City Of Indianapolis
Department of Public Works
Green Infrastructure Supplemental Document
2016

Department of Public Works
INDIANAPOLIS

THIS PAGE LEFT BLANK INTENTIONALLY

Executive Summary

The goal of this document is to introduce Low Impact Development (LID) techniques and the benefits (incentives), as well as to provide sufficient information (description and applicability, advantages, disadvantages, technical guidance, and cost) on each practice to demonstrate the strategies necessary to integrate innovative and highly effective LID stormwater management techniques into design.

LID is an approach to land development that uses various land planning, design practices and technologies to simultaneously conserve and protect natural resource systems. It is an innovative multi-step stormwater management approach that 1) utilizes thoughtful site planning and 2) manages rainfall at its source through the use of integrated and distributed micro-scale stormwater practices (green infrastructure).

Some of the onsite stormwater runoff reduction practices (green infrastructure) included in this document are downspout disconnection, rain barrels, cisterns, rain gardens, green roofs, roof-top storage, swales, and permeable pavement systems, among others. Several of the incentives for incorporating these techniques into design include: ancillary benefits, reduction in stormwater sizing criteria (water quality and quantity), and a reduction in the Stormwater Fee.

LID stormwater management techniques can be used to meet supplementary goals (or in many instances other existing City regulations) in addition to meeting the stormwater requirements. Many LID stormwater management techniques can be integrated into urban site features (rain gardens, flow through planters, swales). A number of the generally accepted benefits from LID techniques (green infrastructure) include: cleaner water, enhanced water supplies, cleaner air, reduced urban temperatures, increased energy efficiency, infrastructure cost savings, and community benefits (quality of life).

In general, the Stormwater sizing criteria provide a strong incentive to reduce impervious cover (through LID techniques) at development and redevelopment sites (e.g., water quality and quantity). Developers could reduce the imperviousness by 20% and potentially reduce the volume of water they have to manage for quality by 30%. Reducing the curve number from 85 to 75 on a development can reduce runoff by nearly 25%. This could potentially reduce the overall cost of development.

The relationship between the measured amount of impervious area and the Stormwater Fee is directly proportional. Reducing the impervious area on a property can result in reducing the monthly Stormwater Fee.

There are many incentives for incorporating LID stormwater management techniques into stormwater design. Developers and Municipalities, alike are realizing these benefits and have started integrating these techniques into both public and private development and redevelopment projects across the country.

THIS PAGE LEFT BLANK INTENTIONALLY

Table of Contents

List of Figures

List of Tables

Appendices

Attachments

1. Introduction

<u>Purpose:</u> The goal of the document is to introduce Low Impact Development (LID) techniques and benefits (incentives), as well as to provide sufficient information (description and applicability, advantages, disadvantages, technical guidance, and cost) on each practice to demonstrate the strategies necessary to integrate innovative and highly effective LID Stormwater management techniques into design. As with any practice, Stormwater management is continuously evolving. Therefore this document should be used as a benchmark, and as LID Stormwater management techniques become more prevalent in Indianapolis, new techniques and data may become available to provide further design suggestions and practices.

1.1. Developing the Stormwater Green Incentive Document (Credibility)

1) Extensive review of other cities'/states' LID techniques/Green Infrastructure and incentives was completed. The following cities'/ states' guidelines were reviewed: Chicago, Portland, Seattle, Minnesota, Milwaukee, Philadelphia, and Maryland (These documents and their URLs are referenced in the bibliography). Many of the reviewed design guidelines/green documents were authored by a consortium of experts in LID techniques including the following organizations: Natural Resources Defense Council (NRDC), `the National Association of Clean Water Agencies, the Environmental Protection Agency (EPA), the Low Impact Development Center, and Universities. The document's intent is to consolidate as many viable sources as concisely and logically as possible into one document for the City of Indianapolis. These documents were reviewed with three main focus points; 1) the city's or state's Stormwater design regulations, 2) technical design information, and 3) applicability to Indianapolis.

2) Philadelphia's and Milwaukee's Stormwater design guidelines were primarily, but not exclusively, used in developing many of the BMP fact sheets for Indianapolis. In addition, the LID technique center and EPA published a document, *LID for Big Box Retailers*, which is used for some of the design examples within this document (provided in Appendix 1). It is essential for the success of green infrastructure to keep in mind, that while some of the concepts in green design are transferable, regional conditions (rainfall intensity and patterns, evaporation, transpiration, soil properties, plant selection, etc.) are extremely crucial in the physical application of green design. Regional experts from both the private sector and academia were utilized to review the green design Fact Sheets.

1.2. Change in Stormwater Design Paradigm

A change in the design paradigm for Stormwater management is currently evolving around the world. Stormwater design was (and often, still is) put off until the last stage of development. However, Stormwater is becoming one of the first planning tools when evaluating a site and is being looked at as a valuable natural resource, not a problem to be piped and conveyed into the nearest ditch, channel, or stream. Many developers and municipalities alike are realizing the benefits of incorporating Stormwater management into the initial planning stages and integrating various green infrastructures into both private and public development and redevelopment projects.

1.3. Why a Change in Design Paradigm

There are a number of reasons for this shift. The primary reasons are:

1) **Regulatory Changes**. Many cities and states have adopted a comprehensive watershed planning approach to further address common Stormwater management problems found across the world such as: combined sewer overflows (CSOs), stream deterioration (chemical, biological, physical, and recreational), and decreased groundwater recharge. Many cities and states have adopted not only quality and quantity design requirements, but also recharge volume, channel protection storage volume, and overbank flood protection volume requirements. Conventional Stormwater design cannot solely be used in order to meet these design criteria. LID/green infrastructure in many cases must be integrated into the design to meet these regulatory requirements.

2) **Availability of Reliable Data.** Many cities and states have been slow to adopt or accept LID techniques and the various green infrastructures into policy because of the lack of historical performance data. Cities and states do not want to rely on potentially maintenance-intensive techniques that may "fail" when the primary objective of Stormwater management has been to protect citizens from flooding. However, in the past decade there has been extensive research completed to provide scientific data on these techniques and the relatively low-maintenance requirements of most of the options. Recently the EPA has encouraged the use of green infrastructure, claiming that it can be both cost-effective and an environmentally preferable approach to reduce Stormwater runoff entering combined or separate sewer systems in combination with or in lieu of centralized hard infrastructure. (EPA, 2007)

3) **Consumer Demand.** Large corporations and companies are beginning to focus on social and environmental responsibility, allocating funds and effort to research into alternative energy sources and actions they can take to be better stewards of the environment.

2. Low Impact Development

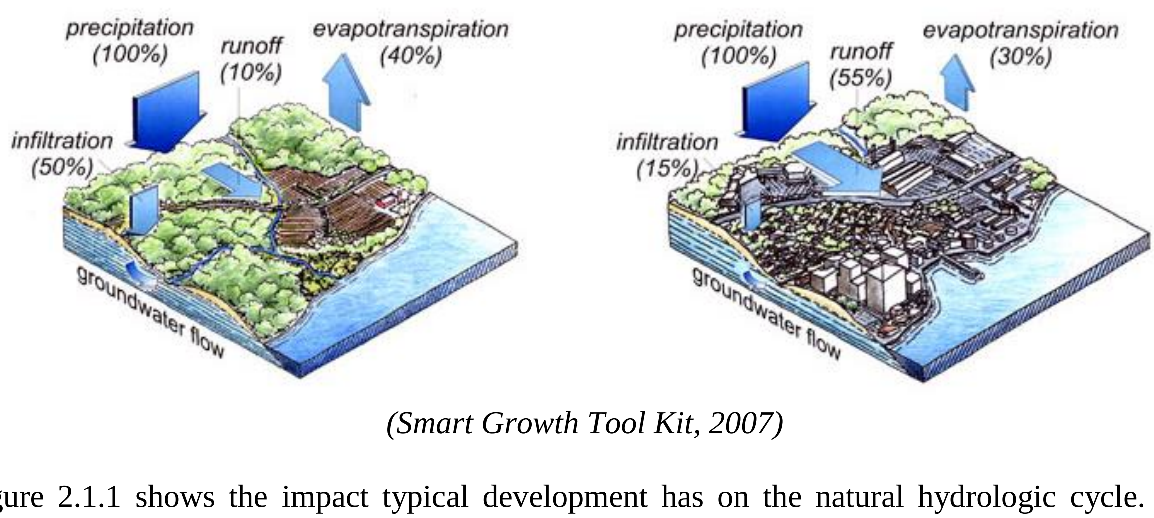
2.1. What is Low Impact Development (LID)?

LID is an approach to land development that uses various land planning techniques, design practices and technologies to simultaneously conserve and protect natural resource systems. It is an innovative multi-step Stormwater management approach that 1) utilizes thoughtful site planning and 2) manages rainfall at its source through the use of integrated and distributed micro-scale Stormwater practices.

Examples of thoughtful site planning include: the preservation/protection of environmentally sensitive site features such as riparian buffers, wetlands, steep slopes, valuable (mature) trees, flood plains, woodlands, and highly permeable soils. Examples of integrated and distributed micro-scale Stormwater practices include: bioretention, permeable pavers, flow through planters, disconnected downspouts, rain barrels, and green roofs, among others (refer to Section 4). Ultimately, natural hydrologic functions such as storage, infiltration, evaporation, transpiration, and groundwater recharge are used to their fullest potential to help minimize the amount of Stormwater runoff that must be managed. This helps users to control pollutants, reduce runoff volume, manage runoff timing, and address other ecological concerns.

In contrast, conventional land development techniques typically begin with clearing and grading the entire parcel, resulting in the removal of all vegetation. The next development steps traditionally include paving areas for roads and parking, building structures, and landscaping areas. This results in large amounts of impervious surface which prohibits Stormwater from infiltrating into the ground to replenish the groundwater or supply local streams and wetlands with baseflow. In order to manage the large amount of runoff generated from the impervious surface created from development, engineers then design structural Stormwater controls such as catch basins, pipes, and detention ponds.

Figure 2.1.1: Impacts of Typical Development to the Natural Water Balance



(Smart Growth Tool Kit, 2007)

Figure 2.1.1 shows the impact typical development has on the natural hydrologic cycle. As mentioned above, typical development creates large areas of impervious surface, which prevents infiltration and subsequently generates larger runoff volumes. Under natural predevelopment conditions, more rain infiltrates through soils and percolates downward to the groundwater table.

Fact sheets and referenced attachments for a number of onsite Stormwater reduction practices are provided in Section 4.

4.1 Green Roofs: A green roof (vegetated roof/eco roof/roof garden) is a system consisting of waterproofing material, growing medium and vegetation. A green roof can be used in place of a traditional roof as a way to limit impervious site area and manage Stormwater runoff. See **Attachment 2** for design guidelines, examples and a typical detail.

4.2 Permeable Pavement Systems: Permeable Pavement provides the structural support of conventional pavement, but allows Stormwater to drain directly through the surface into the underlying stone base and soils, thereby reducing Stormwater runoff. There are permeable varieties of asphalt, concrete, and interlocking pavers. Permeable pavements are designed with an open graded stone sub-base that allows water to pass through to the native soil and provides temporary storage. See **Attachment 3** for design guidelines, examples and a typical detail.

4.3 Rain Water Harvesting: Rain barrels, cisterns, and tanks are structures designed to intercept and store runoff from rooftops. Rain barrels are used on a small scale while cisterns and tanks may be larger. See **Attachment 4** for design guidelines, examples and a typical detail.

4.4 Filter Strips: Filter Strips are densely vegetated lands that treat sheet flow Stormwater from adjacent pervious and impervious areas. They function by slowing runoff, trapping sediment and pollutants, and in some cases infiltrating a portion of the runoff into the ground.

4.5 Bioinfiltration/Bioretention/RainGarden: Bioretention areas typically are landscaping features adapted to treat Stormwater runoff. Bioretention systems are also known as Mesic Prairie Depressions, Rain Gardens, Infiltration Basins, Infiltration swales, bioretention basins, bioretention channels, tree box filters, planter boxes, or streetscapes, to name a few. Bioretention areas typically consist of a flow regulating structure, a pretreatment element, an engineered soil mix planting bed, vegetation, and an outflow regulating structure. See **Attachment 5** for design guidelines, examples and a typical detail.

4.6 Low Impact/Retentive Grading: Low Impact and Retentive Grading techniques focus on utilizing existing topography during Site layout to minimize cost. Proposing structures, roads, and other impervious surfaces along existing high ground will allow for Stormwater to drain onto adjacent Stormwater utilities with a minimum of earthwork required.

4.7 Swales: A swale is a vegetated open channel, planted with a combination of grasses and other herbaceous plants, shrubs, or trees. A traditional swale reduces peak flow at the discharge point by increasing travel time and friction along the flow path. See **Attachment 6** for design guidelines, examples and a typical detail.

4.8 Subsurface Infiltration: Subsurface infiltration systems are designed to provide temporary below grade storage infiltration of Stormwater as it infiltrates into the ground. Dry wells, infiltration trenches and beds are a few examples of these types of systems.

4.9 Inlet and Outlet Control: Inlet and Outlet controls are the structures or landscape features that manage the flow into and out of a Stormwater management facility. Flow splitters, level spreaders, curb openings, energy dissipaters, traditional inlets, and curbless design are all examples and elements of inlet controls.

4.10 Filters: Filters are structures or excavated areas containing a layer of sand, compost, organic material, or other filter media. They reduce pollutant levels in Stormwater runoff by filtering sediments, metals, hydrocarbons, and other pollutants.

4.11 Subsurface Vaults: Subsurface Vaults are specialized underground structures designed similarly as above ground detention or retention basins. These underground basins can be utilized for groundwater recharge by allowing infiltration.

4.12 Detention Basin: Detention Basins can be a cost effective method to provide temporary storage, conveyance, and treatment of runoff when used within the context of Low Impact Development (LID) strategies. Long, linear, interconnected basins can provide the designer with an economically attractive method to provide source control of Stormwater as well as convey water without the slope and cover requirements of conventional storm sewer design.

2.2. Why use LID (Incentives)?

2.2.1. Incentives and Grants

The City has established incentive and grant programs to help encourage the use of green infrastructure. These incentives are designed to help developers offset costs of green improvements through rebates and grants and to help expedite permitting of sustainable projects. The incentives apply to both new construction and renovations. The following are descriptions of those programs that are available:

1.) **Credit Incentive Program.** The Department of Public Works has developed a system of credits for the stormwater user fee imposed on the users of the Marion County Stormwater Management District's stormwater system. The ability of a property owner to receive any of the credits is dependent on the property owner owning and maintaining a Department-approved BMP and providing the document required. Table 2.1 outlines the types of credits available to residential and non-residential property owners. Additional information regarding stormwater credits can be found within the latest version of the City of Indianapolis Stormwater Credit Manual.

Table 2.1 - Available Credits for Residential and Non-Residential Parcels

	Residential Parcels	Non-Residential Parcels		
Credit Category	**Individual Residential Parcel**	**Homeowners or Condominium Association**	**Commercial, Industrial, Mix-Use Development, Other Non-Residential**	**Public/Private School, Primary to 12**
Individual Residential Property Credit	25%			
Tier 1 Stormwater Quality and Quantity Credit		Up to 10%*	Up to 10%	Up to 10%
Tier 2 Stormwater Quality and Quantity Credit		Up to 30%*	Up to 30%	Up to 30%
Infiltrative Credit		20%*	20%	20%
Education Credit				5%
Direct Discharge Credit		Up to 50%	Up to 50%	Up to 50%
Total	**Up to 25%**	**Up to 50%**	**Up to 50%**	**Up to 50%**

*The maximum credit or combination of credits given to any one property shall be 50% for non-residential property owners and 25% for residential property owners.

2) **Green Building Incentive Program.** The green building incentive program is designed to create incentives for property owners and developers who renovate and/or construct new buildings in a sustainable manner, and is the first of its kind in Indianapolis. The program allows for building projects to receive up to a 50% rebate on all building permit fees associated with the green project. The incentive encourages building owners and developers to integrate sustainable design techniques and practices into building projects. More information is available at: http://www.indy.gov/eGov/City/DPW/SustainIndy/Green/Pages/GreenBuildingIncentiveProgram.aspx

3) **Sustainable Infrastructure Initiative.** Plans must still meet the Stormwater requirements outlined in Chapter 700 of the Stormwater Design and Construction Specifications Manual, but designs and plans that use green infrastructure techniques as defined in the Green Supplemental Document to meet those requirements will be approved by the Office Department of Code Enforcement.

Upon submittal of projects that incorporate these green techniques, permit review will be immediately processed and expedited to the greatest extent possible. This will not only encourage newcomers to utilize green infrastructure methods, but it will also reinforce the City's commitment to those already well versed in green infrastructure techniques.

In order to alert the Department of Code Enforcement staff that the project being submitted incorporates green infrastructure, each green project will require a green infrastructure checklist to accompany the green project designs. When Department of Code Enforcement staff sees the Sustainable Infrastructure checklist submitted with a project design, it will alert them that the project incorporates green infrastructure and the permit review will be immediately processed and expedited to the greatest extent possible. More information is available at:
http://www.indy.gov/eGov/City/DPW/SustainIndy/WaterLand/Pages/SustainableInfrastructure.aspx

4) **Green Infrastructure Grant Program.** The City of Indianapolis' Office of Sustainability and United Water have partnered to announce that applications are available for the Green Infrastructure Grant Program. This year, $100,000 in funding will be granted to organizations who utilize green infrastructure projects designed to improve water quality and reduce Stormwater runoff.
Maximum Grant Award: $20,000 (requires 20 percent matching contribution, match may be provided by applicant, LISC, a CDC, or another entity).
Eligible Entities: Not-for-profit organizations committed to efforts in sustainable development within Marion County, For-Profit Organizations (with approval)
More information is available at:
http://www.indy.gov/eGov/City/DPW/SustainIndy/WaterLand/GreenInfra/Pages/GreenInfrastructureGrantProgram.aspx

5) **Rain Garden and Native Planting Programs.** To promote rain gardens and native planting areas, the City of Indianapolis has established a Rain Garden Resource Center outlining supplies, customized planting plans, maintenance guidelines, permitting guidance, and more. The resource center is intended to be used by residents, businesses, developers, and institutions. Rain gardens and native planting areas can vary in size from a small rain garden in the corner of a residential lot to a large bioretention area receiving runoff from a commercial strip mall. Permitting requirements are most likely an issue only for larger projects, especially those that tie into City drainage, but the owners of all rain garden and native planting projects must check the permitting guidance. Information is available at:
www.indy.gov/eGov/City/DPW/SustainIndy/WaterLand/GreenInfra/Pages/RainGardenResources.aspx

2.2.2. Ancillary Benefits from LID Stormwater Management Techniques

LID Stormwater management techniques can be used to meet supplementary goals (or in many instances other existing City regulations) in addition to meeting the existing Stormwater requirements. A development or redevelopment site often has a required amount of green space or landscape requirements that must be met along with the Stormwater management requirements. Many LID Stormwater management techniques can be integrated into urban site features. In addition to meeting regulatory measures, some of the specific ancillary benefits from LID techniques/Green Infrastructure include (*EPA, 2007*):

Cleaner Water - Vegetation and green space reduce the amount of Stormwater runoff and, in combined systems, the volume of combined sewer overflows.

Enhanced Water Supplies - Most green infiltration approaches result in Stormwater percolation through the soil to recharge the groundwater and the base flow for streams.

Cleaner Air - Trees and vegetation improve air quality by filtering many air borne pollutants and can help reduce the amount of respiratory illness.

Reduced Urban temperatures - Summer city temperatures can average 10°F higher than nearby suburban temperatures. High temperatures are linked to higher ground level ozone concentrations. Vegetation increases shade, reduces the amount of heat absorbing materials and emits water vapor - all of which cool hot air.

Increased Energy Efficiency - Green spaces help lower ambient temperatures by shading and insulating buildings. Thereby decreasing energy needed for heating and cooling.

Community Benefits - Trees and plants improve urban aesthetics and community livability by providing recreational and wildlife areas and can raise property values.

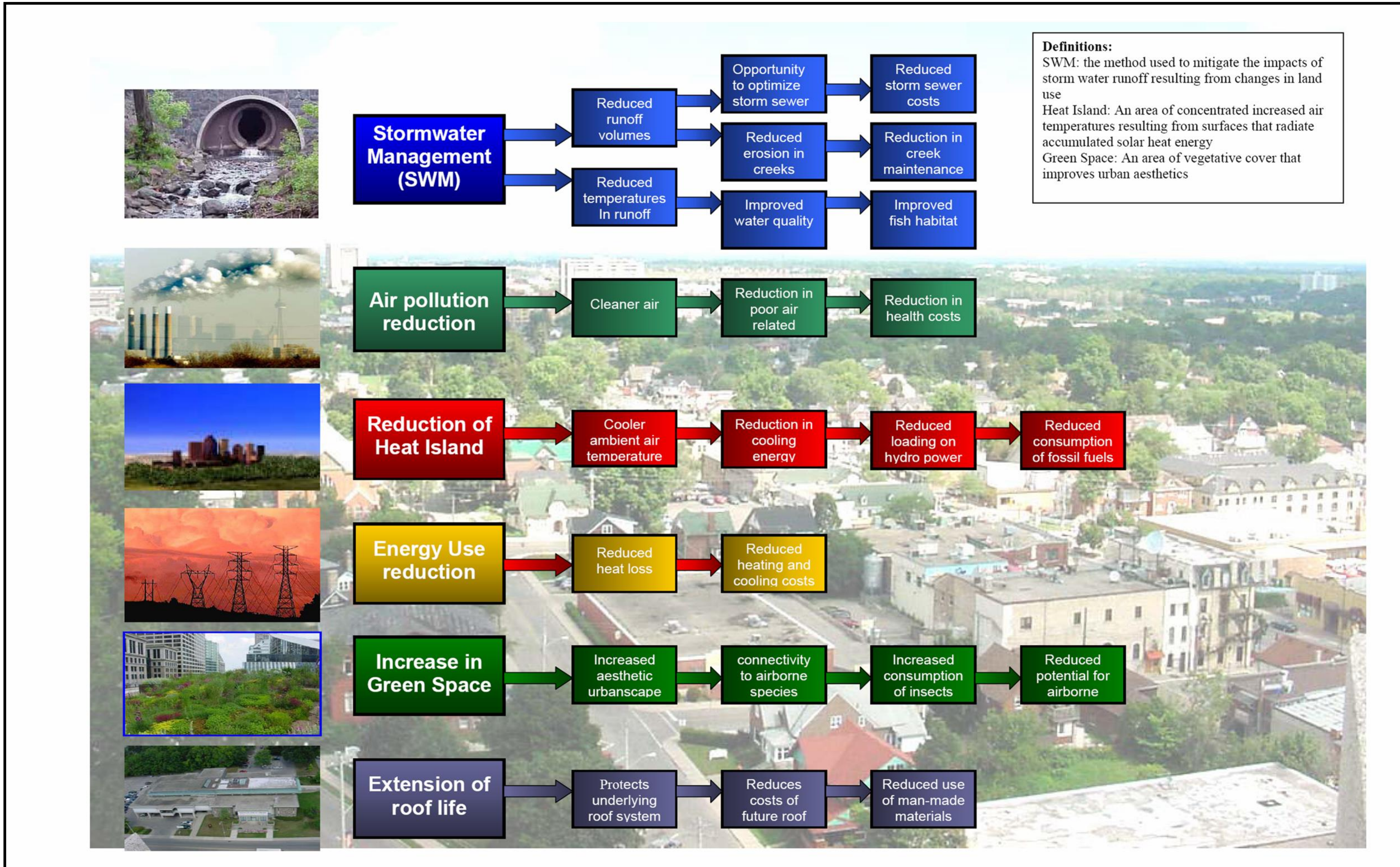
Cost Savings - Green infrastructure may save capital costs on digging big tunnels and Stormwater ponds, operations and maintenance expenses for treatment

Leadership in Energy and Environmental Design (LEED) credits.-The LEED program is used by many organizations and communities to certify buildings as being innovative and environmentally responsible. A LEED certified facility can offer competitive advantage and increase real estate value, thus improving its marketability. Appendix 1 provides a description of potential LEED credits for various Stormwater management techniques.

In general, many of the green infrastructure techniques provide the ancillary benefits listed above; specifically green roofs and their associated benefits are further identified in Figure 2.1.2

THIS PAGE LEFT BLANK INTENTIONALLY

Figure 2.1.2: Green Roof Technology Chain of Benefits
(TSH Associates, 2004)



THIS PAGE LEFT BLANK INTENTIONALLY

There are many ancillary benefits associated with green roofs, supplemental to Stormwater management, as demonstrated by Figure 2.1.2. Although these benefits are well documented, there is not a wide variety of tools available to actualize these benefits monetarily. However, Green Roofs for Healthy Cities (GRHC) and the Athena Institute, with funding by TREMCO Inc, recently developed a comprehensive life cycle costing (LCC) calculator. The LCC calculator allows users to evaluate both the hard and soft costs associated with green roofs versus conventional roofing systems and cool roofing system (white roofs) over a specified time period. Provided below, in Table 2.1.1 is an example case study demonstrating this tool. In addition Appendix 2 provides a publication from TREMCO for immediate release titled *New Life Cycle Calculator Compares the Cost of Green Vegetative Roofs with Conventional Roof Systems* and an abstract titled Life Cycle Cost Calculator-Phase 1 published by Green Roofs for Healthy Cities from the 2007 Proceedings from the Greening Rooftops for Sustainable Communities Conference, Awards and Trade Show.

Table 2.1.1: Green Roof Cost Comparison to Conventional Roofing System and Cool Roofing System (www.greenroofs.net)

Common Assumptions	Input Data		
	Scenario 1	Scenario 2	Scenario 3
	Conventional Mod. Bituminous	**PVC Single Ply Cool Roof**	**Extensive Green Roof**
Project Initiation Year	2007	2007	2007
Study Period in Years	25	25	25
Applicable discount rate (%)	8	8	8
General Price Inflation Factor (%)	2.04	2.04	2.04
Thermal Fuel Energy Price Inflation Factor (%)	9	9	9
Electricity Price Inflation Factor (%)	3	3	3
Investment Data			
Investment Description	**Conventional Mod. Bituminous**	**PVC Single Ply Cool Roof**	**Extensive Green Roof**
Total Installed Capital Cost	49,728.00	41,440.00	103,600.00
Annual Electricity Energy Cost	250.00	233.00	232.00
HVAC Downsizing Capital Savings	0.00	0.00	0.00
Stormwater Control	0.00	0.00	3,850.00
Annual Maintenance Cost	761.00	557.00	306.00
Roofing Replacement Interval (in years)	16.00	12.00	25.00
Periodic Replacement Cost	48,317.00	37,140.00	491.00
Periodic Savage Value (at roof replacement)	0.00	0.00	0.00
End of Life Residual Value	16,653.00	25,548.00	23,206.00
UHI Effect Mitigation (capital cost savings)	0.00	0.00	0.00
Development Fee Reduction (capital cost savings)	0.00	0.00	2,500.00
Annual Increase in Revenue due to Roof System	0.00	0.00	2,500.00
Annual Increase in Revenue due to Productivity and Health	0.00	0.00	2,000.00
Net Capital Cost (year 0)	38,065.00	27,870.00	54,868.00
Other Annual Cost or Benefits	0.00	0.00	0.00
Financial Results Summary			
At a discount rate of (%)	8.00	8.00	8.00
NPV for study period (yrs)	-142,393.00	-136,068.00	-103,562.00
NPV at 1/3 of study period	-66,605.00	-55,014.00	-67,406.00
NPV at 2/3 of study period	-114,592.00	-101,271.00	-84,292.00
Simple Payback Period on total project investment (yrs)	Payback Period Longer than Study Period	Payback Period Longer than Study Period	Payback Period Longer than Study Period

The table above is simply an example of a tool that can be utilized when evaluating different options in project planning for a roofing system. In the example provided above, green roofs are the most favorable option for the entire projected life of the project. However, another favorable roofing option is the PVC single ply cool roof. The PVC single ply cool roof has the best value when evaluating the project at 1/3 of the study period.

A single ply cool roof can be manufactured in a bright-white color for high solar reflectance -or albedo - and increased energy savings. White single ply membranes are highly reflective, as compared to traditional bituminous roofing material, and can help reduce the urban heat island as well as save the building owner cooling costs. Another roofing option, to help reduce the urban heat island is reflective tiles. Reflective tiles are usually made of clay or concrete, and manufactures have begun to develop pigments that reflect in the infrared. Special pigments allow roofing material to keep their traditional colors, such as brown, green, and terra cotta, while reflecting away up to 70% of the sun's energy. These products enable buyers to forego the perceived tradeoff between energy efficiency and the aesthetic concerns with a bright-white roof (EPA, 2007).

2.2.3. Reduction in Stormwater Infrastructure Sizing

In general, the Stormwater sizing criteria provide a strong incentive to reduce impervious cover at development and redevelopment sites (e.g., water quality and quantity). The following section provides examples of how the Stormwater sizing criteria, both water quality and quantity, can be used as an incentive to incorporate LID Stormwater management techniques into design.

2.2.4. Water Quality Volume Reduction

Storage requirements for WQ_v sizing criteria are directly related to impervious cover. Thus, significant reductions in impervious cover result in smaller required storage volumes and, consequently, lower BMP construction costs. Below is the WQ_v sizing criteria equation.

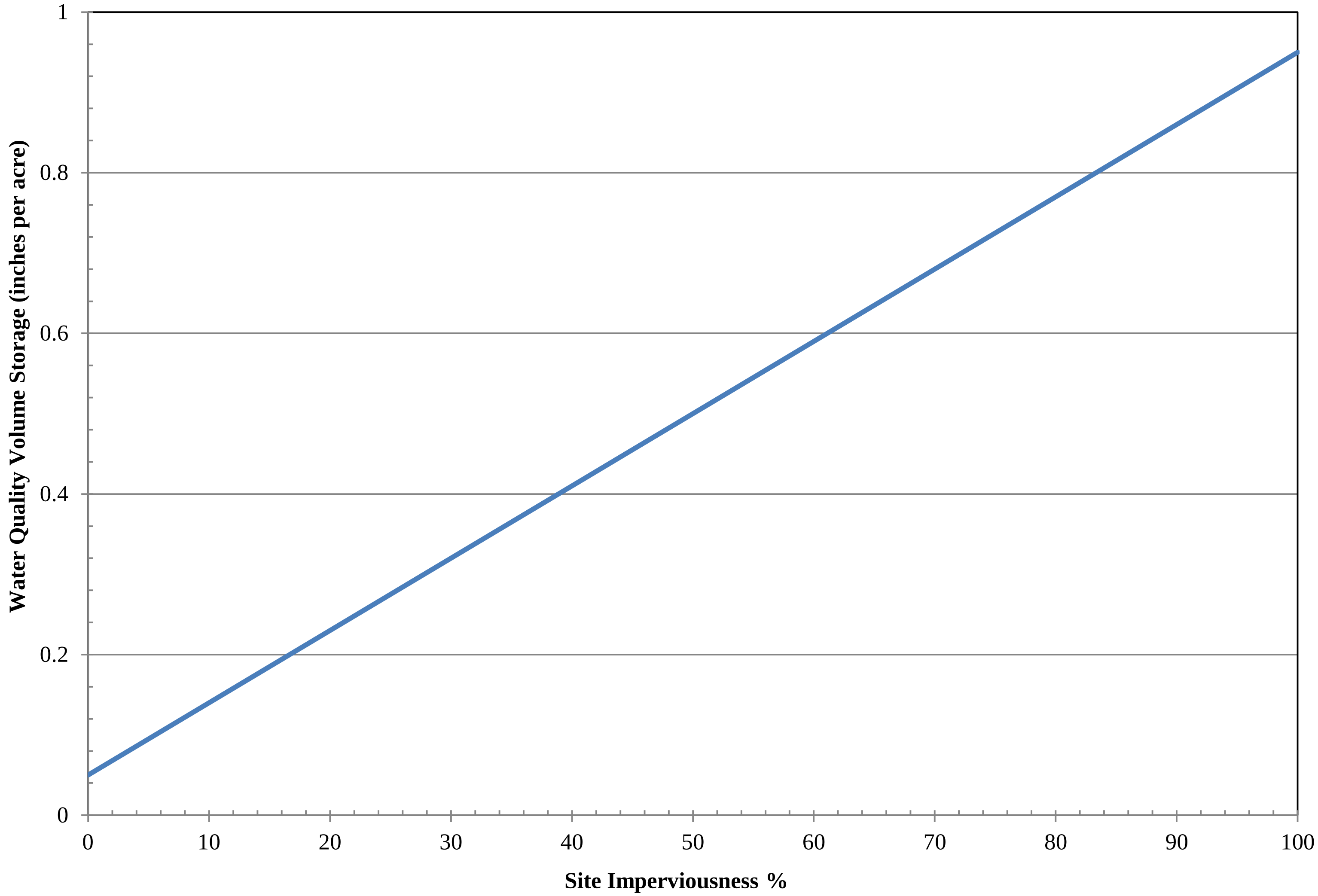
$$WQ_v = \frac{(P)(R_v)(A)}{12}$$

where:

WQ_v = water quality volume (acre-feet)
P = 1 inch of rainfall
R_v = 0.05 + 0.009(I) where I is the percent impervious cover
A = area in acres

The graphical solution to the equation is provided as Figure 2.1.3.

Figure 2.1.3: Relationship Between Required Water Quality Volume Storage and Site Imperviousness (%)



As demonstrated in Figure 2.1.3, if a developer reduces the percent (%) impervious area of a 20 acre parcel from 60% impervious to 40 % impervious by utilizing porous pavement, or other practices demonstrated in Chapter 4 (green infrastructure fact sheets) the resulting water quality volume storage to treat would be decreased from 0.59 inches/acre (11.8 inches) to 0.41 inches/acre (8.2 inches).

2.2.5. Water Quantity Reduction

A commonly used method to determine the Stormwater runoff depth for post development is the NRCS SCS curve number method. The major factors that determine the runoff curve number are the hydrologic soil group (HSG), land cover type, land treatment, hydrologic condition, and antecedent runoff condition. The NRCS (SCS) runoff equation is as follows:

$$Q_v = \frac{(P\ I_a)^2}{(P\ I_a) + S_m}$$

where:
Q_v = runoff (inches)
P = rainfall (inches)
S_m = potential maximum retention after runoff begins
I_a = initial abstraction

The SCS has found the I_a to be approximated by the following empirical equation:

$$I_a = 0.2\,S_m$$

By substituting Equation 205.02 into Equation 205.01, the following runoff equation is derived:

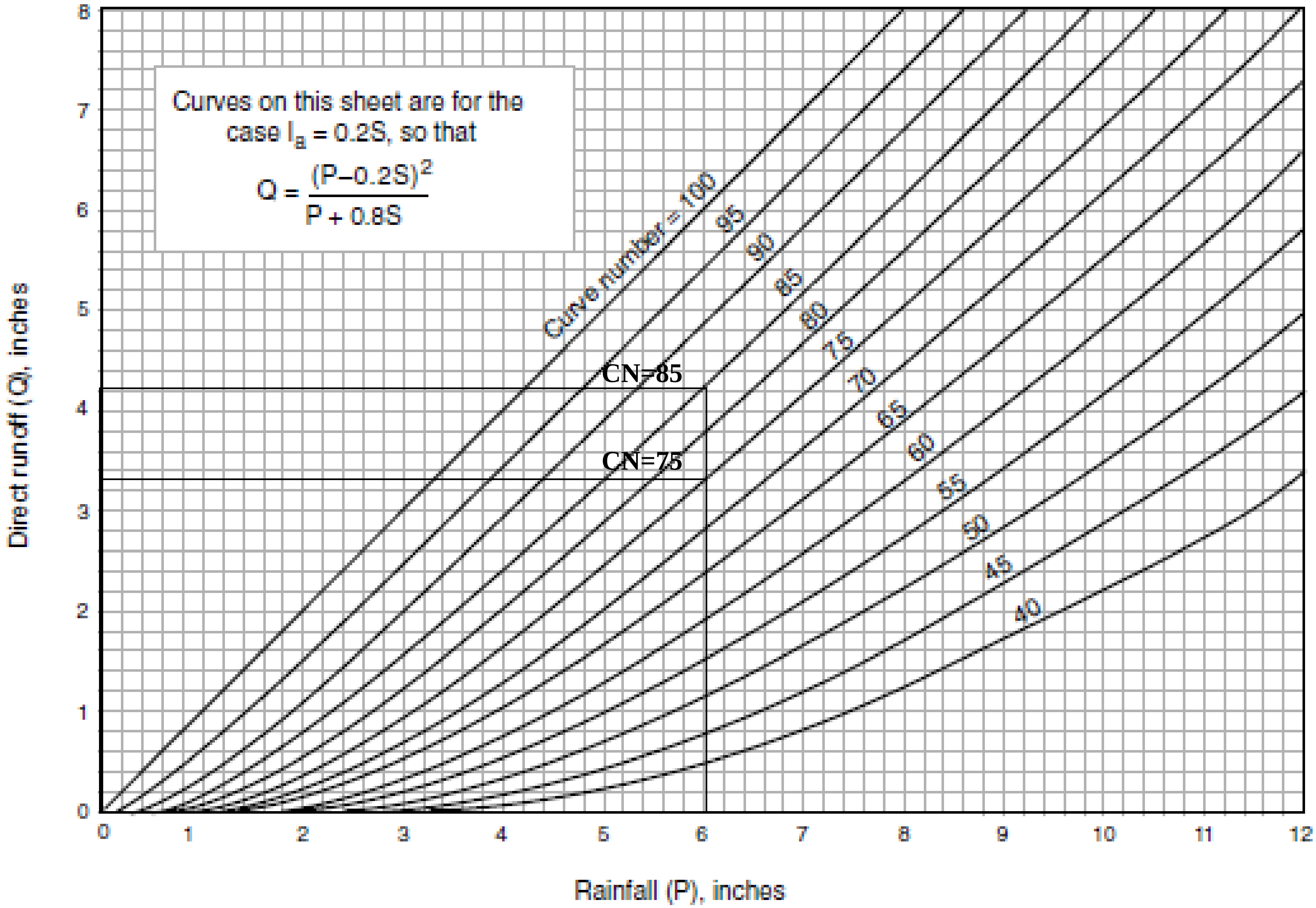
$$Q_v = \frac{(P0.2\,S_m)^2}{P + 0.8\,S_m}$$

The value of S_m is related to the soil and cover conditions of the watershed through the CN. The value of CN has a range of 0 to 100, and S_m is related to CN by the following equation:

$$S_m = (1000/CN) - 10$$

Each of the land use types is assigned a CN. The CNs are traditionally used as a factor to estimate the characteristic runoff from a land surface area as a function of the rainfall amount and pattern. A graphical solution to the runoff equation is provided in Figure 2.1.4:

Figure 2.1.4: SCS Solution of the Runoff Equation
(Source: SCS, TR-55, Second Edition, June 1986)



As demonstrated by Figure 2.1.4, approximately 4.1 inches of direct runoff would result if 5.8 inches of rainfall occurs on a watershed with a curve number of 85. In contrast, approximately 3.1 inches of direct runoff would result if the same 5.8 inches of rainfall occurs on a watershed with a curve number of 75. The amount of direct runoff (Q_v) can be reduced by lowering the CN.

The designer can compute curve numbers (CN) based on the actual measured impervious area at a site using:

$$CN = \frac{(98)I + \sum (CN_P)(P)}{A}$$

Where:

CN_P = curve number for the appropriate pervious cover
I = impervious area at the site
P = pervious area at the site
A = total site area

An example of a conventional site design with the computed CN is provided below. The same site is then designed using various LID Stormwater management techniques and the resulting CN computation is provided. *(The following example problem is from the Milwaukee Metropolitan Sewerage District: Surface Water and Stormwater Rules Guidance Manual Low Impact Development Documentation 2005: Refer to Appendix 3 for further description of a LID design and review spreadsheet that allows users to quickly evaluate various LID techniques to reduce the detention requirement.)*

Figure 2.1.5: Conventional Site Example
(MMSD Low Impact Development Documentation, 2005)

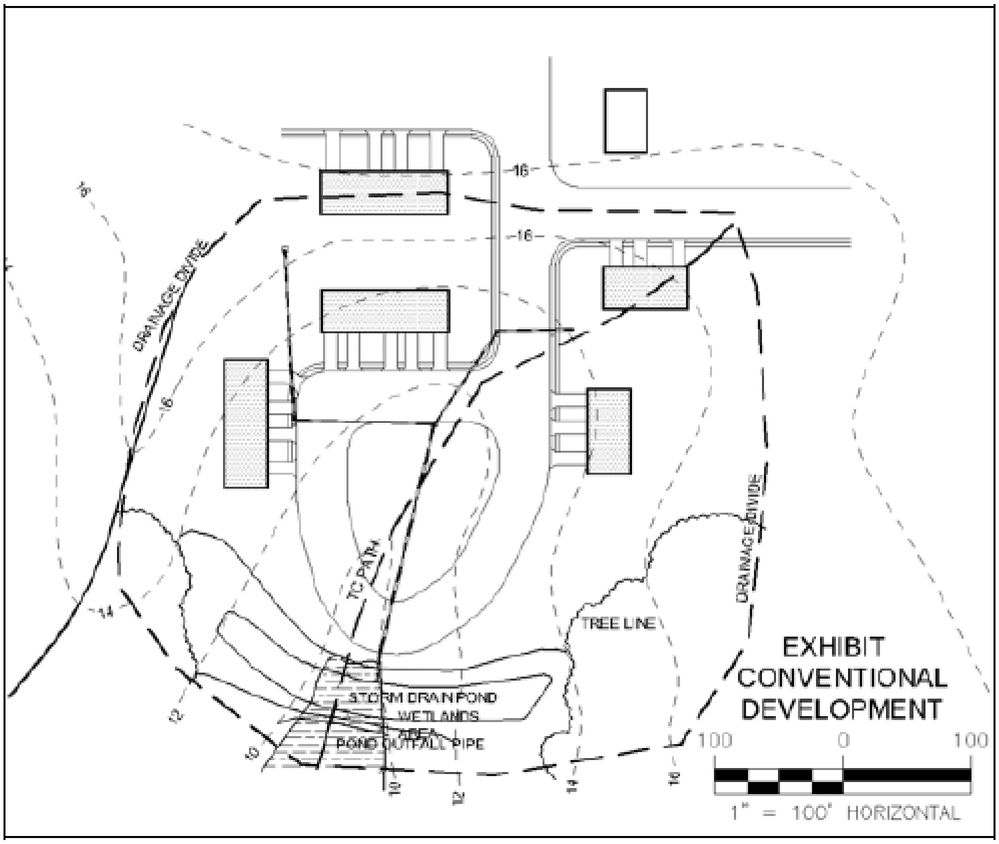


Table 2.1.2: Area-Weighted CN Calculation for Conventional Design
(MMSD Low Impact Development Documentation, 2005)

Hydrologic Soils Group	Cover Description	CN (Table 2-2 TR-55)	Area (Acres)	Product of CN x Area
B	Lawn (fair condition)	69	3.2	220.8
B	Woods, Fair	60	0.7	42.0
B	Impervious	98	2.6	254.8
			Sum of Products	**517.6**
			Divided by Drainage Area	6.5
			Weighted CN	**80**

Figure 2.1.6: LID Site Example
(MMSD Low Impact Development Documentation, 2005)

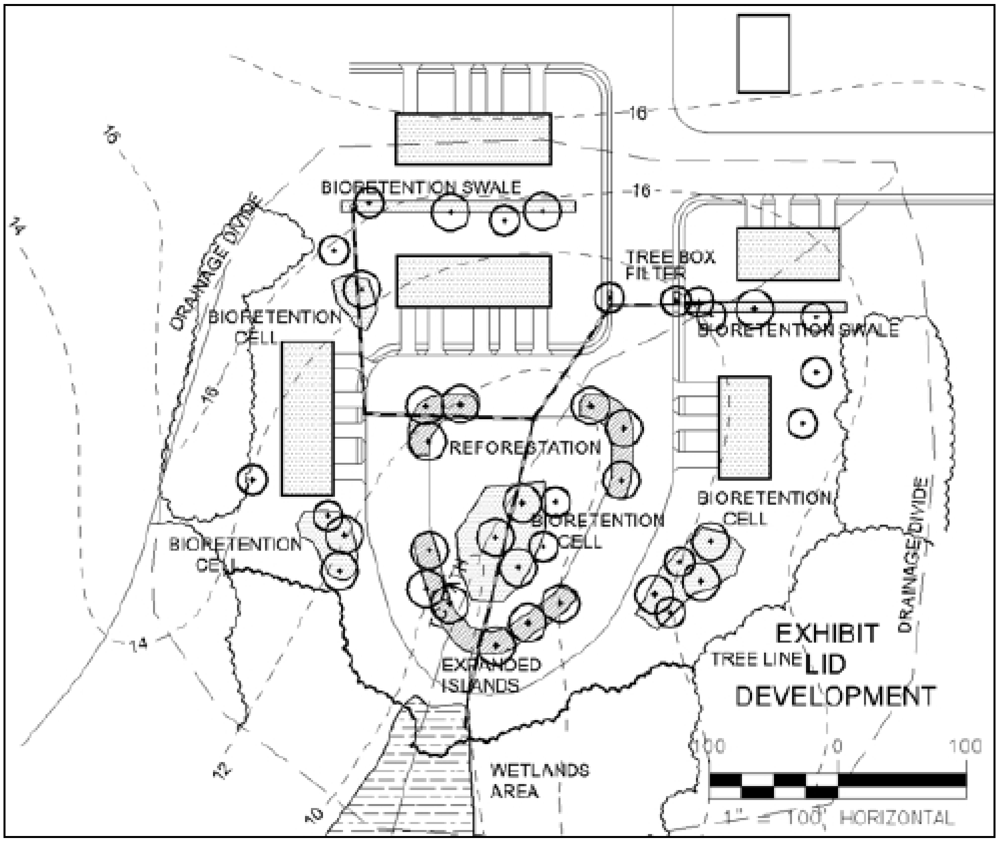


Table 2.1.3: Area Weighted CN Calculation for LID Design
(MMSD Low Impact Development Documentation, 2005)

Hydrologic Soils Group	Cover Description	CN (Table 2-2 TR-55)	Area (Acres)	Product of CN x Area
B	Lawn (good condition)	61	1.8	109.8
B	Woods, Fair	60	2.5	150.0
B	Impervious	98	2.2	215.6
			Sum of Products	**475.4**
			Divided by Drainage Area	6.5
			Weighted CN	**73**

Figures 2.1.5 and 2.1.6 demonstrate conventional and LID site plans for a 6.5 acre residential townhouse development. Tables 2.1.2 and 2.1.3 demonstrate the weighted curve number calculation for each site. The reduction in the curve number from 80 to 73, was achieved primarily by increasing the amount of wooded area. In addition several bioretention areas (rain gardens), and tree box filters were integrated into the design.

According to the standard NRCS runoff depth calculation, for a 2.57-inch storm, the lower curve number will reduce the depth of runoff from 0.9 to 0.6 inches. For this specific example, when the bioretention areas (rain gardens) that have an average ponding depth of 6 inches and a subsurface storage capacity of 3 inches, the LID spreadsheet (provided in Appendix 3), indicates that only 2.2% of the site area is needed to reduce the peak flow to a target level of 0.15 cfs/acre. Without the reduction in curve number, approximately 5.0% of the area would be needed.

Figure 2.1.7 and 2.1.8 are conceptual design examples completed to compare conventional Stormwater design with low impact development. The conceptual site design examples provide a detailed analysis for both a redevelopment and new development site consisting of: site layouts, water quality and quantity calculations, and landscape requirements for both a traditional site layout and an LID layout. The complete redevelopment and new development site reports are provided as Appendix 5 and Appendix 6, respectively.

Figure 2.1.7: Redevelopment Site Design Example Conventional vs. LID

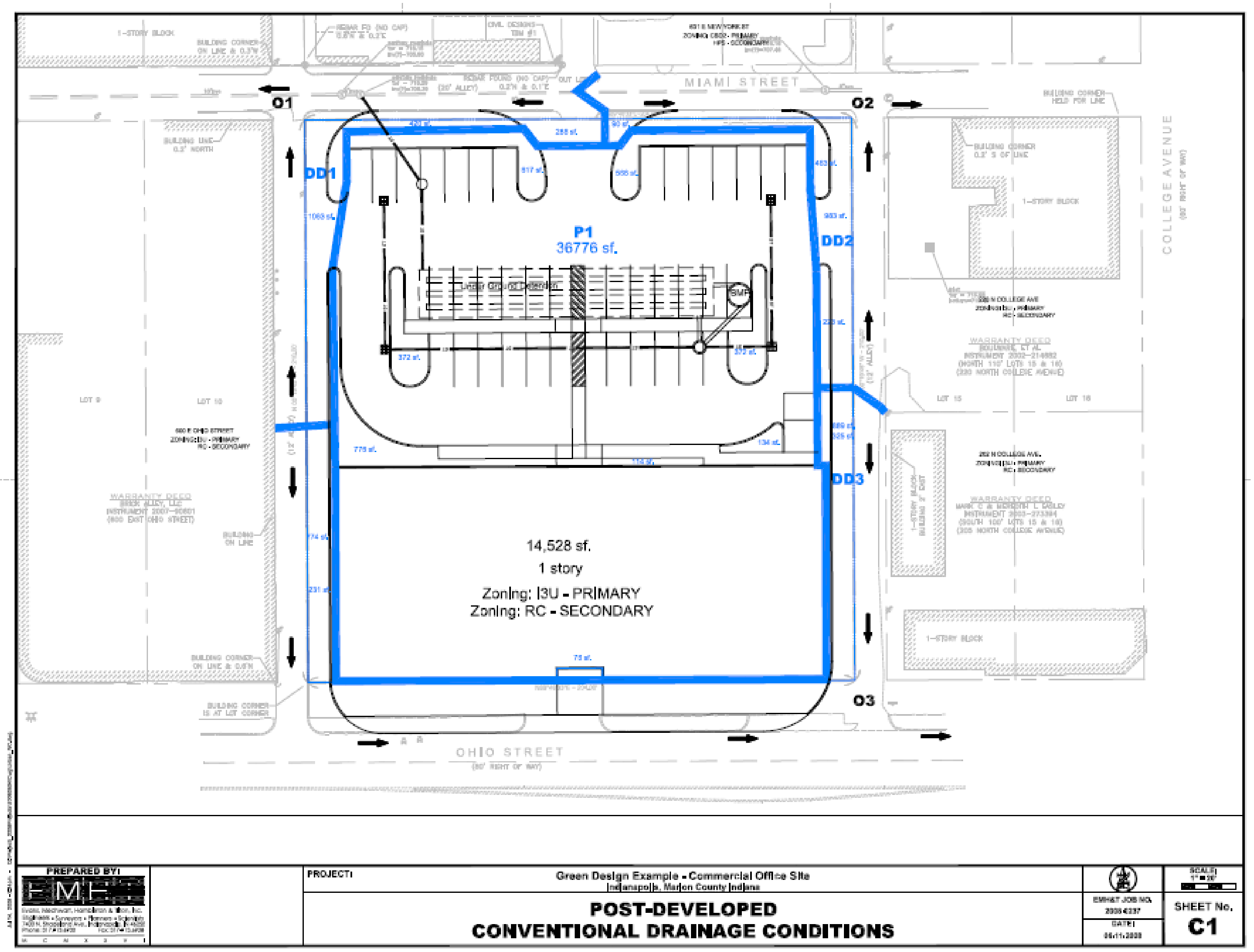


Figure 2.1.7: Redevelopment Site Design Example Conventional vs. LID, cont.

