to prevent infiltration.

Design

1. Bed bottoms must be level (0 percent slope) or nearly level. Sloping bed bottoms will lead to areas of ponding and reduced stormwater distribution within the bed. However, beds may be placed on a slope by benching or terracing parking bays (**Figure 3**). Orienting

parking bays along existing contours will reduce site disturbance and cut/fill requirements.



Figure 3 Slope stepping with berms Source: Andropogon

2. All systems should be designed with an overflow system. Water within the subsurface stone bed should typically never rise to the level of the pavement surface. Inlet boxes can be used for cost-effective overflow structures. All beds should empty within 72 hours, preferably within 48 hours.
3. While infiltration beds are typically sized to handle the increased volume from a two-year design storm, they must also be able to convey and mitigate the peak of the less-frequent, more-intense storms, such as the 100-year storm. Control in the 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 (**Figure 4**). The specific design of these structures may vary, depending on factors such as rate and storage requirements, but it always must include positive overflow from the system to prevent surface ponding.
4. 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 (**Figure 3**).
5. 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 significantly reduced in size.

8. Perforated pipes can also be used as underdrains where necessary. Underdrains must be double-walled. Underdrains can ultimately discharge to daylight or to another

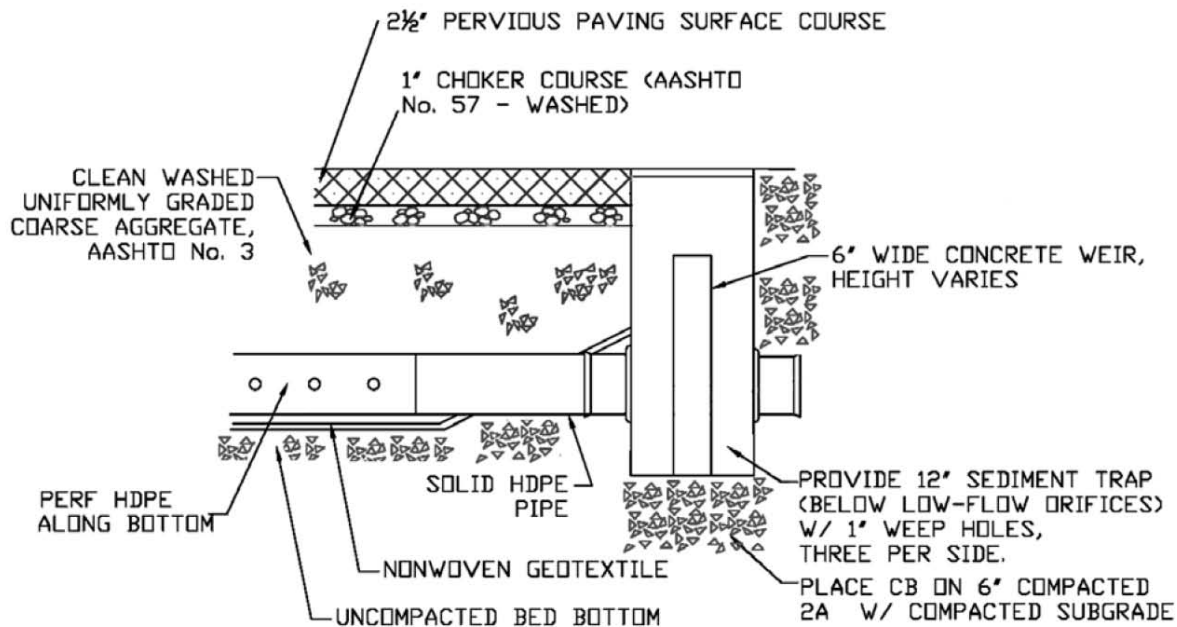


Figure 4 Example cross-section of porous asphalt system

6. Pervious pavement installations should 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 one-to-two foot wide stone edge drain connected directly to the bed. In curbed lots, inlets with sediment traps may be used at low spots. Backup drainage elements will ensure the functionality of the infiltration system if the pervious pavement is compromised.
7. Perforated pipes along the bottom of the bed may be used to evenly distribute runoff over the entire bed bottom (especially if runoff from adjacent areas is being brought into the bed). Continuously perforated pipes should connect structures (such as cleanouts and inlet boxes). Pipes may lay flat along the bed bottom and connect to the overflow structure (Figure 4). Depending on size, these pipes may provide additional storage volume.

stormwater system. They should be accessible for inspection and maintenance via cleanouts, overflow devices (Figure 4), or other structures.

9. Sediment transport to pervious systems should be minimized as much as possible to reduce maintenance requirements and extend the life of these systems. If roof leaders and area inlets convey water from adjacent areas to the bed, then native vegetation, water quality inserts, and/ or sumped inlets should be used to prevent the conveyance of sediment and debris into the bed. Areas of impervious pavement draining directly onto pervious pavements should also be minimized as they can lead to clogging near the impervious-pervious boundary.
10. Infiltration areas should be located within the immediate project area in order to control runoff at its source. Expected use and traffic demands should also be considered in pervious pavement placement. An impervious

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

11. The underlying infiltration bed is typically 8 to 36 inches deep and comprised of clean, uniformly graded aggregate with approximately 40 percent void space. Local aggregate availability typically dictates the size of the aggregate 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 structural needs.
12. Proper pervious pavement applications are resistant to freeze-thaw problems because of their permeable and open-graded components (the pavement surface should not be saturated and the base has a high void content which allows for expansion). In somewhat frost-susceptible soils, it may be necessary to increase the minimum bed depth to 14-22 inches (depending on loading and specific soil conditions). In extremely susceptible soils, the bed and/or improved soils can be placed down to the full frost depth (Smith, 2006).
13. While most pervious pavement installations are underlain by an aggregate bed, alternative subsurface storage products may also be used. These include a variety of proprietary plastic units that contain much greater storage capacity than aggregate, at an increased cost.

Stormwater Functions and Calculations

Infiltration area

The infiltration area is defined as the plan area of the storage reservoir under the pervious pavement. The minimum infiltration area should be based on the following equation:

Minimum infiltration area = Contributing impervious area (including pervious pavement) / 5[#]

[#] - May be increased depending on soil infiltration capacity (where soils are Type A or rapidly draining).

Volume reduction

Pervious pavements with infiltration provide an excellent means of capturing and infiltrating runoff. The storage bed below the pavement provides runoff volume storage during storm events, while the undisturbed subgrade allows infiltration of runoff into the underlying soil mantle. The total volume reduction can be estimated by summing the storage and infiltration volumes described below.

Storage volume = Depth[#] (ft) * Area (ft²) * Void space (i.e., 0.40 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.

Infiltration volume = Bed bottom area (ft²) * Infiltration design rate (in/hr) * Infiltration period[#] (hr) * (1/12)

[#] - Infiltration period is the time when bed is receiving runoff and capable of infiltrating at the design rate. Not to exceed 72 hours.

Peak rate mitigation

Properly designed pervious pavement systems provide effective management of peak rates. The infiltration bed below the pavement acts as a storage reservoir during large storm events, even while runoff exfiltrates through the soil mantle through the process of infiltration. Outlet structures can be designed to manage peak rates with the use of weir and orifice controls and carefully designed systems may be able to manage peak rates for storms up to and including the 100-year storm.

Water quality improvement

Pervious pavement systems are effective in reducing pollutants such as total suspended solids, metals, and oil and grease. Both the pervious pavement surface and the underlying soils below the infiltration bed allow pollutant filtration.

When pervious pavement systems are designed to capture and infiltrate runoff volumes from small

storm events, they provide very high pollutant reductions because there is little if any discharge of runoff carrying the highest pollutant loads. Pervious pavement systems require pretreatment of TSS when adjacent areas drain to them, resulting in a high reduction of TSS and other particulates. However, pervious pavement systems will provide limited treatment of dissolved pollutants, such as nitrates. Typical ranges of pollutant reduction efficiencies for pervious pavements are listed as follows:

- TSS[#] – 65-100%
- TP – 30-90%
- NO₃ – 30%

[#] - Pretreatment for TSS is recommended if adjacent areas drain to pervious pavement

Construction Guidelines

1. Follow the Recommendations for Materials that are specific to porous asphalt and porous concrete in Recommended Materials Appendix.
2. Due to the nature of construction sites, pervious pavement and other infiltration measures should be installed toward the end of the construction period, if possible. Infiltration beds under pervious pavement may be used as temporary sediment basins or traps provided that they are not excavated to within 12 inches of the designated bed bottom elevation. Once the site is stabilized and sediment storage is no longer required, the bed is excavated to its final grade and the pervious pavement system is installed.
3. The existing subgrade under the bed areas should **not** be compacted or subject to excessive construction equipment traffic prior to geotextile and stone bed placement. (Minor areas of unavoidable compaction can be partially remediated by scarifying the soil; see below.)

Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material should be removed with light equipment and the underlying soils

scarified to a minimum depth of six inches with a York rake (or equivalent) and light tractor. All fine grading should be done by hand. All bed bottoms are level grade.

4. Earthen berms (if used) between infiltration beds may be left in place during excavation. These berms do not require compaction if proven stable during construction.
5. Geotextile and bed aggregate should 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 should overlap a minimum of 18 inches. It should also be secured at least four feet outside of bed in order to prevent any runoff or sediment from entering the storage bed. This edge strip should 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.

6. Clean (washed) uniformly graded aggregate is placed in the bed in eight-inch lifts. Each layer should be lightly compacted, with construction equipment kept off the bed bottom. Once bed aggregate is installed to the desired grade, approximately one inch of choker base course crushed aggregate should be installed uniformly over the surface in order to provide an even surface for paving (if required).
7. Cement mix time: Mixtures should be produced in central mixers or in truck mixers. When concrete is delivered in agitating or non-agitating units, the concrete should be mixed in the central mixer for a minimum of 1.5 minutes or until a homogenous mix is achieved. Concrete mixed in truck mixers should be mixed at the speed designated as mixing speed by the manufacturer for 75-100 revolutions.
8. The Portland Cement aggregate mixture may be transported or mixed onsite and should be

used within one hour of the introduction of mix water, unless otherwise approved by an engineer. This time can be increased to 90 minutes when using the specified hydration stabilizer. Each truck should not haul more than two loads before being cycled to another type concrete. Prior to placing concrete, the subbase should be moistened and in a wet condition. Failure to provide a moist subbase will result in reduced strength of the pavement.

9. A minimum of 30 revolutions at the manufacturer's designated mixing speed is required following any water added to the mix. Discharge should be a continuous operation and completed as quickly as possible. Concrete should be deposited as close to its final position as practicable and such that fresh concrete enters the mass of previously placed concrete.
10. Placing and finishing concrete equipment: The contractor should provide mechanical equipment of either slipform or form riding with a following compactive unit that will provide a minimum of 10 psi vertical force. The pervious concrete pavement will be placed to the required cross section and should not deviate more than +/- 3/8 inch in 10 feet from profile grade.

Placement should be continuous and spreading and strikeoff should be rapid. It is recommended to strike off about 1/2 to 3/4 inch above the forms to allow for compaction. This can be accomplished by attaching a temporary wood strip above the top of the form to bring it to the desired height. After strikeoff, the strips are removed and the concrete is consolidated to the height of the forms.

11. Consolidation should be accomplished by rolling over the concrete with a steel roller, and compacting the concrete to the height of the forms. Consolidation should be completed within 10 minutes of placement to prevent problems associated with rapid hardening and evaporation. After mechanical or other approved strike-off and compaction

operation, no other finishing operation is needed. The contractor will be restricted to pavement placement widths of a maximum of 15 feet.

12. Jointing: Control (contraction) joints should be installed at maximum 20-foot intervals. They should be installed at a depth of 1/4 the thickness of the pavement. These joints can be installed in the plastic concrete or saw cut. However, installing in the plastic concrete is recommended. Joints installed in the plastic concrete should be constructed using a small roller (salt or joint roller) to which a beveled fin with a minimum depth of 1/4 the thickness of the slab has been welded around the circumference of a steel roller. When this option is used it should be performed immediately after roller compaction and prior to curing. If saw cut, the procedure should begin as soon as the pavement has hardened sufficiently to prevent raveling and uncontrolled cracking (normally just after curing).

Transverse construction joints should be installed whenever placing is suspended a sufficient length of time that concrete may begin to harden. In order to assure aggregate bond at construction joints, a bonding agent suitable for bonding fresh concrete should be brushed, tolled, or sprayed on the existing pavement surface edge. Isolation (expansion) joints will not be used except when pavement is abutting slabs or other adjoining structures.

13. Curing procedures should begin within 15 minutes after placement. The pavement surface should be covered with a minimum six millimeter thick polyethylene sheet or other approved covering material. Prior to covering, a fog or light mist should be sprayed on the surface. The cover should overlap all exposed edges and should be completely secured (without using dirt) to prevent dislocation due to winds or adjacent traffic conditions.
14. Porous asphalt should not be installed on wet surfaces or when the ambient air temperature is below 50 degrees Fahrenheit. The

temperature of the bituminous mix should be determined by the results of the Draindown test (ASTM D6390), but typically ranges between 275 degrees Fahrenheit and 325 degrees Fahrenheit (as determined by the testing and recommendations of the asphalt supplier).

Pervious pavement should be laid in one lift directly over the storage bed and stone base course to a 2.5- to 3-inch finished thickness. Compaction of the surface course should take place when the surface is cool enough to resist a 10-ton roller. One or two passes is all that is required for proper compaction. More rolling could cause a reduction in the surface course porosity.

15. Do not place Portland Cement pervious pavement mixtures when the ambient temperature is 40 degrees Fahrenheit or lower, unless otherwise permitted in writing by the engineer.
16. Mixing, placement, jointing, finishing, and curing do not apply to permeable paver systems. A manual on Permeable Interlocking Concrete Pavements from the Interlocking Concrete Pavement Institute (Smith, 2006) offers detailed guidance on the design and construction of permeable paver systems.
17. After final pervious asphalt or concrete installation, no vehicular traffic of any kind should be permitted on the pavement surface until cooling and hardening or curing has taken place, and not within the first 72 hours (many permeable paver systems can be used right away). The full permeability of the pavement surface should be tested by applying clean water at the rate of at least five gallons per minute over the surface using a hose or other distribution device. All water should infiltrate directly without puddle formation or surface runoff.

Maintenance

The primary goal of pervious pavement maintenance is to prevent the pavement surface

and/or underlying infiltration bed from being clogged with fine sediments. To keep the system clean and prolong its life span, the pavement surface should be vacuumed twice per year with a commercial cleaning unit. Pavement washing systems or compressed air units are generally not recommended but may be acceptable for certain types of pavement. All inlet structures within or draining to the infiltration beds should also be cleaned out twice a year.

Planted areas adjacent to pervious pavement should be well maintained to prevent soil washout onto the pavement. If any washout does occur, immediately clean it off the pavement to prevent further clogging of the pores. Furthermore, if any bare spots or eroded areas are observed within the planted areas, they should be replanted and/or stabilized at once. Planted areas should be inspected twice a year. All trash and other litter should be removed during these inspections.

Superficial dirt does not necessarily clog the pavement voids. However, dirt that is ground in repeatedly by tires can lead to clogging. Therefore, trucks or other heavy vehicles should be prevented from tracking or spilling dirt onto the pavement. Furthermore, all construction or hazardous materials carriers should be prohibited from entering a pervious pavement lot.

Potholes in pervious pavement are unlikely, though settling might occur if a soft spot in the subgrade is not removed during construction. For damaged areas of less than 50 square feet, a depression could be patched by any means suitable with standard pavement, with the loss of porosity of that area being insignificant. The depression can also be filled with pervious mix.

If an area greater than 50 sq. ft. is in need of repair, approval of patch type must be sought from either the engineer or owner. If feasible, permeable pavers can be taken up and then simply re-installed (replacing damaged pavers if necessary). **Under no circumstance should the pavement surface ever be seal-coated.** Any required repair of drainage structures should be done promptly to ensure continued proper functioning of the system.

Pervious pavement maintenance considerations are summarized below:

Prevent clogging of pavement surface with sediment

- Vacuum pavement twice a year,
- Maintain planted areas adjacent to pavement,
- Immediately clean any soil deposited on pavement,
- Do not allow construction staging, soil/mulch storage, etc., on unprotected pavement surface, and
- Clean inlets draining to the subsurface bed twice a year.

Snow/Ice removal

- Pervious pavement systems generally perform better and require less treatment than standard pavements,
- Do not apply abrasives such as sand or cinders on or adjacent to pervious pavement,
- Snow plowing is fine but should be done carefully (i.e., set the blade slightly higher than usual), and
- Salt application is acceptable, although alternative deicers are preferable.

Repairs

- Surface should never be seal-coated,
- Damaged areas less than 50 sq. ft. can be patched with pervious or standard pavement,
- Larger areas should be patched with an approved pervious pavement,
- Permeable pavers should be repaired/replaced with similar permeable paver block material, and
- Permeable 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 reseeded if bare areas appear.

Winter Considerations

Pervious pavement systems should perform equally well in the winter, provided that infiltration bed design considers the soil frost line, and proper snow removal and deicing procedures are followed. Winter maintenance for pervious pavement may be necessary but is sometimes less intensive than that required for a standard pavement (especially for pervious asphalt). The underlying stone bed tends to absorb and retain heat so that freezing rain and snow melt faster on pervious pavement. Therefore, ice and light snow accumulation are generally not as problematic. However, snow will accumulate during heavier storms.

Abrasives such as sand or cinders should not be applied on or adjacent to the pervious pavement.

Snow plowing is fine, provided it is done carefully (i.e., by setting the blade slightly higher than usual, about an inch). Salt with low non-soluble solids content is acceptable for use as a deicer on the pervious pavement. Non-toxic, organic deicers applied either as blended, magnesium chloride-based liquid products or as pretreated salt, are preferred.

Cost

The majority of added cost of a pervious pavement/infiltration system lies in the underlying stone bed, which is generally deeper than a conventional subbase and wrapped in geotextile. Costs may also be higher in areas where experienced contractors are not readily available. However, these additional costs are often offset by the significant reduction in the required number of inlets and pipes. Also, since pervious pavement areas are often incorporated into the natural topography of a site, there is generally less earthwork and/or deep excavations involved. Furthermore, pervious pavement areas with subsurface infiltration beds often eliminate the need (and associated costs, space, etc.) for detention basins. When all of these factors are considered, pervious pavement with infiltration has often proven itself less expensive than impervious pavement with associated stormwater management.

- Porous asphalt, with additives, is generally 15 percent to 25 percent higher in cost than standard asphalt on a unit area basis. Unit costs for pervious asphalt (without infiltration bed) range from about \$4/ft² to \$5/ft².
- Pervious concrete as a material is generally more expensive than asphalt and requires more labor and expertise to install. Unit cost of a six-inch-thick pervious concrete (without infiltration bed) section is about \$4/ ft² to \$6/ ft².
- Permeable paver blocks vary in cost depending on type and manufacturer.
- NOTE: The data provided are based on average market costs. For greater accuracy, a site and market-specific cost estimate should be developed.

Designer/Reviewer Checklist for Pervious Pavement with Infiltration Bed

Type of pervious pavement(s) proposed: _____

Source of mix design or material source: _____

ITEM	Page No.	YES	NO	N/A	NOTES
Appropriate application of pervious pavement (e.g., use, traffic loading, slopes)?	--				
Was the Soil Infiltration Testing Protocol followed?	1				
Appropriate areas of the site evaluated?	--				
Infiltration rates measured?	1				
Was the Infiltration BMP followed?	1				
Two-foot minimum separation between the bed bottom and bedrock/SHWT?	1				
Soil permeability acceptable?	--				
If not, appropriate underdrain provided?	--				
Adequate separations from wells, structures, etc.?	--				
Natural, uncompacted soils?	2				
Level infiltration area (bed bottom)?	1,5				
Excavation in pervious pavement areas minimized?	-				
Hotspots/pretreatment considered?	1,5				
Loading ratio below 5:1?	--				
Storage depth limited to two feet?	--				
Drawdown time less than 48 hours?	5				
Positive overflow from system?	1,5				
Erosion and Sedimentation control?	2				
Feasible construction process and sequence?	--				
Geotextile specified?	2				
Clean, washed, open-graded aggregate specified?	2				
Properly designed/specified pervious pavement surface?	8-10				
Maintenance accounted for and plan provided?	10				
Signage provided?	5				

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BMP Fact Sheet

PLANTER BOXES

Planter boxes receive runoff from multiple impervious surfaces, which is used for irrigation of the vegetation in the planter box preventing stormwater from directly draining into nearby sewers. They also play an important role in urban areas by minimizing stormwater runoff, reducing water pollution, and creating a greener and healthier appearance of the built environment by providing space for plants and trees near buildings and along streets. There are three main types of planter boxes which can be used on sidewalks, plazas, rooftops, and other impervious areas: contained, infiltration, and flow-through.



Figure 1 Streetside planter, Portland, OR (city of Portland, Bureau of Environmental Services)

Potential Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low/Med
Commercial	Yes	Groundwater Recharge	Low/Med
Ultra Urban	Yes	Peak Rate	Low
Industrial	Limited	Stormwater Quality Functions	
Retrofit	Yes	TSS	Medium
Highway/Road	No	TP	Medium
Recreational	Yes	TN	Low/Med
		Temperature	Low/Med

Additional Considerations	
Cost	High
Maintenance	Medium
Winter Performance	Medium

Variations

- Contained
- Infiltration
- Flow-through

Key Design Features

- May be designed as pretreatment
- May be designed to infiltrate
- Captures runoff to drain out in three to four hours after a storm event
- Receives less than 15,000 ft² of impervious area runoff
- Planters should be made of stone, concrete, brick, or pressure-treated wood

Benefits

- Enhances the area where they are placed
- Potential air quality and climate benefits
- Can be used in a wide range of areas, including ultra-urban

Limitations

- Limited stormwater quantity/quality benefits
- Relatively high cost due to structural components

Description and Function

Planter boxes receive runoff from multiple impervious surfaces, including rooftops, sidewalks, and parking lots. Runoff is used for irrigation purposes, and the vegetation in the planter box absorbs stormwater and releases it back into the atmosphere through evapotranspiration. Boxes can take any form and can be made out of a variety of materials, although many are constructed from wood.

Construction specifications are critical to ensure that an appropriate volume of runoff from smaller storms “feeds” the carefully selected vegetation types in the boxes; however, consistent watering is necessary during dry periods.

In general, planter boxes must be carefully designed to accommodate the desired amount of runoff. In addition, plantings must be carefully selected, and boxes must be carefully maintained, to accomplish stormwater objectives, and perhaps, most importantly, to succeed in a landowner’s overall landscaping objectives.

Stormwater benefits of planter boxes include reduction in runoff volumes and some reduction in peak rates of runoff. Boxes which overflow also effectively reduce peak rates of runoff. Depending on the type of box selected, evapotranspiration will increase along with infiltration and groundwater recharge. Water quality may benefit, depending upon how much runoff is directed into the ground and prevented from worsening erosive stream flows.

When well designed, installed, and maintained, planter boxes are extremely attractive additions to homes, commercial businesses, and office buildings. In fact, an essential objective in developing planter boxes is to enhance overall landscape aesthetics. Boxes are ideal for buffers around structures, foundation plantings, providing seat walls, and for defining walkways, patios, terraces, drives, and courtyards.

Variations

Of all the BMPs listed in this manual, planter boxes are probably the most adaptable to all types of sites with all types of site constraints. The infiltration variation is influenced by all factors which are limiting to any infiltration-oriented BMP (i.e., bedrock/seasonal high water table at or close to the surface, very poorly draining soils, etc., all of which are described in the Infiltration BMP of this manual). However, both the contained and flow-through variations can be used on virtually every type of site - large or small, front yard or backyard, flat or sloping, shady or sunny.

Contained

Contained planter boxes (**Figure 2**) are generally traditional planters that have weep holes to drain excess water from the planter. They effectively reduce impervious area by retaining rainwater which slows stormwater runoff from draining into sewers. Contained planters are used for planting trees, shrubs, perennials, and annuals. The planter is either prefabricated or permanently constructed in a variety of shapes and sizes. Planters are typically placed on impervious surfaces like sidewalks, plazas, and rooftops. Contained planters may drain onto impervious surfaces through their base or into an overflow structure.

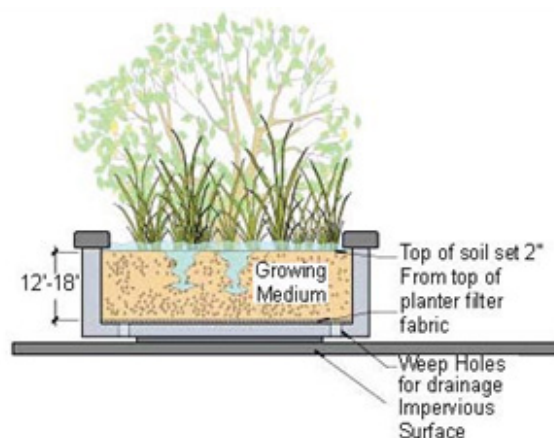


Figure 2 Schematic of Contained Planter Box
Source: City of Portland, OR, Bureau of Environmental Services

Native vegetation should be used in contained planter boxes (Recommended Plant List for BMPs

Appendix). They are hardy and self-sustaining with little need for fertilizers or pesticides. Irrigation needs to be monitored, since plants will need to be watered during dry periods. Sensors can help to regulate moisture in the planter box, ensuring consistent moisture. Smaller trees are highly encouraged because of the canopy and shade they will provide, reducing the urban heat island effect. Planters should be constructed of stone, concrete, brick, wood, or any other suitable material.

This type of planter box can be installed to retrofit an existing urban streetscape or large area of pavement, such as at an entryway to a building.

Infiltration

An infiltration planter box (**Figure 3**) is designed to allow runoff to filter through the planter soils (thus capturing pollutants) and then infiltrate into native soils below the planter. These planters are generally constructed to be flush with surrounding paved areas. The planter is sized to accept runoff and temporarily store the water in a reservoir on top of the soil. Different design variations are encouraged, but should allow a minimum delay in stormwater runoff capture of three to four hours after a wet weather event.

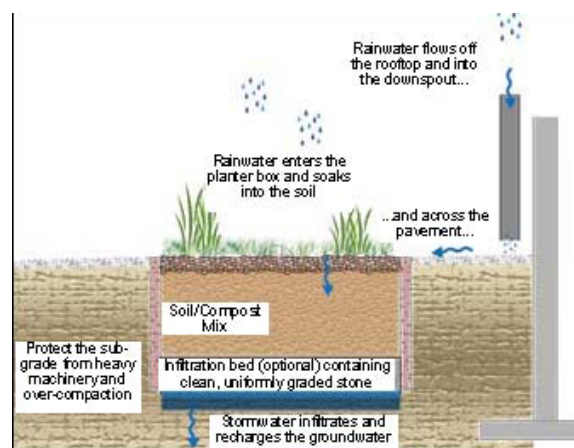


Figure 3 Schematic of Infiltration Planter Box

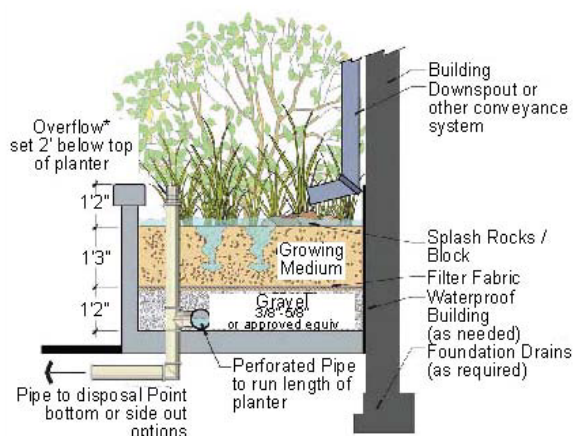
Recommended vegetation includes native rushes, reeds, sedges, irises, dogwoods, and currants. Also, the dimensions of the sand/gravel area used in these designs should be determined by an engineer and designed to receive less than approximately 15,000 square feet of impervious area runoff. The

minimum planter width is typically 30 inches with no minimum length or required shape.

Suggested structural elements of infiltration planter boxes are stone, concrete, brick, or pressure-treated wood. In general, infiltration facilities should be greater than 10 feet from structures and at least five feet from an adjoining property line or as required by local ordinances.

Flow-through

The flow-through planter box (**Figure 4**) is completely contained and drains to a stormwater system. These planters are designed with an impervious bottom or are placed on an impervious surface. Pollutant reduction is achieved as the water filters through the soil/ growing medium. Flow control is obtained by ponding runoff above the soil and in a gravel layer beneath it. In most storm events, runoff flows through the soil into the gravel layer and is slowly discharged via the perforated pipe. In more extreme events, inflow may exceed the capacity of the soil and some runoff may be discharged through surface overflow. This type of planter can be used adjacent to a building if the planter box and/or building are adequately waterproofed to allow for saturated soil and temporary ponded runoff next to the building.



* Water reservoir depth may be reduced if planter surface is increased.

Figure 4 Schematic of Flow-through Planter Box

Flow-through planter boxes should be designed to retain water for no more than three to four hours after an average storm event. Recommended vegetation includes native rushes, reeds, sedges, irises, dogwoods, and currants. The minimum planter width is typically 18 inches with no minimum length or required shape. Planters should be designed to receive less than 15,000 square-feet of impervious area runoff.

Potential Applications

Planter boxes can be used in urbanized areas of high pollutant loads. They are especially applicable where there is limited area for construction of other BMPs. Planter boxes may be used as a pretreatment BMP for other BMPs such as wet ponds or infiltration systems. Areas that would benefit from using a planter box include:

- Parking garage
- Office building
- Residential building
- Other building use (commercial, light industrial, institutional, etc.)
- Transportation facilities
- Urban streetscapes

Design Considerations

- **Suggested structural elements** of planters are stone, concrete, brick, or pressure-treated wood. Flow-through planters are completely contained and, therefore, not designed to drain directly into the ground. Pipes can also be designed to transport water to an approved disposal point. It is recommended that planter boxes have setback distances of 10 feet from structures and five feet from property lines, unless the planter height is less than 30 inches or as required by local ordinances.
- The **flow entrance/inflow** must be designed to prevent erosion in the planter box. Some alternatives include gravel, splash blocks, perforated pipe, and erosion control mats.
- A **positive overflow system** should be designed to safely convey away excess runoff. The overflow can be routed to the surface in a non-erosive manner or to another stormwater system. Some alternatives include domed risers, inlet structures, weirs, and openings in the planter box wall.
- **Planting soil** should be capable of supporting a healthy vegetative cover and should generally be between 12 and 36 inches deep. Planting soil should be approximately four inches deeper than the bottom of the largest root ball.
- A subsurface **gravel layer**, if used, should be at least six inches thick and constructed of clean gravel with a significant void space for runoff storage (typically 40 percent) and wrapped in geotextile (filter) fabric.
- If used, **underdrains** are typically small diameter (412 inches) perforated pipes in a clean gravel trench wrapped in geotextile fabric (or in the gravel layer). Underdrains should be double-walled and have a flow capacity capable of draining the planter box system in approximately 12 hours. They can daylight to the surface or connect to another stormwater system. A way to inspect and clean underdrains should be provided (via cleanouts, inlet, overflow structure, etc.)
- **Native trees and shrubs** may require irrigation during dryer summer months to remain healthy. Monitoring vegetation in planter boxes is critical to the health of the plants, as they may need supplemental watering, in addition to the water received from storms.
- **Many planter box styles and sizes** are used to improve site aesthetics and stormwater management. Incorporating smaller planter boxes over the site adds visual appeal and a greater surface area.

Design variations:

▪ **Contained boxes**

Plants should be relatively self-sustaining, with little need for fertilizers or pesticides. Irrigation is optional, although plant viability should be maintained. Trees are encouraged and will receive added runoff reduction recognitions for the canopy that will extend beyond the planter walls. Structural elements of the planters should be stone, concrete, brick, wood, or other durable material. Treated wood that may leach out any toxic chemicals should not be used.

▪ **Infiltration**

Allow captured runoff to drain out in three to four hours after a storm event. The sand/gravel area width, depth, and length are to be determined by an engineer or a dry well may be required for complete onsite infiltration. Planters should be designed to receive less than 15,000 square-feet of impervious area runoff. Minimum planter width is 30 inches; there is no minimum length or required shape. The structural elements of the planters should be stone, concrete, brick, or pressure-treated wood. Treated wood that may leach out any toxic chemicals should not be used.

▪ **Flow-through**

Allow captured runoff to drain out in three to four hours after a storm event. Minimum planter width is 18 inches; there is no minimum length or required shape. Planters should be designed to receive less than 15,000 square-feet of impervious area runoff. Structural elements of the planters should be stone, concrete, brick, or pressure-treated wood. Treated wood that may leach out any toxic chemicals should not be used. The flow-through planter box is contained and, thus, not designed to drain into the ground near a building. Irrigation is optional, although plant viability should be maintained.

- The plants within the **perimeter planter boxes** are designed to accept stormwater runoff from adjacent impervious areas. Plants and vegetation absorb most of the water volume. Overflow gradually drains to the surface, which slows the peak rates.
- Review the materials list in Recommended Materials Appendix for recommended planter box specifications.

• **Landscaping requirements**

The following quantities are recommended per 100 square feet of planter box area:

- Four large shrubs/small trees in three-gallon containers or equivalent.
- Six shrubs/large grass-like plants in one-gallon containers or equivalent
- Ground cover plants (perennials/annuals) one per 12 inches on center, triangular spacing. Minimum container: four-inch pot. Spacing may vary according to plant type.
- Plantings can include rushes, reeds, sedges, iris, dogwood, currants, and numerous other shrubs, trees, and herbs/grasses (Recommended Plant List for BMPS Appendix).
- Container planting requires that plants be **supplied with nutrients** that they would otherwise receive from being part of an ecosystem. Since they are cut off from these processes, they must be cared for accordingly.
- **Tree planting** in planters is encouraged where practical. Tree planting is also encouraged near planters.
- Generally, plants requiring **moist-wet conditions** are preferred for flow-through planters.

Stormwater Functions and Calculations

Volume reduction

If a planter box is designed to infiltrate, the volume reduction is a function of the area of the filter and the infiltration rate. There is generally less volume reduction for planter boxes that are not designed to infiltrate.

$$\text{Infiltration Volume}^{\#} = \text{Bottom Area (ft}^2\text{)} * \text{Infiltration Rate (in/hr)} * \text{Drawdown time}^{\#\#} \text{ (hr)}$$

[#] - For filters with infiltration only

^{##} - Not to exceed 3-4 hours

Peak rate mitigation

Planter boxes generally provide little, if any, peak rate reduction. However, if the planter box is designed to infiltrate, then a modest level of peak rate attenuation can be expected.

Water Quality Improvement

Planter boxes are considered a moderate stormwater treatment practice with the primary pollutant removal mechanism being filtration and settling. Less significant processes can include evaporation, infiltration (if applicable), transpiration, biological and microbiological uptake, and soil adsorption. The extent to which planter boxes remove pollutants in runoff is primarily a function of their design, configuration, plant species/ density, and soil type.

For planter boxes that are also designed to infiltrate, see the water quality summary in the Subsurface Infiltration Bed section of Infiltration Practices Fact Sheet, or in the other infiltration BMP sections. For manufactured planters, see the manufacturer's information, as well as findings from independent studies.

Construction Guidelines

Constructing or retrofitting planter boxes varies in difficulty at each site. Boxes may be ideal for inclusion in patio or walkway design and integrate easily with roof downspouts. In most cases, a landscape architect is essential, especially if the

more complex infiltration and flow through variation is being constructed, and as the size/scale of the planter box grows larger.

1. Areas for planter boxes, especially the infiltration type, should be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.
2. Planter boxes should generally be installed after the site is stabilized. Excessive sediment generated during construction can clog the planter and prevent or reduce the anticipated post-construction water quality benefits. Stabilize all contributing areas before runoff enters the filters.
3. Structures such as inlet boxes, reinforced concrete boxes, etc. should be installed in accordance with the guidance of the manufacturers or design engineer.
4. Infiltration planter boxes should be excavated in such a manner as to avoid compaction of the subbase. Structures may be set on a layer of clean, lightly compacted gravel (such as AASHTO #57).
5. Infiltration planter boxes should be underlain by a layer of permeable, nonwoven-geotextile.
6. Place underlying gravel/stone in minimum six-inch lifts and lightly compact. Place underdrain pipes in gravel.
7. Wrap and secure nonwoven geotextile to prevent gravel/stone from clogging with sediments.
8. Install planting soil per the recommendations of the landscape architect. Do not compact.
9. Install native vegetation (trees, shrubs, etc.) per the recommendations of the landscape architect.

Maintenance

Planter boxes are relatively high maintenance, as is the case with any containerized garden. Property owners should be especially prepared for maintaining the vegetation itself, which will vary depending upon planting. In many cases, planter boxes may need additional watering during extremely dry periods. Selection of planter box construction material is also important (e.g., masonry construction is easier to maintain than wood construction).

Generally speaking, stormwater facilities need an adequate amount of space for proper maintenance. The minimum required width for maintenance is typically eight feet and the maximum slope is 10 percent. If structural surfaces need to support maintenance vehicles, access routes should be constructed of gravel or other permeable paving surface.

Winter Considerations

Indiana's winter temperatures can go below freezing for a few months every year and surface filtration may not take place in the winter. Winterizing becomes an important issue in plant species selection, especially for larger, hardy or nearly hardy species intended to winter over. In these cases, planter boxes must be designed and dimensioned so that plantings are adequately protected.

Depending on the composition of the planting soil, it may hold water, freeze, and become impervious on the surface. Design options that allow directly for subsurface discharge into the underlying infiltration bed, if applicable, during cold weather may overcome this condition, but at the possible expense of surface filtration.

Cost

Costs for planter boxes are quite modest. However, based on unit cost of cubic foot or gallons of runoff being managed, costs tend to be rather high. Because of the extreme variability of design and construction, costs will range based on the goals of the designer. Smaller boxes with smaller-scale vegetation will be less expensive than larger boxes with more mature vegetation.

Designer/Reviewer Checklist for Planter Boxes

ITEM	Page No.	YES	NO	N/A	NOTES
For infiltration planters, was Soil Testing Infiltration Protocol (Soil Infiltration Testing Protocol Appendix) followed?*	--				
Appropriate areas of the site evaluated?	--				
Infiltration rates measured?	--				
For infiltration planters, was the Infiltration BMP followed?*	--				
Two-foot separation between the bed bottom and bedrock/ seasonally high water table?	--				
Soil permeability acceptable?	--				
If not, appropriate underdrain provided?	-				
Natural, uncompacted soils?	--				
Excavation in infiltration areas minimized?	--				
Drawdown time less than 48 hours?	--				
Erosion and sedimentation control?	--				
Adequately stable inflow point(s)?	4				
Positive overflow from system?	4				
Waterproofing provided, as necessary?	3				
Acceptable soil/growing medium specified? ➤ <i>Between 12 and 36 inches deep; 4 inches deeper than bottom of largest root ball</i>	4				
Gravel layer specified properly? ➤ <i>At least 6 inches thick</i>	4				
Underdrain positioned and sized? ➤ <i>Should be sized to drain within approximately 12 hours</i>	4				
Appropriate native plants selected?	3-5				
Feasible construction process and sequence?	--				
Maintenance accounted for and plan provided? ➤ <i>Minimum maintenance width = 8 ft; max. width = 10 ft</i>	6,7				

➤ Denotes Minimum Design Considerations

* In general, the Protocol and Infiltration BMP should be followed as much as possible (although there is more flexibility for infiltration planters than for other BMPs such as pervious pavement and subsurface infiltration that rely almost entirely on infiltration).

