Alternative Stormwater Best Management Practices (BMP's) Guidelines

Introduction

The purpose of these guidelines are to provide a "tool box" of BMP's for improving water quality and reducing flood and impacts in Lincoln due to urbanization. These guidelines were compiled specifically for Lincoln and were designed to work in our area with our soil types.

Many of the BMP's can be used in individually or in combination, to reduce stormwater pollutants and maintain the natural hydrologic function of an area. The City of Lincoln Drainage Criteria Manual provides additional information about several of the BMP's listed in this guide in Chapter 8 - Stormwater Best Management Practices.

The BMP's listed in this guideline as well as those in the Drainage Criteria Manual have specific application and placement requirements. These guidelines are not a substitute or amendment to any existing City standards for the construction streets or stormwater drainage. Current design standards for streets and stormwater design must be considered when choosing BMP's for a specific area.

We hope you will find this information useful when considering BMP's. Any comments or questions on the guidelines are welcome and appreciated. Please send to Rock Krzycki at rkrzycki@lincoln.ne.gov or 441-4959.

Alternative Stormwater Best Management Practices Guidelines

City of Lincoln, Nebraska
and the
Lower Platte South Natural Resources District

April 2006

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Public Works and Utilities Department
Watershed Management Division
City of Lincoln

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1. INTRODUCTION

Stormwater management is an issue of great importance for the City of Lincoln. Several creeks converge in the vicinity of Lincoln, draining several hundred square miles of land area. One hundred floods have been recorded in Lincoln since 1900, including 17 major floods and 30 moderate floods, with the remainder being minor flood events (Nebraska Department of Natural Resources). The flash flood of August 28, 2002, as shown in the photograph to the right, is a reminder of how Lincoln is susceptible to flooding. These floods result in major inconveniences to the city, property damage, and, sometimes, loss of life.

52.nd and R Street

There are measures that can be taken to help reduce the impacts of rainfall and stormwater runoff in the City. This document introduces alternative best management practices (BMPs) that can be implemented to reduce stormwater runoff impacts. These BMPs maximize infiltration of rainfall and detention of runoff, and slow the volume and rates of water entering the system of streams draining Lincoln.

These guidelines present BMPs that can be used in small urban settings as well as larger, broad-scale developments. Please note that the information provided in this introductory guideline is provided only for explanation and illustration of key concepts. It is not the intent of this guideline document to provide in-depth "how to" guidance, as most BMPs require site-specific design details that require evaluation of hydrologic, soil, and vegetation conditions that impact stormwater flow. The first section of this guideline introduces the concepts and philosophy behind alternative BMPs, and how they can be applied throughout the City. Section 2 explains BMP site selection methods, followed by descriptions of nineteen BMPs in Section 3. Section 4 includes selected articles describing how alternative BMPs have successfully mitigated stormwater issues in other locations, while also enhancing the quality of life and value of land where they have been implemented. Section 5 contains bibliographic information for the sources referenced in this document.

1.1 Re-Defining a Philosophy

In the past, conventional wisdom for stormwater management held that water was a problem to solve rather than a valuable resource to conserve. Historically, the primary objective of conventional stormwater engineering methods has been to convey stormwater away from our developed areas, seeking to quickly export water away from where it falls instead of beneficially storing and using the resource. In nature, by contrast, stormwater is dispersed across the landscape, reducing water runoff volumes and release rates while simultaneously cleaning the water through natural filtration processes.

As native vegetation is replaced by impervious surfaces created by conventional development, these natural stormwater management and treatment functions are lost, resulting in increased runoff, flooding, erosion, and pollution. Plant species imported from other parts of the world, such as many or our turf grasses, do not provide sufficient infiltration of rainwater and, therefore create more runoff than would occur under native vegetation. With increased amounts of paved areas

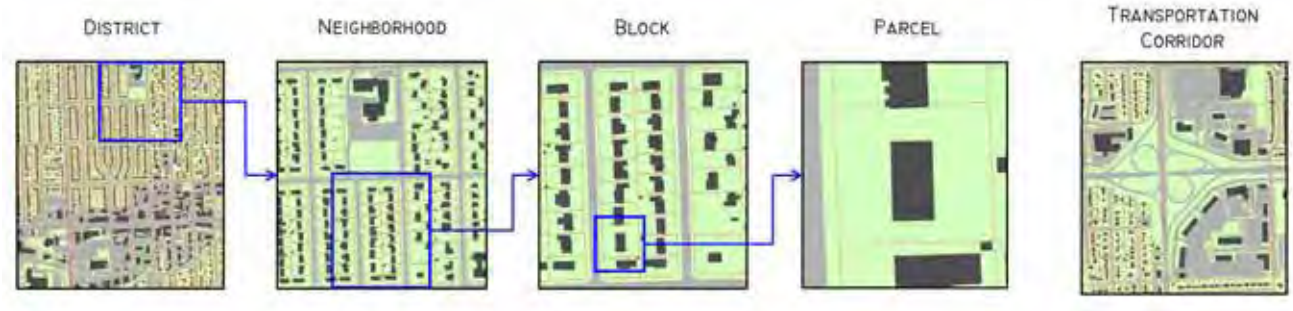
and impervious surfaces, and shallow-rooted vegetation, filtration and infiltration of stormwater that occurs when native vegetation is in place is greatly reduced, and traditional stormwater management quickly sends increased runoff rates and volumes into streams or concrete channels.

1.2 Alternative Stormwater Management

Alternative BMPs for stormwater management emulate natural systems by integrating a variety of dispersed treatments at multiple scales, from backyard rain gardens to district-level biodetention basins (Table 1). They are widely applicable in both urban and rural environments. These treatments can be designed into new developments or retrofit into existing community open spaces, parks, road rights-of-way, side and rear areas of homes and commercial buildings, rooftops of structurally adequate buildings, below parking lots and in many other settings. All aspects of alternative stormwater management can be integrated to contribute to positive community aesthetics and economics.

Table 1 – Suitability of BMP applications at multiple planning and management scales

BMP	Level					
	Parcel		Block	Neighborhood	District	Transportation Corridor
	Residential	Commercial/ Governmental				
Bioretention Area	X	X	X	X	X	X
Wet Detention (Ponds and Lakes)		X	X	X	X	X
Dry Detention Basin		X	X	X	X	X
Filter Strip	X	X	X	X	X	X
Grassed Swale	X	X	X	X	X	X
Green Roof	X	X				
Infiltration Basin		X	X	X	X	X
Infiltration Planter	X	X				
Infiltration Trench	X	X	X			X
Natural/Native Vegetation	X	X	X	X	X	X
Pervious Pavement	X	X	X	X		X
Rain Barrels & Cisterns	X	X				
Rain Garden	X	X	X	X		
Soil Management	X	X	X	X		X
Stormwater Treatment Train	X	X	X	X	X	X
Subsurface Storage		X			X	X
Urban Forest	X	X	X	X	X	X
Vegetated Bioswale	X	X	X	X	X	X
Wetland		X	X	X	X	X



Alternative BMPs, implemented early in the hydrologic cycle, can disperse stormwater and more closely replicate natural hydrology. For example, an approach called the Stormwater Treatment Train™ (STT), a series of alternative BMPs that are sized, engineered and ecologically designed for low maintenance, addresses site-specific stormwater runoff rates and required water quality improvements. The STT is basically a landscape-scale design that slowly moves water through natural features to infiltrate, evaporate, filter and clean stormwater. Flows are not piped or concentrated, but are dispersed and diffused by allowing runoff to slowly move through vegetated swales and prairie plantings rather than pipes. Stormwater can then more effectively re-enter the cycle of soil infiltration, vegetation uptake, evaporation and storage in gardens, landscaping, wetlands and ponds.