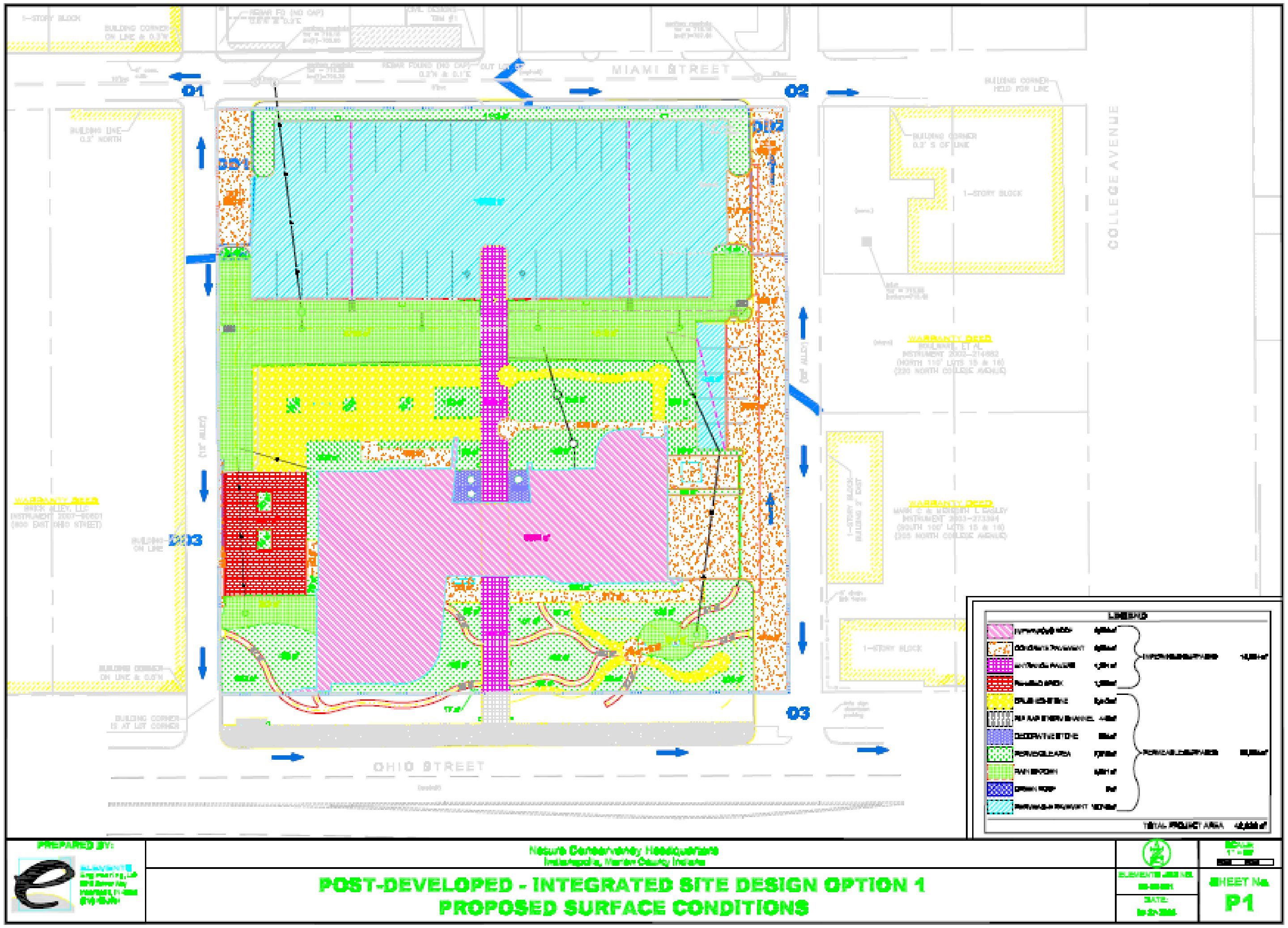
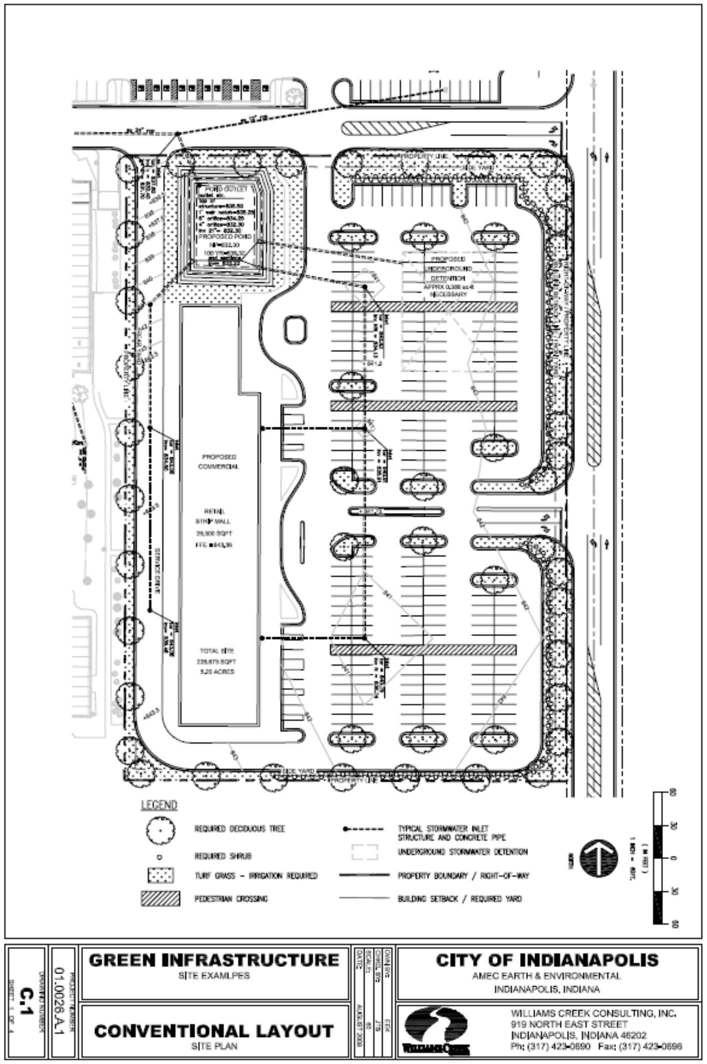
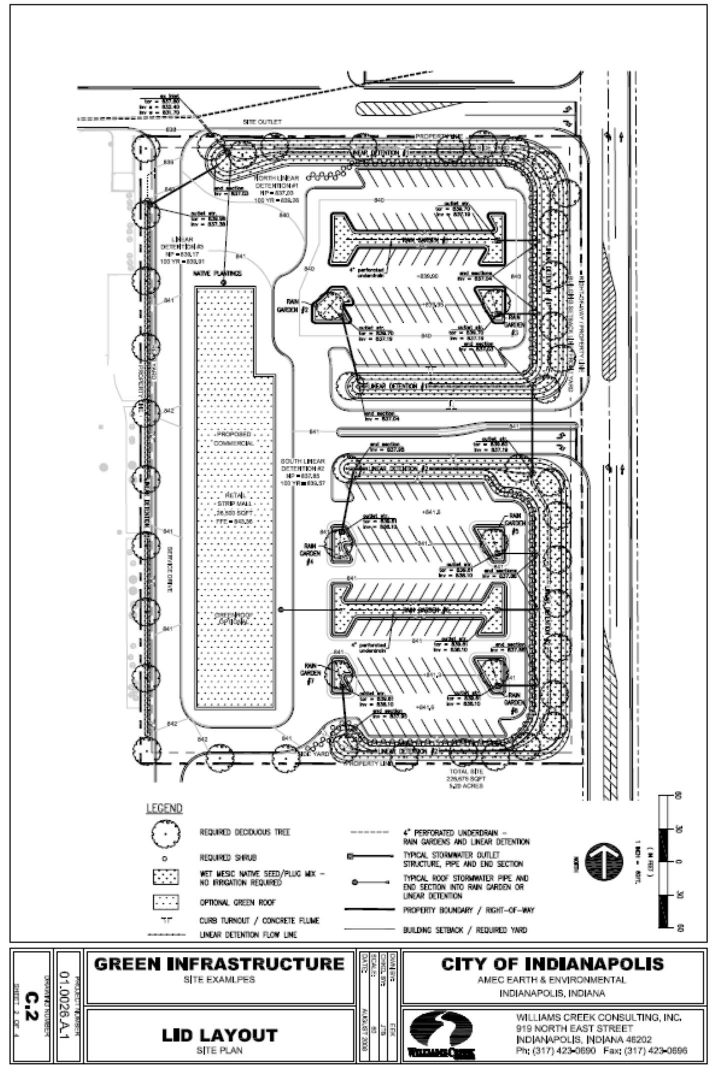


Figure 2.1.8: New Development Site Design Example Conventional vs. LID





2.2.6. Reduction in Stormwater Fee

The City County Council of the City of Indianapolis - Marion County, Indiana passed General Ordinance No. 43, which created a county-wide Marion County Stormwater Management District which is administered by the Indianapolis Department of Public Works.

The monthly stormwater fee is based on the measured amount of impervious surface area or hard surface (rooftops, parking lots, driveways) on the piece of property. The Base Billing Unit (BBU) is represented by 1,000 square feet of impervious area.

Every property within the district is subject to the stormwater user fee which is based on the properties measured amount of impervious area. In 2015 the monthly stormwater fee was approved to be $1.10 per BBU on the property. This assessment structure applies to all parcels that have impervious area. Annual adjustments of $.05 per BBU are included in the approved stormwater fee. The City has measured all parcels for impervious area. The number of BBUs assigned to a property will remain constant unless changes are made on the property that alters the amount of its impervious surface area.

2015 Stormwater Fee Calculation Example
Site Area=17,000 square feet
Site Impervious Area=10,000 square feet
1 BBU= 1,000 sqft
1 BBU = $1.10/month
Annual Stormwater Fee = (10,000 sqft/1,000 sqft) *$1.10/month *12 month
Annual Stormwater Fee = $132.00

By reducing the effective impervious footprint of new development or redevelopment the property owner can reduce his/her fee either directly by reduction of impervious surface or through the credit program by using BMPs that reduce the "effective" imperviousness of the site.

2.2.7. Analysis of Stormwater Fee Incentive

The use of low impact development (LID) techniques/green infrastructure is a way that property owners can reduce their impact on the City's Stormwater management system, become eligible for stormwater credits and thus reduce their monthly stormwater fee. In some cases the utilization of LID techniques/green infrastructure and stormwater credits can impact stormwater fees substantially

The relationship between percent (%) impervious area and the stormwater fee is directly proportional. By decreasing the amount of impervious area at a development site, the stormwater fee will subsequently be reduced. It is important for many development projects to add the stormwater fee into the life cycle cost analysis for the site. Evaluating this over the projected project life will provide further incentive to the property owner to invest in the LID techniques.

2.2.8. Options for Small Spaces/Redevelopment Areas

Redevelopment of downtown properties is a significant issue for Stormwater management and combined sewer programs around the globe. In many, if not most instances, these areas are characterized by wall to wall imperviousness, undersized Stormwater infrastructure, and a growing demand to redevelop the space. In Indianapolis, redevelopment interests exist both in the downtown area and in older suburban residential and commercial areas.

Often times, there is not enough land area for traditional Stormwater management, or in many instances the land area is very valuable and developers do not want to lose the potential profits generated from the developable space. Green infrastructure techniques provide various decentralized Stormwater management methods to address these issues developers might face.

Many older suburban and commercial properties throughout Marion County are being redeveloped. These areas must also comply with the City's Stormwater regulations and are areas that would possibly benefit from incorporating LID techniques/green infrastructure.

An example of a commercial redevelopment that integrates various LID techniques/green infrastructures is provided in Figure 2.1.9 (The following design example is from Low Impact Development for Big Box Retailers, November 2005). This case study illustrates the potential for the retrofit of an existing strip shopping center with water quality management practices as part of a redevelopment plan. The redevelopment includes a drive-through fast-food facility and a new retail strip. Stormwater quantity and quality control are provided for these areas. A retrofit of the existing impervious areas with water quality controls is also shown.

As described above, two conceptual site design examples (redevelopment and new development) demonstrating alternative configurations and multifunctional landscape areas are provided as Appendix 5 and Appendix 6. The conceptual site design examples provide a detailed analysis consisting of site layouts, water quality and quantity calculations for both a traditional site layout and an alternative LID layout.

THIS PAGE LEFT BLANK INTENTIONALLY

Figure 2.1.9: Redevelopment LID Water Quality Design Example
(Low Impact Development for Big Box Retailers, 2005)

Existing Commercial Development Retrofit

- The total site area is 20.5 acres. An existing strip mall is located on the eastern 14.75 acres.
- The western 5.75 acres is being developed as a fast-food drive through and small strip retail shops.
- For the western 5.75 acres, demonstrate how to provide storage for the water quality volume (WQV) and to provide detention to limit the 10-yr, 2-hr peak discharge rate to the predevelopment condition.
- Assume that providing storage for 3” of runoff from the post-development impervious area will provide required detention storage for the 10-yr, 2-hr storm.
- WQV = 0.5” of runoff over impervious area.
- Assume drainage area for western section is limited to the 5.75 acres in that section (no offsite runoff, or runoff from the eastern section).

Existing Conditions

- The site drains from northeast to southwest. Slops are from 2 to 3 percent.
- The eastern section has 8.9 acres of impervious area.
- The western section is undeveloped.

Post-Development Conditions

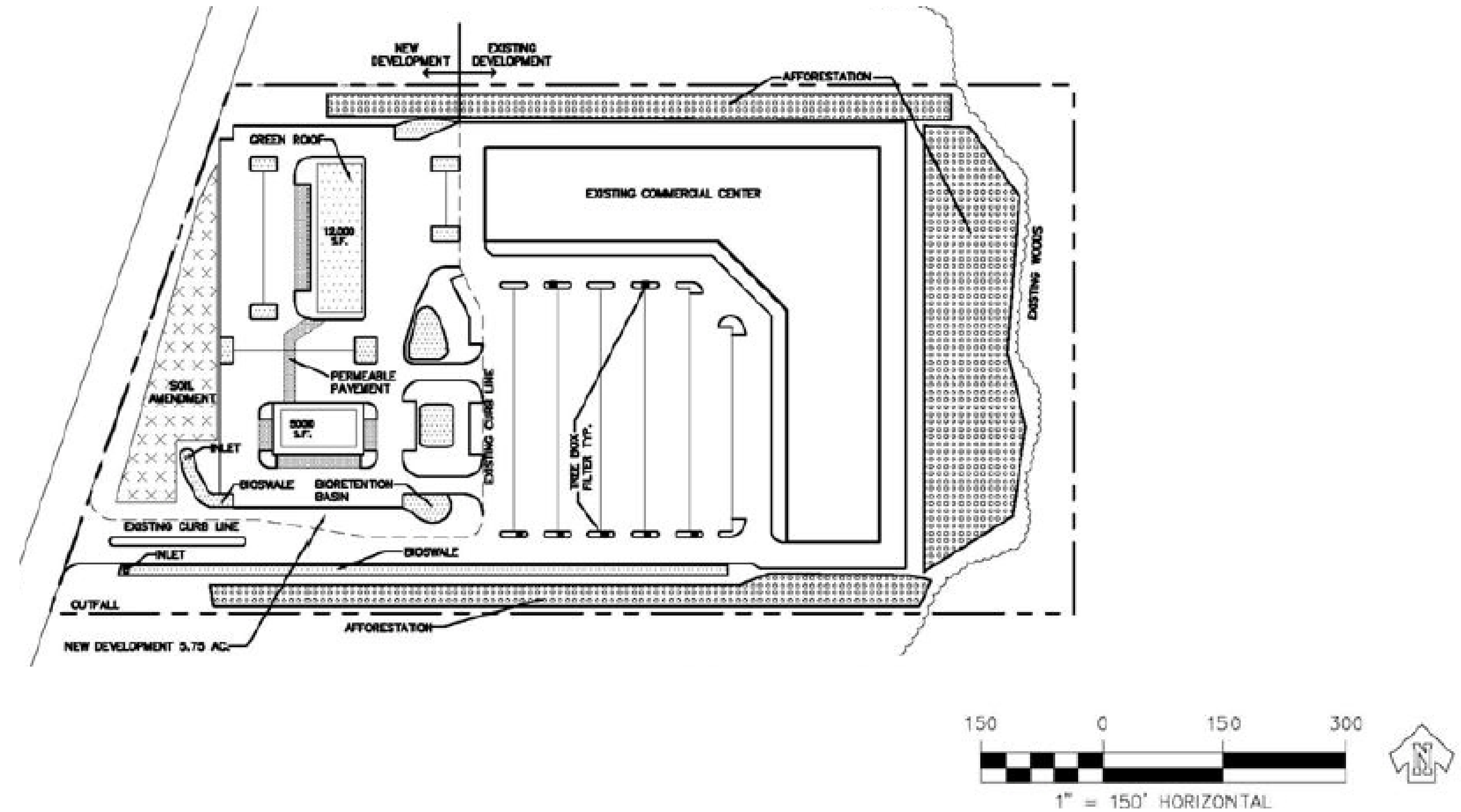
- The western section has 3.4 acres of impervious area.
- Soil amendments are added to 0.66 acres in the western section, increasing the area’s infiltration capacity.
- 2.9 acres across the entire site are afforested.

Result – New Development

- Water quality volume = 6,200 C.F.
  - WQV = 0.5” / (12” per foot) * 3.4 acres * (43,560 S.F. per acre)
- **Detention volume = 37,000 C.F.**
  - Detention volume = 3” / (12” per foot) * 3.4 acres * (43,650 S.F. per acre)
- WQV is contained within the detention volume; therefore, BMPs will be sized to contain the detention volume.

BMPs – New Development

- Use a combination of bioretention basins, bioswales, permeable pavement, and green roof.
- Bioretention basins and bioswales are designed so that surface ponding drains within 24 hours.
- BMPs are sized to collectively capture 3” of runoff from the post-development impervious area.
- One (1) 11,000 S.F. green roof
  - Covers entire 12,000 S.F. roof of strip retail ships except utility areas and access points.
  - Assume 1.5” storage within green roof media and no ponding.
  - Additional storage for roof runoff is provided by adjacent BMPs.



BMPs – Remainder of Site (Existing Development)

- One (1) 10,600 S.F. bioswale with yard inlet
  - Capture runoff from existing roadway to improve water quality.
  - Assume 6” surface storage and 6” subsurface storage area provided.
  - Bioswale is 820’ long and 13” wide.
  - Can also provide conveyance for larger storms.
- Tree box filters provide water quality improvements for existing parking areas in eastern section.

THIS PAGE LEFT BLANK INTENTIONALLY

3. Techniques to Reduce Impervious Cover

As described in the previous section, both the water quality and quantity sizing equations are related to the amount of impervious cover and land surface type. It is encouraged to use thoughtful site planning techniques that include: protecting and utilizing existing site features, clustering and concentrating development, minimizing impact of disturbance, and reducing the impervious cover to be managed.

In many cases, alternative configurations for streets and parking lots can provide the same function as traditional designs with reduced impervious area. In addition, using “cupped” vs. traditional “mounded” landscaped islands, will allow for maximum use of land. Minimizing the area of rooftop and pavement and utilizing the landscaped areas at the site to be multifunctional will assist in reducing the cost of “grey’ infrastructure. Two conceptual site design examples (redevelopment and new development) demonstrating alternative configurations and multifunctional landscape areas are provided as Appendix 5 and Appendix 6. The conceptual site design examples provide a detailed analysis consisting of: site layouts, water quality and quantity calculations for both a traditional site layout and an alternative layout using the above techniques.

3.1. Rooftop Disconnection

An adjustment to the total impervious surface area is permitted when the downspout is disconnected and then directed to a pervious area which allows for infiltration, filtration and increases time of concentration. Minimizing the impervious area will reduce the size and cost of structural BMPs that must be constructed. Depending on the configuration, all or a portion of the disconnected impervious area may be deducted from total imperious cover. Disconnected impervious cover may be treated as pervious when calculating Stormwater quantity and quality volumes. A rooftop is considered to be completely or partially disconnected if it meets the requirements below:

- The contributing area of rooftop to each disconnected discharge is 500 sqft or less, and
- The soil is not designated as a hydrologic soil group “D” or equivalent, and
- The overland flow path has a positive slope of 5% or less.
- Appropriate CN must be utilized when calculating the water quantity requirement.

For designs that meet these requirements, the portion of the roof that may be considered disconnected depends on the length of the overland path as designated in Table 3.1.1.

Table 3.1.1: Partial Rooftop Disconnection

Partial Rooftop Disconnection	
Length of Pervious Flow Path*	Roof Area Treated as Disconnected
(ft)	(% of contributing roof area)
0-14	0
15-29	20
30-44	40
45-59	60
60-74	80
75 or more	100
*Flow path cannot include impervious surfaces and must be at least 15 feet from any impervious surface	

(City of Philadelphia Stormwater Management Guidance Manual, 2006)

For example, consider a 1,000 sqft roof with two roof leaders each draining an area of 500 sqft. Both roof leaders discharge to a lawn. The lawn has type B soils and a slope of 3%. The distance from building to street is 70 ft, and the designer determines that roof runoff must be discharged 5 ft from the building foundation to avoid basement seepage. Therefore, the flow path is 65 ft in length. 80% of the roof area may be considered disconnected and treated as pervious cover when calculating Stormwater management requirements. Disconnection of the roof leaders will significantly reduce the size and cost of Stormwater management facilities at this site.

3.2. Pavement Disconnection

An adjustment to the total impervious surface area is permitted when pavement runoff is directed to a pervious area which allows for infiltration, filtration and increased time of concentration. This method is generally applicable to small or narrow pavement structures such as driveways and narrow pathways through otherwise pervious areas (e.g., a bike path through a park). For structures that meet the requirements, all of the disconnected impervious area may be deducted from the total impervious cover for water quality calculations. However, appropriate CN values listed in Table 205-02 of the City of Indianapolis Stormwater Design and Construction Specifications Manual must be used when performing water *quantity* calculations. Pavement is disconnected if it meets the requirements below:

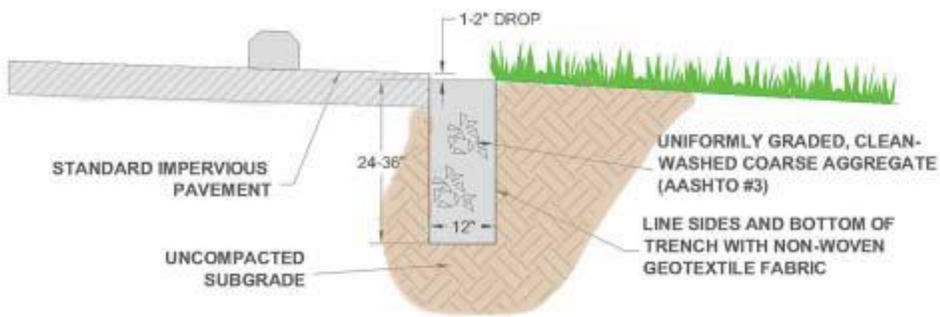
- The contributing flow path over impervious cover is no more than 75 feet, and
- The length of overland flow is greater than or equal to the contributing length, and
- The soil is not designated as hydrologic soil group "D" or equivalent, and
- The slope of the contributing impervious area is 5% or less, and
- The slope of the overland flow path is 5% or less.

If discharge is concentrated at one or more discrete points, no more than 1,000 sqft may discharge to any one point. In addition, a gravel strip, level spreader, or other spreading device is required for concentrated discharges. For non-concentrated discharges along the entire edge of pavement, this requirement is waived; however, there must be provisions for the establishment of vegetation along the pavement edge and temporary stabilization of the area until vegetation becomes established.

For example, in Figure 3.1.1, concentrated runoff from a small parking lot drainage area is directed towards a gravel level spreader which is connected to a filter strip that is part of a larger overall Stormwater treatment system. The level spreader ensures that the runoff entering the filter strip has sheet flow characteristics which aids in the filter strip's effectiveness. Since a flow spreader was installed to handle concentrated runoff, this small parking lot would be considered disconnected.

Note: Filter strips are recommended as only a viable Stormwater management pretreatment option. Filter strips are recommended for use as pretreatment for many intensive structural controls.

Figure 3.1.1: Gravel Level Spreader Connected to Filter Strip



(City of Philadelphia Stormwater Management Guidance Manual, 2006)

3.3. Maximize Tree Canopy Over Impervious Cover

An adjustment to the total impervious surface area is permitted when new or existing tree canopy, appropriate for the site, extends over the impervious cover. Under these circumstances, a portion of impervious cover under tree canopy may be treated as disconnected and deducted from total impervious cover. A curve number of 93 may be used when calculating the water quantity requirements. The tree species must be appropriate for the site. To be eligible for the reduction:

- New trees planted must be planted within 10 feet of ground level impervious area within the limits of earth disturbance.
- New deciduous trees must be at least 2-inch caliper and new evergreen trees must be at least 6 feet tall to be eligible for the reduction.
- A 100 sqft impervious area reduction is permitted for each new tree.
- The maximum reduction permitted, including new and existing trees is 25% of ground level impervious area within the limits of earth disturbance, unless the width of impervious surface area is 10 ft. Up to 100% of narrow impervious areas (i.e. sidewalks and paths) may be disconnected through the application of tree credits.

For further information on specific strategies to incorporate trees into the design of development sites refer to Appendix 4, Urban Watershed Forestry Manual; Part 2: Conserving and Planting Trees at Development Sites.

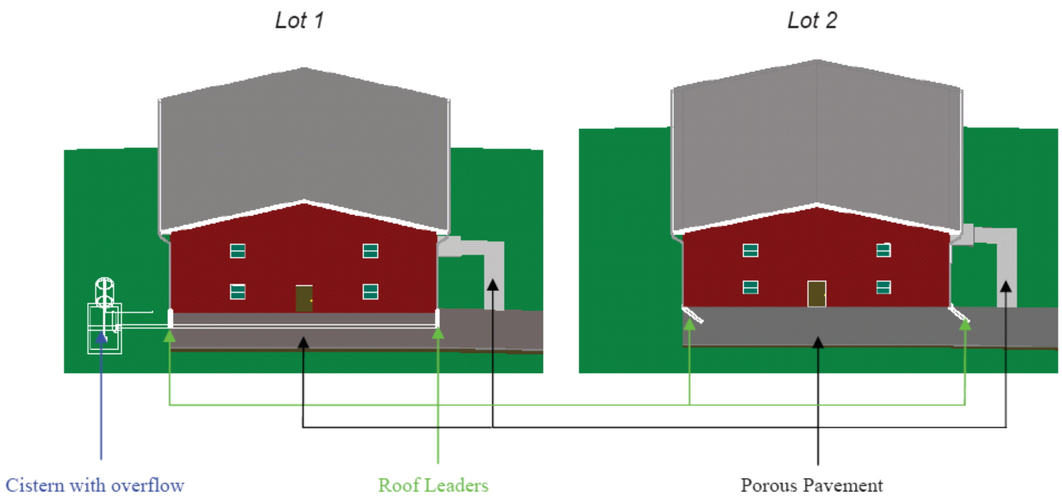
3.4. Install Green Roofs to Reduce Impervious Area

An adjustment to the total impervious surface area is permitted when a green roof is installed on a building. The design, construction, and operation and maintenance agreement must meet the requirements specified by Fact Sheet 4.1. To encourage this emerging technology, the impervious area reduction is permitted equal to the entire area of the green roof. However, since a green roof is not a zero discharges system, the remaining site design must safely convey roof runoff to a designated location. Appropriate CN values must be utilized when performing water quantity calculations. See **Attachment 2** for the appropriate CN values.

3.5. Install Permeable Pavement Systems to Reduce Impervious Area

An adjustment to the total impervious surface area may be permitted when a permeable pavement system is properly designed and installed on the site such that it does not create any areas of concentrated infiltration. Permeable pavement systems, including pervious concrete, porous asphalt, and permeable pavers with at least 40% void space; and other approved porous structural surfaces can be considered to be disconnected if they receive direct rainfall only and are underlain by a #8 crushed stone infiltration bed that is at least 8 inches deep. Permeable pavement systems must meet the requirements specified by the following permeable pavement system Fact Sheet 4.2, including completion of field verified permeability rates by a licensed engineer, geologist, or soil scientist. If the porous surface receives runoff from adjacent conventional pavement surfaces or if the roof or other runoff is directed into the subsurface storage bed, the porous pavement/infiltration bed system will be considered a structural BMP and the porous surface will be considered to be impervious surface this is demonstrated in Figure 3.1.2. A CN value of 98 must be utilized when performing water quantity calculations with the stone below the pavement considered as storage. See **Attachment 3** for example design calculations.

Figure 3.1.2: Example Permeable Pavement System Impervious Area Reduction Technique
(City of Philadelphia Stormwater Management Guidance Manual, 2006)



Roof Area (same for both houses): 25 x 20 x 2 = 1,000 ft^2 Driveway and Sidewalk Area (same for both houses): (60 x 90) + (4 x 19.5) + (5 x5) = 643 ft^2 Impervious Area before Disconnection (same for both houses): (Roof Area + Driveway and Sidewalk Area) = 1,643 ft^2

(City of Philadelphia Stormwater Management Guidance Manual, 2006)

The home on lot 1 has disconnected both the roof, by the use of a cistern with an over flow for larger precipitation events, and the pavement, by use of the porous pavement. The home on lot 2 has also disconnected the roof. However, the roof was disconnected by the use of the porous pavement, since the downspouts run directly into the gravel storage bed of the porous pavement; the porous pavement is considered a structural BMP and is still considered to be impervious area.

Impervious Area of Lot 1 After Disconnection: 0 ft^2 (since roof leaders are disconnected to a cistern) Impervious Area of Lot 2 After Disconnection: 643 ft^2 (since roof leaders discharge directly into porous pavement)

(City of Philadelphia Stormwater Management Guidance Manual, 2006

THIS PAGE LEFT BLANK INTENTIONALLY

4. Green Design Fact Sheets/ Design Techniques

The Fact Sheets were reviewed and updated by a design/review group comprised of local designers (Williams Creek Consulting, Evans, Mechwart, Hambleton, and Tilton Engineering (EMH&T), and Elements Engineering, Inc., in addition various plan review staff from the City of Indianapolis were involved in the review of these documents. Local nurseries, including Spence Restoration Nursery and JF New, were used to review the Recommended Plant Lists.

These documents were created to provide an educational overview, key elements, potential applications, materials, recommended design procedures, construction guidelines, and maintenance guidelines for the following Stormwater management techniques.

4.1 Green Roofs
4.2 Permeable Pavement Systems
4.3 Rain Water Harvesting
4.4 Swales
4.5 Bioinfiltration/Bioretention/RainGarden
4.6 Low Impact and Retentive Grading
4.7 Swales
4.8 Subsurface Infiltration
4.9 Inlet and Outlet Controls
4.10 Filters
4.11 Subsurface Vaults
4.12 Detention Basins

This Manual has been revised as of July 2015. Revisions were made to provide further technical material to support the Stormwater management techniques. To provide further technical guidance, the following attachments have been included:

Attachment 1: Guidelines for Subsurface Investigation and Infiltration Testing
Attachment 2: Green Roof Design Guidelines
Attachment 3: Permeable Pavement Systems Design Guidelines
Attachment 4: Rain Water Harvesting Design Guidelines
Attachment 5: Bioretention Design Guidelines
Attachment 6: Swale Design Guidelines

THIS PAGE LEFT BLANK INTENTIONALLY

4.1. Green Roofs

A green roof (vegetated roof/eco roof/roof garden) is a system consisting of waterproofing material, growing medium and vegetation. A green roof can be used in place of a traditional roof as a way to limit impervious site area and reduce Stormwater runoff. The green roof design should attempt to mimic pre-developed site hydrology, reducing post-developed peak runoff rates to near pre-developed rates. Green roofs also help mitigate runoff temperatures by keeping roofs cool and retaining much of the runoff from typical storm events. Although many green roofs consist of lightweight growing medium and low-growing succulent vegetation, other more heavily planted systems are possible; in either case the design should be self-sustaining.

The structural support must be sufficient to hold the additional weight of the green roof. Greater flexibility and options are available for new buildings than for reroofing existing buildings, however retrofits are possible. For retrofit projects, an architect, structural engineer, or roof consultant can determine the condition of the existing building structure and what might be needed to support a green roof. Alterations might include additional decking, roof trusses, joists, columns, and/or foundations. Generally, the building structure must be adequate to hold an additional 15 to 25 pounds per square-foot (psf) saturated weight, depending on the vegetation and growth medium that will be used (in addition to live load requirements). An existing rock ballast roof may be structurally sufficient to hold a 10-15 psf green roof (ballast typically weigh 10-15psf).

Two additional alternatives, to the traditional bituminous roofing material, are a single ply cool roof and reflective tiles. White single ply membranes are highly reflective, as compared to traditional bituminous roofing material, and can help reduce the urban heat island effect as well as save the building owner cooling costs. Reflective tiles are usually made of clay or concrete, and manufactures have begun to develop pigments that reflect in the infrared. Special pigments allow roofing material to keep their traditional colors, such as brown, green, and terra cotta, while reflecting away up to 70% of the sun's energy. These products enable buyers to forego the perceived tradeoff between energy efficiency and the aesthetic concerns with a bright-white roof (EPA, 2007). It should be noted that these alternatives do not provide stormwater quantity or quality benefits.

Key Elements:

- Green Roofs must be designed in accordance with applicable city, state, and federal building codes and a drainage system and overflow to an approved conveyance and discharge location must be designed in accordance to the Stormwater Design and Construction Specifications Manual.
- Internal drainage, including provisions to cover and protect deck drains, must anticipate the need to manage large rainfall events without inundating the cover.
- Green roofs with engineered growing medium of at least 3 inches in depth can be considered more pervious in Stormwater design calculations for the WQv sizing equation than a standard roof.
- Providing urban green space, aesthetically pleasing views, and habitat.
- May reduce utilities such as heating and cooling costs.
- Can extend roof life by two to three times.
- Improve air quality by filtering dust particles.
- LEED points.

Table 4.1.1: Green Roof Potential Application and Stormwater Regulation

Potential applications			Stormwater regulations		
				Infiltration	No Infiltration
Residential Subdivision:	Yes		Water Quality Benefit:	No	Yes
Commercial:	Yes		Volume Reduction:	No	Yes
Ultra Urban:	Yes		Attenuation Benefit:	No	Yes
Industrial:	Yes				
Retrofit:	Yes				
Highway Road:	No				

Acceptable forms of pre-treatment

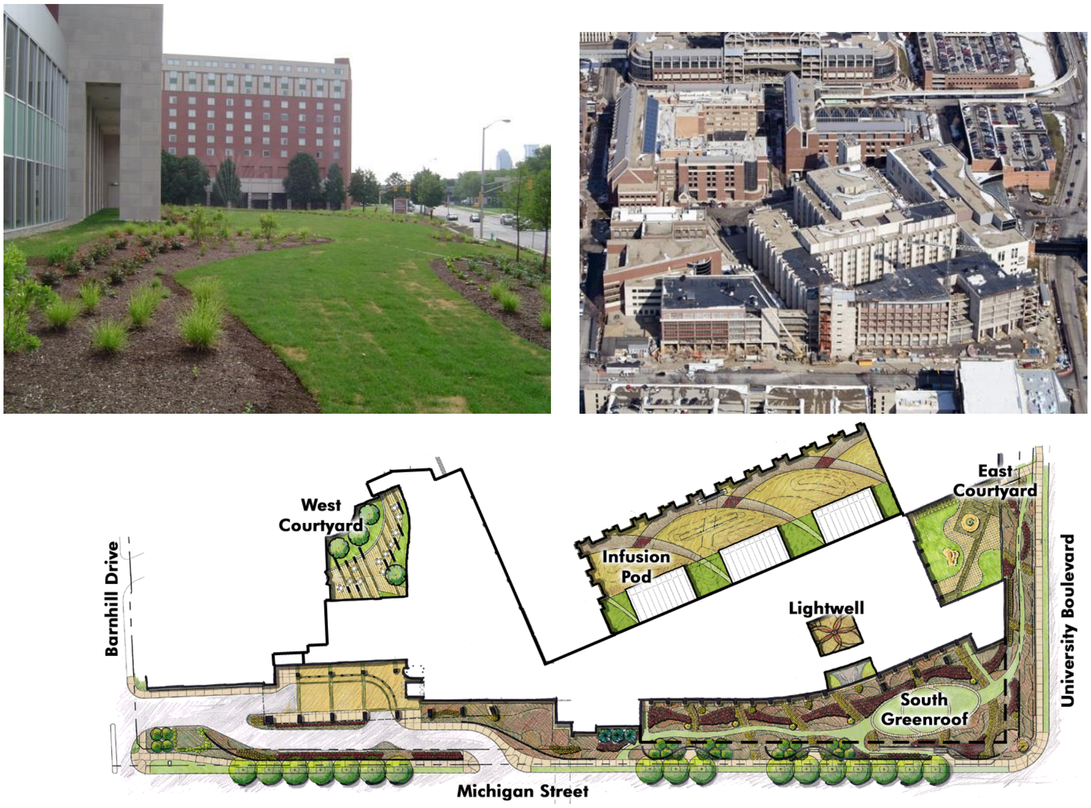
N/A

Green Roofs in the Urban Landscape

Unlike conventional roofing, green roofs promote retention and evapotranspiration of precipitation. This Stormwater management technique is very effective in reducing the volume and velocity of Stormwater runoff from roofs.

Green roofs can be installed on many types of roofs, from small slanting roofs to large commercial flat roofs. The maximum acceptable pitch for conventional green roofs is 25%, unless documentation is provided for runoff control on a steeper slope. Green roofs are an ideal option for new buildings that are taking long term cost savings and energy conservation into consideration. Many existing buildings can also be retrofitted with green roofs if structurally capable.

Although green roofs are more expensive than conventional roofs initially, they provide long term benefits and costs savings. A green roof's underlying waterproofing can extend the life of a roof two to three times by protecting the roof from mechanical damage, shielding the roof from UV radiation, and buffering temperature extremes. Green roofs also reduce energy costs by providing insulation and absorbing/reflecting excess heat and light. The roof slowly absorbs energy from the sun during the day and releases it as the air cools, thereby reducing heating and cooling costs. The benefits will be greatest during the summer months, and low buildings will see the greatest benefits. Green roofs also reduce the urban heat island effect by providing evaporative cooling and can improve air quality by filtering dust particles.

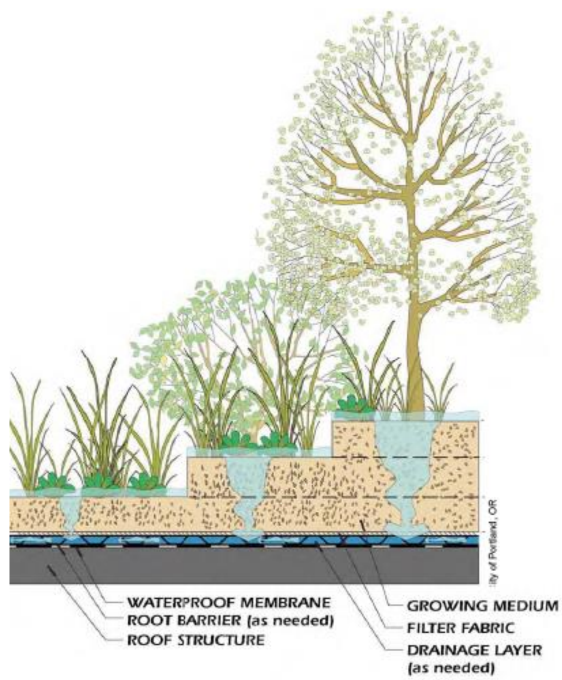


MICHIGAN STREET AND UNIVERSITY BOULEVARD: INDIANAPOLIS
IU MELVIN BREN SIMON CANCER CENTER

Components of a Green Roof

There are three basic types of green roofs (GRHC, 2008). An extensive green roof system is 6 inches or less in depth, and has a water saturation weight of 10-35 lbs/ft². It usually has limited accessibility and is planted with drought-tolerant succulent plants and grasses. A semi-intensive green roof contains material 25% above or below 6 inches. It may be partially accessible, has a water saturation weight of up to 50 lbs/ft² and has potential for greater plant diversity than an extensive roof. An intensive green roof is deeper than 6 inches and typically has a water saturation weight between 50-300 lbs/ft². These roofs are usually accessible to others besides maintenance and allow for great plant diversity. Each green roof project is unique, given the purpose of the building, its architecture and the preferences of its owner and end user. However, green roof systems are typically comprised of the same components:

- Plant material
- Growing medium
- Filter fabric
- Drainage layer
- Insulation (optional)
- Waterproof membrane/root barrier
- Roof structure



TYPICAL COMPONENTS OF A GREEN ROOF

In addition to the three primary green roof categories, there are two main approaches to installing green roofs; these are classified as Modular and Loose Laid. Each of these categories includes a variety of specific construction methods and system design approaches.

MODULAR GREEN ROOF SYSTEM INSTALLATION

DEARBORN, MI-FORD ROUGE CENTER COMPLEX-10-AC GREEN ROOF –PART OF A 600-AC STORMWATER MANAGEMENT SYSTEM AT A BROWNFIELD SITE

PLANT MATERIAL

Plant Material

The plant material chosen for green roofs is designed to take up much of the water that falls on the roof during a storm event and be drought tolerant. Plant material also collects dust, creates oxygen, releases moisture, and provides evaporative cooling. Plant selection is very important to the sustainability of the roof. The extensive green roof should reach 90% growth coverage within two years. The following criteria should be taken into consideration when selecting vegetation for the green roof:

- Drought tolerant, requiring little or no irrigation after establishment
- Self-sustaining, without the need for fertilizers, pesticides, or herbicides
- Able to withstand heat, cold, and high winds
- Very low-maintenance, needing little or no mowing or trimming
- Perennial or self-sowing
- Fire resistant

SEDUM MIX

A mix of sedum/succulent plant communities is recommended because they possess many of these attributes. Herbs, forbs, grasses and other low groundcovers can also be used to provide additional benefits and aesthetics, however these plants may need more watering and maintenance to survive and keep their appearance. Refer to Green Roof Plants by Snodgrass and Snodgrass for a comprehensive list of plants suitable for green roofs.

Growing Medium

The growing medium is a critical element of Stormwater storage and detention on a green roof, and provides a buffer between the roof structure and vegetation for root development. Storage is provided by a green roof primarily through water held in tension in the growing medium pores. The growing medium in an extensive green roof should be a lightweight mineral material with a minimum of organic material and should stand up to freeze/thaw cycles. Semi-intensive and intensive roofs may have organic material and/or sand added to the mineral material. Organic material should not contain peat, because of its nonrenewable nature and burning potential, nor animal waste, which can leach pollutants into Stormwater and may eventually leave the site. The engineered material should be Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL) approved. The FLL is further described in the Materials section.

KENTUCKY SANITATION DISTRICT1-DEMONSTRATION SITE

CROSS SECTION-GROWING MEDIUM

Filter Fabric

An engineered, non-woven filter fabric prevents fine soil particles from passing into the drainage layer of the green roof system.

Drainage Layer

The drainage layer is a lightweight granular medium and/or plastic material resembling egg cartons set beneath the planting medium. The drainage layer needs to provide a balance between water retention and root aeration and is a critical component of the Stormwater retention function. An approved discharge location should be identified for every green roof and drain(s) provided.

Waterproof Membrane/Root Barrier

To maintain structural integrity of the roof, a waterproof material is laid above the roof structure. Some waterproofing materials are inherently root resistant, whereas others require an additional root barrier. It is important that the membrane be of high quality as it will be labor intensive to replace once the green roof components are in place.

Roof Structure

The load capacity of a roof structure must be taken into account when considering the installation of a green roof. Extensive green roofs typically weigh between 15 and 25 psf and are compatible with wood or steel decks. Intensive green roof weigh more than 50 psf and typically require concrete supporting decks.

Recommended Design Procedure

- Early communication between the design team (developer, civil engineer, structural engineer, architect, landscape architect, planner, roofer etc.) is extremely important in the design procedure.
- Investigate the feasibility of the installation of a green roof. A structural engineer should verify that the roof will support the weight of the green roof system. It is important to consider the saturated weight of the roof in the design calculations.

- Determine the portion of roof that will have a green roof. Typically 10% or less of the green roof is composed of non-vegetated components such as gravel ballast, pavers for maintenance access, etc.
- Extensive green roofs that have an engineered growing medium of at least 3 inches thick can be permitted as water quality volume reduction equal to the entire area of the green roof.
- Although green roofs are not considered as impervious surfaces when determining Stormwater management requirements, they are not zero discharge systems. The roof drainage system and the remainder of the site drainage system must safely convey roof runoff
- Develop a planting plan based on the thickness of the planting media.
- Complete construction plans and specifications.
- For additional design information, refer to **Green Roof Design Guidelines (Attachment 2)**.

Materials

Presently (2010), the only widely-accepted, established standards for green roof construction are those developed in Germany by the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL). The FLL guidelines include industry standard tests for the weight, moisture, nutrient content, and grain-size distribution of growing media. FLL also certifies laboratories to conduct critical tests, such as the root penetration resistance of waterproofing membranes. These guidelines are available in English translation directly from FLL. There is also an American Standard Testing Methods (ASTM) task group that is developing comprehensive American standards for green roof installation. Since guidelines are constantly being upgraded and approved, the engineer is responsible for verifying that the design materials meet all current standards at the time of design.

Materials for green roofs will vary somewhat depending on the media thickness, intended uses, and desired appearance. The specifications provided below focus on those for a 3-inch extensive green roof system.

Plant Material

- Green roof plantings should be able to withstand heat, cold, and high winds. After establishment, the plants should be self-sustaining and tolerant of drought conditions.
- For extensive green roofs, about half of the plants should be varieties of sedums. To ensure diversity and viability, at least four different species of sedum should be used. For an extensive green roof, the remainder of the plants should be herbs, meadow grasses, or meadow flowers, depending on the desired appearance.
- *Sedum sarmentosum* also known as star sedum, gold moss, stringy stonecrop, or graveyard moss and *Sedum hispanico* are known to be invasive and should be avoided.
- Green roofs should include a significant percentage of evergreen plants to minimize erosion in winter months.
- When fully established, the selected plantings should thoroughly cover (90% or more), the growing medium.

Growing Medium

- Green roof growing medium should be a lightweight mineral material with a minimum of organic material and should meet the following standards
  - Non-Capillary Pore Space at Field Capacity, 0.333 bar: ≥ 15% (vol)
  - Moisture Content at Field Capacity: ≥ 12% (volume)
  - Maximum water retention: ≥ 30% (volume)
- The nutrients shall be initially incorporated in the formulation of a suitable mix for the support of the specified plant materials.

Filter Fabric

Filter or separation fabric shall allow root penetration, but prevent the growth medium from passing through into the drainage layer. The fabric should be a non-woven polypropylene geotextile.

Drainage Layer

- Drainage layer shall be used to provide conveyance of excess water in the green roof system. The layer shall meet the following specifications:
  - Abrasion resistance (ASTM-C131-96): ≤ 25 % loss
  - Soundness (ASTM-C88 or T103 or T103-91): ≤ 5% loss

- Porosity (ASTM-C29): ≤ 25% loss
- Grain size distribution (ASTM-C136)
  - Percent Passing US#18 sieve: ≤ 1%
  - Percent Passing ¼-inch sieve: ≤ 30%
  - Percent Passing 3/8-inch sieve: ≤ 80%

Waterproof Membrane/Root Barrier

- PVC, EPDM, and thermal polyolefin (TPO) are inherently root resistant; other common waterproofing materials might require a root barrier between waterproofing and vegetative cover. PVC has been shown to release toxins in some situations and should be avoided if other alternatives are available.

- Avoid using herbicides to prevent root penetration of waterproofing.

Irrigation System

- It is recommended that extensive systems be designed to not require irrigation.

- When using an irrigation system pipes should not be placed directly on the waterproof membrane, but on a protection board or among the growing medium to avoid damage to the system from pressure and pipe movement.

Roof Structure

- Typical roof structure should have structural stability inspected by a Structural Engineer.

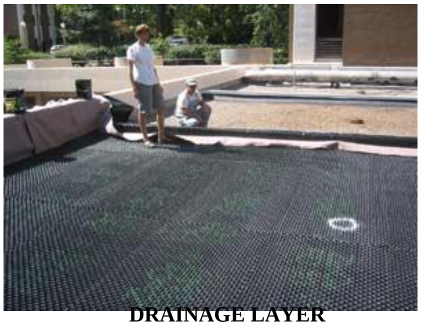
Construction Guidelines

- A safety program is one of the most important considerations for anyone that will be building a green roof. All governmental fall and safety protection regulations must be followed.
- Pre-construction meeting/training for all trades involved in the installation of a green roof is critical to the success of a green roof due to the number of trades involved.
- Contractors should be trained for green roof installation and have a thorough understanding of the overall system that they are installing. Contractors must be aware of the roof access points, load bearing points, material storage requirements, mode of transportation of materials to the jobsite, and scheduling of materials.
- Apply waterproof membrane and inspect for any irregularities that would interfere with its elemental function within the green roof system.
- The waterproof membrane should be protected when exposed to increased moisture levels from construction and in work traffic zones. Membrane protection should be a mandatory requirement of installation for the period of time it is exposed during staging and installation of overburden, i.e. all layers above the membrane. All membrane layers should have enough strength to cope with the weight of construction equipment. The following are membrane protection techniques:
- Restrictions of traffic on membrane
- Physical protection
- Phased construction

- When the waterproofing membrane is installed it must be tested to ensure that there are no leaks, after which it should be continuously protected.

FLOOD TEST

- The design professional is responsible for deciding the best method to test the integrity of the waterproofing membrane. The most common method used is flood testing. A flood test typically involves the following steps:
  - Temporary blockage of drain system
  - Area covered with 2” water for 24 to 48 hours
  - Inspection of the underside of test area for water infiltration
  - Careful removal of water from the site so as not to stress the drainage system



DRAINAGE LAYER

DRAINAGE MAT

- Install drainage layer, taking care to protect the waterproof membrane from damage.
- Test the drainage system.
- Install the filter fabric or separation layer over entire drainage layer.
- Install growing medium component as specified.
- Establish vegetation in the spring for best results, sedums can be established from fresh cutting that are broadcast onto the growing medium.
- In May/June or September/October, sedum plugs can be established by planting them 1 foot on center.
- Perennials can be seeded, except during summer months.
- A biodegradable or photodegradable wind barrier or hydromulch may be used to prevent erosion during the establishment period. It generally takes about two growing seasons for full establishment.

GROWING MEDIUM

PLANTING

Maintenance Guidelines

All facility components, including plant material, growing medium, filter fabric, drainage layer, waterproof membranes, and roof structure should be inspected for proper operations, integrity of the waterproofing, and structural stability throughout the life of the green roof. Detailed maintenance guidelines and a recommended schedule of inspection and maintenance can be found in the Example Green Roof Operation and Maintenance (O & M) Manual.

- Fertilization is not necessary and fertilizers should not be applied, unless there is a documented need. If it is determined that fertilization is required to restore function of the green roof vegetation, the exact fertilization requirements should be determined by testing, and the minimum quantity of fertilizer should be applied to restore function. Fertilizers containing phosphorus should not be used unless testing indicates it is needed.
- During the plant establishment period, maintenance staff should conduct 3-4 visits to conduct basic weeding, fertilization, and in-fill planting. Thereafter, only two annual visits for inspection and light weeding should be required (irrigated assemblies will require more intensive maintenance).
- Spill prevention measures from mechanical systems located on roofs should be exercised when handling substances that can contaminate stormwater.
- If the structure/property where the green roof exists is likely to change hands, a plaque or similar element should be placed on and/or near the roof stating the manufacturer of the green roof elements so warranty details and other information best relayed by the manufacturer are easily obtained.

Table 4.1.2: Engineering / Drainage Report Requirements Summary

Item	Required
Storage Volume Calculations	Yes
Emergency Overflow Calculations	Yes
Water Quality Volume Calculations (if system is part of the stormwater quality management system)	Yes
Water Quantity Volume Calculations (if system is part of the stormwater quantity management system)	Yes
Structural Engineer’s Certification (for Retrofits)	Yes

Table 4.1.3: Plan Requirements

Item	Required
Profile Detail of Proposed Green Roof Showing:	
Soil Depth	Yes
Impermeable membrane	Yes
Filter Fabric	Yes
Soil Specifications	Yes
Drainage Layer	Yes
Area Map Showing Area Covered by Proposed Green Roof	Yes
Plant Specifications	Yes
Filter Fabric Specifications	Yes
Center Coordinates of Green Roof (in State Plane Coordinates) on Cover Sheet Summary Table	Yes

Table 4.1.3: Plan Requirements 1

Table 4.1.4: O & M Manual Requirements

Item	Required
Tabular Inspection Schedule	Yes
Site Diagram with Green Roof Area	Yes
Inspection Checklist	Yes
Narrative description of Inspection Procedure including:	Yes
Startup Maintenance	Yes
Fertilizer Guidance	Yes
Plant Coverage Minimum Requirement (90%)	Yes
Emergency Overflow System Inspection	Yes
Wind and Rain Erosion Inspection	Yes
Weeding	Yes
Self-Inspection Yearly Certification	Yes

4.1.1. Green Roof Example O & M Manual

Green Roof – O & M Manual

Owner Name
Address of Property
Owner Contact Name and Phone Number

BMP Narrative:
Regular inspection and maintenance is critical to the effectiveness of a green roof. It is the responsibility of the property owner to maintain all Stormwater facilities in accordance with the minimum design standards required by the City of Indianapolis and this Operations & Maintenance Manual. All facility components, including plant material, growing medium, filter fabric, drainage layer, waterproof membranes, and roof structure should be inspected for proper operations, integrity of the waterproofing, and structural stability throughout the life of the green roof. The local jurisdiction has the authority to impose additional maintenance required where deemed necessary. The city has the right to inspect the system and to require replacement if it fails or is a threat to public safety. If maintenance does not correct the problem, full or partial replacement may be required.

Green Roofs shall be in accordance with the following inspection and maintenance criteria:

Inspection Activities	**Suggested Frequency**
• Inspect to ensure that the green roof was installed and working properly. • Inspect areas for potential erosion or damage to vegetation.	Post-construction
• Inspect foundation for any leaks and structural deficiencies. • Inspect overflow devices (pipes and inlets) for obstructions or debris that would prevent proper drainage when filtration capacity is exceeded.	Annually and after large storm events
• Inspect for ponding. • Inspect for dead or stressed vegetation. • Inspect for tall or sun scorched grass. • Inspect for weeds. • Inspect mechanical equipment for leaks and spills.	As needed
Maintenance Activities	**Suggested Frequency**
• Repair any leaks or structural deficiencies. • Contact manufacturer for repair or replacement of membrane. • Remove any sediment and plant debris from clogged outlets.	As needed
• Drain inlet pipe should be cleared when soil substrate, vegetation, debris or other materials clog the drain inlet. • Plant material should be maintained to provide **90%** coverage. • Weeds should be pulled manually, and removed regularly and not allowed to accumulate. • If necessary during the establishment period (initial 18 months), irrigation can be provided by hand watering or automatic sprinkler system. • Report any mechanical equipment leaks and spills, proper spill prevention should be exercised.	As needed
• Growing medium should be inspected for evidence of erosion from wind or water. If erosion channels are evident, they can be stabilized with additional growth medium must be similar to the original specified material.	Quarterly

Address of property

Inspector:
Date:
Time:
Weather: Rainfall over previous 2-3 days? Site conditions:
Owner change since last inspection?: Y N

Mark items in the table below using the following key:

- **X** Needs immediate attention
- **–** Not Applicable
- **✓** Okay
- **?** Clarification Required

Green Roof Components:

Items Inspected	Checked		Maintenance Needed		Inspection Frequency
STRUCTURAL COMPONENTS:	Y	N	Y	N	**A**
1. Foundation checks (e.g. are there any leaks or structural deficiencies)?					
2. Tears or perforation of membrane (contact manufacturer for repair or replacement)?					
3. Clogged outlets (remove any sediment and plant debris if necessary)?					
4. Standing water present (all facilities shall drain within 24 to 48 hours. Record time/date, weather, and site conditions when ponding occurs)?					
VEGETATION: (plant material shall cover 90% of the facility)					**M, AMS**
5. Dead or stressed vegetation?					
6. Tall or sun scorched grass?					
7. Weeds?					
GROWING/FILTER MEDIUM:					**M, AMS**
8. Exposed soils?					
9. Gullies?					
10. Ponding?					
OTHER					**A**
11. Are mechanical units free of leaks and spills?					
12. Is there any threat to Public Health? (e.g. mosquito larvae or rats)					
13. Other (describe)?					