References

Stormwater Management Guidance Manual, Version 2.0. Office of Watersheds, Philadelphia, PA: Water Department. www.phillyriverinfo.org/programs/SubProgramMain.aspx?Id=StormwaterManual

Stormwater Management Manual, Revision 3. Portland, OR: Environmental Services, Clean River Works, September 2004. www.portlandonline.com

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BMP Fact Sheet

RIPARIAN BUFFER RESTORATION

A riparian buffer is the area of land that exists between low, aquatic areas such as rivers, streams, lakes, and wetlands, and higher, dry upland areas such as forests, farms, cities, and suburbs. Unaltered riparian buffers may exist as various types of floodplain forest or wetland ecosystems. The Michigan Natural Features Inventory (MNFI) has identified multiple types of distinct natural communities which may occur in Michigan's riparian areas, such as southern floodplain forest, southern wet meadow, emergent marsh, and hardwood conifer swamp.



Figure 1 Suburban riparian buffer - Edward Drain, West Bloomfield, MI
Source: JF New

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low/Med
Commercial	Yes	Groundwater Recharge	Low/Med
Ultra Urban	Yes	Peak Rate	Low/Med
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Yes	TSS	Med/High
Highway/Road	Limited	TP	Med/High
Recreational	Yes	NO ₃	Med/High
		Temperature	Med/High

Additional Considerations	
Cost	Low/Med
Maintenance	Low
Winter Performance	High

Key Design Features

Riparian buffers consist of three distinct zones:

- **Zone 1:** Streamside zone extends a minimum distance of 25 feet
- **Zone 2:** Middle zone extends immediately from the outer edge of Zone 1 for a minimum of 55 feet
- **Zone 3:** Outer zone extends a minimum of 20 feet immediately from outer edge of Zone 2

Site Factors

- Water table to bedrock depth: N/A
- Soils: Match vegetation to soils to maximize long-term viability of plantings
- Slope: N/A
- Potential hotspots: No
- Maximum drainage area: 5 to 20 times the buffer area

Benefits

- Water Quality
- Ecological and aesthetic value
- Low cost

Limitations

- Reduced volume and peak control

Description and Function

A riparian buffer is a permanent restoration area of trees, shrubs, and herbaceous vegetation adjacent to a waterbody that serves to protect water quality and provide critical wildlife habitat. A riparian buffer can be designed to intercept surface runoff and subsurface flow from upland sources for the purpose of removing or buffering the effects of associated nutrients, sediment, organic matter, pesticides, or other pollutants prior to entry into surface waters and groundwater recharge areas.

The riparian buffer is most effective when used as a component of a sound land management system including nutrient management and runoff and sediment and erosion control practices. Use of this practice without other runoff and sediment and erosion control practices can result in adverse impacts on riparian buffer vegetation and hydraulics including high maintenance costs, the need for periodic replanting, and the flow of excess nutrients and sediment through the buffer.

Riparian buffer restoration areas consist of three distinct zones and can be designed to filter surface runoff as sheet flow and down-slope subsurface flow, which occurs as shallow groundwater. For the purposes of these buffer strips, shallow groundwater is defined as saturated conditions which occur near or within the root zone of trees and other woody vegetation and at relatively shallow depths where bacteria, low oxygen concentrations, and soil temperature contribute to denitrification. Riparian buffers are designed to encourage sheet flow and infiltration and impede concentrated flow.

Buffer widths and vegetation types

When developing specific widths for riparian buffers (**Figure 2**), keep site specific factors in mind, and use exact measurements as a guide for each site. Various buffer widths and vegetation types may be appropriate depending on:

- Project goals,
- The natural features of the river valley, wetlands, lake, and floodplain, and
- Wildlife habitat requirements.

Buffer averaging and minimum distances

Buffer ordinances that set specific and minimum buffer dimensions allow the local government to accept buffer averaging in order to accommodate variability in terrain or development plans. For example, a wetland normally entitled by ordinance to a 75-foot minimum buffer may be able to tolerate a 50-foot buffer over part of its margin if a wider buffer is provided along another part. This depends upon such issues as water flow, topography, habitat, and species needs, and other factors that can best be assessed on a case-by-case basis.

Port Townsend, Washington allows buffer averaging if the applicant demonstrates that the averaging will not adversely affect wetland functions and values, that the aggregate area within the buffer is not reduced, and that the buffer is not reduced in any location by more than 50 percent or to less than 25 feet.

Woodbury, Minnesota allows buffer averaging where averaging will provide additional protection to the wetland resource or to environmentally valuable adjacent uplands, provided that the total amount of buffer remains the same.

Source: Environmental Law Institute

Zone 1: Also termed the “streamside zone,” begins at the edge of the stream bank of the active channel and extends a minimum distance of 25 feet; this is measured horizontally on a line perpendicular to the water body.

Undisturbed vegetated area helps protect the physical and ecological integrity of the stream ecosystem. The vegetative target for the streamside zone is undisturbed native woody species with native plants forming canopy, understory, and duff layer where such forest does not grow naturally; then native vegetative cover appropriate for the area (such as grasses, forbs, or shrubs) is the vegetative target. (*HRWC Model Ordinance*, p. 8)

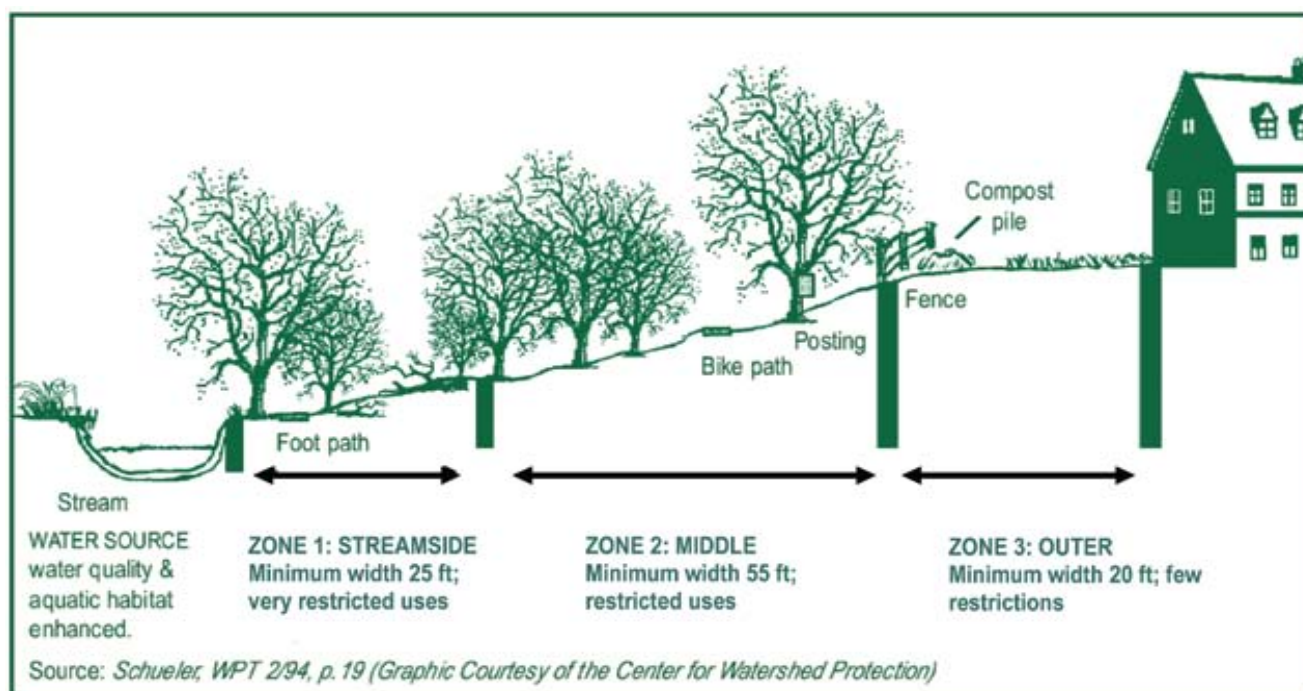


Figure 2 Source of a three-zone buffer

Source: Schueler, Watershed Protection Techniques, 1994 (Graphic courtesy of the Center for Watershed Protection)

Zone 2: Also termed the “middle zone,” extends immediately from the outer edge of Zone 1 for a minimum distance of 55 feet.

This managed area of native vegetation protects key components of the stream ecosystem and provides distance between upland development and the stream-side zone. The vegetative target for the middle zone is either undisturbed or managed native woody species or, in its absence, native vegetative cover of shrubs, grasses, or forbs. Undisturbed forest, as in Zone 1, is strongly encouraged to protect further water quality and the stream ecosystem. (*HRWC Model Ordinance* p. 8)

Zone 3: Also termed the “outer zone,” it extends a minimum of 20 feet immediately from outer edge of Zone 2.

This zone prevents encroachment into the riparian buffer area, filters runoff from adjacent land, and encourages sheet flow of runoff into the buffer. The vegetative target for the outer zone is native woody and herbaceous vegetation to increase the total width of the buffer. Native grasses and forbs are acceptable. (*HRWC Model Ordinance* p. 8)

To maximize wildlife habitat, restoration buffers should reflect the type of riparian vegetation that was found at the site before alteration. If water quality protection is the primary goal, greater emphasis may be placed on installing vegetation that enhances soil stability and absorbs pollutants. If the riparian area is very wet, wetland vegetation may be required.

In addition to installing vegetation, riparian buffer restoration may require physical restoration of soils, topography, or hydrology to achieve the desired result. Geographic factors such as the presence of steep slopes may necessitate an expanded buffer to achieve soil stability. If a river valley is very narrow, the buffer may be adjusted accordingly.

Applications

Riparian buffers are used adjacent to any wetland and bodies of water, such as lakes, streams, swales, and detention ponds. They are not typically applicable in upland areas where water bodies are not present. While riparian buffers provide

significant water quality and ecological benefits, they have only very little benefit for volume control, unless they have some ability to trap and rapidly infiltrate water. Therefore, they should be used with other BMPs that will fulfill any volume control requirements.

Restoring riparian buffers can be applied in many settings:

1. Adjacent to permanent or intermittent streams,
2. At the margins of lakes or ponds,
3. At the margin of intermittent or permanently flooded, environmentally sensitive, open water wetlands,
4. On karst formations at the margin of sinkholes and other small groundwater recharge areas, and
5. Between manicured lawns, cultivated areas or hardscape and swales, streams or rivers to help dissipate and treat runoff and help stabilize the tops of channel banks.

Design Considerations

Restoring riparian buffer areas requires a plan to ensure long-term success. Below is a summary of the steps that groups, designers, engineers, or volunteers should undertake during the planning stages of a riparian buffer project.

1. Confirm suitability for restoration

If stream banks are extensively eroded, consider an alternative location for preparing the riparian buffer, or consider stream bank restoration first. Rapidly eroding stream banks may undermine top of bank restoration efforts.

2. Analyze site's physical conditions

Consider site specific factors to determine the particular width of the individual zones:

- Watershed condition,
- Slope,
- Stream order,
- Soil depth and erodibility,
- Hydrology,

- Seasonal high water table,
- Floodplains,
- Wetlands,
- Streambanks,
- Soil type,
- Vegetation type, and
- Stormwater systems.

3. **Analyze site's vegetative features** Existing vegetation at the restoration site should be examined to determine the overall strategy for buffer protection and establishment. Strategies will differ whether pre-restoration conditions are pasture, overgrown abandoned field, mid-succession forest, predominantly invasive vegetation, or another type of setting. An effort to inventory existing vegetation for protection and to determine type of pre-settlement vegetation should be made to guide efforts.

- *Identify desirable species:* Native tree and shrub species that thrive in riparian habitats in Michigan should be used. These species should be identified in the restoration site and protected. Several native vines and shrubs can provide an effective ground cover when establishing the buffer, though they should be controlled to prevent herbaceous competition.
- *Identify non-native and invasive species:* Consider using undesirable species for shading during buffer establishment. Control invasive plants prior to buffer planting may be necessary.
- *Identify sensitive species:* Because riparian zones are rich in wildlife habitat and wetland plant species, be aware of any rare, threatened, or endangered plant or animal species. Be sure to protect sensitive species during riparian buffer restoration.

4. Map the site

Prepare an existing conditions sketch of the site noting important features such as stream width, length, stream bank condition, adjacent land uses, stream activities, desired width of buffer, discharge pipes, obstructions, etc.

5. Create a design that accomplishes multiple stakeholder objectives

Ideally, the three-zone system should be incorporated into the design to meet landowner, community, and watershed objectives:

- *Landowner objectives:* Consider the current use of the buffer by the landowner, especially if the buffer will be protected by the landowner in perpetuity. How will the riparian buffer complement or conflict with existing and probable future uses of the property?
- *Community objectives:* Consider linking the buffer to an existing or planned green infrastructure system, which may include trails, parks, preserves, and wildlife habitat buffers. How can a buffer help achieve local recreation and green space goals?
- *Watershed objectives:* Examine the local watershed plan to identify goals related to riparian buffers. Have goals related to water quality been emphasized. Is wildlife habitat a primary concern?

6. Design measures

The following elements represent a menu of design measures for riparian and natural resource protection that communities may choose to encourage or require developers to incorporate during the site plan review process.

- *Stream size* – A majority of Indiana's stream system is comprised of small streams (first, second, and third order). It is important to reduce nutrient inputs to these streams.
- *Availability of areas for continuous buffers* – Establishing continuous riparian buffers on the landscape should be given a priority over establishing fragmented

buffers. Continuous buffers provide better shading and water quality protection as well as buffers for the wildlife movement.

- *Degrees of degradation* – Urban streams have often been buried or piped as a result of previous development. Streams in areas without forestation may benefit the most from buffer restoration.
- *Loading rates* - The potential for removing pollutants is generally highest where nutrient and sediment loading are the highest.
- *Land uses* – Land uses adjacent to the riparian buffer may influence the required buffer width and vegetation types. While the three-zone riparian buffers described herein are ideal, the full widths of each zone may not always be feasible to establish, especially in urban areas.
- *Habitats* – Establishing a buffer for habitat enhancement requires additional strategies beyond installing a buffer for increased water quality.

7. Determine the appropriate buffer width

Riparian buffer areas need not have a fixed linear boundary, but may vary in shape, width, and vegetative type and character, depending on the goals of the restoration and the natural geography of the water body and riparian area. The desired function of the buffer (habitat, water quality, etc.) determines buffer width. Many factors, including slope, soil type, adjacent land uses, floodplain, vegetative type, and watershed condition influence the design of the buffer. A rule of thumb is “the bigger, the better.” Buffer widths for water quality and habitat maintenance should generally be 35 to 100 feet. Buffers less than 35 feet generally do not protect aquatic resources in the long term.

- *Streamside buffers*

The minimum width of streamside buffer areas can be determined by a number of methods suitable to the geographic area.

Based on soil hydrologic groups as shown in the soil survey report, the width of Zone 2 should be increased to occupy any soils designated as Hydrologic Group D and those soils of Hydrologic Group C that are subject to frequent flooding. If soils of Hydrologic Groups A or B occur adjacent to intermittent or perennial streams, the combined width of Zones 1 and 2 may be limited to the 80-foot minimum.

Based on area, the width of Zone 2 should be increased to provide a combined width of Zones 1 and 2 equal to one-third of the slope distance from the stream bank to the top of the pollutant source area. The effect is to create a buffer strip between field and stream that occupies approximately one-third of the source area.

- Pond and lake-side buffers

The area of pond or lake-side buffer strips should be at least one-fifth the drainage area of the cropland and pastureland source area. The width of the buffer strip is determined by creating a uniform width buffer of the required area between field and pond. Hydrologic group determining width remains the same as for streamside buffers. Minimum widths apply in all cases.

8. Vegetation selection

Zone 1 and 2 vegetation should consist of native streamside species on soils of Hydrologic Groups C and D and native upland species on soils of Hydrologic Groups A and B.

Deciduous species are important in Zone 2 due to the production of carbon leachate from leaf litter, which drives bacterial processes that remove nitrogen and sequester nutrients in growth processes. In warmer climates, evergreens are also important due to the potential for nutrient uptake during the winter

months. In both cases, a variety of species is important to meet the habitat needs of insects important to the aquatic food chain.

Zone 3 vegetation should consist of perennial grasses and forbs. Species recommendations for restoring riparian buffers depend on the geographic location of the buffer. Suggested species lists can be developed in collaboration with appropriate state and federal forestry agencies, the Natural

Green Development Standards

In 2007, the U.S. Green Building Council finalized pilot rating standards for the new Leadership in Energy and Environmental Design – Neighborhood Development (LEED-ND) certification program, which set standards for environmentally superior development practices. Developers can earn certification credit for preserving a buffer around all wetlands and water bodies located on site in perpetuity. Local governments that adopt buffer ordinances encourage LEED-ND developments.

Source: Environmental Law Institute

Resources Conservation Service, and the USDA Fish and Wildlife Service. Species lists should include trees, shrubs, grasses, legumes, and forbs, as well as site preparation techniques. Please refer to the plant list in Recommended Plant List for BMPs Appendix for a recommended list of native trees and shrubs.

The choice of planting stock (seeds, container seedling, bare-root seedlings, plugs, etc.) is often determined by cost. Larger plants usually cost more, though will generally establish more rapidly.

Many factors threaten the long-term viability of riparian plant protection or establishment. With proper foresight, these problems can be minimized. The following items should be considered during the planning stage:

- Deer control
 - Look for signs of high deer densities, including an overgrazed understory with a browse line five to six feet above the ground.
 - Select plants that deer do not prefer (e.g., paper birch, beech, common elderberry)
 - Apply homemade deer repellants
 - Install tree shelters
- Tree shelters
 - Tree shelters, such as plastic tubes that fit over newly planted trees, are extremely successful in protecting seedlings. They may be secured with a wooden stake and netting may be placed over top of the tree tube. They are recommended for riparian plantings where deer or human intrusion may be a problem. Tree shelters should be removed two to three years after the saplings emerge. ° Tree shelters protect trees from accidental strikes from mowing or trimming.
 - Tree shelters create favorable microclimate for seedlings.
 - Tree shelters should be inspected at least four times per year. The following maintenance should be performed as necessary:
 - Repair broken stakes
 - Tighten stake lines
 - Straighten leaning tubes
 - Clean debris from tube
 - Remove netting as tree grows
 - Remove when tree trunk is approximately two inches wide
- Stream buffer fencing
 - Farm animals may cause great damage to stream banks. Consider permanent

fencing such as high-tensile smooth wire fencing or barbed fencing.

- The least expensive fencing is eight-foot plastic fencing, which is also effective against deer and is easily repaired
- Vegetation
 - Consider using plants that are able to survive frequent or prolonged flooding conditions. Plant trees that can withstand high water table conditions.
 - Soil disturbance can allow for unanticipated infestation by invasive plants.
- Accidental or purposeful destruction by landowners
 - Signage, posts, fencing, boulders, etc., may be required to alert adjacent landowners to the location, purpose, and management aims of riparian buffers. This is particularly important where actively managed landscaped areas abut native plant buffers. Signs that stress no mow/no pesticide and fertilizer zones may need to be in several languages, e.g., English and Spanish.

9. **Restoration design within your budget** The planting design (density and types) must ultimately conform to the financial constraints of the project. See discussion below for estimating direct costs of planting and maintenance.

10. **Draw a restoration planting plan**

- Planting layout: The planting plan should be based on the plant types and density. The plan must show the site with areas denoted for trees and shrub species and plant spacing and buffer width.
- Planting density: Trees should be planted at a density sufficient to provide 320 trees per

Spacing (feet)	Trees (number)	Spacing (feet)	Trees (number)	Spacing (feet)	Trees (number)
2x2	10,890	7x9	691	12x15	242
3x3	4,840	7x10	622	12x18	202
4x4	2,722	7x12	519	12x20	182
4x5	2,178	7x15	415	12x25	145
4x6	1,815	8x8	681	13x13	258
4x7	1,556	8x9	605	13x15	223
4x8	1,361	8x10	544	13x20	168
4x9	1,210	8x12	454	13x25	134
4x10	1,089	8x15	363	14x14	222
5x5	1,742	8x25	218	14x15	207
5x6	1,452	9x9	538	14x20	156
5x7	1,245	9x10	484	14x25	124
5x8	1,089	9x12	403	15x15	194
5x9	968	9x15	323	15x20	145
5x10	871	10x10	436	15x25	116
6x6	1,210	10x12	363	16x16	170
6x7	1,037	10x15	290	16x20	136
6x8	908	10x18	242	16x25	109
6x9	807	11x11	360	18x18	134
6x10	726	11x12	330	18x20	121
6x12	605	11x15	264	18x25	97
6x15	484	11x20	198	20x20	109
7x7	889	11x25	158	20x25	87
7x8	778	12x12	302	25x25	70

Table 1 Tree spacing per acre

acre at maturity. To achieve this density, approximately 436 (10 x 10 feet spacing) to 681 (8 x 8 feet spacing) trees per acre should be planted initially. Some rules of thumb for tree spacing and density based on plant size at installation follow:

- Seedlings 6 to 10 feet spacing (~700 seedlings/acre)
- Bare root stock 4 to 16 feet spacing (~200 plants/acre)
- Larger & Container 16 to 18 feet spacing (~150 plants/acre)

Formula for estimating number of trees and shrubs:

Number of Plants = length x width of buffer (feet) / 50 ft²

This formula assumes each tree will occupy an average of 50 square feet, random placement of

plants approximately 10 feet apart, and a mortality rate of up to 40 percent.

Alternatively, the table below can be used to estimate the number of trees per acre needed for various methods of spacing.

11. **Prepare site for restoration** Existing site conditions determine the degree of preparation needed prior to planting. Invasive plant infestation and vegetative competition are variable and must be considered in the planning stages. Site preparation should begin in the fall prior to planting. Determine whether the use of herbicides is necessary.

Mark the site with flags, or marking paint, so that the plants are placed in the correct locations.

County Regulated Drain Considerations: Special attention needs to be paid regarding the type and density of vegetation used if the natural drainage pathway or stream is or will be a part of the County Regulated Drain system. The County may require

that at least one side of the regulated drain is clear of woody vegetation, with continuous access provided for reconstruction and maintenance. Pre-coordination with the local County Surveyor's Office is highly recommended.

Stormwater Functions and Calculations

Volume and peak rate

Restoration of the riparian buffer will lower runoff volume and peak rates through lowering the runoff coefficient (i.e., curve number). Designers can receive runoff reduction recognition based on the square feet of trees or shrubs being added. Proposed trees and shrubs to be planted under the requirements of these BMPs can be assigned a curve number (CN) reflecting a woodlot in "good" condition associated with the pre-development underlying soil layer for an area of 200 square feet per tree or the estimated tree canopy, whichever is greater. For shrubs, calculate based an area of 25 square feet per shrub. Calculation methodology to account for this BMP is provided in the LID Approach discussion of the Post-Construction Stormwater Management Chapter of Technical Standards.

Water quality improvement

Water quality benefits of restoring riparian buffers are medium to high. The amount of benefit is based on flow characteristics and nutrient, sediment, and pollutant loadings of the runoff as well as the length, slope, type, and density of vegetation in the riparian buffer.

Runoff entering Zone 3 filters sediment, begins nutrient uptake, and converts concentrated flow to uniform, shallow sheet flow. Zone 2 provides contact time and carbon energy sources in which buffering processes can take place. It also provides long-term sequestering of nutrients. Zone 1 provides additional soil and water contact area to further facilitate nutrient buffering processes, provides shade to moderate and stabilize water temperature, and encourages production of beneficial algae.

Maintenance

An effective riparian buffer restoration project should include stewardship guidelines to manage and maintain the site in perpetuity. The most critical period of riparian buffer establishment is canopy closure, which is typically the first three to five years after saplings are planted. Buffer boundaries should be well defined with clear signs or markers. During this time, the riparian buffer should be monitored four times annually (February, May, August, and November are recommended) and inspected after any severe storm. Maintenance measures that should be performed regularly include:

1. Watering

- Plantings need deep, regular watering during the first growing season, either natural watering via rainfall, or planned watering via caretaker.
- Planting in the fall increases the likelihood of sufficient rain during planting establishment.

2. Mulching

- Mulch provides moisture retention in the root zone of plantings, or potentially impacted vegetation from construction, moderate soil temperature, and some weed suppression.
- Use coarse, organic mulch that is slow to decompose in order to reduce the need for repeat application.
- Apply a two to four-inch layer, leaving air space around tree trunk to prevent fungus growth.
- Use a combination of woodchips, leaves, and twigs that have been stockpiled for six months to a year.

3. Weed and invasive plant control

- Invasive plants can overrun even a well-designed planting. It is essential that there is a plan in place to monitor and remove

invasive vegetation as the planting matures. Use the Nature Conservancy's Global Invasive Species Team Web page as a resource for management techniques. (<http://tncweeds.ucdavis.edu/esadocs.html>) Non-chemical weed control methods are preferred since chemicals can easily be washed into the stream.

- *Herbicides*

Using herbicides is a short-term maintenance technique (two to three years) that is generally considered less expensive and more flexible than mowing and will result in a quicker establishment of the buffer. Consider and evaluate the proximity of herbicide use to water features.

- *Mowing*

Mowing controls the height of the existing grasses, yet increases nutrient uptake. Therefore, competition for nutrients will persist until the canopy closure shades out lower layers of growth. A planting layout similar to a grid format will facilitate ease of mowing, but will yield an unnaturally spaced community. Mowing may result in strikes to tree trunks unless protective measures are used. Mowing should occur twice each growing season. Mower height should be set between eight and 12 inches.

- *Weed mats*

Weed mats are geo-textile fabrics used to suppress weed growth around newly planted vegetation by blocking sunlight and preventing seed deposition. Weed mats are installed after planting, and should be removed once the trees have developed a canopy that will naturally shade out weeds.

4. **Stable debris**

As Zone 1 reaches 60 years of age or is hit with pests or disease, it will begin to produce large debris. Large debris, such as logs, create small dams which trap and hold debris for processing by aquatic insects, thus adding

energy to the stream ecosystem, strengthening the food chain, and improving aquatic habitat. Wherever possible, stable debris should be conserved.

- Where debris dams must be removed, try to retain useful, stable portions which can provide storage. (A state permit may be required). For guidance on evaluating debris impacts on streams and methods for managing debris jams, refer to the "Primer on Large Woody Debris Management" developed by the City of Rochester Hills (see References).

Deposit removed material a sufficient distance from the stream so that it will not be refloated by high water.

5. **Resources for assistance** Local land conservancies are excellent resources when considering the long-term stewardship of the area. If a site has critical value, a local conservancy may be interested in holding a conservation easement on the area, or may be able to provide stewardship services and assistance. Wild Ones (www.for-wild.org/) is a national organization with local chapters which may also provide stewardship resources.

Winter Considerations

Volume reduction, peak rate mitigation, and water quality benefits are not as pronounced in winter months compared to the rest of the year in riparian buffers because infiltration rates are generally lower during prolonged cold weather periods. In addition, evapotranspiration rates are lower in winter months because most vegetation is dormant. However, riparian buffers still provide stormwater management benefits even in winter.

Cost

Installing a riparian buffer involves site preparation, planting, second year reinforcement planting, and additional maintenance. Costs may fluctuate based on numerous variables including whether or not volunteer labor is used, and whether plantings and

other supplies are donated or provided at a reduced cost. The following table presents an estimate of typical costs for riparian buffer restoration.

Criteria to receive runoff reduction recognition for Riparian Buffer Restoration

To receive runoff reduction recognition for riparian buffer restoration under a location regulation, the following criteria must be met:

- ☐ Area is protected by having the limits of disturbance clearly shown on all construction drawings and delineated in the field. 3
- ☐ Area to receive runoff reduction recognition for trees is 200 square feet per tree or the estimated tree canopy, whichever is greater.
- ☐ Area to receive runoff reduction recognition for shrubs is 25 square feet per shrub.
- ☐ Area is located on the development project.
- ☐ Area has a maintenance plan that includes weeding and watering requirements from initial installation throughout ongoing maintenance.

Designer/Reviewer Checklist for Riparian Buffer Restoration

ITEM	Page No.	YES	NO	N/A	NOTES
Avoidance of stormwater concentration as much as practical?	--				
Appropriate buffer widths designed? <ul style="list-style-type: none"> ➤ <i>Ideal minimum widths</i> <ul style="list-style-type: none"> ○ <i>Zone 1: 25 feet</i> ○ <i>Zone 2: 55 feet</i> ○ <i>Zone 3: 20 feet</i> ○ <i>Water Quality/Habitat Maintenance: 35-100 feet</i> ➤ <i>Various Buffer widths and vegetation types may be appropriate depending on:</i> <ul style="list-style-type: none"> ○ <i>Project Goals</i> ○ <i>Natural features of river valley, wetlands, lake, and floodplain</i> ○ <i>Wildlife Habitat Requirements</i> 	1-3, 5,6				
Soil erodibility considered?	4				
Slope considered and appropriate?	--				
Appropriate vegetation selected based on soils, hydrology, and ecoregion?	6,7				
Appropriate vegetation selected based on budget and aesthetics?	--				
Appropriate plant spacing designed?	7,8				
Appropriate balance of woody to herbaceous species?	6				
Seasonality of planting/construction considered?	8				
Erosion and sedimentation control provided?	--				
Maintenance accounted for and plan provided?	9,10				

➤ *Denotes Minimum Design Considerations*

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BMP Fact Sheet

SOIL RESTORATION

Soil is a key ingredient in effective stormwater and water quality management, making proper care of soils a key component of low impact development.

Soil restoration is a technique used to enhance and restore soils by physical treatment and/or mixture with additives – such as compost – in areas where soil has been compacted. Soil media restoration increases the water retention capacity of soil, reduces erosion, improves soil structure, immobilizes and degrades pollutants (depending on soil media makeup), supplies nutrients to plants, and provides organic matter. Soil restoration is also used to reestablish the soil's long term capacity for infiltration and to enhance the vitality of the soil as it hosts all manner of microbes and plant root systems in complex, symbiotic relationships.



Table 1 Soil restoration, Colerain Park, OH (Colerain Township)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Medium
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	Yes	Peak Rate	Medium
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Limited	TSS	High*
Highway/Road	Yes	TP	High*
Recreational	Yes	NO ₃	Medium
		Temperature	Medium

Additional Considerations	
Cost	Medium
Maintenance	Low
Winter Performance	High

Key Design Features

- Follow nonstructural BMP to minimize soil compaction
- Evaluate existing soil conditions using methods referenced in Soil Infiltration Testing Protocol (found in AppendixD4) before creating a soil restoration strategy
- Soil media used in restoration is either organic or inorganic (man-made) and is mixed into existing soil

Benefits

- Widely applicable
- Relatively low cost
- Additional benefits such as improved plant health and reduced erosion

Limitations

- Relatively limited stormwater benefits on a unit area basis

*Newly amended soils are susceptible to erosion and release of TSS and phosphorus until stabilized with mulch, erosion blanket, sod, or some other covering.

Description and Function

Soil can be restored after construction to partially recondition that which has been degraded by compaction. Bulk density field tests measure soil compaction and can be used to help determine if soil restoration is necessary. Restoring the soil improves its structure and function, increases infiltration potential, and supports healthy vegetative communities.

A healthy soil (**Figure 1**) provides a number of vital functions including water storage and nutrient storage, regulate the flow of water, and immobilize and degrade pollutants. Healthy soil contains a diverse community of beneficial microorganisms, a sufficient amount of plant nutrients (nitrogen and phosphorous), some trace elements (e.g., calcium and magnesium), and organic matter (generally 5 to 10 percent). Healthy soil typically has a neutral or slightly acidic pH and good structure which includes various sizes of pores to support water movement, oxygenation, and a variety of other soil processes.

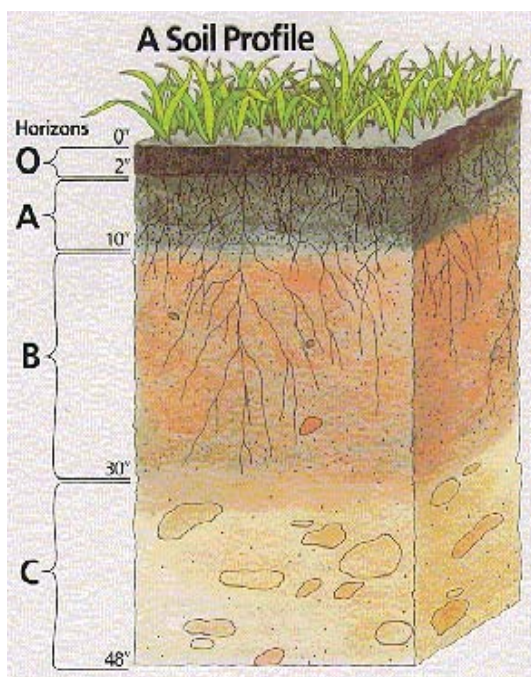


Figure 1 Healthy Soil Profile
Source: USDA NRCS

Caring for soil is also a critical component of water management, especially during development activities, such as construction grading, which often

result in erosion, sedimentation, and soil compaction. Proper protection and restoration of soil is a critical BMP to combat these issues. Soil restoration prevents and controls erosion by enhancing the soil surface to prevent the initial detachment and transport of soil particles.

Soil compaction

Soil compaction is the enemy of water quality protection. Soil compaction occurs when soil particles are pressed together, reducing the pore space necessary to allow for the movement of air and water throughout the soil (**Figure 2**). This decrease in porosity causes an increase in bulk density (weight of solids per unit volume of soil). The greater the bulk density of the soil, the lower the infiltration and therefore, the larger the volume of runoff.

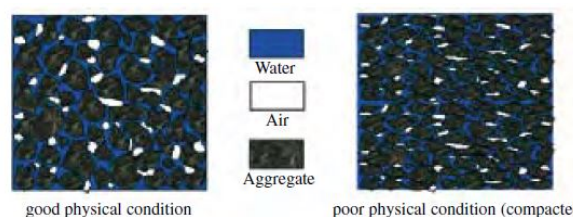


Figure 2 Compacted soil constrains movement of air and water
Source: USDA NRCS

Compaction limits vegetative root growth, restricting the health of plants as well as the biological diversity of the soil. Compaction also affects the infiltrating and water quality capacity of soils. Soil compaction can lead to increased erosion and stormwater runoff, low infiltration rates, increased flooding, and decreased water quality from polluted runoff. After compaction, a typical soil has strength of about 6,000 kilopascals (kPa), while studies have shown that root growth is not possible beyond 3,000 kPa. There are two types of compaction, minor and major, each of which requires a particular restoration technique(s) or method:

- **Minor compaction** – Surface compaction within 8-12 inches due to contact pressure and axle load greater than 20 tons can compact through root zone up to one-foot deep. Soil restoration activities can include: subsoiling, organic matter amendment, and

native landscaping. Tilling/scarifying is an option as long as it is deep enough (i.e., 8-12 inches) and the right equipment is used (should not be performed with common tillage tools such as a disk or chisel plow because they are too shallow and can compact the soil just beneath the tillage depth).

- **Major compaction** – Deep compaction, contact pressure and axle load greater than 20 tons can compact up to two-feet deep (usually large areas are compacted to increase strength for paving and foundation with overlap to “lawn” areas). Soil restoration activities can include: deep tillage, organic matter amendment, and native landscaping.

To evaluate the level of compaction in soils, bulk density field tests are conducted. **Table 2** shows the ideal bulk densities for various textures of soils.

Amending media

Compacted soil can be amended by first tilling the soil, breaking apart the compaction, and then applying various soil media. For minor soil compaction, six inches of soil media (18.5 cubic yards per 1,000 square feet of soil) should be applied, and then tilled into the existing soil up to eight inches. For major soil compaction, 10 inches of soil media (31 cubic yards per 1,000 square feet of soil) should be applied and then tilled into the existing soil up to 20 inches.

Soil media used for amendment may be comprised of either organic or inorganic material. Organic media can increase soil organic matter content,

which improves soil aeration, water infiltration, water and nutrient holding capacity, and is an important energy source for bacteria, fungi, and earthworms.

Organic media:

- Compost,*
- Aged manure,*
- Biosolids* (must be a Grade 1 biosolid),
- Sawdust, (can tie up nitrogen and cause deficiency in plants),
- Wood ash (can be high in pH or salt),
- Wood chips (can tie up nitrogen and cause deficiency in plants),
- Grass clippings,
- Straw, and
- Sphagnum peat (low pH;).

**Materials containing animal wastes can cause phosphorus to be exported from the amended soils.*

Inorganic media:

- Vermiculite,
- Perlite,
- Pea gravel, and
- Sand.

Soil Texture	Ideal Bulk densities, g/cm ³	Bulk densities that may affect root growth, g/cm ³	Bulk densities that restrict root growth, g/cm ³
Sands, loamy sands	<1.60	1.69	1.8
Sandy loams, loams	<1.40	1.63	1.8
Sandy clay loams, loams, clay loams	<1.40	1.6	1.75
Silt, silt loams	<1.30	1.6	1.75
Silt loams, silty clay loams	<1.10	1.55	1.65
Sandy clays, silty clays, some clay loams (35-45% clay)	<1.10	1.49	1.58
Clays (>45% clay)	<1.10	1.39	1.47

Table 2 Bulk Densities for Soil Textures

Source: Protecting Urban Soil Quality, USDA-NRCS

Applications

Soil restoration can occur anywhere to alleviate soil compaction. It can be specifically addressed in the following examples:

- **New development (residential, commercial, industrial)** – Heavily compacted soils can be restored prior to lawn establishment and/or landscaping to increase the porosity of the soils and aid in plant establishment.
- **Detention basin retrofits** – The inside face of detention basins are usually heavily compacted, and tilling the soil mantle will encourage infiltration to take place and aid in establishing vegetative cover.
- **Golf courses** – Using compost as part of landscaping upkeep on the greens has been shown to alleviate soil compaction, erosion, and turf disease problems.

Design Considerations

1. Tilling the soil (also referred to as scarification, ripping, or subsoiling)
 - a. Effective when performed on dry soils.
 - b. Should be performed where subsoil has become compacted by equipment operation, dried out, and crusted, or where necessary to obliterate erosion rills.
 - c. Should be performed using a solid-shank ripper and to a depth of 20 inches, (eight inches for minor compaction).
 - d. Should be performed before amending media is applied and after any excavation is completed.
 - e. Should not be performed within the drip line of any existing trees, over underground utility installations within 30 inches of the surface, where trenching/drainage lines are installed, where compaction is by design, and on inaccessible slopes.