1.3 BMP Applications

Alternative BMPs include a variety of methods that are simple and practical in design, yet provide effective stormwater management as well as aesthetic enhancements for urban, suburban, and rural landscapes. These methods can be cost effective to build while providing long-term sustainability for City infrastructure and conservation of Lincoln's water resources. These guidelines presents information on the following alternative BMP types:

- Bioretention Area
- Wet Detention (Ponds and Lakes)
- Dry-Detention Basin
- Filter Strip
- Grassed Swale
- Green Roof
- Infiltration Basin
- Infiltration Planter
- Infiltration Trench
- Natural/Native Vegetation
- Pervious Pavement
- Rain Barrels and Cisterns
- Rain Garden
- Soil Management
- Stormwater Treatment Train
- Subsurface Storage
- Urban Forest
- Vegetated Bioswale
- Wetland

1.4 Examples of BMP Applications

In relatively small areas, alternative BMPs can effectively reduce stormwater runoff volume and velocity, slowing down and reducing stormwater runoff, allowing infiltration, soil storage, and available water for vegetative uptake. The following descriptions show how BMPs can be used in a variety of applications, from small-scale BMPs located within individual parcels to large-scale BMPs potentially spanning a large number of parcels and zoning classes.

1.4.1 Parcel-Level Applications

A variety of BMP types are well suited to implementation in residential parcels (i.e. on the scale of a single homeowner). BMPs at this scale are relatively inexpensive and easy to install and maintain. Taking advantage of these dispersed watershed management opportunities can greatly reduce the need for expensive, large scale infrastructure construction, expansion, and maintenance. Implementation of BMPs within residential parcels not only facilitates stormwater management for a watershed, it also involves citizens in the management process. The installation of rain gardens, vegetated swales, and various other small-scale BMPs provides homeowners with opportunities to mitigate stormwater runoff from their property while also adding

to the aesthetic value of their homes (Figure 1). Alternative BMPs typically can be retro-fitted into existing landscaping or integrated into new landscaping layouts.

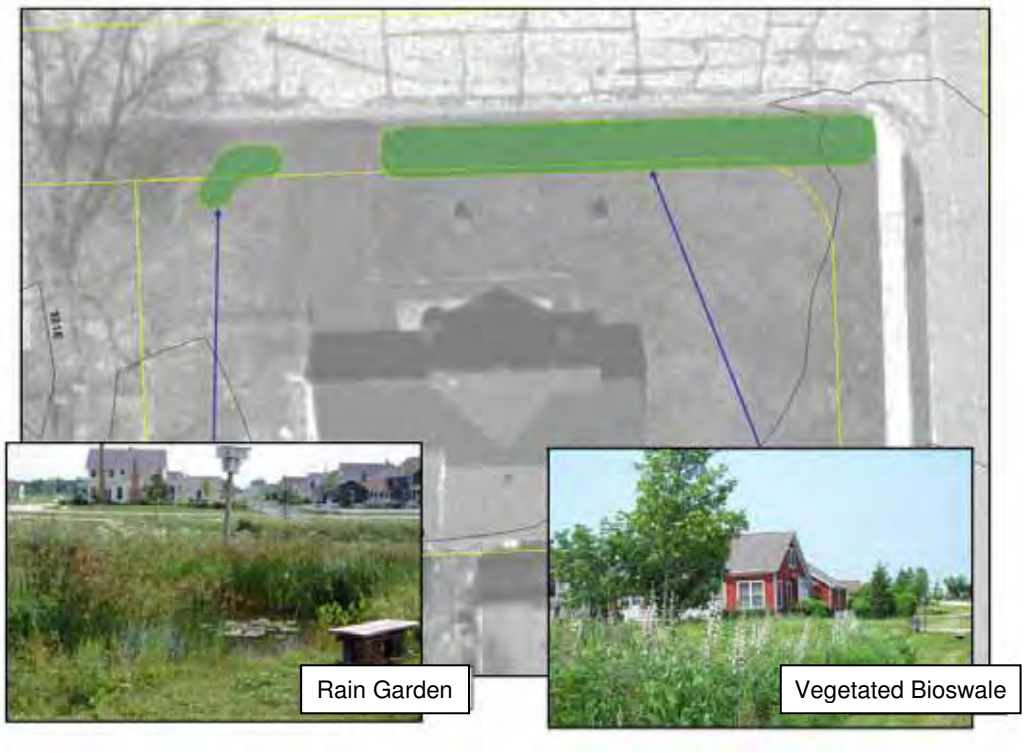


Figure 1: BMP applications at the residential level

Commercial properties by their nature feature extensive areas of impervious surfaces, resulting in large volumes of stormwater runoff. The increased runoff caused by these extensive impervious surfaces can overwhelm the City's stormwater systems and drainageways and rapidly erode and degrade streams. Parking lots are the primary features responsible for creating these increased runoff rates and volumes. They also impair water quality, since water flowing across their surfaces is more likely to pick up sediments and pollutants present there. Though large parking lots are sometimes required to accommodate customers, a variety of BMP types can mitigate these impacts (Figures 2 and 3).