Inspection Frequency Key A= Annual, M= Monthly, AMS= After Major Storm

COMMENTS:

OVERALL CONDITION OF FACILITY:
In accordance with approved design plans? Y / N

In accordance with As Built plans? Y / N
Area of roof covered by green roof on plans = ________
Area of roof covered at time of inspection = __________

Maintenance required as detailed above? Y / N

Compliance with other consent conditions? Y / N

Comments: ____
____

Dates by which maintenance must be completed: _______ / ___ / ___

Dates by which outstanding information as per consent conditions is required by: __________ / ___ / ____

Inspector's signature: ____

Owner/Engineer/Agent's signature: ____

Owner/Engineer/Agent's name printed: ____

4.1.2. Green Roof Designer/Reviewer Checklist

Item	Yes	No	N/A	Notes
Load and structural capacity analyzed?				
Waterproofing layer and protection adequate?				
Leak protection system provided?				
Internal drainage capacity for large storms provided?				
Appropriate growing medium?				
Appropriate drainage media and/or layer?				
Geotextile/filter fabric specified?				
Good detailing (flashings, penetrations, drains, gravel edges, etc.)?				
Slope stability provided, if necessary?				
Appropriate vegetation selected?				
Appropriate drainage location provided?				
Plant establishment (temporary irrigation/fertilization) procedures provided?				
Erosion control / wind protection provided?				

4.2. *Permeable Pavement Systems*

Permeable Pavement provides the structural support of conventional pavement, but allows Stormwater to drain directly through the surface into the underlying stone base then to an underdrain or soils (where the soil type allows for infiltration), thereby reducing Stormwater runoff. There are permeable varieties of asphalt, concrete, and interlocking pavers. Permeable pavements are designed with an open graded stone sub-base that allows water to pass through to the native soil and/or provides temporary storage. Some of the benefits to using permeable pavements include: a reduction in the amount of storm pipes and inlet structures required; the ability to have more parking areas built to accessible slopes (due to flatter grades achievable with porous surfaces); improved growing conditions of plant material in landscape islands due to air and water available through porous surface; pedestrian safety due to improved winter and wet weather pavement conditions.

KEEP INDIANAPOLIS BEAUTIFUL HEADQUARTERS: 1029 FLETCHER AVE. INDIANAPOLIS, IN- INTEGRATED STORMWATER MANAGEMENT- FEATURES PERVIOUS CONCRETE, CISTERN AND RAIN GARDENS TO MEET STORMWATER REGULATIONS

Key Elements of Permeable Pavement:

- Porous structural surface with high infiltration rate.
- Porous surface and #8 stone sub-base suitable for design traffic loads. Can be used on most travel surfaces with slopes less than 5%.
- Uncompacted, level sub-grade allows infiltration of Stormwater.
- Open-graded #8 stone aggregate sub-base provides storage.
- Additional storage and control structures can be incorporated to meet flood control.
- Positive overflow prevents system flooding.

Table 4.2.1: Permeable Pavement Potential Application and Stormwater Regulation

Potential applications			Stormwater regulations		
				Infiltration	No Infiltration
Residential Subdivision:	Yes		Water Quality Benefit	Yes*	No
Commercial:	Yes		Volume Reduction	Yes	No
Ultra Urban:	Yes		Attenuation Benefit	Yes	Yes
Industrial:	Yes				
Retrofit:	Yes				
Highway Road:	Limited, only where approved by DPW				

*If all design storms are captured and infiltrated

Acceptable Forms of Pre-treatment

N/A

Permeable Pavement in the Urban Landscape

Permeable pavement systems can be used to promote infiltration of Stormwater runoff or detain runoff. When designed to infiltrate, this technique is very effective in reducing the volume of Stormwater entering a sewer system and is being studied for its effectiveness for removing pollutants. During a rain event, Stormwater flows through the porous surface, drains into the crushed stone sub-base beneath the pavement, and remains stored until Stormwater can infiltrate into the soil or, in the case of detention, until it can be released in a controlled manner to an "adequate" drainage outlet. Porous asphalt and concrete mixes are similar to their impervious counterparts, but do not include the finer grade particles. Interlocking pavers may have openings that are filled with stone to create a porous surface.

PERMEABLE PAVER SYSTEM APPLICATION-BRENTWOOD SCHOOL-PLAINFIELD, IN

Permeable pavement systems are suitable for any type of development. They are especially well suited for parking lots, walkways, sidewalks, basketball courts, and playgrounds. Proper training of owner, users and maintenance staff will help to prolong the life of the system.

PERVIOUS CONCRETE APPLICATION-PURDUE UNIVERSITY-WEST LAFAYETTE, IN

Alternate for Paved Surfaces

Almost any surface that is traditionally paved with an impervious surface can be converted to a porous pavement system. Porous surfaces are particularly useful in high density areas where there is limited space for other Stormwater management systems. Porous pavement can be used for parking lots, basketball courts, playgrounds, plazas, sidewalks and trails. Interlocking porous pavers can be used to provide an interesting aesthetic alternative to traditional paving. Porous pavement can be designed to meet the loading requirements for most parking lots and travel surfaces. However, for lots or loading areas that receive a high volume of heavy traffic and/or turning movements (as in a restaurant drive-thru lane), porous pavement can be used for parking stalls and conventional pavement for travel lanes and loading areas. In this case the impervious surfaces could be graded toward the porous surfaces.

PERMEABLE PAVER SYSTEM APPLICATION-MORTON ARBORETUM- CHICAGO, IL

It should be noted that porous pavement may not be used within the public right-of-way without approval of the DPW.

Direct connection of roof leaders and/or inlets

The stone sub-base storage of permeable pavement systems can be designed with extra capacity, and roof leaders and inlets from adjacent impervious areas can be tied into the sub-base to capture additional runoff. These stone beds can be sized to accommodate runoff from rooftops via direct connection or to supplement other Stormwater Best Management Practices (BMPs). Pretreatment (sumped inlet with hood) may be necessary to prevent particulate materials from these surfaces from clogging the sub-base of the porous pavement system. All permeable pavement systems must include a positive overflow.

Direction of Impervious Runoff to Permeable Pavement System

Adjacent impervious surfaces can be graded so that the flow from the impervious area flows over the porous pavement and into the sub-base storage below if sufficient capacity is created. Typically, it is recommended that the impervious area does not exceed 3 times the area of the porous pavement receiving the runoff.

PERMEABLE PAVEMENT SYSTEM- INTERCARE-INDIANAPOLIS, INDIANA

PERMEABLE PAVER SYSTEM- ELMHURST COLLEGE-ELMHURST ILLINOIS-

PERVIOUS CONCRETE DRAINAGE IMPROVEMENT- PURDUE UNIVERSITY- WEST LAFAYETTE IN

Components of a Permeable Pavement System

Different porous surfaces are used for porous pavement systems, but all rely on the same primary components:

- Inflow/Surfacing
- Storage
- Infiltration/Outflow

Figure 4.2.1: Permeable Paver System Cross Section

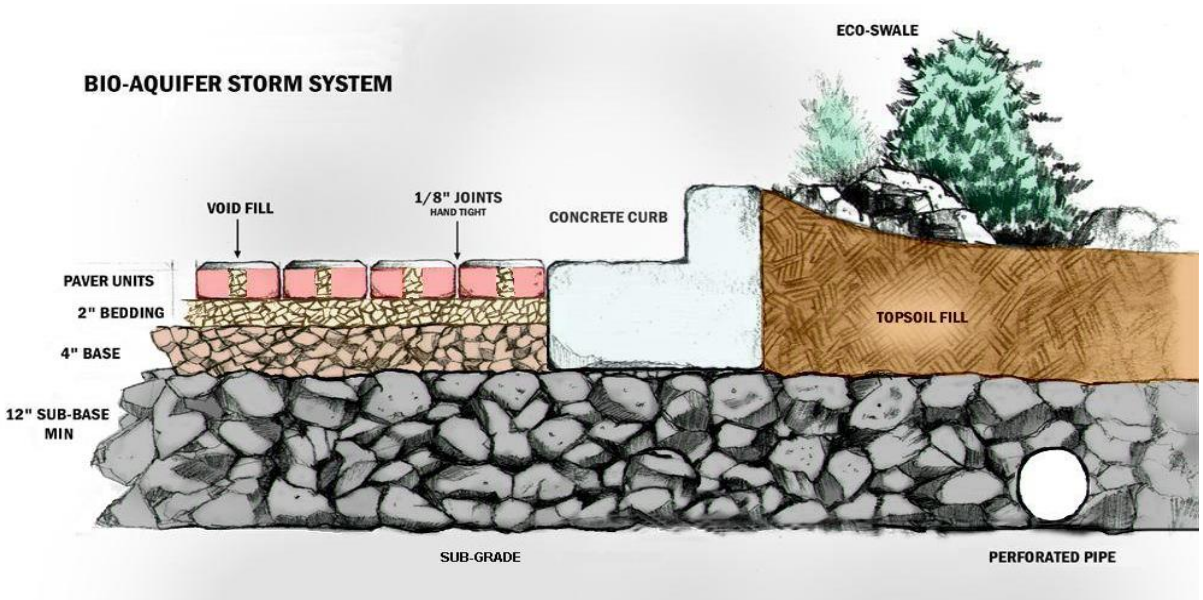
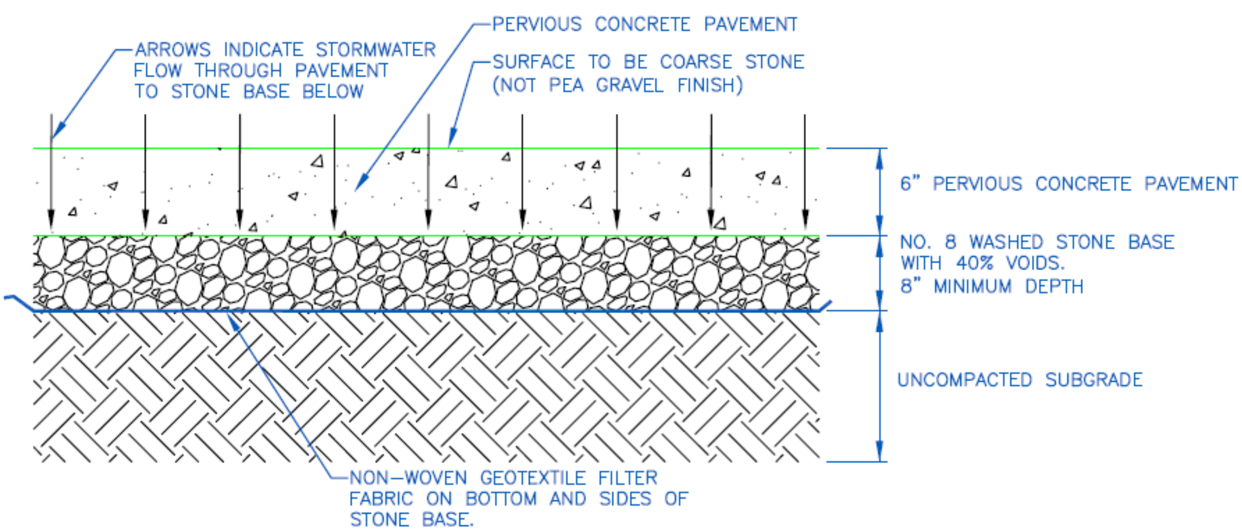


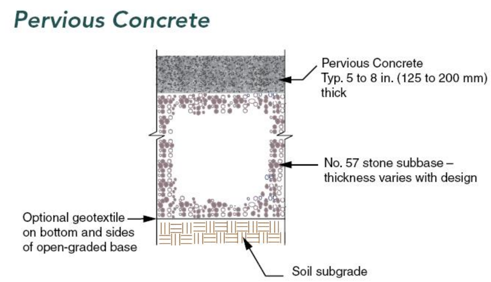
Figure 4.2.2: Pervious Concrete System Cross Section



Inflow/Surfacing

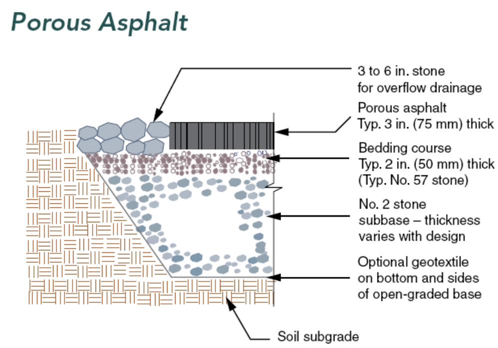
There are many different types of structural surface materials that allow water to flow through void spaces within the material. Any of these alternatives serve as a form of conveyance and filtration for the storage bed below. Several of the most commonly used porous structural surfaces are described below, but this does not represent an exhaustive list of the porous surfaces appropriate for Stormwater management applications.

Porous concrete (a/k/a Portland Cement, Pervious Concrete, or PCPC)



Porous concrete was developed in the U.S. by the Florida Concrete Association in the 1970s. While its early applications remained in Florida and other southern areas, the last ten years have seen an increase in the use of porous concrete in freeze-thaw regions. According to the ACI Committee Report 522R-06, the term "pervious concrete" typically describes a zero-slump, open graded material consisting of Portland cement, coarse aggregate, little or no fine aggregate, admixtures and water. Porous concrete is produced by substantially reducing the number of fines in the mix in order to establish voids for drainage. Porous concrete has a coarser appearance than its conventional counterpart.

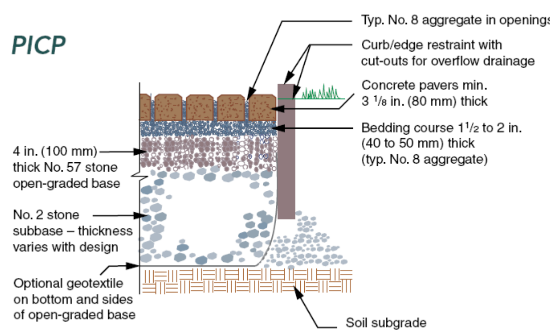
Porous asphalt



Porous asphalt pavement was first developed in the 1970s and consists of standard bituminous asphalt in which the fines have been screened and reduced, allowing water to pass through very small voids. Recent research in open-graded mixes for highway application has led to additional improvements in porous asphalt through the use of additives and binders. Porous asphalt is very similar in appearance to conventional, impervious asphalt.

Permeable pavers

Permeable pavers are interlocking units (often concrete) with openings that can be filled with a pervious material such as gravel. These units are often very attractive and are especially well suited to plazas, patios, small parking areas, etc. There are also plastic grids that can be filled with gravel to create a fully gravel surface that is not as susceptible to rutting and compaction as traditional gravel lots. Gravel used in interlocking concrete pavers or plastic grid systems must be well graded to ensure permeability.



Reinforced turf

Reinforced turf consists of interlocking structural units with openings that can be filled with soil for the growth of turf grass and are suitable for traffic loads and parking. They are often used in overflow or event parking as well as emergency access for fire trucks. Reinforced turf grids are made of concrete or plastic and are underlain by a stone and/or a sand drainage system for Stormwater management. While both plastic and concrete units perform well for Stormwater management and traffic needs, plastic units may provide better turf establishment and longevity, largely because the plastic will not absorb water and diminish soil moisture conditions. The grids protect the root structure of the grass and minimize the impact on the grass by traffic loads.

Storage

In addition to distributing mechanical loads, coarse aggregate laid beneath porous surfaces is designed to store Stormwater prior to infiltration into soils or discharging to a Stormwater BMP. The aggregate is wrapped in a non-woven geotextile to prevent migration of soil into the storage bed and resultant clogging. In porous asphalt and porous paver applications, the storage bed also has a choker course of smaller aggregate to separate the storage bed from the surface course. The storage bed can be designed to manage runoff from areas other than the porous surface above it, or can be designed with additional storage and control structures that meet the parameters required within the Stormwater Design and Construction Specifications Manual. Currently, the approval of a pervious concrete / porous pavement system requires an underdrain with infiltration allowed only when the underlying soils permit.

Infiltration/Outflow

Positive overflow must be provided for porous pavement systems. Positive overflow conveys runoff from larger storms out of the system, prevents flooding and prevents water from standing within the porous structural surface which minimizes freeze-thaw impacts. One solution for a positive overflow is a stone buffer along the edges of a porous pavement lot. The stone, typically river rock or a stone with aesthetic value, is connected to the stone sub-base below the pavement to allow a path for excess water to flow out of the system. The stone should allow positive overflow to occur at an elevation below the structural surface. A perforated pipe system can also convey water from the storage bed to an outflow structure. The storage bed and outflow structure should be designed to meet the detention requirements of the Stormwater Design and Construction Specifications Manual. Inlets can be used to provide positive overflow if additional rate control is not necessary. More information about large underground storage systems can be found in the Subsurface Infiltration Fact Sheet.

SIDE BY SIDE COMPARISON OF STANDARD ASPHALT WITH POROUS ASPHALT

Recommended Design Procedure

Design of porous pavement systems is critical if they are to function properly and efficiently. The area and shape are dependent on the site design, and selection of the surface material is dependent on intended site uses and desired appearance. The depth of the stone base can be adjusted depending on the management objectives, total drainage area, traffic load, and soil characteristics. The following design procedures are general guidelines that designers can follow.

- Determine if site is acceptable for use of porous pavements.
- In order to properly design the porous pavement system, a curve number or runoff coefficient must be established for the pavement. Current standards require that the standard pavement CN of 98 or runoff coefficient of 0.85 be used with the stone base utilized for detention requirements.
- Porous pavement should be designed as a detention system. The outlet control will be the underdrain and / or infiltration rate of the underlying soil. Standard detention calculations per Chapter 300 should be used for determining the depth of the stone base for the volume.
- Current standards require that water quality be addressed separately from the porous pavement system as porous pavement has not been accepted as a water quality practice.

Siting for Porous Pavements

Porous pavements are not suited for every site. Site evaluation is critical for the success of porous pavement. Porous pavements should not be used until the site has met the minimum standards required for their use. Some minimum standards are:

- High water table depth to bottom of stone storage layer must be 2 feet or greater.
- For optimal performance locate systems on well-drained permeable soils with field verified permeability rates. A geotechnical report / analysis is required when infiltration will be utilized. The report must document the soil infiltration rate and the seasonal high water table.
- Land surrounding and draining to the pavement doesn't exceed 20% slope.
- Minimum setback of 100 feet from wells used to supply drinking water or as required by local agency. Not recommended for use in well-head protection zones without an "impermeable" liner and a positive connection to an "acceptable" stormwater outlet.
- Minimum setback of 10 feet from down-gradient of building foundations or as required by building code.
- Determine the detention and water quality requirements on the site. See the Stormwater Design and Construction Specifications Manual for more information.
- Create a Conceptual Site Plan for the entire site and determine what portion of the detention/retention sizing requirements porous pavement will meet.
- Investigate the feasibility of infiltration in the area proposed for a porous pavement (hotspot investigation, infiltration test, and geotechnical analysis). More information is provided in **Attachment 3**.
- Create a conceptual design for the porous pavement system.

Table 4.2.2: Suggested Starting Porous Pavement Design Values	
Area (surface area and infiltration area)	Largest feasible on site
Choker/Aggregate Bed Depth	8-36 inches

- Estimate the total storage volume and adjust area and/or depths as needed to provide required storage. Assume a void ratio of approximately 40% for #8 washed stone.
- Design system with a level bottom; use a terraced system on slopes. Provide a positive slope for the bottom if the underlying soils have a high clay content or low permeability in general.
- Using infiltration area and the saturated vertical infiltration rate of the native soil, estimate how long the stored volume will take to drain. The maximum drain down time for the entire storage volume is 72 hours, but the Engineer may choose a shorter time based on site conditions and Owner preference. If storage does not drain in the time allowed, adjust aggregate depth and/or surface area. Adjust the design until the volume and drainage time constraints are met. Ensure that the storage volume does not occur within the porous structural surface, but is entirely contained within the stone sub-base below it. Underdrains placed at the top of the aggregate bed can serve to minimize or prevent standing water in the structural surface. Also refer to **Permeable Pavement Systems Design Guidelines (Attachment 3)**.
- Per City of Indianapolis requirements, at least one underdrain shall be used for all porous pavement systems. Additional underdrains may be required based on layout and individual site conditions.
- Design distribution and overflow piping to minimize chance of clogging.
- Check that any release rate requirements (including release through any underdrain) are met by the system as designed. Typically, the underdrain pipe can be set at an elevation higher than the stone bottom to allow detention within the stone. See the Stormwater Design and Construction Specifications Manual.

- Design adequate Stormwater quality BMP(s) downstream of the porous pavement to treat the water quality volume per the Stormwater Design and Construction Specifications Manual.
- Complete construction plans and specifications.

Materials

Subsurface Storage Beds

- All aggregates within infiltration beds shall meet the following:

1. Uniformly graded, crushed, washed coarse aggregate
2. Maximum wash loss of 0.5%
3. Minimum Durability Index of 35
4. Maximum abrasion of 10% for 100 revolutions and maximum of 50% for 500 revolutions.

- Choker course aggregate, where needed, shall meet the specifications of AASHTO No. 57.
- Storage stone should meet the specifications of AASHTO No. 3. Additional storage materials are further discussed in the Subsurface Infiltration Fact Sheet.

Table 4.2.3: Required Choker Course Gradation

U.S. Standard Sieve Size	Percent passing
1 ½” (37.5 mm)	100
1” (25 mm)	95 - 100
½” (19 mm)	25-60
4 (4.75 mm)	0 - 10
8 (2.36 mm)	0 - 5

Table 4.2.4: Required Stone Storage Gradation

U.S. Standard Sieve Size	Percent passing
2 ½” (63 mm)	100
2” (50 mm)	95 - 100

Porous pavement mix designs are often ‘local’ to a region as aggregate properties vary depending on the region. Also, advances in mix designs of porous pavements continue to evolve. Therefore, the information listed below for porous asphalt and pervious concrete pavements should be used as a foundation for the mix designs and local suppliers should be consulted to finalize the mix design for the project.

Porous Concrete

- Portland Cement Type I, II or III conforming to ASTM C 150 or Portland Cement Type IP or IS conforming to ASTM C 595.

- No. 8 coarse aggregate (3/8 to No. 16) per ASTM C 33 or No. 89 coarse aggregate (3/8 to no. 50) per ASTM D 448.

- As mentioned above, due to the variations in aggregate, mix designs for pervious concrete vary in the different regions of the country. There is no ideal mix that will produce the same result in all locations. Local concrete suppliers who are certified to produce pervious concrete can provide a mix design that will meet the desired pavement performance. Typically for pervious concrete pavements in central Indiana the:
    - water/cement ratio varies from 0.26 to 0.40
    - concrete mixture void content varies from 15% to 25%
    - cement content is 350 lbs/cubic yard minimum for vehicular traffic loading
    - use of a hydration stabilizing admixture (HSA) is strongly recommended

Test pours are recommended to ensure adequate strength, porosity and appearance of the pervious concrete.

The Indiana Ready Mixed Concrete Association has a system of certifying installers for pervious concrete. The certified installers are listed on their website at www.irmca.com. Only certified installers shall be used for the pervious concrete installations which are to serve as Stormwater infrastructure and detention facilities.

Porous Bituminous Asphalt

- Bituminous surface shall be laid with a bituminous mix of 5.75% to 6% by weight dry aggregate. In accordance with ASTM D6390, drain down of the binder shall be no greater than 0.3%. Aggregate grain in the asphalt shall be a minimum 90% crushed material and have the following gradation.

Table 4.2.5: Porous Bituminous Aggregate Gradation

U.S. Standard Sieve Size	Percent passing
½ (12.5 mm)	100
3/8” (9.5 mm)	92 - 98
4 (4.75 mm)	34 - 40
8 (2.36 mm)	14 - 20
16 (1.18 mm	7 - 13
30 (0.60 mm	0-4
200 (0.075 mm)	0-2

- Neat asphalt binder modified with an elastomeric polymer to produce a binder meeting the requirements of PG 76-22 as specified in AASHTO MP-1. The elastomer polymer shall be styrene-butadiene-styrene (SBS), or approved equal, applied at a rate of 3% by weight of the total binder.
- Hydrated lime should be added at a dosage rate of 1% by weight of the total dry aggregate to mixes containing granite. Hydrated lime shall meet the requirements of ASTM C 977. 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 when tested in accordance with AASHTO T 283. The asphaltic mix shall be tested for its resistance to stripping by water in accordance with ASTM D-1664. If the estimated coating area is not above 95 percent, anti-stripping agents shall be added to the asphalt.

- The asphaltic mix shall be tested for its resistance to stripping by water in accordance with ASTM D-3625. If the estimated coating area is not above 95 percent, anti-stripping agents shall be added to the asphalt.

Paver and Grid Systems

- Paver and grid systems shall conform to manufacturer specifications.

- A minimum flow through rate of 5 in/hr or a void percentage of no less than 10%.

Non-Woven Geotextile

- Geotextile shall consist of needled non-woven polypropylene fibers and meet the following properties:

    - Grab Tensile Strength (ASTM-D4632) ≥ 120 lbs
    - Mullen Burst Strength (ASTM-D3786) ≥ 225 psi
    - Flow Rate (ASTM-D4491) ≥ 95 gal/min/ft^2
    - UV Resistance after 500 hrs (ASTM-D4355) ≥ 70%
    - Heat-set or heat-calendared fabrics are not permitted

Pipe

- Distribution pipe within bed shall be continuously perforated and have a smooth interior with a minimum inside diameter of 6-inches. High-density polyethylene (HDPE) pipe shall meet the specifications of AASHTO M252, Type S or AASHTO M294, Type S.

Construction Guidelines

General Guidelines for all Porous Pavements

The construction guidelines for the installation of the subsurface infiltration beds are applicable to all porous pavement systems. Guidelines are also provided specifically for pervious concrete and porous asphalt.

- Areas for porous pavement systems shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.

- An on-site pre-construction conference is recommended in order to inform the contractor and subcontractors of the special precautions that are required when working around porous pavements. This includes landscape crews, as the improper placement of mulch onto the porous pavement could result in localized clogging. During the pre-construction conference, the porous pavement siting requirements should be reviewed to ensure that no adverse impacts could occur to surrounding properties (basements, etc.).

SUBBASE EXCAVATION AND CONSTRUCTION

- Identify the sources of Stormwater point discharges that could drain toward the pavement surface (roof leaders, etc.). Provide a bypass for these Stormwater sources during the placement and curing period of the porous pavement.

- Excavate porous pavement subsurface area to proposed depth. Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material shall be removed with light equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake or equivalent and light tractor.

- Existing subgrade shall NOT be compacted or subject to excessive construction equipment prior to placement of geotextile and stone bed. If it is essential that equipment be used in the excavated area, all equipment must be approved by the Engineer. Use of equipment with narrow tracks or tires, rubber tires with large lugs, or high pressure tires will cause excessive compaction and shall not be used.

- Bring subgrade of stone infiltration bed to line, grade, and elevations indicated in the Drawings. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction before placing the stone. The bottom of the infiltration bed shall be at a level grade.

- Place geotextile and recharge bed aggregate immediately after approval of subgrade preparation to prevent accumulation of debris or sediment. Prevent runoff and sediment from entering the storage bed during the placement of the geotextile and aggregate bed.

- Place geotextile in accordance with manufacturer's standards and recommendations. Adjacent strips of filter fabric shall overlap a minimum of 16 inches. Fabric shall be secured at least 4 feet outside of 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 can be cut back to the edge of the bed.

- Install aggregate course in lifts of 6-8 inches. Compact each layer with equipment, keeping equipment movement over storage bed subgrades to a minimum. Install aggregate to grades indicated on the drawings.

- After placement and appropriate curing of structural pavement surface (7 days for pervious concrete and 48 hours minimum for porous asphalt hardening), test infiltration ability by applying clean water at a rate of at least 5 gpm over surface. The water applied to the surface should infiltrate without creating puddles or runoff.

- Do not use the porous pavement area for equipment or materials storage; no soil shall be deposited on porous pavement surfaces.

Guidelines for Installation of Pervious Concrete

- Pervious concrete pavement shall be installed by certified contractors only.

- A pre-paving conference with the contractor and engineer is recommended one week prior to beginning placement of pervious concrete. It is recommended that the contractor have the pervious concrete supplier, the foreman and the entire concrete crew that will form and place the concrete in attendance at this meeting.

- Once placed, the pervious concrete shall remain <u>covered and undisturbed</u> for seven (7) days. The covering should be a waterproof polyethylene sheeting with a minimum thickness of 6 mil. This curing period is essential for adequate strength and durability.

- The use of signage is encouraged during the seven day period to minimize the potential damage to the curing concrete occurring from pedestrian traffic.

Guidelines for Installation of Porous Asphalt

- Install and compact choker course aggregate evenly over surface of stone bed. Choker base course shall be sufficient to allow for even placement of asphalt, but no thicker than 1-inch in depth.

- Appropriate vehicles with smooth, clean dump beds shall be used to transport the asphalt mix to the site. Control cooling of asphalt by covering mix. Porous asphalt mix shall not be stored for more than 90 minutes before placement.

- The porous bituminous surface course shall be laid in one lift directly over the storage bed and stone base course and compacted to a 2½-inch finished thickness.

- Compaction of the surface course shall 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 porosity and permeability, which is unacceptable

- After rolling asphalt, no vehicular traffic is permitted on the surface until cooling and hardening has taken place (minimum 48 hours).

- The use of signage is encouraged during the seven day period to minimize the potential damage to the fresh asphalt occurring from pedestrian traffic.

Maintenance

As with most Stormwater management facilities, porous pavement systems require regular maintenance to extend their life. Detailed maintenance guidelines and a recommended schedule of inspection and maintenance can be found in the Example Permeable Pavement O & M Manual.

Sediment Control

Superficial dirt does not necessarily clog the voids in porous surfaces. 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 porous pavement lot. Also, by providing a ‘rumble strip’ surface at the entrance of a porous parking lot, the debris from tires can be isolated and later collected to avoid potential clogging of the entire lot.

Winter Maintenance

Winter maintenance for a porous parking lot may be necessary, but is usually less intensive than that required for a standard asphalt lot. By its very nature, a porous pavement system with subsurface aggregate bed has better snow and ice melting characteristics than standard pavement. Once snow and ice melt, they flow through the porous pavement rather than refreezing. Therefore, ice and light snow accumulation are generally not as problematic. However, snow will accumulate during heavier storms. Abrasives such as sand or cinders shall not be applied on or adjacent to the porous pavement. Snow plowing is acceptable, provided it is done carefully (i.e. by setting the blade about one inch higher than usual or using a rubber tipped blade. Salt is not recommended for use as a deicer on the porous pavement. Non-toxic, organic deicers applied either as blended, magnesium chloride-based liquid products or as pretreated salt, are preferable. Any deicing materials should be used in moderation.

Repairs

Potholes are not common; though settling might occur if a soft spot in the subgrade is not removed during construction. Damaged areas that are smaller than 50 square feet can be patched with a porous or standard asphalt mix, depending on the location within the porous area. In many cases the loss of porous surface will be insignificant. If an area greater than 50 square feet is in need of repair, approval of patch type must be sought from either the engineer or owner. Porous pavement must never be seal coated under any circumstances. Any required repair of drainage structures should be done promptly to ensure continued proper functioning of the system.

Note:

Design of permeable pavement systems are not limited to the examples shown within this text. Successful Stormwater management plans will combine appropriate materials and designs specific to each site.

Table 4.2.6: Engineering Report Requirements

Item	Infiltration / Detention Design	Detention-Only Design
Soil Infiltration Rate and Seasonal High Water Table Elevation Documentation	Report by Geotechnical Engineer or Registered Soil Scientist Required	Not Required
Storage Volume Calculations using 40% Void Space	Yes	Yes
Runoff, Storage, Outlet and Drain-Down Time Calculations	Yes	Yes
Overflow Calculations	Yes	Yes
Discussion of Local Water wells, and / or Wellhead Protection Zones	Yes	Yes

Table 4.2.7: Plan Requirements

Item	Infiltration Design	Detention-Only Design
Watershed Delineation (i.e. area served by the porous pavement) (Impervious area served may not exceed 3x area of porous pavement)	Yes	Yes
Plan View with Porous Pavement Area delineated and Labeled	Yes	Yes
Cross-Section Detail Showing Depth of Pavement, Choker Layer and Storage Layer	Yes	Yes
Detail and Location of Warning Sign (‘Pervious Pavement - No Construction Equipment”)	Yes	Yes
Plan View Showing Underdrain location and Outlet	Yes	Yes
Plan View Showing Location of Water Quality System	Not Required	Yes
Location of Overflow	Yes	Yes
Location of Local Waterwells-	Yes	Yes
Center Coordinates (in State Plane Coordinates) on Cover Sheet Summary Table	Yes	Yes

Table 4.2.8: O & M Manual Requirements

Item	Infiltration Design	Detention-Only Design
Owner Name, Address, Phone Number, email, etc.	Yes	Yes
Water Quality Unit Maintenance per Chapter 700	Not Required	Yes
Site Map with Porous Pavement Delineated and Labeled	Yes	Yes
Tabular Inspection Table	Yes	Yes
Inspection Checklist	Yes	Yes
Narrative Describing Repair Procedures / Requirements for the Porous Pavement	Yes	Yes
Inspection of Pretreatment Systems	Yes	Yes

Green Infrastructure Checklist

Permeable Pavements:

Site requirements for use:

- High water table depth to bottom of stone storage layer must be 2' or greater. (This is to prevent high water table from filling up detention storage area in stone.)
- If buildings adjacent to pavement have basements, make sure that the porous pavement is a minimum of 10' from the building/basement. Also, depending on soil type, a waterproof membrane may be needed on the side adjacent to the building. This should be evaluated on a case by case basis.
- If adjacent buildings don't have basements, the porous pavement should be located a minimum of 5' from the building.

Design Considerations:

- Slope of porous pavement can be flatter than traditional pavement. This helps the stone bed below it to be most efficiently used for Stormwater storage. Some slope is recommended to allow for positive drainage if pavement clogs in some areas.
- Size detention basin (stone base below pavement) based on Stormwater flow entering pavement. For #8 washed stone base, the void area in the stone is typically 40% of the stone volume. The stone must be wrapped in geotextile to ensure that voids in stone remain open for water storage and don't get clogged over time. The contractor can provide a sample of the stone to verify the void space for the stone used if needed.
- **No storage of Stormwater on top of the pavement** (as is allowed with traditional pavement).
- **No storage of Stormwater within porous pavement section**. The design must include a positive overflow from the stone bed to prevent water backing up into pavement section. (This is to prevent issues with freeze-thaw.) This could be an underdrain pipe or simply the stone base exposed so it can overflow to the lawn.
- It is recommended to discharge the overflow from the pavement stone base into a rain garden or bioretention area to improve water quality.
- If soils are adequate for infiltration there might not be runoff from the pavement (if all of it infiltrates). In this case (which is likely rare, but possible) there is no water quality volume or required treatment since there is no runoff.

Construction Considerations:

- Qualified contractors are a MUST. This means that their crew must have experience placing the pavement, not just the foreman.
- When using Portland Cement Pervious Concrete (PCPC) the pavement must remain covered for 7 days during the curing period. During this time it is critical that any Stormwater be diverted from the pavement – especially roof leaders that contribute point discharges.
- Erosion control is a must - any sediment laden water shall not be allowed to flow onto the porous pavement.
- No mulch or landscaping storage shall be allowed on the pavement as it could clog the pores of the pavement and thereby reduce its ability to convey and store Stormwater.
- The pavement should be tested after construction by pouring water over it to see if there are any areas that need to be cleaned or repaired due to construction activities.

4.2.1. Permeable Pavement Example O & M Manual

Permeable Pavement – O & M Manual

Owner Name
Address of Property
Owner Contact Name and Phone Number

BMP Narrative:
Regular inspection and maintenance is critical to the effective use of porous pavement. It is the responsibility of the property owner to maintain all Stormwater facilities in accordance with the minimum design standards required by the City of Indianapolis and this Operations & Maintenance Manual. The local jurisdiction has the authority to impose additional maintenance required where deemed necessary. The city has the right to inspect the system and to require replacement if it fails or is a threat to public safety. Portland Cement Pervious Concrete Pavement (PCPC) is considered to be failing if water can be seen standing on it or in it (within the concrete pavement section), unless the storm event is above a 100-year event. If maintenance does not correct the problem, full or partial replacement may be required.
Porous pavement shall be in accordance with the following inspection and maintenance criteria:

Inspection Activities	**Minimum Frequency**
• Inspect to ensure that pavement was installed and working properly. • Inspect areas for potential erosion or damage to vegetation.	Post-construction
• Visibly inspect porous pavement surface after major storm event for evidence of sediment, debris (e.g., mulch, leaves, trash, etc.), ponding of water, oil-dripping accumulations, clogging of pores and other damage. • Inspect overflow devices (pipes and inlets) for obstructions or debris that would prevent proper drainage when filtration capacity is exceeded. • Ensure that the contributing area upstream of the porous pavement is free of sediment and debris.	Annually and after large storm events
• Verify that the porous pavement dewaters between storms.	Monthly
• Inspect the surface for structural integrity. Inspect for evidence of deterioration or spalling.	Annually
Maintenance Activities	**Minimum Frequency**
• Remove excess sediment from construction area and stabilize adjacent areas with vegetation.	Post-construction
• Prevent soil from being washed onto pavement by ensuring that adjacent areas are stabilized. Keep landscape areas well maintained with lawn clippings removed to prevent clogging pavement. • Rake and remove fallen leaves and debris from deciduous trees and shrubs to reduce the risk of clogging. • Remove debris and clear obstructions from overflow devices (pipes and inlets).	Annually, as needed
• Vacuum sweep porous concrete pavement (with proper disposal of removed material), followed by high pressure hosing (when needed) to free pores on the surface.	2-3 times per year or more frequent as needed.
• If ponding persists, clogged concrete pavement must be repaired or replaced.	If failure exists

Address of property

Inspector:
Date:
Time:
Weather: Rainfall over previous 2-3 days? Site conditions:
Owner change since last inspection?: Y N

Mark items in the table below using the following key:

- **X** Needs immediate attention
- **–** Not Applicable
- ✓ Okay
- **?** Clarification Required

Porous Pavement Components:

Items Inspected	Checked		Maintenance Needed		Inspection Frequency
PAVEMENT SURFACE	Y	N	Y	N	**M**
1. Signs of clogging (e.g. standing water)?					
2. Debris (mulch, trash) accumulation?					
3. Sediment accumulation?					
4. Standing water present?					
ADJACENT AREAS					**A, AMS**
5. Erosion from underdrain?					
6. Exposed soil in areas discharging or adjacent to the porous pavement area?					
7. Is porous pavement adversely affected by any adjacent site feature?					
DEWATERING					**A, AMS**
8. Does runoff discharge from pavement area 24 to 72 hours after the end of a storm event?					
OUTLETS/OVERFLOW SPILLWAY					**A, AMS**
9. Is outlet for storm sewer system free from debris and in good working order?					
OTHER					**A**
10. Have there been complaints from residents?					
11. Public hazards noted?					
12. Other (describe)?					

Inspection Frequency Key A= Annual, M= Monthly, AMS= After Major Storm

Notes:

1. **Sand, cinders or other abrasives should not be used on or adjacent to the porous pavement.**
2. **Signage indicating no heavy or construction traffic permitted should be posted.**
3. **Porous pavement must not be seal coated.**

COMMENTS:

OVERALL CONDITION OF FACILITY:

In accordance with approved design plans? Y / N

In accordance with As Built plans? Y / N

Maintenance required as detailed above? Y / N

Compliance with other consent conditions? Y / N

Comments: ____
____

Dates by which maintenance must be completed: ____/ ___ / ___

Dates by which outstanding information as per consent conditions is required by: ____ / ___ / _____

Inspector's signature: ____

Owner/Engineer/Agent's signature: ____

Owner/Agent's name printed: ____________________________

4.2.2. Permeable Pavement Designer/Reviewer Checklist

Type of pervious pavement(s) proposed: ____

Source of mix design or material source: ____

Item	Yes	No	N/A	Notes
Appropriate application of pervious pavement (e.g., use, traffic loading, slopes)?				
Infiltration rates measured?				
Soil permeability acceptable?				
If not, appropriate underdrain provided?				
Adequate separations from wells, structures, etc.?				
Natural, uncompacted soils specified for base?				
Level infiltration area (bed bottom)?				
Excavation in pervious pavement areas				
Hotspots/pretreatment considered?				
Storage depth limited to 8-36"?				
Drawdown time less than 72 hours?				
Positive overflow from system?				
Erosion and Sedimentation control?				
Feasible construction process and sequence?				
Geotextile specified?				
Clean, washed, open-graded aggregate specified?				
Properly designed/specified pervious pavement surface?				
Maintenance accounted for and plan provided?				
Signage provided to prevent construction traffic and compaction?				

4.3. Rain Water Harvesting

Rain barrels, cisterns, and tanks are structures designed to intercept and store runoff from rooftops and other limited access surfaces (e.g. no transportation access). Rain barrels are used on a small scale while cisterns and tanks may be larger. These systems may be above or below ground, and they may drain by gravity or be pumped. Stored water may be slowly released to a pervious area, used for irrigation, or plumbed into buildings per code for use inside. *These techniques only serve as an effective Stormwater control function if the stored water is emptied between most storms, freeing up storage volume for the next storm.*

Key elements:

- Storage devices designed to capture small, frequent storm events with opportunity for larger storm volume capture.

- Storage techniques may include rain barrels, underground concrete or prefabricated tanks, above ground vertical storage tanks, or other systems.

- Systems must provide for storage, overflow or bypass of large storm events per local the City of Indianapolis Stormwater Design and Construction Specifications Manual.

- Placement of storage elements higher than areas where water will be reused may reduce or eliminate pumping needs.

- For effective Stormwater control, water must be used or discharged before the next storm event (i.e. <72 hours).

- Most effective when designed to meet a specific water need for reuse.

Table 4.3.1: Rain Barrel Potential Application and Stormwater Regulation

Potential applications			Stormwater regulations				
				Infiltration		No Infiltration	
Residential Subdivision:	Yes			RB	Cistern	RB	Cistern
Commercial:	Yes		Water Quality Benefit	Yes	Yes	Yes	Yes
Ultra Urban:	Limited		Volume Reduction	Yes	Yes	Yes	Yes
Industrial:	Yes		Attenuation Benefit	Yes	Yes	Yes	Yes
Retrofit:	Yes						
Highway Road:	No		Level of Benefit dependent on design criteria				

Acceptable forms of pre-treatment

- Screens
- First Flush bypass

Rain Barrels, Cisterns, and Tanks in the Urban Landscape

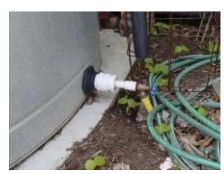
Rain barrels, cisterns, and other tanks are storage devices meant to promote detention of Stormwater runoff. Collectively or alone, these systems can be effective at preventing large volumes of Stormwater from entering the sewer system. Rain barrels, cisterns, and vertical storage are suitable where there is a use and need for the stored water or where there are areas to which water can be slowly released between storms. Rain harvesting storage can be used with existing buildings, new development, and redevelopment areas. Each of these areas can incorporate these systems into their Stormwater management plan. The design of these systems can be flexible due to the numerous design opportunities to capture and reuse Stormwater. The application and use of rain barrels, cisterns, or other tank storage systems are not limited to the examples provided below.

Rain Barrels on Individual Homes

The most common use of rain barrels is connection of one roof leader (downspout) to a single barrel on a residential property. Stored water can provide irrigation for a garden or can be released slowly to a lawn. Barrels can either be purchased or can be built by the homeowner. They are ideal for gardeners and concerned citizens who want to manage Stormwater without a large initial investment. They are also an easy retrofit. A design professional and Stormwater design calculations are typically not needed. The labor and installation can generally be performed by the property owner or handyman. The materials necessary are generally low cost and can be found at local retail hardware or plumbing supply stores.

Large Surface Tanks

Surface tanks may be larger than rain barrels but serve the same function. They can be integrated into sites where a significant water need exists or rain harvesting and reuse is desired. They may drain by gravity or be pumped. These typically need design professional assistance for more complex water collection and delivery system design. Typically need to be installed to local code by a certified and bonded plumbing or construction contractor.



Subsurface Storage and Water Reuse

Subsurface systems can be larger and more elaborate than rain barrels. These systems are typically pumped and may be used to supply water for building use or for irrigation systems. Because the cisterns are below the surface, they do not interfere with the landscape. These systems have higher initial costs than rain barrels and are ideal for commercial and institutional sites.

Water Features in Public and Institutional Landscapes

Architectural designs have incorporated water storage into site design. Features such as water fountains and ponds capture Stormwater from design storms to provide a water sources for these landscape features. These typically need design professional assistance for more complex water collection and delivery system design. Typically need to be installed to local code by a certified and bonded plumbing or construction contractor.

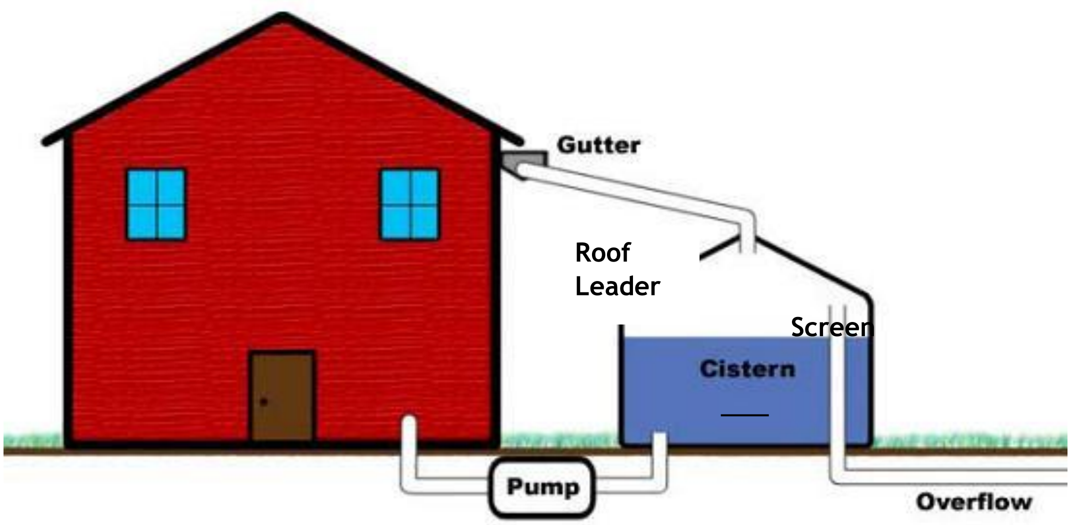
Reusing Stormwater for Indoor Use

Roof runoff can be captured and stored for reuse for residential, commercial or industrial needs. Roof runoff used in toilets does not need to meet potable water standards, but care must be used in plumbing to the building. Potable re-use systems for harvested rain water must comply with local plumbing and health codes. Supplementary and/or backup potable water systems must be maintained separately with all appropriate backflow prevention protection.

Components of Rain Barrels, Cisterns, and Tanks

Rain barrels, cisterns, and tanks all require the following basic components:

- a roof leader or other means of conveying roof runoff to the storage element,
- a screen to prevent debris and mosquitoes from entering,
- a storage element,
- a slow release mechanism or pump, a reuse opportunity, or infiltration area, and
- an overflow mechanism to bypass larger storms, after the storage element has filled.



Roof Leader

The gutter and roof leader system collects rooftop runoff and conveys it to the rain barrel, cistern, or other storage element. In most cases conventional roof leaders and downspouts can be used for this purpose.

Screen

A screen keeps leaves and other debris from entering and clogging the storage element. A screen also prevents mosquitoes from breeding in the storage element. A screen is typically placed at the end of the roof leader, before flow enters the rain barrel or cistern. A leaf strainer may also be placed where the gutter connects to the roof leader.

Storage Element
The storage element is the barrel, cistern, or tank itself. Rain barrels are typically made of plastic. Underground cisterns may be poured concrete or prefabricated plastic tanks similar to septic tanks. Proprietary products that store water in a variety of structures are also available. Tanks larger than rain barrels may be used above or below ground.

Slow Release Mechanism or Pump
For the storage element to serve its Stormwater control function, it must be partially or completely drained between most wet weather events. Rain barrels are typically drained in one of two ways: manually by means of a spigot similar to ordinary outside water faucets; and, the continual, slow release using a soaker hose to a garden or infiltration area. Larger surface tanks may drain by gravity or may be pumped. Subsurface systems and systems where Stormwater is reused for needs other than irrigation are typically pumped.

Overflow Mechanism
The storage capacity of rain barrels, cisterns, and other tanks may be exceeded in large storms. In rain barrels, a flexible hose is provided at an elevation near the top of the barrel. The diameter of the hose is at least equal in size to the roof leader to allow runoff to flow unimpeded during large events. The overflow from cisterns and larger tanks can occur through a weir, pipe, or other mechanism.

Table 4.3.2: Suggested Storage Design Values for Rain Barrels	
Rain Barrel	50 - 150 gallons
Cistern	500 - 7,000 gallons
Larger Above Ground Tank	3,000 - 12,000 gallons

Siting Procedure Recommendation
Identify opportunities and areas where water can be reused for irrigation, released to an infiltration area, or meet indoor use needs. Estimate the rate at which water can be reused. If the process of reuse is proposed to meet the Water Quality requirement, check the local Stormwater design codes and ordinances. For irrigation or garden use, determine the water needs of the plants; an assumption of 1 inch per week over the soil area may be used for approximate results. Identify potential infiltration areas where water may be discharged to at a slow rate. Refer to **Rain Water Harvesting Design Guidelines (Attachment 4)** for additional design information.

Rain Barrels

- Identify roof leaders where rain barrels can be installed.

- Decide whether to purchase a commercial rain barrel or to construct your own rain barrel.

- Choose between a faucet and a soaker hose. Position the outlet as low on the barrel as the design will allow to maximize storage volume. It is recommended that the design allow retention of 2 inches at the bottom of the barrel to help trap sediment and provide stability.

- Consider elevating the barrel by placing it on a stable platform (ie. cinder blocks) to increase water pressure at ground level.

- It is easiest to install soaker hoses on the ground surface. The hoses can then be easily reconfigured and moved whenever necessary. However, underground soaker hoses provide greater irrigation benefits for gardens, because the water does not evaporate. If buried, soaker hoses should be placed 2-4 inches under soil or 1-2 inches under mulch. Soaker hoses that are buried too deep can be difficult to monitor and are more prone to damage from root growth. Solid hose can be use if desired location of soaker hose is away from rain barrel.

- If emptying the barrel manually, develop a plan so that it is partially or completely emptied on average every 3 to 4 days. This is necessary so that the entire storage capacity is available at the beginning of most storms.

- Position the overflow hose to discharge larger storms. The overflow should be discharged to an area protected from erosion. At a minimum, direct the overflow to the same location as the roof leader before placing rain barrel.

Cisterns (Subsurface or Surface)

- Identify which roof leaders can drain to the cistern, and the area of roof draining to each leader.

- Estimate the storage needed. A rough estimate may be obtained by performing a weekly water balance of rainfall and water reuse. Depending on the complexity of system and/or intended reuse options, a Design Professional may need to be contracted to perform more rigorous analysis in order to best meet water demand needs.

- Design to local codes and ordinances, preparing complete construction plans and specifications.

Materials and Construction Guidelines
Rain Barrels

- Rain barrels are commonly pre-fabricated structures constructed with plastic, wood or steel.

- The container should be made of an opaque material to prevent algae growth in the stored water.

- Debris screen to keep leaves and other debris from entering and clogging the storage element.

Cisterns
Cisterns may be constructed of fiberglass, concrete, plastic, brick, or other materials.

Maintenance
As with most Stormwater management systems, cisterns and rain barrels require regular inspection and maintenance to insure their functionality and to extend their life. Detailed maintenance guidelines and a recommended schedule of inspection and maintenance can be found in the Example Cistern/Rain Barrel O & M Manual.