- f. The final pass should be parallel to slope contours to reduce runoff and erosion.
 - g. Tilled areas should be loosened to less than 1,400 kPa (200 psi) to a depth of 20 inches below final topsoil grade.
 - h. The subsoil should be in a loose, friable condition to a depth of 20 inches below final topsoil grade and there should be no erosion rills or washouts in the subsoil surface exceeding three inches in depth.
 - i. Tilling should form a two-directional grid. Channels should be created by a commercially available, multi-shanked, parallelogram implement (solid-shank ripper), capable of exerting a penetration force necessary for the site.
 - j. No disc cultivators, chisel plows, or spring-loaded equipment should be used for tilling. The grid channels should be spaced a minimum of 12 inches to a maximum of 36 inches apart, depending on equipment, site conditions, and the soil management plan.
 - k. The channel depth should be a minimum of 20 inches or as specified in the soil management plan. If soils are saturated, delay operations until the soil, except for clay, will not hold a ball when squeezed.
 - l. Only one pass should be performed on erodible slopes greater than one vertical to three horizontal.
2. Applying soil media for amendment
 - a. Soil media should not be used on slopes greater than 30 percent. In these areas, deep-rooted vegetation can be used to increase stability.
 - b. Soil restoration should not take place within the critical root zone of a tree to avoid damaging the root system. (Where one inch of tree trunk diameter at breast height (DBH) is equal to one foot of soil area on the ground away from the tree trunk.)

- c. Onsite soils with an organic content of at least five percent can be stockpiled and reused to amend compacted soils, saving costs. Note: These soils must be properly stockpiled to maintain organic content.
- d. Soils should generally be amended at about a 2:1 ratio of native soil to media. If a proprietary product is used, follow the manufacturer's instructions for the mixing and application rate.
- e. Add six inches compost or other media and till up to eight inches for minor compaction. (Six inches of compost equates to 18.5 yd³ per 1,000 ft² of soil.)
- f. Add 10 inches compost or other amendment and till up to 20 inches for major compaction. 10 inches of compost equates to approx. 30.9 yd³ per 1,000 ft².
- g. Compost can be amended with bulking agents, such as aged crumb rubber from used tires, or wood chips. This can be a cost-effective alternative that reuses waste materials while increasing permeability of the soil.

Stormwater Functions and Calculations

Volume and peak rate reduction

Restored soils result in increased infiltration, decreased volume of runoff, and significantly delayed runoff.

Soil restoration will lower runoff volume and peak rates by lowering the runoff coefficient (i.e., curve number). Designers can receive runoff reduction recognition based on areas (acres) complying with the requirements of these BMPs. These areas can be assigned a curve number (CN) reflecting the pre-development hydrologic soil group of underlying soil layer type instead of what is required for other disturbed pervious areas. The LID Approach discussion of Post-Construction Stormwater Management Chapter of Technical Standards show how to calculate the runoff reduction recognition for this BMP.

Water quality improvement

Although either organic or inorganic materials may be used as soil media, only organic matter can improve water quality by increasing the nutrient holding capacity of soils. Soils rich in organic matter contain microorganisms that immobilize or degrade pollutants. See LID Approach discussion of Post-Construction Stormwater Management Chapter of Technical Standards for information on how to calculate the volume of runoff that needs treatment for water quality improvement.

Organic materials that include fecal matter or animal renderings should not be used where water may infiltrate through the soil and carry nutrients, primarily phosphorus, to surface waters (Hunt and Lord, 2006).

Maintenance

Soil restoration may need to be repeated over time, due to compaction by use and/or settling. Taking soil core samples will help to determine the degree of soil compaction and if additional media application is necessary.

Winter Considerations

Since soil restoration is performed in conjunction with plantings, this BMP should be undertaken in spring or autumn and during dry weather, so that plantings can establish.

Cost

Cost information has been compiled by Cahill Associates and reflects 2007 conditions:

- Tilling costs range from \$800/acre to \$1,000/acre
- Compost costs range from \$860/acre to \$1,000/acre. Costs of other soil media would vary greatly depending on their individual material costs and the amounts used.

Criteria to receive runoff reduction recognition for Soil Restoration

To receive runoff reduction recognition for soil restoration under a location regulation, the following criteria must be met:

- ☐ Area is clearly shown on all construction drawings and delineated in the field.
- ☐ Tilling the soil is required if subsoil is compacted; needs to occur before amending media is applied.
- ☐ Area is not located on slopes greater than 30 percent.
- ☐ Area is not within the critical root zone of any tree.
- ☐ Amendment consists of six inches for minor compaction; 10 inches of amendment for major compaction.
- ☐ Area is located on the development project.

Designer/Reviewer Checklist for Soil Restoration

Type of soil amendment(s) proposed: _____

Amount of amendments(s) to be used: _____

ITEM	Page No.	YES	NO	N/A	NOTES
Appropriate soil amendment(s) for the site conditions? ➤ <i>Do not use soil media on slopes > 30%</i>	3,4				
Adequate amount of amendment materials?	3				
Bulk density/degree of compaction considered?	2,3				
Appropriate decompaction techniques and equipment?	4				
Appropriate construction sequencing?	--				
Sensitive areas (e.g., near existing trees, shallow utilities, and steep slopes) accounted for?	4				
Appropriate vegetation selected?	--				
Seasonality of planting/construction considered?	5				
Erosion and sedimentation control provided?	--				
Maintenance accounted for and plan provided?	5				

➤ *Denotes Minimum Design Considerations*

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BMP Fact Sheet

VEGETATED FILTER STRIP

A vegetated filter strip is a permanent, maintained strip of vegetation designed to slow runoff velocities and filter out sediment and other pollutants from urban stormwater. Filter strips require the presence of sheet flow across the strip, which can be achieved through the use of level spreaders. Frequently, filter strips are designed where runoff is directed from a parking lot into a stone trench, a grass strip, and a longer naturally vegetative strip.

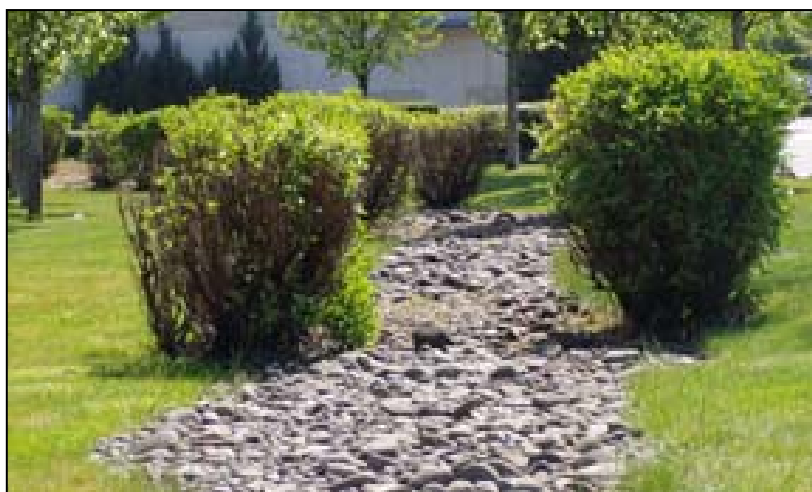


Figure 1 Gravel trench directing water from the parking lot to a vegetated filter strip in Springfield, OR (Springfield Environmental Services Division)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	Limited*	Peak Rate	Low
Industrial	Limited*	Stormwater Quality Functions	
Retrofit	Yes	TSS	Med/High
Highway/Road	Yes	TP	Med/High
Recreational	Yes	NO ₃	Med/High
		Temperature	Med/High

* According to site characteristics

Additional Considerations	
Cost	Low
Maintenance	Low/Medium Varies dependent on type of vegetation
Winter Performance	High

Variations

- Turf grasses
- Prairie grasses, shrubs, and groundcover vegetation, including trees
- Indigenous woods and dense vegetation

Key Design Features

- Use with level spreaders to promote sheet flow across strips
- Longitudinal slope from 1-6 percent
- Maintain dense vegetation

Site Factors

- Water table to bedrock depth: N/A
- Soils: N/A for permeability
- Slope: 2-5 percent preferred (1-10 percent if soils/vegetation allow)
- Potential hotspots: Yes with special design considerations
- Max. drainage area: 100 feet impervious or 150 feet pervious up gradient

Benefits

- Low cost
- Good water quality performance
- Aesthetic and habitat benefits

Limitations

- Generally should be coupled with other BMPs for comprehensive stormwater management

Description and Function

Filter strips (**Figure 2**) are gently sloping areas that combine a grass strip and dense vegetation to filter, slow, and infiltrate sheet flowing stormwater. Filter strips are best used to treat runoff from roads and highways, roof downspouts, small parking lots, and other impervious surfaces. They are generally not recommended as stand-alone features, but as pretreatment systems for other BMPs, such as infiltration trenches or bioretention areas. Therefore, filter strips generally should be combined with other BMPs as part of a treatment train so that water quality and quantity benefits are sufficient to meet recommended site design criteria.

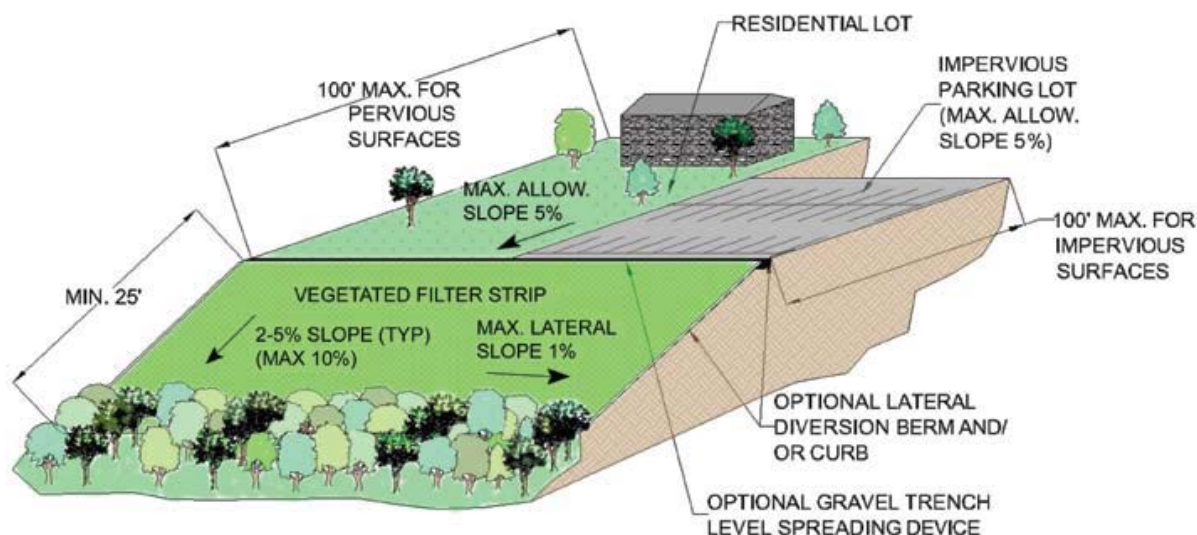


Figure 2 Diagram showing elements of a vegetated filter strip

Maintaining a dense growth pattern that includes turf-forming grasses and vegetation on a filter strip is critical for maximizing pollutant removal efficiency and erosion prevention.

The grass portion of the filter strip provides a pretreatment of the stormwater before it reaches the densely vegetated, or wooded area. In addition, a stone drop can be located at the edge of the impervious surface to prevent sediment from depositing at this critical entry point.

In addition to a stone drop, a pervious berm can reduce runoff velocity and increase volume reduction by providing a temporary, shallow

ponded area for the runoff. The berm should have a height of not more than six to 12 inches and be constructed of sand, gravel, and sandy loam to encourage growth of a vegetative cover.

An outlet pipe(s) or an overflow weir may be provided and sized to ensure that the area drains within 24 hours or to allow larger storm events to pass. The berm must be erosion resistant under the full range of storm events. Likewise, the ponded area should be planted with vegetation that is resistant to frequent inundation.

Filter strips are primarily designed to reduce total suspended solids (TSS) levels. However, pollutants such as hydrocarbons, heavy metals, and nutrients

may also be reduced. Pollutant removal mechanisms include sedimentation, filtration, absorption, infiltration, biological uptake, and microbial activity. Depending on soil properties, vegetative cover type, slope, and length of the filter strip, a reduction in runoff volume may also be achieved by infiltration.

Applications

Vegetated filter strips can be used in a wide variety of applications from residential/commercial developments to industrial sites and even transportation projects where the required space is available. Lack of available space limits use in ultra urban areas and some redevelopment projects.

Design Considerations

1. The design of vegetated filter strips is determined by existing drainage area conditions including drainage area size, length, and slope. In addition, the filter strip soil groups, proposed cover type, and slope needs to be determined. This information is used to determine the length of the filter strip using the appropriate graph (Figures 5 through 9).
2. Level spreading devices are highly recommended to provide uniform sheet flow conditions at the interface of the adjacent site area and the filter strip (see Level Spreader BMP Fact Sheet for detailed information). Concentrated flows should not be allowed to flow onto filter strips, as they can lead to erosion and, thus, failure of the system. Examples of level spreaders include:
 - a. A gravel-filled trench (**Figure 3**), installed along the entire up-gradient edge of the strip. The gravel in the trenches may range from pea gravel (ASTM D 448 size no. 6, 1/8" to 3/8") for most cases to shoulder ballast for roadways. Trenches are typically 12" wide, 24-36" deep, and lined with a nonwoven geotextile. When placed directly adjacent to an impervious surface, a drop (between the pavement edge and the trench) of 1-2" is recommended, in order to inhibit the formation of the initial deposition barrier.
 - b. A concrete curb stop with cutouts (**Figure 4**) can be used to provide uniform sheet flow across a vegetated filter strip.
 - c. Concrete sill (or lip).
 - d. An earthen berm (**Figure 5**) with optional perforated pipe.
3. Where possible, natural spreader designs and materials, such as earthen berms, are generally recommended, though they can be more susceptible to failure due to irregularities in berm elevation and density of vegetation. When it is desired to treat runoff from roofs or curbed impervious areas, a more structural approach, such as a gravel trench, is required. In this case, runoff should be directly conveyed, via pipe from downspout or inlet, into the subsurface gravel and uniformly distributed by a perforated pipe along the trench bottom.
4. The upstream edge of a filter strip should be level and directly abut the contributing drainage area.
5. In areas where the soil infiltration rate has been compromised (e.g., by excessive compaction), the filter strip should be tilled prior to establishing vegetation. However, tilling will only have an effect on the top 12-18 inches of the soil layer. Therefore, other measures, such as planting trees and shrubs,

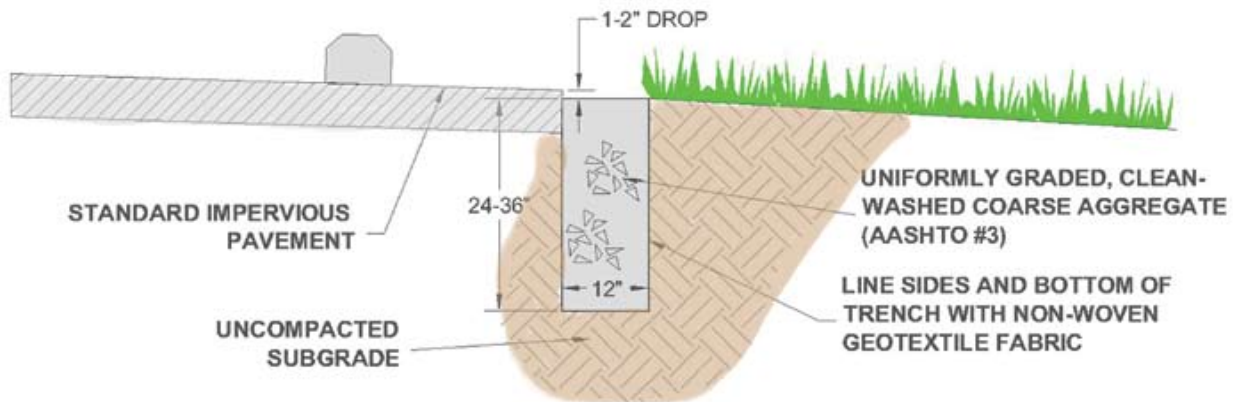


Figure 3 A Level Spreader device (gravel-filled trench)

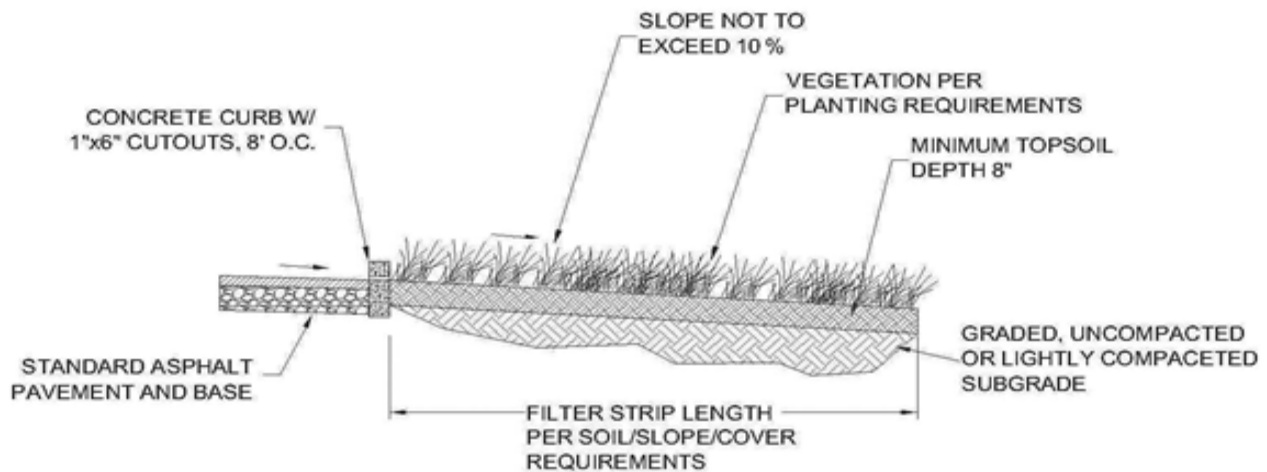


Figure 4 Concrete curb stop schematic

may be needed to provide deeper aeration. Deep root penetration will promote greater absorptive capacity of the soil.

6. The ratio of contributing drainage area to filter strip area should never exceed 6:1.
7. The filter strip area should be densely vegetated with a mix of salt-tolerant, drought-tolerant, and erosion-resistant plant species. Filter strip vegetation, whether planted or existing, may range from turf and native grasses to herbaceous and woody vegetation. The optimal vegetation strategy consists of plants with dense growth patterns, a fibrous root system for stability, good regrowth ability (following dormancy and cutting), and adaptability to local soil and climatic conditions. Native vegetation is always

preferred. (See Recommended Plant List for BMPs Appendix for vegetation recommendations.)

8. Natural areas, such as forests and meadows, should never be unduly disturbed when creating a filter strip. If these areas are not already functional as natural filters, they may be enhanced by restorative methods or by constructing a level spreader.
9. The maximum lateral slope of a filter strip is one percent.
10. To prohibit runoff from laterally bypassing a strip, berms and/or curbs can be installed along the sides of the strip, parallel to the direction of flow.

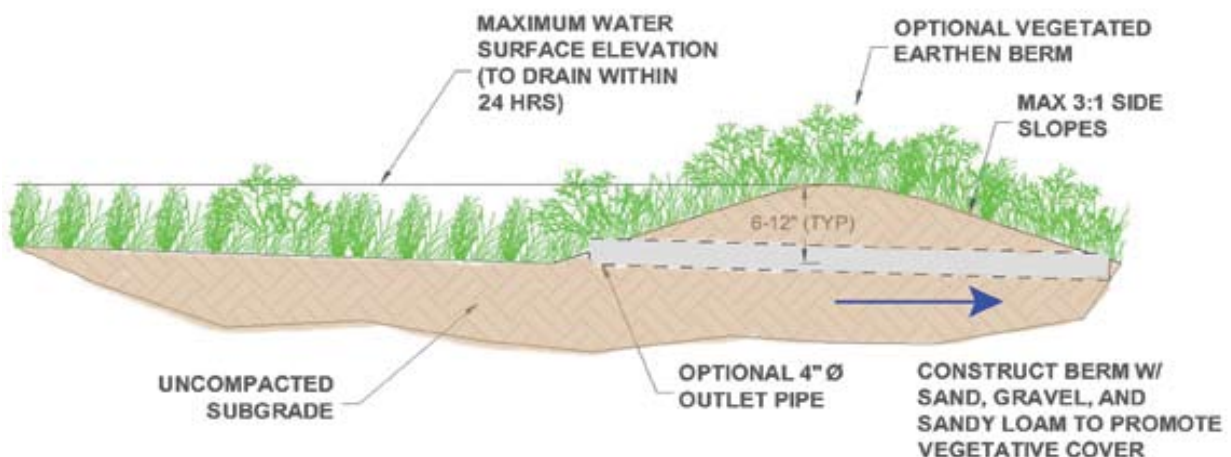


Figure 5 Optional earthen berm at bottom of vegetated filter strip

As shown in **Figure 6, Figure 7, Figure 8, Figure 9, and Figure 10**, the recommended filter strip length varies depending on the type of soil, the type of vegetation, and the filter strip slope. Generally, the more permeable the soil and/or the lower the slope, the shorter the filter strip may be for equivalent storm-water benefits.

County Regulated Drain Considerations: Special attention needs to be paid regarding the type and density of vegetation used if the natural drainage pathway or stream is or will be a part of the County Regulated Drain system. The County may require that at least one side of the regulated drain is clear of woody vegetation, with continuous access provided for reconstruction and maintenance. Pre-coordination with the County Surveyor's Office is highly recommended.

Filter Strip Soil Type	Hydrologic Soil Group	Maximum Filter Strip Slope (Percent)	
		Turf Grass, Native Grasses and Meadows	Planted and Indigenous Woods
Sand	A	7	5
Sandy Loam	B	8	7
Loam, Silt Loam	B	8	8
Sandy Clay Loam	C	8	8
Clay Loam, Silty Clay, Clay	D	8	8

Table 1 Recommended Length as a Function of Slope, Soil Cover

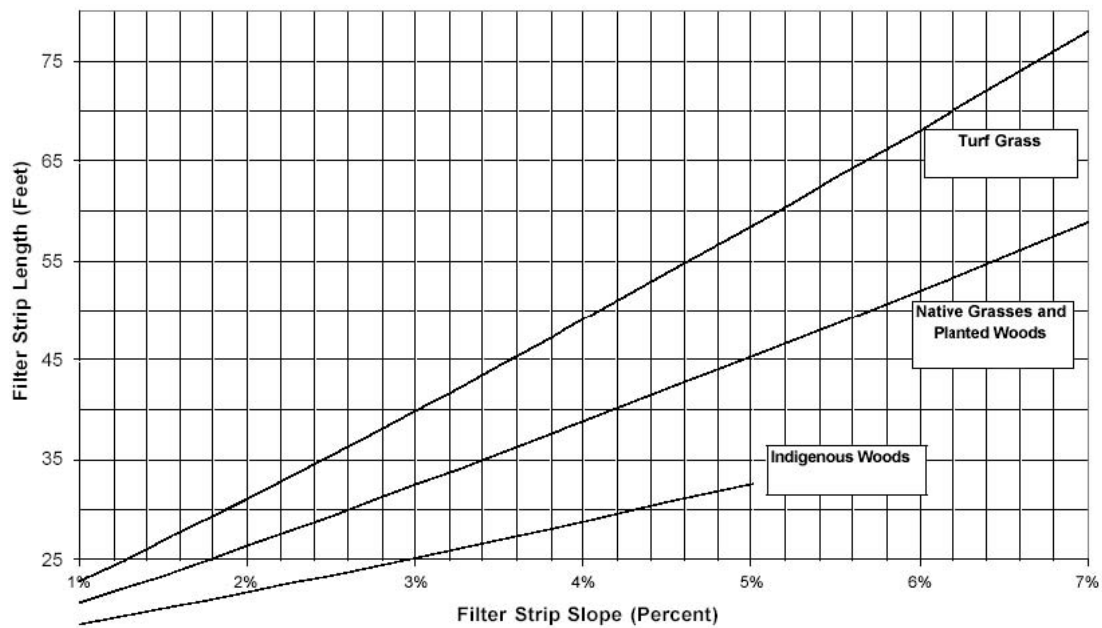


Figure 6 Sandy Soils with Hydrologic Soil Group A
Source: New Jersey Stormwater Best Management Practices Manual, February 2004

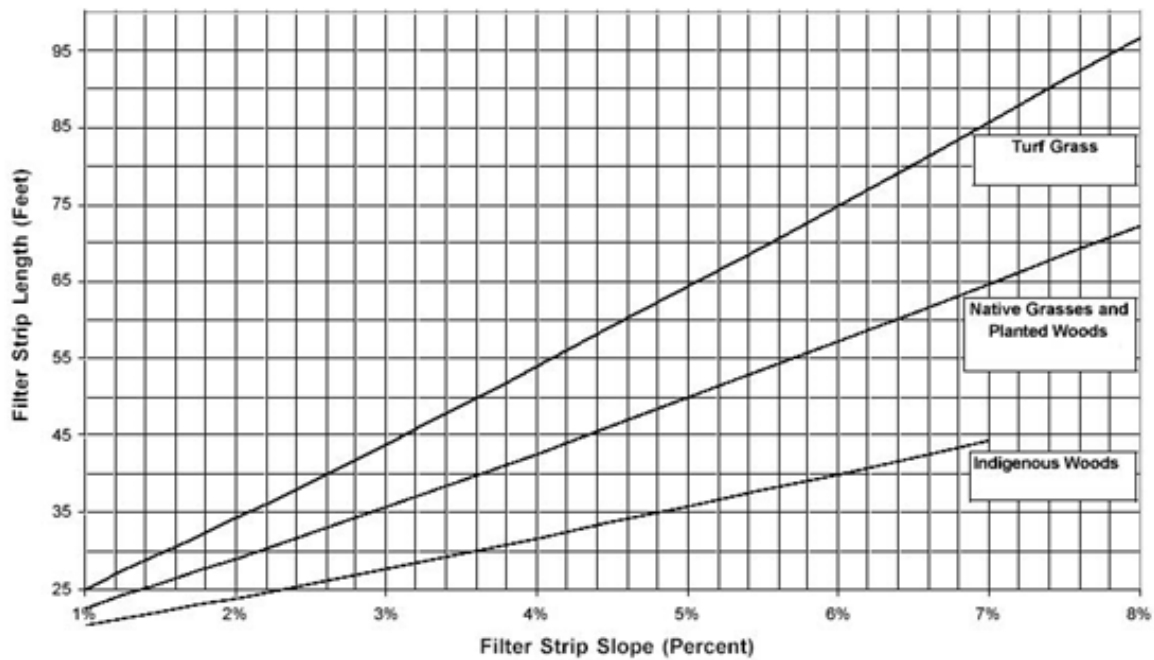


Figure 7 Sandy Loam Soils with Hydrologic Soil Group B
Source: New Jersey Stormwater Best Management Practices Manual, February 2004

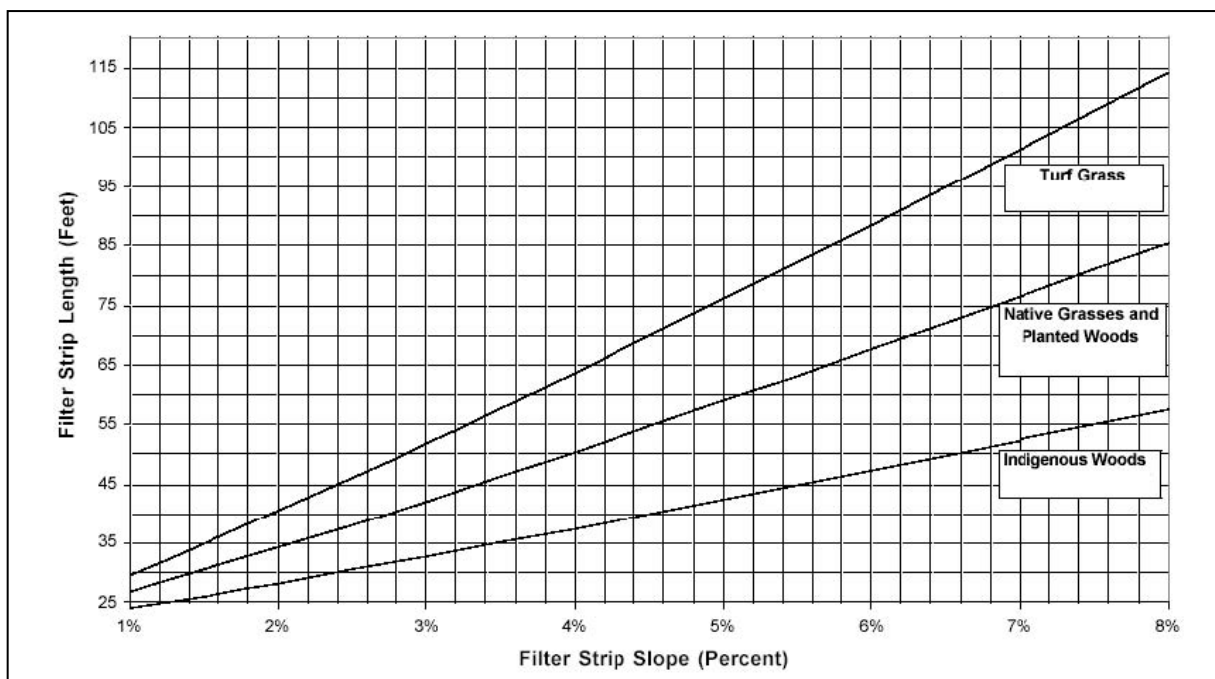


Figure 8 Loam, Silt-Loam Soils Hydrologic Soil Group B
Source: New Jersey Stormwater Best Management Practices Manual, February 2004

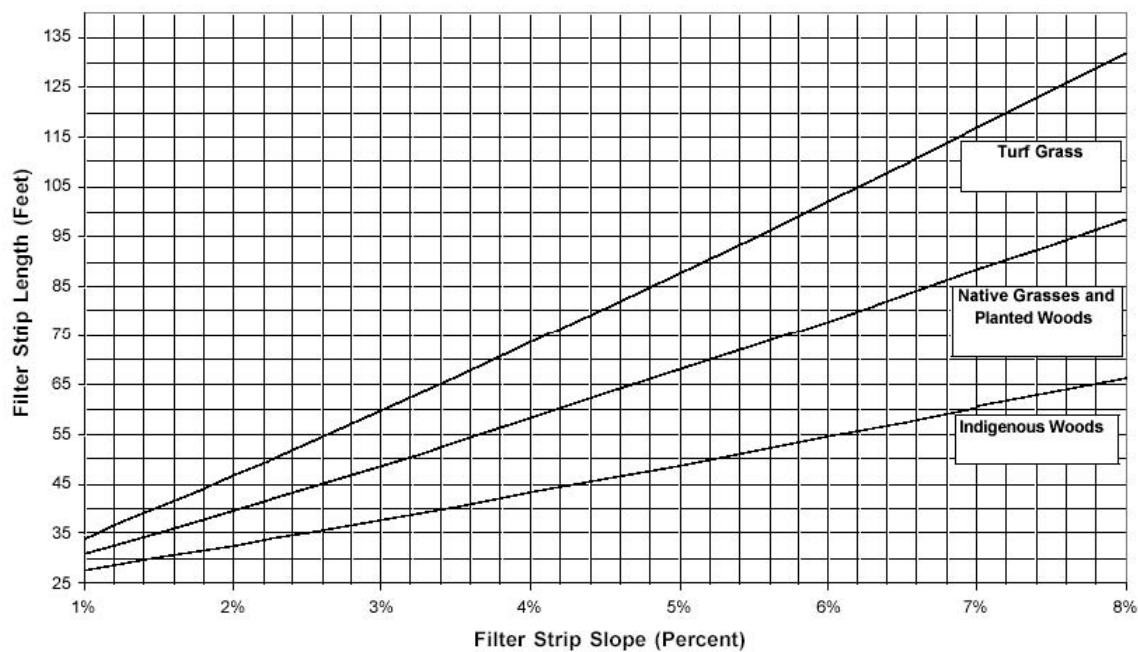


Figure 9 Sandy Clay Loam Soils with Hydrologic Soil Group C
Source: New Jersey Stormwater Best Management Practices Manual, February 2004

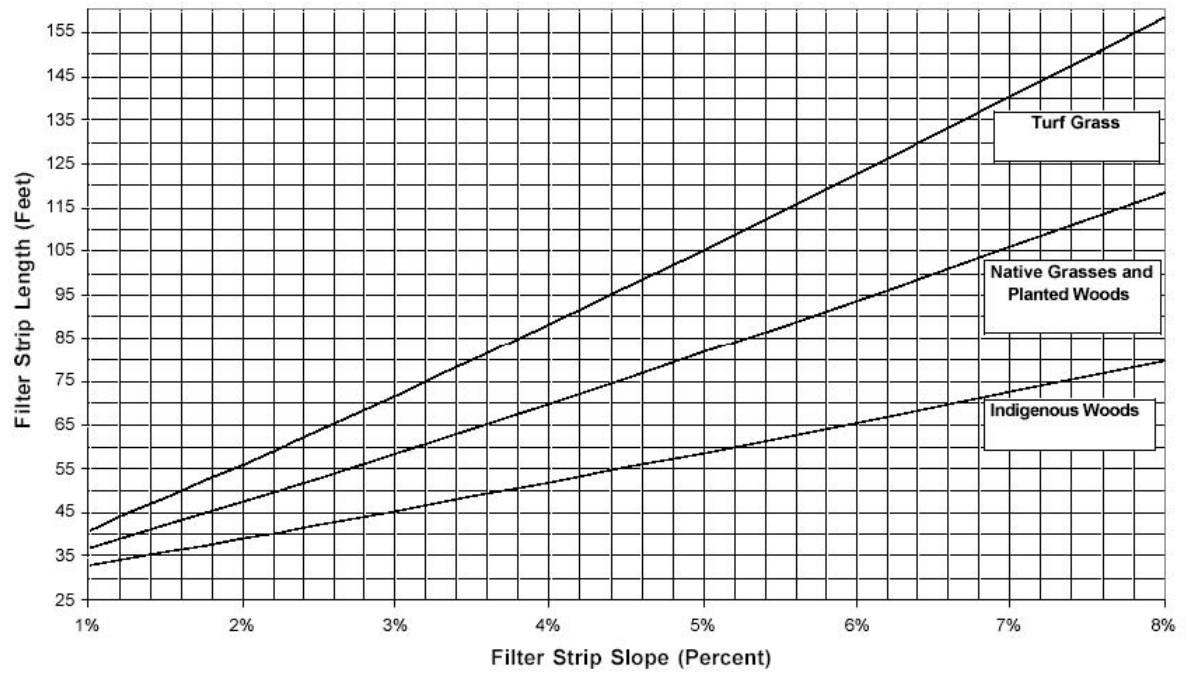


Figure 10 Clay Loam, Silty Clay or Clay Soils with Hydrologic Soil Group D
Source: New Jersey Stormwater Best Management Practices Manual, February 2004

Stormwater Functions and Calculations

Volume reduction

Although not typically considered a volume-reducing BMP, vegetated filter strips can achieve some volume reduction through infiltration and evapotranspiration, especially during small storms (storms less than approximately one inch). The volume reduction benefit of a filter strip can be estimated through hydrologic calculations. Two recommended methods are weighting the curve number of the drainage area with that of the filter strip (see LID discussion in Post-Construction Stormwater Quality Management Chapter of Technical Standards) or routing the runoff from the drainage area onto the filter strip area as inflow in addition to incident precipitation.

Large areas with dense vegetation may absorb unconcentrated flows that result from small storms, while areas covered by turf grass will absorb limited runoff. If a berm is constructed at the down-gradient end of the filter strip, an additional volume will be detained and may infiltrate the underlying soil.

Peak rate mitigation

Vegetated filter strips do not substantially reduce the peak rate of discharge. However, if a volume reduction is achieved through infiltration and evapotranspiration, a related reduction in peak rate will occur. If a berm is constructed at the down-gradient end of the filter strip, the rate of release of the detained volume may be controlled by an outlet structure.

Water quality improvement

Water quality benefits of vegetated filter strips are medium to high. The amount of benefit is based on flow characteristics and nutrient, sediment, and pollutant loadings of the runoff, as well as the length, slope, type, and density of vegetation in the filter strip.

Studies have shown 85 to 90 percent reductions in TSS and 40 to 65 percent reductions in nitrates (NO₂) from runoff being treated by vegetated filter strips. In these studies, the vegetated filter strips were between 25 and 29 feet wide with mild (0.7

percent to 1.7 percent) slopes, with grass and mixed vegetation.

Other studies have shown that suspended solids and metals are reduced to steady state amounts within several meters of the edge of the filter strip. (Note: If a filter strip is used for temporary sediment control, it should be regraded and reseeded immediately after construction and stabilization has occurred.)

Construction Guidelines

1. Follow the recommendations for materials in Recommended Materials Appendix.
2. Begin filter strip construction only when the up-gradient site has been sufficiently stabilized and temporary erosion and sediment control measures are in place. The strip should be installed at a time of the year when successful establishment without irrigation is most likely. However, temporary irrigation may be needed in periods of little rain or drought.
3. For non-indigenous filter strips, clear and grade site as needed. Care should be taken to disturb as little existing vegetation as possible, whether in the designated filter strip area or in adjacent areas, and to avoid soil compaction. Grading a level slope may require removing existing vegetation.
4. Grade the filter strip area, including the berm at the toe of the slope. Pressure applied by construction equipment should be limited to four pounds per square inch to avoid excessive compaction or land disturbance.
5. Construct level spreader device at the upgradient edge of the filter strip. For gravel trenches, do not compact the subgrade. (Follow construction sequence for Infiltration Trench.)
6. Fine grade the filter strip area. Accurate grading is crucial for filter strips. Even the smallest irregularities may compromise sheet flow conditions.

7. Seed, sod, or plant more substantial vegetation, as proposed. If sod is proposed, place tiles tightly to avoid gaps, and stagger the ends to prevent channelization along the strip. Use a roller on sod to prevent air pockets from forming between the sod and soil.
8. Stabilize seeded filter strips with appropriate permanent soil stabilization methods, such as erosion control matting or blankets. Erosion control for seeded filter strips should be required for at least the first 75 days following the first storm event of the season.
9. Once the filter strip is sufficiently stabilized after one full growing season, remove temporary erosion and sediment controls.

Maintenance

As with other vegetated BMPs, filter strips must be properly maintained to ensure their effectiveness. In particular, it is critical that sheet flow conditions are sustained throughout the life of the filter strip. Field observations of strips in urban settings show that their effectiveness can deteriorate due to lack of maintenance, inadequate design or location, and poor vegetative cover. Compared with other vegetated BMPs, filter strips require only minimal maintenance efforts, many of which may overlap with standard landscaping demands.