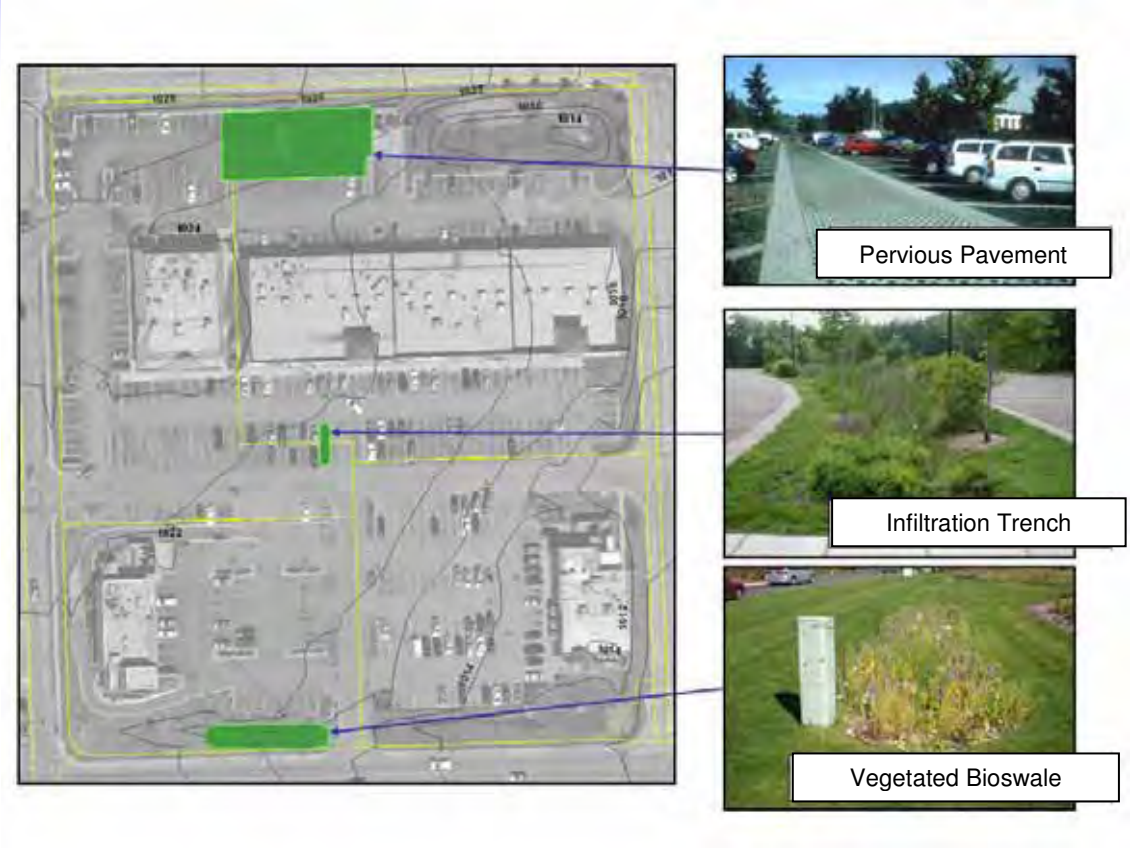


Figure 2: Examples of potential BMP applications in a commercial parking lot

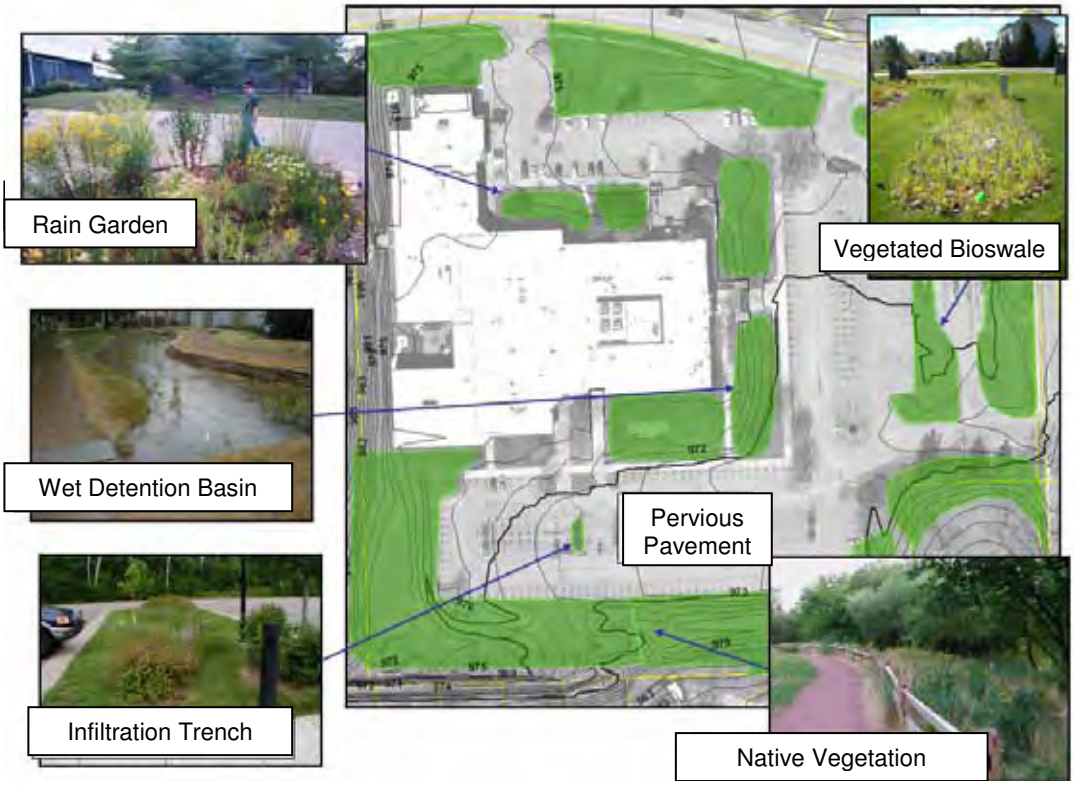


Figure 3: More examples of potential BMP applications in a commercial parking lot.

1.4.2 Block and Neighborhood-Level Applications

At the block- and neighborhood levels, BMPs can be coordinated between landowners and installed across several properties to optimize their impact for controlling stormwater runoff. Neighborhoods may consider installation of rear-yard and road right-of-way interconnected rain gardens and bioswales, pocket parks, and restored wetlands and prairie patches. At the block- and neighborhood-level, BMPs take advantage of open spaces overlapping numerous residential parcels. Sometimes, these open spaces occur in areas held as utility or rights-of-way easements, and they may simply represent management issues for homeowners who must maintain them, but are not able to place improvements on them.

Figure 4: Applications of BMPs at the Block or Neighborhood Level

1.4.3 District-Level Applications

The implementation of bioretention areas, bio-detention basins, infiltration basins, corridor and pocket parks, stream, prairie and wetlands restoration BMPs can be completed for more wide-scale stormwater management.