Technical Design Requirements Summary Tables

Table 4.3.3: Engineering / Drainage Report Requirements Summary

Item	**Required**
Runoff Calculations (for Cisterns and Storage Tanks)	Yes
Storage Volume Calculations (for Cisterns and Storage Tanks)	Yes
Drain Down Time (72 hrs max) for Systems Designed as Part of the Stormwater Quantity or Quality System	Yes
Inflow / Outflow pipe size calculations (10-yr minimum) (for Cisterns and Storage Tanks)	Yes
Emergency Overflow Calculations (for Cisterns and Storage Tanks)	Yes
Water Quality Volume Calculations (if system is part of the stormwater quality management system)	Yes
Water Quantity Volume Calculations (if system is part of the stormwater quantity management system)	Yes

Table 4.3.4: Plan Requirements

Item	Required
Detail of Storage System Showing:	Yes
Dimensions	Yes
Inlet and Outlet	Yes
Location of Screens or other Pretreatment	Yes
Backfill	Yes
Basin Map Showing Area Served by Storage System	Yes
Pretreatment Detail (e.g. screen opening size and location)	Yes
Easements (If Storage System is Part of the Water Quantity or Quality System)	Yes
Center Coordinates of Storage Tank (in State Plane Coordinates) on Cover Sheet Summary Table	Yes

Table 4.3.5: O & M Manual Requirements

Item	Required
Tabular Inspection Schedule	Yes
Site Diagram with Storage System Location and Details of Areas to be Inspected	Yes
Inspection Checklist	Yes
Narrative description of Inspection Procedure including:	Yes
Sediment Gauging	Yes
Pretreatment Inspection	Yes
Emergency Overflow System	Yes
Note to Drain Storage System Prior to Winter if Freezing Possible*	Yes

*Systems drained for winter may not qualify as a water quantity or quality practice.

4.3.1. Rain Water Harvesting Example O & M Manual

Rain Water Harvesting – O & M Manual

Owner Name
Address of Property
Owner Contact Name and Phone Number

BMP Narrative:
Regular inspection and maintenance is critical to the effective use of a cistern/rain barrel. It is the responsibility of the property owner to maintain all Stormwater facilities in accordance with the minimum design standards required by the City of Indianapolis and this Operations & Maintenance Manual. The local jurisdiction has the authority to impose additional maintenance required where deemed necessary. The city has the right to inspect the system and to require replacement if it fails or is a threat to public safety. If maintenance does not correct the problem, full or partial replacement may be required.
Cisterns/Rain Barrels shall be in accordance with the following inspection and maintenance criteria:

Inspection Activities	**Suggested Frequency**
• Inspect to ensure that cistern/rain barrel was installed and working properly. • Certification shall be required that the constructed system meets the conditions specified on the approved plans. • Certification regarding the water tightness of the underground storage tank is required after its installation.	Post-construction
• Leaf screens, gutters, and downspouts should be inspected and cleaned to prevent clogging. • Inspect overflow device for obstructions or debris that would prevent proper drainage when storage capacity is exceeded. • Inspect to ensure overflow runoff is safely conveyed to a stable outfall that causes no problems to down gradient properties. • Dewatering in between rain events so that the required storage volume is available. • Inspect for presence of mosquito larvae.	Annually and after large storm events
• Inspect all fittings and valves for water tightness seal.	Monthly
• Above-ground systems should be disconnected, drained, and cleaned at the start of the Winter season.	Annually
Maintenance Activities	**Suggested Frequency**
• Clean leaf screens, gutters, and downspouts. • Replace overflow device if any obstructions or debris prevent proper drainage when storage capacity is exceeded. • If overflow runoff is not safely conveyed to a stable outfall and/or signs of erosion exist, stabilize and remedy problem. • Dewater in between rain events so that the required storage volume is available and sediment is removed. • Replace any system components that are not performing properly.	Annually, as needed
• Above-ground systems should be disconnected, drained, and cleaned at the start of the Winter season.	Annually

Address of property

Inspector:
Date:
Time:
Weather: Rainfall over previous 2-3 days? Site conditions:
Owner change since last inspection?: Y N

Mark items in the table below using the following key:

- **X** Needs immediate attention
- **–** Not Applicable
- ✓ Okay
- **?** Clarification Required

Cistern Components:

Items Inspected	Checked		Maintenance Needed		Inspection Frequency
SYSTEM COMPONENTS	Y	N	Y	N	**A, AMS**
1. Signs of clogging (e.g. screens, gutters, downspouts)?					
2. Debris accumulation?					
3. Sediment accumulation?					
4. Standing water present around base?					
5. Are valves and fittings watertight?					
ADJACENT AREAS/OVERFLOW SPILLWAY					**A, AMS**
6. Is overflow outlet clean of debris?					
7. Erosion from overflow path?					
8. Signs of water ponding?					
9. Is outlet for storm sewer system free from debris and in good working order?					
DEWATERING					**A**
10. When was Cistern/Rain Barrel Last Drained?					
OTHER					**A**
11. Physical appearance of water, any odor?					
12. Are mosquito larvae present?					
13. Have there been complaints from residents?					
14. Public hazards noted?					
15. Other (describe)?					

Inspection Frequency Key A= Annual, M= Monthly, AMS= After Major Storm

COMMENTS:

OVERALL CONDITION OF FACILITY:

In accordance with approved design plans? Y / N

In accordance with As Built plans? Y / N

Maintenance required as detailed above? Y / N

Compliance with other consent conditions? Y / N

Comments: ____
____

Dates by which maintenance must be completed: ____/ ___ / ___

Dates by which outstanding information as per consent conditions is required by: ____ / ___ / _____

Inspector's signature: ____

Owner/Engineer/Agent's signature: ____

Owner/Engineer/Agent's name printed: _____________________________

4.3.2 Rain Water Harvesting Designer/Reviewer Checklist

Type and size (gallons) of storage system provided: ___________________

Item	Yes	No	N/A	Notes
Capture area defined and calculations performed?				
Pretreatment provided to prevent debris/sediment from entering storage system?				
Water use identified and calculations performed?				
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?				
Acceptable overflow provided?				
Winter operation (protection from freezing) considered?				
Observation/clean-out port provided?				
Maintenance accounted for and plan provided?				

4.4. Filter Strips


Pennsylvania Stormwater BMP Manual

Filter Strips are densely vegetated lands that treat sheet flow Stormwater from adjacent pervious and impervious areas. They function by slowing runoff, trapping sediment and pollutants, and in some cases infiltrating a portion of the runoff into the ground. To be effective, they require the presence of sheet flow across the entire strip. Since they can be incorporated into landscaped areas, filter strips can provide dual functionality to satisfy Stormwater pre-treatment and landscape requirements in one location. Filter strips are a sensible and cost-effective Stormwater management pretreatment option applicable to a variety of development sites including roads and highways.

Key elements:

Filter Strips must be designed within parameters required by the Indianapolis Stormwater Design and Construction Specifications Manual.

- Filters strips are only considered a viable pretreatment option for other BMPs and do not provide adequate pollutant removal benefits to act as a stand-alone BMP.
- Sheet flow across the vegetated filter strip is mandatory for proper filter strip function.
- Filter strip length is a function of slope, vegetation type, soil type, drainage area, and desired amount of pretreatment. See Table 4.4.2 for filter strip length criteria, as common terminology for filter strips uses the word ‘length’ for what would normally be considered the width as well as the length. A unit width of filter strip is assumed, with the length being the dimension parallel to the flow path. The length dimension is specified with respect to the flow path in both parallel and perpendicular directions.
- Level spreading devices are recommended to provide uniform sheet flow conditions at the interface of the filter strip and the adjacent land cover.
- The longest flow path to a filter strip, without the installation of energy dissipaters and/ or flow spreaders, is 75 feet for impervious ground covers and 150 feet for pervious ground covers. (See Chapter 700, Section 702.06 for additional requirements)
- Filter strip slope should never exceed 10%. Slopes less than 6% are generally preferred. Slopes greater than 2% are recommended to promote positive drainage flow to and through the filter strip.
- Maximum contributing drainage area is less than 5 acres, and should also never exceed a drainage area to filter strip area ratio of 6:1.
- Maximum contributing drainage area slope is generally recommended to be less than 5%, unless energy dissipation and/or flow spreaders are provided.
- Construction of filter strips shall entail as little disturbance to existing vegetation at the site as possible.

- Use of native plants within filter strips can serve to stabilize soils to prevent erosion. This is most beneficial in areas along stream banks and shorelines.

Table 4.4.1: Filter Strips Potential Application and Stormwater Regulation

Potential applications			Stormwater regulations		
				Infiltration	No Infiltration
Residential Subdivision:	Yes		Water Quality Benefit	No	Yes
Commercial:	Yes*		Volume Reduction	No	No
Ultra Urban:	Limited*		Attenuation Benefit	No	No
Industrial:	Limited*				
Retrofit:	Yes				
Highway Road:	Yes				

Acceptable forms of pre-treatment

N/A

Filter Strips in the Urban Landscape

Filter strips are effective at slowing runoff velocities, removing pollutant loads, and promoting infiltration of runoff produced by both impervious and pervious areas. Filter strips are suitable for many types of development projects. Filter strips can be used as pretreatment facilities for other BMPs in residential, commercial, and light industrial development; roads and highways; and parking lots.

FILTER STRIP IN FORESTED AREA

Filter strips are recommended for use as a pretreatment component of other BMPs including but not limited to: bioretention, constructed wetlands, detention, filters, ponds/wet basins, porous pavement, and vegetated swales. The use of a properly maintained filter strip extends the life of the associated BMPs and decreases its hydraulic residence time. It also increases the amount of time before these structures need maintenance.

Components of a Filter Strip System

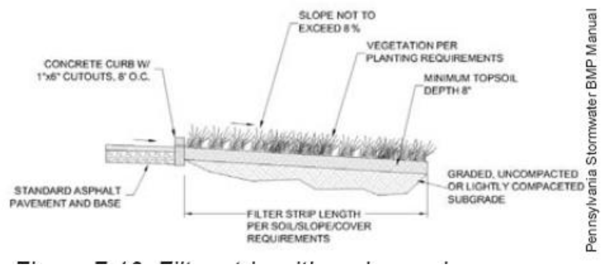
Inlet Control

Filter strips are typically combined with a level spreader or flow control device. A flow control device functions to lessen the flow energy of Stormwater prior to entering the filter strip area. Filter strips function best when flows are evenly distributed over their width. Concentrated flows can have an erosive effect that can damage the filter strip by short circuiting it and rendering the strip ineffective. Curb openings combined with a gravel level spreader are a common type of flow control. See Section 4.9: Inlet and Outlet Controls for more information. Slotted or depressed curbs installed at a level grade at the edge of the impervious area should ensure a well distributed flow to the filter strip. These slotted openings should be spaced along the length of the curb.

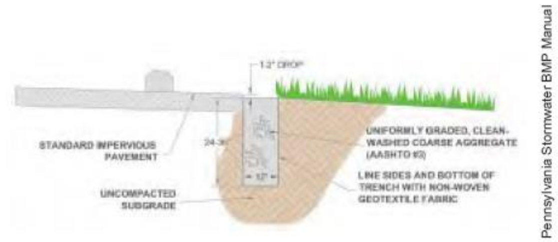
FILTER STRIP PROVIDING PRETREATMENT FROM A PARKING LOT TO A BIORETENTION SYSTEM

Vegetation

The vegetation for filter strips may be comprised of turf grasses, meadow grasses, shrubs, and native vegetation. It can include trees or indigenous areas of woods and vegetation. Vegetation adds aesthetic value as well as water quality benefits. The use of indigenous vegetated areas that have surface features that disperse runoff is encouraged, as the use of these areas will also reduce overall site disturbance and soil compaction. Native vegetation also helps to minimize erosion by stabilizing the soil with the deep root structure common in native plants. The use of turf grasses will increase the required length of the filter strip compared to other vegetation options. See Chapter 5: Stormwater Landscape Guidance.



FILTER STRIP WITH CURB OPENING



FILTER STRIP WITH GRAVEL TRENCH LEVEL SPREADER

Retentive Grading

Filter strip effectiveness may be enhanced by installing retentive grading perpendicular to the flow path. A pervious berm allows for a greater reduction in both runoff velocity and volume, thus improving pollutant removal capabilities by providing a temporary (very shallow) ponded area. The berm should be constructed according to the design provided in Section 4.6: Berms and Retentive Grading.

Check Dams

Filter strips with slopes that exceed 6% should implement check dams to encourage ponding and prevent scour and erosion of the filter strip area. More information on check dams is available in Section 4.9: Inlet and Outlet Controls.

CHECK DAMS: NOTE CHANNEL STORAGE CAPACITY CREATED BY CHECK DAMS. NOTCHED CENTER ALLOWS SAFE OVERFLOW WITHOUT SCOUR AROUND SIDES

Recommended Design Procedure

- Determine the Water Quality and Quantity requirements for the site per the Stormwater Design and Construction Specifications Manual.

- Create a Conceptual Site Plan for the entire site and determine what portion of the sizing requirements filter strips will accommodate (for pretreatment purposes).

- Investigate the feasibility of infiltration according to soil and vegetative conditions in the area proposed for the filter strip. If infiltration is feasible, determine the saturated vertical infiltration rate. Refer to **Attachment 1**, **Guidelines for Infiltration Practices** for soil infiltrating testing guidelines.

- Examine size and slope of the drainage area. The maximum contributing drainage area to a filter strip area shall never exceed 5 acres, and should also never exceed a drainage area to filter strip area ratio of 6:1.

- If the slope of the filter strip parallel to the proposed flow path is ≥ 5%, energy dissipater and/or flow spreaders must be installed.

- Design an inlet control to meet energy dissipation requirements. See Section 4.9: Inlet and Outlet Controls.

- A flow spreader which stretches the entire length (perpendicular to flow path) of the contributing drainage area should be designed to limit flow velocity to prevent erosion and to spread the flow equally across the filter strip. If necessary, a bypass should be installed to prevent excessive, damaging flows.

- Create a conceptual design for the pretreatment filter strip.

Table 4.4.2: Suggested Starting Design Values for Filter Strip Length	
Strip Length Perpendicular to Flow Path	Largest feasible on site
Strip Length Parallel to Flow Path	10* - 150 feet
*The minimum pretreatment filter strip value is based on the length of the receiving flow path. The graph below shows how the minimum length requirement changes as both flow path and filter strip slope change.	

- Determine the longest flow path length for the contributing drainage area.

- For contributing drainage areas with flow paths < 30 feet use the following graph to help determine the filter strip length parallel to the flow path.

- For filter strips with contributing flow paths > 30 feet, use the suggested flow characteristics for maximum velocity and depth as design restrictions. When choosing an initial filter strip length (parallel to flow), the suggested minimum starting design value is 10 feet.

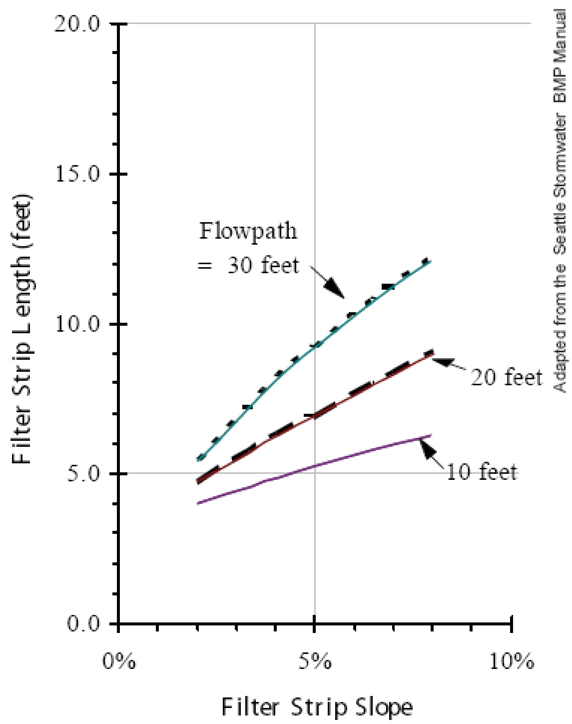


Table 4.4.3: Suggested Maximum Velocities and Water Depths for Filter Strip Area	
Maximum Velocity (ft/s)	1.0, Less than 0.5 preferred
Maximum Water Depth (in.)	1.0, Less than 0.5 preferred
The values for both maximum Velocity and Water depth were taken from the US DOT Stormwater Best Management Practices (BMPs) in an Ultra-Urban Setting: Selection and Monitoring and the Seattle BMP Manual.	

- Adjust filter strip design characteristics to provide desired amount of pretreatment.

- When considering retentive grading, use the infiltration area and the saturated vertical infiltration rate of the native soil to estimate how long the surface ponding will take to drain. The maximum drain down time for the ponded volume is 72 hours, but a drain down time of 24 - 48 hours is recommended. If ponded water does not drain in the time allowed, adjust water surface depth, soil depth, and/or surface area. Adjust the design until the volume and drainage time constraints are met.

- All retentive grading techniques should encourage soil stabilization and erosion control with vegetative growth. See Section 4.6: Low Impact and Retentive Grading.

- Choose plants and trees appropriate and compatible with the site conditions and local landscape requirements. See Chapter 5: Stormwater Landscape Guidance.
- Filter strips may not be used in high use areas unless precautions are taken to minimize disturbance (i.e. signage, placement of sidewalks or paths to minimize disturbance of the filter strip). Educational signage is encouraged and may be required in the Operations & Maintenance Manual to ensure that the owner understands the purpose of the filter strip (to avoid future mowing and removal).

- Determine final contours of the filter strip.

- Complete construction plans and specifications.

Materials

All material/ plant specifications should appear on the plans.

- Recommendations for plant materials and soils can be found in Chapter 5: Stormwater Landscape Guidance.

Construction Guidelines

- Areas for filter strips shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.

- In areas where soil is compacted, tilling to depths of 12-18 inches is necessary. A minimum of 6 inches of top soil must be added into the tilled soil column, and small trees and shrubs with capabilities for deep root penetrations should be introduced to maximize the soil infiltrative capacity. Chapter 5: Stormwater Landscape Guidance, for more specification on soil types and preferred plantings.

- Provide erosion and sedimentation control protection on the site such that construction runoff is directed away from the proposed filter strip location.

- Complete site elevation and retentive grading, if proposed. Stabilize the soil disturbed within the limit of earth disturbance.

- Install energy dissipaters and flow spreaders. Refer to Section 4.9 Inlet and Outlet Controls for more detailed construction information.

- The slope (parallel to the flow path) of the top of the filter strip, after the flow spreading device, shall be less than 1 % and gradually increase to designed value to protect from erosion and undermining of the control device.

- Construct inlet protection as specified in the design.

- Seed and plant vegetation (plants, shrubs, and trees) as indicated on the plans and specifications listed in Chapter 5: Stormwater Landscape Guidance.

- Once site vegetation is stabilized, remove erosion and sediment control protection.

Maintenance Guidelines

All areas of the filter strip should be inspected after significant storm events for ponding that exceeds maximum depth and duration guidelines. Corrective measures should be taken when excessive ponding occurs. An Operations & Maintenance Manual should be included in the design documents to instruct the owner/operator of the maintenance required to maintain the filter strip functioning in accordance with the design.

Table 4.4.4: Filter Strips Maintenance Guidelines		
	Activity	Schedule
	Mowing and/or trimming of vegetation (not applicable to all filter strips). Filter strips that need mowing are to be cut to a height no less than 4 inches. Greater than 5 inches is preferred.	As needed
	Inspect all vegetated strip components expected to receive and/or trap debris and sediment for clogging and excessive debris and sediment accumulation; remove sediment during dry periods.	Quarterly
	Vegetated areas should be inspected for erosion, scour, and unwanted growth. This should be removed with minimum disruption to the planting soil bed and remaining vegetation. Inspect all level spreading devices for trapped sediment and flow spreading abilities. Remove sediment and correct grading and flow channels during dry periods.	Biannually
	Maintain records of all inspections and maintenance activity.	Ongoing

- When correcting grading of a flow spreading device, use proper erosion and sediment control precautions in the concentrated area of disturbance to ensure protection of the remaining portion of the filter.

- Disturbance to filter strips should be minimal during maintenance. At no time should any vehicle be driven on the filter strip. In addition, foot traffic should be kept to a minimum.

- If the filter strip is of the type that needs mowing (i.e., turf grass and possibly other native grasses), the lightest possible mowing equipment (i.e., push mowers, not riding mowers) should be used. The filter strip should be mowed perpendicular to the flow path (however not exactly the same path every mowing) to prevent any erosion and scour due to channeling of flow in the maintenance depressions.

- When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. For more information on vegetative maintenance, refer to Chapter 5: Stormwater Landscape Guidance.

- Bi-weekly inspections of erosion control and flow spreading devices should be performed until soil settlement and vegetative establishment has occurred.

Note:
Design of filter strips are not limited to the examples shown within this text. Successful Stormwater management plans will combine appropriate materials and designs specific to each site

4.4.1. Filter Strip Designer/Reviewer Checklist

Item	Yes	No	N/A	Notes
Sheet flow provided?				
Recommended slope ranges followed?				
Appropriate length for soil, vegetation, and slope?				
Slope of drainage area below five percent?				
If not, is energy dissipation provided?				
Length/area of incoming drainage appropriately limited?				
Receiving vegetation considered?				
Located in undisturbed virgin soil?				
If not, will soil be properly compacted and stabilized?				
Appropriate vegetation selected for stabilization?				
Feasible construction process and sequence?				
Soil compaction avoided or mitigated?				
Erosion and sedimentation control provided to protect filter strip.				

4.5. Bioretention, Micro-bioretention and Rain Gardens

Bioretention

Bioretention areas typically are landscaping features adapted to treat Stormwater runoff. Bioretention systems are also known as Mesic Prairie Depressions, Rain Gardens, Infiltration Basins, Infiltration Swales, bioretention basins, micro-bioretention systems, bioretention channels, tree box filters, planter boxes, or streetscapes, to name a few. Bioretention areas typically consist of a flow regulating structure, a pretreatment element, an engineered soil mix planting bed, vegetation, and an outflow regulating structure. Bioretention systems provide both water quality and quantity Stormwater management opportunities.

Bioretention systems are flexible, adaptable and versatile Stormwater management facilities that are effective for new development as well as highly urban re-development situations. Bioretention can readily adapt to a site by modifying the conventional “mounded landscape” philosophy to that of a shallow landscape “cup” depression. Such landscape depression storage and treatment areas fit readily into: parking lot islands; small pockets of open areas; residential, commercial and industrial campus landscaping; and, urban and suburban green spaces and corridors.

Bioretention works by routing Stormwater runoff into shallow, landscaped depressions. These landscaped depressions are designed to hold and remove many of the pollutants in a manner similar to natural ecosystems. During storm events, runoff ponds above the mulch and Engineered Soil Mix in the system. Runoff from larger storms is generally diverted past the facility to the storm drain system. The runoff remaining in the bioretention facility filters through the Engineered Soil Mix. The filtered runoff can either be designed to enhance groundwater infiltration or can be collected in an underdrain and discharged per local Stormwater management requirements.

Key elements:

- Stormwater management design intended to replicate a site’s pre-developed natural hydrologic processes through runoff storage and filtration.
- Flexible in size and configuration; can be used for a wide variety of applications. Can be used for Water Quality Volume (WQv) requirements for most local ordinances.
- Water Quality and Quantity volume that drains down in no more than 48 hours.
- Engineered Soil Mix that provides Stormwater treatment through filtration while enhancing plant growth.
- Native and/or ornamental vegetation that provide evapotranspiration of Stormwater, pollutant filtration, and an aesthetically designed landscape area.
- Flood control bypass system for runoff in excess of designed filtration capacity.
- Maintenance of Engineered Soil Mix and vegetation is required.

Highlights:

- Contributes to enhanced air quality, water quality and can assist in directly reducing urban heat island impacts.
- Can improve property value through attractive landscaping.

Effectiveness

- Structural Stormwater management practices such as bioretention can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. Bioretention systems tend to behave similarly to swales; their pollutant removal rates are relatively high.

SEATTLE STREET EDGE ALTERNATIVES (SEA)

Table 4.5.1: Bioretention Potential Application and Stormwater Regulation

Potential applications			Stormwater regulations		
				Infiltration	No Infiltration
Residential Subdivision:	Yes		Water Quality Benefit	Yes	Yes
Commercial:	Yes		Water Quantity Benefit	Yes	Yes
Ultra Urban:	Yes		Volume Reduction	Yes	Yes
Industrial:	Yes		Attenuation Benefit	Yes	Yes
Retrofit:	Yes		Level of Benefit dependent on design criteria		
Highway Road:	Yes				

PRE-TREATMENT IN INDIANAPOLIS CULTURAL TRAIL BIORETENTION (ALABAMA STREET)

Acceptable forms of pre-treatment

- Energy dissipation to prevent erosion and scour of BMP.
- Pretreatment pollutant removal areas for concentrated collection of trash, debris, sediment, and other suspended and dissolved pollutants, i.e. forebay.
- Grass Filter Strips

Bioretention in the Urban Landscape

Bioretention systems are shallow, vegetated depressions used to promote absorption and infiltration of Stormwater runoff. This management practice is very effective at removing pollutants and reducing runoff volume. Stormwater flows into the bioretention area, ponds on the surface, infiltrates into the soil bed, and is used by plants and trees in the system.

OVERFLOW PIPE

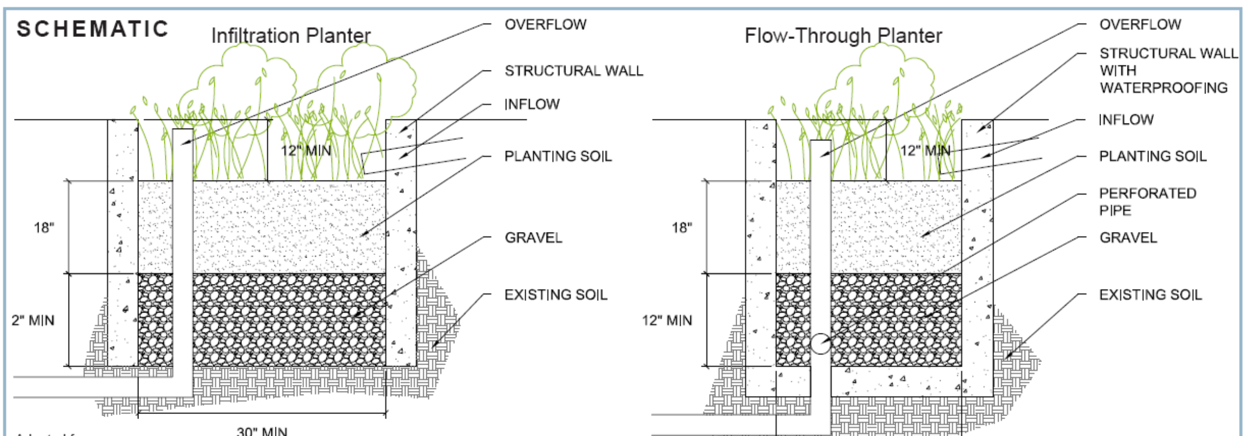
Bioretention areas are suitable for many types and sizes of development, including single-family residential, high-density commercial, and ultra-urban re-development projects. Bioinfiltration/bioretention areas are generally relatively small landscaped areas that can be integrated throughout a site to manage all or part of the site's Stormwater runoff. Flexible and easy to incorporate in landscaped areas, bioretention facilities are ideal for placement in roadway median strips and parking lot islands. They can also provide water quality treatment from pervious areas, such as golf courses, filter stripswales and other large lawn areas.

In highly urbanized watersheds, bioinfiltration/bioretention is often one of the few retrofit options that can be cost effectively employed by modifying existing landscaped areas, converting islands or under-used parking areas, or integrating into the resurfacing of a parking lot. Applications of bioinfiltration/bioretention systems in urban environments include planter boxes, residential, commercial and/or industrial on site landscaping, parking lots, and roadways, which can capture both site and roof runoff. The applications of bioinfiltration/bioretention systems are not limited to this list; however, examples for each of these alternatives are provided below.

Bioretention systems and especially rain gardens may be mistaken as areas not being maintained. The City of Indianapolis maintains a voluntary registry of rain gardens in order to clearly distinguish a constructed rain garden from unmaintained ground. All owners of rain gardens should register their rain gardens with the City.

Planter Boxes

A flow-through the planter box is designed with an impervious bottom or is placed on an impervious surface. Pollutant reduction is achieved as the water filters through the soil. Flow control is obtained by storing the water in a reservoir above the soil and detaining it as it flows through the soil. This planter can be used adjacent to a building if the box is properly lined.



Adapted from:
Portland: Stomwater Management Manual (Adopted July 1, 19999, Revised September 1, 2004)
http://www.portlandonline.com/bes/index.cfm?c=dfbbh Accessed 01/29/2008

Residential On-lot

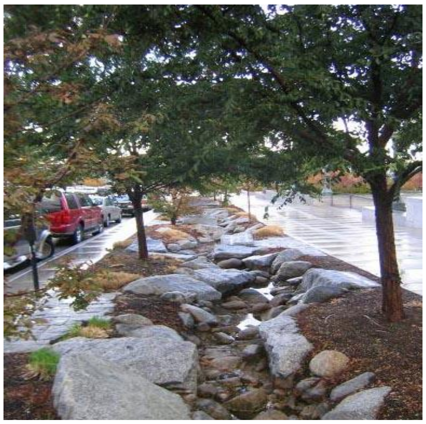
Landscaped garden areas (rain gardens) can be designed with bioretention systems to create decorative features, habitat, and Stormwater treatment at a residential site. The design can be as simple as incorporating a planting bed into the lowest point on a site. It is recommended that downspouts be directed into these systems after appropriate pre-treatment.

Tree Wells

Bioretention principles can be incorporated into a tree well design to create mini- treatment areas throughout a site.

Care should be taken to ensure that the Engineered Soil Mix, in-situ soils and ponding area depth is appropriate to the tree size and species.

BIORETENTION INTEGRATED INTO URBAN LANDSCAPE (ALABAMA STREET, INDIANAPOLIS)



ALTERNATIVE "STREAM BED" URBAN BIORETENTION

Parking Lots

Parking lots are an ideal location for bioretention systems. Bioretention can be incorporated as an island, median, or along the perimeter of the parking area. Bioretention areas can enhance the aesthetics of a parking lot while managing Stormwater from the site. Bioretention is an excellent discharge location for parking lot pervious pavement sub-drain seep or direct discharges. Whether by curb cuts, sheet flow or sub-drains, runoff flowing into bioretention must not result in erosive velocities.

Roads and Highways

Linear bioretention basins can be constructed alongside roads or highways, in roadway medians, or in bump-outs that double as traffic calming devices. The system will manage runoff from the street and help to control automotive pollutants. The systems can also help to control roadway flooding.

Commercial/Industrial/Institutional

At commercial, industrial, and institutional sites, areas for Stormwater management and green space are often limited. At these sites, bioretention systems serve the multiple purposes of Stormwater management and landscaping. Bioretention areas can be used to manage runoff from impervious site areas such as parking lots, sidewalks, and rooftops.

NATIVE/ORNAMENTAL MIX PARKING ISLAND LANDSCAPING

Rain Garden and Native Planting Programs

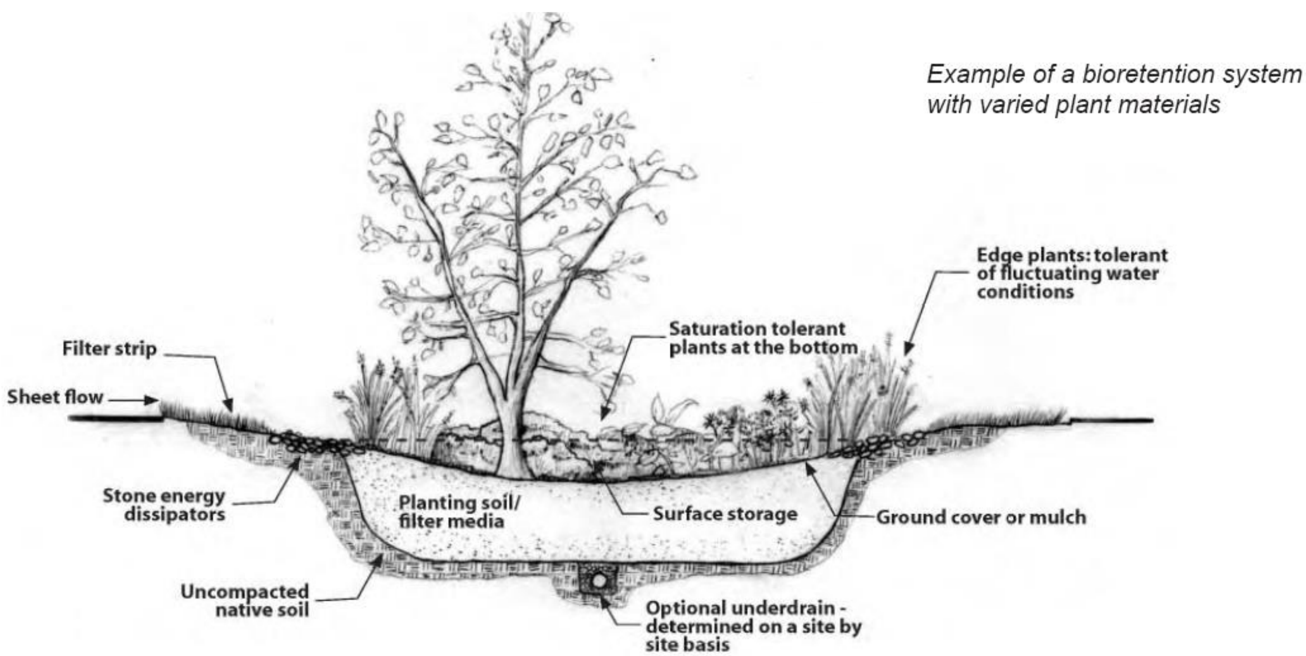
To promote rain gardens and native planting areas, the City of Indianapolis has established a Rain Garden Resource Center outlining supplies, customized planting plans, maintenance guidelines, permitting guidance, and more. The resource center is intended to be used by residents, businesses, developers, and institutions. Rain gardens and native planting areas can vary in size from a small rain garden in the corner of a residential lot to a large bioretention area receiving runoff from a commercial strip mall. Permitting requirements are most likely an issue only for larger projects, especially those that tie into City drainage, but the owners of all rain garden and native planting projects must check the permitting guidance. Information is available at:

www.indy.gov/eGov/City/DPW/SustainIndy/WaterLand/GreenInfra/Pages/RainGardenResources.aspx

Typical Components of a Bioinfiltration/Bioretention System

Bioretention systems can be designed to infiltrate all or some of the flow that they treat. The primary components of a bioretention system are:

- Pretreatment
- Flow entrance/inlet
- Surface storage (ponding area)
- Organic layer or mulch
- Engineered Planting Soil Mix filter media
- Vegetation (Native and Ornamental plantings)
- Sand bed or stone filter and underdrain, if required
- Stone storage for additional storage, if needed
- Positive overflow



Pretreatment

Pretreatment is required for all bioretention systems in order to protect the soil-plant system that provides treatment. Pretreatment protects and prolongs the life of the system by reducing sediment and other pollutant loads.

CURB CUT INLET – INDIANAPOLIS CULTURAL TRAIL BIORETENTION (ALABAMA STREET)

Flow Entrance / Inlet

It is recommended that runoff is conveyed to bioretention areas via sheet flow over a vegetated or gravel filter level spreader strip. This is not always possible due to site constraints or space limitations. On sites where curb removal is not an option or where flow is concentrated by the time it reaches the bioretention area, energy dissipation and equal flow distribution is required. Roof leaders that flow into bioretention areas also require flow energy dissipaters and equal distribution to prevent erosion in the bed.

Surface Storage (Ponding Area)

Surface storage provides temporary storage of Stormwater runoff before infiltration, filtration, evaporation, and uptake (evapotranspiration) can occur within the bioretention system. Ponding time provides water quality benefits by allowing larger debris and sediment to settle out of the water. Ponding design depths are directly related to the Engineered Soil Mix design criteria and are limited to a 24-inches in order to reduce hydraulic loading of underlying soils, minimize facility drainage time, and prevent standing water.

Engineered Planting Soil Mix and Filter Media

The Engineered Soil Mix provides a medium suitable for plant growth. This designed media acts as a physical filter between the surface storage and the native soil or sub-drainage system. It provides additional storage and a place for biological and chemical pollutant treatment before the water infiltrates into the native soil or sub-drainage system. Storage area is a function of both soil depth and bioretention surface area.

Native and Ornamental Vegetation

The plant material in a bioretention system provides a physical barrier for pollutant filtration and energy dissipation; removes nutrients and Stormwater pollutants through vegetative uptake; removes water through evapotranspiration; and, creates pathways for infiltration through root development and plant growth. A varied plant community is recommended to avoid susceptibility to insect and disease infestation and to ensure viability. A mixture of groundcover, grasses, shrubs, and trees is recommended to create a microclimate that can improve urban stresses as well as discourage weed growth and reduce maintenance.(Refer to Chapter 5: Stormwater Landscape Guidance) Do not use invasive species as listed by local, state and federal; agencies.

Organic layer or mulch

The organic layer or mulch provides a medium for biological growth, decomposition of organic material, adsorption, and binding of heavy metals. The mulch layer can also serve as a sponge that absorbs water during storms and retains water for plant growth during dry periods. It is recommended that double shredded hardwood mulch be utilized to minimize washout from Stormwater flows.

Stone bed or filter and Underdrain (if necessary)

An underdrain is generally a perforated pipe or protected bed of gravel that collects water at the bottom of the system and conveys it to the system outlet. Underdrains eliminate most infiltration because they provide a preferential pathway for flow. A large diameter rock or gravel filter should surround the underdrain to facilitate flow to the underdrain. The underdrain stone bed should be surrounded by a non-woven, geotextile filter fabric to prevent clogging.

INSTALLATION OF BIORETENTION UNDERDRAIN

Stone Storage (if necessary)
A stone storage layer can be included to provide higher void space storage if needed in addition to the surface and soil storage.

Positive Overflows
A positive overflow must be provided at the maximum ponding depth. When runoff exceeds system storage capacity, the excess flow leaves the system through the positive overflow. If additional Stormwater controls are required on the site, the overflow can connect to a system that will provide further quantity control. If no additional Stormwater controls are required, the overflow can be connected to storm sewer or receiving water in compliance with local Stormwater management requirements.

Liners
In some instances, an impermeable liner should be used with a bioretention system. If the nearby or adjoining structures include a basement or floor below the top elevation of the bioretention system, a liner should be considered to reduce the possibility of water migration into the structure. Also, construction within a Wellhead Protection District may require the installation of a liner.

Design Considerations
Design of bioretention systems is somewhat flexible. The area, depth, and shape of the system can be varied to accommodate site conditions and constraints. The following design procedures are general guidelines that designers can follow.

- Determine the Water Quality and Quantity requirements on the site. See City of Indianapolis Stormwater Design and Construction Specifications Manual.
- Investigate the feasibility of infiltration in the area proposed for bioretention according to the infiltration guidelines outlined in **Attachment 1**. If infiltration is not feasible, consider an underdrained bioretention system or an alternate location for the bioretention area. If infiltration is feasible, determine the saturated vertical infiltration rate.
- A geotechnical report should be provided documenting the seasonal high groundwater table for the site/area certified by a professional geotechnical engineer or soil scientist.

Table 4.5.2: Suggested Starting Design Values for Areas and Depths

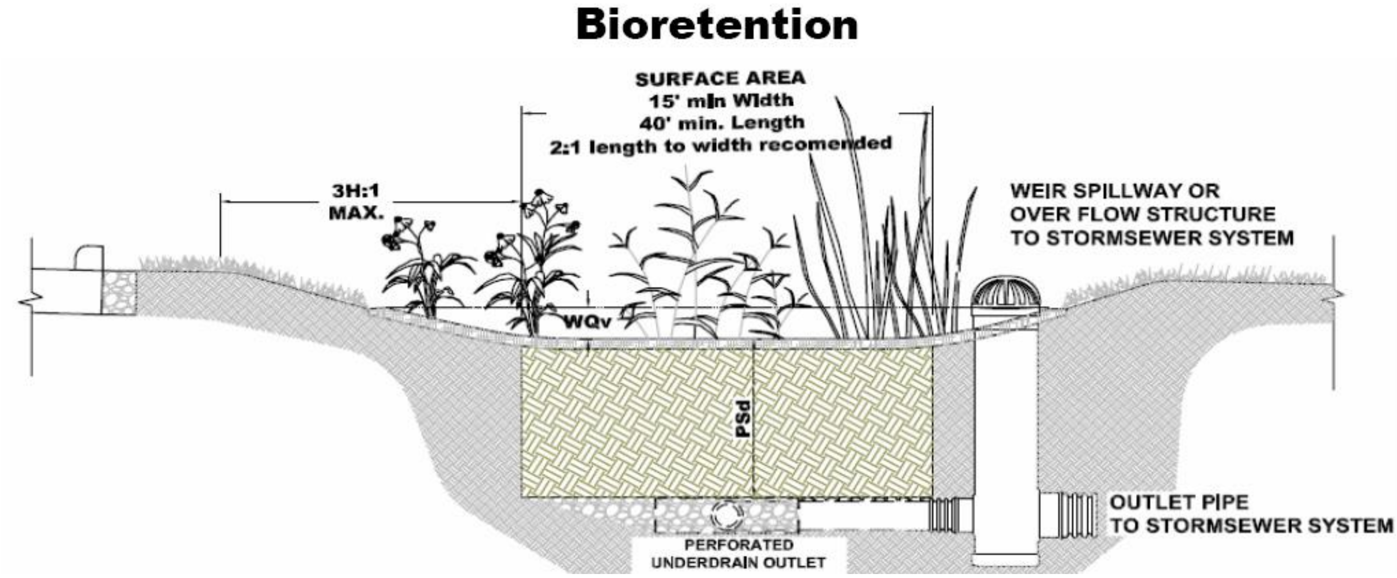
Area (surface area and infiltration area)	Largest feasible on site (*sized for expected runoff volume)
Typical Ponding Depth	6-18 inches (maximum 24 inches)
Soil Depth	2-4 feet

*Note pond depth may not exceed 2 feet

- Estimate the total storage volume and adjust area and/or depths as needed to provide required storage.
- Estimate how long the surface ponding and soil storage will take to drain based on the infiltration area and the saturated vertical infiltration rate of the native soil. The maximum drain down time for the surface storage volume is 48 hours. If storage does not drain in the time allowed, adjust

surface depth, soil depth, and/or surface area. Adjust the design until the volume, drainage time, and site constraints are met.

- Underdrain if necessary.
- Choose plants, trees, and either mulch or seeding appropriate to the site.
- Additional design information is available in the **Bioretention Design Guidelines** and **Design Example (Attachment 5)**.



Materials

Planting Soil

Refer to Chapter 5: Stormwater Landscape Guidance.

Mulch

Organic mulch shall be aged, double-shredded hardwood bark mulch or composted leaf mulch.

Plants

It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select bioretention plants that will survive within the selected zone of ponding, drain down time, sunlight, salt tolerance, and other site specific conditions. Refer to Chapter 5: Stormwater Landscape guidance for plant selection. Although plants will be subject to ponding, they may also be subject to lack of water (drought) especially in areas that get a lot of sunlight or are in otherwise highly impervious areas.

Construction Guidelines and Considerations

- Areas for bioretention shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.
- Provide erosion and sedimentation control protection on the site such that construction runoff is directed away from the proposed bioretention location. Proposed bioretention areas may only be used as sediment traps during construction if at least two feet of soil are removed and replaced.
- Complete site elevation grading and stabilize the soil disturbed within the limits of disturbance. Do not finalize bioretention excavation and construction until the drainage area is fully stabilized.
- Excavate bioretention area to proposed invert depth and manually scarify the existing soil surfaces. Do not compact in-situ soils. Heavy equipment shall not be used within the bioretention basin. All equipment shall be kept out of the excavated area to the maximum extent possible.

- If using an underdrain and/or a gravel storage bed, place filter fabric or gravel filter, then place the rock, and set the underdrain according to the plans.
- Backfill the excavated area as soon as the subgrade preparation is complete to avoid accumulation of debris. Place bioretention soil in 12-18 inch lifts without compaction. Overfilling will be necessary to account for settlement. Presoak soil at least one day prior to final grading and landscaping to allow for settlement.
- After allowing soil to settle, complete final grading within 2 inches of the proposed design elevations, leaving space for top dressing of mulch or mulch/compost blend.
- Seed and plant vegetation as indicated on the plans and specifications.
- Place mulch and hand grade to final elevations.
- Water vegetation regularly during first year to ensure successful establishment.

Maintenance Guidelines

Properly designed and installed bioretention systems require little maintenance. Bioretention requires landscaping maintenance to ensure that the area is functioning properly. Bioretention areas initially require intense maintenance, but less maintenance is needed over time. In many cases, maintenance tasks can be completed by a landscaping contractor, who may already be hired at the site. Landscaping maintenance requirements can be less resource intensive than with traditional landscaping practices such as elevated landscaped islands in parking areas. During periods of extended drought, bioretention systems may require watering as needed. Detailed maintenance guidelines and a recommended schedule of inspection and maintenance can be found in the Example Bioretention O & M Manual.

Curb Inlet, Pre-treatment and Raised Outlet for Indianapolis Cultural Trail Bioretention (Alabama Street)

Note: Design of bioretention systems are not limited to the examples shown within this text. Successful Stormwater management plans will combine appropriate materials and designs specific to each site.

Technical Design / Engineering Requirements

The following tables summarize the requirements for engineering reports, plans and the O & M manual for bioretention, microbioretention and rain gardens.

Table 4.5.3: *Bioretention* Engineering / Drainage Report Requirements Summary

Item	**Required**
Storage Volume Calculations	Yes
Overflow Calculations (10-yr minimum)	Yes
Water Quality Volume Calculations (if system is part of the stormwater quality management system)	Yes
Water Quantity Volume Calculations (if system is part of the stormwater quantity management system)	Yes
Drain –Down Time (< 48 hrs, Permeability Coefficient = 0.5 in./day)	Yes
Runoff Entrance Velocity (=1.5 fps max)	Yes
Seasonal High Water Table Determination by Soil Scientist or Geotechnical Engineer within a Geotechnical Report/Investigation (water table >2 ft below underdrain or bottom of system)	Yes

Table 4.5.4: *Microbioretention* Engineering / Drainage Report Requirements Summary

Item	**Required**
Storage Volume Calculations	Yes
Overflow Calculations (10-yr minimum and non-erosive channel)	Yes
Water Quality Volume Calculations (if system is part of the stormwater quality management system)	Yes
Water Quantity Volume Calculations (if system is part of the stormwater quantity management system)	Yes
Drain –Down Time (< 48 hrs, Permeability Coefficient = 0.5 in./day)	Yes
Runoff Entrance Velocity (=1.5 fps max)	Yes
Seasonal High Water Table Determination by Soil Scientist or Geotechnical Engineer within a Geotechnical Report/Investigation (water table >2 ft below underdrain or bottom of system)	Yes

Table 4.5.5: *Bioretention* Plan Requirements

Item	Required
Profile Detail of Proposed Bioretention, Showing:	
Soil Depth (2 ft Minimum)	Yes
Maximum Ponding Depth (24 in.)	Yes
Filter Fabric	Yes
Mulch Layer (2 in. min)	Yes
Drainage Layer	Yes
Pretreatment System Including Forebay	Yes
Area Map Showing Basin Area Served by Proposed Biosystem (<5 ac)	Yes
Scaled drawing of Proposed Bioretention Showing Minimum Size > 200 sq ft, 2:1 Length to Width Ratio (Measured from Inlet to Overflow)	Yes
Filter Fabric Specifications	Yes
Soil and Mulch Specifications	Yes
Underdrain Layout, Size, Slope and Specification (6 in. minimum diameter, 8 in gravel layer)	Yes
Easement Delineation (20 ft around outside perimeter)	Yes
Center Coordinates of Bioretention System (in State Plane Coordinates) on Cover Sheet Summary Table	Yes

Table 4.5.6: *Microbioretention* Plan Requirements

Item	Required
Profile Detail of Proposed Bioretention, Showing:	
Soil Depth (2 ft Minimum)	Yes
Maximum Ponding Depth (24 in.)	Yes
Filter Fabric	Yes
Mulch Layer (2 in. min)	Yes
Drainage Layer	Yes
Impermeable Liner (where top of microretention system is above lowest floor of structures)	Yes
Pretreatment System Including Forebay	Yes
Area Map Showing Basin Area Served by Proposed Biosystem (< 20,000 sq ft)	Yes
Scaled drawing of Proposed Bioretention Showing Minimum Size > 200 sq ft, 2:1 Length to Width Ratio (Measured from Inlet to Overflow)	Yes
Filter Fabric Specifications	Yes
Soil and Mulch Specifications	Yes
Underdrain Layout, Size, Slope and Specification (6 in. minimum diameter, 8 in gravel layer)	Yes
Easement Delineation (20 ft around outside perimeter, when system is part of water quality unit)	Yes
Scaled Plan with Location of Nearest Structures, Water Wells mad Septic Systems:	
Structures (> 10ft separation)	Yes
Water Wells (>30 ft separation)	Yes
Structures (.10 ft separation)	Yes
Center Coordinates of Microbioretention System (in State Plane Coordinates) on Cover Sheet Summary Table	Yes

Table 4.5.7: *Rain Garden* Engineering / Drainage Report Requirements Summary

Item	**Required**
Storage Volume Calculations	Yes
Overflow Calculations (10-yr minimum and non-erosive channel)	Yes
Water Quality Volume Calculations (if system is part of the stormwater quality management system)	Yes
Water Quantity Volume Calculations (if system is part of the stormwater quantity management system)	Yes
Drain –Down Time (< 48 hrs, Permeability Coefficient = 0.5 in./day)	Yes
Seasonal High Water Table Determination by Soil Scientist or Geotechnical Investigation (water table >2 ft below underdrain or bottom)	Yes

Table 4.5.8: *Rain Garden* Plan Requirements

Item	Required
Profile Detail of Proposed Rain Garden Showing:	
Soil Depth (1 ft Minimum)	Yes
Maximum Ponding Depth (24 in.)	Yes
Filter Fabric	Yes
Mulch Layer (2 in. min)	Yes
Drainage Layer	Yes
Pretreatment System Such as a Forebay (for commercial, industrial and institutional facilities)	Yes
Area Map Showing Basin Area Served by Proposed Rain Garden (10,000 sq ft max or 2,000 sq ft for a single residential lot)	Yes
Soil Map	Yes
Scaled drawing of Proposed Rain Garden	Yes
Filter Fabric Specifications	Yes
Soil and Mulch Specifications	Yes
Underdrain Layout, Size, Slope and Specification (6 in. minimum diameter, 8 in gravel layer)	Yes
Center Coordinates of Rain Garden (in State Plane Coordinates) on Cover Sheet Summary Table	Yes

Table 4.5.9: ***Bioretention, Microbioretention and Rain Gardens*** **O & M Manual Requirements**

Item	**Required**
Tabular Inspection Schedule	Yes
Site Diagram with Green Roof Area	Yes
Inspection Checklist	Yes
Narrative description of Inspection Procedure including:	Yes
Startup Maintenance	Yes
Fertilizer Guidance	Yes
Plant Coverage Minimum Requirement (90%)	Yes
Emergency Overflow System Inspection	Yes
Erosion Inspection	Yes
Weeding	Yes
Replacing Mulch Layer Annually (when adjacent to parking lots and other hotspots) and maintaining 2 inch depth	Yes
Drain-Down Time Observation (<48 hrs)	Yes
Maintenance Guidelines (table 4.5.3)	Yes

Green Infrastructure Checklist

Bioretention:

Site requirements for use:

- Seasonal high groundwater table depth to top of subgrade must be 2' or greater. (This is to prevent high water table from reducing infiltration effectiveness.)
- If buildings adjacent to rain garden have basements make sure that the rain garden is a minimum of 10' from the building/basement. Also, depending on soil type, a waterproof membrane may be needed on the side adjacent to the building. This should be evaluated on a case by case basis.
- If adjacent buildings don't have basements, the rain garden should be located a minimum of 5' from the building.
- Note any buildings offsite near the proposed rain garden & verify city complaints/maintenance records regarding sewer backups, basement flooding, etc. for the area. If a seasonal high groundwater table exists, extensive use of infiltration methods where none previously existed could aggravate an existing problem, especially if there are basements.

Design Considerations:

- Slope of rain garden bottom can be flat to allow uniform infiltration over the entire bottom area.
- Use of an underdrain is required for areas with Hydrologic Group C & D soils. Underdrain should have positive outlet to open area, level spreader or inlet structure.
- Use of amended soils to be evaluated on a case by case basis as needed for achieving desired infiltration rate. Depth of amended soil shall be determined by type of vegetation used. 18" for plants/shrubs, deeper section when trees are used.

Construction Considerations:

- Erosion control is a must - any sediment laden water shall not be allowed to flow into the rain garden. Use of a sediment forebay/basin during construction is recommended for easier removal of sediment.
- Roof leaders and other impervious areas draining to the newly constructed rain garden should be adequately protected so as to prevent erosion. Operations & Maintenance Manual shall provide for an item to monitor erosion and replace mulch/gravel as needed. Once plants are established this should not be an issue.

4.5.1. Bioretention Example O & M Manual

Rain Garden O & M Manual

Owner Name
Address of Property
Owner Contact Name and Phone Number

BMP Narrative:
Rain Gardens shall be in accordance with the following inspection and maintenance criteria:

Inspection:
Inspection of the rain garden is required after each major rain (more than 1” of rainfall) or at least 4 times per year during the growing season (March - November).
During inspection the following should be noted on the inspection form attached:

- Presence of any trash, debris and soil accumulation
    - Ensure that the depth is maintained as shown on the plans.
- Presence of weeds
- Depth of mulch material present
- Condition of plants (note any plants that appear to be dead or dying)
- Condition of rain garden overflow structure. (Most rain gardens do not have overflow structures; however, they are used in this project to ensure Stormwater has a viable outlet.)
- Visible indication of rain garden clogging or overtopping.