- Inspect sediment devices quarterly for clogging, excessive accumulations, and channelization for the first two years following installation, and then twice a year thereafter. Inspections should also be made after every storm event greater than one inch during the establishment period.
- Sediment and debris should be removed when buildup exceeds two inches in depth in either the filter strip or the level spreader. Improve the level spreader if erosion is observed. Rills and gullies observed along the strip may be filled with topsoil, stabilized with erosion control matting, and either seeded or sodded. For channels less than 12 inches wide, filling with crushed gravel, which allows grass to creep in over time, is acceptable. For wider

channels (greater than 12 inches), regrading and reseeding may be necessary. Small bare areas may only require overseeding. Regrading may also be required when pools of standing water are observed along the slope. In no case should standing water be tolerated for longer than 48 to 72 hours.

- If check dams are proposed, inspect for cracks, rot, structural damage, obstructions, or any other factors that cause altered flow patterns or channelization. Inlets or sediment sumps that drain to filter strips should be cleaned periodically or as needed.
- Remove sediment when the filter strip is thoroughly dry. Dispose of sediment and debris at a suitable disposal or recycling site that complies with applicable local, state, and federal waste regulations.
- When a filter strip is used for sediment control, it should be regraded and reseeded immediately after construction.
- Guidance information, usually in written manual form, for operating and maintaining filter strips, should be provided to all facility owners and tenants. Facility owners are encouraged to keep an inspection log, for recording all inspection dates, observations, and maintenance activities.
- Grass cover should be mowed to maintain a height of 4-6 inches.
- Invasive plants should be removed on an annual basis. Vegetative cover should be sustained at 85 percent and reestablished if damage greater than 50 percent is observed.
- If a filter strip exhibits signs of poor drainage, periodic soil aeration or liming may help to improve infiltration.

Winter Considerations

Filter strips often make convenient areas for snow storage. Thus, vegetation should be salt-tolerant and

the maintenance schedule should include removing sand buildup at the toe of the slope.

The bottom of the gravel trench (if used as the level spreader) should be placed below the frost line to prohibit water from freezing in the trench. The perforated pipe in the trench should be at least eight inches in diameter to further discourage freezing. Other water quality options may be explored to provide backup to filter strips during the winter, when pollutant removal ability is reduced.

Cost

The cost of constructing filter strips includes grading, sodding (when applicable), installing vegetation, constructing a level spreader, and constructing a pervious berm, if proposed. Depending on whether seed or sod is applied, enhanced vegetation use or design variations such as check dams, construction costs may range anywhere from no cost (assuming the area was to be grassed regardless of use as treatment) to \$50,000 per acre. The annual cost of maintaining filter strips (mowing, weeding, inspecting, litter removal, etc.) generally runs from \$100 to \$1,400 per acre and may overlap with standard landscape maintenance costs. Maintenance costs are highly variable, as they are a function of frequency and local labor rates.

Designer/Reviewer Checklist for Vegetated Filter Strips

Soil type and HSG category: _____

ITEM	Page No.	YES	NO	N/A	NOTES
➤ Sheet flow provided?	1				
Recommended slope ranges followed? ➤ <i>Max. lateral slope = 1%</i>	1				
➤ Appropriate length for soil, vegetation, and slope?	4-7				
Slope of drainage area below five percent?	--				
If not, is energy dissipation provided?	3				
➤ Length/area of incoming drainage appropriately limited?	3				
Receiving vegetation considered?	2				
Located in undisturbed virgin soil?	4				
If not, will soil be properly compacted and stabilized?	8,9				
Appropriate vegetation selected for stabilization?	3,4				
Feasible construction process and sequence?	8,9				
Soil compaction avoided or mitigated?	--				
Erosion and sedimentation control provided to protect filter strip during construction?	8,9				
Maintenance accounted for and plan provided? <i>Remove sediment/debris if > 2 inches deep.</i> <i>Standing water should not exceed 48-72 hours</i> <i>Grass cover: 4-6 inches high</i>	9				
Additional Design Considerations <i>Underlying soils should have low permeability, ranging between 0.06 and 0.6 inches/hour</i> <i>Hydraulic residence time no less than 5 minutes; optimal time is 9 minutes</i> <i>Average velocity no greater than 0.9 feet/second</i> <i>Average depth of flow no more than 0.5 inches</i>	--				

➤ Denotes Minimum Design Considerations

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BMP Fact Sheet

VEGETATED ROOF

Vegetated roofs, or green roofs, are conventional rooftops that include a thin covering of vegetation allowing the roof to function more like a vegetated surface. The overall thickness of the vegetated roof may range from 2 to 6 inches, typically containing multiple layers consisting of waterproofing, synthetic insulation, non-soil engineered growth media, fabrics, synthetic components, and foliage.

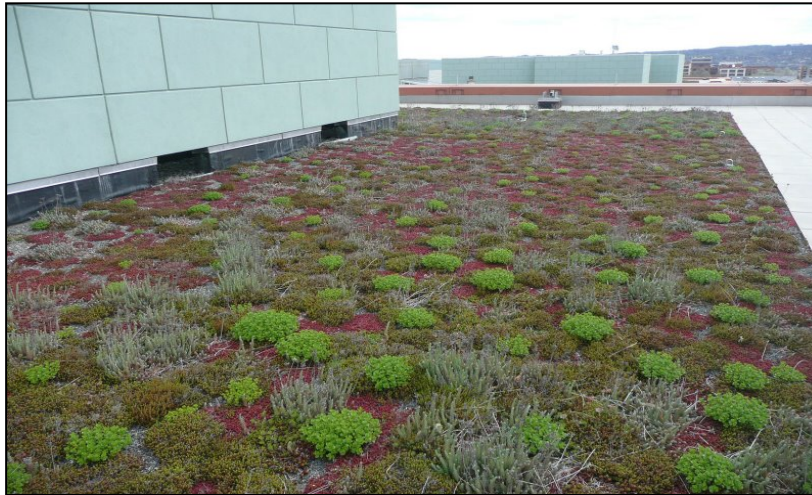


Figure 1 Vegetated Roof, Washington, DC (USEPA, picasaweb)

Applications		Stormwater Quantity Functions	
Residential	Limited	Volume	Med/High
Commercial	Yes	Groundwater Recharge	Low*
Ultra Urban	Yes	Peak Rate	Medium
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Yes	TSS	Medium
Highway/Road	N/A	TP	Medium
Recreational	Yes	TN	Medium
		Temperature	High

Additional Considerations	
Cost	High
Maintenance	Medium
Winter Performance	Medium

Variations

- Intensive
- Semi-intensive
- Extensive

Key Design Features

- Extensive roofs are most commonly used for rainfall runoff migration
- Roofs with pitches steeper than 2:12 (9.5 degrees) must incorporate supplemental measures

Benefits

- Good stormwater volume control
- Heating and cooling energy benefits
- Increased lifespan of roof
- Heat island reduction
- Enhance habitat value

Limitations

- Cost (intensive systems)
- Careful design and construction required
- Maintenance requirements until plants established
- Can't store or treat stormwater from other parts of the property

* Although vegetated roofs can be used very successfully in combination with infiltration systems.

Description and Function

Vegetated roofs involve growing plants on rooftops, thus replacing the vegetated footprint that was removed when the building was constructed. Vegetated roof covers are an “at source” measure for reducing the rate and volume of runoff released during rainfall events. The water retention and detention properties of vegetated roof covers can be enhanced through selection of the engineered media and plants. Depending on the plant material and planned usage for the roof area, modern vegetated roofs can be categorized as systems that are intensive, semi-intensive, or extensive (**Table 1**).

Intensive vegetated roofs utilize a wide variety of plant species that may include trees and shrubs, require deeper substrate layers (usually greater than four inches), are generally limited to flat roofs, require ‘intense’ maintenance, and are often park-like areas accessible to the general public.

Extensive vegetated roofs are limited to herbs, grasses, mosses, and drought tolerant succulents such as sedum, can be sustained in a shallow substrate layer (less than four inches), require minimal maintenance once established, and are generally not designed for access by the public. These vegetated roofs are typically intended to achieve a specific environmental benefit, such as rainfall runoff mitigation. Extensive roofs are well suited to rooftops with little load bearing capacity and sites which are not meant to be used as roof gardens. The mineral substrate layer, containing little nutrients, is not very deep but suitable for less demanding and low-growing plant communities.

Semi-intensive vegetated roofs fall between intensive and extensive vegetated roof systems. More maintenance, higher costs and more weight are the characteristics for this intermediate system compared to that of the extensive vegetated roof.

Vegetated system layers

A proprietary system provides a growing environment on the roof which adequately compensates for the plant’s natural environment. It ensures reliable technical and ecological functionality for decades. Vegetated roof systems

contain the following functional layers (from bottom to top):

Root barrier: The root barrier protects the roof construction from being damaged by roots. If the waterproofing is not root resistant a separate root barrier has to be installed.

Waterproof membrane: This layer protects the roof structure from moisture and can include a unique root-resistant compound to prevent roots from penetrating.

Protection layer: A specially designed perforation resistant protection mat prevents mechanical damage of the root barrier and roof construction during the installation phase. Depending on the thickness and the material the protection layer can also retain water and nutrients.

Drainage Layer: The drainage layer allows for excess water to run-off into the water outlets. Depending on the design and the material the drainage layer has additional functions such as water storage, enlargement of the root zone, space for aeration of the system and protection for the layers below it. Due to the weight constraints of the roof, the drainage layer is made of light-weight materials. Molded drainage elements made of rubber or plastic are used quite often. Other drainage layers are made of gravel, lava, expanded clay or clay tiles.

Filter layer: The filter layer separates the plant and substrate layers from the drainage layer below. Especially small particles, humic and organic materials, are retained by the filter sheet and are therefore available for the plants. In addition, the filter sheet ensures that the drainage layer and the water outlet are not clogged with silt. Filter layers are preferably made of geo-textiles such as fleece or other woven materials.

Growing medium: The growing medium is the basis of the vegetated roof. A sufficient depth for the root zone has to be ensured as well as an adequate nutrient supply and a well balanced water-air relation. Depending on the type of vegetated roof and the construction requirements, a variety of different system substrates are available.

	Extensive Vegetated Roof	Semi-Intensive Vegetated Roof	Intensive Vegetated Roof
Maintenance	Low	Periodically	High
Irrigation (after plants are established)*	No	Periodically	Regularly
Plant Communities	Moss, Sedum, Herbs, and Grasses	Grass, Herbs, and Shrubs	Perennials, Shrubs, and Trees
System build-up height	60-200 mm	120-250 mm	150-400 mm Underground garages = > 1000 mm
Weight	60 - 150 kg/m ² 13-30 lbs/ ft ²	120 - 200 kg/m ² 25-40 lbs/ ft ²	180 - 500 kg/m ² 35-100 lbs/ft ²
Construction costs	Low	Medium	High
Desired use	Ecological protection layer	Designed vegetated roof	Park-like garden

Table 1 Vegetated roof types

*Irrigation is required regularly to establish plant communities, especially during the first season.

Source: Adapted from International Green Roof Association

Light-weight mineral materials, with high water retention capacity and good water permeability, such as lava, pumice, expanded clay, expanded schist, and clay tiles, have proven to be reliable for many years. Untreated organic material and top soil have disadvantages in terms of weight and drainage function; they are only used as additions to mineral substrates.

Plant level: The plant selection depends on the growing medium as well as local conditions, available maintenance and the desired appearance. Low maintenance, durable and drought resistant plants are used for extensive vegetated roofs, versus, a nearly limitless plant selection for intensive vegetated roofs.

Variations

Some specialized vegetated roof companies offer installation using vegetated blankets/mats or trays. Pre-vegetated blankets/mats are grown off-site and brought to the site for installation (similar to the concept of sod for grass). They can provide an immediate vegetative coverage which can prevent erosion, reduce installation times, and reduce maintenance during what would otherwise be the establishment period for vegetation.

Modular systems are manufactured trays filled with various vegetated roof layers (often pre-vegetated as well) that are delivered to the site and installed on a prepared roof. Manufacturers of these systems claim that benefits include faster installation and

easier access to the roof if maintenance or leak repairs are necessary (in addition to the potential benefits of a pre-vegetated system). Others argue that these benefits are not significant and that trays can have drawbacks such as increased cost, poor aesthetics (module edges being visible), and reduced performance (wet and dry spots resulting from the barriers between modules in the system).

Extensive vegetated roofs

Extensive vegetated roofs are the most commonly used systems due to their higher mitigation of stormwater runoff as well as their lower cost compared to the other systems. Extensive systems have three variations of assemblies that can be considered in design.

Single media assemblies

Single media assemblies (**Figure 2**) are commonly used for pitched roof applications and for thin and lightweight installations. These systems typically incorporate very drought tolerant plants and utilize coarse engineered media with high permeability. A typical profile would include the following layers:

1. Waterproofing membrane
2. Protection layer
3. Root barrier (optional, depending on the root-fastness of the waterproofing)
4. Drainage layer
5. Filter layer
6. Growth media
7. Vegetation

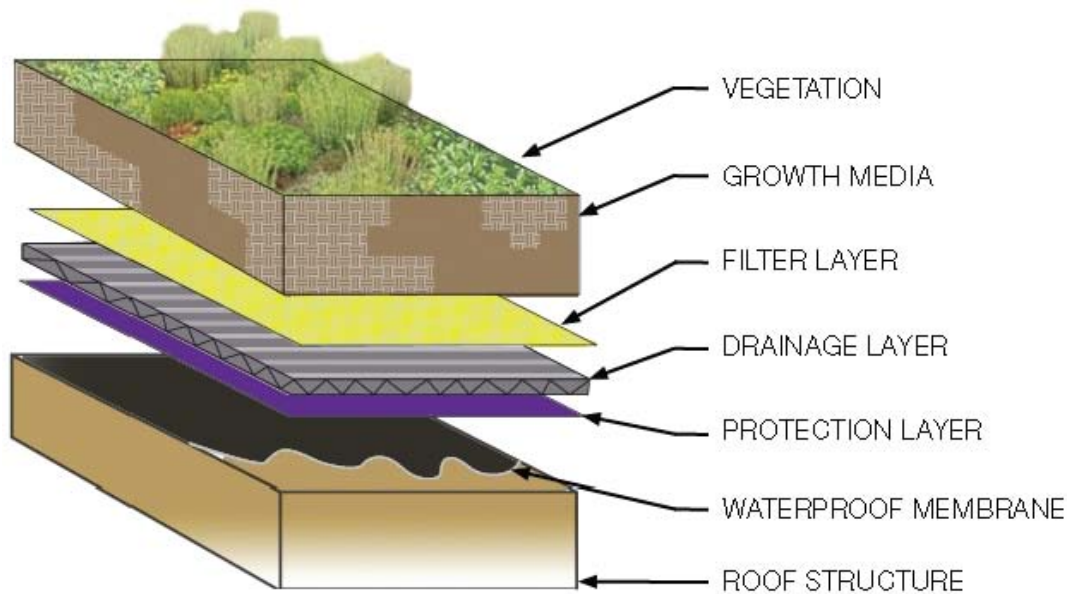


Figure 2 Single media assembly

Pitched roof applications may require the addition of slope bars, rigid slope stabilization panels, cribbing, reinforcing mesh, or similar method of preventing sliding instability.

Flat roof applications with mats as foundations typically require a network of perforated internal drainage conduit to enhance drainage of percolated rainfall to the deck drains or scuppers.

Dual media assemblies

Dual media (**Figure 3**) assemblies utilize two types of non-soil growth media. In this case a finer-grained media with some organic content is placed over a base layer of coarse lightweight mineral aggregate. They do not include a geocomposite drain.

The objective is to improve drought resistance by replicating a natural alpine growing environment in which sandy topsoil overlies gravelly subsoil. These assemblies are typically 4 to 6 inches thick and include the following layers:

1. Waterproofing membrane
2. Root barrier/ protection layer
3. Coarse-grained drainage media
4. Filter layer
5. Growth media
6. Vegetation

These assemblies are suitable for roofs with pitches less than, or equal to about 1.5:12 (7.1 degrees). Large vegetated covers will generally incorporate a network of perforated internal drainage conduit located within the coarse grained drainage layer.

Dual media with synthetic retention/detention layer

These assemblies introduce impervious plastic panels with cup-like receptacles on their upper surface (i.e., a modified geocomposite drain sheet). The panels are in-filled with coarse lightweight mineral aggregate. The cups trap and retain water. They also introduce an air layer at the bottom of the assembly. A typical profile would include:

1. Waterproof membrane
2. Protection layer
3. Retention/detention panel
4. Coarse-grained drainage media
5. Filter layer
6. Growth media
7. Vegetation

These assemblies are suitable on roof with pitches less than or equal to 1:12 (4.8 degrees). Due to their complexity, these systems are usually a minimum of five inches deep. If required, irrigation can be provided via surface spray or mid-level drip.

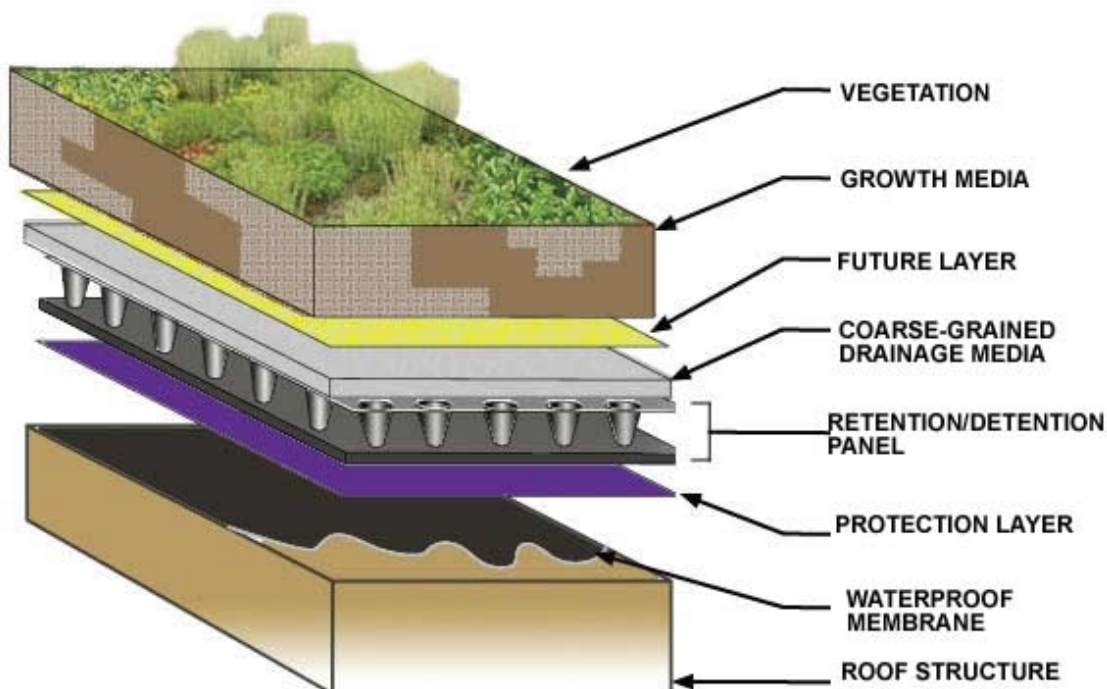


Figure 3 Dual media assembly

Treatment Train

Vegetated roof covers are frequently combined with ground infiltration measures. This combination can be extremely effective for stormwater management and is one of the best ways to replicate the natural hydrologic cycle. Vegetated roofs evapotranspire a significant fraction of annual rainfall and typically discharge larger storm events relatively slowly. If overflow is directed to an infiltration system, the discharge can be infiltrated efficiently as the system has more time to absorb water as it is slowly released from the roof. Vegetated roof covers improve the efficiency of infiltration devices by:

- Reducing the peak runoff rate,
- Prolonging the runoff, and
- Filtering runoff to produce a cleaner effluent.

Benefits

Establishing plant material on rooftops provides numerous ecological and economic benefits including stormwater management, energy conservation, mitigation of the urban heat island effect, increased longevity of roofing membranes, as well as providing a more aesthetically pleasing environment to work and live. A major benefit of green roofs is their ability to absorb stormwater and

release it slowly over a period of several hours, retaining 60-100 percent of the stormwater they receive, depending on the duration and the intensity of the storm.

In addition, green roofs have a longer life-span than standard roofs because they are protected from ultraviolet radiation and the extreme fluctuations in temperature that cause roof membranes to deteriorate. A vegetated roof has a life expectancy of 60 years — three times as long as a traditional roof.

As pervious surfaces are replaced with impervious surfaces due to urban development, the need to recover green space is becoming increasingly critical for the health of our environment. Vegetated roof covers have been used to create functional meadows and wetlands to mitigate the development of open space. This can be accomplished with assemblies as thin as six inches.

Design Considerations

Roof substructure

Wooden constructions, metal sheeting as well as reinforced concrete decks can be considered as

appropriate roof substructures. The base for the vegetated roof is a waterproof roof construction with appropriate load bearing capacity.

Root barrier

Root barriers should be thermoplastic membranes with a thickness of at least 30 mils. Thermoplastic sheets can be bonded using hot-air fusion methods, rendering the seams safe from root penetration. Membranes that have been certified for use as root-barriers are recommended.

Over a period of time roots can damage the waterproofing and roof construction if there have been no corresponding protection measures taken. The root resistance of the waterproofing is determined from the “Procedure for investigating resistance to root penetration at green-roof sites” by the FLL (The Landscaping and Landscape Development Research Society). Over 70 different waterproofing products meet the requirements of this test. If the waterproofing is not root resistant, an additional root barrier has to be installed. Aside from the roof surface, the upstands, perimeters, joints and roof edges also have to be protected against root penetration.

Growth media

Growth media should be a soil-like mixture containing not more than 15 percent organic content. The appropriate grain-size distribution is essential for achieving the proper moisture content, permeability, nutrient management, and non-capillary porosity, and ‘soil’ structure. The grain-size guidelines vary for single and dual media vegetated cover assemblies.

Separation fabric

Separation fabric should be readily penetrated by roots, but provide a durable separation between the drainage and growth media layers. (Only lightweight nonwoven geotextiles are recommended for this function.)

Roof penetrations

For vegetated roofs, the following upstand and perimeter heights have to be considered:

- Upstand height for adjacent building parts and penetrations: minimum of 6 inches.
- Upstand height for roof edges: minimum of 4 inches.

Important: The upstand height is always measured from the upper surface of the vegetated roof system build up or gravel strip. Clamping profiles

Even though it is possible to build pitched green roofs with a slope of 45°, it is not recommended to exceed 10° due to significant limited accessibility for upkeep and maintenance.

guarantee reliable protection and a tight connection of the upstand areas. Roof penetrations (e.g. water connections, building parts for the usage of the roof area, etc.), when possible, should be grouped in order to keep roof penetration to a minimum.

Roof slope

Using modern technologies it is possible to install a reliable vegetated roof system not only on conventional flat roofs, but also on saddle roofs, shed roofs and barrel roofs. Special technical precautions for the mitigation of existing shear forces and erosion are only necessary for a roof slope over 10°.

Roofs with a slope of more than 45° are normally not suitable for a vegetated roof system. Roofs with a slope of less than two percent are special roof constructions on which puddles often develop.

In order to avoid damage to extensive vegetated roofs by water retention, specific arrangements for the roof drainage are necessary. In contrast, it can be beneficial for intensive vegetated roofs to design the roof construction without slope to allow for dam up irrigation.

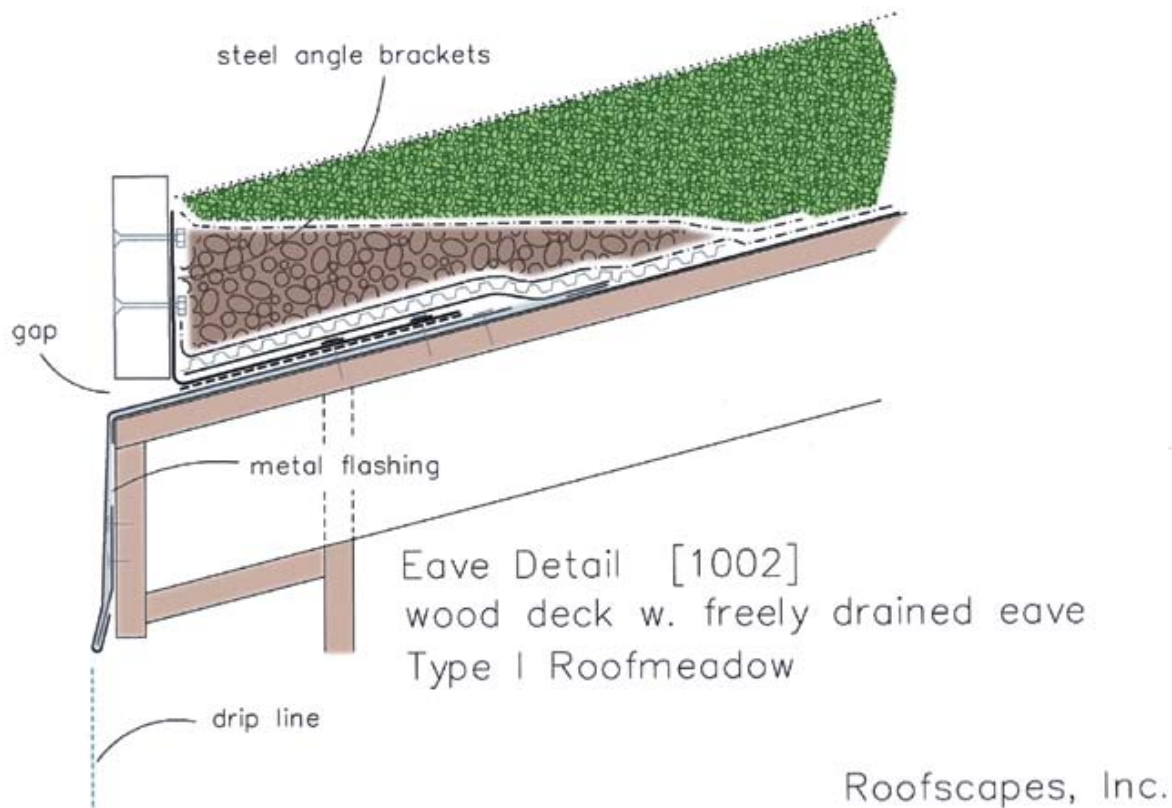


Figure 4 Example Eave Detail for sloped roof
Source: Roofscapes, Inc.

Load calculations

The maximum load bearing capacity of the roof construction must be considered when installing vegetated roofs. Therefore, the water saturated weight of the green roof system, including vegetation must be calculated as permanent load. Extensive vegetated roofs weigh between 60-150 kg/m² (13.0-30.0 lb/ft².) depending on the thickness of the vegetated roof system build-up. Trees, shrubs, and construction elements such as pergolas and walkways cause high point loads and, therefore, have to be calculated accordingly.

Wind uplift

A vegetated roof must be tight to the roof, especially in cases of strong wind. When designing and installing the vegetated roof, safety measures against wind uplift are to be considered.

This is especially important when the vegetated roof provides the load for a loose laid waterproofing and root barrier. The actual influence from the wind depends on the local wind zone, height of the

building, roof type, slope, and area (whether corner, middle or edge) and the substructure.

Roof drainage

Vegetated roof systems store a major part of the annual precipitation and release it to the atmosphere by transpiration. Depending on the thickness of the vegetated roof system build-up and rain intensity, surplus water may accumulate at certain times and must be drained off the roof area. The number of roof outlets and the penetrability factor, or more precisely, the water retaining capacity of the vegetated roof system build-up, has to be adjusted to the average local precipitation.

Roof outlets are to be kept free of substrate and vegetation and have to be controllable at all times. For this purpose “inspection chambers” are installed over the roof outlets. Due to safety precautions, roof areas with inlayed drainage must always have two drainage outlets or one outlet and one safety overflow. For facades and roof areas, gravel strips,

Pitched Vegetated Roofs

Technical Requirements

Root resistant waterproofing is necessary for pitched vegetated roofs; installing an additional root barrier, requires much effort and increases the risk of slippage. Stable abutments have to be installed on the eaves edges to transfer shear forces from the vegetated roof system build-up and the additional snow load into the roof construction. Additional shear barriers may be necessary to transfer the shear forces depending on the roof slope and the roof length. It is recommended the design for the shear barriers and the eaves profiles be done by a structural engineer. With increasing slope, the vegetated roof system build-up is more complicated and the substrate has to be protected from erosion; plastic grid elements can be used for this purpose.

Plant Selection

The success of the landscaping on pitched roofs depends on the plants. Fast surface coverage is the highest priority. A dense planting of root ball plants or pre-cultivated vegetation mats are used in cases of steep slopes and allow for rapid coverage. It is also important to consider the exposure of the roof area, the slope and the location of the building when selecting plants. Perennials and grasses can be used whereas Sedum is the most suitable for pitched roofs, due to the species' high water retention capacity and erosion protection. The water run-off is much faster on pitched roofs compared to a flat roof. It is advisable to plan for an additional irrigation system to provide water during dry periods. The irrigation can be provided either by drip irrigation or by sprinkler systems.

gullies and grids provide fast drainage of rainwater into the drainage system.

Irrigation

Extensive vegetated roofs with drought resistant plant species have to be irrigated only during planting and installation maintenance over the first two years. After its establishment, the annual rainfall is sufficient to sustain the vegetation. In

contrast, the requirements are more involved for intensive vegetated roofs with lawn, shrubs, or trees. An adequate number of precisely dimensioned hoses with automatic irrigation units make plant maintenance during drought periods more manageable. The water supply for roof gardens with no slope can be increased through additional dam-up irrigation. Vegetated roofs can also be irrigated with cistern water.

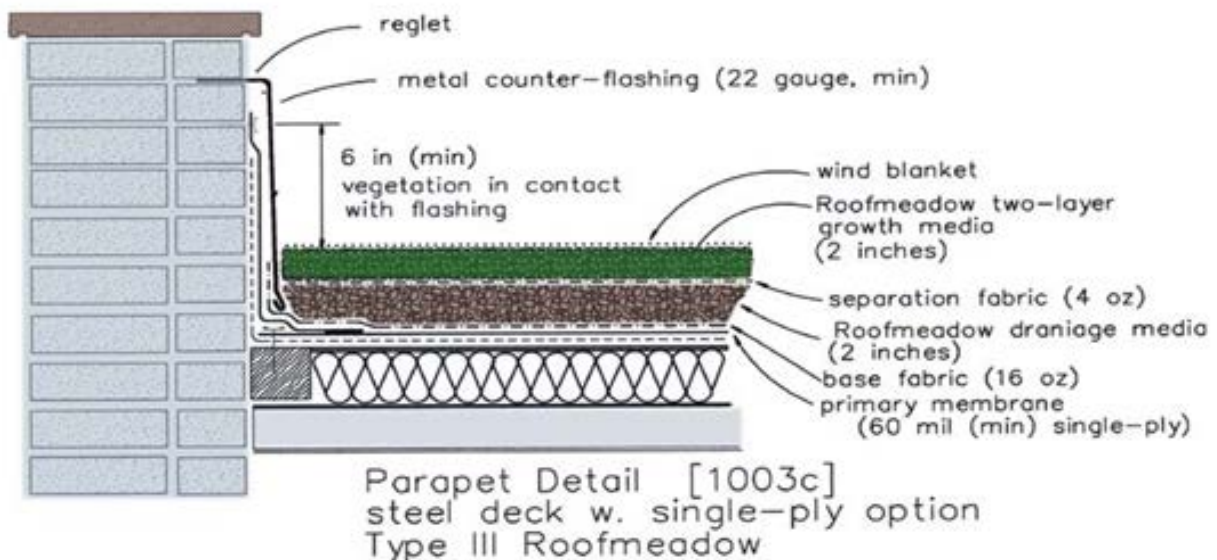


Figure 5 Example parapet flashing detail for flat roof
Source: Roofscapes, Inc.

Fire prevention

As a part of the “hard roof” classification, intensive vegetated roofs provide preventative fire protection in the case of sparks and radiating heat. The criteria that extensive vegetated roofs must meet in order to be considered fire resistant, are already met by most vegetated roof systems that are offered by suppliers. Openings within the vegetated roof (e.g. skylights) need to be installed with a vegetation free zone (approximately 20 inches). On larger roof areas a vegetation free zone (e.g. gravel strip or concrete slabs) are to be installed at least every 130 feet.

Vegetation Considerations

Extensive vegetated roofs

Plants for extensive vegetated roofs have to survive intense solar radiation, wind exposure, drought, low nutrient supply, freezing temperatures and limited root area. Suitable plant varieties are those growing in severe locations with little moisture and nutrient supply, such as dry meadows. The main varieties are sedum, and delosperma. The plants are able to store high amounts of water in the leaves, are stress resistant and recover easily from periods of drought. Other varieties such as dianthus species, asteraceae and ornamental grasses are also suitable for these conditions.

Intensive green roofs

Having an appropriate vegetated roof system and sufficient growing medium (with higher root penetration volume, nutrients and water supply) growth of sophisticated plant varieties on the roof is possible. The selected plants need to be resistant to intense solar radiation and strong winds. Vegetation with various plant varieties such as perennials, herbs, grasses and trees allow for a natural character on the roof. Having a broader plant community increases the amount of maintenance required.

Stormwater Functions and Calculations

The performance of vegetated roof covers as stormwater best management practices cannot be represented by simple algebraic expressions used for surface runoff. In the analysis of vegetated roof covers, the water that is discharged from the roof is

not surface runoff, but rather underflow, i.e., percolated water. The rate and quantity of water released during a particular storm can be predicted based on knowledge of key physical properties, including:

- Maximum media water retention
- Field capacity
- Plant cover type
- Saturated hydraulic conductivity
- Non-capillary porosity

The maximum media water retention is the maximum quantity of water that can be held against gravity under drained conditions. Standards that have been developed specifically for measuring this quantity in roof media are available from FLL and ASTM (E2399).

Conventional runoff coefficients, such as the NRCS runoff curve number, CN, can be back-calculated from computer simulation or measurements of vegetated roof cover assemblies. However, these coefficients will only apply for the specific design storm for which they have been determined. Runoff reduction recognition in CN determination for this practice is discussed under LID Approach in Post-Construction Stormwater Management Chapter of Technical Standards.

Volume reduction

All vegetated roof covers have both retention and detention volume components. Benchmarks for these volumes can be developed from the physical properties described above.

Peak rate mitigation

Vegetated roof covers can exert a large influence on peak rate, especially in less extreme storms such as the 1-, 2-, and 5-year storms. Because volume is reduced, there is some peak rate reduction achieved for all storms. 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 (i.e., NRCS curve number of about 65) for storm events with total rainfall volumes up to three times the

maximum media water retention of the assembly. For example, a representative vegetated roof cover with maximum moisture retention of one inch will react like open space for storms up to and including the three-inch magnitude storm.

Using computer simulations, municipalities could generate a table of CN values for specific design storms and green roof types. The table would relate maximum moisture capacity to the CN coefficients. Runoff reduction recognition in CN determination for this practice is discussed under LID Approach in Post-Construction Stormwater Management Chapter of Technical Standards.

Water quality improvement

Direct runoff from roofs is a contributor to pollutants in stormwater runoff. Vegetated roof covers can significantly reduce this source of pollution. Assemblies intended to produce water quality benefits will employ engineered media with almost 100 percent mineral content. Furthermore, following the plant establishment period (usually about 18 months), on-going fertilization of the cover is no longer needed. Experience indicates that it may take five or more years for a water quality vegetated cover to attain its maximum pollutant removal efficiency.

Maintenance

- Irrigation will be required as necessary during the plant establishment period and in times of drought.
- During the plant establishment period, three to four visits to conduct basic weeding, fertilization, and infill planting is recommended.
- The soluble nitrogen content (nitrate plus ammonium ion) of the soil should be adjusted to between one and five parts per million, based on soil test.
- Once plants are established, it is crucial to maintain the roof once or twice a year. Weeds and other unwanted plants on the entire roof, at the perimeters and at the upstands need to be removed. For grass and herb vegetation

the organic buildup has to be removed once a year. Intensive vegetated roofs require higher maintenance and service throughout the year.

Dam-up Irrigation in Vegetated Roof

Intensive Vegetated Roofs depend mainly on additional irrigation. To install an irrigation system which does not use fresh water, a water dam-up irrigation unit is recommended.

Requirements of a dam-up irrigation unit:

- flat roof
- dam-up elements above roof outlets
- an appropriate drainage layer with the necessary height

In case of heavy rain the reservoir is filled primarily and any excess water is collected in the cistern. During dry periods the water on the roof is used first, then water is pumped from the cistern onto the roof and supplied to the plants.

This process can be carried out either manually or electronically. The water in the cistern can also be used for other purposes, provided the reservoir is big enough.

Winter Considerations

Applicable snow load must be considered in the design of the roof structure.

Cost

The construction cost of vegetated roof covers varies greatly, depending on factors such as:

- Height of the building
- Accessibility to the structure by large equipment such as cranes and trailers
- Depth and complexity of the assembly
- Remoteness of the project from sources of material supply
- Size of the project

However, under 2007 market conditions, extensive vegetated covers for roof will typically range

between \$8 and \$16 per square foot, including design, installation, and warranty service (not including waterproofing). Basic maintenance for extensive vegetated covers typically requires about 2-3 person-hours per 1,000 square feet, annually.

Although vegetated roofs are relatively expensive compared to other BMPs in terms of stormwater management, they can have other significant benefits which serve to reduce their life-cycle costs. For example, the longevity of the roof system may be greatly increased. In addition, heating and cooling costs can be significantly reduced.

Designer/Reviewer Checklist for Vegetated Roofs

Type of vegetated roof(s) proposed: _____

ITEM	Page No.	YES	NO	N/A	NOTES
Load and structural capacity analyzed?	7				
Waterproofing layer and protection adequate?	2,6				
Leak protection system provided?	3-5				
Internal drainage capacity for large storms?	--				
Appropriate growing medium?	3,6				
Appropriate drainage media and/or layer?	2				
Geotextile/filter fabric specified?	2,6				
Good detailing (flashings, penetrations, drains, gravel edges, etc.)?	--				
Slope stability provided, if necessary?	4,8				
Appropriate vegetation selected?	3,6, 8,9				
Plant establishment (temporary irrigation/fertilization) procedures provided?	8				
Erosion control / wind protection provided?	7				
Maintenance accounted for and plan provided?	10				

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BMP Fact Sheet

VEGETATED SWALE

A vegetated swale (or bioswale) is a shallow stormwater channel that is densely planted with a variety of grasses, shrubs, and/or trees designed to slow, filter, and infiltrate stormwater runoff. Check dams can be used to improve performance and maximize infiltration, especially in steeper areas.