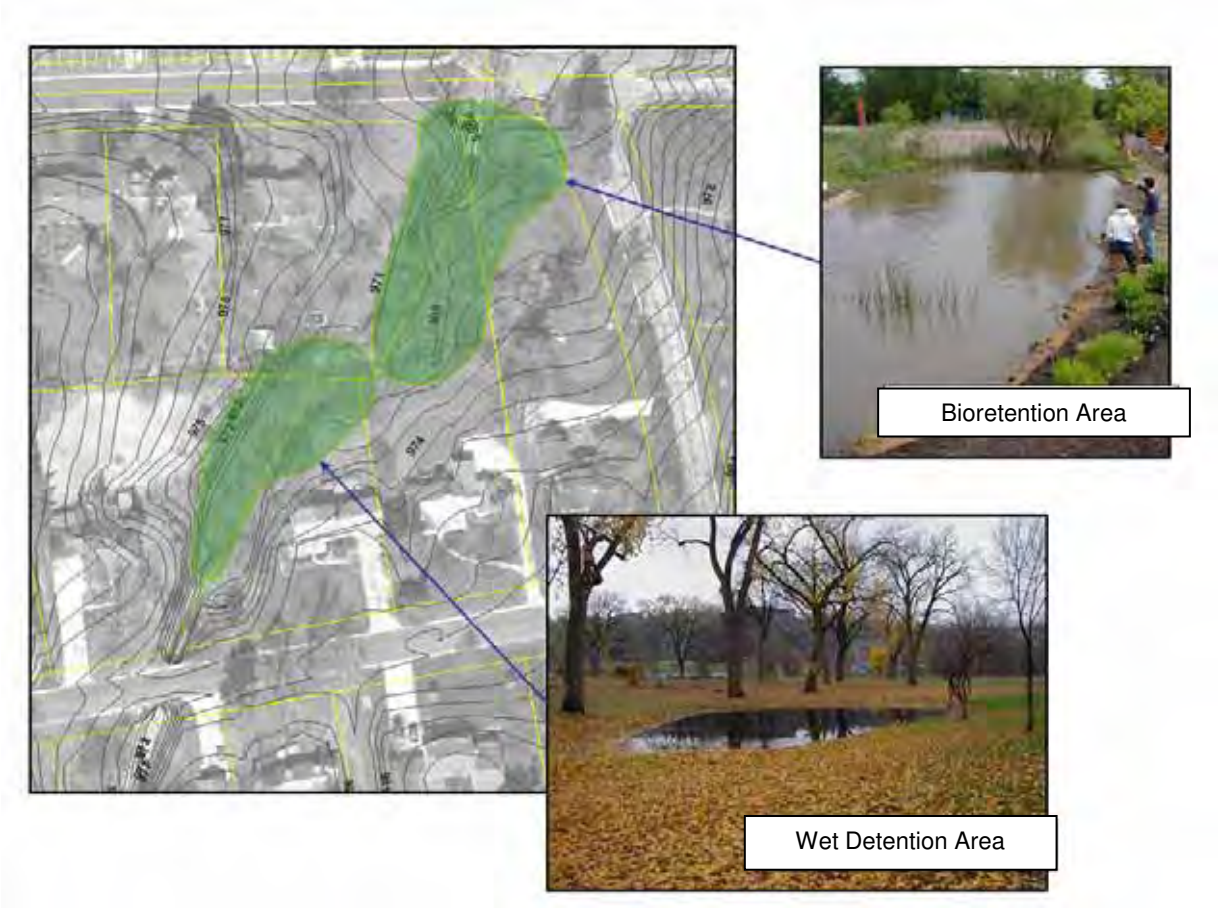


Figure 5: District-level implementations include large-scale BMPs such as bioretention areas and wet detention areas.

1.4.4 Transportation Corridor Applications

Transportation corridors often contain relatively large, open spaces requiring regular maintenance, such as mowing, herbiciding, and erosion control. These areas may be among the only open spaces remaining once an area is fully developed, and offer important opportunities for the implementation of various BMP types. BMPs such as bioretention areas, detention basins, infiltration basins, and prairie and wetland restoration can be implemented within cloverleaf interchanges, while corridor parks, filter strips, infiltration trenches, and vegetated bioswales fit well within road medians and rights-of-way. The selection of appropriate BMPs can be determined by the amount and type of space available, as well as the topography of the transportation features.

Figure 7: Examples of how BMPs can be implemented with transportation corridors

2. BMP SELECTION

Selection of appropriate methods for controlling stormwater runoff requires an understanding of how rainfall, surface water hydrology, soils, and vegetation interrelate. This section provides an overview of stormwater runoff – that is the flow of water after rainfall hits the ground – and information about how soils and vegetation affect the flow of water across the ground, and how paved, impervious surfaces affect stormwater runoff. The second part of this section provides a guideline of how BMPs can be selected for a site.

2.1 Factors Affecting Stormwater Management

Stormwater runoff is a natural part of the hydrologic cycle. The volume and speed of runoff depends on the size of the storm, including how much rain falls in a period of time, and the land features of the area. Land features include the size of the catchment area, the slope of the land, the vegetation (or lack of vegetation) covering the land, and the soil present. An area of land where all of the water that falls flows to, from the highest point to the lowest, is called a watershed. Watersheds are comprised of sub-watersheds drained by streams and tributaries within the watershed.

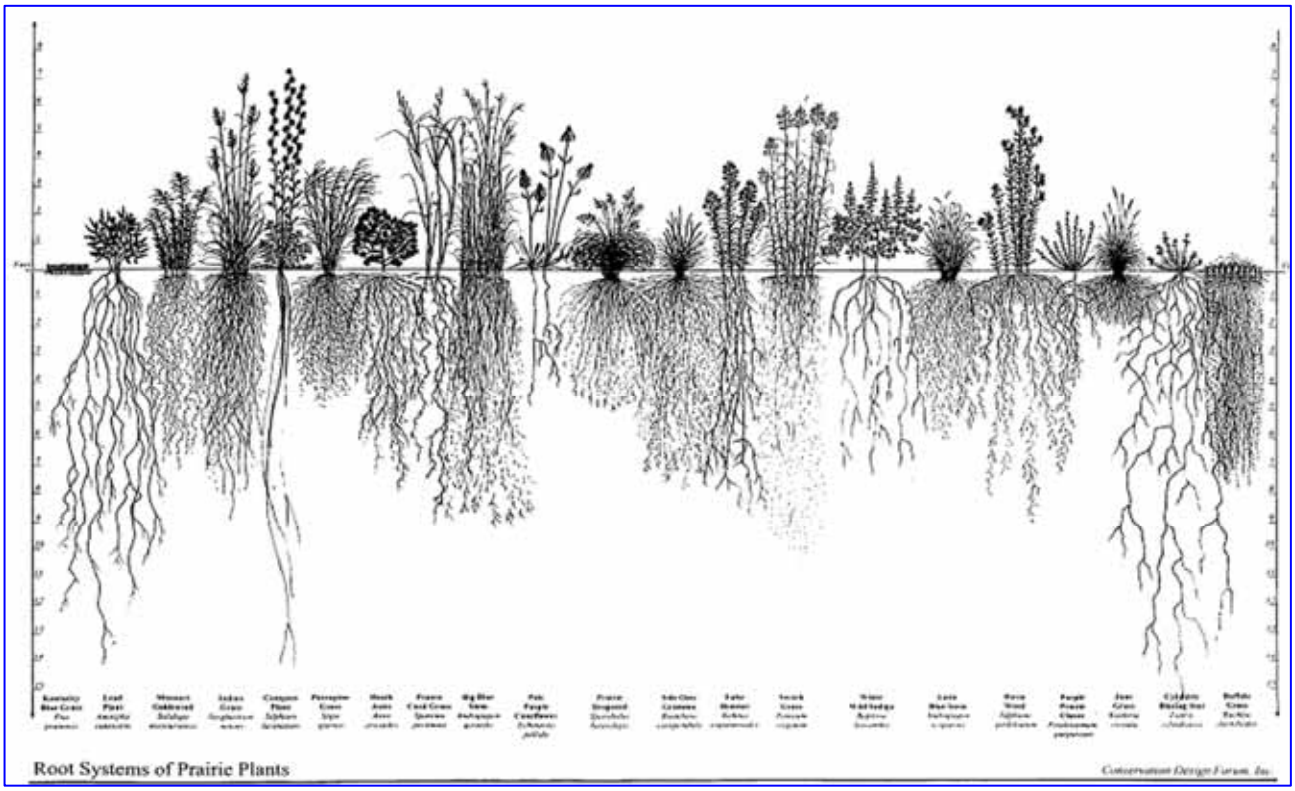
In a natural, undeveloped setting, as rainfall hits the ground it begins percolating into the soil. The amount of rain that will percolate into the soil is controlled by the type of soil and the amount of water hitting it at a given time. Typically, soils with higher amounts of clay, such as many of the soils in and around Lincoln, will rapidly accept water hitting the ground initially, but because water is slow to move through the smaller pores in clayey soils, excess rainfall will runoff. In sandier soils, more water will percolate downward, and less runoff will occur for the same amount of rain.