Maintenance:
Maintenance of the rain garden is required when inspection reveals the following are present:

- Trash, debris and soil accumulation
    - Remove all trash and debris and dispose in accordance with city regulations
    - Remove soil accumulation and use on-site in other areas or dispose in accordance with city regulations.
    - Ensure depth of rain garden is maintained to the design depth shown on the plans.
- Weeds
    - Remove weeds regularly during the establishment period (the first couple of years). Hand weed to ensure that the soil in the rain garden does not get compacted and to minimize disturbance to plants and mulch.
    - Remove invasive weeds (Canada Thistle, Garlic Mustard and any tree seedlings) immediately to discourage their establishment.
    - Weed after watering or after a rain event for minimal disturbance and ease of removal.
- Mulch depth less than 3 inches
    - Maintain a mulch depth of 2 to 4 inches. Use hardwood mulch material. Mulch should be reapplied annually to maintain desired depth.
- Water needed (Plants appear to be dead or dying)
    - Watering is required to maintain plants during the establishment period to ensure healthy growth. Once established, plants should only require water during drought conditions.
- Overflow structure in need of cleaning (ex: grate covered with grass/leaves)
    - Keep inlet grate clear of obstructions to maintain storm outlet.

    - If damage to the inlet structure exists, repair immediately in accordance with the City of Indianapolis Drainage Standards.
- Indication that rain garden has insufficient capacity (debris on pavement surrounding the rain garden, etc.). Rain garden maximum ponding time is 48 hours. If evidence that rain garden does not drain down within the required 48 hour period, soil maintenance will be required to restore the soil porosity to the required level to obtain the drain down time.
- The amended soils must be sandy loam, loamy sand or loam mixture with clay content rating from 10 to 25 percent. The soil must have an infiltration rate of **at least 0.5 inches per hour** and a pH between 5.5 and 6.5. In addition, the planting soil should have a 1.5 to 3 percent organic content and a maximum 500-ppm concentration of soluble salts. The mulch layer must consist of 3-4 inches of commercially available fine shredded hardwood mulch or shredded hardwood chips.

Address of property

Inspector:
Date:
Time:
Weather: Rainfall over previous 2-3 days?
Rain Garden Location: Rain Garden 1 (At entrance from Fletcher Avenue)

Mark items in the table below using the following key:

- **X** Needs immediate attention
- **–** Not Applicable
- ✓ Okay
- **?** Clarification Required

Rain Garden Components:

Items Inspected	Checked		Maintenance Needed		Inspection Frequency
DEBRIS CLEANOUT	Y	N	Y	N	**M**
1. Rain gardens and contributing areas clean of debris.					
2. No dumping of yard wastes into rain garden.					
3. Litter (trash, debris, etc.) have been removed.					
VEGETATION					**M**
4. No evidence of erosion.					
5. Is plant composition still according to approved plans?					
6. No placement of inappropriate plants.					
DEWATERING AND SEDIMENTATION					
7. Rain garden dewaters between storms.					
8. No evidence of standing water.					
9. No evidence of surface clogging.					
10. Sediments should not be greater than 20% of swale design depth.					
OUTLETS/OVERFLOW SPILLWAY					**A, AMS**
11. Good condition, no need for repair.					
12. No evidence of erosion.					
13. No evidence of any blockages.					
INTEGRITY OF BIOFILTER					**A**
14. Rain garden has not been blocked or filled inappropriately.					
15. Mulch layer is still in place (depth of at least 2”).					
16. Noxious plants or weeds removed.					

Inspection Frequency Key A= Annual, M= Monthly, AMS= After Major Storm

COMMENTS:

OVERALL CONDITION OF FACILITY:

In accordance with approved design plans? Y / N In accordance with As Built plans? Y / N
Dimension on as built:
Field Verified Dimension:
Maintenance required as detailed above?Y / N Compliance with other consent conditions? Y / N

Comments: ____
____

Dates by which maintenance must be completed: ________ / ___ / ____

Dates by which outstanding information as per consent conditions is required by: __________ / ___ / _____

Inspector's signature: ____

Owner/Engineer/Agent's signature: ____

Owner/Engineer/Agent's name printed: ____

4.5.2. Bioretention Designer/Reviewer Checklist

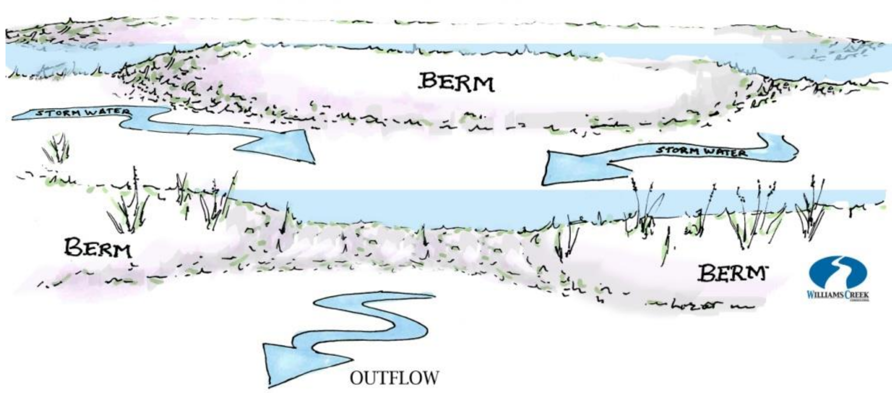
Item	Yes	No	N/A	Notes
Appropriate areas of the site evaluated?				
Infiltration rates measured?				
Were the bioretention design guidelines followed?				
Soil permeability acceptable?				
If not, appropriate underdrain provided?				
Natural, uncompacted soils?				
Level infiltration area (bed bottom)?				
Excavation in bioretention areas minimized?				
Hotspots/pretreatment considered?				
Ponding depth limited to 24 inches?				
Drawdown time less than 48 hours?				
Positive overflow from system?				
Erosion and Sedimentation control?				
Feasible construction process and sequence?				
Entering flow velocities non-erosive or erosion control devices?				
Acceptable planting soil specified?				
Was appropriate vegetation selected per the City of Indianapolis's Stormwater Landscape Guidance (Section 5) and Table 5.3.1?				
Maintenance accounted for and plan provided?				
Review of treatment volume?				
Review of calculations?				

THIS PAGE LEFT BLANK INTENTIONALLY

4.6. Low Impact and Retentive Grading

Low Impact Grading techniques focus on utilizing existing topography during Site layout to minimize cost. Proposing structures, roads, and other impervious surfaces along existing high ground will allow for Stormwater to drain onto adjacent Stormwater utilities with a minimum of earthwork required. In doing so, low impact grading can promote the use of existing drainage patterns on-site, minimizing the impact to downstream receiving bodies. The advantages associated with low impact grading are maximized when the existing topography is exceedingly flat, and slope and cover requirements of conventional pipe networks are at a premium. If Stormwater is kept out of traditional piping infrastructure and conveyed via swale or pond, water quality benefits will be maximized while earthwork and infrastructure costs are minimized. Storage observed en route to primary detention will decrease primary detention requirements further separating Low Impact Grading from traditional development on an economic scale.

Retentive grading techniques, alternatively, can be utilized on Sites in which the vertical fall from Development to the Stormwater outlet is high. If topographic variation is plentiful on site, retentive grading can be an effective method of slowing velocities in open channels, preventing scour, encouraging infiltration, and increasing site retention in route to primary Stormwater detention facilities. The use of retentive grading can therefore decrease the potential size of primary facilities. If retentive grading is utilized on adequately infiltrating soils, the volume of Stormwater impounded upstream of the berm may be removed from the Stormwater treatment system, and support ground water recharge. If adequately infiltrating soils are not present on the Site, underdrains placed below amended soils can help to delay and spread out the inflow hydrograph to primary detention facilities, thereby decreasing the required storage capacity of primary facilities. The filtering of Stormwater to underdrains will facilitate removal of Total Suspended Solids (TSS), when properly designed. The use of organic soil amendments can facilitate uptake of excess nutrients and provide a medium for the sorption of fecal coliforms. Berms and retentive grading systems may function alone in grassy areas or may be incorporated into the design of other Stormwater control facilities such as bioretention and constructed wetlands. When adequate freeboard exists to intermittently stage Stormwater en route, the cost of conventional Stormwater facilities may be decreased.



Low Impact and Retentive grading key elements:

- High quality topsoil in outer layer of berm that provides growing medium for plants (minimum 4 inches).
- Inner layer of berm constructed of a stable fill material.
- Established vegetation to prevent erosion and improve appearance.
- An overflow weir or runoff bypass mechanism.
- Soil amendments and underdrain placement at designer discretion.

Table 4.6.1: Low Impact and Retentive Grading Potential Application and Stormwater Regulation

Potential applications			Stormwater regulations		
				Infiltration	No Infiltration
Residential Subdivision:	Yes		Water Quality Benefit	Yes	Yes
Commercial:	Yes		Volume Reduction	Yes	No
Ultra Urban:	Limited		Attenuation Benefit	Yes	Yes
Industrial:	Yes				
Retrofit:	Yes				
Highway Road:	Yes				

Acceptable forms of pre-treatment

- Sediment forebays
- Filter strips
- Vegetated swales
- Bioretention gardens
- Wetlands
- General Disconnection of impervious areas from detention facilities

Low Impact and Retentive Grading Techniques in the Urban Landscape

Utilizing existing topography minimizes the amount of grading that needs to be conducted. Berms and retentive grading can provide an efficient method of reusing soil on site to manage Stormwater, by moving structural soil small distances and creating storage. In addition, appropriate soils upstream of a berm may be excavated to provide structural fill, and subsequently provide a location to deposit top soil removed from other parts of the Site. Addition of topsoil to berm excavations can help to support a healthy vegetative system and increased infiltration potential.

Pretreatment for other Facilities

A berm and small depression can act as a sediment forebay before Stormwater enters a bioretention basin, subsurface infiltration facility, or other facility.

Retention and Increased Capacity for other Facilities

A berm placed on the down slope side of a bioretention basin or other facility built on a mild slope can help retain Stormwater in that facility and increase its capacity without additional excavation.

Retention and Infiltration in a Shallow Depression

A shallow depression can be created behind a berm to provide an infiltration area without the need for a more complex Stormwater facility.

Flow Diversion

A berm can be placed across a slope to divert low or high flow water to a nearby channel or facility.

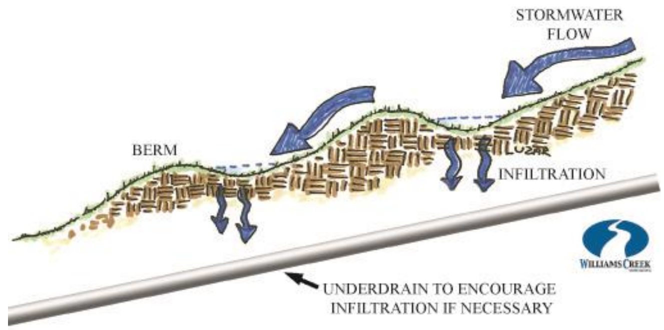
Berms in Series

A series of small berms and depressions can be placed along a slope within any surface- based conveyance system, to provide infiltration and detention while stabilizing the slope.

Components of Low Impact and Retentive Grading Techniques

Low impact techniques and retentive grading systems may be designed to convey and infiltrate all of the Stormwater they receive in small storms. These systems often include the following components:

- Topsoil
- Fill
- Vegetation
- Weir or Bypass Mechanism



RETENTIVE GRADING
CONVEYANCE, STORAGE AND TREATMENT

Topsoil

The outer portion of the berm consists of high quality topsoil to provide a growing medium for plants. A topsoil containing 30% organic material by weight can be expected to support plant growth, aid in regulation of soil nutrients, and provide a medium for adsorption of pathogens. A berm may consist entirely of high quality topsoil. To reduce cost, only the top 4 to 8 inches needs to consist of high quality topsoil, with well-drained soil, or an underdrain system making up the remainder of the berm.

Fill

A berm may consist entirely of high quality topsoil. However, cost may be reduced by constructing the inner portion of the berm of a stable fill material. In many cases, soil may be reused from elsewhere on the site.

Vegetation

Vegetation stabilizes and prevents erosion of the soil layer. Native trees and grasses are encouraged for aesthetic reasons and because of their deeper root systems which preserve long-term infiltration potentials, but turf is acceptable.

Weir or Bypass Mechanism

The berm may not be able to retain all flow during large events. An overflow weir may be designed to allow flow to overtop the berm without causing erosion. In other cases, the contours of the site may allow excess flow to bypass around the end of the berm.

Recommended Design Procedure

- Water quality–and quantity requirements must be designed within parameters required by the <u>Stormwater Design and Construction Specifications Manual</u>.
- Create a Conceptual Site Plan for the entire site, and determine what portion of the sizing requirements berms and retentive grading can help meet. Determine the general location of these features and the role they will play on the site. These techniques can be applied anywhere in

advance of Site discharge so long as the Stormwater is kept on the surface of the Site and not discharged to a pie.

- Create a conceptual design for the berm (or berms), including height of berm and depth of depression.

Table 4.6.2: Starting Design Values for Berm Areas and Depths	
Area (surface area and infiltration area)	Largest feasible on site (Minimum of 1 square foot of infiltration area for every 5 square feet of contributing DCIA recommended.)
Average Ponding Depth	6 -12 inches
Berm Height	6 - 24 inches

- For a berm-depression system intended to promote infiltration, investigate the feasibility of infiltration in the proposed location. The NRCS soil surveys can provide guidance as to where adequately infiltrating soils are likely to be found. However, Infiltration testing should be performed within 25 feet of the infiltration footprint. In addition infiltration characteristics should be based upon the post-construction condition of the soil. Refer to **Attachment 1** for **Guidelines for Infiltration Testing**.

- Estimate runoff reaching the system during the design storm and the maximum water level reached at the berm.

- Using infiltration area and the saturated vertical infiltration rate of the native soil, estimate how long the surface ponding will take to drain. If storage does not drain within the expected time interval between design storms, credit for volume reductions may not be allowed, due to inability to accommodate back to back storm events. The designer may adjust the design until the volume and drainage time constraints are met. A geotechnical report / analysis is required when infiltration will be utilized.

- Design an overflow or bypass mechanism for large storms.

- Consider maintenance activities when choosing berm materials and shape. For example, providing more storage than taken credit for in quantity calculations will allow for long-term sediment accrual without maintenance requirements. If native plantings are designed to develop over time into a diverse ecosystem within the depressional area, the aesthetic and ecological value of the systems will be enhanced.

- 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 may promote increased runoff rate and erosive conditions. If underdrains are installed to simulate the water quality and flowrate benefits of infiltration, woody vegetation is not recommended per the long term health of the underdrain system. Berm side slopes should never exceed a 2:1 ratio.

- To minimize cost, check the volume of cut and fill material. Berm height and depression depth may be adjusted to more closely balance the two.

Materials

Soil

- Topsoil stripped and stockpiled on the site should be used for fine grading. Topsoil is defined as the top layer of earth on the site, which produces heavy growths of crops, grass or other vegetation. Top soil is typically high in organic content making it unsuitable for structural fill but advantageous for promoting infiltration, nutrient transformation, and fecal coliform sorption.

- Soils excavated from on-site may be used for berm construction provided they are deemed satisfactory as per the above recommendations or by a soil scientist.

Vegetation

- It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Native trees and grasses are strongly recommended but turf grass is acceptable. Select plants from Chapter 5: Stormwater Landscape Guidance. Take ponding depth, drain down time, sunlight, and other conditions into consideration when selecting plants from this list. Although plants will be subject to ponding, they may also be subject to drought.

- Trees and shrubs shall be freshly dug and planted in accordance with standard nursery practice.

- Perennials, grass-like plants, and groundcover plants shall be healthy, well-rooted specimens.

- Plantings shall be designed to minimize the need for mowing, pruning, and irrigation.

- A native grass/wildflower seed mix can be used as an alternative to groundcover planting. Seed mix shall be free of weed seeds.

Construction Guidelines

- Clearly marking areas for infiltration berms before any site work begins can discourage soil disturbance and compaction during construction and preserve the existing infiltration characteristics of the underlying soil.

- Provide erosion and sedimentation control protection on the site such that construction runoff is directly away from the proposed infiltration berm location. Alternatively, ensure that any sediment accrual associated with construction activities is removed to design grade before the cessation of construction activities.

- Complete site elevation grading and stabilize the soil disturbed within the limit of disturbance. Do not finalize berm excavation and construction until the drainage area is fully stabilized.

- Manually scarify the existing soil surfaces of the proposed infiltration berm locations. Do not compact in-situ soils. Heavy equipment shall not be used within the berm area.

- Backfill the excavated area as soon as the subgrade preparation is complete to avoid accumulation of debris. Place berm soil in 8 inch lifts and compact after each lift is added according to design specification. Grade berm area as fill is added.

- Protect the surface ponding area at the base of the berm from compaction. If compaction occurs scarify soil to a depth of at least 8 inches.

- After allowing for settlement, complete final grading within 2 inches of proposed design elevations. The crest and base of the berm should be level along the contour.

- Seed and plant vegetation as indicated on the plans and specifications.

- Place mulch to prevent erosion and protect establishing vegetation and manually grade to final elevations.

- Water vegetation at the end of each day for two weeks after planting is completed.

Maintenance Guidelines

Berms have low to moderate maintenance requirements, depending on the design.

Table 4.6.3: Berm & Grading Maintenance Guidelines

	Activity	Schedule
	Remove trash and debris Remove invasive plants. If desired, mow grass to maintain 2 -4 inch height.	As needed
	Inspect soil for erosion and repair eroded areas.	Monthly
	Maintain records of all inspections and maintenance activity concurrent with post-construction requirements listed in *City of Indianapolis Stormwater Design and Construction Specifications Manual*.	Ongoing

Note:

Design of berms and grading techniques are not limited to the examples shown within this text. Successful Stormwater management plans will combine appropriate materials and designs specific to each site. Berms may be used within larger basins (e.g., wetlands, wet ponds) to lengthen flow paths; these applications are discussed in-various LID literature.

4.6.1. Low Impact and Retentive Grading Designer/Reviewer Checklist

Item	Yes	No	N/A	Notes
Appropriate overflow or bypass provided?				
Berm side slopes less than 2:1?				
Berm Height limited to 24 inches?				
Appropriate slope for vegetation type and mowing requirements?				
Feasible construction process and sequence?				
Acceptable planting soil specified?				
Maintenance accounted for and plan provided?				

THIS PAGE LEFT BLANK INTENTIONALLY

4.7. *Swales*

A swale is a vegetated open channel, planted with a combination of grasses and other herbaceous plants, shrubs, or trees. A traditional swale reduces peak flow at the discharge point by increasing travel time and friction along the flow path. Swales can provide some infiltration and water quality treatment; these functions can be enhanced by incorporating retentive grading, or check dams periodically along the length of the swale. In cohesive soil types, installation of a filtering substrate (for example, a mixture of 1/3 each soil, sand and organic matter) and a perforated underdrain enhance simulated infiltration capacity of swales in order to provide additional water quality treatment. In this manner, the perennial outlet is the underdrain with the retentive grading or check dams providing high flow relief. Therefore, the volume of Stormwater forced to infiltrate to the underdrain is temporarily providing storage en route to the primary detention facility. This will decrease the required size of primary detention facilities versus conventional pipe conveyance. The Designer should be encouraged to incorporate swales into the landscape and hardscape to the extent possible in order to increase aesthetic value, decrease construction cost, and provide attenuation characteristics throughout the Stormwater system. Swales planted with turf grass provide some of these functions but turf grass is not as effective as deeper-rooted vegetation at decreasing peaks, encouraging infiltration, and decreasing erosion. A swale can be more aesthetically pleasing than a rock-lined drainage system and is generally less expensive to construct.

Key elements:

- Open channel design that balances storage, treatment, and infiltration with peak flow conveyance needs
- Check dams or lateral, permeable berms to increase storage, dissipate energy, and control erosion
- Native vegetation to increase frictional resistance and stabilize soil
- Designed to fit into many types of landscapes in an aesthetically pleasing manner
- Pretreatment, such as a forebay or sediment accumulating feature
- Sediment depth marker

Table 4.7.1: Swales Potential Application and Stormwater Regulation

Potential applications			Stormwater regulations		
				Infiltration	No Infiltration
Residential Subdivision:	Yes		Water Quality Benefit	Yes	Yes
Commercial:	Yes		Volume Reduction	Yes	No
Ultra Urban:	Limited		Attenuation Benefit	Yes	Yes
Industrial:	Yes				
Retrofit:	Yes				
Highway Road:	Yes				

Acceptable forms of pre-treatment

Filter strips
Sediment Forebay

Swales in the Urban Landscape

Swales are landscaped channels that convey Stormwater and reduce peak flows by increasing travel time and flow resistance. Depending on design and underlying soil permeability, they can effectively reduce runoff volume and improve water quality. Check dams increase these functions by creating ponding areas where settling and infiltration can occur. As the number of check dams increases, a swale may resemble a series of bioretention basins while still being designed to convey peak flows. The first ponding area may be designed as a sediment forebay and function as a pretreatment practice for the remainder of the swale or other Stormwater management facilities.

Swales are applicable in many urban settings such as parking, commercial and light industrial facilities, roads and highways, and residential developments. For instance, a swale is a practical replacement for roadway median strips and parking lot curb and gutter. Swales can be an effective means of decentralizing Stormwater management so that primary detention facilities become less necessary.

SWALE IN EASEMENT OF SUBDIVISION

Commercial, Light Industrial, and Institutional Sites
These facilities often have landscaped or grassed areas that can also function as drainage pathways and infiltration areas.

Roads and Highways
Swales can be installed in some median strips and shoulders. In some cases, these systems may replace costly curb and gutter systems.

Residential Development
With approved property agreements, swales can be constructed parallel to the sidewalks and streets. Alternatively they can collect Stormwater from multiple properties and convey it to a shared facility.

Components of a Swale

Swale systems often include the following components:

- Inlet Control
- Pretreatment
- Excavated Channel
- Permeable Soil
- Outlet Control
- Check dams or lateral, permeable berms
- Stone (Optional)
- Underdrain (Limited Application)
- Vegetation

Inlet Control

Runoff can enter the swale through a curb opening, pipe, weir, or other design. Runoff may flow off a curbless parking lot or road and down a swale slope in a diffuse manner.

RIVER ROCK SWALE

Pretreatment

Pretreatment can extend the life of the design if the swales are designed to accrue sediment. Vegetated or stone filter strips are options for pretreatment. A sediment forebay may be constructed at the swale inlet, or the first swale segment and a check dam may be designed as a sediment forebay and the primary maintenance point.

Excavated Channel

The channel itself provides the storage volume and conveyance capacity of the swale. Swale design should balance the infiltration and treatment requirements of small storms with needs for conveyance during large storms.

Soil and Stone

The soil provides a growing medium for plants and allows for infiltration. Growing medium may consist of amended native soils or soil mixtures specified for infiltration. A crushed stone layer may be added beneath the soil to increase storage and promote infiltration. Stone will perform this function most effectively when placed in ponded areas.

Check Dams

It is recommended that swale designs include check dams or lateral, permeable berms. Ponding behind check dams provides storage, increases infiltration, increases travel time, reduces peaks, and helps prevent erosion by dissipating energy. Lateral, permeable berms provide a similar function, providing longitudinal filtration in addition to the functions described above.

Underdrain

In some cases, an underdrain and piping system may be provided to prevent prolonged ponding of Stormwater or to collect and convey water to another facility such as an infiltration trench. Underdrained systems may be appropriate in locations where conditions are not ideal for infiltration. In general underdrains should be installed unless the underlying soil is permeable and the saturated infiltration rate has been certified by a registered geologist, soil scientist, or engineer as well as the seasonal high water table.

Outlet Control
A swale may have an outlet control to convey water to a sewer or receiving water.

Recommended Design Procedures

Water Quality Swales must also meet the design requirements in Section 702.05 of the Indianapolis Stormwater Design and Construction Specifications Manual.

- Determine the desired Water Quality and Quantity requirements to be met by the swale on the site. The designer may choose to provide all necessary storage within the swales, or just decrease the demands at the most downstream detention facility.

- Create a Conceptual Site Plan for the entire site, and determine what portion of the requirements the vegetated swale will meet. Consider the site's natural topography in siting the swale; if possible, locate the swale along contours and natural drainage pathways.

- Investigate the feasibility of infiltration according to conditions in the area proposed for the vegetated swale. If infiltration is feasible (according to **Attachment 1, Guidelines for Infiltration Testing**), determine the saturated vertical infiltration rate. Infiltration to groundwater will remove Stormwater volume. Infiltration must be verified through field investigation by a geotechnical engineer or certified soil scientist. The seasonal high water table must also be included in the investigation and documented.

- Create a conceptual design for the vegetated swale.

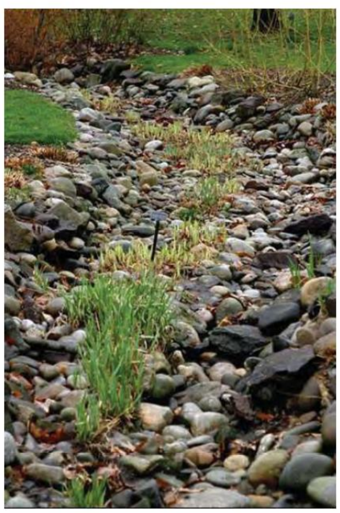


Table 4.7.2: Suggested Swale Starting Design Values	
Bottom Width	2-8 Feet
Side Slopes	3-4 horizontal to one vertical recommended; 2:1 maximum*
Check Dams	Evenly spaced, 6-12 inches high**

*Swales may be trapezoidal or parabolic in shape. Recommended widths and slopes in this table may be used as a general guide for parabolic channels
**Check dams are recommended for most applications to improve infiltration and water quality. They are strongly recommended for swales in which flow in combination with soil, slope, and vegetation may result in erosive conditions.

- Consider an underdrain under any of the following conditions:

  - in areas with separate storm sewers or direct discharge to receiving waters where infiltration is infeasible and the vegetated swale is needed only to provide water quality treatment;

  - in areas with combined sewers where sufficient detention or travel time can be designed into the system to meet release rate requirements; or

  - in combination with other storm infrastructure where the system as a whole meets storage and release criteria.

- Estimate the portion of Water Quality and Water Quantity requirements met by the design.

- Using infiltration area and the saturated vertical infiltration rate of the native soil, estimate how long storage behind check dams will take to drain. The maximum drain time for the entire storage volume is 48 hours, but the Designer may choose a shorter time based on site conditions and Owner preference but no shorter than 24 hours. If storage does not drain in the time allowed, adjust channel shape, number of check dams, check dam height, or optional underdrain design. Adjust the design so that performance and drainage time constraints are met concurrently.

- Check the capacity of the swale system to perform during the 100 year regulatory event defined in the Stormwater Design and Construction Specifications Manual. An average ponding depth of 12 inches or less, and a maximum ponding depth of 24 inches is required. If higher stages are anticipated, vegetation should be selected per expected hydrologic conditions. Flow over check dams should be estimated using a weir equation, while underdrain conveyance should be modeled as a series outlet representing (1) infiltration rate over horizontal wetted area to (2) orifice flow at the underdrain daylight. Ultimately, the level of service provided on the site during large events is a joint decision of the Engineer and Owner based on safety, appearance, and potential property damage.

- Choose soil mix and swale vegetation. A minimum of 6 inches of prepared soil is recommended for the channel bottom and slopes. A detail should be included on the plan sheets including the proposed soil mixture.

- Check resistance of the swale to erosion. For long term functionality, it is recommended that the swale convey the 2-year, 24-hour design storm without erosion. For water quality purposes, channel velocities during a water quality event should not exceed resuspension velocities (2.5 ft/sec). Adjusting soil mix, vegetation, and temporary or permanent stabilization measures as needed.

- Design inlet controls, outlet controls, and pretreatment if desired.

- Check that the design meets all requirements concurrently, and adjust design as needed.

- Complete construction plans and specifications.

- Additional guidelines are summarized in the **Swale Design Guidelines (Attachment 6)**.

Materials

All material specifications should appear on the plans.

Soil

- Swale soil shall have a sandy loam, loamy sand, or loam texture per USDA textural triangle. The soil shall have a high permeability (fc>0.5in/hr) and a seasonal high water table greater than 2 feet flow the bottom of the swale.

Vegetation

- It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select plants from the list of native species provided in Chapter 5: Stormwater Landscape Guidance. Consider ponding depth, drain time, sunlight, salt tolerance, and other conditions when selecting plants from this list. Turf grass is generally not recommended but may be acceptable provided the designer can show it meets all requirements.

Check Dams

- Check dams can be constructed from natural wood, concrete, stone, boulders, earth, or other materials. The Designer should coordinate with the Department of Metropolitan Development regarding the use of non-conventional materials in the Stormwater infrastructure.

- If a stone check-dam is designed to be overtopped, appropriate selection of aggregate will ensure stability during flooding events. In general, one stone size for a dam is recommended for ease of construction. However, two or more stone sizes may be used, provided a larger stone (e.g. R-4) is placed on the downstream side, since flows are concentrated at the exit channel of the weir. Several feet of smaller stone (e.g. AASHTO #57) can then be placed on the upstream side. Smaller stone may also be more appropriate at the base of the dam for constructability purposes.

Storage Stone

- Stone used to provide additional storage shall be uniformly-graded, crushed, washed stone meeting the specifications of AASHTO No. 3 or AASHTO No. 5.

- Stone shall be separated from soil medium by a non-woven geotextile or a pea gravel filter.

Non-Woven Geotextile

- Geotextile shall consist of needled non-woven polypropylene fibers and meet the following properties:
  - Grab Tensile Strength (ASTM-D4632) ≥ 120 lbs
  - Mullen Burst Strength (ASTM-D3786) ≥ 225 psi
  - Flow Rate (ASTM-D4491) ≥ 95 gal/min/ft2
  - UV Resistance after 500 hrs (ASTM-D4355) ≥ 70%
  - Heat-set or heat-calendared fabrics are not permitted

Pipe

- Pipe used for an underdrain shall be continuously perforated and have a smooth interior with a minimum inside diameter of 6-inches. High-density polyethylene (HDPE) pipe shall meet the specifications of AASHTO M252, Type S or AASHTO M294, Type S.

Construction Guidelines

- Begin vegetated swale construction only when the up gradient 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. If the swales are constructed to assist with temporary drainage during construction, the facilities should be graded to final design grade and stabilized at the cessation of mass earthwork.

- Rough grade the vegetated swale. Equipment shall 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), 18 inches shall be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth. At the very least, topsoil shall be rototilled 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.

- Construct check dams, if specified.

- Fine grade the vegetated swale. Accurate grading is crucial for swales. Even the smallest nonconformities may compromise flow conditions and may lead to ponding in undesirable locations. The accidental creation of a preferential flow path in the swale will encourage scour rather than the desired smooth laminar flow across the cross-section.

- Seed and vegetate according to final planting list. Initial seeding with an annual turf grass is recommended to provide temporary stabilization. Plant the swale 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. Vegetation should be established as soon as possible to prevent erosion and scour.

- Concurrent with the previous step, stabilize freshly seeded swales with appropriate temporary or permanent soil stabilization methods, such as erosion control matting or blankets. If runoff velocities are high, consider sodding the swale or diverting runoff until vegetation is fully established.

- Once the swale is sufficiently stabilized, remove temporary erosion and sediment controls. It is very important that the swale be stabilized before receiving Stormwater flow.

Maintenance Guidelines

The following schedule of inspection and maintenance activities must be included in the O&M Manual:

Table 4.7.3: Swale Maintenance Guidelines	
Activity	Schedule
Remulch void areas. Treat or replace diseased trees and shrubs. Keep overflow free and clear of obstructions.	As needed
Inspect soil and repair eroded areas. Remove litter and debris. Clear leaves and debris from overflow.	Monthly
Inspect trees and shrubs to evaluate health.	Biannually
Add additional mulch. Inspect for sediment buildup, erosion, vegetative conditions, etc.	Annually
Maintain records of all inspections and maintenance activity.	Ongoing
Mowing of vegetated swales is design dependent	Ongoing

Note:

Design of swales are not limited to the examples shown within this text. Successful Stormwater management plans will combine appropriate materials and designs specific to each site.

4.7.1. Swale Designer/Reviewer Checklist

Item	Yes	No	N/A	Notes
Can the swale safely (with freeboard) convey the 10-year event?				
Are bottom slopes between one percent and six percent?				
Are check dams provided for slopes > 3%?				
Are check dams adequately keyed into swale bottom and sides?				
Are two-year 24hr storms non-erosive?				
Will the swale completely drain in 48 hours?				
Are side slopes between 3:1 and 5:1 H:V?				
Are swale soils loam, loamy sand or sandy loam?				
Vegetation and Mannings coefficient selected?				
Was appropriate vegetation selected per the City of Indianapolis's Stormwater Landscape Guidance (Section 5) and Table 5.3.1?				
Non-erosive inflow condition(s)?				
Erosion control provided during construction?				
Maintenance accounted for and plan provided?				

Other O & M Manual Requirements

See Section 702.05 of the Stormwater Design and Construction Specifications Manual.

THIS PAGE LEFT BLANK INTENTIONALLY

4.8. Subsurface Infiltration

SUBSURFACE INFILTRATION COLLECTING DRAINAGE FROM AN IMPERVIOUS AREA

Subsurface infiltration systems are designed to provide temporary below grade storage infiltration of Stormwater as it infiltrates into the ground. Dry wells, infiltration trenches and beds are a few examples of these types of systems. Infiltration is a preferred method for Stormwater management where appropriate site conditions and soils exist. The use of infiltration methods helps to minimize the Stormwater loading on existing storm sewer systems and can reduce the amount of overflows for combined sewer systems. By infiltrating Stormwater on-site, downstream impacts resulting from Stormwater flows are reduced or in some cases eliminated.

Note: some subsurface infiltration systems could be classified as Class V injection wells and may require additional permitting by both EPA and IDEM.

Key elements:

- Infiltration testing, outlined in **Attachment 1**, is required for this Stormwater management practice. *A factor of safety of two (2) or three (3) should be applied to the infiltration rate determine from the geotechnical report to account for future reductions in the infiltration rate due to sediment.*
- Reduce volume of runoff from a drainage area by promoting infiltration through uncompacted subgrade.
- Can be sited beneath lawns, parking areas, and recreational areas.
- Maintain minimum distance from building foundation (typically 10 feet down-gradient minimum). In addition, the top elevation of ponding in the subsurface system should be below the lowest floor of the nearby buildings.
- Storage is provided within voids of open-graded aggregate or other approved material. • System must be designed to drain down in less than 72 hours.
- Greater than 2 feet from any limiting zone such as groundwater or bedrock.
- Pre-treatment is required.
- Positive overflow required for large storms.
- Areas of soil contamination or areas of unstable soils should be avoided.

Table 4.8.1: Subsurface Infiltration Potential Application and Stormwater Regulation

Potential applications			Stormwater regulations		
				Infiltration	No Infiltration
Residential Subdivision:	Yes		Water Quality Benefit	Yes	Yes
Commercial:	Yes		Volume Reduction	Yes	No
Ultra Urban:	Yes		Attenuation Benefit	Yes	Yes
Industrial:	Yes				
Retrofit:	Yes				
Highway Road:	Yes				

Acceptable forms of pre-treatment

- Filter
- Bioretention

- Filter Strips
- Appropriate prefabricated and proprietary design
- Sumped inlets with traps
- Some systems, e.g. StormTech may require the use of an SQU or other pretreatment prior to runoff entering the system.

Subsurface Infiltration in the Urban Landscape

Subsurface infiltration systems are typically stone-filled beds or trenches beneath landscaped or paved surfaces. Stormwater flows into the subsurface infiltration system, collects within the aggregate void space, and slowly infiltrates into surrounding soils. Subsurface infiltration is a versatile management practice suitable for many different types of land uses. Both high-density development and individual residences can implement subsurface infiltration systems for Stormwater control. Their flexibility also makes them an option for a Stormwater retrofit. Several example uses for subsurface infiltration are provided below.

SUBSURFACE INFILTRATION INSTALLED AT A SCHOOL ATHLETIC FIELD

Parking Lots and Roadways

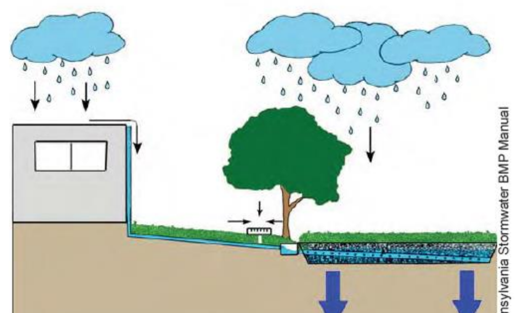
Stormwater inlets in parking lots or streets can be directly connected to subsurface infiltration systems. Sumped or trapped inlets prevent sediment and debris from migrating into the infiltration bed. The inlets can be connected to subsurface infiltration systems located underneath landscaped areas, recreation areas, or under the impervious surfaces themselves.

Lawns and Recreational Areas

Open green spaces can collect, store, and infiltrate runoff from impervious surfaces.

Direct Connection of Rooftops

Downspouts can be connected to subsurface infiltration beds at both residential and commercial sites. Small subsurface infiltration areas that manage roof runoff from residential roofs or that are distributed around a larger building to manage runoff from smaller sections of roof are often called dry wells. Although roofs do not often generate high sediment loads, sumped cleanouts must be located between the roof and the infiltration area. The roof leader connects to perforated piping when it reaches the subsurface infiltration area.

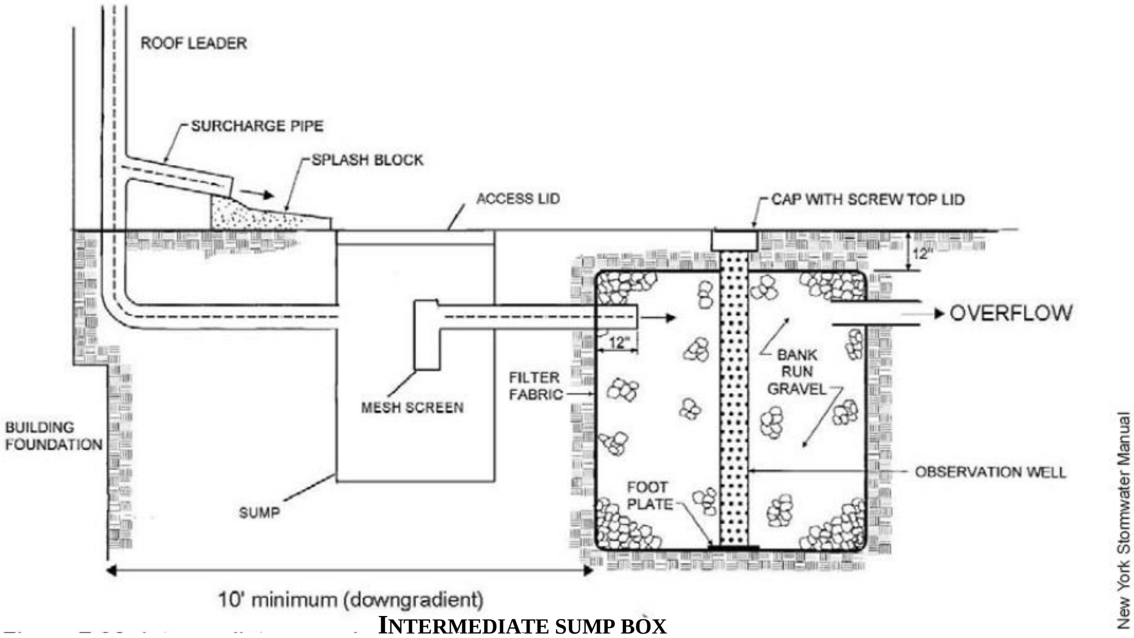


DIRECT CONNECTION OF A ROOF INTO A SUBSURFACE INFILTRATION BED

Components of a Subsurface Infiltration System

There are many variations of subsurface infiltration systems, but they are often comprised of these components:

- Inflow/Pretreatment
- Storage
- Observation well
- Infiltration/Outflow



INTERMEDIATE SUMP BOX AND DRY WELL

Inflow/Pretreatment

Subsurface infiltration systems are capable of intercepting Stormwater inflow from many sources, including rooftops, parking lots, roads, sidewalks, and driveways. It is important to prevent coarse sediments and debris from entering subsurface infiltration systems, because they could contribute to clogging and failure of the system. The following are acceptable forms of pretreatment.

PREFABRICATED STORAGE

- Roof leader sump, or an intermediate sump box
- Roof gutter guard (may require additional sump unit depending on structure design).
- Filter Strips, (See Section 4.4 Filter Strip Fact Sheet and the Stormwater Design and Construction Specifications Manual).
- Vegetated Swales, (See Section 4.7 Swales Fact Sheet and the Stormwater Design and Construction Specifications Manual).
- Stormwater Quality Treatment Unit (SQU)

Storage

The storage component of a subsurface infiltration area is typically provided by a stone filled, level-bottomed bed or trench. The void spaces between the stones stores Stormwater until it can percolate into surrounding soils. Alternative subsurface storage products may also be used to provide temporary storage. These include a variety of proprietary, interlocking plastic units with much greater storage capacity than stone fill (up to 96% void space). Perforated pipe in a stone bed can also increase the effective void space of the system. The higher void ratio of underground storage units requires a smaller footprint and can allow more flexibility in an urban environment, but proper analysis should be completed to ensure that the in-situ soils will adequately drain with the additional loading and that loading ratio and effective head maximums are not exceeded.

Observation Well

An observation well should be located at the center of the trench to monitor water drainage from the system. In a subsurface infiltration system, the water level is the primary means of measuring infiltration rates and drain-down times. A lockable above ground cap is recommended. Adequate inspection and maintenance access to the observation well should be provided. Observation wells not only provide necessary access to the system, but they also provide a means through which pumping of stored runoff can be accomplished in a failed system.

Infiltration/Outflow

Outflow occurs via infiltration through subsurface soil surrounding the infiltration storage area. A bypass system should be implemented for all infiltration systems to convey high flows around the system to downstream drainage systems. Depending on the level of Stormwater management required at the site, overflows can connect to an approved discharge point or other Stormwater management practices.

Recommended Design Procedure

- Determine actual site soil conditions using a registered geologist, soil scientist or engineer.

- Determine the Water Quality and Quantity requirements on the site. (See City of Indianapolis Stormwater Design and Construction Specifications Manual.)

- Must be greater than 10 feet down-gradient and 100 feet up-gradient. In addition, the top elevation of ponding in the subsurface system should be below the lowest floor of the nearby buildings.

- Create a Conceptual Site Plan for the entire site and determine what portion of the sizing requirements subsurface infiltration will meet. (See City of Indianapolis Stormwater Design and Construction Specifications Manual.)

- Investigate the feasibility of infiltration in the area proposed for a subsurface infiltration system. Investigate the feasibility of infiltration in the area proposed for subsurface infiltration according to **Attachment 1** (hotspot investigation, infiltration test, and geotechnical analysis). Infiltration testing must be within 25 feet of the infiltration footprint.

- Create a conceptual design for the subsurface infiltration system.

Table 4.8.2: Starting Design Values for Subsurface Infiltration Areas and Depths	
Area (surface area and infiltration area)	Largest feasible in moderately sloped areas of the site (Minimum of 1 square foot of infiltration area for every 5 square feet of contributing DCIA.)
Maximum Storage Depth	2 feet of effective head. (2 cubic feet of storage volume per square foot of infiltration area.)
Minimum distance above limiting zone	2 feet
Minimum/Maximum drain down time	24/72 hours

- Estimate the total storage volume and adjust area and/or depths as needed to provide required storage. Open-graded aggregate sub-base may be assumed to have 40% void space for storage.

- Using infiltration area and the saturated vertical infiltration rate of the native soil, estimate how long the surface ponding and soil storage will take to drain. The maximum drain down time for the entire storage volume is 72 hours, but the Engineer may choose a shorter time based on site conditions and Owner preference. If storage does not drain in the time allowed, adjust the depth and/or surface area. Adjust the design until the volume and drainage time constraints are met.

- Design a positive overflow or bypass system for larger design storms. All systems must design overflow structures and pipes to convey at least the 10-year storm.

- Include acceptable form(s) of pretreatment into design.

- Observation well to be designed with a minimum 4 inch diameter perforated plastic pipe, and placed at the invert of infiltration bed with a lockable above-ground cap.

- Complete construction plans and specifications.

Materials

All material specifications should appear on the plans.

Storage Stone

- Stone used for subsurface storage shall be uniformly-graded, crushed, washed stone meeting the specifications of the City of Indianapolis.

- Stone shall be separated from soil by a non-woven geotextile filter fabric or a pea gravel filter.

Non-Woven Geotextile

- Geotextile shall consist of needled non-woven polypropylene fibers and meet the following properties:

    - Grab Tensile Strength (ASTM-D4632) ≥ 120 lbs
    - Mullen Burst Strength (ASTM-D3786) ≥ 225 psi
    - Flow Rate (ASTM-D4491) ≥ 95 gal/min/ft2
    - UV Resistance after 500 hrs (ASTM-D4355) ≥ 70%
    - Heat-set or heat-calendared fabrics are not permitted

Pipe

- Pipe used within the subsurface system shall be continuously perforated and have a smooth interior with a minimum inside diameter of 6-inches. High-density polyethylene (HDPE) pipe shall meet the specifications of AASHTO M252, Type S or AASHTO M294, Type S.

- Any pipe materials outside the Stormwater management practice are to meet City Plumbing Code Standards.

INSTALLATION OF A SUBSURFACE INFILTRATION TRENCH

Construction Guidelines

- Areas for proposed subsurface infiltration systems shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction. If areas are compacted during construction additional infiltration testing may be required.

- Provide erosion and sedimentation control protection on the site such that construction runoff is directed away from the proposed subsurface infiltration system.

- If the infiltration area is being used as a sediment basin during construction the bottom elevation of the sediment basin must be a minimum of 2 feet above the infiltration bed invert elevation.

- Complete site elevation grading and stabilize the soil disturbed within the limit of disturbance. Do not finalize the subsurface infiltration system's excavation and construction until the drainage area is fully stabilized.

- Excavate subsurface infiltration area to proposed invert depth and manually grade and scarify the existing soil surface. The bottom of the infiltration bed shall be at a level grade.

- Existing subgrade shall NOT be compacted or subject to excessive construction equipment prior to placement of geotextile and stone bed. If it is essential that equipment be used in the excavated area, all equipment must be approved by the Engineer. Use of equipment with narrow tracks or tires, rubber tires with large lugs, or high pressure tires will cause excessive compaction and shall not be used. Should the subgrade be compacted during construction additional testing of soil infiltration rates and system redesign may be required.

- Place geotextile and recharge bed aggregate immediately after approval of subgrade preparation to prevent accumulation of debris or sediment. Prevent runoff and sediment from entering the storage bed during the placement of the geotextile and aggregate bed.
- Place geotextile in accordance with manufacturer's standards and recommendations. Adjacent strips of filter fabric shall overlap a minimum of 16 inches. Fabric shall be secured at least 4 feet outside of bed.

- Install aggregate course in lifts of 6-8 inches. Lightly compact each layer with equipment, keeping equipment movement over storage bed subgrades to a minimum. Install aggregate to grades indicated on the drawings.

- Complete surface grading above subsurface infiltration system, using suitable equipment to avoid excess compaction.

Maintenance Guidelines

As with all infiltration practices, subsurface infiltration systems require regular and effective maintenance to ensure prolonged functioning. The following table describes minimum maintenance requirements for subsurface infiltration systems that must be included in the O&M Manual.

Table 4.8.3: Subsurface Infiltration Maintenance Guidelines

Activity	Schedule
• Regularly clean out gutters and catch basins to reduce sediment load to infiltration system. Clean intermediate sump boxes, replace filters, and otherwise clean pretreatment areas in directly connected systems.	As needed
• Inspect and clean as needed all components of and connections to subsurface infiltration systems. • Evaluate the drain-down time of the subsurface infiltration system to ensure the drain-down time of 24- 72 hours.	Biannually
Maintain records of all inspections and maintenance activity.	Ongoing

Note:
Design of subsurface infiltration systems are not limited to the examples shown within this text.
Successful Stormwater management plans will combine appropriate materials and designs specific to each site.

4.8.1. Subsurface Infiltration Trench Designer/Reviewer Checklist

Item	Yes	No	N/A	Notes
Infiltration rates measured?				
Soil permeability acceptable?				
If not, appropriate underdrain provided?				
Adequate separations from wells, structures, etc.?				
Natural, uncompacted soils?				
Level infiltration area (e.g., trench bottom, bed bottom)?				
Excavation in infiltration area minimized?				
Hotspots/pretreatment considered?				
Storage depth limited to two feet?				
Drawdown time less than 72 hours?				
Positive overflow from system?				
Erosion and sedimentation control?				
Feasible construction process and sequence?				
Geotextile specified?				
Pretreatment provided?				
Clean, washed, open-graded aggregate specified?				
Stable inflows provided (infiltration basin)?				
Appropriate perforated pipe, if applicable?				
Appropriate plants selected, if applicable?				
Observation well/clean out provided, if applicable?				
Maintenance accounted for and plan provided?				

4.9. Inlet and Outlet Controls

Inlet &Outlet Controls are the structures or landscape features that manage the flow into and out of a Stormwater management facility. Flow splitters, level spreaders, curb openings, energy dissipaters, traditional inlets, and curbless design are all examples and elements of inlet controls. Outlet controls regulate the release of Stormwater from a management facility. Examples of outlet controls include risers and orifices, underdrains, permeable weirs, positive overflows, sub-thermocline basin release, and impervious liners. Outlet control structures limit flow quantity and velocity to meet release rate requirements, reduce discharge flow energy and bypass flows in excess of designed Stormwater quality volume to prevent re-suspension of sediment, hydraulic overload, or erosion of management practices.

Key elements:

Inlet and Outlet controls must be designed within parameters required by the Indianapolis's Stormwater Design and Construction Specifications Manual.

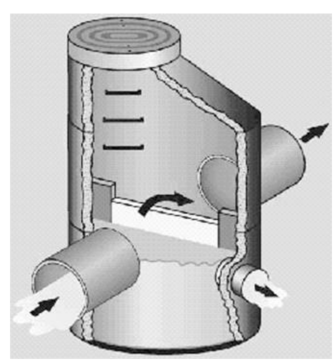
Inlet Controls:

- Flow splitters divert the design water quality volume portion of the storm hydrograph to a management facility or series of facilities, while allowing the flow of larger storms to bypass the facility.
- Curbless roads, streets, and parking lots allow Stormwater to sheet flow into a BMP.
- Curb openings allow water to flow through a curb that would otherwise block the flow.
- Level spreaders spread out concentrated flow and release it as low velocity, non-erosive diffuse flow.
- Energy dissipaters slow down and spread flow from culverts and steeper slopes.

Outlet Controls:

- Risers and orifices release ponded water at a reduced rate and reduced energy.
- Positive overflows allow Stormwater to safely flow out of a BMP.
- Underdrains collect water that has filtered through a porous medium and convey it to an outlet.
- Impervious liners prevent water from infiltrating the soil where infiltration is not desirable, such as in designated "hotspot" land uses and/or wellfield protection areas.
- Permeable weirs allow water to flow slowly through smaller openings and more quickly over the top of the weir.
- Level Spreaders spread out concentrated flow and release it as low velocity, non-erosive diffuse flow.
- Energy dissipaters slow down and spread flow from culverts and steeper slopes.
- Sub-thermocline basin outlet provides direct discharge from the
- lower area of the water quality and/or quantity storage basin, reducing thermal impacts from heat island land use conditions.

Flow Splitter



Flow splitting devices are used to direct a designed water quality storm event into a Stormwater management facility, while bypassing excess flows from larger events around the facility into a bypass pipe or channel. The bypass typically connects to another Stormwater management facility or to the receiving drainage system, depending on the design and management requirements. This type of inlet control can also serve as the positive overflow for the BMP. Flow splitters can be constructed by installing diversion weirs in Stormwater control structures such as inlets and manholes. On a larger scale, they can be constructed using concrete baffles in manholes. Depending on design intent, the flow splitter can also function as a pretreatment facility for other BMP's. Pretreatment facilities can provide a greater level of protection for the BMP as well as decreasing short and long term maintenance. An alternative to a diversion weir could be offsetting the outlet pipes to allow flow to the BMP prior to outlet to the structure/bypass.

Design Criteria

There are two basic components involved in the design of flow splitters: the elevation of the bypass structure, which is based on the designed maximum ponding elevation in the BMP, and capacity of the inlet and outlet control structures of the BMP, which control the maximum flow the BMP can receive and discharge.

Bypass Elevation:

The elevation of the bypass baffle or weir dictates the maximum elevation of the water in the BMP or the maximum rate of flow that enters the BMP. The bypass elevation can be selected by setting it equal to the design storage elevation in the BMP or the height of the peak flow rate. Flow will only start to bypass the BMP once it exceeds the design elevation of the bypass structure. The water level in the BMP may exceed the design level for large infrequent storms that utilize the bypass, so the BMP should provide adequate freeboard to prevent overflow.

Pipe Capacity:

The capacity of the influent and effluent pipes can also limit flow into and out of the BMP. Controlling flows in this fashion can help to minimize erosion and scour in the BMP and at the outlet structure. However, minimum pipe diameters required by the design manual should be noted and other structures such as orifices used as appropriate. Adequate bypass capacity should be provided for conveyance of storm flow in excess of BMP design.