Figure 1 Vegetated Swale, Philadelphia, PA (USEPA, picasaweb)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low/Med
Commercial	Yes	Groundwater Recharge	Low/Med
Ultra Urban	Limited	Peak Rate	Low/Med
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Limited	TSS	Med/High
Highway/Road	Yes	TP	Low/High
Recreational	Yes	TN	Medium
		Temperature	Medium

Additional Considerations	
Cost	Low/Med
Maintenance	Low/Med
Winter Performance	Medium

Variations

- Vegetated swale with infiltration trench
- Linear wetland swale
- Grass swale

Key Design Features

- Handles the 10-year storm event with some freeboard
- Two-year storm flows do not cause erosion
- Maximum size is five acres
- Bottom width of two to eight feet
- Side slopes from 3:1 (H:V) to 5:1
- Longitudinal slope from one to six percent
- Check dams can provide additional storage and infiltration

Site Factors

- Water table to bedrock depth: 2 foot minimum.*
- Soils: A, B preferred; C & D may require an underdrain (see infiltration BMP)
- Slope: 1 to 6 percent. (less than one percent can be used w/ infiltration)
- Potential hotspots: No
- Maximum drainage area: 5 acres

Benefits

- Can replace curb and gutter for site drainage and provide significant cost savings
- Water quality
- Peak and volume control with

Limitations

- Limited application in areas where space is a concern
- Unless designed for infiltration, there is limited peak and volume control

* four feet recommended, if possible

Description and Function

Vegetated swales are broad, shallow, earthen channels designed to slow runoff, promote infiltration, and filter pollutants and sediments in the process of conveying runoff. Water is filtered through the soil to under drains and the swale is quickly dewatered, preventing standing water. Vegetated swales are an excellent alternative to conventional curb and gutter conveyance systems, because they provide pretreatment and can distribute stormwater flows to subsequent BMPs.

Vegetated swales are sometimes used as pretreatment devices for other structural BMPs, especially from roadway runoff. While swales themselves are intended to effectively treat runoff from highly impervious surfaces, pretreatment measures are recommended to enhance swale performance. Pretreatment can dramatically extend the functional life of any BMP, as well as increase its pollutant removal efficiency by settling out some of the coarser sediments. This treatment volume is typically obtained by installing check dams at pipe inlets and/or driveway crossings. Other

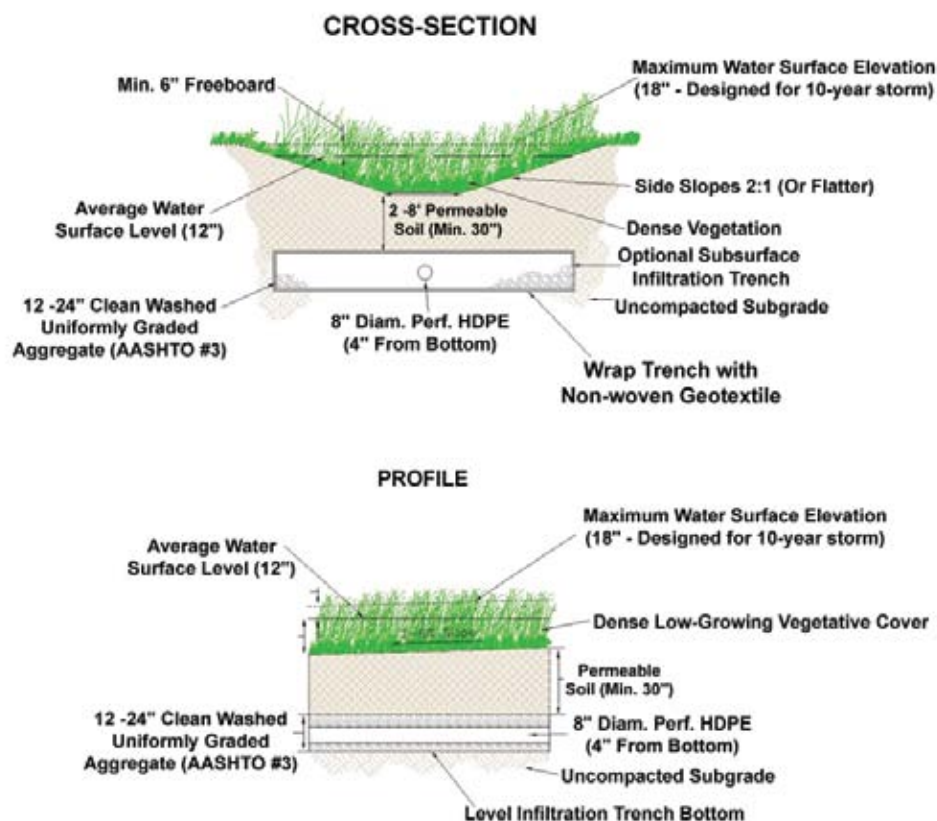


Figure 2 Schematics of Vegetated Swale with an underlying aggregate layer
Source: Pennsylvania Stormwater BMP Manual, 2006

A vegetated swale typically consists of a band of dense vegetation, underlain by at least 12 inches of permeable soil (greater than 0.5 inches/hour). Swales constructed with an underlying aggregate layer (**Figure 2**) can provide significant volume and peak rate reductions. The permeable soil media should have a minimum infiltration rate of 0.5 inches per hour.

pretreatment options include a vegetated filter strip, a sediment fore-bay (or plunge pool) for concentrated flows, or a pea gravel diaphragm (or alternative) with a six-inch drop where parking lot sheet flow is directed into a swale.

Check dams made of wood, stone, or concrete are often employed to enhance infiltration capacity, decrease runoff volume, rate, and velocity. They

also promote additional filtering and settling of nutrients and other pollutants. Check-dams create a series of small, temporary pools along the length of the swale, which drain down within a maximum of 48 hours.

Weep holes may be added to a wood or concrete check dam to allow the retained volume to slowly drain out. Care should be taken to ensure that the weep holes are not subject to clogging. For stone check dams, allow lower flows (two-year storm) to drain through the stone, while allowing higher flows (10-year storm) to drain through a lower section in the center (thereby reducing the potential erosion from water flowing around the sides of the check dam). Flows through a stone check dam are a function of stone size, flow depth, flow width, and flow path length through the dam.

Conveyance

It is highly recommended that a flow splitter or diversion structure be provided to allow larger flows to bypass this practice as needed. Contributing drainage areas should be limited to five acres and an overflow should be provided within the practice to pass the excess flows to a stabilized water course or storm drain. Weirs are common overflow systems with media filters and can control velocities so that they are non-erosive at the outlet point to prevent downstream erosion.

Media filters should be equipped with a minimum eight-inch diameter underdrain in a one-foot gravel bed. Increasing the size of the underdrain makes freezing less likely. The porous gravel bed prevents standing water in the system by promoting drainage. Gravel is also less susceptible to frost heaving than finer grained media. It is also highly recommended that a permeable filter fabric be placed between the underdrain and gravel layer but not extend laterally from the pipe more than two feet on either side (**Figure 2**).

Variations

Vegetated swale with infiltration trench

This option includes a six to 24-inch aggregate bed or trench, wrapped in a nonwoven geotextile (See Infiltration BMP for further design guidelines). The

addition of an aggregate bed or trench can substantially increase volume control and water quality performance although cost is also increased.

Vegetated swales with infiltration trenches are best fitted for milder sloped swales (< 1 percent) or poorly-drained soils where the addition of the aggregated bed system can help to make sure that the maximum allowable ponding time of 48 hours is not exceeded. Ideally, the subsurface system should be designed like an infiltration trench (see Infiltration Practices BMP Fact Sheet). The subsurface trench should be comprised of terraced levels, though sloping trench bottoms may also be acceptable. The storage capacity of the infiltration trench may be added to the surface storage volume to achieve the desired storage.

Grass swale

Grass swales are essentially conventional drainage ditches. They typically have milder side and longitudinal slopes than their vegetated counterparts. Grass swales are usually less expensive than vegetated swales. However, they provide far less infiltration and pollutant removal opportunities and should be used only as pretreatment for other structural BMPs. Grassed swales, where appropriate, are preferred over catch basins and pipes because of their ability to increase travel time and reduce peak flow rates from a site.

Linear wetland swale

Wetland swales occur when the water table is located very close to the surface, incorporating long, shallow, permanent pools or marshy conditions that can sustain wetland vegetation. Like the dry swale, the entire water quality treatment volume is stored within a series of cells created by check dams.

Potential Applications

1. Residential – Swales can be used along road rights of ways and for side yard and backyard drainage.
2. Commercial/Industrial – Swales can provide site drainage around a site, within a site and can help take/slow discharge from other BMPs that outlet to the swale (**Figure 3**).

3. Ultra-urban – There may be some opportunity for swales in ultra-urban areas. However, swales are usually no less than two feet deep. With horizontal to vertical side slopes between 3:1 to 5:1 (horizontal to vertical), the top width of the swale can prohibit its use in this setting where space is usually at a premium.

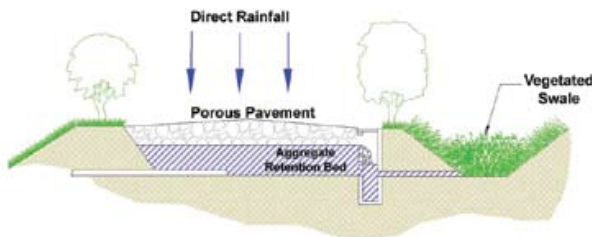


Figure 3 Slow discharge from porous pavement bed to vegetated swale

Source: Pennsylvania Stormwater BMP Manual 2006

4. Retrofit – Potential application in retrofit situations will depend strongly on space and topographic limitations. On sites with little to no slope, swales may not be the best drainage option. In these areas, swales may end up not moving water fast enough or may be prone to long periods of flooding or inundation in areas meant to be mostly dry.
5. Highway/Road – Vegetated swales are an excellent alternative to curb and gutter systems. Appropriately sized roadside swales should be able to handle all the runoff from the roadway and may also be able to handle runoff from areas outside the road surface.

Design Considerations

1. Sizing
 - a. Convey the calculated peak discharge from a 10- year storm event. Use Manning's equation to calculate the velocity associated with the flow to make sure velocities are not larger than permissible velocities discussed in Technical Standards.
 - b. Temporarily store and infiltrate the one-inch storm event, while providing capacity for up to the 10-year storm with 12 inches of freeboard.
 - c. Flows for up to the 2-year storm should be conveyed without causing erosion.
 - d. Maintain a maximum ponding depth of 18 inches at the end point of the channel, with a 12-inch average maintained throughout.
 - e. The maximum ponding time should be 24 hours. It is critical that swale vegetation not be submerged during smaller storms, because it could cause the vegetation to bend over with the flow. This leads to reduced roughness of the swale, higher flow velocities, and reduced contact filtering opportunities.
 - f. Bottom widths typically range from two to eight feet. The maximum bottom width to depth ratio for a trapezoidal swale should be 12:1.
2. Longitudinal slopes between one and six percent are recommended.
3. Swale side slopes are best within a range of 3:1 to 5:1 and should never be greater than 2:1 for ease of maintenance and side inflow from sheet flow.
4. Check dams
 - a. Recommended for vegetated swales with longitudinal slopes greater than three percent or when additional detention or infiltration is desired.
 - b. Should be constructed to a height of six to 18 inches and regularly spaced.
 - c. Should be keyed into the bottom and sides of the swale, usually at least one to two feet on all sides. The height of the key on both sides should exceed the water surface elevation of the 10-year event by at least six inches.

- d. The middle of the check dam crest should be below the sides of the check dam to help focus flow over the check dam and away from the channel sides.
5. Maximum drainage area is five acres.
6. Soil testing is required when infiltration is planned (Soil Infiltration Testing Protocol Appendix).
7. Runoff can be directed as concentrated flows or as lateral sheet flow drainage. Both are acceptable provided sufficient stabilization or energy dissipation is included. If flow is to be directed into a swale via curb cuts, provide a two- to three-inch drop at the interface of pavement and swale. Curb cuts should be at least 12 inches wide to prevent clogging and should be spaced appropriately to minimize the number of cuts but maximize area drained.
8. Soil should be at least 12 inches of loamy or sand with an infiltration rate of at least 0.5 inches per hour.
9. Inundation time is 24 hours. Rototill and replant swale if draw down time is more than 24 hours.
10. Prior to establishment of vegetation, a swale is particularly vulnerable to scour and erosion and therefore its seed bed must be protected with temporary erosion control, such as straw matting, straw-coconut matting, compost blankets, or fiberglass roving. Most vendors will provide information about the Manning's 'n' value and will specify the maximum permissible velocity. It is critical that the selected erosion control measure is adequate to prevent scour.

Stormwater Functions and Calculations

Utilize Manning's equation to calculate the velocity associated with the flow from the peak discharge of the 10 year storm or local standard. Maintain

velocity of the 10 year and water quality criteria at non-erosive rates.

Manning's Equation

$$Q = VA = \frac{1.49}{n} \left(\frac{A}{WP} \right)^{2/3} S^{1/2}$$

Where;

Q = Flow in cfs

V = Velocity in ft/sec

A = Area in ft²

n = Manning's roughness coefficient

WP = Wetted Perimeter in ft

S = Slope in ft/ft

Manning's roughness coefficient, or 'n' value in the equation, varies with the type of vegetative cover and design flow depth. Therefore, more conservative, lower numbers in the "n" value guidance tables should be used in design to determine flow velocities.

If driveways or roads cross a swale, culvert capacity may supersede Manning's equation for determination of design flow depth. In these cases, use standard culvert calculations to establish that the backwater elevation would not exceed the banks of the swale. If the maximum permissible velocity is exceeded at the culvert outlet, energy dissipation measures must be implemented.

Volume calculations (as it relates to the use of check dams)

The volume stored behind each check-dam (**Figure 4**) can be approximated from the following equation:

$$\text{Storage Volume} = 0.5 * (\text{Length of Swale Impoundment Area per Check Dam}) * (\text{Depth of Check Dam}) * [(\text{Top Width of Check Dam}) + (\text{Bottom Width of Check Dam})] / 2$$

Active infiltration during the storm should also be accounted for when appropriate according to guidance provided in the Infiltration Practices BMP Fact Sheet.

Peak rate mitigation

Vegetated swales can help reduce peak flows by increasing travel times, reducing volume through infiltration, and storing runoff behind check dams, culverts, etc.

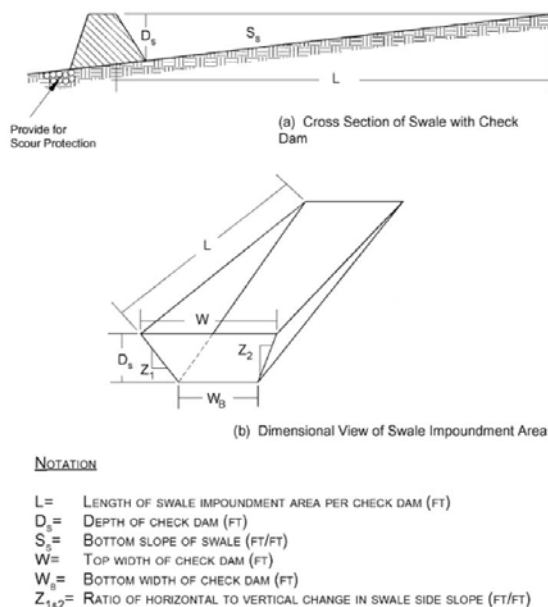


Figure 4 Storage behind check dam

Source: Northern Virginia Planning District Commission, 1992

Water quality improvement

Although the reported water quality benefits of vegetated swales vary widely, they can be expected to remove a high amount of total suspended solids (typically 70 percent to 90 percent), a low-to-medium amount of total phosphorus (approximately 10 percent to 50 percent), and a medium amount of total nitrogen (often 40 percent to 75 percent). There is some research to suggest that longer swales provide additional treatment. Vegetated swales can be used effectively for pretreatment prior to discharge to other BMPs (see Post-Construction Stormwater Management Chapter of Technical Standards for water quality criteria and calculations).

Construction Guidelines

1. Begin vegetated swale construction only when the upgradient site has been sufficiently stabilized and temporary erosion and

sediment control measures are in place. Vegetated swales should be constructed and stabilized very early in the construction schedule, preferably before mass earthwork and paving increase the rate and volume of runoff.

2. Rough grade the vegetated swale. Equipment should avoid excessive compaction and/or land disturbance. Excavating equipment should operate from the side of the swale and never on the bottom. If excavation leads to substantial compaction of the subgrade (where an infiltration trench is not proposed), the compacted soils should be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth. At the very least, topsoil should be thoroughly deep plowed into the subgrade in order to penetrate the compacted zone and promote aeration and the formation of macropores. Following this, the area should be disked prior to final grading of topsoil.
3. After rough grading, fine grade the vegetated swale. Accurate grading is crucial for swales. Even the smallest non-conformities may compromise flow capacity or soil stability.
4. Vegetation should consist of a dense and diverse selection of close-growing, water-tolerant plants (See Recommended Plant List for BMPs Appendix for complete list). Common species used in vegetated swales in Michigan include Canada Bluejoint (*Calamagrostis canadensis*), Virginia Wild Rye (*Elymus virginicus*), Switch Grass (*Panicum virgatum*), and Prairie Cord Grass (*Spartina pectinata*). Additionally, a cover crop of seed oats (*Avena sativa*) and Annual Rye (*Lolium multiflorum*) should be used for quick germination and stability.

Maintenance

1. Irrigation will be necessary during plant establishment and may be needed in periods of little rain or drought. Vegetation should be established as soon as possible to prevent erosion and scour.

2. Stabilize freshly seeded swales with appropriate temporary or permanent soil stabilization methods, such as erosion control matting or blankets. Erosion control for seeded swales should be required for at least the first 75 days following the first storm event after planting. If runoff velocities are high, consider sodding the swale or diverting runoff until vegetation is fully established.
3. Annually inspect and correct erosion problems, damage to vegetation, and sediment and debris accumulation (address when greater than three inches at any spot or covering vegetation).
4. Annually mow and trim vegetation to ensure safety, aesthetics, proper swale operation, or to suppress weeds and invasive vegetation. Dispose of cuttings in a local composting facility; mow only when swale is dry to avoid rutting.
5. Annually inspect for uniformity in cross-section and longitudinal slope; correct as needed.
6. Inspect and correctly check dams when signs of altered water flow (channelization, obstructions, etc.) are identified.

Winter Considerations

Plowing snow into swales will help insulate the bottom of the swale. However, snow that has accumulated salt or sand from de-icing operations should not be pushed into swales. Winter conditions also necessitate additional maintenance concerns, which include the following:

1. Inspect swale immediately after the spring melt, remove residuals (e.g., sand) and replace damaged vegetation without disturbing remaining vegetation.
2. If roadside or parking lot runoff is directed to the swale, mulching and/or soil aeration/manipulation may be required in the spring to restore soil structure and moisture capacity and to reduce the impacts of de-icing agents.
3. Use nontoxic, organic de-icing agents, applied either as blended, magnesium chloride-based liquid products or as pretreated salt.
4. Consider the use of salt-tolerant vegetation in swales.

Cost

Vegetated swales provide a cost-effective alternative to traditional curbs and gutters, including associated underground storm sewers (**Table 1**). The following table compares the cost of a typical vegetated swale (15-foot top width) with the cost of traditional conveyance elements.

It is important to note that the costs listed are strictly estimates and should be used for rough estimating purposes only. Also, these costs do not include the cost of activities such as clearing, grubbing, leveling, filling, and sodding of vegetated swale (if required). When all construction, operation, and maintenance activities are considered, the cost of vegetated swale installation and maintenance is far less than that of traditional conveyance elements.

	SWALE	Underground Pipe	Curb & Gutter
Construction Cost (per linear foot)	\$4.50 - \$8.50 (from seed)	\$2 per foot per inch of diameter	\$13 - \$15
	\$15 - \$20 (from sod)	(e.g. a 12" pipe would cost \$24 per linear foot)	
Annual O & M Cost (per linear foot)	\$0.75	No Data	No Data
Total annual cost (per linear foot)	\$1 from seed \$2 from sod	No Data	No Data
Lifetime (years)	50		20

*Table 1 Cost Comparison showing vegetated swale to pipe, curb, and gutter
Source: Bay Area Stormwater Management Agencies Association, June 1997*

Designer/Reviewer Checklist for Vegetated Swales

Type of vegetated swale proposed: _____

ITEM	Page No.	YES	NO	N/A	NOTES
Can the swale safely (with freeboard) convey the 10-year event? <i>Max. drainage area: 5 acres</i> <i>Max. ponding depth at end point of channel: 18 inches</i> <i>Max. ponding time: 24 hours</i>	1,4				
Are bottom slopes between one percent and six percent?	1,4				
Are check dams provided for slopes > 3%?	4				
Are check dams adequately keyed into swale bottom and sides?	4				
Are two-year and ten-year flows non-erosive?	1,4,5				
Will the swale completely drain in 48 hours?	2,3				
Are side slopes between 3:1 and 5:1 H:V?	1,3,4				
Are swale soils loam, loamy sand or sandy loam? <i>Min. infiltration rate of permeable media: 0.5 in/hr</i>	5				
Underdrain provided for infiltration swales? <i>Min. diameter of underdrain: 8 inches</i>	2,3				
Vegetation and Manning's coefficient selected?	4,6				
Non-erosive inflow condition(s)?	--				
Erosion control provided during construction?	5				
Maintenance accounted for and plan provided?	6,7				
Additional Design Factors ➤ <i>Hydraulic residence time no less than 5 minutes; optimal time is 9 minutes</i> ➤ <i>Average velocity no greater than 0.9 ft/sec</i> ➤ <i>Bottom width at least 2 feet</i> ➤ <i>Denotes Minimum Design Considerations</i>					

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BMP Fact Sheet

WATER QUALITY DEVICES

Various proprietary, commercially available BMPs have been designed to remove non-point source pollutants from the conveyance system for storm-water runoff. These structural BMPs vary in size and function, but all utilize some form of filtration, settling, or hydrodynamic separation to remove particulate pollutants from overland or piped flow. The devices are generally configured to remove pollutants including coarse sediment, oil and grease, litter, and debris. Some filtration devices employ additional absorbent/adsorbent material for removal of toxic pollutants. Pollutants attached to sediment such as phosphorus, nitrates, and metals may be removed from stormwater by effective filtration or settling of suspended solids. Regular maintenance is critical for the continued proper functioning of water quality devices.



Figure 1 Installation of hydrodynamic separator (Johnson County, Kansas Stormwater Management Program)

Variations

- Filtration
- Settling
- Hydrodynamic separation

Key Design Features

- Located below ground, as part of the stormwater conveyance system
- Devices may be internal to the conveyance system
- Devices may be installed in an offline configuration, so that a certain flow will be treated while allowing a surcharge flow to bypass the treatment.

Benefits

- Can be used in a variety of applications including retrofitting existing stormwater systems

Limitations

- Virtually no water quantity benefits
- Potentially high costs
- Typically require frequent maintenance

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	None
Commercial	Yes	Groundwater Recharge	None
Ultra Urban	Yes	Peak Rate	None
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Yes	TSS	Varies
Highway/Road	Yes	TP	Varies
Recreational	Yes	TN	Varies
		Temperature	None

Additional Considerations	
Cost	Varies
Maintenance	Varies, but no less than two inspections and cleanings per year
Winter Performance	High

Description and Function

Water quality devices are generally proprietary, commercially available units designed to improve the quality of stormwater by removing pollutants as the stormwater flows through the system. Devices designed to reduce particulate solids may also reduce pollutants since pollutants can be bound to solid particles.

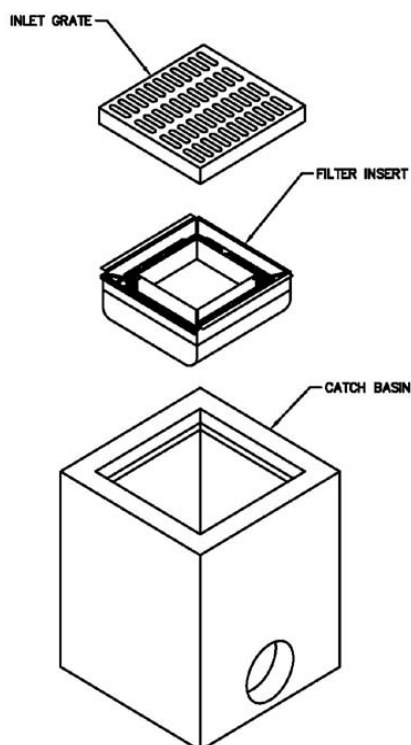


Figure 2 Tray type insert

Source: Pennsylvania Stormwater BMP Manual, 2004

Water quality devices are often employed in areas with high concentrations of pollutants in runoff and may effectively reduce sediment particles in stormwater runoff before they reach other BMPs, such as infiltration systems. Manufacturers of the devices usually provide the internal design specifications and installation instructions. Most are designed to treat a “first flush” of stormwater and provide an overflow or bypass route for large storm events. The first flush is generally measured as a volume of runoff from a specified storm.

The advantage of the manufactured devices is their adaptability to ultra urban and retrofit situations, where they can be installed beneath most surface infrastructure such as roads and parking lots.

Variations

Water quality devices may be separated into three categories: filtration (including absorption and adsorption), settling, and hydrodynamic separation.

Filtration devices

These devices usually take the form of catch basin inserts. They are installed within catch basins directly below the grates, and may be tray, bag, or basket types. Runoff passes through the device before discharging into the outlet pipe. Some modification of the catch basin inlet is sometimes necessary to accommodate and support the insert, and to allow bypass from large storms. Trays, baskets and bag type inserts perform similar functions – removing debris and sediment.

Tray type inserts

Tray type inserts (**Figure 2**) allow flow to pass through filtration media contained in a tray around the perimeter of the catch basin. High flows pass over the tray and into the catch basin directly.

Bag type inserts

Bag type inserts are made of fabric that hangs down below the catch basin grate. Overflow holes are usually provided to allow larger flows to pass without causing flooding at the grate. Certain manufactured products include polymer textiles that are intended to increase pollutant removal effectiveness.

Basket type inserts

Basket type inserts (**Figure 3**) are also installed in catch basins. Most have a handle to remove the basket for maintenance. Tray and basket inserts can



Figure 3 Catch basin insert showing basket frame

Source Stormwater 360

be fitted with packets of absorbent or adsorbent material to aid with removal of oil, grease, or toxic pollutants. Small orifices allow small storm events to weep through, while larger storms overflow the basket. Tray and basket inserts are generally useful for debris and large sediment, and require consistent maintenance.

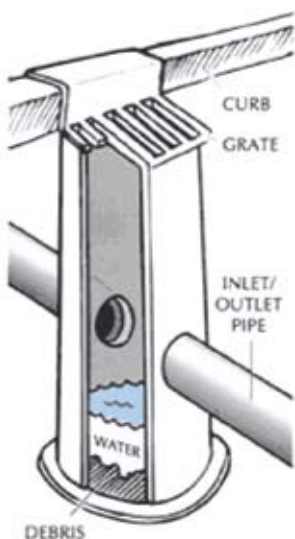


Figure 4 Sumped catch basin
Source: City of Farmington Hills, MI

Settling devices

Settling devices provide sump areas where stormwater can collect within the conveyance system. Stormwater pools in the sump area, where velocity decreases and suspended solids settle out. Cleaner water pours over the top to the next link in the conveyance system. An example of a settling water quality device is a sumped catch basin.

Sumped catch basins

Sumped catch basins (**Figure 4**) are constructed in the same way as standard catch basins, but are constructed with approximately 12 to 24 inches of storage depth below the invert of the outlet pipe. Where suitable soils exist and groundwater is not a concern, weep holes should be drilled into the bottom of the inlet to prevent standing water from remaining in the inlet for long periods of time.

Hydrodynamic devices

Hydrodynamic devices (**Figure 5**) are flow-through devices designed to serve within the stormwater conveyance system. Many products available from various manufacturers employ various mechanical methods to remove sediment, debris, and pollutants from storm-water. These methods include inclined plane settlement plates, vortexes, baffle systems, tubular settlement chambers, or combinations of these. Sediment, debris, and pollutant removal efficiencies vary widely among devices and according to the rate, quantity, and quality characteristics of the flow reaching the device. These devices work most effectively in combination with other BMPs.

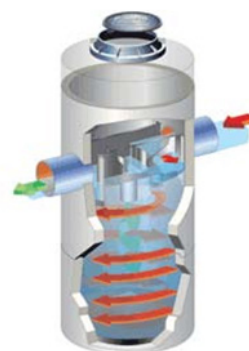
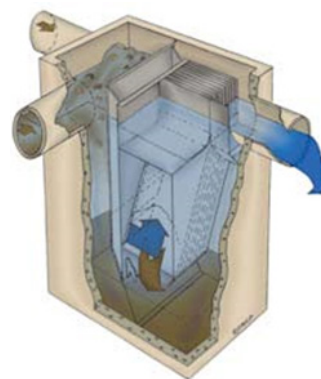


Figure 5 Example of Hydrodynamic Devices
Sources: Stormwater Solutions (top) and Terre Hill Stormwater Solutions (bottom)

Applications

The wide variety of commercially available water quality devices allows for them to be used in many different applications. However, their use in low-density residential projects is likely to be limited by their maintenance burden and the fact that other BMPs are more cost effective for stormwater management in residential projects (they are generally used for areas with high impervious cover).

Water quality devices are useful in any existing or proposed conveyance systems that have or are expected to have significant levels of sediment or debris, or in areas that have pollutant hot spots. Such areas include, but are not limited to: parking lots, gas stations, golf courses, streets, driveways, and material handling at industrial or commercial sites.

Water quality devices are commonly used as pre-treatment before other structural BMPs. Long term functionality of these devices is dependent on regular long term inspection and cleaning. Long term maintenance must be considered when specifying these devices.

Design Considerations

1. Consider the requirements of the site including anticipated sediment loading and the components of each water quality device. The proposed land use should determine specific pollutants to be removed from runoff.
2. Design to ensure easy access to the device for people and also the necessary tools for maintenance. Frequent inspection and maintenance is required. To avoid re-suspension of pollutants, perform maintenance well before sediment or debris has filled the device to capacity.
3. Consider the head requirements for the device to work properly, especially when determining the total head requirements for a treatment train. Catch basin inserts have the advantage of fitting into existing drainage

systems at points where head loss already occurs.

4. The stormwater management system for the site should be designed to provide treatment for bypassed water. This occurs when storms in excess of the device's hydraulic capacity bypass the device and fail to achieve the designed runoff treatment standard for the site.
5. Properly design and select water quality devices to prevent re-suspension of captured sediments during storm events that exceed the system capacity.

Stormwater Functions and Calculations

Volume reduction

Water quality devices do not provide volume reduction.

Peak rate mitigation

Water quality devices do not provide peak rate reduction.

Water quality improvement

Water quality benefits may be quantified according to a third party review and testing of the technology, such as the U.S. EPA which offers a searchable clearinghouse of approximately 220 independent tests of BMP performance at: <http://www.bmpdatabase.org/>

If third party test results are not available for a device, the manufacturers' specifications and tests for removal efficiencies of a device may be considered.

For the purpose of this Technical Standards, accepted treatment rates for Water Quality Devices must be based on procedure described in the Post-Construction Stormwater Management Chapter of Technical Standards.

Winter Considerations

A limited amount of data is available concerning cold weather effects on water quality insert effectiveness. Freezing may result in runoff

bypassing the treatment system. Salt stratification may also reduce detention time. Colder temperatures reduce the settling velocity of particles, which can result in fewer particles being “trapped”. Salt and sand loadings may significantly increase in the winter and may warrant more frequent maintenance.

Water quality inserts (tray, bag, or basket types) as well as hydrodynamic devices should be inspected and maintained during winter months. Application of sand, ash, cinders, or other anti-skid materials may cause water quality devices to fill more quickly. Clogged inserts in cold weather can be especially problematic if flow is restricted and ponded water freezes over to create a safety hazard or render a portion of the site unusable.

Maintenance

Follow the manufacturer’s guidelines for maintenance taking into account expected sediment and pollutant load and site conditions.

Inspect each water quality device at least twice per year and after all major storm events if possible. Post-construction, they should be emptied when full of sediment (and trash) and cleaned at least twice a year.

Vactor trucks may be an efficient cleaning mechanism for devices with firm or solid floors or sumps. Vactors should not be used for bag type filters or other devices where they could damage filter membranes or absorptive/adsorptive materials.

Maintenance is crucial to the effectiveness of water quality devices. The more frequent a water quality insert is cleaned, the more effective it will be. One study (Pitt, 1985) found that water quality inserts can effectively store sediment up to 60 percent of their sump volumes. Once the stored volume exceeds 60 percent, the inflow re-suspends the sediments into the stormwater. Keeping a maintenance log of sediment amounts and dates removed is helpful in planning a maintenance schedule.

Cost

Costs vary widely according to manufacturer, type, and size of water quality devices. Contact manufacturers to determine current costs.

Installation and maintenance costs for in-line or off-line devices installed below ground can run significantly higher than for vegetative filters and infiltration devices that provide similar levels of treatment.

Designer/Reviewer Checklist for Water Quality Devices

Type of water quality device(s) proposed: _____

Manufacturer(s) & model(s) proposed: _____

Independent Verifications (ETV, TARP, etc.): _____

ITEM	Page No.	YES	NO	N/A	NOTES
If system is off-line, adequate flow diversion system?	--				
If system is on-line, adequate bypass/overflow that minimizes release of captured pollutants?	--				
Adequate hydraulic head available for device to operate?	5				
Properly sized for drainage area, flow, pollutant capture?	--				
Has device been independently verified for adequate pollutant removal for appropriate particle sizes (especially if it is the primary water quality BMP)?	4				
Manufacturer's recommendations followed?	--				
Details provided for device and connections?	--				
Erosion control provided, if necessary?	--				
Easy access/visibility for maintenance?	4				
Maintenance accounted for and a detailed plan provided (including the amount sediment/debris accumulation that triggers the need for cleaning)?	5				

References

Innovative Stormwater Treatment Technologies BMP Manual. New Hampshire Watershed Management Bureau, Watershed Assistance Section, 2002.

Pennsylvania Department of Environmental Protection. *Pennsylvania Stormwater Best Management Practices Manual*, 2006

Pitt, R. Characterizing and Controlling Urban Runoff through Street and Sewerage Cleaning. U.S. Environmental Protection Agency, June 1985.

Recommended Plant Lists for Best Management Practices

Appendix D2

RECOMMENDED PLANT LISTS FOR BEST MANAGEMENT PRACTICES

This appendix contains recommended native and non-native (when appropriate) plant species for the Best Management Practices detailed throughout the manual. The recommended list contains species that are considered suitable to conditions in Central Indiana, which is located in Ecoregion 55. Species have been recommended based on hardiness, aesthetics, functionality, and commercial availability. It is certain that species exist outside the confines of this list that will perform in a comparable way to those listed; however, commercial availability is often a limiting factor in obtaining material for native plantings. Over time, and in certain locales, additional species will become available to supplement those listed below.

An array of planting zones is provided based on normal water levels (**Figure 1**). Using these zones will provide the best chances for long-term success of native planting in the context of LID. While plants may

naturally occur outside of the given ranges, these ranges are intended to be guidelines for plant installation. Whenever possible and practical in standing water conditions, native plants should be installed in live plant form (rather than seed). Seed or a combination of seed and live plants may be used in upland situations.

Recommendations are given for height, bloom color, bloom time, sun requirements, and salt tolerance. Please note that these are recommendations based on a range of situations, and a specific plant or population may vary from site-to-site. For sun requirements, F = full sun required, P = partial sun tolerated, and S = shade tolerated. Salt tolerance is classified as Yes (Y) or No (N). This was determined through literature reviews and anecdotal evidence. If there is no information confirming tolerance, a “No” was listed.

	Zone A — 2”-4” Below Water Level	Zone B — 0”-2” Below Water Level	Zone C — 0”-2” Above Water Level	Zone D — 2”-4” Above Water Level	Zone E — 4”-18” Above Water Level	Zone F — 18”+ Above Water Level	Zone G — Planter Boxes	Zone H — Vegetated Roofs
Rain gardens/Bioretenion	✱	✱	✱	✱	✱	✱		
Vegetated Filter Strips			✱	✱	✱	✱		
Vegetated Swales		✱	✱	✱				
Infiltration Basin		✱	✱					
Subsurface Infiltration Basins				✱	✱	✱		
Infiltration Trenches				✱	✱	✱		
Infiltration Berns	✱	✱	✱	✱	✱	✱		
Planter Boxes							✱	
Vegetated Roofs								✱
Constructed Wetlands	✱	✱	✱	✱				
Wet Ponds	✱	✱	✱					
Dry Extended Detention Basins			✱	✱	✱	✱		
Riparian Corridor Restoration			✱	✱				
Native Revegetation	✱	✱	✱	✱	✱	✱	✱	✱

Figure 1 Planting Zone/BMP Matrix

Plant Installation

Native Seeding

Seasonal consideration: October 1-June 15 (note: seeds should not be planted on frozen ground).

Native seeding is generally recommended for areas above the water line or 1-2" below the water line. Live plant material should be used to establish vegetation at deeper water levels.

Broadcast seeding

Broadcast seeding is preferred over drill seeding on graded, bare soil sites. Apply the seed uniformly over the surface using a combination seeder/cultipacker unit such as a Brillion or Truax Trillion seeder. The Trillion seeder is preferred as it is designed to handle native seeds.

A cone seeder or other similar broadcasting equipment may also be used if the seed mix does not contain fluffy seeds in amounts sufficient to prevent free flowing without plugging. Seed should then be pressed into the surface using a cultipacker or roller.

Drill seeding

A rangeland-type no-till drill designed to plant native grasses and forbs may be used in bare soils although this equipment is specifically designed to plant through existing vegetation which is killed with an herbicide. Cultipacking or rolling before seeding may be required to prevent seed placement depths exceeding 0.25 inch, but cultipacking or rolling after seeding is not required.

All seeding equipment, whether broadcast or drill, should be calibrated to deliver the seed at the rates and proportions specified in the plans. Equipment should be operated to ensure complete coverage of the entire area to be seeded, and seed must be placed no deeper than 0.25 inch in the soil. No fertilizers or soil conditioners will be required or allowed.

Native Planting

Seasonal considerations: May 1-July 1

Plant plugs should be installed in holes drilled with an auger the same diameter and depth as the plug within +0.75 inch/- 0.25 inch. In wetland plantings where soil is soft and moist enough, a dibble bar or trowel may also be used. The planting layout should consider the requirements of the individual species regarding soil type, moisture, slope, shading, and other factors for the particular plant species.

Planting densities vary according to budget and project goals and can range from three-to-five foot spacing for plug supplements of seeded areas to six inches to two foot spacing for high visibility landscaping projects with large budgets. Groups of five-to-seven plugs of the same species planted approximately one foot apart is usually preferable to planting all species intermixed randomly across the site at a uniform density.

In wetland or shoreline areas with potential for high wave action or wildlife predation that may dislodge newly planted plugs, plugs should be secured with 6-inch or 8-inch U-shaped wire erosion control blanket staples. Staple length is determined by the density of the planting substrate; softer substrates require longer length to hold plugs adequately.

In areas where potential for wildlife predation exists, such as retention basins or other planting areas adjacent to open water, waterfowl barriers should be installed around a minimum of 50 percent of the plugs. All plugs not protected by barriers should be stapled into the substrate as described above. Barriers may consist of plastic or wire mesh enclosures supported with wooden stakes, adequately constructed to inhibit access by waterfowl for one growing season. Enclosures should extend at least two feet above the plant tops. Methodology should be approved by the project designer with input from a restoration ecologist if necessary. Barriers may be removed after one growing season.