How fast water runs off the soil is also dependent on the vegetation covering the soil. If thick, dense vegetation is covering the soil, the flow of water across the ground surface is slowed. When slowed in this manner, water has more opportunity to infiltrate into the ground. The more vegetative canopy that there is - the leaves of grass and the branches and leaves of trees and shrubs - the more rain is intercepted and slowed in its descent to the ground, again, allowing more rainfall to either infiltrate into the ground, or to evaporate after the rainfall has stopped.

Dense growth of prairie grasses allows rainfall to infiltrate into the ground.

While the amount of vegetation above the ground affects how much rain can runoff across the ground surface, the amount of vegetative matter below the ground – the roots – also significantly affect how much rain will infiltrate into the soil, or how much may runoff. As roots grow into the soil they create channels in which rainwater will flow down into the ground. In addition, as the roots grow and die from season to season, the organic matter in the soil retains those macro-pores, creating a much more open, permeable soil. As larger roots die and decay, they leave larger macropores, and other biological activity, such as the work of earthworms and insects that thrive in the root-rich soil, create even more macropores for rain to flow into the soil.

Even clay soils, with a high amount of organic matter, can be porous enough to allow substantial amounts of rainfall to infiltrate.



Native plants send their roots deep into the round, contrasted by the roots of turfgrass (left side). The deeper roots open pores into the soil, providing more storage of rain where it falls.

In the Midwest and Plains States, prairie vegetation created deep, organically-rich soils. Rainfall readily infiltrated into the soil where it continued to flow through the subsurface to slowly fill streams and rivers. Native prairie grasses and forbs – flowering plants and shrubs – sent their roots deep into the soil, in some cases in excess of eight feet below the soil surface. This benefits the plants in two ways: first, the deep roots had more access to life-sustaining water so they could withstand the dry periods. Second, the roots provided firm anchors for the plants that allowed them to stay firmly in place and out compete other, non-native plants, and withstand strong flows of water when extreme storm events did occur. In contrast, non-native plants, such as many turf grasses and exotic flowers, have shallow root systems that don't facilitate movement of rain into the soil, nor are these plants well-sustained during dry periods. Because of their shallow roots, rainfall infiltration is limited and more water will be lost as runoff.

With the growth and development of Lincoln, increasing amounts of the once-permeable soil have become paved or planted to turf grasses. With the increased amounts of pavement, the amount of rainfall runoff from the ground surface increases dramatically, flowing quickly, almost un-impeded, to storm drains and their eventual outflow into the streams. Consider that for every acre of paved surface, nearly all of the rain that falls will flow to streams that nature did not design to carry in such quantities or at such velocities.

For comparison, consider the engineering term often used in stormwater design, the runoff coefficient. For impervious, paved areas, such as streets, sidewalks, and parking lots, the runoff coefficient is typically a value from 0.7 to 0.95, meaning that from 70 to 95 percent of rainwater will

run off the site. For vegetated areas, the runoff coefficient will typically have a value from 0.05 to 0.5, depending on the type of soil and the type of vegetation covering the site. As a result, one acre of parking lot can produce 16 times more stormwater runoff than one acre of meadow each year (Maryland Dept. of Environment, 1998). The dramatic increases in stormwater runoff have profound impacts on stream stability and quality, quickly producing flooding, damages to stream banks, and erosion and damage to property.

The goal of alternative stormwater BMPs is to restore some of the capacity of natural systems within developed areas and treat stormwater where it falls, allowing it to infiltrate into the soil, to slow its movement to streams and channels, improve water quality, and to reduce peak flows and floods. The types of BMPs selected to achieve these goals depends on the characteristics of each area as described above. A BMP selection matrix can help determine which BMPs are appropriate for small urban sites (Minneapolis Metropolitan Council Environmental Services, 2001). A summary of the BMP selection matrix is presented on the following pages as an example of an approach Lincoln can use to implement BMPs in our city.

2.2 Stormwater Treatment BMP Selection Matrix

A BMP Selection Matrix that was previously developed is attached to guide the user through three steps that progressively screen:

- BMP suitability for treating stormwater,
- physical feasibility of implementing the BMP(s), and
- community and environmental factors.

The full version of the BMP selection matrix is provided in Attachment A.

Step 1 assesses the suitability of the BMP for treating stormwater with the following question: Can the BMP meet the stormwater rate, volume, and water quality treatment requirements recommended or potentially mandated in the future by local regulations, or are a number of BMPs needed? The designer uses the matrix to determine if a particular BMP can meet the rate, volume, and water quality requirements identified in the site characterization. If a particular BMP cannot meet the rate control or volume reduction criteria, it does not mean the BMP should be eliminated from consideration, but that other BMPs may be necessary to achieve these goals.

This step also assesses the potential of the BMP to improve water quality by evaluating four criteria: Total Suspended Solids (TSS), phosphorus and nitrogen, metals, and fecal coliform. The ability of the BMP to provide “benefits” in regard to each criteria are ranked as “primary,” indicating that the BMP has a primary affect of controlling the pollutant; “secondary,” indicating that there may be some benefit, and “minor,” indicating that the BMP has little or no benefit in controlling the pollutant.

Step 2 asks: Are there any physical constraints at the site that may restrict or preclude the use of a particular BMP? In this step, the designer uses the matrix to determine if the soils, water table, drainage area, slope or hydraulic head conditions present at the site might limit the use of particular BMPs. This step evaluates BMPs by six primary factors:

- Soils: information based on data from USDA-NRCS soil surveys for the site.
- Water table: indicates the minimum recommended depth to the seasonally-high water table from the floor of the BMP.
- Drainage area: indicates if the BMP is suitable for small sites.

- Head: provides an estimate of the elevation difference needed at a site to allow for gravity operation within the BMP.
- Area requirements: examines the typical space or area requirements for a BMP.
- Ability to accept hotspot runoff: this examines the ability of the BMP to accept and treat runoff from an exceptionally contaminated hot spot. This last criteria may or may not be relevant to the BMP selection for a particular site.

Step 3 asks: Do the remaining BMPs have any important community or environmental benefits or drawbacks that might influence the selection? The designer uses the matrix to compare BMP options with regard to:

- Maintenance: this criteria assesses the relative maintenance effort for the BMP relative to frequency of inspection, scheduled maintenance, and chronic maintenance problems.
- Community acceptance: This criteria assesses the Community acceptance as measured by market and/or preference surveys, potential or reported nuisance problems, and visual orientation (prominence or attractiveness).
- Construction cost: BMPs are ranked according to their relative construction costs per impervious acre treated.
- Wildlife and/or natural habitat: BMPs are evaluated for their ability to provide wildlife or wetland habitat.