CURBLESS INLET TO BIORETENTION – INDIANAPOLIS, IN

Curbless Design

Curbless designs allow Stormwater to flow directly from the impervious source to the BMP. This type of design discourages concentration of flow and reduces the energy of Stormwater entering a management facility. Curbless designs are often used with parking bioretention islands or roadside swales.

Curb Openings

Curb openings provide an alternative inlet control when a curbless design is not possible. Bioretention and landscaped islands in curbed parking lots or roadways often use curb openings as inlet controls. If flow is to be introduced through curb openings, the pavement edge should be slightly higher than the elevation of the vegetated areas. Curb openings should be at least 12 -18 inches wide to prevent clogging (CA Stormwater Manual). Inlet design of the curb openings need to address energy reduction, erosion protection and flow dispersion.

CURB CUT INLET – BURNSVILLE, MN

CURB CUT OUTLET TO FILTER STRIP – RICHMOND VILLAGE SHOPS, RICHMOND, IN

Level Spreaders

Level spreaders are controls that are designed to uniformly distribute concentrated flow into a BMP. There are many types of level spreaders that can be selected based on the peak rate of inflow, the duration of use, and the site conditions. Level spreaders help reduce concentrated flow, thereby reducing energy, erosion and increasing the design life of many Stormwater facilities. All level spreader designs follow the same principles:

- Concentrated flow enters the spreader via pipes, swales, or curb openings.
- The flow is slowed and energy is dissipated.
- The flow is distributed throughout a long linear shallow trench, behind a low berm, through a channel drain or through a perforated pipe.
- Water then flows over the berm or edge of trench/channel drain uniformly along the entire length.

SEQUENTIAL INFILTRATING LEVEL SPREADERS AND FILTER STRIPS – COFFEE CREEK, CHESTERTON, IN

The following considerations are important when designing and constructing level spreaders:

STABILIZED UPSTREAM AND DOWNSTREAM OF LEVEL SPREADER

- It is critical that the edge over which flow is distributed is level. If there are small variations in height on the downstream lip small rivulets will form. Experience suggests that design variations on the downstream side of the discharge can stop water from re-concentrating and potentially causing erosion downstream of the level spreader. Typically the design includes porous media such as a gravel seam around the discharge area on the downstream side.

- The downslope side of the level spreader should be clear of debris. After construction, debris such as soil, wood, and other organic matter might accumulate immediately upstream and/or downstream of the level spreader. This effectively blocks the level spreader's capability to discharge a diffused flow, forcing it to reconcentrate.

- The downstream side of the level spreader should be fully stabilized before the level spreader is activated. If a level spreader is installed above a disturbed area without sufficient established vegetative cover or other adequate ground cover such as construction matting (straw-coconut blanket), erosion rills will quickly form. Even sheet flow can cause significant downstream erosion on disturbed areas.

- Do not construct level spreaders in newly deposited fill without adequate compaction. Undisturbed and/or compacted earth is much more resistant to erosion than fill. Erosion is even likely to occur over a well-established young stand of grass planted on fill.

- Typical level spreaders are not generally designed for large diameter sediment removal facilities and may require pretreatment of flow prior to entering BMP. Significant sediment and debris deposition in the spreader can render it ineffective.

Types of Level Spreaders

Rock lined or vegetated Channel

Rock-lined and vegetated channels function as level spreaders when the lower (downslope) lip of the channel is level. The channel works best when it is placed along an elevation contour. Channel depths and widths vary greatly upon design need. The depth of the channel depends on the flow and pretreatment design considerations. Smaller rock-lined or vegetated channels do not typically serve as detention devices.

Concrete Troughs and Half Pipes

Concrete troughs 4-12 inches deep can be used as level spreaders. Half sections of pipe can also be used for the same function. The depths of the trough or pipe will depend on the flow. Concrete troughs are a more expensive level spreader alternative; however, they are easy to maintain and have a longer design life. If sediment or debris accumulates in the trough or pipe, it can be easily removed. Concrete level spreaders have design lives of up to 20 years while other level spreader designs may be able to effectively function for a period of 5-20 years. Accordingly, long term maintenance and replacement costs should be lower if installed properly.

Treated and Untreated Lumber

Treated and untreated lumber is not allowed as a level spreading device due to issues with deformation and decomposition.

Composite or plastic lumber

Composite and/or plastic lumber can be beneficial components of a level spreader design.

Level Spreader System Configuration

A typical level spreader system consists of pre-treatment (e.g., a forebay), principal treatment (e.g., a level spreader with grassed buffer), and emergency treatment (e.g., a reinforced grassy swale downslope of spreader). A stilling area such as a forebay is particularly useful upstream of a level spreader, because low energy should be dissipated before the flow enters a level spreader. The forebay will periodically fill with sediment, which must be removed.

Energy Dissipaters

Energy dissipaters are typically engineered devices such as rip-rap aprons or concrete baffles designed to reduce the velocity, energy, and turbulence of the flow. Where applicable, more aesthetically available landscape boulders can also be used. These structures can be employed when highly erosive velocities are encountered at the end of culverts or at the bottom of steep slopes where aesthetics are not a concern. A standard reference for design of these structures is U.S. Army Corps of Engineers, Hydraulic Engineering Center Circular 14 (HEC-14).

Riprap Aprons

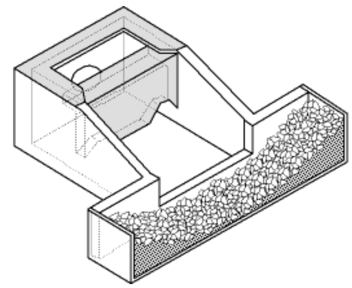
Riprap aprons are commonly used for energy dissipation, due to their relatively low cost and ease of installation. A flat riprap apron can be used to prevent erosion at the transition from a pipe or box culvert outlet to a natural channel. Riprap aprons will provide adequate protection if there is sufficient length and flare to dissipate energy by expanding the flow. City of Indianapolis Transportation and/or Indiana Department of Transportation (INDOT) typical riprap design standards provide a sound approach for riprap apron design.

Riprap Basins

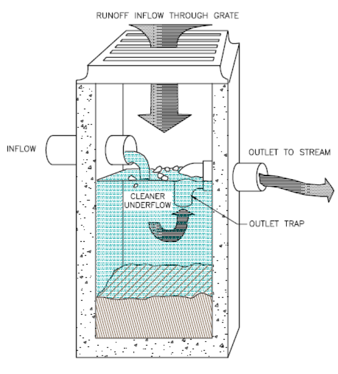
A riprap outlet basin is a pre-shaped scour hole lined with riprap that functions as an energy dissipater. It is recommended that temporary or if necessary permanent upstream sediment pretreatment controls are required to protect the riprap basin.

Baffled Outlets

A baffled outlet is a boxlike structure with a vertical hanging baffle and an end sill. Energy is dissipated primarily through the impact of the water striking the baffle and through the resulting turbulence.



ISOMETRIC VIEW OF BAFFLED OUTLET



Inlets and Catch Basins

Traditional inlets and catch basins, although not recommended, may be used as an inflow device for Stormwater facilities where curb and gutter design is desired or required. The disadvantage of traditional inlets is that the inverts of the outlet pipes are relatively deep, and excavation of Stormwater facilities may need to be deeper than with curb openings or a curbless design. A standard reference for designing traditional drainage systems is U.S. Army Corps of Engineers, Hydraulic Engineering Center Circular 22 (HEC-22). Any inlet or catch basin that connects to a BMP must have at least a one (1) foot sump.

Maintenance Concerns for Inlet Controls

The following maintenance items must be included in the O & M Manual.

Table 4.9.1: Inlet Maintenance Guidelines

	Activity	Schedule
	Inlet control devices should be inspected after several storms to ensure that they are functioning properly and that there are no erosion or debris problems developing. Source of sediment contamination should be identified and controlled when native soil is exposed or erosion channels are present.	As needed from monthly (minimum) inspection
	Inspected for sediment and debris buildup. Sediment buildup exceeding 2 inches in depth or that begins to constrict the flow path should be removed. Clean out leaves, trash, debris, etc.	As needed from monthly (minimum) inspection
	Maintain records of all inspections and maintenance activity. Include estimate of sediment and/or debris removed Indicate sediment and/or debris disposal methods	Ongoing, with documentation of each monthly inspection report

Outlet Controls

Risers and Orifices

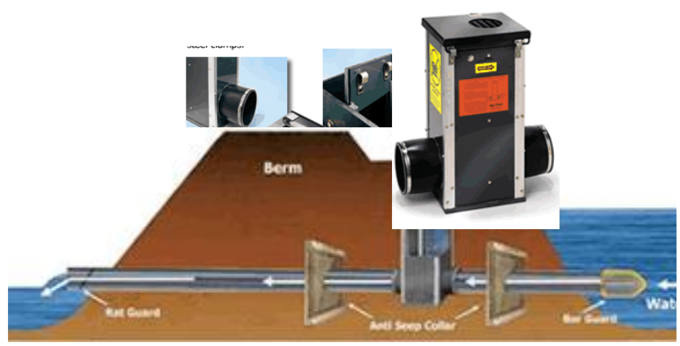
An orifice is a circular or rectangular opening of a prescribed shape and size that allows a controlled rate of outflow when the orifice is submerged. When it is not submerged, the opening acts as a weir. The flow rate depends on the height of the water above the opening and the size and edge treatment of the orifice. A riser is a vertical structure with one or more orifices that provide the controlled release in combination.

Control structures may consist of several orifices and weirs at different elevations to meet Stormwater management requirements. Multiple orifices may be necessary to meet the water quality volume and/or flood protection performance requirements for a detention system. Orifices may be located at the same elevation if necessary to meet performance requirements. Small orifices are sometimes needed when a Stormwater management system must meet low flow rate requirements.

CURB CUT INLET AND OVERFLOW OUTLET, BIORETENTION, INDIANAPOLIS, IN

Protection from Clogging

Protection from clogging is required for any orifice size. Small orifices used for slow release applications can be susceptible to clogging, which prevents the structural control from performing its function and potentially causing adverse impacts. Design measures, e.g. trash racks or screens, can be taken to prevent clogging. These measures are most effective when used in combination with periodic inspection and maintenance. The use of sumped inlets should include a hood on the outlet pipe.



BIORETENTION POSITIVE OVERFLOW OUTLET – DILLON PARK, HAMILTON COUNTY, IN

Positive Overflows

A positive overflow permits Stormwater to flow out of the BMP when the water level reaches a maximum design elevation in a subsurface feature or a maximum ponding depth in a surface feature. Flow through the positive overflow can either connect to another BMP or an approved point of discharge. A multi-stage outlet control may include a number of orifices for controlled flow and a positive overflow to quickly pass flow during extreme events. Overflow structures should be sized to safely convey larger storms from the BMP. If flow reaches the BMP via a flow splitter, this structure can provide the positive overflow.

Underdrains

Underdrains are conduits, such as perforated pipes, horizontal gravel seams, and/or gravel filled trenches that intercept, collect, and convey Stormwater that has percolated through soil, and engineered media, a suitable aggregate, and/or geotextile. Perforated underdrains are an outlet control when the collected water contributes to storm discharges as regulated under the Indianapolis's Stormwater Design and Construction Specifications Manual. Underdrains may be used in combination with other techniques such as bioretention to regulate outflow. Design of underdrains should consider the following criteria based on site specific conditions and the Indianapolis's Stormwater Design and Construction Specifications Manual:

- A permeable filter fabric is placed between the gravel layer and surrounding soil to prevent sediment contamination.
- Clean out access must be provided for all underdrain systems. Clean outs shall be placed, at a minimum, at each underdrain turn fitting.

Impervious Liners

Impervious liners are considered an outlet control because they prevent water from infiltrating and thus crossing a system boundary. Impervious liners may be selected from the following four types: compacted till liners, clay liners, geomembrane liners, and concrete liners. Underdrains can be used in conjunction with impervious liner design as long as the underdrain outlet does not conflict with the impervious liner function.

Permeable Weirs

Permeable weirs are typically constructed from composite or plastic lumber stacked with spaces between each timber to provide long, narrow openings that slowly pass Stormwater. They have the appearance of a wooden fence. Under low flow conditions, water ponds behind the permeable weir and slowly seeps through the openings between the timbers, functioning like a dry extended storage pond. Under high flow conditions, water flows both over and through the weir.

Permeable weirs are generally used in wetland areas, constructed water quality treatment ponds, water quality swales, and/or pretreatment forebays. They promote sedimentation by slowing flow velocities as water ponds behind the weir. They also provide a means of spreading runoff as it is discharged, helping to decrease concentrated flow and reduce velocities as the water travels downstream.

Maintenance Concerns for Outlet Controls

Table 4.9.2: Outlet Maintenance Guidelines		
	Activity	Schedule
	Outlet control devices should be inspected after several storms to ensure that they are functioning properly and that there are no erosion or debris problems developing. Source of sediment contamination should be identified and controlled when native soil is exposed or erosion channels are present.	As needed from monthly (minimum) inspection
	Inspected for sediment and debris buildup. Sediment buildup exceeding 2 inches in depth or that begins to constrict the flow path should be removed. Clean out leaves, trash, debris, etc.	As needed from monthly (minimum) inspection
	Maintain records of all inspections and maintenance activity. • Include estimate of sediment and/or debris removed • Indicate sediment and/or debris disposal methods	Ongoing, with documentation of each monthly inspection report

Note:

Design of inlet and outlet controls are not limited to the examples shown within this text. Successful Stormwater management plans will combine appropriate materials and designs specific to each site.

4.9.1. Inlet and Outlet Controls Designer/Reviewer Checklist

Type of inlet control proposed____

Type of outlet control proposed ____

Item	Yes	No	N/A	Notes
Rate of inflow/outflow calculated?				
Properly sized for drainage area, flow, pollutant capture?				
Adequate freeboard to prevent overflow?				
Proper bypass elevation?				
Manufacturer's recommendations followed?				
Details provided for device and connections?				
Erosion control provided, if necessary?				
Easy access/visibility for maintenance?				
Orifice protected from clogging?				
Avoidance of Stormwater concentration as much as practical?				
Slope considered and appropriate?				
Receiving vegetation considered?				
Located in undisturbed virgin soil?				
If not, will soil be properly compacted and stabilized?				
Acceptable minimum flow path length below BMP?				
Appropriate vegetation selected for stabilization?				
Feasible construction process and sequence?				
Erosion and sedimentation control provided to protect spreader?				
Maintenance accounted for and plan provided?				
If used during construction, are accumulated soils removed?				

THIS PAGE LEFT BLANK INTENTIONALLY

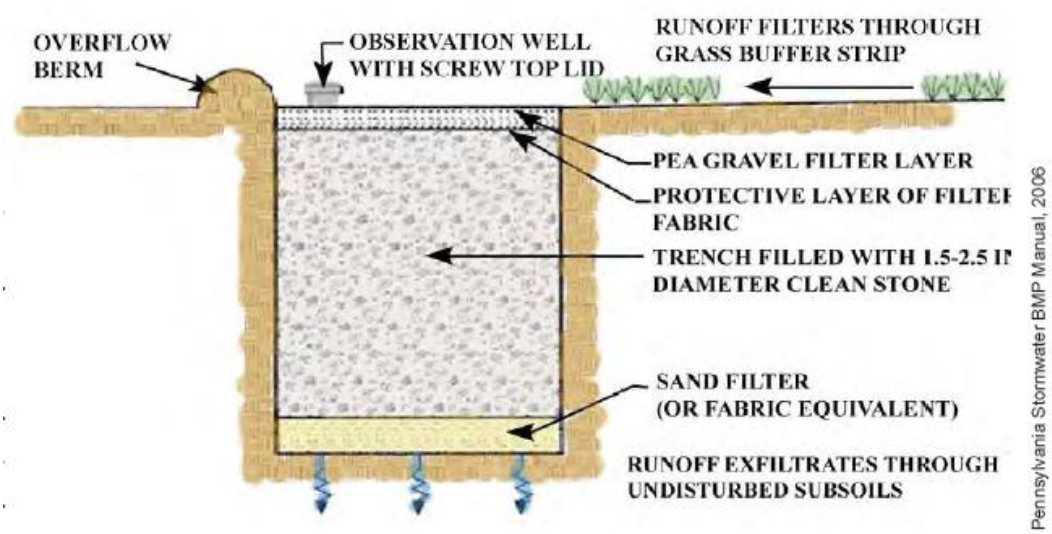
4.10. Filters

Filters are structures or excavated areas containing a layer of sand, compost, organic material, or other filter media. They reduce pollutant levels in Stormwater runoff by filtering sediments, metals, hydrocarbons, and other pollutants. Filtered Stormwater may be infiltrated or released to a sewer or receiving water. Depending on design, the filter media may provide significant detention time or may be combined with an outlet control. Filters are best used in high density urban areas where there is little opportunity of clogging from drainage areas with high pervious cover or high sediment yield sites.

There are three primary types of filters: surface, perimeter and underground filters.

- Surface filters can be an excavated trench or concrete structure.
- Perimeter filters are typically enclosed vaults located along the edge of parking areas.
- Underground filters are primarily used for areas where available space is extremely limited.

When properly designed, constructed and maintained, filters have the ability to remove 80% of the total suspended solids load in urban runoff.



FILTER WITH INFILTRATION

Key elements:

- Acceptable technique on sites where vegetated systems are impractical.
- Surface ponding that drains down in no more than 48 hours.
- Filter medium (typically sand, peat, or a mixture) removes pollutants and provides some travel time. The filter medium shall have a high permeability (fc>0.5in/hr).
- Typically two or more chambers are used in a filter system. The first is the sedimentation chamber or forebay which removes floatables and heavy sediments. The second is the filtration chamber which removes pollutants from the runoff by filtering through the sand bed or other filter media.

- Underdrain allowed on sites where infiltration is infeasible, in Wellfield Protection Areas or where a filter is used in combination with other practices.

- Flow splitter or positive overflow bypasses large storms. Typically an 'off-line' Stormwater quality system. To control flow rate, filters are usually combined with another structural control.

- Maintenance required to maintain capacity of system.

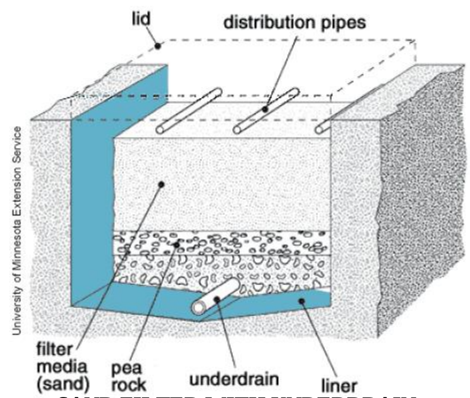
- Observation well is required for visual inspection.

Table 4.10.1: Filters Potential Application and Stormwater Regulation

Potential applications			Stormwater regulations		
				Infiltration	No Infiltration
Residential Subdivision:	Limited		Water Quality Benefit	Yes	Yes
Commercial:	Yes		Volume Reduction	Yes	No
Ultra Urban:	Yes		Attenuation Benefit	Yes	Yes
Industrial:	Yes				
Retrofit:	Yes				
Highway Road:	Yes				

Acceptable forms of pre-treatment

- Filter strips
- Appropriate prefabricated and proprietary designs
- Swales
- Sediment forebays
- Bioretention
- Planter boxes



SAND FILTER WITH UNDERDRAIN.

Stormwater Filters in the Urban Landscape

Stormwater filters are suitable for sites without sufficient surface area available for vegetated bioretention basins. Filters are designed to either infiltrate or to treat and convey runoff to a disposal point. The two biggest differences between a filter and a bioretention basin, as defined in this Manual, are surface vegetation and the use of underground containment structures. Vegetated basins often include a filtering layer that may be designed according to the guidelines in this section. Filters are recommended as a viable Stormwater Quality Practices for use in:

- Parking lots
- Roadways and Highways
- Light Industrial sites
- Transportation facilities
- Fast food and shopping areas
- Waste Transfer Stations
- Urban Streetscapes

STORMWATER FILTER

Filters may be visible from the surface or completely subsurface as shown in the two figures below. They may be designed as a single large chamber or filter bed (often with a small chamber or forebay for pretreatment) or as a long, narrow underground structure at the perimeter of a parking lot.

Larger underground filter structures are used where space is limited and contributing areas are of high density.

Components of a Stormwater Filter System

Stormwater filters can be designed to infiltrate all or some of the flow. Components of Stormwater filter system shall include:

VEGETATED FILTER

- Excavation or container
- Pretreatment
- Flow entrance/inlet
- Surface storage (ponding area)
- Filter media
- Underdrain, if required
- Positive overflow

Excavation or Container

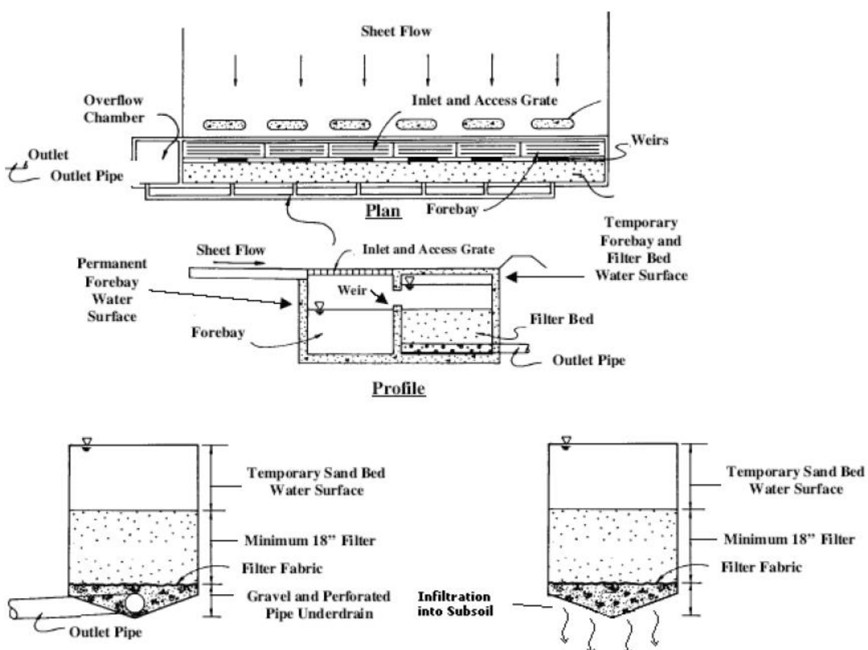
The filer media may be contained in a simple trench lined with a geotextile, or it may be contained in a more structural facility such as concrete. In either case, the container may be designed either to allow infiltration or to collect flow in an underdrain system.

Pretreatment

A chamber or forebay may be installed for pretreatment, including the removal of coarse particles and trash.

Flow Entrance/Inlet

Flow may be introduced to a filter through any of the controls discussed in the Inlet and Outlet Controls Fact Sheet (Chapter4.9). If Stormwater does not enter as sheet flow, a flow spreader is required.



SURFACE SAND FILTER

Surface Storage (ponding area)

The filter allows water to pond during intense storms as water flows slowly through the filter media.

Filter Media

Stormwater flows onto filter media where sediments and other pollutants are separated from the Stormwater. Filter materials such as sand, peat, granular activated carbon (GAC), leaf compost, pea gravel and others are used for water quality treatment. Coarser materials allow faster transmission, but finer media filters particles of a smaller size. Sand has been found to be a good balance between these two criteria (Urbonas, 1999), but different types of media remove different pollutants. While sand is a reliable material to remove TSS, (Debusk and Langston, 1997) peat removes slightly more TP, Cu, Cd, and Ni than sand. Depending on the characteristics of the Stormwater runoff, a combination of these filter materials will provide the best quality results. In addition to determining the degree of filtration, media particle size determines travel time in the filter and plays a role in meeting release rate requirements.

Underdrain (if required)

Infiltration is required where feasible unless the filter is combined with another facility that provides infiltration. Filters that do not infiltrate collect water through an underdrain system. Systems that utilize infiltration must have a soil investigation performed by a geotechnical engineer or soil scientist. The investigation must include documentation of the seasonal high water table and infiltration rate.

Positive Overflow

Filters must be designed to allow overflow or bypass of larger storm volumes. Flow splitters, diversion chambers, or proprietary devices can be used to divert a portion of flow to a filter in an off-line design. A design that is considered on-line allows water to flow across the surface of the filter before being discharged over a weir or other control.

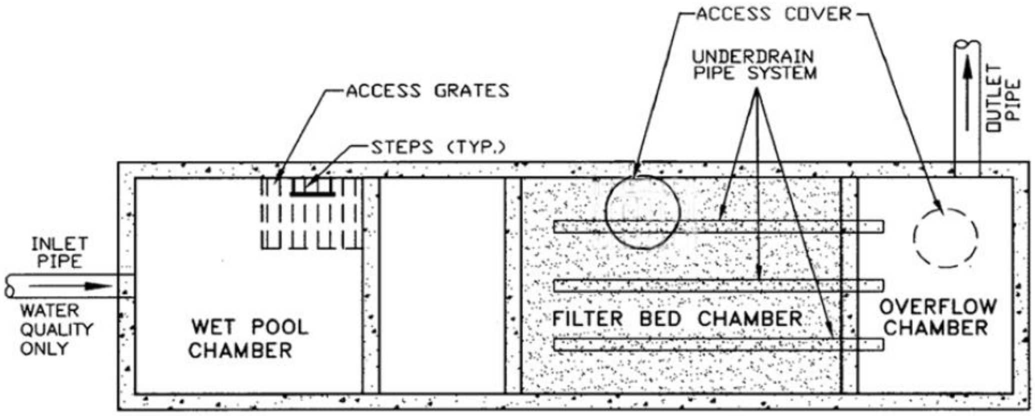
Recommended Design Procedures

- Determine the Water Quality and Quantity requirements for the site. See the City of Indianapolis Stormwater Design and Construction Specifications Manual.

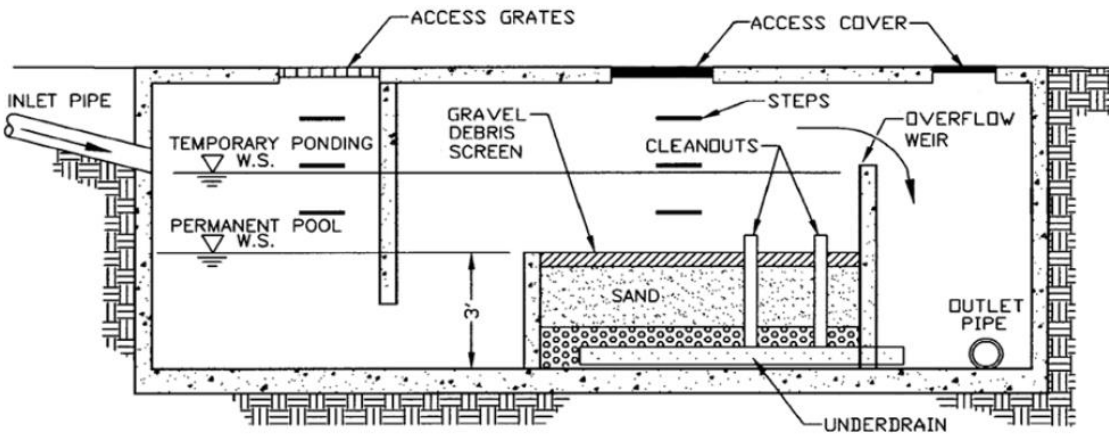
- Create a Conceptual Site Plan for the entire site and determine what portion of the Stormwater control requirements the filters will meet. See the City of Indianapolis Stormwater Design and Construction Specifications Manual.

- Investigate the feasibility of infiltration in the area proposed for the Stormwater filter. If infiltration is feasible, determine the saturated vertical infiltration rate. Design proceeds differently depending on the feasibility of infiltration. Refer to **Attachment 1, Guidelines for Infiltration Testing**.

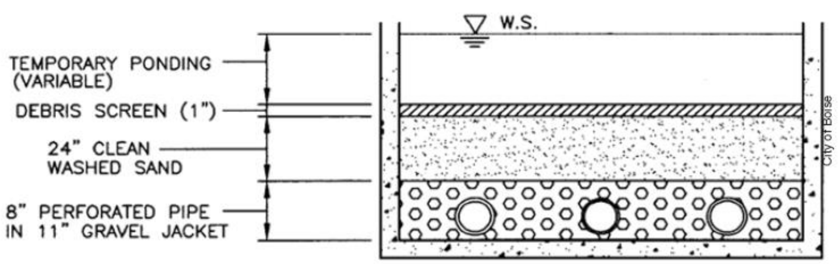
- Create a conceptual design for the Stormwater filter.



PLAN VIEW



PROFILE



• The filter area may be estimated initially using Darcy's Law, assuming the soil media is saturated.
Af = (V x d) / [k x t (h + d)]
Af = Surface area of filter bed (square feet)
V = Volume to be managed, i.e. water quality volume (cubic feet)
d = Depth of filter media (feet)
t = Filter bed drain time (days)
h = Head (average in feet)
k = Saturated hydraulic conductivity of filter media (feet/day)
k Design values: sand = 3.5 feet/day; peat = 2.5 feet/day; leaf compost = 8.7 feet/day

- For filters designed for infiltration, estimate the total storage volume and adjust area and/or depths as needed to provide required storage.

Table 4.10.2: Suggested Starting Design Values for Ponding and Media Depths	
Average Ponding Depth	3-6 inches
Filter Media Depth	18 - 30 inches

- Using Stormwater filter area and the saturated vertical infiltration rate of the filter media, estimate the drainage time for ponded surface water. The saturated vertical infiltration rate may be based on the estimated saturated hydraulic conductivity of the proposed filter materials. The maximum drain down time for the entire storage volume is 72 hours, but a surface drain down time of 24-48 hours is recommended. If storage does not drain in the time allowed, adjust pretreatment depth, filter media depth, and surface area. Adjust the design until the volume and drainage time constraints are met.
- Design underdrains to minimize the chances of clogging. Pea gravel filters can be used for this purpose. Pea gravel filters should include at least 3 inches of gravel under the pipe and 6 inches above the pipe.
    - Consider an underdrain only under one of the following conditions:
        - in areas with separate storm sewers or direct discharge to receiving waters where infiltration is infeasible and the filter system is needed only to provide water quality treatment;
        - in areas located within a Wellfield Protection District;
        - in areas with combined sewers where sufficient detention or travel time can be designed into the system to meet release rate requirements; or
        - in combination with other BMPs where the system as a whole meets storage and release criteria.
- Design any structural components required.
- Complete construction plans and specifications.

Materials

All material specification should be included on the plans.

Stone Storage (if used)

- Stone used to provide additional storage shall be uniformly-graded, crushed, washed stone meeting the specifications of AASHTO No. 3 or AASHTO No. 5.

- Stone shall be separated from filter medium by a non-woven filter fabric or a pea gravel filter.

Filter Media

- Peat shall have ash content <15%, pH range 3.3-5.2, loose bulk density range 0.12-0.14 g/cc.

- Sand shall be clean, medium to fine sand, and have organic material meeting specifications of AASHTO M-6 (0.02” - 0.04”) or ASTM-C-33.

- Prefabricated filter media shall meet filter design and water quality specifications.

Piping

- Pipe shall have continuous perforations, smooth interior, and minimum diameter of 6 inches. High density polyethylene (HDPE) pipe shall meet specifications of AASHTO M252, Type S or AASHTO M294, Type S.

Construction Guidelines

- Areas for Stormwater filters shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.
- Permanent filters should not be installed until site is stabilized. Excessive sediment generated during construction can clog filter and prevent its function prior to post-construction benefits.
- Structures such as inlet boxes, reinforced concrete boxes, inlet controls, and outlet structures should be constructed in accordance with manufacturer's guidelines or Engineer's guidance.
- Excavated filters or structural filters that infiltrate should be excavated in such a manner as to avoid compaction of the sub-base. Structures should be set on a layer of clean, lightly compacted gravel specified as AASHTO No. 57.
- A layer of permeable non-woven geotextile should underlie infiltration filters.
- Place underlying gravel/stone in minimum 6 inch lifts and lightly compact. Place underdrain pipes in gravel during placement (if applicable).
- Wrap and secure non-woven geotextile to prevent gravel/stone from clogging with sediments.

Maintenance Guidelines

For filters located entirely underground, unobstructed access for must be provided over the entire sand filter, including inlet and outlet pipe structures, by either doors or removable panels. Ladder access is required for vault heights greater than 4 feet. The O & M Manual should also note when entrance into the filter is considered as an OSHA confined space.

The following table provides items that must be included in the O & M Manual.

Table 4.10.3: Filter Maintenance Guidelines

Activity	Schedule
Rake filter media surface for the removal of trash and debris from control openings. Repair of leaks from the sedimentation chamber or deterioration of structural components.	As needed
Inspect filter for standing water (filter drainage is not optimal) and discoloration (organics or debris have clogged filter surface).	Quarterly
Removal of the top few inches of filter media and cultivation of the surface when filter bed is clogged. Clean out accumulated sediment from filter bed chamber. Clean out accumulated sediment from sedimentation chamber.	Annually
Maintain records of all inspections and maintenance activity.	Ongoing

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 concerns

Indiana's low temperature dips below freezing for about four months out of every year, and surface filtration may not take place as well in the winter. Peat and compost may hold water, freeze, and become impervious on the surface. Design options that allow direct sub-surface discharge into the filter media during cold weather may help overcome this condition.

Siting constraints:

For a surface filter that infiltrates into the existing soil, the minimum distance between the bottom of the filter and the elevation of the seasonally high water table is 2 feet.

To protect the aquifer, infiltration shall not be used on hotspot sites or within well field protection areas.

Note:

Design of Stormwater filters are not limited to the examples shown within this text. Successful Stormwater management plans will combine appropriate materials and designs specific to each site.

4.10.1. Filter Designer/Reviewer Checklist

Item	Yes	No	N/A	Notes
Adequate depth of filter media?				
Acceptable drawdown time (72 hour max.)?				
Pretreatment provided?				
Adequate hydraulic head available for filter to operate?				
Flow bypass and/or overflow provided?				
Permeability of filter media acceptable?				
Hotspots/pretreatment considered?				
Underdrain provided for non infiltration systems?				
Appropriate placement of nonwoven filter fabric?				
Gravel layer provided beneath filter media?				
Non-erosive inflow condition?				
Adequate surface area provided?				
Construction timing places installation after site stabilization?				
Erosion control provided during construction?				
Cleanouts included?				
Maintenance accounted for and plan provided?				

Other O & M Manual Requirements

See Section 702.04 (Figure 702-17) for other O&M Manual requirements.

THIS PAGE LEFT BLANK INTENTIONALLY

4.11. Subsurface Vaults

Subsurface Vaults are specialized underground structures designed similarly as above ground detention or retention basins. These underground basins can be utilized for groundwater recharge by allowing infiltration. They are usually constructed of either concrete or plastic and must account for the potential loading from the expected bearing weight from the intended land use above them. Subsurface vaults are used commonly for Stormwater storage for small parcels where it is infeasible to have adequate surface storage via an open basin. It is also very common to design such facilities for various vehicle loadings as parking lots or for recreational surfaces, such as tennis and basketball courts. Water quality structures are required to treat Stormwater runoff and remove debris before filling a subsurface vault. Subsurface vaults are typically dry systems, primarily used for Stormwater quantity control. Less common are wet water quality systems designed to maintain a permanent pool to dissipate energy and settle particulate Stormwater pollutants. The City of Indianapolis does not allow for subsurface quantity control vaults to act as water quality control treatment facilities, therefore wet systems are typically not utilized locally.

Key elements:

- Effective for urban areas with high valued land and limited space.
- Equally effective in areas of combined sewer and separate storm sewers areas.
- Provides peak rate control.
- Pretreatment water quality facilities are required before Stormwater can discharge into subsurface vaults.
- Weight bearing loading capabilities for anticipated land use above vault.
- Maintenance required periodically to remove sediment and debris.

STORMTRAP® SUBSURFACE VAULT WITH INFILTRATION, GARY, IN

Table 4.11.1: Subsurface Vaults Potential Application and Stormwater Regulation

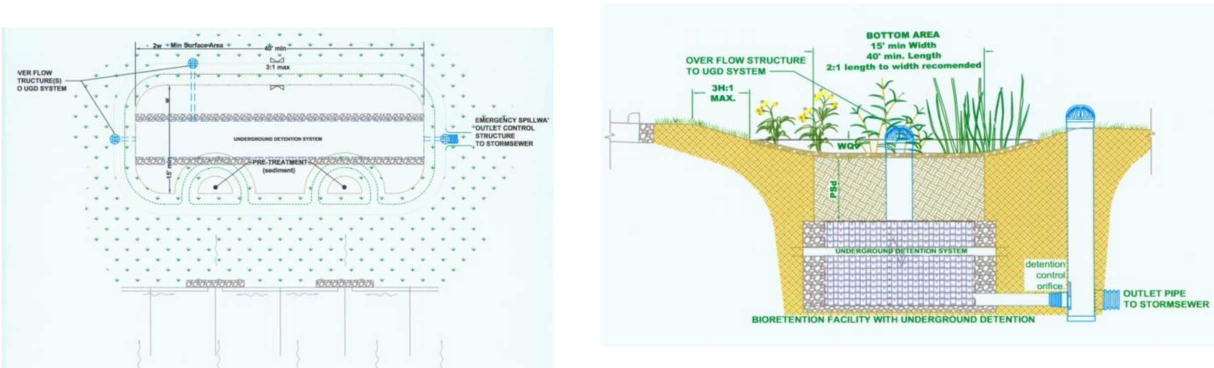
Potential applications			Stormwater regulations		
				Infiltration	No Infiltration
Residential Subdivision:	Yes		Water Quality Benefit	Yes	No
Commercial:	Yes		Volume Reduction	Yes	Yes
Ultra Urban:	Yes		Attenuation Benefit	Yes	Yes
Industrial:	Yes				
Retrofit:	Yes				
Highway Road:	Yes				

Acceptable forms of pre-treatment

- Sediment chamber or wet subsurface vault
- Sediment forebay (rain gardens, bioretention, open basin, etc.)
- Appropriate prefabricated mechanical and propriety designs. Some systems, e.g. StormTech may require the use of an SQU or other pretreatment prior to the system.

Subsurface Vaults in the Urban Landscape

Subsurface vault systems are suitable for projects where space is limited and other Stormwater management systems are not feasible. Subsurface vaults may be used for commercial, industrial, or roadway projects. The presence of a subsurface vault in most cases does not alter the intended land use at the surface. The subsurface vault must meet structural requirements for overburden support and land use loading to be applicable in urban settings. Some applications of subsurface vaults are provided; however, examples are not limited to this list.



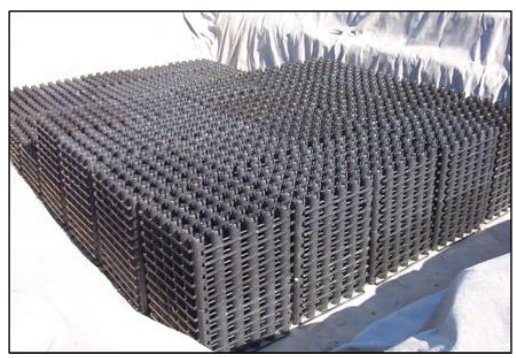
BIORETENTION USED FOR PRETREATMENT, WATER QUALITY VOLUME AND INLET CONTROL PRIOR TO INFILTRATIVE SUBSURFACE VAULT DETENTION - ZIONSVILLE, IN

Components of a Subsurface Vault

Subsurface vault systems contain a combination of the following components:

Pretreatment

Pretreatment can include a forebay/grit chamber, subsurface wet vault, or water quality treatment structure (SQU). Pretreatment is required to also include features to trap floatables and where land use dictates an oil/water separator. Baffles or walls within the subsurface vault separate the entire volume into multiple chambers. Storage volume present in a pretreatment structure may be considered part of the total design storage volume required.



INVISIBLE STRUCTURES® INFILTRATION FEATURE – PORTER COUNTY JAIL, VALPARAISO, IN

Inlet Control

The inlet control of a subsurface vault should be connected to the Stormwater water quality pretreatment facilities. The subsurface vault should be sized according to the area entering into the system. Parking lots, roadways, and large rooftop areas are typically the drainage areas contributing to the subsurface vault system. The inlet control may include a flow splitter to regulate the rate and volume of water entering the vault.

Storage Structure

Storage often provided by a concrete structure, a large pipe, or a group of pipes.

Infiltration Feature

Infiltration is typically not a major function of a subsurface vault; however, some designs may allow it. The designer must consider soil conditions and maximize the ratio of infiltration area to drainage area. Guidelines for infiltration practices are outlined in **Attachment 1**. Infiltration must be verified through field investigation by a geotechnical engineer or certified soil scientist. The seasonal high water table and infiltration rate must also be included in the investigation and documented.

Permanent Pool

A permanent pool of water may be incorporated to dissipate energy. When a permanent pool is incorporated in a design, the design may be referred to as a "wet vault". This design provides a benefit similar to that of a surface wet pond. Wet subsurface vaults cannot be used for water quality treatment and the permanent pool area cannot be utilized for Stormwater quantity control.

CONTECH® SUBSURFACE VAULT, FEDERAL EXPRESS ® FACILITY – INDIANAPOLIS AIRPORT

Slow Release Structure

The slow release structure regulates the rate of outflow for storms up to the design capacity. The storage volume and slow release together allow a subsurface vault to meet channel protection and peak release rate criteria.

Overflow Structure

An overflow structure allows storms in excess of the design storm to pass through the structure without being detained. An overflow structure at the outlet, a flow splitter at the inlet, or a combination may be used to safely convey large storms.

Access Feature

This feature is used for maintenance and inspection purposes and most commonly consists of a panel or manhole entry port leading to the storage area.

Recommended Design Procedure

- Determine the water quality/recharge, stream bank protection, and peak rate control requirements for the site.
- Create a Conceptual Site Plan for the entire site, and determine what portion of the sizing requirements the subsurface vault will meet.
- Create a conceptual design for the subsurface vault, including enough volume to meet storage requirements.
- Estimate the total storage volume and adjust facility sizing as needed to provide required storage. Any permanent pool areas should not be included in the storage volume estimation.
- Choose and design pretreatment as appropriate. The pretreatment volume is part of the total volume. An oil/water separator should be considered to treat incoming flow from industrial sites or parking lots.
- Decide whether to design for infiltration. The procedure followed and requirements are similar to that for bioretention or infiltration basin design.
- Design the release structure to comply with site release rate requirements.

- Design a positive overflow or bypass system for large storms. The outlet structure and design head should provide adequate flow to avoid overtopping the vault.

- Design adequate maintenance access for each vault to connect to ground level.

- Complete construction plans and specifications. At a minimum, plans should include plan view, cross sections, and inlet and outlet details.

CONTECH® SUBSURFACE VAULT – KMART, BLOOMINGTON, IN

STORMTRAP® SUBSURFACE VAULT - MUNICIPAL BUILDING, LEBANON, IN

Maintenance Guidelines

The systems must be designed so that the vault can have easy access for inspection and maintenance. Subsurface vaults can be considered confined spaces. All maintenance procedures must comply with all local, state and federal requirements.

Table 4.11.2: Subsurface Vaults Maintenance Guidelines

Activity	Schedule
Removal of sediment and debris from subsurface vault chamber(s) when the sediment zone is full. Sediments should be tested for toxicants in compliance with current disposal requirements if land uses in the catchments include commercial or industrial zones, or if indications of pollution are noticed.	As needed
Inspection of subsurface vault and control structures. Floating debris and accumulated petroleum products should be removed.	Quarterly
Maintain records of all inspections and maintenance activity	Ongoing

Note:

The designs of subsurface vaults are not limited to the examples shown within this text. Successful Stormwater management plans will combine appropriate materials and Stormwater quantity and quality designs specific to each site.

4.11.1. Subsurface Vault Designer/Reviewer Checklist

Item	Yes	No	N/A	Notes
Level infiltration area (e.g., trench bottom, bed bottom)?				
Excavation in infiltration area minimized?				
Hotspots/pretreatment considered?				
Feasible construction process and sequence?				
Geotextile specified?				
Pretreatment provided?				
Slow release structure used?				
Appropriate pipe, if applicable?				
Storage requirements met?				
Observation well/clean out provided, if applicable?				
Maintenance accounted for and plan provided?				

THIS PAGE LEFT BLANK INTENTIONALLY

4.12. Detention Basins

LONG, LINEAR, INTERCONNECTED BASIN

Detention Basins can be a cost effective method to provide temporary storage, conveyance, and treatment of runoff when used within the context of Low Impact Development (LID) strategies. Long, linear, interconnected basins can provide the designer with an economically attractive method to provide source control of Stormwater as well as convey water without the slope and cover requirements of conventional storm sewer design. This allows for the drainage of the proposed development to more closely mimic existing conditions, minimizing earth work and the ecological impact to downstream receiving bodies. Further, the associated open vegetated aesthetics can provide for passive recreation, quality of life, and increase property values.

Detention basins provide storage on the surface or subsurface either by impoundment within a natural depression, or in an excavated area. Traditional detention basins function primarily to provide water quantity control. The designer should note that detention basins can also be configured to provide water quality treatment. These designs should incorporate methods that remove target pollutants. More information on incorporating methods and designs for water quality must be designed within parameters required by the Stormwater Design and Construction Specifications Manual.

Key elements:

- Most basins are designed to provide channel protection and flood control only.
- Pretreatment, such as rain gardens or wetland entrainment facilities can help decrease maintenance.
- Over-excavation in anticipation of sediment accrual can prolong the design life of the basin.
- Vegetation stabilizes the soil in the basin.
- Outlet structure design is critical and determines how the basin meets Stormwater control requirements.

Table 4.12.1: Detention Basins Potential Application and Stormwater Regulation

Potential applications			Stormwater regulations		
				Infiltration	No Infiltration
Residential Subdivision:	Yes		Water Quality Benefit	Yes	Yes
Commercial:	Yes		Volume Reduction	Yes	No
Ultra Urban:	Limited		Attenuation Benefit	Yes	Yes
Industrial:	Yes				
Retrofit:	Yes				
Highway Road:	Yes				

Acceptable forms of pre-treatment

- Sediment forebays
- Filter strips
- Vegetated swales
- Bioretention gardens
- Wetlands
- General Disconnection of impervious areas from detention facilities

Detention Basins in the Urban Landscape

Detention basins are suitable for large developments and high-density commercial projects. They can often be designed for use between storm events, creating an open space available for recreational purposes.

Components of a Detention Basin

Detention basins are typically comprised of the following components:

- Pretreatment
- Vegetation
- Micropool
- Outflow structure

SEDIMENT FOREBAY

Sediment Forebay (Pretreatment)

Supplementing a dry pond design with a sediment forebay is required to increase the treatment efficiency. The sediment forebay improves pollutant reduction by trapping larger particles near the inlet of the pond. The forebay should include a permanent pool to minimize the potential for scour and re-suspension. Sediment forebays should be designed with ease of maintenance. Forebays must be accessible to heavy machinery. Those constructed with a bottom made of concrete or other solid material make sediment removal easier and more accessible by heavy machinery.

Keeping Stormwater out of a pipe and within a minimally sloped, vegetated landscape in advance of a detention basin can be considered another source control to provide pre-treatment. If no pretreatment is proposed, then the entire Detention Basin can be viewed as the forebay. The design volume of the Basin should reflect a summation of volume necessary for attenuation requirements as well as the accumulation of sediment over a prescribed design life such as 50 or 100 years. Sediment accrual rates based upon land use and / or soil type are available and should be referenced in the design.

Vegetation

Surface vegetation in the basin provides erosion control, sediment entrapment, aesthetic value, and acts as a water fowl (Canadian Geese) deterrent. The images below demonstrate a traditional detention pond planted with turf grass, which does not provide the above items, and a detention pond edge planted with native forbes and grasses. Side slopes, berms, and basin surface should be planted with species concurrent with expected hydrologic conditions. Appropriate species can be found in Chapter 5: Stormwater Landscape Guidance.

WET AND/OR DRY POND EDGE OPTIONS- CONVENTIONAL TURF EDGE

WET AND/OR DRY POND EDGE OPTIONS- NATIVE FORB AND GRASS EDGE

Micropool at the Outlet (Optional)

Applying a micropool design to a detention basin can increase water quality performance. The micropool is typically shallow and permanently inundated. Its function is to reduce re-suspension and to guard against vegetation encroachments toward the outlet. The micropool can be planted with wetland vegetation species but should be deep enough at the outlet pipe to discourage vegetative encroachments that could encourage clogging over the design life. Refer to Chapter 5: Stormwater Landscape Guidance.

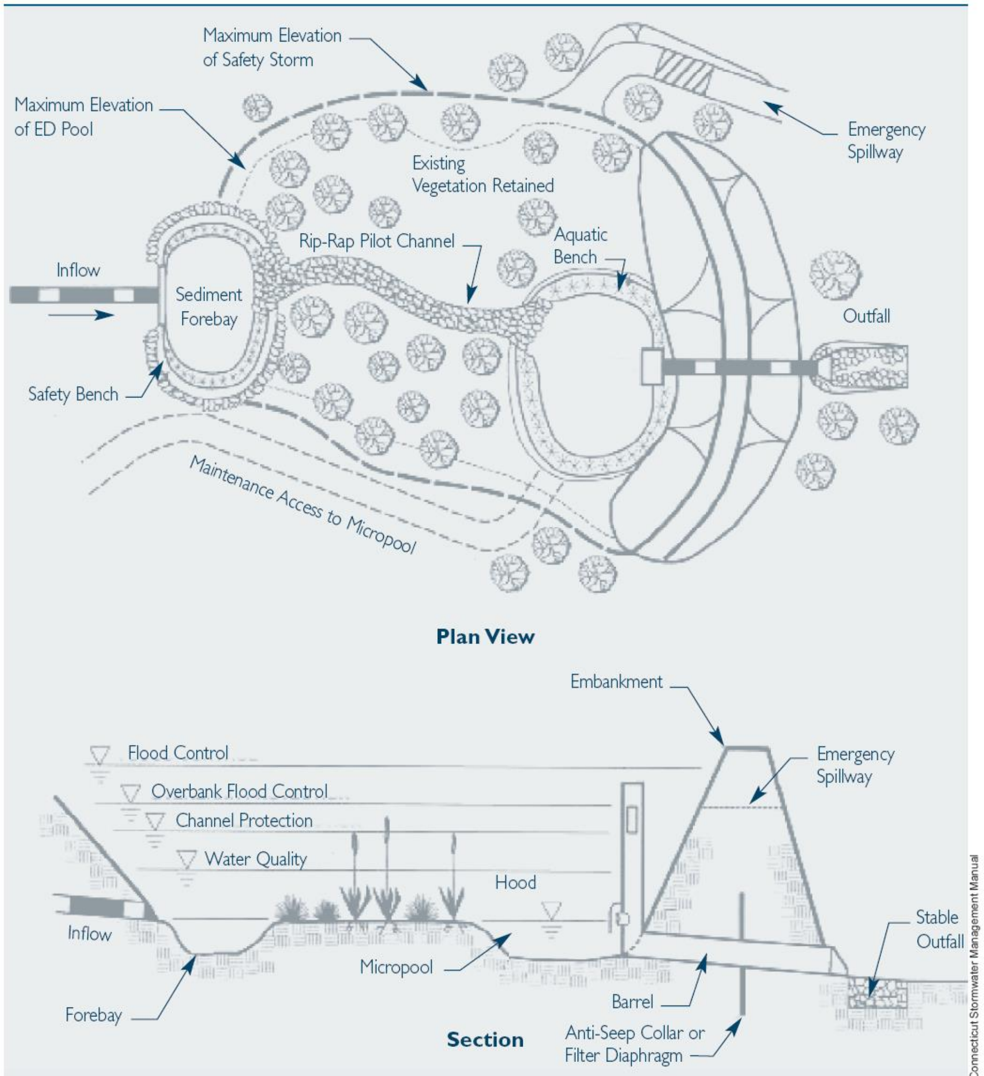
Pennsylvania Stormwater BMP Manual

Athletic field to be used as a detention basin

Outflow Structure

The outlet structure determines the performance of the basin. By installing a multi-stage outlet, the basin can be designed to meet both Water Quality and Flood Control requirements.

A gate valve or orifice plate may be used to regulate the drawdown time. In general, the outflow structure should have an acceptable means of preventing clogging, i.e. trash rack or screen, at the entrance to the structure over the design life to minimize maintenance requirements. The design must be designed within parameters required by the Stormwater Design and Construction Specifications Manual.



Extended detention basin schematic

Recommended Design Procedure

- Determine the Stormwater management requirements for the site within parameters required by the Stormwater Design and Construction Specifications Manual.

- Create a Conceptual Site Plan for the entire site and determine what portion of the control requirements the detention basin will meet.

- Consider a dry extended detention basin to provide water quality treatment if infiltration is infeasible on the site. Organic soil amendments may be utilized above proposed underdrain systems in order to simulate infiltration to remove dissolved metals and *E. coli*.

- Detention basins should be considered in existing low areas so that the facility can be constructed with low impact and minimal earth work.
- Extended detention basins should not be considered within USACE or IDNR jurisdictional waters~~,~~ unless the applicable permit is first obtained.

- Create a conceptual design for the basin. Estimate required basin size according to design parameters as well as approved calculation method required by the Stormwater Design and Construction Specifications Manual.

Table 4.12.2: Starting Design Parameters for Detention Basins	
Detention time for water quality volume	Designer should reference the Stormwater Design and Construction Specifications Manual.
Water depth	Designer should reference the Stormwater Design and Construction Specifications Manual.
Width	depends on design
Shape	Design basin to maximize length of Stormwater flow pathways, and to minimize short-circuiting from inlet to outlet

- Design an outlet structure (or multiple structures) that provides the level of control required. (A multistage outlet structure will generally reduce the necessary size of the facility)

- Energy dissipaters are to be placed at the end of the primary inlets to discourage erosion.