Tree and Shrub Planting

See "[Planting & Transplanting Landscape Trees & Shrubs](#)" from the Purdue University Cooperative Extension Service – Department of Horticulture, Publication HO-100-W.

Maintenance and Management

Maintaining vegetated BMPs is typically most important during the first few years following installation. Supplemental irrigation may be needed to help establish plants in drought conditions. Plants may need to be replaced due to predation or other unseen factors. Most commonly, management includes removing invasive species via mowing, hand-pulling, or spot herbicide applications. In larger areas, broadcast herbicide applications may be appropriate. Over time in upland areas, controlled burning may be used as a way to invigorate the plantings and control certain invasive species. If not feasible for social or cultural reasons, an annual or biennial mowing may be used instead of fire.

Long-term management may be necessary, but is typically significantly less intensive. The site should be periodically checked for invasive species infestations. Any prairie or open area may need occasional (every three to five years) burning or mowing to remove woody vegetation that may encroach.

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Zone A

Planting Zone = Two-to-four inches below water level

These species require continual inundation within the given water depths in order to thrive. Although slight, short-term variances may be tolerated (\pm five inches for a period of 48 hours or less), water levels must remain in this range for a majority of the growing season for maximum plant growth and survival.

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Woody Species:						
<i>Cephalanthus occidentalis</i>	Buttonbush	15'	White	Jun-Aug	F/P/S	N
Grasses/Sedges/Rushes:						
<i>Acorus calamus</i>	Sweet flag	1'-4'	Green	May-Jun	F/P	N
<i>Scirpus acutus</i>	Hard-stemmed bulrush	4'-6'	Brown	Apr-Aug	F	Y
<i>Scirpus validus</i>	Great bulrush	4'-8'	Brown	May-Aug	F	Y
<i>Sparganium americanum</i>	American bur reed	2'-5'	Green	Jun-Aug	F/P	N
<i>Sparganium eurycarpum</i>	Common bur reed	2'-6'	Green	May-Aug	F	N
Forbs:						
<i>Asclepias incarnata</i>	Swamp milkweed	3'-5'	Pink	Jun-Sep	F/P	N
<i>Decodon verticillatus</i>	Swamp loosestrife	2'-4'	Purple	Jul-Sep	F/P	N
<i>Iris virginica</i>	Blue flag iris	2'-3'	Purple	May-Jul	F/P/S	N
<i>Peltandra virginica</i>	Arrow arum	2'-5'	Green	Jun-Jul	F/P/S	N
<i>Pontedaria cordata</i>	Pickernelweed	1'-3'	Violet	Jun-Sep	F/P	N
<i>Sagittaria latifolia</i>	Arrowhead	1'-4'	White	Jun-Sep	F/P	N

Representative Zone A Species

Buttonbush



Arrowhead



Pickerel Weed

Blue Flag Iris



Swamp Milkweed

Source: JFNew

Zone B

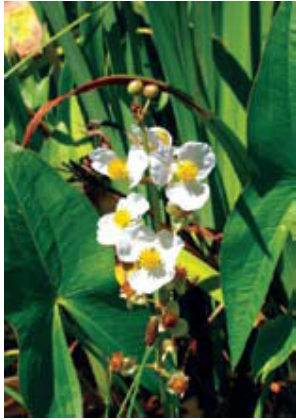
Planting Zone = Zero-to-two inches below water level

These species tolerate fluctuating water levels within this range. Although slight, short-term variances may be tolerated (\pm five inches for a period of 48 hours or less), water levels must remain in this range for most of the growing season for maximum plant growth and survival.

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
<i>Woody Species:</i>						
<i>Cephalanthus occidentalis</i>	Buttonbush	15'	White	Jun-Aug	F/P/S	N
<i>Grasses/Sedges/Rushes:</i>						
<i>Acorus calamus</i>	Sweet flag	1'-4'	Green	May-Jun	F/P	N
<i>Carex comosa</i>	Bristly sedge	2'-3'	Green	May-Jun	F	N
<i>Carex lacustris</i>	Lake sedge	2'-4'	Brown	May-Jun	F/P/S	N
<i>Carex stricta</i>	Tussock sedge	2'-3'	Brown	Apr-Jun	F/P	N
<i>Eleocharis acicularis</i>	Needle spike rush	6"	Green	May-Oct	F	N
<i>Eleocharis obtusa</i>	Blunt spike rush	1'-2'	Green	May-Sep	F/P	N
<i>Glyceria striata</i>	Fowl manna grass	1'-5'	Green	May-Jun	F/P/S	N
<i>Juncus effusus</i>	Soft rush	1'-4'	Brown	July	F/P	N
<i>Scirpus acutus</i>	Hard-stemmed bulrush	4'-6'	Brown	Apr-Aug	F	Y
<i>Scirpus cyperinus</i>	Wool grass	3'-5'	Tan	Jun-Sep	F	Y
<i>Scirpus pendulus</i>	Red bulrush	2'-4'	Brown	May-Jun	F	N
<i>Scirpus validus</i>	Great bulrush	4'-8'	Brown	May-Aug	F	Y
<i>Sparganium americanum</i>	American bur reed	2'-5'	Green	Jun-Aug	F/P	N
<i>Sparganium eurycarpum</i>	Common bur reed	2'-6'	Green	May-Aug	F	N
<i>Forbs:</i>						
<i>Alisma plantago-aquatica</i>	Water plantain	2'-4'	White	Jul-Sep	F	N
<i>Asclepias incarnata</i>	Swamp milkweed	3'-5'	Pink	Jun-Sep	F/P	N
<i>Decodon verticillatus</i>	Swamp loosestrife	2'-4'	Purple	Jul-Sep	F/P	N
<i>Iris virginica</i>	Blue flag iris	2'-3'	Purple	May-Jul	F/P/S	N
<i>Peltandra virginica</i>	Arrow arum	2'-5'	Green	Jun-Jul	F/P/S	N
<i>Pontederia cordata</i>	Pickernelweed	1'-3'	Violet	Jun-Sep	F/P	N
<i>Sagittaria latifolia</i>	Arrowhead	1'-4'	White	Jun-Sep	F/P	N
<i>Saururus cernuus</i>	Lizard's tail	2'-4'	White	Jun-Aug	P/S	N

Representative Zone B Species

Blue Flag Iris



Arrowhead



Bristly Sedge



Pickerel Weed



Swamp Milkweed

Source: JFNew

Zone C

Planting Zone = Zero-to-two inches above water level

These plants are tolerant of fluctuating water levels within this range. They will also tolerate short periods of inundation, not to exceed 48 hours in most situations, making them appropriate for BMP settings.

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Woody Species:						
<i>Acer rubrum</i>	Red maple	90'	Green/ red	Mar-May	F/P/S	N
<i>Alnus rugosa</i>	Speckled alder	25'	Brown	Mar-May	F/P	N
<i>Amelanchier arborea</i>	Downy serviceberry	40'	White	April	F/P/S	N
<i>Aronia prunifolia</i>	Purple chokeberry	10'	White	Apr-Jul	F/P	N
<i>Betula alleghaniensis</i>	Yellow birch	100'	Purple/ Yellow	Apr-May	P/S	N
<i>Betula papyrifera</i>	Paper birch	70'	Brown	Apr-May	F/P	N
<i>Cephalanthus occidentalis</i>	Buttonbush	15'	White	Jun/Aug	F/P/S	N
<i>Cornus amomum</i>	Silky dogwood	10'	White	May-Jul	F/P	N
<i>Cornus sericea</i>	Red-osier dogwood	10'	White	May-Sep	F/P	N
<i>Ilex verticillata</i>	Winterberry	10'	White	June	F/P/S	Y
<i>Larix laricina</i>	American larch	75'	Brown	May	F/P	N
<i>Lindera benzoin</i>	Spicebush	15'	Yellow	Apr-May	P/S	N
<i>Morus rubra</i>	Red mulberry	50'	Green	May-Jun	F/P/S	N
<i>Nyssa sylvatica</i>	Black gum	100'	Green	May-Jul	F/P/S	Y
<i>Physocarpus opulifolius</i>	Ninebark	10'	White	May-Jun	F/P	N
<i>Picea mariana</i>	Black spruce	60'	Brown	May-Jun	F/P/S	N
<i>Quercus bicolor</i>	Swamp white oak	70'	Green/ yellow	May	F/P/S	Y
<i>Quercus palustris</i>	Pin oak	90'	Green/ yellow	Apr-May	F/P/S	Y
<i>Ribes americanum</i>	Wild black currant	5'	Yellow	Apr-Jun	F/P/S	N
<i>Rosa palustris</i>	Swamp rose	2'-7'	Pink	Jun-Aug	F/P/S	N
<i>Thuja occidentalis</i>	White cedar	50'	Brown	Apr-May	F/P/S	N
<i>Ulmus americana</i>	American elm	100'	Brown	Mar-Apr	F/P/S	N
<i>Ulmus rubra</i>	Slippery elm	80'	Green	Mar-Apr	F/P/S	N
<i>Viburnum lentago</i>	Nannyberry	20'	White	Apr-Jun	P/S	Y
Grasses/Sedges/Rushes:						
<i>Calamagrostis canadensis</i>	Blue joint grass	2'-4'	Brown	June	F/P	N
<i>Carex comosa</i>	Bristly sedge	2'-3'	Green	May-June	F/P	N
<i>Carex crinita</i>	Fringed sedge	2'-5'	Green	May	F/P/S	N
<i>Carex hystericina</i>	Porcupine sedge	2'-3'	Green	May-June	F/P/S	N
<i>Carex lupulina</i>	Common hop sedge	2'-3'	Green/ Brown	May-June	F/P/S	N
<i>Carex muskingumensis</i>	Palm sedge	1'-2'	Brown	May-June	S	N
<i>Carex stipata</i>	Common fox sedge	1'-3'	Brown	Apr-May	F/P/S	N
<i>Carex stricta</i>	Tussock sedge	2'-3'	Brown	Apr-Jun	F/P	N
<i>Carex vulpinoidea</i>	Brown fox sedge	2'-3'	Brown	May-Jun	F/P	N
<i>Cinna arundinacea</i>	Common wood reed	3'-4'	Green	Aug-Sep	P/S	N
<i>Eleocharis acicularis</i>	Needle spike rush	6"	Green	May-Oct	F	N
<i>Eleocharis obtusa</i>	Blunt spike rush	1'-2'	Green	May-Sep	F/P	N
<i>Glyceria striata</i>	Fowl manna grass	1'-5'	Green	May-Jun	F/P/S	N
<i>Juncus effusus</i>	Soft rush	1'-4'	Brown	July	F/P	N
<i>Juncus tenuis</i>	Path rush	6"-2'	Brown	June	F/P/S	N
<i>Juncus torreyi</i>	Torrey's rush	1'-2'	Brown	Jun-Sep	F	Y
<i>Scirpus acutus</i>	Hard-stemmed bulrush	4'-6'	Brown	Apr-Aug	F	Y
<i>Scirpus atrovirens</i>	Dark green rush	3'-5'	Brown	Jun-Aug	F	N
<i>Scirpus cyperinus</i>	Wool grass	3'-5'	Tan	Jun-Sep	F	Y
<i>Scirpus pendulus</i>	Red bulrush	2'-4'	Brown	May-Jun	F	N
<i>Scirpus validus</i>	Great bulrush	4'-8'	Brown	May-Aug	F	Y

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Forbs:						
<i>Alisma plantago-aquatica</i>	Water plantain	2'-4'	White	Jul-Sep	F	N
<i>Anemone canadensis</i>	Canada anemone	1'-2'	White	May-Sep	F/P	N
<i>Angelica atropurpurea</i>	Great angelica	6'-9'	White	May-Jun	F/P	N
<i>Asclepias incarnata</i>	Swamp milkweed	3'-5'	Pink	Jun-Sep	F/P	N
<i>Aster novae-angliae</i>	New England aster	3'-6'	Violet	Jul-Oct	F/P	N
<i>Aster puniceus</i>	Swamp aster	3'-6'	Lav/ White	Aug-Oct	F	Y
<i>Aster umbellatus</i>	Flat-topped aster	1'-4'	White	Jul-Oct	F/P	N
<i>Cassia hebecarpa</i>	Wild senna	3'-5'	Yellow	Jul-Aug	F/P	N
<i>Chelone glabra</i>	Turtlehead	2'-4'	Cream	Aug-Sep	F/P/S	N
<i>Eupatorium maculatum</i>	Spotted Joe-pye weed	4'-7'	Pink	Jun-Oct	F/P	N
<i>Eupatorium perfoliatum</i>	Boneset	3'-5'	White	Jul-Oct	F/P	Y
<i>Euthamia graminifolia</i>	Grass-leaved goldenrod	1'-4'	Yellow	Jul-Sep	F/P	N
<i>Gentiana andrewsii</i>	Bottle gentian	1'-3'	Blue	Aug-Oct	F/P	N
<i>Helenium autumnale</i>	Sneezeweed	3'-5'	Yellow	Jul-Nov	F/P	Y
<i>Helianthus giganteus</i>	Tall sunflower	5'-12'	Yellow	Jul-Sep	F/P	N
<i>Iris virginica</i>	Blue flag iris	2'-3'	Purple	May-Jul	F/P/S	N
<i>Liatris spicata</i>	Marsh blazing star	3'-5'	Pink	Jul-Sep	F/P	N
<i>Lilium michiganense</i>	Michigan lily	3'-8'	Orange	Jul-Aug	P/S	N
<i>Lobelia cardinalis</i>	Cardinal flower	2'-5'	Red	Jul-Oct	F/P/S	N
<i>Lobelia siphilitica</i>	Great blue lobelia	1'-4'	Blue	Jul-Oct	F/P/S	N
<i>Lobelia spicata</i>	Pale spiked lobelia	1'-3'	Lavender	May-Aug	F/P	N
<i>Mimulus ringens</i>	Monkeyflower	2'-4'	Lavender	Jun-Sep	F/P	N
<i>Physostegia virginiana</i>	Obedient plant	2'-5'	Pink	Aug-Oct	F	Y
<i>Pycnanthemum virginianum</i>	Mountain mint	1'-3'	White	Jun-Oct	F/P	N
<i>Rudbeckia laciniata</i>	Cutleaf coneflower	3'-10'	Yellow	Jul-Nov	F/P/S	N
<i>Sagittaria latifolia</i>	Arrowhead	1'-4'	White	Jun-Sep	F/P	N
<i>Saururus cernuus</i>	Lizard's tail	2'-4'	White	Jun-Aug	P/S	N
<i>Sisyrinchium angustifolium</i>	Stout blue-eyed grass	1'	Blue	May-Aug	F/P	N
<i>Solidago ohioensis</i>	Ohio goldenrod	2'-3'	Yellow	Jul-Oct	F/P	N
<i>Solidago patula</i>	Swamp goldenrod	3'-6'	Yellow	Aug-Oct	F/P/S	N
<i>Solidago riddellii</i>	Riddell's goldenrod	2'-5'	Yellow	Sep-Nov	F	N
<i>Spiraea alba</i>	Meadowsweet	3'-6'	White	June-Sep	F/P	Y
<i>Spiraea tomentosa</i>	Steeplebush	2'-5'	Pink	Jul-Sep	F/P	Y
<i>Thalictrum dasycarpum</i>	Purple meadow-rue	3'-6'	Cream	May-Jul	F/P	N
<i>Verbena hastata</i>	Blue vervain	3'-6'	Violet	Jun-Sep	F	N
<i>Vernonia missurica</i>	Missouri ironweed	3'-5'	Purple	Jul-Sep	F	N
<i>Zizia aurea</i>	Golden Alexanders	1'-3'	Yellow	Apr-Jun	F/P/S	Y

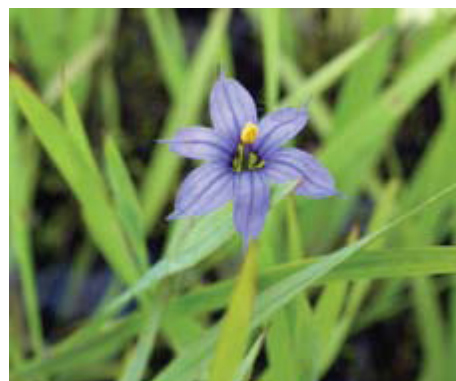
Representative Zone C Species



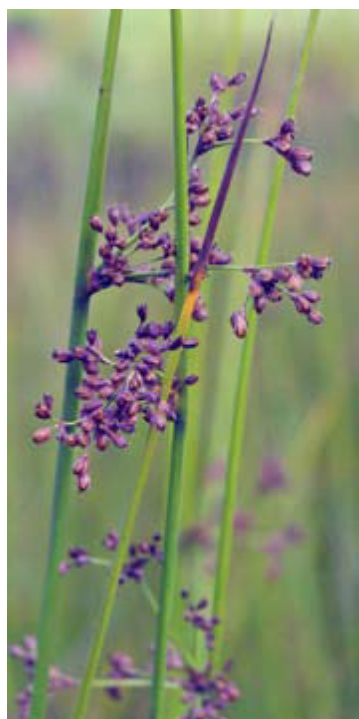
Cardinal Flower



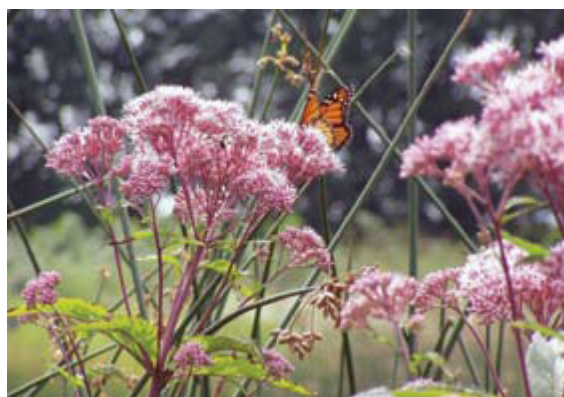
Swamp Milkweed



Blue-Eyed Grass



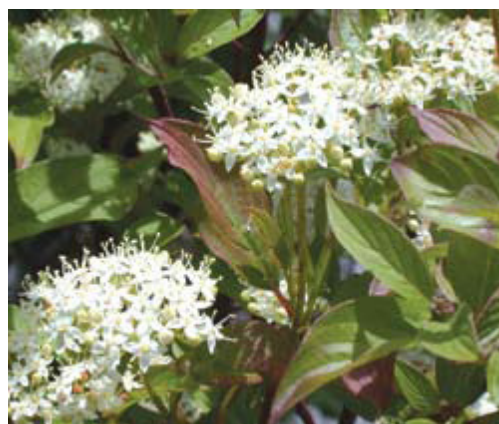
Path Rush



Joe-Pye Weed



Obedient Plant



Red-Osier Dogwood



Monkey Flower

Source: JFNew

Zone D

Planting Zone = Two-to-four inches above water level

These plants tolerate fluctuating water levels within this range. They will also tolerate short periods of inundation, not to exceed 48 hours in most situations, making them appropriate for BMP settings.

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Woody Species:						
<i>Acer rubrum</i>	Red maple	90'	Green/ red	Mar-May	F/P/S	N
<i>Acer saccharinum</i>	Silver Maple	100'	Yellow	Mar-Apr	F/P	N
<i>Amelanchier arborea</i>	Downy serviceberry	40'	White	April	F/P/S	N
<i>Aronia prunifolia</i>	Purple chokeberry	10'	White	Apr-Jul	F/P	N
<i>Betula alleghaniensis</i>	Yellow birch	100'	Purple/ Yellow	Apr-May	P/S	N
<i>Betula papyrifera</i>	Paper birch	70'	Brown	Apr-May	F/P	N
<i>Celtis occidentalis</i>	Hackberry	60'	Green	May	F/P/S	N
<i>Cercis canadensis</i>	Redbud	25'	Red	Apr-May	F/P/S	N
<i>Cornus amomum</i>	Silky dogwood	10'	White	May-Jul	F/P	N
<i>Cornus sericea</i>	Red-osier dogwood	10'	White	May-Sep	F/P	N
<i>Corylus americana</i>	American hazelnut	10'	Yellow	Apr-May	F/P	N
<i>Ilex verticillata</i>	Winterberry	10'	White	June	F/P/S	Y
<i>Juglans nigra</i>	Black walnut	90'	Green	May	F/P	N
<i>Juniperus virginiana</i>	Red-cedar	50'	Brown	Apr-May	F/P	N
<i>Larix laricina</i>	American larch	75'	Brown	May	F/P	N
<i>Lindera benzoin</i>	Spicebush	15'	Yellow	Apr-May	P/S	N
<i>Liriodendron tulipifera</i>	Tulip tree	110'	Green	May-Jun	F/P	N
<i>Morus rubra</i>	Red mulberry	50'	Green	May-Jun	F/P/S	N
<i>Nyssa sylvatica</i>	Black gum	100'	Green	May-Jul	F/P/S	Y
<i>Physocarpus opulifolius</i>	Ninebark	10'	White	May-Jun	F/P	N
<i>Picea mariana</i>	Black spruce	60'	Brown	May-Jun	F/P/S	N
<i>Platanus occidentalis</i>	Sycamore	100'	Green	May	F/P	N
<i>Quercus bicolor</i>	Swamp white oak	70'	Green/ yellow	May	F/P/S	N
<i>Quercus macrocarpa</i>	Bur oak	85'	Yellow	May-Jun	F/P/S	N
<i>Quercus palustris</i>	Pin oak	90'	Green/ yellow	Apr-May	F/P/S	Y
<i>Ribes americanum</i>	Wild black currant	5'	Yellow	Apr-Jun	F/P/S	N
<i>Rosa carolina</i>	Pasture rose	3'	Pink	Jun-Sep	F/P	N
<i>Rosa palustris</i>	Swamp rose	2'-7'	Pink	Jun-Aug	F/P/S	N
<i>Thuja occidentalis</i>	White cedar	50'	Brown	Apr-May	F/P/S	N
<i>Tilia americana</i>	Basswood	100'	White	Jun-Jul	F/P/S	N
<i>Tsuga canadensis</i>	Hemlock	100'	Brown	Apr-May	F/P/S	N
<i>Ulmus americana</i>	American elm	100'	Brown	Mar-Apr	F/P/S	N
<i>Ulmus rubra</i>	Slippery elm	80'	Green	Mar-Apr	F/P/S	N
<i>Viburnum dentatum</i>	Arrowwood	10'	White	May-Jun	F/P/S	N
<i>Viburnum lentago</i>	Nannyberry	20'	White	Apr-Jun	P/S	Y
<i>Viburnum prunifolium</i>	Black haw	10'	White	Apr-May	F/P	N
<i>Viburnum trilobum</i>	Cranberry Viburnum	10'	White	Apr-May	F/P/S	N
Grasses/Sedges/Rushes:						
<i>Andropogon gerardii</i>	Big bluestem	4'-8'	Purple	Jul-Sep	F	N
<i>Calamagrostis canadensis</i>	Blue joint grass	2'-4'	Brown	June	F/P	N
<i>Carex comosa</i>	Bristly sedge	2'-3'	Green	May-June	F/P	N
<i>Carex crinita</i>	Fringed sedge	2'-5'	Green	May	F/P/S	N
<i>Carex hystericina</i>	Porcupine sedge	2'-3'	Green	May-June	F/P/S	N
<i>Carex lupulina</i>	Common hop sedge	2'-3'	Green/ Brown	May-June	F/P/S	N
<i>Carex muskingumensis</i>	Palm sedge	1'-2'	Brown	May-June	S	N
<i>Carex stipata</i>	Common fox sedge	1'-3'	Brown	Apr-May	F/P/S	N
<i>Carex stricta</i>	Tussock sedge	2'-3'	Brown	Apr-Jun	F/P	N
<i>Carex vulpinoidea</i>	Brown fox sedge	2'-3'	Brown	May-Jun	F/P	N
<i>Cinna arundinacea</i>	Common wood reed	3'-4'	Green	Aug-Sep	P/S	N
<i>Elymus canadensis</i>	Canada wild rye	3'-6'	Green	Jun-Sep	F/P	N

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
<i>Glyceria striata</i>	Fowl manna grass	1'-5'	Green	May-Jun	F/P/S	N
<i>Juncus tenuis</i>	Path rush	6"-2'	Brown	June	F/P/S	N
<i>Juncus torreyi</i>	Torrey's rush	1'-2'	Brown	Jun-Sep	F	Y
<i>Panicum virgatum</i>	Switch grass	3'-5'	Green/ Purple	Jun-Oct	F/P	Y
<i>Scirpus atrovirens</i>	Dark green rush	3'-5'	Brown	Jun-Aug	F	N
<i>Scirpus cyperinus</i>	Wool grass	3'-5'	Tan	Jun-Sep	F	Y
<i>Scirpus pendulus</i>	Red bulrush	2'-4'	Brown	May-Jun	F	N
<i>Spartina pectinata</i>	Prairie cordgrass	6'-7'	Green	Jul-Aug	F	Y
Forbs:						
<i>Anemone canadensis</i>	Canada anemone	1'-2'	White	May-Sep	F/P	N
<i>Angelica atropurpurea</i>	Great angelica	6'-9'	White	May-Jun	F/P	N
<i>Asclepias incarnata</i>	Swamp milkweed	3'-5'	Pink	Jun-Sep	F/P	N
<i>Aster novae-angliae</i>	New England aster	3'-6'	Violet	Jul-Oct	F/P	N
<i>Aster puniceus</i>	Swamp aster	3'-6'	Lav/ White	Aug-Oct	F	Y
<i>Aster umbellatus</i>	Flat-topped aster	1'-4'	White	Jul-Oct	F/P	N
<i>Cacalia atriplicifolia</i>	Pale Indian plantain	3'-8'	White	Jun-Oct	F/P/S	N
<i>Cassia hebecarpa</i>	Wild senna	3'-5'	Yellow	Jul-Aug	F/P	N
<i>Chelone glabra</i>	Turtlehead	2'-4'	Cream	Aug-Sep	F/P/S	N
<i>Coreopsis tripteris</i>	Tall coreopsis	4'-8'	Yellow	Aug-Sep	F/P	N
<i>Desmodium canadense</i>	Showy tick-trefoil	2'-5'	Purple	Jun-Sep	F/P	N
<i>Eryngium yuccifolium</i>	Rattlesnake master	3'-5'	White	Jul-Sep	F	N
<i>Eupatorium maculatum</i>	Spotted Joe-pye weed	4'-7'	Pink	Jun-Oct	F/P	N
<i>Eupatorium perfoliatum</i>	Boneset	3'-5'	White	Jul-Oct	F/P	Y
<i>Euthamia graminifolia</i>	Grass-leaved goldenrod	1'-4'	Yellow	Jul-Sep	F/P	N
<i>Gentiana andrewsii</i>	Bottle gentian	1'-3'	Blue	Aug-Oct	F/P	N
<i>Helenium autumnale</i>	Sneezeweed	3'-5'	Yellow	Jul-Nov	F/P	Y
<i>Helianthus giganteus</i>	Tall sunflower	5'-12'	Yellow	Jul-Sep	F/P	N
<i>Heliopsis helianthoides</i>	False sunflower	4'-6'	Yellow	Jun-Oct	F/P	N
<i>Iris virginica</i>	Blue flag iris	2'-3'	Purple	May-Jul	F/P/S	N
<i>Liatris spicata</i>	Marsh blazing star	3'-5'	Pink	Jul-Sep	F/P	N
<i>Lilium michiganense</i>	Michigan lily	3'-8'	Orange	Jul-Aug	P/S	N
<i>Lobelia cardinalis</i>	Cardinal flower	2'-5'	Red	Jul-Oct	F/P/S	N
<i>Lobelia siphilitica</i>	Great blue lobelia	1'-4'	Blue	Jul-Oct	F/P/S	N
<i>Lobelia spicata</i>	Pale spiked lobelia	1'-3'	Lavender	May-Aug	F/P	N
<i>Mimulus ringens</i>	Monkeyflower	2'-4'	Lavender	Jun-Sep	F/P	N
<i>Monarda fistulosa</i>	Wild bergamot	2'-5'	Lavender	Jul-Sep	F/P	N
<i>Physostegia virginiana</i>	Obedient plant	2'-5'	Pink	Aug-Oct	F	Y
<i>Polygonatum biflorum</i>	Solomon seal	1'-4'	Green/ White	May/Jul	P/S	N
<i>Pycnanthemum virginianum</i>	Mountain mint	1'-3'	White	Jun-Oct	F/P	N
<i>Rudbeckia laciniata</i>	Cutleaf coneflower	3'-10'	Yellow	Jul-Nov	F/P/S	N
<i>Rudbeckia triloba</i>	Three-lobed coneflower	2'-5'	Yellow	Aug-Oct	F/P	N
<i>Solidago caesia</i>	Bluestem goldenrod	1'-2'	Yellow	Sep-Oct	P/S	N
<i>Solidago flexicaulis</i>	Zigzag goldenrod	1'-3'	Yellow	Aug/Oct	P/S	N
<i>Solidago ohioensis</i>	Ohio goldenrod	2'-3'	Yellow	Jul-Oct	F/P	N
<i>Solidago patula</i>	Swamp goldenrod	3'-6'	Yellow	Aug-Oct	F/P/S	N
<i>Solidago riddellii</i>	Riddell's goldenrod	2'-5'	Yellow	Sep-Nov	F	N
<i>Spiraea alba</i>	Meadowsweet	3'-6'	White	June-Sep	F/P	Y
<i>Spiraea tomentosa</i>	Steeplebush	2'-5'	Pink	Jul-Sep	F/P	Y
<i>Thalictrum dasycarpum</i>	Purple meadow-rue	3'-6'	Cream	May-Jul	F/P	N
<i>Verbena hastata</i>	Blue vervain	3'-6'	Violet	Jun-Sep	F	N
<i>Vernonia missurica</i>	Missouri ironweed	3'-5'	Purple	Jul-Sep	F	N
<i>Veronicastrum virginicum</i>	Culver's root	3'-6'	White	Jun-Aug	F/P	N
<i>Zizia aurea</i>	Golden Alexanders	1'-3'	Yellow	Apr-Jun	F/P/S	Y

Representative Zone D Species



Big Bluestem



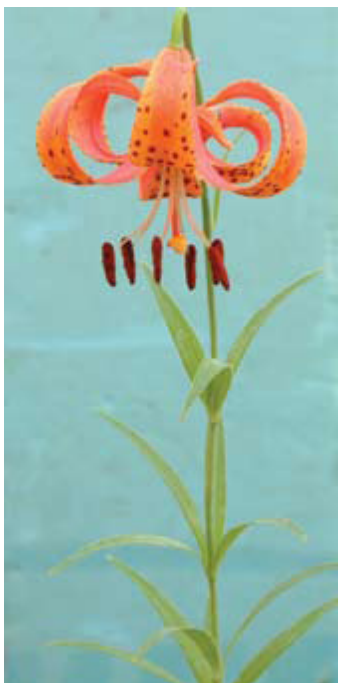
Marsh Blazing Star



Wild Columbine



Great Blue Lobelia



Michigan Lily



Virginia Mountain Mint



Meadowsweet



Blue Vervain

Source: JFNew

Zone E

Planting Zone = Four-to-18 inches above water level

These plants tolerate fluctuating water levels within this range. They will also tolerate short periods of inundation, not to exceed 48 hours in most situations, making them appropriate for BMP settings.

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Woody Species:						
<i>Acer rubrum</i>	Red maple	90'	Green/red	Mar-May	F/P/S	N
<i>Acer saccharum</i>	Sugar maple	100'	Green	Apr-May	F/P/S	N
<i>Acer saccharinum</i>	Silver Maple	100'	Yellow	Mar-Apr	F/P	N
<i>Amelanchier arborea</i>	Downy serviceberry	40'	White	April	F/P/S	N
<i>Aronia prunifolia</i>	Purple chokeberry	10'	White	Apr-Jul	F/P	N
<i>Betula papyrifera</i>	Paper birch	70'	Brown	Apr-May	F/P	N
<i>Carya ovata</i>	Shagbark hickory	80'	Green	May-Jun	F/P/S	N
<i>Ceanothus americanus</i>	New Jersey tea	1'-3'	White	Jun-Oct	F/P	N
<i>Celtis occidentalis</i>	Hackberry	60'	Green	May	F/P/S	N
<i>Cercis canadensis</i>	Redbud	25'	Red	Apr-May	F/P/S	N
<i>Cornus amomum</i>	Silky dogwood	10'	White	May-Jul	F/P	N
<i>Cornus florida</i>	Flowering dogwood	30'	White	May-Jun	F/P/S	N
<i>Cornus sericea</i>	Red-osier dogwood	10'	White	May-Sep	F/P	N
<i>Corylus americana</i>	American hazelnut	10'	Yellow	Apr-May	F/P	N
<i>Gymnocladus dioica</i>	Kentucky coffee tree	85'	White	Jun	F/P	N
<i>Juglans nigra</i>	Black walnut	90'	Green	May	F/P	N
<i>Juniperus virginiana</i>	Red-cedar	50'	Brown	Apr-May	F/P	N
<i>Larix laricina</i>	American larch	75'	Brown	May	F/P	N
<i>Lindera benzoin</i>	Spicebush	15'	Yellow	Apr-May	P/S	N
<i>Liriodendron tulipifera</i>	Tulip tree	110'	Green	May-Jun	F/P	N
<i>Morus rubra</i>	Red mulberry	50'	Green	May-Jun	F/P/S	N
<i>Nyssa sylvatica</i>	Black gum	100'	Green	May-Jul	F/P/S	Y
<i>Physocarpus opulifolius</i>	Ninebark	10'	White	May-Jun	F/P	N
<i>Picea mariana</i>	Black spruce	60'	Brown	May-Jun	F/P/S	N
<i>Pinus banksiana</i>	Jack pine	60'	Brown	May-Jun	F/P	N
<i>Pinus resinosa</i>	Red pine	100'	Brown	Apr-May	F/P	N
<i>Pinus strobus</i>	White pine	100'	Brown	Jun	F/P/S	N
<i>Platanus occidentalis</i>	Sycamore	100'	Green	May	F/P	N
<i>Prunus americana</i>	American plum	30'	Red	Apr-May	F/P	N
<i>Prunus virginiana</i>	Choke cherry	30'	White	May-Jun	F/P/S	N
<i>Quercus bicolor</i>	Swamp white oak	70'	Green/yellow	May	F/P/S	N
<i>Quercus macrocarpa</i>	Bur oak	85'	Yellow	May-Jun	F/P/S	N
<i>Quercus palustris</i>	Pin oak	90'	Green/yellow	Apr-May	F/P/S	Y
<i>Quercus rubra</i>	Red Oak	90'	Green	May-Jun	F/P/S	N
<i>Ribes americanum</i>	Wild black currant	5'	Yellow	Apr-Jun	F/P/S	N
<i>Rosa carolina</i>	Pasture rose	3'	Pink	Jun-Sep	F/P	N
<i>Tilia americana</i>	Basswood	100'	White	Jun-Jul	F/P/S	N
<i>Thuja occidentalis</i>	White cedar	50'	Brown	Apr-May	F/P/S	N
<i>Tsuga canadensis</i>	Hemlock	100'	Brown	Apr-May	F/P/S	N
<i>Ulmus americana</i>	American elm	100'	Brown	Mar-Apr	F/P/S	N
<i>Ulmus rubra</i>	Slippery elm	80'	Green	Mar-Apr	F/P/S	N
<i>Viburnum acerifolium</i>	Maple-leaved Viburnum	7'	White	May-Aug	F/P	N
<i>Viburnum dentatum</i>	Arrowwood	10'	White	May-Jun	F/P/S	N
<i>Viburnum prunifolium</i>	Black haw	10'	White	Apr-May	F/P	N
Grasses/Sedges/Rushes:						
<i>Andropogon gerardii</i>	Big bluestem	4'-8'	Purple	Jul-Sep	F	N
<i>Carex bicknellii</i>	Copper-shouldered oval sedge	1'-2'	Brown	May-Jun	F	N
<i>Carex mühlenbergii</i>	Sand bracted sedge	1'-3'	Brown	May-Jun	F/P/S	N
<i>Elymus canadensis</i>	Canada wild rye	3'-6'	Green	Jun-Sep	F/P	N