3. BMP DESCRIPTIONS

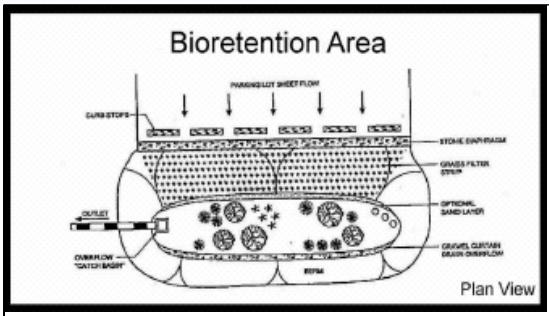
The following pages provide descriptions of nineteen BMPs that can be implemented in Lincoln for effective stormwater management. As has been described in these guidelines, these descriptions provide basic information to provide ideas of how and what practices can be used. This guide presents several practical site design and drainage Best Management Practices for developments in the City of Lincoln. Most of the BMPs apply to residential, commercial and industrial developments. All of them are effective in reducing the quantity and improving the quality of stormwater runoff. The following information is presented for each of the recommended BMP approaches:

- Description
- Effectiveness
- Advantages and Disadvantages
- Implementation Considerations
- Cost
- Main Design Components

The following BMP descriptions are provided:

- Bioretention Area
- Wet Detention (Ponds and Lakes)
- Dry Detention Basin
- Filter Strip
- Grassed Swale
- Green Roof
- Infiltration Basin
- Infiltration Planter
- Infiltration Trench
- Natural/Native Vegetation
- Pervious Pavement
- Rain Barrels and Cisterns
- Rain Garden
- Soil Management
- Stormwater Treatment Train
- Subsurface Storage
- Urban Forest
- Vegetated Bioswale
- Wetland

3.1 Bioretention Area

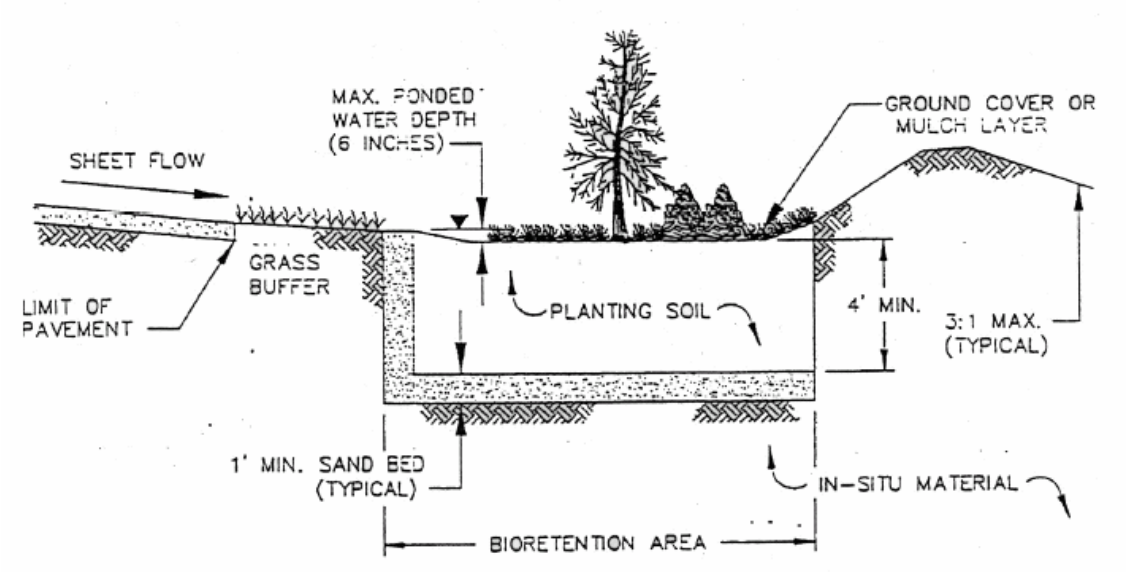


Bioretention Area at 63rd Street and Platte. Lincoln

Description	Bioretention areas are soil- and plant-based stormwater management practices that filter runoff from developed sites by mimicking natural vegetated systems; these naturally control hydrology through infiltration and evapotranspiration. A typical application for a bioretention area is to infiltrate and treat surface runoff from parking lots, in which the bioretention area may consist of a recessed, slotted-curb parking island. Bioretention areas are small vegetated depressions into which surface water is diverted. Stormwater flows into the bioretention area, ponds on the surface, and gradually infiltrates into the soil bed. Pollutants are removed by processes that include adsorption, filtration, volatilization, ion exchange, and decomposition. Treated water is allowed to infiltrate into the surrounding soil, or is collected by an underdrain system and discharged to the stormwater system or directly to receiving waters.
Effectiveness	Improves water quality. According to estimates, bioretention areas have the potential to remove 90 percent of suspended solids, 65 percent of phosphorous, 50 percent of nitrogen, and 80 percent of metals from stormwater.
Advantages	• Provides effective stormwater flood control by slowing down runoff and increasing water infiltration into the soil. • Minimally consumes land. • Reduces site runoff. • Provides aesthetic enhancement. • Increases groundwater recharge. • Can be used as a stormwater retrofit.
Disadvantages	• Should not be installed until the entire contributing drainage area has been stabilized. • Requires proper plant selection and maintenance.

Disadvantages	• Susceptible to clogging by sediment, may require pretreatment. • Treats a relatively small drainage area.
Implementation Considerations	• Pine mulch and wood chips are not acceptable in the mulch layer because they are displaced during storm events. • Provide clean-out pipes on the underdrain to facilitate cleaning. • Incorporate a uniform mix of the planting soil during construction so that stormwater infiltrates evenly and does not create preferential pathways. • Minimize compaction of the base and planting soil as compaction results in design failure because it reduces infiltration. • Vegetation for the bioretention area should consist of native plant species with hydric tolerances. Do not place woody vegetation near the stormwater inflow location. Plant trees primarily along the perimeter of the bioretention area. • Water should remain on site for less than 48 hours to prevent mosquito breeding.
Cost	Typical costs can be from $0.50 to over $1.00 per cubic foot (USEPA, 1999). Cost range reflects economies of scale in designing detention basins.
Main Design Components	• The surface area of the bioretention system should be between 5 to 10 percent of the impervious area it is draining. • Bioretention areas are best applied to areas with relatively shallow slopes (usually about 5 percent or less). • Bioretention areas can be applied in almost any soils as runoff percolates through a made soil bed and is returned to the stormwater system. It is also possible to design a bioretention system like an infiltration system. • Bioretention should be separated from the water table to ensure that the groundwater does not intersect with the bottom of the bioretention area. A typical bioretention system involves the following components: • Pretreatment: Because bioretention areas are susceptible to clogging from sediments, pretreatment to remove suspended sediments is recommended. • Ponding area: A ponding area provides surface storage of stormwater before it filters through the soil bed. • Organic mulch layer: This layer protects the soil layer from erosion, retains moisture to sustain plants, and provides a medium for biological activity to decompose organic pollutants and adsorb inorganic pollutants. • Planting soil bed: Provides water and nutrients to support plant life in the bioretention system. Stormwater filters through the planting soil bed where pollutants are removed by sorption and biodegradation. • Under-drain: An under-drain is a perforated pipe in a gravel bed installed along the bottom of a sand bed to collect and filter stormwater directing it to an outflow or stormwater systems.

Main Design Components	• Provide redundant overflow structures to convey flow from large storms to the storm drain system. • Plants: Plants are an important component of a bioretention system. They remove water through transpiration, remove pollutants, enhance soil biological activity, and promote water infiltration. The plant species selected should replicate a native forest or grassland system, and be able to survive flooded conditions.