- If the basin discharges to a channel with dry weather flow care shall be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone between the outlet and natural channel.

- The hydraulic design of all outlet structures must consider any tailwater effects of downstream waterways within parameters required by the Stormwater Design and Construction Specifications Manual.

- The primary and low flow outlet shall be protected from clogging by an acceptable means.

- On sites that have the potential for accidental spills, the outflow structure should be fitted with a valve so that discharge from the basin can be halted. This same valve also can be used to regulate the rate of discharge from the basin.

- Emergency overflow design should agree with design criteria within parameters required by the Stormwater Design and Construction Specifications Manual.

- Determine the final contours of the basin.

Table 4.12.3: Contour Design Parameters for Detention Basins	
Lowest basin elevation	2 feet above seasonal high water table (Minimum) if infiltration is accounted for in hydraulic calculations.
Basin shape	Irregularly shaped to lengthen effective flow path and provide natural appearance
Low flow channels	may be used to discourage severe ponding due to native soils if necessary Always vegetate with a maximum slope of 3% to encourage sedimentation Consider other BMPs such as wet ponds, constructed wetlands or bioretention
Vegetated embankments	Less than or equal to 3 feet in height (Recommended) 20 feet in height (Maximum)* Maximum slope 3:1 (Horizontal to vertical)
Basin freeboard	Minimum 1 foot above the 100-yr design storm
* 20 feet or higher or that which will impound more than 100 acre-feet of runoff or drain more than 1 square mile will be regulated as dams by IDNR. Consult . IC 14-27-7.5 for further detail.	

- Design an inlet control so that inflow energies can be dissipated. If specified, the sediment forebay volume may be considered to meet a portion of the water quality volume if non-turbulent conditions are expected to dominate during inflows.

Table 4.12.4: Inlet Control and Sediment Forebay	
Forebay length	10 percent of projected flow path (Minimum)
Storage	Designed to trap sediment over a period of 2 to 10 years

- Verify that the basin meets all control requirements concurrently as designed.

- Choose appropriate vegetation using the guidelines in Chapter 5: Stormwater Landscape Guidance. Fertilizers containing phosphorus shall not be used. The use of pesticides is discouraged.

- Complete construction plans and specifications.

Materials

Basin Soil

- A minimum of 6 inches of planting soil is recommended. Soil shall be a high-quality topsoil with a loam or sandy loam texture. The use of 30% organic content by volume is recommended for dry basins that discharge to waterways listed on the IDEM 303(d) for dissolved metals or fecal coliforms.

- Clay cores may be necessary in basins designed to withstand excessive pressures and seepage forces.

Plants

- It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select plants from Chapter 5: Stormwater Landscape Guidance.

- Trees and shrubs shall be freshly dug and grown in accordance with good nursery practice.

- Perennials, grass-like plants, and groundcover plants shall be healthy, well-rooted specimens.

- Plantings shall be designed to minimize the need for mowing, pruning, and irrigation.

Construction Guidelines

- Install all temporary erosion and sedimentation controls. The area immediately adjacent to the basin must be stabilized in accordance with IDEM Rule 5 during construction activities and Rule 13 at the cessation of construction activities.

- Prepare site for excavation and/or embankment construction.

- All existing vegetation should be left in place if feasible, and shall 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 to be excavated of all vegetation.

- Excavate bottom of basin to desired elevation (if necessary).

- Install surrounding embankments and inlet and outlet control structures.

- Grade subsoil in bottom of basin, taking care to prevent compaction. Compact surrounding embankment areas and around inlet and outlet structures.

- Apply and grade planting soil.

- Apply geotextile and other erosion-control measures.

- Seed, plant, and mulch according to Planting Plan.

Maintenance Guidelines

- Properly designed Detention Basins should require little to no maintenance throughout the design life. However, maintenance is expected for the proper operation of detention basins. Plans for detention basins should identify owners, parties responsible for maintenance, and an inspection and maintenance schedule for extended storage detention basins.

Table 4.12.5: Detention Basin Maintenance Guidelines	
Activity	Schedule
Remove trash and debris Remove invasive plants. Grassed areas may require periodic prudent fertilizing, dethatching and soil conditioning. Trees, shrubs, and other vegetative cover may require periodic maintenance such as fertilizing, pruning, and pest control. Mow/trim detention basin vegetation if desired.	As needed
Sediment should be removed from the basin at such time as the sediment accrues to an extent such that the Basin loses design attenuation capacity.	As needed
Inspect outlet control structure	Quarterly and after every storm greater than 1 inch
Inspect detention basin for potential problems including: subsidence, erosion, cracking or tree growth on the embankment; damage to the emergency spillway; sediment accumulation around the outlet; inadequacy of the inlet/outlet channel erosion control measures; changes in the condition of the pilot channel; and erosion within the basin and banks.	Annually
Maintain records of all inspections and maintenance activity.	Throughout the design life
*The frequency of sediment removal depends on the design, which should account for site conditions such as soil type, impervious percentage, and drainage area, all of which influence the sediment load on the basin.	

- In most cases, no specific limitations have been placed on disposal of sediments removed from detention basins. Studies to date indicate that pond sediments are likely to meet toxicity limits and can be safely landfilled. On-site sediment disposal is always preferable as long as the sediments are deposited away from the shoreline to prevent their re-entry into the pond and away from recreation areas where people could inhale resulting dust. Sediment disposal should be included in the Operations and Maintenance (O & M) Plan and will be evaluated on a site by site basis. Designers are encouraged to plan for long-term sediment-accumulation within detention basins, which is more economical, and environmentally preferable to dredging and disposing of sediments.

- Sediments should be tested for toxicants in compliance with current disposal requirements if land uses in the drainage area include commercial or industrial zones, or if visual or olfactory indications of pollution are noticed.

4.12.1. Detention Basin Designer/Reviewer Checklist

Item	Yes	No	N/A	Notes
Pretreatment considered?				
Forebay provided?				
Minimum depths of 10 feet for wet ponds used?				
Appropriate inlet and outlet structures?				
Outlets protected from clogging?				
Trash rack provided to prevent clogging?				
Lowest base elevation above seasonal water table?				
Feasible construction process and sequence?				
Bank vegetation requirements met?				
Appropriate plant species indicated?				
Bank slope requirements met?				
Soil requirements met?				
Storage requirements met?				
Maintenance accounted for and plan provided?				

Other O & M Manual Requirements

See Section 702.01 of the Stormwater Design and Construction Specifications Manual.

5. Stormwater Landscape Guidance

Landscaping is a critical element to improve both the function and appearance of Stormwater management practices. Integrated Stormwater landscapes can provide many benefits such as construction cost savings, reduced maintenance, aesthetic enhancement, and the improved long-term functionality. A well-designed and established landscape will also prevent post-construction soil erosion. Additionally, these approaches can help mitigate urban heat island effects, improve air quality, and reduce atmospheric carbon levels. These benefits only exist if the right tree and plant are selected for the right place and properly maintained.

Vegetated Stormwater management systems are a preferred practice. Stormwater management practices can be integrated within planned landscape areas, with minor modifications to conventional landscape design. <u>It is essential that impervious surfaces be graded toward the vegetated areas that are used as the Stormwater management facility and that these facilities are depressed to allow for flow and/or surface ponding. Guidance for the design of inlets to vegetated Stormwater management practices can be found in Section 4.9: Inlet and Outlet Controls. Since these design approaches are still new to many construction contractors it is advisable to clearly show these details in cross section and plan view drawings.</u>

This section provides landscaping and plant selection guidance for effective Stormwater management and is organized as follows: Section 5.1: Planting Guidance contains general guidance that should be considered when landscaping any Stormwater management practice. Section 5.2: Stormwater management Specific Landscaping Requirements includes specific planting and site preparation information for selected design. Section 5.3: Native and Recommended Non-invasive Plant lists appropriate plants for use in Stormwater management practices in the Midwest. Table 5.3.2 provides a comprehensive list of plants that was reviewed and revised by two local native plant nurseries. Key information useful for the selection of plant material for Stormwater landscaping is presented, including National Wetland Indicator Status, preferred hydrologic zones, and aesthetic considerations.

5.1. Planting Recommendations / Guidelines

General guidance for all Stormwater management plantings:

Planting selection and arrangement

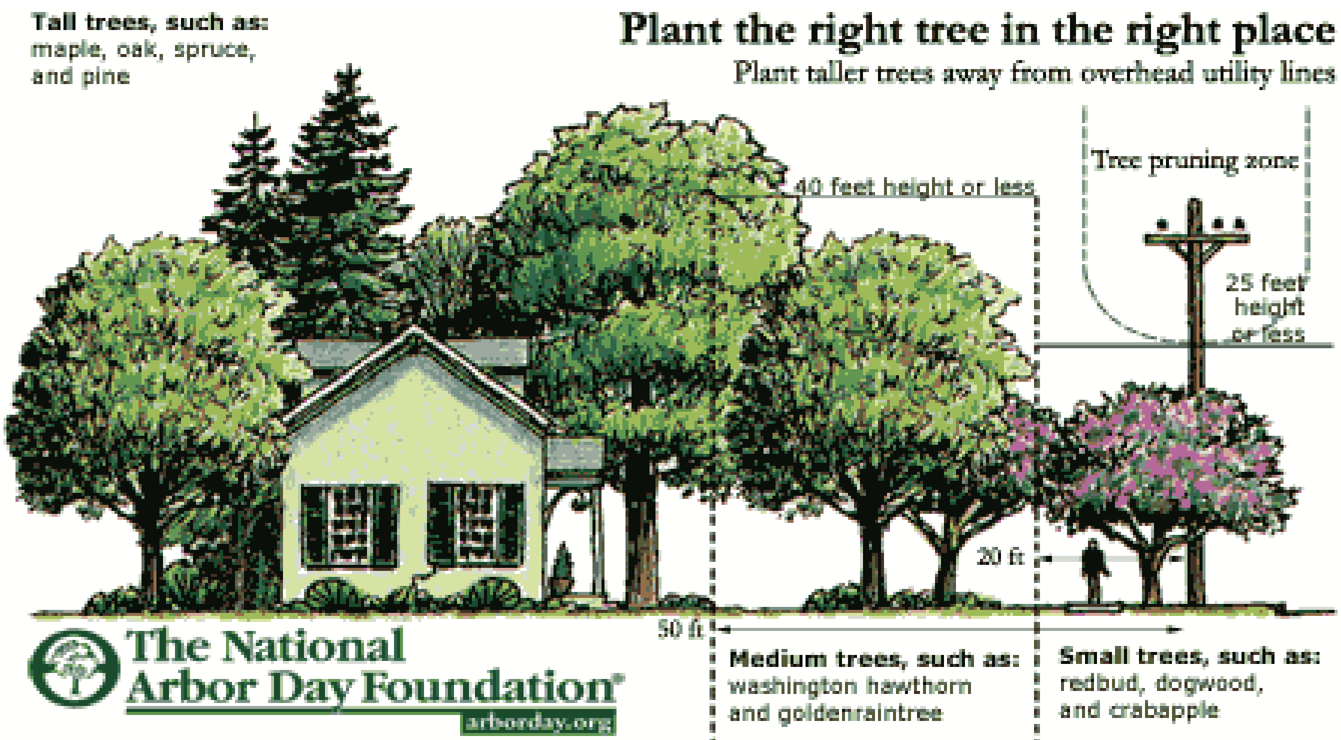
- Existing native and non-invasive vegetation should be preserved where possible.
- Noxious weeds and invasive species shall not be specified or used.
- Selection and placement of trees is important for the long
- Plant stream and water buffers with trees, shrubs, ornamental grasses, and herbaceous materials where possible, to stabilize banks and provide shade. This will help to reduce thermal warming, reduce erosion, increase roughness and protect habitat.
- Avoid plantings that will require routine or intensive chemical applications (i.e. turf area). Use low maintenance ground cover as an alternative to turf.

- Stressors (e.g. wind, exposure, exposure to deicing salt, insects, drought and inundation tolerance, and disease), micro-climates, and sunlight conditions should also be considered when laying out the planting plan.

- Aesthetics and visual characteristics should be a prime consideration. Plant form, texture, color, bloom time and fragrance are important to the overall feel of the site. Plants can be used to enhance and frame desirable views or screen undesirable views. Care should be taken to not block views at entrances, exits, or along difficult road curves.

- Trees and shrubs should be placed in a manner that restricts pedestrian access to steep pools or slopes without blocking maintenance access.

- Existing and proposed utilities must be identified and considered. Large trees next to utility lines must be avoided. Refer to Right Tree Right Place, provided by the National Arbor Day Foundation for more information.



Maintenance Considerations

- The designer should carefully consider the long-term vegetation management strategy for the Stormwater management practice, keeping in mind the maintenance legacy for future owners. <u>The Stormwater management maintenance agreement must include requirements to ensure vegetation cover in perpetuity</u>.

- Provide signage to help educate the public about Stormwater management practices and to designate limits of mowing (wildflower areas, meadows, etc.)

Embankments, spillways, dams, and orifices

- Planting of trees, shrubs, and/or any type of woody vegetation is not allowed on structural embankments.

- All emergency spillways should be stabilized with plant material that can withstand strong flows. Root material should be fibrous and substantial but lack a taproot.

- Trees or shrubs known to have long taproots should not be planted within the vicinity of an earthen dam or subsurface drainage facilities.

- Plant trees and shrubs at least 25 feet away from a principal spillway structures.

- Plant trees and shrubs at least 15 feet away from the toe of slope of a dam.

Soils

Stormwater management practice soils should provide adequate infiltration rates and be suitable for healthy tree and vegetation growth. Soil analysis should be conducted within the Stormwater management area to determine appropriate levels and types of soil amendments.

If topsoil exists on site and is stockpiled for re-use, appropriate erosion control measures as required by the Indiana Department of Environmental Management (IDEM) shall be used.

Site Selection, Preparation and Grading

When selecting a location for the Stormwater management practice, take into consideration the physical variables of the site and the effects they will have on the design. Some variables to consider include amount of sunlight received and solar orientation, wind speed and direction, temperature gain and surface characteristics. For example: sites facing northeast receive morning sun and tend to be cooler and wetter than those facing southwest; runoff from asphalt will be hotter than that from concrete; etc. Combinations of these variables create different micro-climates and should be taken into account when placing the Stormwater management practice and selecting plants.

Unwanted vegetation in the Stormwater management practice area shall be removed during site preparation with equipment appropriate for the type of material encountered and site conditions. It is recommended that the maximum amount of pre-existing native vegetation be retained and protected.

No material storage or heavy equipment is allowed within the Stormwater management practice design area after site cleaning and grading has been completed, except to excavate and grade as needed to build the system. No compaction of infiltration areas should occur during this excavation.

After the Stormwater management practice area is cleared and graded, any necessary soil amendments should be added and tilled into the existing soil to the depth specified for each Stormwater management practice. <u>No tilling shall occur within the drip line of existing trees</u>. After tilling is complete, no other construction traffic shall be allowed in the area, except for planting and related work. Where topsoil is needed, (for example swales and dry detention basins) it should be spread to a depth of 4-8 inches and lightly compacted to minimum thickness of 4 inches. This provides organic matter and important nutrients for the plant material. The use of topsoil allows vegetation to become established faster and roots to penetrate deeper. This ensures quicker and more complete stabilization, making it less likely that the plants will wash out during a heavy storm.

Mulch

The mulch layer helps maintain soil moisture and avoid surface sealing which reduces permeability. Mulch helps prevent erosion, and provides a micro-environment suitable for soil biota at the much/soil interface. It also serves as a pretreatment layer, trapping the finer sediments which remain suspended after the primary pretreatment. Mulch shall not be mounded around the base of trees; this can cause the trunks to rot. Approved mulching materials include organic materials such as compost, bark mulch, leaves, as well as small river gravel, pumice, or other inert materials. Grass clippings should not be used as mulch. For ground cover plantings, the much shall be applied to cover all soil between plants. Care should be exercised to use the appropriate amount of mulch - any more than 3-4 inches can negatively impact growing conditions and cause excessive nutrients to leach into the Stormwater management area. Mulch shall be weed-free. Manure mulching and high-fertilizer hydroseeding are prohibited in a Stormwater management practice area during and after construction.

Irrigation

Newly installed plant material requires water in order to recover from the shock of being transplanted. Be sure that some source of water is provided during establishment of the Stormwater management practice, especially during dry periods. This will reduce plant loss and provide the new plant materials with a chance to establish root growth.

Permanent irrigation systems are allowed, but designers are encouraged to minimize the need for permanent irrigation. Innovative methods for watering vegetation are encouraged, such as the use of cisterns.

Stormwater Management Practice Screening

Stormwater management practice elements such as chain link fences, concrete bulkheads, outfalls, rip-rap, gabions, large steel grates, steep side slopes, manhole covers/vault lids, berm embankments planted only with grasses, exposed pipe, banks, retaining walls greater than 2 feet high, and access roads are generally not aesthetically pleasing. When these elements face public right-of-way or other private property, it is recommended that they be screened with plant materials. Designers are strongly encouraged to integrate aesthetically pleasing landscape design with Stormwater management practices.

Pollution Prevention

Stormwater pollution prevention practices related to landscaping can be categorized into two broad categories: Toxic Substances Use Reduction and Pollutant Source Reduction.

Toxic Substance Use Reduction
Projects shall be designed to minimize the need for toxic or potentially polluting materials such as herbicides, pesticides, fertilizers, or petroleum based fuels within the Stormwater management area before, during, and after construction. Use of these materials creates the risk of spills, misuse, and future draining or leaching of pollutants into facilities or the surrounding area.

Pollutant Source Reduction
Materials that could leach pollutants or pose a hazard to people and wildlife shall not be used as components of a Stormwater management practice. Some examples of these materials are

chemically treated railroad ties and lumber and galvanized metals. Many alternatives to these materials are available.

Stormwater Management Area Establishment and Maintenance

Establishment procedures should include: control of invasive weeds, prevention of damage from animals and vandals, use of erosion control mats and fabrics in channels, temporary diversion of flows from seeded areas until stabilized, mulching, re-staking, watering, and mesh or tube protection replacement, to the extent needed to ensure plant survival. To ensure landscape plant survival and overall Stormwater facility functional success, the design and construction documents must include elements that help achieve these results. <u>Construction specifications and details need to include staking, irrigation schedule, soil amendments, and plant protection</u>.

Table 5.1.1: Planting Specifications

Specification Element	Elements
Sequence of Construction	Describe site preparation activities, soil amendments, etc.; address erosion and sediment control procedures; specify step-by-step procedure for plant installation through site clean-up.
Contractor's Responsibilities	Specify the contractors responsibilities, such as watering, care of plant material during transport, timeliness of installation, repairs due to vandalism, etc.
Planting Schedule and Specifications	Specify the materials to be installed, the type of materials (e.g., B&B bare root, containerized); time of year of installations, sequence of installation of types of plants; fertilization, stabilization seeding, if required; watering and general care.
Maintenance	Specify inspection periods; mulching frequency (annual mulching is most common); removal and replacement of dead and diseased vegetation; treatment of diseased trees; watering amount and schedule after initial installation (once per day for 14 days is common); repair and replacement of staking and wires.
Warranty	All plants shall contain a 2 year warranty. Specifications should contain the warranty period, the required survival rate, and expected condition of plant species at the end of the warranty period.

5.2. Facility Specific Landscaping Guidance

The planting recommendations shown under this section are based on research, local experience and/or standard landscape industry methods for design and construction. It is critical that selected plant materials are appropriate for soil, hydrologic, and other site conditions. Stormwater Management plans should use appropriate native and recommended non-invasive species from the Recommended Plant Lists in Table 5.3.1. The design for planting shall minimize the need for herbicides, fertilizers, pesticides, or soil amendments at any time before, during, and after construction and on a long-term basis. Plantings should be designed to minimize the need for mowing, pruning, and irrigation. Grass or wildflower seed shall be applied at the rates specified by the suppliers. If plant establishment cannot be achieved with seeding by the time of substantial completion of the Stormwater management practice portion of the project, the contractor shall plant the area with wildflower sod, plugs, container plants, or some other means to complete the specified plantings and protect against erosion.

Green Roof Landscaping Requirements

Plantings used on green roofs shall be self-sustaining, with little to no need for fertilizers or pesticides. Shrubs, herbs, succulents, and/or grasses shall be used to cover most of the green roof. See **Chapter 4.1**: Green Roofs for more specific information on green roof recommendations.

Planter Box Landscaping Requirements

The following quantities per 100 square feet of planter box area are suggested:

- 4 - Large shrubs/small trees 3-gallon containers or equivalent.
- 6 - Shrubs/large grass-like plants 1-gallon containers or equivalent.
- Ground cover plants: 1 per 12 inches on center, triangular spacing. Minimum container: 4-inch pot. Spacing may vary according to plant type.

Note: 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.

Infiltration and Filter System Recommendations

Infiltration and filter systems either take advantage of existing permeable soils or create a permeable medium such as sand for water quality and groundwater recharge. The most common systems include infiltration trenches, infiltration basins, sand filters, and organic filters. When properly planted, vegetation will thrive and enhance the functioning of these systems. For example, pre-treatment buffers will trap sediment that is often bound with phosphorous and metals. Vegetation planted in the Stormwater Management Practice will aid in nutrient uptake and water storage. Additionally, plant roots will create macropores for Stormwater to permeate soil for groundwater recharge. Finally, successful plantings provide aesthetic value and wildlife habitat, making these facilities more desirable to the public.

Design Constraints:
Along with the guidelines listed at the start of this section, the following should be adhered to:

- Determine areas that will be saturated with water and water table depth so that appropriate plants may be selected (hydrology will be similar to bioretention facilities, see Figure 5.2.1 and associated tables for planting material guidance).
- Plants shall be located so that access is possible for structure maintenance.

Vegetated Swale Landscaping Requirements

The following quantities per 200 square feet of swale area are suggested:

- 1 Evergreen or Deciduous tree:
  - Evergreen trees: Minimum height: 6 feet.
  - Deciduous trees: Minimum caliper: 1 ½ inches at 6 inches above base.
  - Multi-sterm trees: Minimum root ball diameter: 20 inches and 6' tall
- Grass: Seed or sod is required to completely cover the swale bottom and side slopes.
- (Shrubs are optional)

Vegetation or ground cover within the swale should be suitable for expected velocities. For the swale flow path, approved native grass mixes are preferable. The applicant shall have plants established at the time of Stormwater management plan completion (at least 3 months after seeding). No runoff should be allowed to flow in the swale until grass is established or soil is otherwise stabilized. Native wildflowers, grasses, and ground covers are preferred to turf and lawn areas. These types of landscape can be designed to require mowing only once or twice annually.

Vegetated Infiltration Basin and Dry Detention Pond Landscaping Requirements

Vegetation increases evapotranspiration, helps improve infiltration functions, protects from rain and wind erosion and enhances aesthetic conditions. The following quantities per 300 square feet of basin area are suggested.

- 1 Evergreen or Deciduous tree:
  - Evergreen trees: Minimum height: 6 feet.
  - Deciduous trees: Minimum caliper: 1 ½ inches at 6 inches above base.
  - Multi-sterm trees: Minimum root ball diameter: 20 inches and 6' tall
- 4 Large shrubs/small trees 3-gallon containers or equivalent
- 6 Shrubs/large grass-like plants 1-gallon containers or equivalent
- Ground cover plants: 1 per 12 inches on center, triangular spacing, for the ground cover planting area only, unless seed or sod is specified. Minimum container: 4-inch pot. At least 50 percent of the Stormwater management area shall be planted with grasses or grass-like plants.

Native wildflowers, grasses, and ground covers are preferred to turf and lawn areas. These types of landscape can be designed to require mowing only once or twice annually.

Appropriate plants should be selected based on ponding depth and drain-down time in the basin. Infiltration systems will be dry much of the time and should be vegetated with drought tolerant species especially if they will not be irrigated.

Bioretention Landscaping Requirements

Planting Soil Bed Characteristics

The characteristics of the soil for the bioretention system are perhaps as important as the facility location, size, and treatment volume. The soil must be permeable enough to allow runoff to filter through the media, while having characteristics suitable to promote and sustain a robust vegetative cover crop. In addition, much of the nutrient pollutant uptake (nitrogen and phosphorus) is accomplished through adsorption and microbial activity within the soil profile. Therefore, the soils must balance soil chemistry and physical properties to support biotic communities above and below ground. Planting soil should meet the following specifications, which are also outlined in the typical detail in **Attachment 1**:

1. The intent of the amended soil specification is to allow for proper operation of the Stormwater system; provide for adequate infiltration; and foster the healthy growth of the vegetated Stormwater system. The soil specification is for any vegetated Stormwater system (e.g. Rain garden, bioretention, swale, etc.).

2. Amended soil shall be a well-blended homogeneous mixture of 15 to 30% compost, 20-30% top soil or amended topsoil, and the remainder coarse, washed sand. Compost, top soil or amended topsoil and sand are further specified in items 3-5.

3. Compost shall be organic leaf compost, aged leaf mulch, or other compost mature with regard to its suitability for serving as a soil amendment. The compost shall have a moisture content that has no visible free water or dust produced when handling the material. Compost shall meet the following:

	Min.	Max.
Percent passing 1” sieve:	99%	100%
Percent passing 5/8” sieve:	90%	100%
Percent passing ¼” sieve:	40%	90%

4. The topsoil texture must be silt loam, sand, sandy loam, loamy sand, or loam. The topsoil shall not contribute clay content such that the amended soil mixture is >5% clay. If the topsoil does not meet these characteristics, then it shall be adjusted by the addition of an acceptable planting soil.

5. Sand shall be USDA coarse sand (0.02-0.04”) conforming to ASTM C33 (fine aggregate concrete sand) and shall be clean construction sand, free of deleterious materials. <5% fines.

6. The amended soil shall be a uniform mix, free of stones, stumps, roots, or similar objects larger than one inch in diameter. The amended soil shall be less than 5% clay. The amended soil shall be free of brush or seeds from noxious weeds.

7. The amended soil shall have a pH range of 5.5 to 6.5; an infiltration rate of no less than 0.5 inches per hour; 4 to 8% organic matter; and a maximum of 500 ppm concentration of soluble salts. Soil tests for these parameters shall be performed for every 500 cubic yards of planting soil, with the exception of pH and organic content tests, which are required only once per vegetated Stormwater system area.

8. Soil compaction in the area of the vegetated Stormwater system shall be minimized by limiting construction traffic and utilizing tracked vehicles. Amended soil shall be placed in lifts of 12-18 inches, loosely compacted (tamped lightly with a dozer or backhoe bucket) after placement in the vegetated Stormwater system area.

Planting Plan Guidance

- Trees and shrubs shall be freshly dug and grown in accordance with good nursery practice.
- Perennials, grass-like plants, and ground-cover plants shall be healthy, well-rooted specimens.
- Plantings shall be designed to minimize the need for mowing, pruning, and irrigation.

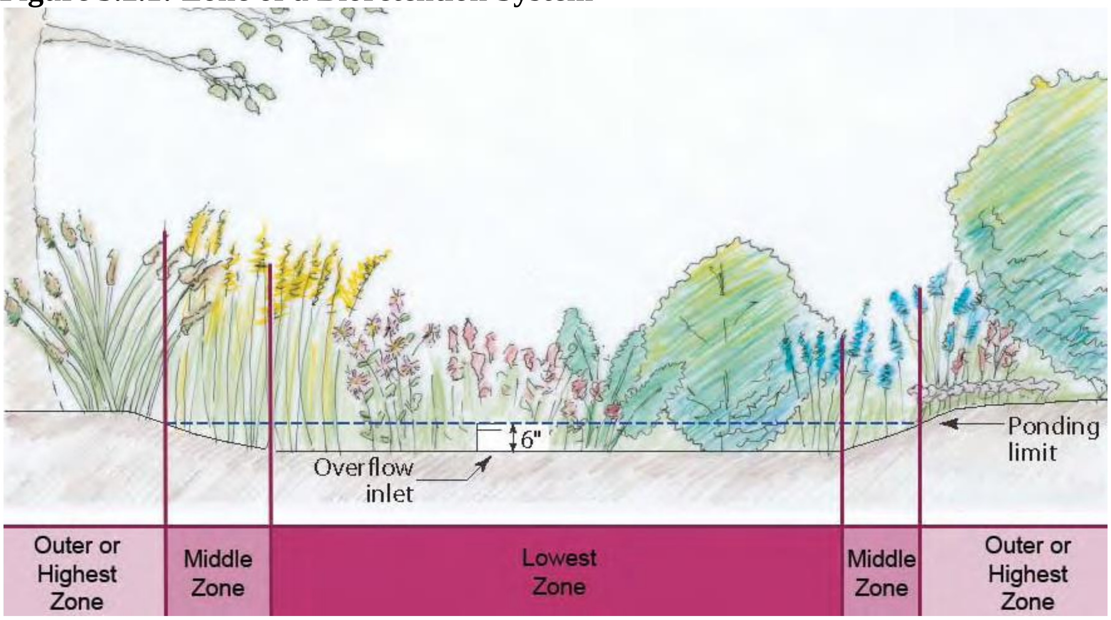
The following quantities per 100 square feet of bioretention area are suggested:

- 1 large tree per 100 square feet of bioretention area
- 2-4 small trees or shrubs per 100 square feet of bioretention area
- 6 ferns or grass-like plants per 100 square feet of bioretention area (1-gallon containers)
- Groundcover plantings and wildflower plugs on 12 inch centers with triangular spacing.
- A native grass/wildflower seed mix can be used as an alternative to groundcover planting. Seed mix shall be free of weed seeds.

Plant material selection should be based on the goal of simulating a terrestrial forested community of native species. Bioretention simulates an ecosystem consisting of an upland-oriented community dominated by trees, but having a distinct community, or sub-canopy, of understory trees, shrubs and herbaceous materials. The intent is to establish a diverse, dense plant cover to treat Stormwater runoff and withstand urban stresses from insect and disease infestations, drought, temperature, wind, and exposure.

The proper selection and installation of plant materials is key to a successful system. There are essentially three zones within a bioretention system (Figure 5.2.1). The lowest elevation supports plant species adapted to standing and fluctuating water levels. The middle elevation supports a slightly drier group of plants, but still tolerates fluctuating water levels. The outer edge is the highest elevation and generally supports plants adapted to dryer conditions. However, plants in all the zones should be drought tolerant. Plants should also have high salt tolerance if bioretention area receives runoff from ground level impervious surfaces.

Figure 5.2.1: Zone of a Bioretention System



Lowest Zone (Hydrologic zones 2-4):
Plant species adapted to standing and fluctuating water levels. Frequently used native plants include*:

Table 5.2.1: Lowest Zone (Hydrologic zones 2-4) Suggested Plants

asters (Aster spp.)	winterberry (llex verticillata)
goldenrods (Solidago spp.)	arrowwood (Viburnum dentatum)
bergamot (Monarda fistulosa)	sweet pepperbush (Clethra alnifolia)
blue-flag iris (Iris versicolor)	bayberry (Myrica pensylvanica)
sedges (Carex spp.)	buttonbush (Cephalanthus occidentalis)
ironweed (Vernonia spp)	white oak (Quercus bicolor)
blue vervain (Verbena hastate)	elderberry (Sambucus Canadensis)
joe-pye weed (Eupatorium spp.)	bald cypress (Taxodium distichum)
swamp milkweed (Asclepias incarnata)	river birch (Betula nigra)
switchgrass (Panicum virgatum)	sweetgum (Liquidambar styraciflua)
shrub dogwoods (Cornus spp.)	northern white cedar (Juniperus virginiana)
swamp rose (Rosa palustris)	red maple (Acer rubrum)

* Refer to the plant list for a complete listing

Middle Zone (Hydrologic zones 4-5):
This zone is slightly drier than the lowest zone, but plants should still tolerate fluctuating water levels. Some commonly planted native species include*:

Table 5.2.2: Middle Zone (Hydrologic zones 4-5)

black snakeroot (Cimicifuga racemosa)	spicebush (Lindera benzoin)
switchgrass (Panicum virgatum)	hackberry (Celtis occidentalis)
spotted joe-pye weed (Eupatorium maculatum)	willow oak (Quercus phellos)
cutleaf coneflower (Rudbeckia lacinata)	winterberry (llex verticillata)
frosted hawthorn (Crataegus pruinosa)	slippery elm (Ulmus rubra)
ostrich fern (matteuccia struthiopteris)	blackhaw viburnum (Viburnum prunifolium)
sensitive fern (onoclea sensibilis)	Nannyberry (Viburnum)
ironwood (Carpinus caroliniana)	witch-hazel (Hamamelis virgniana)
obedient plant (Physostegia virginiana)	steeplebush (Spiraea tomentosa)

*Refer to the plant list for a complete listing

Outer Zone (Hydrologic zones 5-6):
Generally supports plants adapted to drier conditions. Examples of commonly planted native species include*:

Table 5.2.3: Outer Zone (Hydrologic zones 5-6)

many grasses & wildflowers	juniper (Juniperus communis)
basswood (Tilia americana)	sweet-fern (Comptonia peregrina)
white oak (Quercus alba)	eastern red cedar (Juniperus virginiana)
scarlet oak (Quercus coccinea)	smooth serviceberry (Amelanchier laevis)
black oak (Quercus velutina)	american holly (llex opaca)
american beech (Fagus grandifolia)	sassafras (Sassafras albidum)
burr oak (Quercus macrocarpa)**	shummard oak (Quercus shumardii)**
mapleleaf viburnum (viburnum acerifolium)	wild hydrangea (Hydrangea arborescens)
black chokecherry (Aronia melanocarpa)	white pine (Pinus strobus)

*Refer to the plant list for a complete listing
**Can be used in both the middle zone and outer zone-most adaptable oaks to constructed sites and variable hydrology.
.

Filter Strip Landscaping Requirements

It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select vegetation from the list of native species found in this section (Table 5.3.1). Take soil infiltration capacities, sunlight, pollution tolerances, root structure, and other considerations into account when selecting plants from this list.

Filter strips should be planted with meadow grasses, shrubs, and native vegetation (including trees) from the list provided in Section 5.3: Native and Recommended Non-invasive Plants.

For the filter strip, approved native grass mixes are preferable. Seed shall be applied at the rates specified by the supplier. The applicant shall have plants established at the time of Stormwater management area completion (at least 3 months after seeding). No runoff shall be allowed to flow across the filter strip until the vegetation is established. Trees and shrubs may be allowed in the flow path if the filter strip exceeds the minimum length and widths specified.

Filter strips often make a convenient area for snow storage. Therefore, filter strip vegetation should be salt-tolerant, and the maintenance schedule should involve removal of sand build-up at the toes of the slope. If the filter strip cannot provide pretreatment in the winter due to snow storage or vegetation choice, other pretreatment should be provided.

Vegetation cover should be maintained at 85 percent. If vegetation is damaged, the damaged areas should be reestablished in accordance with the original specifications. In all design cases where vegetation is to be established, the planting regime should be as dense as the soil conditions can sustain. This is especially true at the top portions of the filter strip where the highest sheet flow velocities are found. Soils that can sustain higher quantities and qualities of vegetation may need to be added to insure thick vegetative densities needed for sustainable filter strip performance. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides if possible.

5.3. Native and Recommended Non-invasive Plants

Native plant species are recommended over exotic foreign species because they are well adapted to local climate conditions. This will result in less replacement and maintenance, while supporting the local ecology.

<u>The list is intended as a guide for general planting purposes and planning considerations. Knowledgeable landscape designers and nursery suppliers may provide additional information for considering specific conditions for successful plant establishment and accounting for the variable nature of Stormwater hydrology. Because individual plants often have unique growing requirements difficult to convey in a general listing, it will be necessary to research specific information on the plant species proposed in order to ensure successful plant establishment.</u>

Chapter 701 of the municipal code of the City of Indianapolis references the most up to date prohibited species list. Table 5.3.1 lists native and recommended plants and is organized by Type and Latin name. Additional information given for each species includes: Common name, National Wetland Indicator Status, hydrologic zone, inundation tolerance, drought tolerance, salt tolerance, mature canopy spread, mature height, light requirements, nativity, commercial availability, and notes to provide guidance for application and selection. For example, some trees are well suited to landscaped areas that will receive Stormwater runoff, while others may not tolerate the additional moisture.

Hydrologic Zones

For planting within a Stormwater management area, it is necessary to determine what hydrologic zones will be created. Hydrologic zones describe the degree to which an area is inundated by water (see Figure 5.2.1 for an example of hydrologic zones in a bioretention basin). Plants have differing tolerances to inundations and as an aid to landscape designers, these tolerance levels have been divided into six zones and corresponding plant species have been identified. In Table 5.3.1 each plant species has a corresponding hydrologic zone provided to indicate the most suitable planting location for successful establishment. While the most common zones for planting are listed in parenthesis, the listing of additional zones indicates that a plant may survive over a broad range of hydrologic conditions. Just as plants may, on occasion, be found outside of their hardiness zone, they may also be found outside of their hydrologic zone. Additionally, hydrologic conditions in a Stormwater management facility may fluctuate in unpredictable ways; thus the use of plants capable of tolerating wide varieties of hydrologic conditions greatly increases a successful planting. Conversely, plants suited for specific hydrologic conditions may perish when hydrologic conditions fluctuate, thus exposing the soil and increasing the chance for erosion.

Wetland Indicator Status

The Wetland Indicator Status (from Region 1, Reed, 1988) has been included to show "the estimated probability of a species occurring in wetlands versus non-wetlands: (Reed, 1988). Reed defines the indicator categories as follows:

- Obligate wetland (OBL): Plants, which nearly always (more than 99% of the time) occur in wetlands under natural conditions.
- Facultative Wetland (FACW): Plants, which usually occur in wetlands (from 67 to 99% of the time), but occasionally found in non wetlands.
- Facultative (FAC): Plants, which are equally likely to occur in wetlands and non wetlands and are found in wetlands form 34 to 66% of the time.
- Facultative Upland (FACU): Plants, which usually occur in non wetlands (from 67 to 99% of the time), but occasionally found in wetlands.
- Upland (UPL): Plants, which almost always (more than 99% of the time) under natural conditions occur in non wetlands.
- A given indicator status shown with a "+" or a "-" means that the species is more (+) or less (-) often found in wetlands than other plants with the same indicator status without the "+" or "-" designation.

Inundation Tolerance

Since the Wetland Indicator Status alone does not provide an indication of the depth or duration of flooding that a plant will tolerate, the "Inundation tolerance" column is designed to provide further guidance. If a plant is capable of withstanding permanent saturation, the depth of this saturation is listed (for example, "saturated" indicates the soil can be moist at all times, "sat, 0-6" indicates that the species can survive in constantly moist soil conditions with up to 6" of standing water). Conversely, a plant may only tolerate seasonal inundation - such as after a storm event - or may tolerate inundation - such as after a storm event - or may not tolerate inundation at all. This type of plant would be well suited for a Stormwater management area that is expected to drain quickly or in the drier zones of the Stormwater management practice.

Drought Tolerance (N=none; L=low; M=medium; H=high)

The drought tolerance column is meant to provide a way for Stormwater management plan designers to select appropriate native plants that can survive in hot summer conditions, with a minimum of irrigation. Drought tolerance is defined as the relative tolerance of the plant to drought conditions compared to other plants in the same region (USDA, 2005).

Salt Tolerance (N=none; L=low; M=medium; H=high; U=Unknown)

This column ranks the relative tolerance of a species to salt content in the soil. If U (unknown) is displayed, no research was found for that particular species.

Height Range

This column provides the approximate mature height of plant species in optimal growing conditions. This height may be reduced dramatically in the urban environment where light, space, and other factors may not be as readily available as in a forest or field setting. However, by providing as much space as possible for a plant to grow and by choosing appropriate species for a planting area, improved - if not optimal - growing conditions can be achieved. For example, a tree planted in a sidewalk pit measuring 4 feet x 4 feet may only reach half its mature height, while a tree planted in a 4 foot wide “trough” style planting bed will grow taller and live longer, because it will have greater access to air and water.

Light Requirement

The light requirements for each species are listed as ranges between full shade and full sun. At the bottom of the range - full shade - plants thrive in conditions where they receive filtered, or dappled, light for the entire day (such as under an oak tree). In the middle of the range are plants that grow best in part shade, where they are in full shade for 2-3 hours during midday. Plants that require full sun should be sited so that they receive 5 or more hours of direct sun during the growing season. Some plants requiring full sun may still do well in a part shade environment, depending on the quality and duration of the light the plants receive when they are not in the shade.

Container-grown plants include trees, shrubs, wildflowers, ferns, grasses, and sedges. This is an excellent alternative to the far more expensive balled-and-burlapped (B&B) form of trees and shrubs, although the size of the tree is almost always smaller. Nurseries often provide a few container sizes for each species.

THIS PAGE LEFT BLANK INTENTIONALLY

Table 5.3.1: Recommended Plant List (the excel spreadsheet is available online to download for easier use)

Latin Name	Common Name	National Wetland Indicator	Hydrologic Zone	Indundation Tolerance	Community	Drought Tolerance (N=None; L=Low, M=Medium, H=High)	Salt Tolerance (N=None, L=Low, M=Medium,H=High, U=Unkown)	Deer Tolerance, discourages deer predation. Seldom damaged (S), Rarely Damaged (R) Occasionally Damaged (O)	Sun	Height range variable depending on soil conditions, hydrology, light	Flower Season	Color	Notes
Forbs (Wildflowers)													
Acorus calamus	Sweet Flag	OBL	3, 4	SAT, 0-6"	sedge meadow, shallow water emergent	L	M	R	sun	2-3 ft	May-June	Green	occurs in shallow water of ponds, tolerated moving water, installation of plugs 0-2".
Actinomeris alternifolia	Wingstem	FACW			wet mesic woods			R	psun-shade	4-7 ft	July-Sept	Yellow	Easy to establish from seed.
Alisma subcordatum	Water Plantain	OBL	2	SAT, 0-1'	sedge meadow, shallow water emergent	N	N	R	sun	1-2 ft	June-Sept	White	emergent aquatic, slow moving water, installation depth 0-1", will spread, great for parasitic wasp .
Allium cernuum	Nodding Wild Onion	UPL			mesic prairie , dry woods, mesic savanna			R	sun-psun	1-2 ft	July-Aug	Pink	Beautiful pinlish white flowers for wide range of habits.
Angelica atropurpurea	Angelica	OBL			sedge meadow, wet wood edge,			R	sun-psun	5-8 ft	June	White	Stricking large round multi-compound umbels of white flowers, "large white balls".Plant juices can cause dermatitis to sl
Aquilegia canadensis	Columbine	UPL			dry woods, open prairie		L	O	psun-shade	2-3 ft	May-June	Salmon/yellow	Very popular species, good humming bird attractant.
Asclepias incarnata	Marsh Milkweed	OBL	2 (3, 4)	SAT, 0-6"	sedge meadow, wet prairie	N	N	S	sun	3-4 ft	July-Aug	Pink	pink-rose purple flowers in several umbels
Asclepias tuberosa	Butterflyweed	UPL	5, 6	NO	dry prairie	H	L	S	sun	1-2 ft	June-July	Orange	bright orange flowers in umbels
Aster azureus	Sky-Blue Aster	UPL			dry prairie, mesic prairie, mesic savanna		L	O	sun-psun	1-2 ft	Sept	Blue	Easy to establish from seed.
Aster cordifolius	Heart-Leaved Blue Wood Aster	UPL	5, 6	NO	mesic woods	M	L	O	psun-shade	1-3 ft	Sept-Oct	Blue	blue-violet to rose disk and ray flowers, very easy to eastablish in wide range woodland soils.
Aster ericoides	Heath Aster	FACU-			dry prairie, mesic prairie		M	O	sun	1-2 ft	Sept-Oct	White	Minute white rays, yellow center.
Aster firmus	Shining Aster	OBL			sedge meadow, wet prairie			O	sun	3-4 ft	Sept-Oct	Lavender	Easy to establish from seed.
Aster laevis	Smooth Aster	UPL			mesic prairie, dry savanna		L	O	sun-psun	3-5 ft	Sept-Oct	Blue	Easy to establish from seed.
Aster lateriflorus	Side-Flowering Aster	FACW-			mesic woods, wet-mesic woods			O	shade	1-3 ft	Sept-Oct	White	Easy to establish from seed.
Aster novae-angliae	New England Aster	FACW+	(3, 4) 5	L	sedge meadow, wet prairie, wet-mesic prairie, m	N		O	sun	3-5 ft	Sept-Oct	Purple	violet to blue rays with yellow disks
Aster puniceus	Swamp Aster	OBL		SEASONAL	sedge meadow		M	O	sun-psun	3-6 ft	Sept-Oct	Lavender	Easy to establish from seed.
Aster sericeus	Silky Aster	UPL			dry prairie			O	sun	1 ft	Sept-Oct	Purple	Delicate whispy stems, flowers and plants, excellent sandy soil species
Aster shortii	Short's Aster	UPL			mesic woods			O	shade	2-3 ft	Sept-Oct	Purple	Easy to establish from seed.
Aster simplex	Panicled Aster	OBL		SEASONAL	sedge meadow, wet mesic prairie, wet mesic woods			O	sun-psun	3-5 ft	Sept-Oct	White	Easy to establish from seed.
Aster umbellatus	Flat-Topped Aster	FACW			sedge meadow, wet prairie			O	sun	3-5 ft	Sept-Oct	White	Easy to establish from seed.
Baptisia australis	Blue False Indigo	UPL	4, 5, 6	SEASONAL	wet-mesic prairie	L	M	R	sun-psun	2-4 ft	May-June	Blue	showy blue flowers; shrub-like; nitrogen fixer; adaptable
Baptisia leucantha	White False Indigo	UPL			mesic prairie, dry prairie		M	R	sun-psun	3-4 ft	June-July	White	Stricking white flowers, interesting persitant black seed pods
Blephilia hirsuta	Hairy Wood Mint	FACU-			mesic woods			R	shade	1-3 ft	July-Aug	White	Beautiful flower heads, persitant seed structure.
Boltonia latisquama	False Aster	OBL			sedge meadow		L	no listing or possible food preference.	sun	3-6 ft	Aug-Sept	White	Easy to establish.
Caltha palustris	Marsh Marigold	OBL			sedge meadow, wet woodlands	L		no listing or possible food preference.	psun-shade	1-2 ft	April	Yellow	Best success if consistant water levels or constant dampness.
Cassia hebecarpa	Wild Senna	FACW			sedge meadow, wet prairie			no listing or possible food preference.	sun-psun	3-5 ft	July-Aug	Yellow/Black	Easy to establish from seed, good legume.
Chelone glabra	White Turtlehead	OBL	3, 4, 6	SEASONAL	sedge meadow	L	N	O	partial shade	2-4 ft	Aug-Sept	White	snapdragon-type white flowers
Chelone obliqua	Pink Turtlehead	OBL			sedge meadow			O	partial shade	2-4 ft	Aug-Sept	Pink	snapdragon-type pink flowers
Coreopsis palmata	Plains Coreopsis	UPL			dry prairie			R	sun	1-2 ft	July-Aug	Yellow	Spreads from emergent roots all directions
Coreopsis tripteris	Tall Coreopsis	UPL			mesic prairie			R	sun	6-8 ft	Aug-Sept	Yellow	Spreads from emergent roots all directions
Decodon verticillatus	Swamp Loosestrife	OBL		SEASONAL	emergent			R	sun	3-4 ft	July-Aug	Pink	Excellent shore line protector.
Desmodium illinoiense	Illinois Tick Trefoil	UPL			mesic prairie			no listing or possible food preference.	sun	3-5 ft	July-Sept	Pink	Easy to establish from seed, good legume.
Echinacea pallida	Pale Purple Coneflower	UPL			mesic prairie			S	sun	4-6 ft	May-June	Pink	Easy to establish from seed.
Echinacea purpurea	Purple Coneflower	UPL			mesic prairie, mesic savanna, dry woods		M	S	sun-psun	3-4 ft	June-Aug	Pink	Easy to establish from seed.
Eryngium yuccifolium	Rattlesnake Master	FAC+			mesic prairie, dry prairie			O	sun	3-4 ft	July-Sept	White	Unusual leafs, flowers and seed heads, a must for applicable habits.
Eupatorium coelestinum	Blue Mist Flower	FAC	4, 5, 6	SEASONAL	wet mesic woods	M	N	S	psun	1-2 ft	Sept-Oct	Blue	groundcover; blue flowers on neat foliage; spreads easily
Eupatorium fistulosum	Hollow Joe-Pye Weed	FACW	(3, 4) 5	SEASONAL	sedge meadow	L	N	S	sun	7-10 ft	Aug -Sept	Pink	many white flowers in large, branching cluserts
Eupatorium maculatum	Spotted Joe-Pye Weed	FACW	(3, 4) 5	SEASONAL	sedge meadow	L	N	S	sun	4-6 ft	Aug - Sept	Pink	light purple flowers; attracts butterflies (swallow tails)
Eupatorium perfoliatum	Boneset	FACW+	(2, 3) 4	SEASONAL	sedge meadow, wet prairie	L	M	S	sun	3-5 ft	Aug-Sept	White	clusters of grayish-white flowers
Eupatorium purpureum	Sweet Joe-Pye Weed	FAC	3 (4, 5)	SEASONAL	mesic woods	L	U	S	psun-shade	4-6 ft	July-Aug	Pink	vanilla scented flowers
Eupatorium rugosum	White Snakeroot	UPL	5, 6	NO	mesic woods	M	M	S	psun-shade	2-4 ft	Sept	White	white flowers in large clusters
Filipendula rubra	Queen of the Prairie	FACW	4, 5, 6	SEASONAL	sedge meadow	N	U	no listing or possible food preference.	sun	4-7 ft	June-July	Pink	prefers well-drained moist soils; foamy clusters of blooms
Gentiana andrewsii	Bottle Gentian	FACW			sedge meadow, wet prairie, wet-mesic prairie			no listing or possible food preference.	sun	1-2 ft	Sept-Oct	Blue	Unique purpulish blue flowers, when conditions are optimal excellent spread potential.
Geranium maculatum	Wild Geranium	FACU	5, 6	NO	mesic woods	M	U	no listing or possible food preference.	shade	1-2 ft	Apr-May	Pink	groundcover; rose-purple flowers in small clusters
Helenium autumnale	Autumn Sneezeweed	FACW+	3, 4, 5	SEASONAL	sedge meadow, wet prairie	L	M	S	sun-psun	3-5 ft	Sept-Oct	Yellow	showy yellow daisy-like flowers; moist meadows; stream banks
Helianthus grossesseratus	Sawtooth Sunflower	FACW-			wet mesic prairie, mesic prairie			no listing or possible food preference.	sun	5-10 ft	Aug-Sept	Yellow	Does utilize illiliopathy (chemical that inhibits other copeting species)
Helianthus mollis	Downy Sunflower	UPL			mesic prairie , dry prairie			no listing or possible food preference.	sun	2-4 ft	Aug-Sept	Yellow	Does utilize illiliopathy (chemical that inhibits other copeting species)
Helianthus occidentalis	Western Sunflower	UPL			mesic prairie , dry prairie			no listing or possible food preference.	sun	2-3 ft	Aug-Sept	Yellow	Does utilize illiliopathy (chemical that inhibits other copeting species)
Helianthus rigidus	Showy Sunflower	UPL			mesic prairie , dry prairie			no listing or possible food preference.	sun	3-5 ft	Aug-Sept	Yellow	Does utilize illiliopathy (chemical that inhibits other copeting species)
Heliopsis helianthoides	False Sunflower	UPL	3, 4, 5, 6	SEASONAL	mesic prairie , mesic woods , mesic savanna	M	U	no listing or possible food preference.	sun-psun	3-5 ft	July-Sept	Yellow	pale yellow cone-shaped rays with yellow disks, has milder version of (illiliopathy)
Hibiscus palustris	Swamp Rose Mallow	OBL		SEASONAL	sedge meadow		M	no listing or possible food preference.	sun	3-6 ft	July-Sept	White-Pink	Excellent shore line protector.
Hypericum pyramidatum	Great St.John's Wort	FAC+			sedge meadow			S	sun	4-6 ft	July-Aug	Yellow	Vibrant "fluorescent" yellow flowers
Iris versicolor	Wild Iris	OBL	2 (3, 4)	SAT, 0-6"	sedge meadow, shallow water emergent	N	L	R	sun-psun	2-3 ft	May-June	Blue	blue-violet flowers, excellent shoreline prtection.
Iris virginica shrevei	Blue Flag Iris	OBL		SEASONAL	sedge meadow			R	sun-psun	2-3 ft	May-June	Blue	Excellent shore line protector.
Justicia americana	Water Willow	OBL		SEASONAL	emergent		L	no listing or possible food preference.	sun	1-2 ft	June-July	Pink	Excellent shore line protector, grows from cuttings, first to colonize new sand bar, tolerates flow.