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
<i>Elymus hystrix</i>	Bottlebrush Grass	3'-5'	Green	Jun-Jul	P/S	N
<i>Elymus virginicus</i>	Virginia wild rye	2'-4'	Green	Jun	F/P/S	N
<i>Eragrostis spectabilis</i>	Purple love grass	1'-2'	Purple	Aug-Oct	F	N
<i>Juncus tenuis</i>	Path rush	6"-2'	Brown	June	F/P/S	N
<i>Panicum virgatum</i>	Switch grass	3'-6'	Green/ Purple	Jun-Oct	F/P	Y
<i>Schizachyrium scoparium</i>	Little bluestem	2'-4'	Brown	Aug-Sep	F/P	Y
<i>Sorghastrum nutans</i>	Indian grass	4'-9'	Green	Aug-Sep	F	N
<i>Spartina pectinata</i>	Prairie cordgrass	6'-7'	Green	Jul-Aug	F	Y
<i>Stipa spartea</i>	Porcupine grass	2'-4'	Green	Aug-Sep	F	Y
Forbs:						
<i>Allium cernuum</i>	Nodding wild onion	1'-2'	Lavender	Jun-Oct	F/P	N
<i>Aquilegia canadensis</i>	Wild columbine	1'-3'	Red/ Yellow	Apr-Jun	F/P/S	Y
<i>Asclepias syriaca</i>	Common milkweed	2'-4'	Pink	Jun-Aug	F/P	N
<i>Asclepias tuberosa</i>	Butterflyweed	1'-3'	Orange	Jun-Sep	F/P	Y
<i>Asclepias verticillata</i>	Whorled milkweed	1'-2'	White	Jun-Sep	F/P	N
<i>Aster cordifolius</i>	Heart-leaved aster	2'-4'	Blue/ White	Sep-Oct	P/S	N
<i>Aster laevis</i>	Smooth aster	3'-5'	Blue	Aug-Oct	F	Y
<i>Aster lateriflorus</i>	Calico aster	1'-3'	White	Jul-Oct	F/P/S	N
<i>Aster macrophyllus</i>	Big-leaved aster	6"-2'	Lav/ White	Jul-Oct	P/S	N
<i>Aster novae-angliae</i>	New England aster	3'-6'	Violet	Jul-Oct	F/P	N
<i>Aster oolentangiensis</i>	Sky-blue aster	1'-4'	Blue	Jul-Nov	F/P	Y
<i>Aster shortii</i>	Short's aster	1'-4'	Blue	Aug-Oct	P/S	N
<i>Cacalia atriplicifolia</i>	Pale Indian plantain	3'-8'	White	Jun-Oct	F/P/S	N
<i>Campanula americana</i>	Tall bellflower	2'-6'	Blue	Jul-Nov	P/S	N
<i>Cassia hebecarpa</i>	Wild senna	3'-5'	Yellow	Jul-Aug	F/P	N
<i>Clematis virginiana</i>	Virgin's bower	9' long	White	Jul-Aug	F/P	N
<i>Coreopsis tripteris</i>	Tall coreopsis	4'-8'	Yellow	Aug-Sep	F/P	N
<i>Desmodium canadense</i>	Showy tick-trefoil	2'-5'	Purple	Jun-Sep	F/P	N
<i>Echinacea pallida</i>	Purple coneflower	2'-5'	Lavender	May-Aug	F	N
<i>Eryngium yuccifolium</i>	Rattlesnake master	3'-5'	White	Jul-Sep	F	N
<i>Eupatorium purpureum</i>	Purple Joe-pye weed	3'-6'	Pink	Jul-Sep	P	N
<i>Euphorbia corollata</i>	Flowering spurge	2'-4'	White	May-Oct	F/P	N
<i>Geranium maculatum</i>	Wild geranium	1'-2'	Pink	Apr-Jul	F/P/S	N
<i>Helianthus divaricatus</i>	Woodland sunflower	2'-6'	Yellow	Jun-Sep	P/S	N
<i>Helianthus giganteus</i>	Tall sunflower	5'-12'	Yellow	Jul-Sep	F/P	N
<i>Helianthus pauciflorus</i>	Prairie sunflower	3'-5'	Yellow	Jul-Oct	F	N
<i>Heliopsis helianthoides</i>	False sunflower	4'-6'	Yellow	Jun-Oct	F/P	N
<i>Lespedeza capitata</i>	Round-headed bush clover	2'-4'	Green	Jul-Sep	F/P	N
<i>Liatris aspera</i>	Rough blazing star	2'-3'	Violet	Jul-Nov	F/P	Y
<i>Liatris spicata</i>	Marsh blazing star	3'-5'	Pink	Jul-Sep	F/P/S	N
<i>Liatris scariosa</i>	Savanna blazing star	3'-5'	Violet	Aug-Oct	F/P	N
<i>Monarda fistulosa</i>	Wild bergamot	2'-5'	Lavender	Jul-Sep	F/P	N
<i>Penstemon digitalis</i>	Foxglove beardtongue	2'-4'	White	May-Jul	F/P	N
<i>Penstemon hirsutus</i>	Hairy beardtongue	1'-2'	Purple	May-Jul	F/P	N
<i>Phlox divaricata</i>	Wild blue phlox	1'-2'	Blue	Apr-Jun	P/S	N
<i>Phlox pilosa</i>	Sand prairie phlox	1'-2'	Pink	May-Aug	F/P	N
<i>Physostegia virginiana</i>	Obedient plant	2'-5'	Pink	Aug-Oct	F	Y
<i>Polygonatum biflorum</i>	Solomon seal	1'-4'	Green/ White	May/Jul	P/S	N
<i>Polygonatum pubescens</i>	Downy Solomon seal	1'-3'	White	May-Jul	P/S	N
<i>Pycnanthemum virginianum</i>	Mountain mint	1'-3'	White	Jun-Oct	F/P	N
<i>Ratibida pinnata</i>	Yellow coneflower	3'-6'	Yellow	Jul-Oct	F	N
<i>Rudbeckia hirta</i>	Black-eyed Susan	1'-3'	Yellow	May-Oct	F/P	Y
<i>Rudbeckia triloba</i>	Three-lobed coneflower	2'-5'	Yellow	Aug-Oct	F/P	N
<i>Silphium terebinthinaceum</i>	Prairie-dock	3'-8'	Yellow	Jun-Sep	F	N
<i>Smilacina racemosa</i>	Feathery false Solomon's seal	1'-3'	White	Apr-Jun	P/S	N
<i>Smilacina stellata</i>	Starry false Solomon's seal	1'-2'	White	Apr-Jun	F/P	N
<i>Solidago caesia</i>	Bluestem goldenrod	1'-2'	Yellow	Sep-Oct	P/S	N
<i>Solidago flexicaulis</i>	Zigzag goldenrod	1'-3'	Yellow	Aug/Oct	P/S	N

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
<i>Solidago juncea</i>	Early goldenrod	2'-4'	Yellow	Jul-Sep	F/P	N
<i>Solidago speciosa</i>	Showy goldenrod	1'-3'	Yellow	Jul-Oct	F/P	Y
<i>Thalictrum dioicum</i>	Early meadow-rue	1'-3'	Green	Apr-May	P/S	N
<i>Tradescantia ohimensis</i>	Spiderwort	2'-4'	Blue	May-Oct	F/P	N
<i>Vernonia missurica</i>	Missouri ironweed	3'-5'	Purple	Jul-Sep	F	N

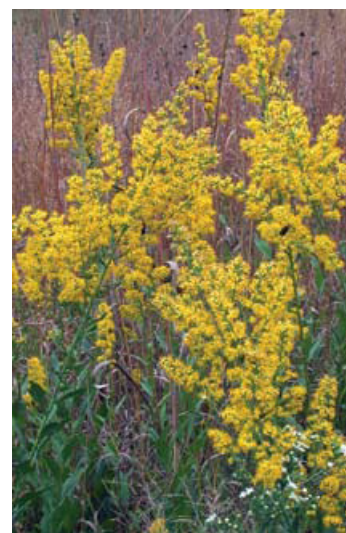
Representative Zone E Species



New England Aster



Wild Bergamot



Showy Goldenrod



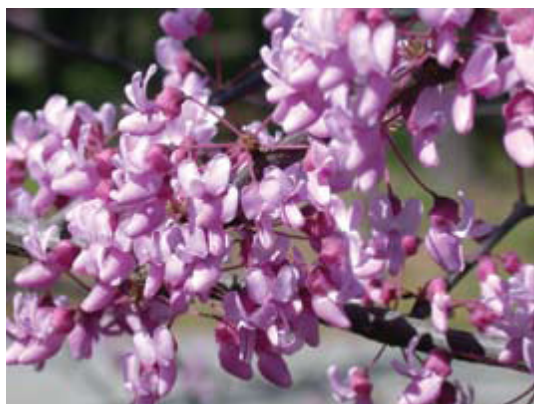
Tall Bellflower



Wild Geranium



Tall Coreopsis



Redbud



Indian Grass

Source: JFNew

Zone F

Planting Zone = 18 inches or more above water level

These plants tolerate fluctuating water levels within this range, although they are generally less tolerant than most wetter species. They may tolerate short periods of inundation, not to exceed 48 hours in most situations, making them appropriate for upland BMP settings.

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Woody Species:						
<i>Acer rubrum</i>	Red maple	90'	Green/red	Mar-May	F/P/S	N
<i>Acer saccharum</i>	Sugar maple	100'	Green	Apr-May	F/P/S	N
<i>Acer saccharinum</i>	Silver Maple	100'	Yellow	Mar-Apr	F/P	N
<i>Betula papyrifera</i>	Paper birch	70'	Brown	Apr-May	F/P	N
<i>Carya ovata</i>	Shagbark hickory	80'	Green	May-Jun	F/P/S	N
<i>Ceanothus americanus</i>	New Jersey tea	1'-3'	White	Jun-Oct	F/P	N
<i>Celtis occidentalis</i>	Hackberry	60'	Green	May	F/P/S	N
<i>Cercis canadensis</i>	Redbud	25'	Red	Apr-May	F/P/S	N
<i>Cornus florida</i>	Flowering dogwood	30'	White	May-Jun	F/P/S	N
<i>Corylus americana</i>	American hazelnut	10'	Yellow	Apr-May	F/P	N
<i>Gymnocladus dioicus</i>	Kentucky coffee tree	85'	White	Jun	F/P	N
<i>Hamamelis virginiana</i>	Witch hazel	30'	Yellow	Oct-Nov	F/P/S	N
<i>Juglans nigra</i>	Black walnut	90'	Green	May	F/P	N
<i>Juniperus virginiana</i>	Red-cedar	50'	Brown	Apr-May	F/P	N
<i>Liriodendron tulipifera</i>	Tulip tree	110'	Green	May-Jun	F/P	N
<i>Morus rubra</i>	Red mulberry	50'	Green	May-Jun	F/P/S	N
<i>Nyssa sylvatica</i>	Black gum	100'	Green	May-Jul	F/P/S	Y
<i>Pinus banksiana</i>	Jack pine	60'	Brown	May-Jun	F/P	N
<i>Pinus resinosa</i>	Red pine	100'	Brown	Apr-May	F/P	N
<i>Pinus strobus</i>	White pine	100'	Brown	Jun	F/P/S	N
<i>Prunus americana</i>	American plum	30'	Red	Apr-May	F/P	N
<i>Prunus virginiana</i>	Choke cherry	30'	White	May-Jun	F/P/S	N
<i>Quercus macrocarpa</i>	Bur oak	85'	Yellow	May-Jun	F/P/S	N
<i>Quercus palustris</i>	Pin oak	90'	Green/yellow	Apr-May	F/P/S	Y
<i>Quercus rubra</i>	Red Oak	90'	Green	May-Jun	F/P/S	N
<i>Rosa carolina</i>	Pasture rose	3'	Pink	Jun-Sep	F/P	N
<i>Tilia americana</i>	Basswood	100'	Yellow	Jun-Jul	F/P/S	N
<i>Tsuga canadensis</i>	Hemlock	100'	Brown	Apr-May	F/P/S	N
<i>Viburnum acerifolium</i>	Maple-leaved Viburnum	7'	White	May-Aug	F/P	N
<i>Viburnum dentatum</i>	Arrowwood	10'	White	May-Jun	F/P/S	N
Grasses/Sedges/Rushes:						
<i>Andropogon gerardii</i>	Big bluestem	4'-8'	Purple	Jul-Sep	F	N
<i>Carex bicknellii</i>	Copper-shouldered oval sedge	1'-2'	Brown	May-Jun	F	N
<i>Carex muhlenbergii</i>	Sand bracted sedge	1'-3'	Brown	May-Jun	F/P/S	N
<i>Elymus canadensis</i>	Canada wild rye	3'-6'	Green	Jun-Sep	F/P	N
<i>Elymus hystrix</i>	Bottlebrush Grass	3'-5'	Green	Jun-Jul	P/S	N
<i>Eragrostis spectabilis</i>	Purple love grass	1'-2'	Purple	Aug-Oct	F	N
<i>Koeleria macrantha</i>	June grass	1'-2'	White	May-Jul	F/P	N
<i>Panicum virgatum</i>	Switch grass	3'-6'	Green/Purple	Jun-Oct	F/P	Y
<i>Schizachyrium scoparium</i>	Little bluestem	2'-4'	Brown	Aug-Sep	F/P	Y
<i>Sorghastrum nutans</i>	Indian Grass	4'-9'	Green	Aug-Sep	F	N
<i>Spartina pectinata</i>	Prairie Cordgrass	6'-7'	Green	Jul-Aug	F	Y

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
<i>Stipa spartea</i>	Porcupine grass	2'-4'	Green	Aug-Sep	F	Y
Forbs:						
<i>Allium cernuum</i>	Nodding wild onion	1'-2'	Lavender	Jun-Oct	F/P	N
<i>Asclepias syriaca</i>	Common milkweed	2'-4'	Pink	Jun-Aug	F/P	N
<i>Asclepias tuberosa</i>	Butterflyweed	1'-3'	Orange	Jun-Sep	F/P	Y
<i>Asclepias verticillata</i>	Whorled milkweed	1'-2'	White	Jun-Sep	F/P	N
<i>Aster cordifolius</i>	Heart-leaved aster	2'-4'	Blue/White	Sep-Oct	P/S	N
<i>Aster laevis</i>	Smooth aster	3'-5'	Blue	Aug-Oct	F	Y
<i>Aster oolentangiensis</i>	Sky-blue aster	1'-4'	Blue	Jul-Nov	F/P	Y
<i>Aster shortii</i>	Short's aster	1'-4'	Blue	Aug-Oct	P/S	N
<i>Cacalia atriplicifolia</i>	Pale Indian plantain	3'-8'	White	Jun-Oct	F/P/S	N
<i>Campanula americana</i>	Tall bellflower	2'-6'	Blue	Jul-Nov	P/S	N
<i>Clematis virginiana</i>	Virgin's bower	9' long	White	Jul-Aug	F/P	N
<i>Coreopsis lanceolata</i>	Sand coreopsis	1'-2'	Yellow	May-Aug	F/P	N
<i>Coreopsis palmata</i>	Prairie coreopsis	1'-2'	Yellow	Jun-Aug	F/P	N
<i>Coreopsis tripteris</i>	Tall coreopsis	4'-8'	Yellow	Aug-Sep	F/P	N
<i>Echinacea pallida</i>	Purple coneflower	2'-5'	Lavender	May-Aug	F	N
<i>Eryngium yuccifolium</i>	Rattlesnake master	3'-5'	White	Jul-Sep	F	N
<i>Eupatorium purpureum</i>	Purple Joe-pye weed	3'-6'	Pink	Jul-Sep	P	N
<i>Euphorbia corollata</i>	Flowering spurge	2'-4'	White	May-Oct	F/P	N
<i>Geranium maculatum</i>	Wild geranium	1'-2'	Pink	Apr-Jul	F/P/S	N
<i>Helianthus divaricatus</i>	Woodland sunflower	2'-6'	Yellow	Jun-Sep	P/S	N
<i>Helianthus occidentalis</i>	Western sunflower	2'-4'	Yellow	Aug-Sep	F/P	N
<i>Helianthus pauciflorus</i>	Prairie sunflower	3'-5'	Yellow	Jul-Oct	F	N
<i>Heliopsis helianthoides</i>	False sunflower	4'-6'	Yellow	Jun-Oct	F/P	N
<i>Lespedeza capitata</i>	Round-headed bush clover	2'-4'	Green	Jul-Sep	F/P	N
<i>Liatris aspera</i>	Rough blazing star	2'-3'	Violet	Jul-Nov	F/P	Y
<i>Liatris cylindracea</i>	Cylindrical blazing star	1'-2'	Violet	Jul-Oct	F/P	N
<i>Liatris scariosa</i>	Savanna blazing star	3'-5'	Violet	Aug-Oct	F/P	N
<i>Lupinus perennis</i>	Wild lupine	1'-2'	Purple	Apr-Jun	F/P	N
<i>Monarda fistulosa</i>	Wild bergamot	2'-5'	Lavender	Jul-Sep	F/P	N
<i>Penstemon digitalis</i>	Foxglove beardtongue	2'-4'	White	May-Jul	F/P	N
<i>Phlox pilosa</i>	Sand prairie phlox	1'-2'	Pink	May-Aug	F/P	N
<i>Polygonatum biflorum</i>	Solomon seal	1'-4'	Green/ White	May/Jul	P/S	N
<i>Polygonatum pubescens</i>	Downy Solomon seal	1'-3'	White	May-Jul	P/S	N
<i>Ratibida pinnata</i>	Yellow coneflower	3'-6'	Yellow	Jul-Oct	F	N
<i>Rudbeckia hirta</i>	Black-eyed Susan	1'-3'	Yellow	May-Oct	F/P	Y
<i>Silphium terebinthinaceum</i>	Prairie-dock	3'-8'	Yellow	Jun-Sep	F	N
<i>Smilacina racemosa</i>	Feathery false Solomon's seal	1'-3'	White	Apr-Jun	P/S	N
<i>Smilacina stellata</i>	Starry false Solomon's seal	1'-2'	White	Apr-Jun	F/P	N
<i>Solidago caesia</i>	Bluestem goldenrod	1'-2'	Yellow	Sep-Oct	P/S	N
<i>Solidago juncea</i>	Early goldenrod	2'-4'	Yellow	Jul-Sep	F/P	N
<i>Solidago speciosa</i>	Showy goldenrod	1'-3'	Yellow	Jul-Oct	F/P	Y
<i>Tradescantia ohiensis</i>	Spiderwort	2'-4'	Blue	May-Oct	F/P	N
<i>Veronicastrum virginicum</i>	Culver's root	3'-6'	White	June-Aug	F/P	N

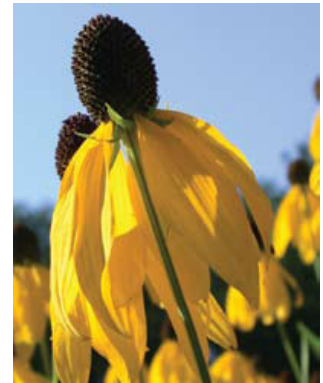
Representative Zone F Species



Spiderwort



Butterfly Weed



Yellow Coneflower



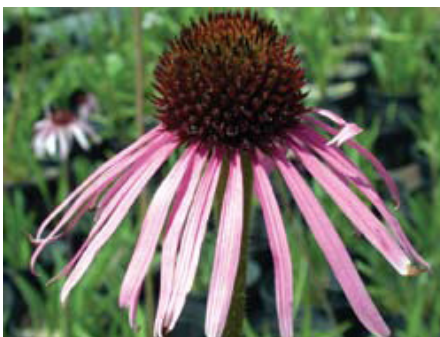
Little Bluestem



Foxglove Beardtongue



Wild Lupine



Pale Purple Coneflower



Rattlesnake Master



Sand Coreopsis

Source: JFNew

Zone G

Planter Box Plantings

Although this manual typically recommends using native plants wherever possible, certain situations call for nonnative plants due to particular site conditions. Because planter boxes traditionally have a short soil column and are exposed to drier conditions, non-native plants should be considered as long as they are considered non-invasive. Therefore, the list below contains both native and non-native species. Many planter boxes have traditionally used annual flowers. However, we recommend using perennial plants for establishing root systems and lowering maintenance in the long term. Many more species are available for planter boxes than are listed.

Botanical Name	Common Name	Height	Color	Bloom Time	Sun
<i>Ajuga reptans</i> 'Bronze Beauty'	Bronze Beauty Ajuga	6"	Blue	May-Jun	F
<i>Allium maximowiczii</i> 'Alba'	White Flowered Ornamental Chive	6"-1'	White	May-Jun	F
<i>Allium schoenoprasum</i> 'Glaucum'	Blue Flowered Ornamental Chive	6"-1'	Blue	Jun-Jul	F
<i>Allium senescens montanum</i>	Mountain Garlic	6"-1'	Pink/Purple	Jun-Aug	F
<i>Allium senescens glaucum</i>	Curly Onion	6"-1'	Pink	Jul-Sep	F
<i>Allium tanguticum</i> 'Summer Beauty'	Summer Beauty Ornamental Chive	6"-1'	Pink	Jul-Aug	F
<i>Aster</i> 'Wood's Light Blue'	Wood's Light Blue Aster	1'-3'	Blue	Aug-Sep	F
<i>Athyrium filix-femina</i>	Lady Fern	1'-3'	Green	NA	F/P/S
<i>Blechnum spicant</i>	Deer Fern	1'-2'	Green	NA	F/P/S
<i>Dryopteris erythrosora</i>	Autumn Fern	1'-2'	Green	NA	F/P/S
<i>Euphorbia myrsinites</i>	Myrtle Spurge	6"-1'	Yellow	May-Jun	F
<i>Dryopteris intermedia</i>	Fancy Fern	1'-3'	Green	NA	F/P/S
<i>Dryopteris marginalis</i>	Leatherleaf Fern	1'-2'	Green	NA	F/P/S
<i>Geranium x</i> 'Rozanne'	Rozanne Geranium	1'-2'	Violet	Jun-Sep	F/P
<i>Hemerocallis</i> 'Barbara Mitchell'	Barbara Mitchell Daylily	2'-3'	Pink	Jun-Aug	F/P
<i>Hemerocallis</i> 'Bill Norris'	Bill Norris Daylily	2'-3'	Yellow	Jun-Aug	F/P
<i>Hemerocallis</i> 'Chicago Apache'	Chicago Apache Daylily	2'-3'	Red	Jul-Sep	F/P
<i>Hosta</i> 'Francee'	Francee Hosta	1'-2'	Lavender	Jul-Aug	F/P/S
<i>Hosta</i> 'Guacamole'	Guacamole Hosta	1'-2'	Pink	Aug-Sep	F/P/S
<i>Hosta</i> 'Summer Fragrance'	Summer Fragrance Hosta	1'-2'	Lavender	Aug-Sep	F/P/S
<i>Hosta sieboldiana</i> 'Elegans'	Elegans Hosta	1'-2'	White	Jul-Aug	F/P/S
<i>Sedum</i> 'Autumn Charm'	Autumn Charm Sedum	6"-1'	Pink	Jun-Jul	F
<i>Sedum</i> 'Joyce Henderson'	Joyce Henderson Sedum	6"-1'	Pink	May-Jun	F
<i>Sedum</i> 'Mini Me'	Mini Me Sedum	6"-1'	Green	NA	F
<i>Sedum acre</i> 'Oktoberfest'	Oktoberfest Sedum	6"-1'	Yellow	Jul-Sep	F
<i>Sedum album</i> 'Athoum'	Jelly Bean Sedum	6"-1'	Pink	Aug-Sep	F
<i>Sedum album</i> 'Coral Carpet'	Coral Carpet Sedum	6"-1'	White	Jun-Aug	F
<i>Sedum album</i> 'Faro Island'	Faro Island Sedum	6"-1'	White	Jun-Aug	F
<i>Sedum album</i> 'Green Ice'	Green Ice Sedum	6"-1'	White	Jun-Jul	F
<i>Sedum album</i> 'Murale'	Wall Sedum	6"-1'	White	Jun-Jul	F
<i>Sedum caudicicola</i> 'Sunset Cloud'	Sunset Cloud Sedum	6"-1'	Pink	Jul-Aug	F
<i>Sedum divergens</i>	Cascade Sedum	6"-1'	Yellow	Jun-Jul	F
<i>Sedum ellacombianum</i>	Ellacombe's Sedum	6"-1'	Yellow	May-Jun	F
<i>Sedum ellacombianum</i> 'Variegatum'	Variegated Ellacombe's Sedum	6"-1'	Yellow	May-Jun	F
<i>Sedum floriferum</i> 'Weihenstephaner Gold'	Weihenstephaner Gold Sedum	6"-1'	Yellow	Jun-Jul	F
<i>Sedum grisebachii</i>	Griseback Sedum	6"-1'	Yellow	Jul-Aug	F
<i>Sedum hybridum</i> 'Tekaridake'	Tekaridake Kamtschatka Sedum	6"-1'	Yellow	Jun	F
<i>Sedum kamtschaticum</i> 'Variegatum'	Variegated Kamtschatka Sedum	6"-1'	Orange	Jul-Aug	F
<i>Sedum middendorffianum</i> var. <i>diffusum</i>	Diffuse Middendorf's Sedum	6"-1'	Yellow	May-Jun	F

Representative Zone G Species



Guacamole Hosta



Mountain Garlic



Wall Sedum



Lady Fern

Source: JFNew

Zone H

Vegetated Roof Plantings

Research to-date shows that native plants do not typically thrive in vegetated roofs. Therefore, the list below reflects species that are known to thrive in green roof situations. All species listed below will generally grow to a height of 6-to-18 inches.

Botanical Name	Common Name	Height	Color	Bloom Time	Sun
<i>Ajuga reptans</i> 'Bronze Beauty'	Bronze Beauty Ajuga	6"	Blue	May-Jun	F
<i>Allium maximowiczii</i> 'Alba'	White Flowered Ornamental Chive	6"-1'	White	May-Jun	F
<i>Allium schoenoprasum</i> 'Glaucum'	Blue Flowered Ornamental Chive	6"-1'	Blue	Jun-Jul	F
<i>Allium senescens montanum</i>	Mountain Garlic	6"-1'	Pink/Purple	Jun-Aug	F
<i>Allium senescens glaucum</i>	Curly Onion	6"-1'	Pink	Jul-Sep	F
<i>Allium tanguticum</i> 'Summer Beauty'	Summer Beauty Ornamental Chive	6"-1'	Pink	Jul-Aug	F
<i>Aster</i> 'Wood's Light Blue'	Wood's Light Blue Aster	1'-3'	Blue	Aug-Sep	F
<i>Athyrium filix-femina</i>	Lady Fern	1'-3'	Green	NA	F/P/S
<i>Blechnum spicant</i>	Deer Fern	1'-2'	Green	NA	F/P/S
<i>Dryopteris erythrosora</i>	Autumn Fern	1'-2'	Green	NA	F/P/S
<i>Euphorbia myrsinites</i>	Mytle Spurge	6"-1'	Yellow	May-Jun	F
<i>Dryopteris intermedia</i>	Fancy Fern	1'-3'	Green	NA	F/P/S
<i>Dryopteris marginalis</i>	Leatherleaf Fern	1'-2'	Green	NA	F/P/S
<i>Geranium x</i> 'Rozanne'	Rozanne Geranium	1'-2'	Violet	Jun-Sep	F/P
<i>Hemerocallis</i> 'Barbara Mitchell'	Barbara Mitchell Daylily	2'-3'	Pink	Jun-Aug	F/P
<i>Hemerocallis</i> 'Bill Norris'	Bill Norris Daylily	2'-3'	Yellow	Jun-Aug	F/P
<i>Hemerocallis</i> 'Chicago Apache'	Chicago Apache Daylily	2'-3'	Red	Jul-Sep	F/P
<i>Hosta</i> 'Francee'	Francee Hosta	1'-2'	Lavender	Jul-Aug	F/P/S
<i>Hosta</i> 'Guacamole'	Guacamole Hosta	1'-2'	Pink	Aug-Sep	F/P/S
<i>Hosta</i> 'Summer Fragrance'	Summer Fragrance Hosta	1'-2'	Lavender	Aug-Sep	F/P/S
<i>Hosta sieboldiana</i> 'Elegans'	Elegans Hosta	1'-2'	White	Jul-Aug	F/P/S
<i>Sedum</i> 'Autumn Charm'	Autumn Charm Sedum	6"-1'	Pink	Jun-Jul	F
<i>Sedum</i> 'Joyce Henderson'	Joyce Henderson Sedum	6"-1'	Pink	May-Jun	F
<i>Sedum</i> 'Mini Me'	Mini Me Sedum	6"-1'	Green	NA	F
<i>Sedum acre</i> 'Oktoberfest'	Oktoberfest Sedum	6"-1'	Yellow	Jul-Sep	F
<i>Sedum album</i> 'Athoum'	Jelly Bean Sedum	6"-1'	Pink	Aug-Sep	F
<i>Sedum album</i> 'Coral Carpet'	Coral Carpet Sedum	6"-1'	White	Jun-Aug	F
<i>Sedum album</i> 'Faro Island'	Faro Island Sedum	6"-1'	White	Jun-Aug	F
<i>Sedum album</i> 'Green Ice'	Green Ice Sedum	6"-1'	White	Jun-Jul	F
<i>Sedum album</i> 'Murale'	Wall Sedum	6"-1'	White	Jun-Jul	F
<i>Sedum cauticola</i> 'Sunset Cloud'	Sunset Cloud Sedum	6"-1'	Pink	Jul-Aug	F
<i>Sedum divergens</i>	Cascade Sedum	6"-1'	Yellow	Jun-Jul	F
<i>Sedum ellacombianum</i>	Ellacombe's Sedum	6"-1'	Yellow	May-Jun	F
<i>Sedum ellacombianum</i> 'Variegatum'	Variegated Ellacombe's Sedum	6"-1'	Yellow	May-Jun	F
<i>Sedum floriferum</i> 'Weihenstephaner Gold'	Weihenstephaner Gold Sedum	6"-1'	Yellow	Jun-Jul	F
<i>Sedum grisbachii</i>	Griseback Sedum	6"-1'	Yellow	Jul-Aug	F
<i>Sedum hybridum</i> 'Tekaridake'	Tekaridake Kamtschatka Sedum	6"-1'	Yellow	Jun	F
<i>Sedum kamtschaticum</i> 'Variegatum'	Variegated Kamtschatka Sedum	6"-1'	Orange	Jul-Aug	F
<i>Sedum middendorffianum</i> var. <i>diffusum</i>	Diffuse Middendorf's Sedum	6"-1'	Yellow	May-Jun	F

Representative Zone H Species



Mountain Garlic



Cascade Sedum



Ellacombe's Sedum



Wall Sedum

Source: JFNew

Credits and Acknowledgments

This Appendix has been developed by Christopher B. Burke Engineering, LLC, and is primarily based upon similar segments contained in “Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers” published in 2009 by the Southeast Michigan Council of Governments (SEMCOG). A selection of material contained in the noted SEMCOG publication has been modified to reflect conditions in Indiana and used, with permission, for development of this Appendix. The valuable contribution of SEMCOG through sharing of this material for use in this Appendix is hereby acknowledged.

Recommended Materials

Appendix D3

Recommended Materials

Numerous BMPs in this manual have similar material needs. These BMPs are listed in the table below. Detailed information on each material requirement follows. In addition, Porous Pavement and Vegetated Roofs have significant material requirements that are listed according to their individual needs.

	Constructed Filters	Dry Well	Infiltration Trench	Planter Boxes	Porous Pavement	Subsurface Infiltration	Vegetated Filter Strip	Vegetated Swale
Check dams							X	X
Non-Woven Geotextile	X	X	X	X	X	X	X	
Pea Gravel							X	
Peat	X			X				
Pervious Berms							X	
Pipe – 8”	X	X	X	X	X	X	X	
Sand	X			X				X
Stone/Gravel	X			X				
Stone – 30%							X	
Stone – 40%			X		X			

Check dams (Vegetated Filter Strip, Vegetated Swale)

An earthen check dam shall be constructed of sand, gravel, and sandy loam to encourage grass cover. (Sand: ASTM C-33 fine aggregate concrete sand 0.02 in to 0.04 in, Gravel: AASHTO M-43 0.5 in to 1.0 in). A stone check dam shall be constructed of R-4 rip rap, or equivalent.

Non-Woven Geotextile (Constructed Filter, Dry Well, Infiltration Trench, Planter Boxes, Vegetated Filter Strip)

Should consist of needled nonwoven polypropylene fibers and meet the following properties:

- | | |
|---|-------------------------------------|
| a. Grab Tensile Strength (ASTM-D4632) | 120 lbs minimum |
| b. Mullen Burst Strength (ASTM-D3786) | 225 psi minimum |
| c. Flow Rate (ASTM-D4491) | 110 gal/min/ft ² minimum |
| d. UV Resistance after 500 hrs (ASTM-D4355) | 70% minimum |
| e. Puncture strength (ASTM D-4833-00) | 90 lbs minimum |
| f. Apparent opening size (ASTM D-4751-99A) | 60-70 US Sieve |

Heat-set or heat-calendared fabrics are not permitted. Acceptable types include Mirafi 140N, Amoco 4547, Geotex 451, or approved others.

Pea Gravel (Vegetated Filter Strip)

Clean bank-run gravel may also be used and should meet ASTM D 448 and be sized as per No.6 or 1/8” to 3/8”.

Peat (Constructed Filter, Planter Boxes)

Should have ash content <15%, pH range 3.3-5.2, loose bulk density range 0.12-0.14 g/cc.

Pervious Berms (Vegetated Filter Strip)

The berm shall have a height of 6-12 inches and be constructed of sand, gravel, and sandy loam to encourage grass cover. (Sand: ASTM C-33 fine aggregate concrete sand 0.02”-0.04”, Gravel: AASHTO M-43, ½” to 1”)

Pipe - (Dry Well, Porous Pavement, Subsurface Infiltration, Constructed Filter, Infiltration Trench, Planter Boxes, Vegetated Filter Strip)

Should be continuously perforated, double-wall, smooth interior (smooth bore), with a minimum inside diameter as required. High-density polyethylene (HDPE) pipe shall meet AASHTO M252, Type S or M294, Type S (12-gauge aluminum or pipe may also be used in seepage pits).

Sand (Constructed Filter, Planter Boxes, Vegetated Swale)

Should be ASTM-C-33 (or AASHTO M-6) size (0.02” – 0.04”), concrete sand, clean, medium to fine sand.

Soil Testing (all BMPs)

Should be completed in accordance to the Purdue University Cooperative Extension Service Department of Horticulture “Collecting Soil Samples for Testing” HO-71-W” <http://www.hort.purdue.edu/ext/HO-71.pdf>

Stone/Gravel (Constructed Filter, Planter Boxes):

Should be uniformly graded coarse aggregate, 1-inch to ½-inch with a wash loss of no more than 0.5%, AASHTO size number 5 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and have voids of 40% as measured by ASTM-C29.

Stone – 40% voids (Infiltration Trench, Porous Pavement, Subsurface Infiltration Bed,)

Infiltration trenches should have stone 2-inch to 1-inch uniformly graded coarse aggregate, with a wash loss of no more than 0.5%, AASHTO size number 3 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and shall have voids 40% as measured by ASTM-C29.

Porous Pavement

General

Choker base course aggregate for beds shall be 3/8 inch to 3/4 inch clean, uniformly-graded, coarse, crushed aggregate AASHTO size number 57 per Table 4, AASHTO Specifications, Part I, 19th Ed., 1998 (p. 47).

Porous Asphalt

Bituminous surface course for porous paving shall be 2.5 to 3 inches thick with a bituminous mix of 5.75% to 6.75% by total weight as determined by testing below. Use neat asphalt binder modified with an elastomeric polymer to produce a binder meeting the requirements of PG 76-22P as specified in AASHTO MP-1. The composite materials shall be thoroughly blended at the asphalt refinery or terminal prior to being loaded into the transport vehicle. The polymer modified asphalt binder shall be heat and storage stable.

Determination of optimal asphalt content should be determined according the following tests:

- Draindown Test (ASTM Method D6390)
- Moisture Susceptibility Test using the Modified Lottman Method (AASHTO T283) with the following:
 - Compact using 50 gyrations of Superpave gyratory compactor
 - Apply partial vacuum of 26 inches of Hg for 10 minutes to whatever saturation is achieved.
 - Keep specimens submerged in water during freeze cycle.
 - Required retained tensile strength (TSR) ≥ 80%

- Air Voids Test (AASHTO T269/ASTM D3203)

Hydrated lime, if required, shall meet the requirements of AASHTO M 303 Type 1 and shall be blended with the damp aggregate at a rate of 1.0% by weight of the total dry aggregate. The additive must be able to prevent the separation of the asphalt binder from the aggregate and achieve a required tensile strength ratio (TSR) of at least 80% on the asphalt mix.

Fibers, if used, shall consist of either cellulose fibers or mineral fibers which are to be treated with a cationic sizing agent to enhance dispersement of the fiber as well as increase cohesion of the fiber to the bitumen. Fiber is to be added at a dosage rate between 0.2% and 0.4% by weight of total mix.

- Mineral fibers shall be from virgin, basalt, diabase, or slag with a maximum average fiber length of 6.35 mm and a maximum average fiber thickness of 0.005 mm.
- Cellulose fiber – Fiber length shall be 6.4 mm (max), Ash Content 18% non-volatiles ($\pm 5\%$), pH 7.5 (± 1), Oil absorption (times fiber weight) 5.0 (± 1), Moisture Content 5.0 (max).

Porous Concrete

The use of Installers or Craftsmen who have been certified by the NRMCA's Pervious Concrete Contractor Certification Program is strongly recommended. Contractor shall furnish a proposed mix design with all applicable information to the Engineer prior to commencement of work. Critical mix characteristics typically include the following:

- Cement Content: 550 to 650 lb/yd³
- Fine aggregate, if used: maximum 3 cubic feet per cubic yard
- Admixtures: use in accordance with the manufacturer's instructions and recommendations
- An aggregate/cement (A/C) ratio: 4:1 to 4.5:1
- Water/cement (W/C) ratio: 0.27 to 0.34
- Curing: shall begin within 15 minutes after placement and continue for 7 days

The data shall include unit weights determined in accordance with ASTM C29 paragraph 11, jigging procedure.

Cement: Portland Cement Type II or V conforming to ASTM C150 or Portland Cement Type IP or IS conforming to ASTM C595. The total cementitious material shall be between 550 and 650 lb/yd³.

Aggregate: Use No 8 coarse aggregate (3/8 to No. 16) per ASTM C33 or No. 89 coarse aggregate (3/8 to No. 50) per ASTM D 448. If other gradation of aggregate is to be used, submit data on proposed material to owner for approval. The volume of aggregate per cubic yard shall be equal to 27 cubic feet when calculated as a function of the unit weight determined in accordance with ASTM C29 jigging procedure. Fine aggregate, if used, should not exceed 3 cubic feet and shall be included in the total aggregate volume.

Air Entraining Agent: Shall comply with ASTM C 260 and shall be used to improve workability and resistance to freeze/thaw cycles.

Admixtures: The following admixtures shall be used:

- Type D Water Reducing/Retarding – ASTM C 494.
- A hydration stabilizer that also meets the requirements of ASTM C 494 Type B Retarding or Type D Water Reducing/Retarding admixtures may be used. This stabilizer suspends cement hydration by forming a protective barrier around the cementitious particles, which delays the particles from achieving initial set.

Water: Potable shall be used and shall comply with ASTM C1602. Mix water shall be such that the cement paste displays a wet metallic sheen without causing the paste to flow from the aggregate. (Mix water yielding a cement paste with a dull-dry appearance has insufficient water for hydration).

- Insufficient water results in inconsistency in the mix and poor bond strength.
- High water content results in the paste sealing the void system primarily at the bottom and poor surface bond.

An aggregate/cement (A/C) ratio range of 4:1 to 4.5:1 and a water/cement (W/C) ratio range of 0.27 to 0.34 should produce pervious pavement of satisfactory properties in regard to permeability, load carrying capacity, and durability characteristics.

Vegetated roofs

Some key components and associated performance-related properties are as follows:

Root-barriers should be thermoplastic membranes with a thickness of at least 30 mils. Thermoplastic sheets can be bonded using hot-air fusion methods, rendering the seams safe from root penetration. Membranes that have been certified for use as root-barriers are recommended. At present only FLL offers a recognized test for root-barriers. Several FLL-certified materials are available in the United States. Interested American manufactures can submit products for testing to FLL-certified labs.