Example of the Basic Lay-Out of a Bioretention System

3.2 Wet Detention (Ponds and Lakes)

Kennedy and Rockford Drive Pond, Lincoln

Description	Wet detention is typically a constructed pond or lake, or it may be a pond or lake incorporated into a stormwater treatment system. They are generally considered "end-of-the-pipe" BMPs. Lakes and ponds are standing bodies of water defined in terms of capacity, effective height, and effective storage. Lakes are larger than ponds, generally with total storage greater than 50 acre-feet, and the product of the effective height (in feet) and effective storage (in acre-feet) greater than 1,250. All developments involving lake and pond construction must conform to local, state, and federal regulations. Preserve undisturbed ponds and lakes during development according to federal and state laws and regulations. Preserving the natural drainage system, instead of replacing it with stormwater systems or concrete channels, reduces the potential for downstream degradation because of increased runoff. Ponds can be modified to increase their storage capacity and enhanced with vegetation to increase their water-quality treatment effectiveness. The primary pollutant removal mechanism in wet detention is sedimentation, with a moderate to high potential for removing metals, nutrients, and organics. Since wet ponds have the capability of removing soluble pollutants, they are suitable for sites where nutrient or pollutant loads are expected to be high.
Effectiveness	Efficient pollutant removal. Studies indicate that wet detention ponds can remove up to 50 to 90 percent of suspended solids, 30 to 90 percent of total phosphorous, 40 to 80 percent of soluble nutrients, 40 to 80 percent of metals, and 20 to 40 percent of biochemical compounds.

Advantages	• Improve runoff control, including reductions of overall runoff from adjacent sites with proper design. • Create wildlife habitat. • Encourage community recreation facilities. • Aesthetically pleasing. • May increase property values. Requires significantly less expense for maintenance if natural vegetation is used along the banks.
Disadvantages	• Reduces the amount of developable land. • May require approval from dam safety authorities. • May require maintenance at regular intervals to remove sediments deposited in the base of the pool. • If not designed or maintained correctly, could become a mosquito vector.
Implementation Considerations	• Vegetation on dams may need to be monitored and invasive species removed. • May require cleaning and removal of debris after major storm events. • May require removal of accumulated sediment. • May require monitoring and maintenance of erosion in the emergency spillway during establishment of vegetation.
Cost	Variable, depending on the size and amount of construction needed to create the lake or pond. Typical costs can be from $0.50 to over $1.00 per cubic foot (USEPA, 1999). Cost range reflects economies of scale based on the size of the pond, as well as pre-existing conditions.
Main Design Components	• Storage volume: The City of Lincoln has established requirements in the Drainage Criteria Manual. • Sediment control: A sediment forebay is highly recommended. • An emergency spillway should be included in the basin design. • The basin should include a low-flow drain to assist in maintenance of the detention area. • Sediment storage life span. Typically, in most areas, the 25-year sediment volume is calculated for the pond. • Pond or lake depth: An average pool depth of 3 to 6 feet is recommended. Depths greater than 10 feet may have thermal stratification and anoxic conditions. Depths less than 3 feet increase sediment resuspension, water temperature, and algal blooms. • Flow path: Maximize the flowpath length between the inlet and outlet. The length to width ratio should be at least 3:1.

Main Design Components	• Slopes: Side slopes of a permanent pool should not be greater than 3:1. Flatter slopes minimize bank erosion. Slopes leading to the pool should be less than 3:1. • Inlet points should be designed with energy dissipaters to reduce inflow velocity.

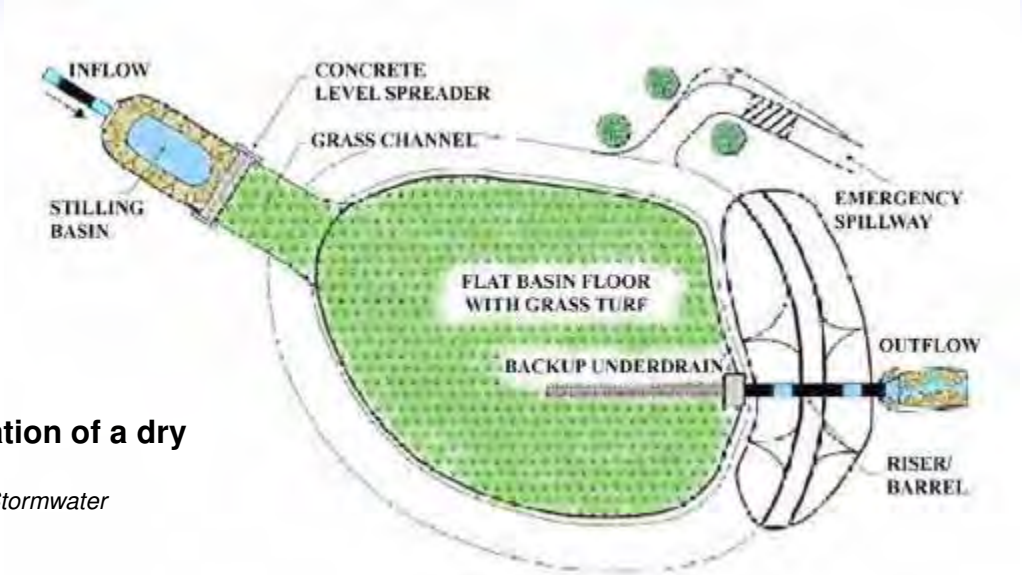
Holmes Park Road and Sherman Street, Lincoln

3.3 Dry Detention Basin

Dry Detention Basin at NW 12th St & Keating Drive,

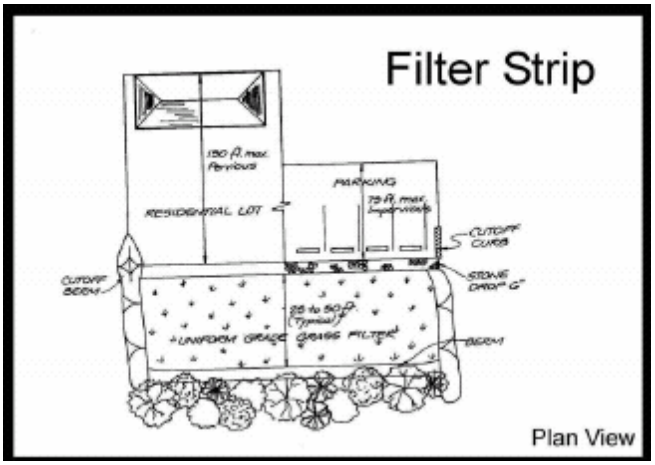
Description	Dry detention basins, also called dry ponds, are stormwater basins that are designed to intercept a volume of stormwater runoff and temporarily impound the water for gradual release to the receiving stream or stormwater system. Dry detention basins are typically on-line, end-of-pipe BMPs. Dry detention basins are designed to completely empty out between runoff events, typically within 48 hours, and therefore provide mainly runoff control as opposed to water quality control. They can provide limited settling of particulate matter, but a large portion of this material can be resuspended by subsequent runoff events. Detention basins can limit downstream scour and loss of aquatic habitat by reducing the peak flow rate and energy of stormwater discharges. As a general rule, dry detention basins should be designed for drainage of areas greater than 10 acres. In many areas, the detention basins, when dry, can be used for other recreational purposes.
Effectiveness	Detention basins may remove from 10 to 90 percent of suspended solids depending on the volume of stormwater held in the basin, and how long it resides there. Removal of pollutants is less efficient, and generally contingent on holding period of stormwater, which is typically substantially greater than the holding period required for reducing the peak period of storm periods.
Advantages	• Reduces peak flow rate and energy of stormwater discharges, therefore limiting downstream erosion and scouring. • Good potential for removal of sediments. • Can be used for recreation when dry. • Can serve as green space, supporting wet prairie functions and wildlife habitat. • Using native plants reduces mowing costs.