Table 5.3.1: Recommended Plant List, continued

Latin Name	Common Name	National Wetland Indicator	Hydrologic Zone	Indundation Tolerance	Community	Drought Tolerance (N=None; L=Low, M=Medium, H=High)	Salt Tolerance (N=None, L=Low, M=Medium,H=High, U=Unkown)	Deer Tolerance, discourages deer predation. Seldom damaged (S), Rarely Damaged (R) Occasionally Damaged (O)	Sun	Height range variable depending on soil conditions, hydrology, light	Flower Season	Color	Notes
Forbs (Wildflowers)													
Lespedeza captiata	Round-Headed Bush Clover	UPL			mesic prairie, dry prairie			no listing or possible food preference.	sun	2-4 ft	Aug-Sept	Yellow	Important legume
Liatris aspera	Rough Blazing Star	UPL			mesic prairie, dry praire		L	S	sun	1-3 ft	Aug-Sept	Purple	Beautiful purple "sticks"
Liatris scariosa nieuwlandii	Savanna Blazing Star	UPL			mesic prairie, mesic savanna			S	sun-psun	2-3 ft	Aug-Sept	Purple	Beautiful purple "sticks"
Liatris spicata	Dense Blazing Star	FAC+	4, 5	SEASONAL	mesic prairie, wet mesic prairie, sedge meadow	L	L	S	sun	3-5 ft	July-Aug	Purple	easy to grow; tall spikes of lavender blooms, beautiful purple "sticks"
Lobelia cardinalis	Cardinal Flower	OBL		SEASONAL	wet woods, sedge meadow			S	sun-shade	1-3 ft	Aug-Sept	Red	Vibrant red, basal plant parts prefer shading, short lived in full sun.
Lobelia siphilitica	Great Blue Lobelia	FACW+	3, 4	SATURATED	wet woods, sedge meadow	N	U	S	sun-shade	1-3 ft	Aug-Sept	Blue	blue-white flowers
Lycopus americanus	Common Water Horehound	OBL		SEASONAL	sedge meadow			no listing or possible food preference.	sun	1-2 ft	July-Aug	White	Can grow somewhat weedy.
Mimulus ringens	Monkeyflower	OBL	3, 4	SATURATED	sedge meadow	N	U	S	sun	2-4 ft	July- Sept	Lavender	blue-violet flowers
Monarda fistulosa	Bergamot	UPL	5, 6	NO	mesic prairie	N	L	R	sun	2-4 ft	July-Aug	Lavender	pink to lavender flowers, scented leaves, anti-predation species, when deer are heavy.
Parthenium integrifolium	Wild Quinine	UPL			mesic prairie, mesic savanna			no listing or possible food preference.	sun-psun	2-3 ft	July-Aug	White	Unusual white flower clusters
Peltandra virginica	Arrow Arum	OBL	(1, 2) 3	SAT, 0-1'	shallow water emergent	N	L	no listing or possible food preference.	sun	2-3 ft	June-July	Green	Excellent shoreline protector, tolerates flow, emergent aquatic; resembles an arrowhead (see leaf veins)
Penstemon calycosus	Smooth Penstemon	FACU			wet mesic woods, mesic woods			no listing or possible food preference.	psun-shade	2-3 ft	June	Purple	Striking white tubular flowers
Penstemon digitalis	Foxglove Penstemon	FAC	5, 6	NO	wet mesic prairie,mesic prairie,	H	M	no listing or possible food preference.	sun-psun	2-3 ft	June	White	white with purple tinged tubular flowers
Penstemon hirsutus	Hairy Penstemon	UPL			mesic prairie, dry prairie, mesic savanna			no listing or possible food preference.	sun-psun	1-2 ft	May-June	Purple	Darker purple tinge then digitalis, excellent contrast when blooming side by side/mixed.
Petalostemum candidum	White Prairie Clover	UPL			mesic prairie, dry prairie			no listing or possible food preference.	sun	1-2 ft	July-Aug	White	Can't beat the persistent white flowers and vegetation.
Petalostemum purpureum	Purple Prairie Clover	UPL			mesic prairie, dry prairie		L	no listing or possible food preference.	sun	1-2 ft	July-Aug	Purple	Can't beat the persistent purple flowers and vegetation.
Physostegia virginiana	Obedient Plant	FAC+	4, 5	SEASONAL	sedge meadow, wet prairie, wet mesic prairie	L	L	S	sun	2-4 ft	Aug-Sept	Pink	tall graceful plant with pink tubular flowers; very tolerant
Polygonum coccineum	Red Smartweed	OBL			shallow water emergent, sedge meadow		M	no listing or possible food preference.	sun	2-3 ft	Aug-Sept	Pink	Can grow somewhat weedy.
Pontederia cordata	Pickerel Weed	OBL	(2, 3) 4	SATURATED	shallow water emergent	N	L	no listing or possible food preference.	sun	2-3 ft	July-Sept	Blue	Excellent shoreline component, may suffer mortality if exposed to freeze. Heart-shaped leaves with purple flowers
Potentilla arguta	Prairie Cinquefoil	FACU-			mesic prairie, dry prairie			R	sun	2-3 ft	July-Aug	Sulphur	Unusual yellow flowers, seed head very persitant and interesting.
Pycnanthemum tenuifolium	Narrow-Leaf Mountain Mint	FAC			mesic prairie, dry prairie			R	sun	1-2 ft	July-Aug	White	Great anti-predation sprecies to seed heavy when deer problems.
Pycnanthemum virginianum	Common Mountain Mint	FACW+			sedge meadow, wet prairie, mesic prairie			R	sun	1-2 ft	July-Aug	White	Great anti-predation sprecies to seed heavy when deer problems.
Ratibida pinnata	Yellow Coneflower	UPL			mesic prairie			S	sun	3-5 ft	July-Aug	Yellow	Easy to grow from seed, favored yellow prairie species
Rudbeckia fulgida speciosa	Showy Black-Eyed Susan	UPL			sedge meadow, wet mesic prairie			no listing or possible food preference.	sun	2-3 ft	Aug-Sept	Gold	Easy to grow from seed, favored yellow prairie species
Rudbeckia laciniata	Green-Headed Coneflower	FACW	4, 5	SEASONAL	wet-mesic woods	H	N	no listing or possible food preference.	psun	5-8 ft	July-Aug	Yellow	yellow flowers with drooping rays and green eyes; moist thickets; swamps
Rudbeckia subtomentosa	Sweet Black-Eyed Susan	FACU+			mesic prairie, wet mesic prairie			no listing or possible food preference.	sun	3-5 ft	Aug-Sept	Yellow	Long lived species, beautiful!
Sagittaria latifolia	Common Arrowhead	OBL	1, 2, 3	SAT, 0-2'	shallow water emergent	N	N	no listing or possible food preference.	sun	1-3 ft	July-Sept	White	emergent aquatic, tubers are edible
Saururus cernuus	Lizard's Tail	OBL	2, 3, 4	SAT, 0-1'	shallow water emergent, sedge meadow	N	U	no listing or possible food preference.	sun-shade	1-2 ft	June-July	White	emergent aquatic, fragrant white flowers, rapid root spread once established, tolerates flow.
Sedum ternatum	Wild Stonecrop	UPL	6	NO	mesic woods	M	U	no listing or possible food preference.	shade	3 in	May	White	groundcover; likes rocky banks
Senecio aureas	Golden Ragwort	FACW	4, 5	SEASONAL	sedge meadow, wet woods	L	N	no listing or possible food preference.	psun-sun	1 ft	May	Yellow	groundcover; flowers in terminal clusters with many golden "fluorescent" rays
Senecio obovatus	Round-Leaf Ragwort	FACU-			dry woods,mesic woods			no listing or possible food preference.	psun-shade	1ft	April-May	Yellow	clusters with many golden "fluorescent" rays
Silene regia	Royal Catchfly	UPL			mesic prairie			no listing or possible food preference.	sun	2-4 ft	July-Aug	Red	Vibrant red five petal flowers, likes rich soil, full sun.
Silphium integrifolium	Rosinweed	UPL			mesic prairie, wet mesic prairie			no listing or possible food preference.	sun	3-6 ft	July-Aug	Yellow	Great reate of spread, favored wild life seed source
Silphium laciniatum	Compass Plant	UPL			mesic prairie			no listing or possible food preference.	sun	5-8 ft	July-Sept	Yellow	Great reate of spread, favored wild life seed source, manificent leafs size and shape!
Silphium perfoliatum	Cup Plant	FACW-			wet mesic woods, wet mesic prairie			no listing or possible food preference.	sun-psun	5-9 ft	July-Sept	Yellow	Can grow very aggressive, use sparingly.
Silphium terebinthinaceum	Prairie Dock	UPL			wet mesic prairie, mesic prairie			no listing or possible food preference.	sun	5-10 ft	July-Sept	Yellow	Great reate of spread, favored wild life seed source, magnificent leaf size and shape, very tall.
Solidago caesia	Blue-stemmed Goldenrod	UPL			mesic woods, dry woods			no listing or possible food preference.	shade	1-2 ft	Sept-Oct	Yellow	Very easy to establish in wide range of woodland soils.
Solidago flexicaulis	Zig-Zag Goldenrod	FACU			wet mesic woods, mesic woods			S	shade	1-2 ft	Sept-Oct	Yellow	Gread rate of spread once established.
Solidago gigantea	Late Goldenrod	FACW			sedge meadow, wet mesic prairie, wet mesic woods			S	sun-shade	3-5 ft	Sept-Oct	Yellow	Can be somewhat aggressive.
Solidago graminifolia	Grass-Leaved Goldernrod	FACW-			sedge meadow.wet mesic prairie			S	sun	3-4 ft	Sept-Oct	Yellow	Very easy to establish in wide range of woodland soils.
Solidago juncea	Early Goldenrod	UPL			mesic prairie, dry prairie			S	sun	1-2 ft	July-Aug	Yellow	Very easy to establish in wide range of woodland soils.
Solidago nemoralis	Grey Goldenrod	UPL	6	NO	mesic prairie, dry prairie	M	N	S	sun	1-2 ft	Sept-Oct	Yellow	dry, sterile soils; yellow flower clusters
Solidago ohioensis	Ohio Goldenrod	OBL			sedge meadow			S	sun	2-3 ft	Sept	Yellow	Very bright yellow flowers
Solidago patula	Swamp Goldenrod	OBL		SEASONAL	sedge meadow			S	sun-psun	3-6 ft	Sept	Yellow	Excellent wet-wetland species, notable basal leafs.
Solidago riddellii	Riddell's Goldenrod	OBL			sedge meadow, wet-mesic prairie			S	sun	2-4 ft	Sept-Oct	Yellow	Very bright yellow flowers
Solidago rigida	Stiff Goldenrod	FACU-			mesic prairie, dry prairie		L	S	sun	3-5 ft	Sept-Oct	Yellow	Very easy to establish in wide range of woodland soils.
Solidago rugosa	Wrinkled Goldenrod	FAC	3, 4, 5	NO	sedge meadow	M	N	S	sun-psun	2-3 ft	Sept	Yellow	yellow flowers, also very easy to establish, spreads from root emergents all directions.
Solidago speciosa	Showy Goldenrod	UPL			mesic prairie, dry prairie, mesic savanna		L	S	sun-psun	1-3 ft	Sept-Oct	Yellow	Very easy to establish in wide range of woodland soils.
Sparganium androcladum	Branched Burreed	OBL			shallow water emergent			no listing or possible food preference.	sun	1-2 ft	June-July	Green	Excellent rate of spread, good shorline protection.
Sparganium eurycarpum	Giant Burreed	OBL	1 (2, 3)	SAT, 0-12'	shallow water emergent	N	N	no listing or possible food preference.	sun	3-6 ft	June-July	Green	emergent aquatic, excellent rate of spread, good shorline protection.
Stylophorum diphyllum	Celandine Poppy	UPL			mesic woods			no listing or possible food preference.	shade	1-2 ft	April-May	Yellow	Unusual woodland species, spreads well once established.
Verbena hastata	Blue Vervain	FACW+	3, 4	SAT	sedge meadow	N	L	no listing or possible food preference.	sun	3-5 ft	July-Sept	Blue	violet blue flowers in erect spikes
Vernonia altissima	Tall Ironweed	UPL			wet mesic prairie, mesic prairie, mesic savanna			S	sun-psun	5-10 ft	Aug-Sept	Purple	Striking purple/magenta flowers, very versitle plants
Vernonia fasciculata	Smooth Ironweed	FACW			wet mesic prairie			S	sun	3-6 ft	Aug-Sept	Purple	Striking purple/magenta flowers, very versitle plants
Veronicastrum virginicum	Culver's Root	FAC			wet mesic prairie			no listing or possible food preference.	sun-psun	3-6 ft	July-Aug	White	Impressive white candle obreas.
Zizia aurea	Golden Alexanders	FAC+			sedge meadow, wet mesic prairie, mesic prairie		L	no listing or possible food preference.	sun-psun	2-3 ft	May	Yellow	Very bright yellow flowers, spreads rapidly once established.

Table 5.3.1: Recommended Plant List, continued

Latin Name	Common Name	National Wetland Indicator	Hydrologic Zone	Indundation Tolerance	Community	Drought Tolerance (N=None; L=Low, M=Medium, H=High)	Salt Tolerance (N=None, L=Low, M=Medium,H=High, U=Unkown)	Deer Tolerance, discourages deer predation. Seldom damaged (S), Rarely Damaged (R) Occasionally Damaged (O)	Sun	Height range variable depending on soil conditions, hydrology, light	Flower Season	Color	Notes
Graminoids (Grasses, Rushes, & Sedges)												**Texture**	
Andropogon gerardii	Big Bluestem	FACW	(4, 5) 6	NO	mesic prairie, wet mesic prairie	H	M	R	sun	5-8 ft	July-Aug	Coarse	warm-season grass, used with Sorgastrum provides nice contract (reddish brown, blondish tan)
Bouteloua curtipendula	Side-Oats Grama	UPL			dry prairie		M	no listing or possible food preference.	sun	1-3 ft	July-Aug	Medium	Easy to establish, beautiful when seed heads present.
Bromus latiglumis	Tall Brome	UPL			wet-mesic woods			no listing or possible food preference.	psun-shade	3-4 ft	July-Aug	Medium	Robust species for flood planr applications
Bromus pubescens	Woodland Brome	UPL			mesic woods, dry woods			no listing or possible food preference.	psun-shade	1-3 ft	June-July	Medium	Easy to establish in wide range of woodland soils.
Calamagrostis canadensis	Blue-Joint Grass	OBL		SEASONAL	sedge meadow, wet prairie			R	sun	2-4 ft	June-July	Medium	Clump former that spreads well once established
Calamovilfa longifolia var magna	Sand Reed	UPL			sand dunes		L	R	sun	4-6 ft	July-Aug	Coarse	Excellent sandy soil full sun sprecies, tolerates foot trafic
Carex annectans var xanthocarpa	Yellow Fox Sedge	OBL		SEASONAL	sedge meadow, wet-mesic prairie			S/R	sun	2-3 ft	May-June	Fine	Sedges are excellent foundation species.
Carex bicknellii	Prairie Oval Sedge	UPL			dry prairie, mesic prairie		M	S/R	sun	1-2 ft	May	Fine	Sedges are excellent foundation species.
Carex brevior	Plains Oval Sedge	UPL			dry prairie		M	S/R	sun	1-2 ft	May-June	Medium	Sedges are excellent foundation species.
Carex bromoides	Brome Hummock Sedge	OBL			wet woods, sedge meadow			S/R	psun-shade	1-2 ft	May	Fine	Sedges are excellent foundation species.
Carex cephalophora	Short-headed Bracted Sedge	FACU			mesic woods, dry woods			S/R	psun-shade	1 ft	May	Fine	Sedges are excellent foundation species.
Carex comosa	Bristly Sedge	OBL		SEASONAL	shallow water emergent , sedge meadow			S/R	sun	1-3 ft	June-July	Coarse	Sedges are excellent foundation species, great shoreline component.
Carex crinita	Fringed Sedge	OBL		SEASONAL	sedge meadow			S/R	sun-shade	2-4 ft	May-June	Medium	Sedges are excellent foundation species.
Carex cristatella	Crested Sedge	FACW+		SEASONAL	sedge meadow		M	S/R	sun-psun	2-3 ft	May-June	Fine	Sedges are excellent foundation species.
Carex davisii	Davis Wood Sedge	FACW+			mesic woods			S/R	psun-shade	2 ft	May	Medium	Sedges are excellent foundation species.
Carex emoryi	Riverbank Tussock Sedge	UPL			sedge meadow			S/R	sun-psun	2 ft	May	Medium	Sedges are excellent foundation species.
Carex frankii	Frank's Sedge	OBL			sedge meadow, wet mesic woods			S/R	sun-shade	1-2 ft	June-July	Coarse	Sedges are excellent foundation species.
Carex gracillima	Gracefull Wood Sedge	FACU+			mesic woods			S/R	shade	1-2 ft	May	Medium	Sedges are excellent foundation species.
Carex granularis	Meadow Sedge	FACW+			sedge meadow, wet mesic woods			S/R	sun-shade	1-2 ft	May-June	Medium	Sedges are excellent foundation species.
Carex grayi	Burr Sedge	FACW		SEASONAL	wet mesic woods			S/R	psun-shade	1-2 ft	May-June	Medium	Sedges are excellent foundation species, unusual star shapped (persistant) seed head.
Carex hirtifolia	Hairy Wood Sedge	UPL			mesic woods			S/R	pshade-shade	1-2 ft	May-June	Medium	Sedges are excellent foundation species.
Carex hystericina	Porcupine Sedge	OBL		SEASONAL	sedge meadow			S/R	sun	1-2 ft	May-June	Medium	Sedges are excellent foundation species.
Carex jamesii	Grass Sedge	UPL			mesic woods			S/R	shade	6 in	April-May	Fine	Sedges are excellent foundation species.
Carex lacustris	Lake Sedge	OBL		SEASONAL	sedge meadow, shallow water emergent		L	S/R	sun-shade	2-4 ft	May	Coarse	Sedges are excellent foundation species, great shoreline component.
Carex laxiflora	Beech Wood Sedge	UPL			mesic woods			S/R	shade	1 ft	April	Coarse	Sedges are excellent foundation species.
Carex lupulina	Hop Sedge	OBL		SEASONAL	wet woods		L	S/R	psun-shade	1-2 ft	May-June	Medium	Sedges are excellent foundation species, great shoreline component.
Carex lurida	Lurid Sedge	OBL		SEASONAL	sedge meadow		L	S/R	sun-psun	1-2 ft	May-June	Medium	Sedges are excellent foundation species, great shoreline component.
Carex molesta	Field Oval Sedge	UPL			sedge meadow			S/R	sun-psun	2 ft	May-June	Medium	Sedges are excellent foundation species.
Carex muhlenbergii	Sand Bracted Sedge	UPL			dry prairie, dry savanna			S/R	sun-psun	1-2 ft	May-June	Fine	Sedges are excellent foundation species.
Carex muskingumensis	Palm Sedge	OBL		SEASONAL	wet woods, wet mesic woods			S/R	shade	1-2 ft	May-June	Fine	Sedges are excellent foundation species, common wet woods species.
Carex normalis	Spreading Oval Sedge	FAC			wet mesic woods, mesic woods			S/R	psun-shade	1-3 ft	May-June	Medium	Sedges are excellent foundation species.
Carex pellita	Wooly Sedge	OBL			sedge meadow, wet mesic prairie			S/R	sun	1-2 fet	May	Medium	Sedges are excellent foundation species.
Carex radiata	Straight-Styled Wood Sedge	FAC-			wet mesic woods, mesic woods			S/R	shade	1 ft	April-May	Fine	Sedges are excellent foundation species.
Carex scoparia	Lance-Fruited Oval Sedge	FACW		SEASONAL	sedge meadow, wet mesic prairie			S/R	sun	2-3 ft	May	Medium	Sedges are excellent foundation species.
Carex shortiana	Short's Sedge	FAC			sedge meadow, wet mesic woods			S/R	sun-psun	2-3 ft	May	Medium	Sedges are excellent foundation species.
Carex sparganioides	Burreed Sedge	FAC			mesic woods			S/R	psun-shade	1-2 ft	May	Fine	Sedges are excellent foundation species.
Carex squarrosa	Narrow-Leaved Cattail Sedge	OBL		SEASONAL	sedge meadow, wet woods			S/R	psun-shade	1-2 ft	May	Medium	Sedges are excellent foundation species.
Carex stipata	Awl-Fruited Sedge	OBL		SEASONAL	sedge meadow			S/R	sun-shade	2-3 ft	May	Medium	Sedges are excellent foundation species.
Carex stricta	Tussock Sedge	OBL		SEASONAL	sedge meadow		L	S/R	sun-psun	2 ft	May	Fine	Sedges are excellent foundation species, great shoreline component.
Carex tribuloides	Pointed Oval Sedge	FACW+		SEASONAL	sedge meadow, wet woods			S/R	sun-shade	2-3 ft	May	Medium	Sedges are excellent foundation species.
Carex trichocarpa	Hairy-Fruited Lake Sedge	OBL		SEASONAL	sedge meadow			S/R	sun-psun	2-4 ft	May	Medium	Sedges are excellent foundation species.
Carex vulpinoidea	Fox Sedge	OBL		SEASONAL	sedge meadow- wet mesic		M	S/R	sun-psun	2-3 ft	May-June	Fine	Sedges are excellent foundation species, great shoreline component.
Chasmanthium latifolium	Northern Sea Oats	FACU	4, 5	SEASONAL	mesic woods	M	N	R	psun-shade	2-3 ft	July-Aug	Medium	Groundcover/clump former; dangling "oats" seed formation very persistant!
Cinna arundinacea	Common Wood Reed	FACW		SEASONAL	wet-mesic woods			no listing or possible food preference.	shade	3-5 ft	Aug-Sept	Medium	Common wet woods species.

Table 5.3.1: Recommended Plant List, continued

Latin Name	Common Name	National Wetland Indicator	Hydrologic Zone	Indundation Tolerance	Community	Drought Tolerance (N=None; L=Low, M=Medium, H=High)	Salt Tolerance (N=None, L=Low, M=Medium,H=High, U=Unkown)	Deer Tolerance, discourages deer predation. Seldom damaged (S), Rarely Damaged (R) Occasionally Damaged (O)	Sun	Height range variable depending on soil conditions, hydrology, light	Flower Season	Color	Notes
Graminoids (Grasses, Rushes, & Sedges)												**Texture**	
Deschampsia caespitosa	Tufted Hair Grass	OBL		SEASONAL	sedge meadow		L	no listing or possible food preference.	sun	2-3 ft	May-June	Fine	Whispy flowering stalks and nice clump former
Diarrhena americana	Beak Grass	FACU			mesic woods			no listing or possible food preference.	shade	1-2 ft	Aug	Medium	Excellent woodland grass species.
Eleocharis erythropoda	Creeping Spike-Rush	OBL		SEASONAL	shallow water emergent		M	no listing or possible food preference.	sun	1-2 ft	May-July	Fine	Great rate of spread.
Elymus canadensis	Canada Wild Rye	FACU+	4, 5, 6	SEASONAL	mesic praire, dry prairie, mesic savanna	M	M	no listing or possible food preference.	sun-psun	3-4 ft	June-July	Coarse	cool season, clump-forming grass with wheat-like spikes that remain until winter
Elymus riparius	Riverbank Wild Rye	FAC-		SEASONAL	wet mesic woods, mesic woods			no listing or possible food preference.	psun-shade	3-5 ft	July-August	Coarse	Common wet edge wooded species.
Elymus villosus	Silky Wild Rye	UPL			mesic woods			no listing or possible food preference.	shade	1-2 ft	June	Medium	Common woodland species
Elymus virginicus	Virginia Wild Rye	FACW-	4, 5	SEASONAL	mesic woods, wet-mesic woods	M	N	no listing or possible food preference.	sun-shade	2-3 ft	June-July	Coarse	spreads easilty; good for erosion control; very tolerant
Eragrostis spectablis	Purple Love Grass	UPL	5, 6	NO	dry prairie	H	N	no listing or possible food preference.	sun	1 ft	July-Sept	Medium	groundcover; delicate purple flowers seem to float above the plant
Glyceria striata	Fowl Manna Grass	OBL	(2, 3) 4	SEASONAL	sedge meadow, wet woods	L	N	no listing or possible food preference.	sun-shade	2-4 ft	May-June	Medium	Common wet woods species, clump forming, rapid spread rate potential.
Hystrix patula	Bottlebrush Grass	UPL			mesic woods			S	psun-shade	3-5 ft	June-Aug	Medium	Wooded slopes component, establishes easily.
Juncus canadensis	Canada Rush	OBL		SEASONAL	sedge meadow		M	R	sun	1-2 ft	June-July	Fine	Spreads from root emergents all direction and from seed (very minute dust)
Juncus effusus	Soft Rush	FACW+	(2, 3) 4	SAT, 0-1'	shallow water emergent	M	L	R	sun-psun	2-4 ft	May-June	Medium	Great rate of spread, clump former, great component to shoreline, seed fine like dust.
Juncus torreyi	Torrey's Rush	OBL		SEASONAL	sedge meadow		M	R	sun	1-2 ft	June	Medium	Interesting seed heads, little balls on sticks.
Koeleria cristata	June Grass	UPL			dry prairie, dry savanna			R	sun-psun	1-2 ft	May-June	Fine	Short lived, but establishes easily from seed, clump forming.
Leersia oryzoides	Rice-Cut Grass	OBL		SEASONAL	sedge meadow			no listing or possible food preference.	sun-psun	2-4 ft	Aug-Sept	Medium	Can be very aggressive, leaves known to slice into skin easily, shallow menacing cuts.
Panicum virgatum	Switch Grass	FAC+			wet-mesic prairie		H	S	sun	3-5 ft	July-Aug	Medium	Very aggressive, use sparingly.
Schizachyrium scoparium	Little Bluestem	FACU	6	NO	mesic prairie, dry prairie	H	L	R	sun	2-3 ft	Aug-Sept	Medium	warm-season grass, tolerates poor, dry soils
Scirpus acutus	Hardstem Bulrush	OBL		SEASONAL	sedge meadow, shallow water emergent		M	S	sun	4-6 ft	May-June	Coarse	Excellent shoreline component, good rate of spread, introduction should be 0-3"
Scirpus atrovirens	Dark Green Bulrush	OBL		SEASONAL	sedge meadow			S	sun	3-5 ft	May-June	Coarse	Spreads and establishes easily
Scirpus cyperinus	Woolgrass	OBL		SEASONAL	sedge meadow		M	S	sun	3-5 ft	July-Aug	Medium	Spreads and establishes easily, tolerates dry downs quite well!
Scirpus fluviatilis	River Bulrush	OBL		SEASONAL	shallow water emergent			S	sun	3-7 ft	May-June	Coarse	Excellent shoreline component, good rate of spread, introduction should be 0-3"
Scirpus pendulus	Reddish Bulrush	OBL		SEASONAL	sedge meadow		M	S	sun	3-5 ft	May-June	Medium	Spreads and establishes easily, tolerates dry downs quite well!
Scirpus pungens	Three-Square Bulrush	OBL		SEASONAL	sedge meadow, shallow water emergent		M	S	sun	2-5 ft	June	Medium	Excellent shoreline component, good rate of spread, introduction should be 0-3"
Scirpus validus	Soft-Stem Bulrush	OBL		SEASONAL	sedge meadow, shallow water emergent		M	S	sun	4-8 ft	May-June	Coarse	Excellent shoreline component, good rate of spread, introduction should be 0-3"
Sorghastrum nutans	Indian Grass	UPL	6	NO	mesic prairie, dry prairie	M	M	R	sun	4-6 ft	Aug-Sept	Medium	warm-season grass
Spartina pectinata	Prairie Cordgrass	FACW+			wet mesic prairie, wet prairie, sedge meadow		H	no listing or possible food preference.	sun	4-7 ft	July-Aug	Coarse	Very versitile species, tolerates wet/dry extreemes, tends to grow in mon-typic stands.
Sporobolus heterolepis	Prairie Dropseed	FACU-			mesic prairie, dry prairie		L	no listing or possible food preference.	sun	1-3 ft	July-Sept	Fine	Excellent clump former, smells like coriander when blooming, hard to establish from seed (seed very perishable)
Woody Plants												Color	
Amorpha canescens	Leadplant	UPL			mesic prairie, dry prairie, mesic savanna				sun-psun	1-3 ft	June-July	Purple	Excellent legume, prairie shrub
Ceanothus americanus	New Jersey Tea	UPL			mesic prairie, dry prairie, mesic savanna				sun-psun	1-3 ft	June-July	White	Dificult to establish from seed (special pre-treatments neccesary)
Cephalanthus occidentalis	Buttonbush	OBL		SEASONAL	shallow water emergent, sedge meadow				sun-shade	6-10 ft	June-Aug	White	Excellent shoreline component, common wet woods shrub, grows well from cuttings.
Clematis virginiana	Virgin's Bower	FAC			sedge meadow, wet woods				sun-psun	4-8 ft	Aug-Sept	White	Excellent wet woods vine.

Table 5.3.1: Recommended Plant List, continued

*** WET LAND INDICATOR (probability of occurring in a wetland):**

OBL	Obligate wetland species	99%
FACW	Faculative wetland species	67-99%
FACW	Faculative species	34-66%
FACU	Faculative upland species	1-33%
UPL	Upland species	1%
(+)	indicates that the species occurs in the higher portion of the range	
(-)	indicates that the species occurs in the lower portion of the range	

Those species with no wetland indicator are virtually intolerant of flooding or prolonged soil saturation during the growing season.

**** HYDROLOGIC ZONES**

Zone 1: Open water - Permanent pool (12 inches - 6 feet)
This zone is best colonized by submergent plants, if at all. This deep water zone is not usually planted for several reasons: there are few species that can grow in this zone, and many are not commercially available: open water areas provide unique habitat; and deep water aquatic plants may clog the stormwater facility outlet structure. The benefits of planting in this zone include the absorption of nutrients in the water column; enhanced sediment deposition; improved oxidation; and the creation of additional habitat.

Zone 2: Shallow water terrace/Aquatic bench (6 inches - 1 foot)
This zone offers ideal conditions for a wide variety of emergent wetland plants. These areas typically fringe the ponding area and are permanently inundated.

Zone 3: BMP Fringe - Low marsh (0-6 inches regular inundation)
This zone is typically the shore line of a pond or wetland - its width determined by the design slope. This zone is usually inundated except during periods of drought and is the interface between the emergent wetland plantings and the upland plantings. Plants must be able to withstand periods of inundation as well as periods of drought and should have some capacity for slop stablization.

Zone 4: BMP Fringe - High Marsh (periodic inundation, saturated soils)
This zone extends upslope from zone 3 and may be inundated after storms. It constitutes the majority of the temporary extended detention area. Plants selected should be able to withstand periodic inundation after storms as well as significant drought during the summer.

Zone 5: Floodplain terrace (infrequent inundation, temporarily saturated soils)
Zone 5 is infrequently saturated by floodwaters that quickly recede in a day or less. Plants should be able to withstand infrequent inundation as well as drought and should offer some slope stabilization.

Zone 6: Upland (never inundated)
This zone extends above the maximum design water surface elevation. Plant selection should be based on local soil and light conditions, and on the amount of available space for plantings.

THIS PAGE LEFT BLANK INTENTIONALLY

6. Applicability and Comparison

The performance and effectiveness of a Best Management Practice (BMP) for treating and/or controlling Stormwater runoff depend on project type, site conditions, design, operation, and maintenance of the BMP. The initial selection of a BMP appropriate for the site sets the stage for effective Stormwater management. The numerous combinations of potential projects, locations, land use, and available space make this selection challenging.

Table 6.0.1 shows which BMPs are potentially suited for a site based on land use and land area. For example, a detention basin may be less suited to an ultra urban site than it is to a single family residential subdivision. Each BMP can be adapted to most land uses and other factors must be considered. The issue of available land area is specifically addressed in the last column of Table 6.0.1. Some BMPs, such as green roofs, have little to no space requirements, while others, such as detention ponds, take up a large amount of space on the site. BMPs requiring a high level of dedicated land would not be appropriate for sites where most of the land will be developed for other uses, typical in ultra urban areas.

Table 6.0.1: Green Stormwater Infrastructure Land Use and Land Area Selection Matrix

	Criteria								
	Land Use								**Land Area Req'd**
Practices	**SF Res.**	**MF Res.**	**Com.**	**Schools**	**Ultra Urban**	**Indust.**	**Retrofit**	**Road/ Roadside**	
Green Roofs	○	○	●	●	●	●	◉		○
Permeable Pavement	◉	◉	●	●	●	○	◉	◉	○
Rain Water Harvesting	●	●	●	●	◉	●	●		○
Filter Strips	●	●	●	●	◉	◉	◉	●	◉
Bioretention	●	●	●	●	●	●	●	●	◉
Low Impact/ Retentive Grading	●	●	●	●	◉	●	●	●	○
Swales	●	●	●	●	◉	●	●	●	◉
Subsurface Infiltration	●	●	●	●	●	●	●	●	●
Inlet and Outlet Control	●	●	●	●	●	●	●	●	○
Filters		◉	●	●	●	●	●	●	◉
Subsurface Vaults	○	○	●	●	●	●	○	○	◉
Detention Basin*	○	●	●	●	○	●		○	●

● - Well suitability for land use applications or high relative dedicated land area required.
◉ - Average suitability for land use applications or moderate relative dedicated land area required.
○ - Low suitability for land use or relative low dedicated land area required.
Blank – Not applicable for land use.
*Note: In retrofit cases consider enhancing an existing detention basin/pond with a native planting buffer.

Once BMP selection has been narrowed down based on land use and space requirements; the effectiveness of the BMP for volume reduction, peak discharge control, and water quality should be evaluated. Table 6.0.2 shows the effectiveness of the BMPs in meeting these Stormwater management objectives, assuming they are designed, operated, and maintained effectively. BMPs differ in their ability to store, attenuate, and treat Stormwater. When a BMP does not meet a Stormwater management objective, another BMP can be added to form a treatment train. Some BMPs can be designed with or without infiltration and this will affect its ability to meet the objectives.

Table 6.0.2: Effectiveness of BMPs in Meeting Stormwater Management Objectives

Practices	Volume	Peak Discharge	Water Quality
Green Roofs	●	●	●
Green Roof w/Infiltration	○	○	○
Permeable Pavement	●	●	○
Permeable Pavement w/Infiltration	●	●	●
Rain Water Harvesting*	●	●	●
Filter Strips	○	○	●
Filter Strips w/Infiltration	○	○	○
Bioretention	●	●	●
Low Impact/ Retentive Grading	○	●	●
Low Impact/ Retentive Grading w/Infiltration	●	●	●
Swales	○	●	●
Swales w/Infiltration	●	●	●
Subsurface Infiltration	○	●	●
Subsurface Infiltration w/Infiltration	●	●	●
Inlet and Outlet Control	○	⦿	⦿
Filters	○	●	●
Filters w/Infiltration	●	●	●
Subsurface Vaults	●	●	○
Subsurface Vaults w/Infiltration	●	●	●
Detention Basin	○	●	●
Detention Basin w/Infiltration	●	●	●

* A single cistern typically provides greater volume reduction than a single rain tank.

Key: ● High effectiveness ⦿ Medium effectiveness ○ Low effectiveness

Rankings are qualitative. "High effectiveness" means that one of the GIP's primary functions is to meet the objective. "Medium effectiveness" means that a GIP can partially meet the objective but should be used in conjunction with other BMPs. "Low effectiveness" means that the GIP's contribution to the objective is a byproduct of its other functions, and another decentralized control should be used if that objective is important.

Other criteria, such as maintenance requirements, safety concerns, potential pollutants, aesthetics, and public amenities must also be taken into consideration. Planning for Stormwater management early in the design phase can allow opportunities to enhance the property and benefit the environment. Examples based on road/roadside, parks/open space, and multiple family residential areas are given below.

Road/Roadside projects are typically designed with the primary purpose of transportation with Stormwater management taken into account late in the design process. The result is often an end of pipe BMP, such as a mechanical unit. Mechanical units do meet water quality requirements, but lack additional benefits that can be found in other BMPs. Maintaining Stormwater quality units also requires the use of specialized equipment and it can be difficult to access and inspect the unit. If the roadway is instead designed with a swale or ditch, the additional benefit of volume and flow rate reduction can be seen. If space for a swale or ditch is limited, hybrid ditches typically have a smaller footprint than conventional ditches and can be connected to the storm drain system via a subsurface pipe. Unlike a mechanical unit, Stormwater entering the swale from the roadway receives some pretreatment along the side slope. The swale or ditch itself can also be designed to encourage filtering and infiltration. This treatment reduces erosion from concentrated flow and reduces pollutants.

In the design of schools and parks as new development or redevelopment projects, there is generally open land available for the installation of BMPs. However, some opportunities for the installation of BMPs to improve Stormwater quality are often not utilized. Schools and parks provide an excellent opportunity for demonstration sites of green infrastructure BMPs including: permeable pavement, rain gardens, bioretention, vegetated swales, native plantings, and riparian or stream bank restoration. Routine maintenance is generally already being done at these sites. The use of native plants and rain gardens may reduce maintenance cost by reducing the need to mow, spray, and water nonnative plants or turf grass that is commonly used. Demonstration sites can be used to promote the use of native plants and rain gardens to residents who visit the schools or park areas. Schools and parks are also an excellent location to showcase permeable pavement, rain gardens and rain water harvesting. The City can promote permeable pavement sites to developers through literature and tours. Rainwater harvesting is highly visible and can be appealing to both private homeowners and developers when shown to be an easy way to conserve water and help the environment.

Multiple family residential sites are usually developed to maximize living units and parking and then ponds or mechanical units are inserted to treat the resulting Stormwater runoff. By considering Stormwater management earlier in the design process, natural features can be preserved or restored and storage can be distributed in several areas. Preserving natural features (e.g. forested areas and wetlands) at a development site often leads to an increased value to the lots that are adjacent to the natural feature. By using distributed storage (e.g. rain gardens) at a development site this enhances both the landscape and the quality of Stormwater and also could be used to educate the public about Stormwater quality and create awareness of the City’s rain garden and native planting program. Adding walkways or common areas around BMPs can create valuable site amenities to promote sustainability and livability throughout the neighborhood.

6.1. Evaluation of Green Design Techniques

The integrated approach to Stormwater management requires consideration of many new concepts and practices. In addition to identifying the appropriate BMP based on land use and

Stormwater Management objectives, as described above, cost and performance comparisons between Stormwater Management options are often conducted. However, a direct comparison of the costs and performance of these new practices to conventional engineered storm drainage systems, or for that matter to each other, should be handled with caution for a number of reasons:

1. The practices apply to different areas and situations. Some, such as rain barrels, apply only to residential areas, whereas others, such as rooftop storage, would be implemented only in large commercial/industrial/ institutional buildings, and others, such as inlet restrictors, would be installed in paved areas. The level of performance (amount of water controlled) also varies widely.

2. Onsite Stormwater reduction practices offer a widely-varying range of benefits beyond Stormwater reduction, such as water quality benefits, groundwater recharge, habitat improvement, and educational values.

3. The integrated approach involves small scale, distributed practices that will have accumulated results - maybe not always more efficiently than engineered solutions, but often more effective, with improved benefits and increased participation and long term implementation.

4. The concepts of green infrastructure, sustainable development, and improved site design will require a mix of structural, nonstructural, institutional, and educational elements. Implementation of these elements will necessitate increased partnerships. The onsite practices attractive to private residents offer partnership opportunities with community and neighborhood groups, special interest groups (such as garden clubs), and municipalities. The practices that are more appropriate for institutional or commercial property owners offer the City the opportunity to partner with existing organizations that have many properties, such as school districts, banks, or developers.

5. The onsite practices offer a wonderful opportunity to educate the public about Stormwater and watershed health and protection. Residential programs lend themselves to enhancing homeowner understanding of Stormwater issues.
Practices such as rain gardens or downspout disconnects are very tangible, easily understood concepts. Practices that involve established institutions allow the City to raise awareness among large groups of people, such as service organizations or tenants of properties. Practices such as green roofs, when partnered with a school district, offer the City the chance to build an education program for school children and their parents. Establishing some sort of recognition program to residents/institutions who participate in Stormwater reduction practices provide the City with additional education/awareness opportunities through publicity and media coverage.

It is helpful to evaluate the attributes and limitations of the Stormwater reduction practices and to understand the conditions under which these practices perform best. For each practice, Table 6.1.1 summarizes the flow benefits, environmental features, implementability, function, operation and maintenance needs, and potential to promote environmental awareness.

1. All practices provide some reduction in Stormwater flow (otherwise, of course, they would not be included in the table). However, the level of hydrologic/hydraulic performance varies widely.

2. Three-fourths of the practices have the potential - depending on the design - to provide at least marginal benefits during “major” (> 1”) storms.

3. All but two of the practices may be expected to provide pollutant removal and water quality benefits.

4. While many practices are believed to be acceptable to the public, a fairly intensive public education program will be needed for successful implementation.

5. Over three fourths of the practices offer opportunities for partnerships.

6. About 65% of the practices utilize vegetation; 82% increase infiltration; and
53% involve Stormwater storage.

7. Over one-half of the practices have a “good” or “very good” potential to help promote environmental responsibility and awareness.

8. A few practices - French drains, dry wells, and infiltration sumps - may have limitations that merit site specific soils investigations.

Table 6.1.2 presents the cost effectiveness of the practices. Capital costs and costs per impervious acre served are provided. Note that the amount of Stormwater reduction varies: a rain barrel may store only ¼” of runoff from a roof, while a green roof may accommodate more than 2” of rainfall. The cost effectiveness estimates do not reflect these variations in performance. The cost per impervious acre served ranges from less than $1,000 per acre to $653,400 per acre. The median cost is approximately $16,000 per impervious acre.

THIS PAGE LEFT BLANK INTENTIONALLY

Table 6.1.1: Evaluation of Stormwater Reduction BMPs
(Milwaukee Metropolitan Sewerage District (MMSD), 2005)

	Flow					Environmental		Implementability							Function				
Stormwater Reduction Practice	Delays Runoff	Reduces Runoff Volume	Reduces Peak Flow	Increases Infiltration	Effective in Major Storms	Water Quality Protection	Ecology/ Habitat Improvement	Public Acceptance	Public Education Needed	Financial Incentive Needed	Sensitive to Proper Operation	Opportunity for Partnership	Applicability	Limitations	Plant Uptake	Infiltration	Storage	Operations and Maintenance Needs	Environmental Awareness
1. Downspout Disconnection	Yes	Yes	Yes	Yes	Yes	Yes	No	Good	Yes	Yes	No	Yes	CSSA only.	Interior downspouts. House foundations. Basement flooding. Safety / ice concerns.	*	*		Low. Inspections.	Good. Residential / neighborhood.
2. Rain Barrels	Yes	Yes	Yes	Maybe	No	Maybe	No	Good	Yes	Yes	Yes	Yes	Residential.	Mosquitos. Small lots. House foundations. Winter.	*	*	*	Moderate. Must be emptied. Winter storage. Check fittings and connections.	Very good. Residential.
3. Cisterns	Yes	Yes	Yes	Maybe	Yes	Maybe	No	Fair/Poor	Yes	Yes	Yes	Yes	Residential. Commercial. Industrial.	May reuse water (potential: laundry, toilet, outdoor uses). Winter.			*	Moderate. Check fittings and connections. Disconnect / empty in winter.	Average.
4. Rain Gardens	Yes	Yes	Yes	Yes	No	Yes	Yes	Good	Yes	Maybe	Yes	Yes	Residential and light commercial/industrial.	Land availability. Unsuitable soils.	*	*		Moderate. Plant upkeep. Weed control. Occasional watering.	Very good. Residential/community.
5. Green Roofs	Yes	Yes	Yes	No	Maybe	Yes	Yes	Fair	No	Yes	Yes	Yes	Flat roofs (subject to limitations). Industrial. Commercial.	Load-bearing capacity. Moisture and root penetration resistance.	*	*	*	Moderate. Plant upkeep and maintenance of roof structure. More maintenance than a conventional roof.	Good. Institutions/commercial/industrial.
6. Rooftop Storage	Yes	Maybe	Yes	No	Yes	No	No	Good	No	No	No	Yes	Commercial, industrial, and institutional flat roofs.	Load-bearing capacity. Waterproofing. Mosquitos.			*	Low.	Good.
7. Green Parking Lots	Yes	Yes	Yes	Yes	Maybe	Maybe	Yes	Good	Yes	No	No	Yes	Commercial, industrial, institutional.	Open space. Suitable soil	*	*		Moderate. Maintain vegetation.	Good public display.
8. Stormwater Trees	Yes	Yes	Yes	Yes	Maybe	Maybe	Yes	Good	Yes	Yes	No	Yes	Most pervious areas, and in planters.	Pervious open space.	*	*		Moderate. Routine tree maintenance and watering.	Good for community group participation.
9. Porous Pavement	Yes	Yes	Yes	Yes	Yes	Yes	No	Fair	Yes	Maybe	Yes	Yes	Low traffic areas and parking lots. Sidewalks.	Winter freeze/thaw.		*		High. High maintenance and cleaning needed to prevent clogging. Monthly vacuuming and power	Good.
10. Inlet Restrictors/ Pavement Storage	Yes	No	Yes	No	Yes	No	No	Poor	Yes	No	No	No	Streets with flat grades, low traffic, and curbs and berms to impound water. Residential feeder streets.	Safety. Street access.			*	Low. Minimal.	Average. Maybe good for municipal recognition.

Table 6.1.1: Evaluation of Stormwater Reduction BMPs, continued

Stormwater Reduction Practice	Flow					Environmental		Implementability							Function			Operations and Maintenance Needs	Environmental Awareness
	Delays Runoff	Reduces Runoff Volume	Reduces Peak Flow	Increases Infiltration	Effective in Major Storms	Water Quality Protection	Ecology/ Habitat Improvement	Public Acceptance	Public Education Needed	Financial Incentive Needed	Sensitive to Proper Operation	Opportunity for Partnership	Applicability	Limitations	Plant Uptake	Infiltration	Storage		
11. Bioretention	Yes	Yes	Yes	Maybe	Maybe	Maybe	Yes	Good	No	No	No	Yes	Open land areas. Well-drained soils (or w/ under drain).	Land availability. Unsuitable soils.	*	*	*	Low. Vegetation upkeep - mowing, removal of invasive species, replanting, removal of debris, and corrosion control.	Average.
12. On-site Filtering Practices	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Fair	Yes	Yes	Yes	Yes	Small drainage area.	No steep slopes. Risk of clogging. Standing water.	*	*		High. Inspections and cleaning to prevent clogging.	Average.
13. Pocket Wetlands	Yes	Yes	Yes	No	Yes	Yes	Yes	Fair/Poor	No	No	No	Yes	Parking lots. Small sites.	Supplemental irrigation. Site requirements. Mosquitos. Winter & salt.	*	*	*	Low. Sediment removed. Invasive species.	Good.
14. French Drains and Dry Wells	Yes	Yes	Yes	Yes	Maybe	Yes	No	Poor	Yes	No	No	Yes	Small drainage areas. Residential.	Permeable soils. Adequate depth to gw. Clean water.		*	*	Low. Annual training. Replace rock and clean out sediment.	Average.
15. Infiltration Sumps	Yes	Yes	Yes	Yes	Maybe	Yes	No	Fair	No	No	No	No	Residential areas <50% impervious. Placed in rights of way of smaller streets.	Permeable soils. Adequate depth to gw.		*		Low. Clean out sumps every 2-3 years. Every year inspection.	Average.
16. Compost Amendments	Yes	Yes	Yes	Yes	No	Yes	Maybe	Fair	Yes	Yes	No	Yes	Highly compacted soils with low organic matter and nutrients.	Temporarily disturbs vegetative cover.	*	*		Low. None.	Average.
17. Stormwater Rules and Redevelopment Policies	Yes	Yes	Yes	Maybe	Yes	Yes	Maybe	Fair	No	No	No	No	New development and redevelopment.	Prescriptive. Rigid criteria.	*	*	*	Low. None.	Average.

Table 6.1.2: Cost Effectiveness of Stormwater Reduction BMPs

(Milwaukee Metropolitan Sewerage District (MMSD), 2005)

Stormwater Reduction Practice	Capital Cost	$/Impervious Acre Served (min)	$/Impervious Acre Served (max)	Vol of Runoff/ Imp Ac [gal]	$/gal (min)	$/gal (max)	Assumptions
1. Downspout Disconnection	$50 to $250/downspout.	$4,400	$21,800	12,938	0.34	1.68	Each downspout disconnection drains 500 square feet of roof
2. Rain Barrels	$150/each rain barrel.	$13,100	--	10,345	1.27	NA	Each rainbarrel drains 500 square feet of roof and captures 0.4".
3. Cisterns	$1,000 (500 gallon) to $5,000 (6,500 gallon underground).	$43,600 $10,000		19,400 12,938	2.25 0.77	NA 1.55	500-gallon cistern drains 1,000 square feet of roof for 0.75" rain. Two 6,500 gal can capture 1". Water re-use may reduce water supply costs.
4. Rain Gardens	$5 to $10/square foot.	$21,800	$43,600	25,875	0.84	1.69	100 square foot rain garden drains 1,000 feet of roof.
5. Green Roofs	$15/square foot of roof $8/sq ft (net)	$348,480	$653,400	12,938	26.93	50.5	Complete green roof system includes watertight membrane, protective layer, insulation, drainage system, filter layer, soil, and plants.
6. Rooftop Storage	$100/drain restrictor. $5/square foot waterproofing	$4,356	$222,200	25,875	0.17	8.59	One restrictor per 1,000 square feet of roof. Waterproof entire roof.
7. Green Parking Lots	$200/tree pit. $13,000-$30,000/acre bioretention. $2/square foot turf pavers.	$10,000	$11,700	25,875	0.39	0.45	10% of parking lot area is bioretention, and 10% is turf paved.
8. Stormwater Trees	$200 - $340/tree	$27,800	$47,260	22,869	1.22	2.07	Each acre of trees receives drainage from one impervious acre. $670 per residential acre; $3,300 per commercial/industrial acre. Street trees assume 20' diam. canopy/tree (314 sq ft).
9. Porous Pavement	$2-$4/square foot	$81,700	$174,000	25,875	3.16	6.72	Lower cost is turf or gravel paver; higher cost is porous asphalt or concrete.
10. Inlet Restrictors / Pavement Storage	$400-$1,200 per restrictor	$450	$1,350	54,450	0.01	0.02	Each inlet restrictor serves 1.5 acres @ 60% impervious.
11. Bioretention	$13,000-$30,000/acre.	$6,500	$15,000	25,875	0.25	0.58	Each bioretention acre drains two impervious acres.
12. On-site Filtering	Swales: $3,500/5-acre residential site. Sand filter: $35,000-$75,000/5-ac commercial site. Filter Strips: $13,000/$30,000/acre.	$1,200 $8,700 $2,600		25,875 25,875 25,875	0.05 0.34 0.10	NA 0.72 NA	Swales: 5-acre 80% impervious residential site. Sand Filters: 5-acre 80% impervious commercial site. Filter Strips: Each acre of filter strip serves 5 impervious acres.
13. Pocket Wetlands	$60,000/acre/foot.	$16,000		25,875	0.62	NA	0.5 acre, 3-foot deep pocket wetland serves 5 acres, 1/2 of which is impervious.
14. French Drains and Dry Wells	French drain: $15-$17 linear foot. Dry Well: $900 to $1,400/each	$26,136 $78,400	$29,621 $122,000	12,938 12,938	2.02 6.06	2.29 9.43	Each dry well drains 500 square feet of roof.
15. Infiltration Sumps	$5,000 to $10,000 per sump.	$5,500	$11,000	25,875	0.21	0.43	Each sump serves 1.5 acres @ 60% impervious.
16. Compost Amendments	$1-$2/square foot.	$21,800	$43,600	12,938	1.68	3.37	Each acre of compost amended soil drains two impervious acres.

Notes:
Volume of runoff per impervious acre based on assumption that practices treat between 0.4 and 1.0 inches, depending on the practice. WQv =(Rv)(A)(P), Rv = 0.95 assuming 1ac of impv.
1" yields (0.95)(43560 sqft)(1"/12)(7.5 gal/cuft)=25,875 gal
0.75" yields (0.95)(43560 sqft)(0.75"/12)(7.5 gal/cuft)=19,400 gal
0.5" yields (0.95)(43560 sqft)(0.5"/12)(7.5 gal/cuft)=12,938 gal
0.4" yields (0.95)(43560 sqft)(0.4"/12)(7.5 gal/cuft)=10,345 gal
Street tree assumptions are based on installed costs of b/w $200-$340 per tree,rainfall interception of 0.525 gal/sqft(22,869 gal per canopy ac),average canopy per tree of 314 sq ft (139 trees per canopy acre).
Inlet restrictor assumes 0.75' depth at gutter, 0% longitudinal street slope, and 7260 cuft of runoff.

THIS PAGE LEFT BLANK INTENTIONALLY

References

Maryland
Maryland Stormwater Design Manual, Volumes I and II (Effective October 2000).
http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp

Milwaukee, Wisconsin
Milwaukee Metropolitan Sewerage District (MMSD), Surface Water and Storm Water Rules Guidance Manual: Low Impact Development Documentation (Effective January 1, 2002, revised September 2005).
http://www.mmsd.com/stormwaterweb/index.htm

Philadelphia, Pennsylvania
City of Philadelphia Stormwater Management Guidance Manual (Effective 2006)
http://www.phillyriverinfo.org/Programs/SubprogramMain.aspx?Id=StormwaterManual

Portland, Oregon
City of Portland Bureau of Environmental Services Stormwater Management Manual Adopted July 1, 1999; revised September 1, 2004)
http://www.portlandonline.com/bes/index.cfm?c=35117

Seattle, Washington
City of Seattle Flow Control Technical Requirements Manual (November 2000).
http://www.ci.seattle.wa.us/dclu/codes/DR/dr2000-26.pdf

Natural Resources Defense Council
Rooftops to Rivers: Green Strategies for Controlling Stormwater and Combined Sewer Overflows. (June 2006)
https://nrdc.org/water/pollution/rooftops/rooft

THIS PAGE LEFT BLANK INTENTIONALLY