Granular drainage media should be a non-carbonate mineral aggregate conforming to the following specifications:

- | | |
|---|-------------|
| • Saturated Hydraulic Conductivity | ≥ 25 in/min |
| • Total Organic Matter, by Wet Combustion (MSA) | ≤ 1% |
| • Abrasion Resistance (ASTM-C131-96) | ≤ 25% loss |
| • Soundness (ASTM-C88 or T103 or T103-91) | ≤ 5% loss |
| • Porosity (ASTM-C29) | ≥ 25% |
| • Alkalinity, CaCO ₃ equivalents (MSA) | ≤ 1% |
| • Grain-Size Distribution (ASTM-C136) | |
| ○ Percentage Passing US#18 sieve | ≤ 1% |
| ○ Percentage Passing ¼-inch sieve | ≤ 30% |
| ○ Percentage Passing 3/8-inch sieve | ≤ 80% |

Growth media should be a soil-like mixture containing not more than 15% organic content (wet combustion or loss on ignition methods). The appropriate grain-size distribution is essential for achieving the proper moisture content, permeability, nutrient management, and non-capillary porosity, and 'soil' structure. The grain-size guidelines vary

- | | |
|--|-----------------|
| • Non-capillary Pore Space at Field Capacity, 0.333 bar (TMECC 03.01, A) | ≥ 15% (vol) |
| • Moisture Content at Field Capacity (TMECC 03.01, A) | ≥ 12% (vol) |
| • Maximum Media Water Retention (FLL) | ≥ 30% (vol) |
| • Alkalinity, Ca CO ₃ equivalents (MSA) | ≤ 2.5% |
| • Total Organic Matter by Wet Combustion (MSA) | 3-15% (dry wt.) |
| • pH (RCSTP) | 6.5 - 8.0 |
| • Soluble Salts (DTPA saturated media extraction) (RCSTP) | ≤ 6 mmhos/cm |
| • Cation exchange capacity (MSA) | ≥ 10 meq/100g |

- Saturated Hydraulic Conductivity for Single Media Assemblies (FLL) ≥ 0.05 in/min
- Saturated Hydraulic Conductivity for Dual Media Assemblies (FLL) ≥ 0.30 in/min

Grain-size Distribution of the Mineral Fraction (ASTM-D422)

- Single Media Assemblies:
 - Clay fraction (2 micron) 0
 - Pct. Passing US#200 sieve (i.e., silt fraction) $\leq 5\%$
 - Pct. Passing US#60 sieve $\leq 10\%$
 - Pct. Passing US#18 sieve 5 - 50%
 - Pct. Passing 1/8-inch sieve 0 - 70%
 - Pct. Passing 3/8-inch sieve 75 -100%
- Dual Media Assemblies:
 - Clay fraction (2 micron) 0
 - Pct. Passing US#200 sieve (i.e., silt fraction) 5 - 15%
 - Pct. Passing US#60 sieve 10 - 25%
 - Pct. Passing US#18 sieve 20 - 50%
 - Pct. Passing 1/8-inch sieve 55 - 95%
 - Pct. Passing 3/8-inch sieve 90 - 100%

Macro- and micro-nutrients shall be incorporated in the formulation in initial proportions suitable for support the specified planting.

Separation fabric should be readily penetrated by roots, but provide a durable separation between the drainage and growth media layers (Only lightweight nonwoven geotextiles are recommended for this function.

- Unit Weight (ASTM-D3776) ≤ 4.25 oz/yd²
- Grab tensile (ASTM-D4632) ≤ 90 lb
- Mullen Burst Strength (ASTM-D4632) ≥ 135 lb/in
- Permittivity (ASTM-D4491) ≥ 2 per second

Credits and Acknowledgments

This Appendix has been developed by Christopher B. Burke Engineering, LLC, and is primarily based upon similar segments contained in “Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers” published in 2009 by the Southeast Michigan Council of Governments (SEMCOG). A selection of material contained in the noted SEMCOG publication has been modified to reflect conditions in Indiana and used, with permission, for development of this Appendix. The valuable contribution of SEMCOG through sharing of this material for use in this Appendix is hereby acknowledged.

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Soil Infiltration Testing Protocol

Appendix D4

Soil Infiltration Testing Protocol

Purpose of this Protocol

The soil infiltration testing protocol describes evaluation and field testing procedures to determine if infiltration BMPs are suitable at a site, as well as to obtain the required data for infiltration BMP design.

When to Conduct Testing

It is recommended that soil evaluation and investigation be conducted following development of a concept plan or early in the development of a preliminary plan.

Who Should Conduct Testing

Soil evaluation and investigation may be conducted by soil scientists, design engineers, professional geologists, and other qualified professionals and technicians. The stormwater designer is *strongly* encouraged to directly observe the testing process to obtain a first-hand understanding of site conditions.

Importance of Stormwater BMP Areas

Sites are often defined as unsuitable for infiltration BMPs and soil-based BMPs due to proposed grade changes (excessive cut or fill) or lack of suitable areas. Many sites will be constrained and unsuitable for infiltration BMPs. However, if suitable areas exist, these areas should be identified early in the design process and should not be subject to a building program that precludes infiltration BMPs. When pursuing the LID Approach, full build-out of site areas otherwise deemed to be suitable for infiltration should not provide an exemption or waiver for adequate storm-water volume control or groundwater recharge.

Safety

As with all field work and testing, attention to all applicable Occupational Safety and Health Administration (OSHA) regulations and local guidelines related to earthwork and excavation is required. Digging and excavation should never be conducted without adequate notification through the Indiana Underground Plant Protection Service (IUPPS) at www.IUPSS.org. Excavations should never be left

unsecured and unmarked, and all applicable authorities should be notified prior to any work.

Infiltration Testing: A Multi-Step Process

Infiltration testing is a four-step process to obtain the necessary data for the design of the stormwater management plan. The four steps include:

- 1. Background evaluation**
 - Based on available published and site specific data
 - Includes consideration of proposed development plan
 - Used to identify potential BMP locations and testing locations
 - Prior to field work (desktop)
- 2. Test pit (deep hole) observations**
 - Includes multiple testing locations
 - Provides an understanding of sub-surface conditions
 - Identifies limiting conditions
- 3. Infiltration testing**
 - Must be conducted onsite
 - Different testing methods available
- 4. Design considerations**
 - Determine suitable infiltration rate for design calculations
 - Consider BMP drawdown
 - Consider peak rate attenuation

Step 1. Background evaluation

Prior to performing testing and developing a detailed site plan, existing conditions at the site should be inventoried and mapped including, but not limited to:

- Existing mapped soils and USDA Hydrologic Soil Group classifications.
- Existing geology, including depth to bedrock, karst conditions, or other features of note.
- Existing streams (perennial and intermittent, including intermittent swales), 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 use conditions.

- Other natural or man-made features or conditions that may impact design, such as past uses of site, existing nearby structures (buildings, walls), abandoned wells, etc.
- A concept plan or preliminary layout plan for development should be evaluated, including:
 - Preliminary grading plan and areas of cut and fill,
 - Location of all existing and proposed water supply sources and wells,
 - Location of all former, existing, and proposed onsite wastewater systems,
 - Location of other features of note such as utility rights-of-way, water and sewer lines, etc.,
 - Existing data such as structural borings, and
 - Proposed location of development features (buildings, roads, utilities, walls, etc.).

In Step 1, the designer should determine the potential location of infiltration BMPs. The approximate location of these BMPs should be on the proposed development plan and serve as the basis for the location and number of tests to be performed onsite.

Important: If the proposed development is located on areas that may otherwise be a suitable BMP location, or if the proposed grading plan is such that potential BMP locations are eliminated, the designer is *strongly* encouraged to revisit the proposed layout and grading plan and adjust the development plan as necessary. Full build-out of areas suitable for infiltration BMPs should *not* preclude the use of BMPs for runoff volume reduction and groundwater recharge.

Step 2. Test pits (deep holes)

A test pit (deep hole) allows visual observation of the soil horizons and overall soil conditions both horizontally and vertically in that portion of the site. An extensive number of test pit observations can be made across a site at a relatively low cost and in a short time period. The use of soil borings as a substitute for test pits is strongly discouraged, as visual observation is narrowly limited in a soil boring and the soil horizons cannot be observed in-situ, but must be observed from the extracted borings.

A test pit (deep hole) consists of a backhoe-excavated trench, 2½-3 feet wide, to a depth of 6-7½ feet, or until bedrock or fully saturated conditions are encountered.

The trench should be benched at a depth of 2-3 feet for access and/or infiltration testing.

At each test pit, the following conditions are to be noted and described. Depth measurements should be described as depth below the ground surface:

- Soil horizons (upper and lower boundary),
- Soil texture, structure, and color for each horizon,
- Color patterns (mottling) and observed depth,
- Depth to water table,
- Depth to bedrock,
- Observance of pores or roots (size, depth),
- Estimated type and percent coarse fragments,
- Hardpan or limiting layers,
- Strike and dip of horizons (especially lateral direction of flow at limiting layers), and
- Additional comments or observations.

The Sample Soil Log Form at the end of this protocol may be used for documenting each test pit.

At the designer's discretion, soil samples may be collected at various horizons for additional analysis. Following testing, the test pits should be refilled with the original soil and the topsoil replaced. A test pit should *never* be accessed if soil conditions are unsuitable or unstable for safe entry, or if site constraints preclude entry. OSHA regulations should always be observed.

It is important that the test pit provide information related to conditions at the bottom of the proposed infiltration BMP. If the BMP depth will be greater than 90 inches below existing grade, deeper excavation of the test pit will be required. The designer is cautioned regarding the proposal of systems that are significantly deeper than the existing topography, as the suitability for infiltration is likely to decrease. The design engineer is encouraged to consider reducing grading and earthwork as needed to reduce site disturbance and provide greater opportunity for stormwater management.

The number of test pits varies depending on site conditions and the proposed development plan. General guidelines are as follows:

- For single-family residential subdivisions with on-lot infiltration BMPs, one test pit per lot is recommended, preferably within 100 feet of the proposed BMP area.

- For multi-family and high-density residential developments, one test pit per BMP area or acre is recommended.
- For large infiltration areas (basins, commercial, institutional, industrial, and other proposed land uses), multiple test pits should be evenly distributed at the rate of four to six pits per acre of BMP area.

The recommendations above are guidelines. Additional tests should be conducted if local conditions indicate significant variability in soil types, geology, water table levels, depth and type of bedrock, topography, etc. Similarly, uniform site conditions may indicate that fewer test pits are required. Excessive testing and disturbance of the site prior to construction is not recommended.

Step 3. Infiltration tests

A variety of field tests exists for determining the infiltration capacity of a soil. Laboratory tests are not recommended, as a homogeneous laboratory sample does not represent field conditions. Infiltration tests should be conducted in the field. Infiltration tests should not be conducted in the rain, within 24 hours of significant rainfall events (> 0.5 inches), or when the temperature is below freezing.

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 recommended. Based on observed field conditions, the designer may elect to modify the proposed bottom elevation of a BMP. Personnel conducting infiltration tests should be prepared to adjust test locations and depths depending on observed conditions.

Methodologies discussed in this protocol include:

- Double-ring infiltrometer tests.
- Percolation tests (such as for onsite wastewater systems).

There are differences between the two methods. A double-ring infiltrometer test estimates the vertical movement of water through the bottom of the test area. The outer ring helps to reduce the lateral movement of water in the soil from the inner ring. A percolation test allows water movement through both the bottom and sides of the test area. For this reason, the measured rate of water level drop in a percolation test must be adjusted

to represent the discharge that is occurring on both the bottom and sides of the percolation test hole.

Other testing methodologies and standards that are available but not discussed in detail in this protocol include (but are not limited to):

- Constant head double-ring infiltrometer.
- Testing as described in the *Maryland Stormwater Manual*, Appendix D.1, using five-inch diameter casing.
- ASTM 2003 Volume 4.08, Soil and Rock (I): Designation D 3385-03, Standard Test Method for Infiltration Rate of Soils in Field Using a Double-Ring Infiltrometer.
- ASTM 2002 Volume 4.09, Soil and Rock (II): Designation D 5093-90, Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring.
- Guelph permeameter.
- Constant head permeameter (Amoozometer).

Methodology for double-ring infiltrometer field test

A double-ring infiltrometer consists of two concentric metal rings. The rings are driven into the ground and filled with water. The outer ring helps to prevent divergent flow. The drop-in water level or volume in the inner ring is used to calculate an infiltration rate. The infiltration rate is the amount of water per surface area and time unit which penetrates the soils. The diameter of the inner ring should be approximately 50-70 percent of the diameter of the outer ring, with a minimum inner ring size of four inches. Double-ring infiltrometer testing equipment designed specifically for that purpose may be purchased. However, field testing for storm-water BMP design may also be conducted with readily available materials.

Equipment for double-ring infiltrometer test:

Two concentric cylinder rings six inches or greater in height. Inner ring diameter equal to 50-70 percent of outer ring diameter (i.e., an 8-inch ring and a 12-inch ring). Material typically available at a hardware store may be acceptable.

- Water supply,
- Stopwatch or timer,
- Ruler or metal measuring tape,
- Flat wooden board for driving cylinders uniformly into soil,

- Rubber mallet, and
- Log sheets for recording data.

Procedure for double-ring infiltrometer test

- Prepare level testing area.
- Place outer ring in place; place flat board on ring and drive ring into soil to a minimum depth of two inches.
- Place inner ring in center of 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 water level indicator mark or rim at 30-minute intervals for one hour. The minimum water depth should be four inches. The drop in the water level during the last 30 minutes of the 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 measurement 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 the final period or the average stabilized rate, expressed as inches per hour, should represent the infiltration rate for that test location.

Methodology for percolation test

Equipment for percolation test

- Post hole digger or auger,
- Water supply,
- Stopwatch or timer,
- Ruler or metal measuring tape,
- Log sheets for recording data,

- Knife blade or sharp-pointed instrument (for soil scarification),
- Course sand or fine gravel, and
- 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 not 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 a depth of 8-12 inches. The bottom and sides of the hole should be scarified with a knife blade 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 the soil from scouring and clogging of the pores.
- Test holes should be presoaked immediately prior to testing. Water should be placed in the hole to a minimum depth of six inches over the bottom and readjusted every 30 minutes for one hour.
- 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 again be 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 following formula:

Infiltration Rate = (Percolation Rate)/ (Reduction Factor)

Where the Reduction Factor is given by[#]:

$$R_f = \frac{2d_i - \Delta d}{DIA} + 1$$

With:

d_i = Initial Water Depth (in.)

Δd = 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 or shown in Table 1 below 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.

The area reduction factor accounts for the exfiltration occurring through the sides of percolation hole. It assumes that the percolation rate is affected by the depth of water in the hole and that the percolating surface of the hole is in uniform soil. If there are significant problems with either of these assumptions then other adjustments may be necessary.

Step 4. Use design considerations provided in the infiltration BMP.

Perc. Hole Diameter, DIA (in.)	Initial Water Depth, d_i (in.)	Ave./Final Water Level Drop, Δd (in.)	Reduction Factor, R_f
6	6	0.1	3.0
		0.5	2.9
		2.5	2.6
	8	0.1	3.7
		0.5	3.6
		2.5	3.3
	10	0.1	4.3
		0.5	4.3
		2.5	3.9
8	6	0.1	2.5
		0.5	2.4
		2.5	2.2
	8	0.1	3.0
		0.5	2.9
		2.5	2.7
	10	0.1	3.5
		0.5	3.4
		2.5	3.2
10	6	0.1	2.2
		0.5	2.2
		2.5	2.0
	8	0.1	2.6
		0.5	2.6
		2.5	2.4
	10	0.1	3.0
		0.5	3.0
		2.5	2.8

Table 1 Sample Percolation Rate Adjustments

Additional Potential Testing – Bulk Density

Bulk density tests measure the level of compaction of a soil, which is an indicator of a soil's ability to absorb rainfall. Developed and urbanized sites often have very high bulk densities and, therefore, possess limited ability to absorb rainfall (and have high rates of stormwater runoff). Vegetative and soil improvement programs can lower the soil bulk density and improve the site's ability to absorb rainfall and reduce runoff.

Macropores occur primarily in the upper soil horizons and are formed by plant roots (both living and decaying), soil fauna such as insects, the weathering processes caused by movement of water, the freeze-thaw cycle, soil shrinkage due to desiccation of clays, chemical processes, and other mechanisms. These macropores provide an important mechanism for infiltration prior to development, extending vertically and horizontally for considerable distances. It is the intent of good engineering and design practice to maintain these macropores when installing infiltration BMPs as much as possible. Bulk density tests can help determine the relative compaction of soils before and after site disturbance and/or restoration and should be used at the discretion of the designer/reviewer.

Soil Test Pit Log Sheet

Project: _____
 Name: _____
 Location: _____
 Test Pit #: _____

Date: _____
 Soil Series: _____
 Other: _____

Horizon	Depth (in.)	Color	Redox Features	Texture	Notes (if applicable)	Boundary

Notes:

REDOX FEATURES

Abundance

Few..... < 2%

Common... 2-20%

Many..... > 20%

Contrast

faint

hue and chroma of matrix
and redox are closely related

distinct

matrix & redox features vary
1-2 units of hue and several
units of chroma & value

prominent

Matrix & redox features vary
several units in hue, value & chroma

COARSE FRAGMENTS (% of profile)

15-35%

gravelly

channery

cobbly

flaggy

stony

35-65% > 65%

very gravelly

very channery

very cobbly

very flaggy

very stony

extremely gravelly

extremely channery

extremely cobbly

extremely flaggy

extremely stony

BOUNDARY

Distinctness

abrupt... < 1" (thick)

clear.... 1" – 2.5"

gradual... 2.5" – 5"

diffuse... > 5"

HORIZONS

O – organic layers of decaying plant and animal tissue (must be greater than 12-18% organic carbon, excluding live roots)

A (topsoil) – mineral horizon at or near the surface in which an accumulation of humified organic matter is mixed with the mineral material

E – mineral horizon which the main feature is loss of silicate clay, iron, aluminum. Must be underlain by B (alluvial) horizon.

B (subsoil) – mineral horizon with evidence of pedogenesis or illuviation (movement into the horizon)

C (substratum) – the un-weathered geologic material the soil formed in. Shows little or no sign of soil formation

Credits and Acknowledgments

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Maintenance Inspection Checklists

Appendix D5

MAINTENANCE INSPECTION CHECKLISTS

This appendix contains nine checklists available as guides for maintenance inspections of specific BMPs. The checklists are designed to help identify key components of BMPs that require ongoing maintenance as well as a basic schedule of when the maintenance should occur.

It is suggested that the inspection be undertaken by a licensed PE and/or a person knowledgeable about the design and function of the BMP.

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BIORETENTION (RAIN GARDEN) & VEGETATED SWALE (BIOSWALE) MAINTENANCE INSPECTION CHECKLIST

BMP Location:	Inspector's Remarks:
Overall Condition (circle one): <i>ACCEPTABLE</i> <i>UNACCEPTABLE</i>	
Inspection Date:	

FREQUENCY	MAINTENANCE ACTIVITY	COMMENTS
As Needed & Following > 1" Rainfall	<input type="checkbox"/> Irrigate if plants appear wilted or unhealthy; replace dead plants <input type="checkbox"/> Check for erosion, cracking, embankment failure, burrowing animals, and sediment clogging the drain and other pipes <input type="checkbox"/> Repair erosion with additional plant material similar to original and/or small stones for stability <input type="checkbox"/> Remove trash, debris, and sediment <input type="checkbox"/> Remove weeds and invasive plants <input type="checkbox"/> Replace bark mulch on bare, exposed soil	
Monthly (during growing season)	<input type="checkbox"/> Irrigate 1" water/week during the first growing season <input type="checkbox"/> Check/clean inlets, outlets/overflows and curb cuts from debris <input type="checkbox"/> Check plants for pest damage or disease <input type="checkbox"/> Remove trash, debris, and sediment <input type="checkbox"/> Remove weeds and invasive plants	
Semi-Annually (spring & fall)	<input type="checkbox"/> Redefine lawn edge	
Annually	<input type="checkbox"/> Cut perennial plantings and divide grasses and perennials to prevent overcrowding (fall) <input type="checkbox"/> Mow bioswale (> 6") (fall) <input type="checkbox"/> Check overflow and subsurface drain; check infiltration and flow-through rates (0.5"/hr) <input type="checkbox"/> Check pH of infiltration/planting soil (<5.2 add limestone; >7.0 add iron sulfate plus sulfur) <input type="checkbox"/> Check/correct for uniformity in cross-section and longitudinal slope (bioswale) <input type="checkbox"/> Replace mulch. Minimum every 3 years <input type="checkbox"/> Remove accumulated sediment and replace with approved soil mix, bark mulch, and vegetation (> 25% ponding depth for bioretention; >50% checkdam height for bioswale). Minimum every 5 years	
Upon Failure	<input type="checkbox"/> Redesign and reconstruct	

CONSTRUCTED WETLAND MAINTENANCE INSPECTION CHECKLIST

BMP Location:	Inspector's Remarks:
Overall Condition (circle one): <i>ACCEPTABLE</i> <i>UNACCEPTABLE</i>	
Inspection Date:	

FREQUENCY	MAINTENANCE ACTIVITY	COMMENTS
As Needed & Following > 1" Rainfall	<input type="checkbox"/> Irrigate if plants appear wilted or unhealthy; replace dead plants <input type="checkbox"/> Check for erosion, cracking, embankment failure, burrowing animals, and sediment clogging the drain and other pipes <input type="checkbox"/> Repair erosion and bare soil with additional plant material similar to original and/or small stones for stability <input type="checkbox"/> Remove weeds and woody vegetation < 15' toe of embankment and < 25' from spillway <input type="checkbox"/> Remove trash, debris, and sediment <input type="checkbox"/> Remove weeds and invasive plants	
Monthly (during growing season)	<input type="checkbox"/> Irrigate 1" water/week during the first growing season; maintain low water levels to allow sufficient oxygen to the roots of establishing plants <input type="checkbox"/> Check/clean inlets, outlets/overflows and trash racks from debris <input type="checkbox"/> Check plants for pest damage or disease <input type="checkbox"/> Remove trash, debris, and sediment <input type="checkbox"/> Remove weeds and invasive plants	
Semi-Annually (spring & fall)	<input type="checkbox"/> Check/remove sediment build-up and plant debris (especially < 18" of outlet) <input type="checkbox"/> Check water levels with design specifications <input type="checkbox"/> Check/remove burrowing animals; repair holes in embankments <input type="checkbox"/> Mow side slopes and embankments, emergency spillways, and access road <input type="checkbox"/> Divide grasses and perennials (fall) to prevent overcrowding	
Annually	<input type="checkbox"/> Remove large colonies of cattails <input type="checkbox"/> Manage weeds through burning or trimming plant stalks when new growth is 4-6" tall <input type="checkbox"/> Replace mulch. Minimum every 3 years <input type="checkbox"/> Replace soil. Minimum every 20 years <input type="checkbox"/> Remove accumulated sediment (> 50% capacity forebay, > 25% capacity wetland). Minimum every 5 years. Wetland should be drained and dry prior to sediment removal and immediately stabilized and re-vegetated	
Upon Failure	<input type="checkbox"/> Redesign and reconstruct	

DRY POND & WET POND MAINTENANCE INSPECTION CHECKLIST

BMP Location:	Inspector's Remarks:
Overall Condition (circle one): <i>ACCEPTABLE</i> <i>UNACCEPTABLE</i>	
Inspection Date:	

FREQUENCY	MAINTENANCE ACTIVITY	COMMENTS
As Needed & Following > 1" Rainfall	<input type="checkbox"/> Irrigate if plants appear wilted or unhealthy; replace dead plants <input type="checkbox"/> Check/repair areas with erosion, cracking, embankment failure, burrowing animals, and sediment clogging the drain and other pipes <input type="checkbox"/> Repair erosion and bare soil <input type="checkbox"/> Remove woody vegetation < 15' toe of embankment and mow < 25' from spillway <input type="checkbox"/> Remove trash, debris, and sediment <input type="checkbox"/> Remove weeds and invasive plants	
Monthly (during growing season)	<input type="checkbox"/> Irrigate 1" water/week during the first growing season; maintain low water levels to allow sufficient oxygen to the roots of establishing plants (wet pond shelf) <input type="checkbox"/> Check/clean inlets, outlets/overflows and trash racks from debris <input type="checkbox"/> Check plants for pest damage or disease <input type="checkbox"/> Remove trash, debris, and sediment <input type="checkbox"/> Mow side slopes and embankments, emergency spillways, and access road (dry pond – maintain bottom at 6-8"; wet pond – allow 5-10' of embankment to grow 24-30")	
Semi-Annually (spring & fall)	<input type="checkbox"/> Check/remove sediment build-up and plant debris (especially < 18" of outlet) <input type="checkbox"/> Check water levels with design specifications (wet pond) <input type="checkbox"/> Check/repair any settlement of berms <input type="checkbox"/> Check/remove burrowing animals; repair holes in embankments	
Annually	<input type="checkbox"/> Seed or sod to restore dead or dying grass/groundcover <input type="checkbox"/> Replace mulch every 3 years (min); replace topsoil every 10 years (min) <input type="checkbox"/> Remove accumulated sediment (> 50% capacity forebay, > 25% capacity pond). Minimum 2-10 years (dry pond), 5-10 years (wet pond)	
Upon Failure	<input type="checkbox"/> Redesign and reconstruct	

VEGETATED ROOF (GREEN ROOF) MAINTENANCE INSPECTION CHECKLIST

BMP Location:	Inspector's Remarks:
Overall Condition (circle one): <i>ACCEPTABLE</i> <i>UNACCEPTABLE</i>	
Inspection Date:	

FREQUENCY	MAINTENANCE ACTIVITY	COMMENTS
As Needed & Following > 1" Rainfall	<input type="checkbox"/> Irrigate if plants appear wilted or unhealthy; replace dead plants <input type="checkbox"/> Check for sediment clogging the drain and weirs <input type="checkbox"/> Remove trash, debris, and sediment <input type="checkbox"/> Remove weeds and invasive plants <input type="checkbox"/> Replace bark mulch on bare, exposed soil <input type="checkbox"/> Check mechanical equipment for leaks or spills	
Monthly (during growing season)	<input type="checkbox"/> Irrigate 1" water/week during the first growing season <input type="checkbox"/> Check/clean outlets/overflows and weirs from debris <input type="checkbox"/> Check plants for pest damage or disease <input type="checkbox"/> Remove trash, debris, and sediment <input type="checkbox"/> Remove weeds and invasive plants	
Semi-Annually (spring and fall)	<input type="checkbox"/> Check roof and building interior for leaks from mechanical equipment and structural deficiencies to waterproof membrane <input type="checkbox"/> Add bark mulch	
Annually	<input type="checkbox"/> Cut perennial plantings at end of growing season; divide grasses and perennials to prevent overcrowding (fall) <input type="checkbox"/> Check outlet/overflow drain; check infiltration and flow-through rates (0.5"/hr) <input type="checkbox"/> Check pH of infiltration/planting soil (<5.2 add limestone; >7.0 add iron sulfate plus sulfur) <input type="checkbox"/> Replace mulch. Minimum every 3 years <input type="checkbox"/> Remove accumulated sediment and replace with approved soil mix, bark mulch, and vegetation (> 25% ponding depth) <input type="checkbox"/> Remove trees/shrubs and replace with smaller specimens (10-25 years) (intensive green roof)	
Upon Failure	<input type="checkbox"/> Redesign and reconstruct	

INFILTRATION PRACTICE (TRENCH) MAINTENANCE INSPECTION CHECKLIST

BMP Location:	Inspector's Remarks:
Overall Condition (circle one): <i>ACCEPTABLE</i> <i>UNACCEPTABLE</i>	
Inspection Date:	

FREQUENCY	MAINTENANCE ACTIVITY	COMMENTS
As Needed & Following > 1" Rainfall	<input type="checkbox"/> Check infiltration rate (< 3"/hr) <input type="checkbox"/> Mow or trim grassed edge of trench; remove clippings to prevent clogging <input type="checkbox"/> Check observation well for clogging; clean subsurface drain	
Monthly (during growing season)	<input type="checkbox"/> Remove trash, debris, and sediment	
Semi-Annually (spring & fall)	<input type="checkbox"/> Check/clean gutters and downspouts <input type="checkbox"/> Check/clean pre-treatment BMPs or diversion structures for clogging, sediment/debris accumulation, or structural damage	
Annually	<input type="checkbox"/> Check/clean silt trap and intermediate sump pump (if applicable)	
Upon Failure	<input type="checkbox"/> Replace filter from roof drain <input type="checkbox"/> Remove and install clean, washed trench aggregate; trench walls should be excavated to expose clean soil; replace filter fabric and piping	

PERVIOUS PAVEMENT MAINTENANCE INSPECTION CHECKLIST

BMP Location:	Inspector's Remarks:
Overall Condition (circle one): <i>ACCEPTABLE</i> <i>UNACCEPTABLE</i>	
Inspection Date:	

FREQUENCY	MAINTENANCE ACTIVITY	COMMENTS
As Needed & Following > 1" Rainfall	<input type="checkbox"/> Repair potholes and patch cracks <input type="checkbox"/> Remove trash, debris, and sediment <input type="checkbox"/> Remove weeds and unwanted grass including grass clippings and vegetation trimmings from adjacent landscaped areas <input type="checkbox"/> Sweep or vacuum more frequently depending on traffic, sediment, and debris <input type="checkbox"/> Monitor infiltration rate (20"/hr)	
Monthly (during growing season)	<input type="checkbox"/> Remove trash, debris, and sediment	
Semi-Annually (spring & fall)	<input type="checkbox"/> Monitor infiltration rate (20"/hr) <input type="checkbox"/> Sweep or vacuum; pressure wash (concrete pavement only) <input type="checkbox"/> Clean inlets draining to subsurface bed and subsurface drain <input type="checkbox"/> Check overflow outlet for clogging	
Annually	<input type="checkbox"/> Check and replenish lost aggregate between pavers <input type="checkbox"/> Check and reseed grassed pavers	
Upon Failure	<input type="checkbox"/> Remove existing pervious pavement and aggregate, wash and/or replace and reinstall per manufacture specifications	

PLANTER BOX / TREE BOX MAINTENANCE INSPECTION CHECKLIST

BMP Location:	Inspector's Remarks:
Overall Condition (circle one): <i>ACCEPTABLE</i> <i>UNACCEPTABLE</i>	
Inspection Date:	

FREQUENCY	MAINTENANCE ACTIVITY	COMMENTS
As Needed & Following > 1" Rainfall	<input type="checkbox"/> Irrigate if plants appear wilted or unhealthy; replace dead plants <input type="checkbox"/> Check for sediment clogging the drain and other pipes <input type="checkbox"/> Remove trash, debris, and sediment <input type="checkbox"/> Remove weeds and invasive plants <input type="checkbox"/> Replace bark mulch on bare, exposed soil	
Monthly (during growing season)	<input type="checkbox"/> Irrigate 1" water/week during the first growing season; stake/tie younger trees <input type="checkbox"/> Check/clean inlets and outlets/overflows and curb cuts from debris <input type="checkbox"/> Check plants for pest damage or disease; remove weeds and invasive plants <input type="checkbox"/> Remove trash, debris, and sediment <input type="checkbox"/> Sweep surrounding area	
Semi-Annually (spring & fall)	<input type="checkbox"/> Check stakes and ties on trees; replace if worn or damaged <input type="checkbox"/> Prune/trim vegetation <input type="checkbox"/> Add bark mulch	
Annually	<input type="checkbox"/> Cut perennial planting; divide grasses and perennials to prevent overcrowding (fall) <input type="checkbox"/> Check infiltration and flow-through rates (0.5"/hr) <input type="checkbox"/> Check pH of infiltration/planting soil (<5.2 add limestone; >7.0 add iron sulfate plus sulfur) <input type="checkbox"/> Replace mulch every 3 years (min) <input type="checkbox"/> Remove accumulated sediment and replace with approved soil mix, bark mulch, and vegetation (> 25% ponding depth) <input type="checkbox"/> Replace trees and shrubs with smaller specimens (10-25 years)	
Upon Failure	<input type="checkbox"/> Redesign and reconstruct	

RAINWATER HARVESTING MAINTENANCE INSPECTION CHECKLIST

BMP Location:	Inspector's Remarks:
Overall Condition (circle one): <i>ACCEPTABLE</i> <i>UNACCEPTABLE</i>	
Inspection Date:	

FREQUENCY	MAINTENANCE ACTIVITY	COMMENTS
As Needed & Following > 1" Rainfall	<input type="checkbox"/> Check/ clean sediment or debris from within the tank <input type="checkbox"/> Check/clean diverts, cleanout plugs, screens, seals, covers, and overflow pipes; repair and replace damaged components <input type="checkbox"/> Empty tank when full (within 48 hrs) <input type="checkbox"/> Replace components and/or tank if leaking	
Monthly (during growing season)	<input type="checkbox"/> Remove trash, debris, and sediment from inlet, screen, and outlet	
Semi-Annually (spring & fall)	<input type="checkbox"/> Check and clean with brush; disinfect tank <input type="checkbox"/> Check pump	
Annually	<input type="checkbox"/> Pressure wash area draining to system <input type="checkbox"/> Flush and remove debris and sediment from tank <input type="checkbox"/> Replace pump on large systems (5 years)	
Upon Failure	<input type="checkbox"/> Contact manufacturer for corrective solution	

RIPARIAN RESTORATION & NATIVE REVEGETATION MAINTENANCE INSPECTION CHECKLIST

BMP Location:	Inspector's Remarks:
Overall Condition (circle one): <i>ACCEPTABLE</i> <i>UNACCEPTABLE</i>	
Inspection Date:	

FREQUENCY	MAINTENANCE ACTIVITY	COMMENTS
As Needed & Following > 1" Rainfall	<input type="checkbox"/> Irrigate if plants appear wilted or unhealthy; replace dead plants <input type="checkbox"/> Check for erosion and slope stability; repair with additional plant material similar to original and/or small stones for stability <input type="checkbox"/> Remove trash, debris, and sediment <input type="checkbox"/> Remove weeds and invasive plants <input type="checkbox"/> Replace bark mulch on bare, exposed soil	
Monthly (during growing season)	<input type="checkbox"/> Irrigate 1" water/week during the first growing season <input type="checkbox"/> Check plants for pest damage or disease <input type="checkbox"/> Remove trash, debris, and sediment <input type="checkbox"/> Remove weeds and invasive plants	
Semi-Annually (spring & fall)	<input type="checkbox"/> Check for erosion, embankment failure, and sediment accumulation <input type="checkbox"/> Prune/trim plants <input type="checkbox"/> Mow or spot apply herbicide (until canopy and/or vegetation established) <input type="checkbox"/> Redefine landward edge <input type="checkbox"/> Add bark mulch	
Annually	<input type="checkbox"/> Prescribed burn (prairie only) end of second year OR mow to very close to ground; remove plant debris from site to expose soil to sun; repeat on 2 to 5 year cycle	
Upon Failure	<input type="checkbox"/> Redesign and reconstruct	

Stormwater Management Practices Maintenance Agreement

Appendix D6

STORMWATER MANAGEMENT PRACTICES/BMPs MAINTENANCE AGREEMENT

THIS AGREEMENT is made this _____ day of _____, 20____, by _____ [Owner Name] of _____ [Company Name] with principal offices located _____ [Owner/Company Address], hereinafter “Owner”.

In accordance with _____ [Community Regulations], the Owner agrees to install and maintain stormwater management practice(s) (also known as BMPs) on the subject property, known as _____ [Property’s Common Name] located at _____ [Property’s Address], hereinafter “Property” in accordance with Exhibit A. The Owner further agrees to the terms stated in this document to ensure that the stormwater management practice(s) continues serving the intended function in perpetuity. This Agreement includes the following exhibit:

Exhibit A: BMP Operation and Maintenance Manual (“Manual”).

Note: This agreement and all Exhibits shall be recorded with the deed of property by the Owner at the [County Name] County Recorder’s Office and two (2) copies of the recorded document provided to [Community ‘s Name], hereinafter “Community”.

Through this Agreement, the Owner hereby subjects the Property to the following covenants, conditions, and restrictions:

1. The Owner shall be solely responsible for the installation, maintenance, and repair of the stormwater management practices, drainage easements, and associated landscaping identified in the Manual.
2. No alterations or changes to the stormwater management practice(s) identified in the Manual shall be permitted unless they are deemed to comply with this Agreement and are approved in writing by the Community.
3. The Owner shall retain the services of a qualified individual or company to operate and ensure the maintenance of the stormwater management practice(s) identified in the Manual.
4. The Owner shall annually, by December 30th, provide to the Community records of inspections, maintenance, and repair of the stormwater management practices in accordance with the Manual.
5. The Community or its designee is authorized to access the property as necessary to conduct inspections of the stormwater management practices or drainage easements to ascertain compliance with the intent of this Agreement and the activities prescribed in the Manual. Upon written notification by the Community or its designee of required maintenance or repairs, the Owner shall complete the specified maintenance or repairs within a reasonable time frame determined by the Community. The Owner(s) shall be liable for the failure to undertake any maintenance or repairs so that the public health, safety and welfare shall not be endangered nor the road improvement damaged.
6. If the Owner fails to properly maintain the stormwater management practice(s) in accordance with the Manual and this Agreement, the Community is authorized, but not required, to perform the specified inspections, maintenance, or repairs in order to preserve the intended functions of the practice(s) and prevent the practice(s) from becoming a threat to public health, safety, general welfare or the environment. In the case of an emergency, as determined by the Community, no notice shall be required prior to the Community performing emergency maintenance or repairs. The Community may levy the costs and expenses of such inspections, maintenance, or repairs plus a ten percent (10%) administrative fee against the Owner. The Community at the time of entering upon said stormwater management practice for the purpose of maintenance or repair may file a notice of lien in the office of the Register of Deeds of [County’s Name] County upon the property affected by the lien. If said

costs and expenses are not paid by the Owner, the Community may pursue the collection of same through appropriate court actions and in such a case, the Owner shall pay in addition to said costs and expenses all costs of litigation, including attorney fees.

7. The Owner hereby conveys to the Community an easement over, on, and in the Property or otherwise grants perpetual access rights for the purpose of access to the stormwater management practice for the inspection, maintenance, and repair thereof, should the Owner fail to properly inspect, maintain, and repair the practice(s).
8. The Owner agrees that this Agreement shall be recorded and that the Property shall be subject to the covenants and obligations contained herein, and this Agreement shall bind all current and future owners of the property.
9. The Owner agrees in the event that the Property is sold, transferred, or leased to provide information to the new owner, operator, or lessee regarding proper inspection, maintenance, and repair of the stormwater management practice(s). The information shall accompany the first deed transfer and include this Agreement and all Exhibits. The transfer of this information shall also be required with any subsequent sale, transfer, or lease of the Property.
10. The Owner agrees that the rights, obligations, and responsibilities hereunder shall commence upon execution of the Agreement.
11. The Owner whose signatures appear below hereby represent and warrant that they have the authority and capacity to sign this agreement and bind the respective parties hereto.
12. The Owner, its agents, representatives, successors, and assigns shall defend, indemnify and hold the Community harmless from and against any claims, demands, actions, damages, injuries, costs or expenses of any nature whatsoever, hereinafter "Claims", fixed or contingent, known or unknown, arising out of or in any way connected with the design, construction, use, maintenance, repair or operation (or omissions in such regard) of the stormwater management practice(s) referred to in Exhibit A which are the subject of this Agreement. This indemnity and hold harmless shall include any costs, expenses, and attorney fees incurred by the Community in connection with such Claims or the enforcement of this Agreement.

IN WITNESS WHEREOF, the Owner has executed this Agreement on the day and year first above written.

Owner Signature

Date

Printed Name

Company

Title

STATE OF INDIANA)

)

SS:

COUNTY OF [County Name])

)

BEFORE ME, the undersigned, a Notary Public in and for said County and State, personally appeared _____ Owner subscribed and sworn before this _____ day of _____, 20 ____.

Commission Expiration Date

County of Residence

Signature

Printed Name

WHEN RECORDED, RETURN FILE STAMPED COPY TO:

[Community's Name]
[Community's Address]
[City, IN, zip code]

.....
Accepted by [Community's name]:

Signature: _____

Date: _____

Printed Name: _____

Title: _____