Disadvantages	• Generally not prescribed for drainages less than 10 acres. • Potential for clogging of outlets. • Can be considered unattractive by residents if not designed or maintained correctly. • Limited ability to remove pollutants. • Depending on size and volume of stormwater capture, basin designs may require approval of dam safety authorities.
Implementation Considerations	• The required volume of the dry detention basin, called the "flood storage volume," is dependent on the City's policies as provided in the City's Drainage Criteria Manual. Typically, storm volumes ranging from the 2- to the 100-year events are required. • A detention time of 48 hours or less should be targeted. Water should not remain more than 48 hours after a runoff event. • Smaller drainage areas can be considered if the dry detention is part of a stormwater treatment train. • Maximum depth of water, when full, should be 6 to 10 feet.
Cost	Costs may range from less than $1.00 to more than $1.50 per cubic foot of detention, depending on the size of the basin. Costs will also vary depending on the existing condition, vegetation, and amount of excavation and construction to be completed.
Main Design Components	• The outlet area should be a deeper micropool to provide final settling and prevent resuspension of sediments. The outlet pipe should be located in the pond embankment wherever possible for ease of maintenance. • In some cases, emergency spillways should be included in the basin design. • The basin should include a low-flow drain to assist in maintenance of the detention area. • Proper design and maintenance of the embankments will prolong the integrity of the basin structure. The embankments should have minimum side slopes of 3:1 and a top width of at least 4 feet, and should be well vegetated. • A low flow vegetated channel may need to be installed in the basin to ensure that the basin dries out completely between storm events. • Scour control is important to maintain the function of the dry detention basin and reduce erosion. • All federal, state, and local permit requirements must be established prior to construction of the dry detention basin.



Typical configuration of a dry detention basin
Source: Pennsylvania Stormwater Management Manual

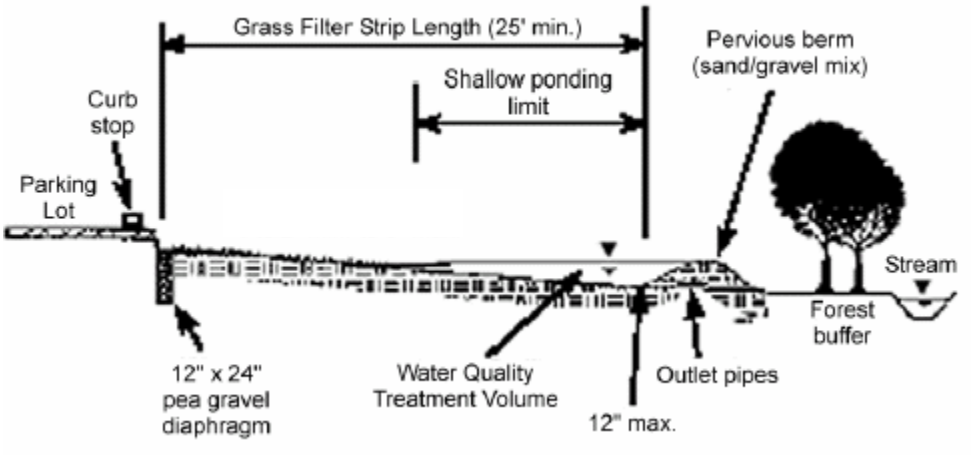
3.4 Filter Strip



Description	Filter Strips are densely-vegetated, often grassed practices that accept sheet flow runoff from adjacent surfaces. They slow runoff; filter out sediment and other pollutants; and enhance infiltration of surface water runoff. Use filter strips to treat shallow sheet flows and evenly distribute storm flows over very short contributing distance areas. Filter strips are well suited to areas adjacent to parking lots and other impervious surfaces where runoff can be conveyed and filtered before it is discharged into swales, stormwater systems, or surface water bodies. Filter strips are also appropriate for construction sites and developing land to filter sediment from overland sheet flow. Well maintained filter strips can be very effective in reducing runoff volumes, particularly when the impervious drainage area is not overly large. Filter strips are most effective in reducing surface runoff volumes – by up to 40 percent – for small storm events (storms up to the magnitude that may occur, on average, once every year or every other year).
Effectiveness	Depending on the type of vegetation and the size of the filter strip, effectiveness of this BMP will vary. Filter strips with dense, high vegetation can remove up to 80 percent of suspended solids. Filter strips utilizing grass only, particularly turf grass, are much less effective in slowing water and/or removing solids. If the filter strip is constructed with porous media in which water will readily infiltrate, the removal capability for sediments and pollutants will be as high as 98 percent (USEPA, 1999).
Advantages	• Provides effective stormwater flood control by slowing down runoff and storing water, including water infiltration into the soil. • Improves water quality by filtering pollutants from stormwater (oils, greases, metals, and sediments that can be picked up from paved surfaces).

Advantages	• Can be used as a system by itself, or in conjunction with other BMPs. • Easy to plan and build. • Reduces erosion. • May help maintain temperature of receiving waters. • Flexible to incorporate existing natural features and a variety of vegetation types. • Preserves natural/native vegetation and provides habitat for wildlife. • Protects adjacent properties.
Disadvantages	• Need to maintain vegetative cover for controlling erosion and reducing particulates in the runoff. • Not appropriate for hilly or highly impervious terrain. • Requires maintenance to remove trash.
Implementation Considerations	• The maximum drainage area into the filter strip should be 5 acres. • The filter strip width (dimension perpendicular to the flow path) should be as close to the width of the impervious area flowing into the filter strip as practical. • The filter strip length (dimension parallel to flow) depends on the filter strip width and drainage area. • The maximum slope of a filter strip should be 6 percent, unless additional flow spreader devices are installed every 100 feet to maintain sheet flow.
Cost	Low. In most cases there is no additional cost associated with establishing filter strips. Typically, all that is required is to direct runoff to an open vegetated area rather than a stormwater system. Costs may range from $0 to $1,200 per 1,000 square feet, depending on site preparation and vegetation.
Main Design Components	• Filter slopes should be no less than 1 or 2 percent slope, and no greater than 6 percent. Greater slopes will encourage concentrated flow and flatter slopes may result in ponding. • Top and toe of slope should be as flat as possible to encourage sheet flow. • Concentrated flow should not be dischared into filter strips. If flow are concentrated, a level spreader should be included to spread the flow over the entire length of the filter strip. • To enhance the effectiveness of the filter strip, install a pervious berm of sand and gravel at the toe of the slope. • Select plants that are able to withstand flowing water and both wet and dry periods.

Main Design Components	• Depending on adjacent land use and traffic, filter strips may require fencing to control destructive access by vehicles, pedestrians, and animals. • Filter strips are typically designed to handle flows from 1- to 2-year storm events and are usually not able to reduce flows from larger storms.



Typical design cross section for a filter strip

3.5 Grassed Swale

Source: City of Eugene Stormwater Management Manual

Description	Grassed swales are low-cost alternatives to conventional hard-engineered conveyance in residential and commercial neighborhoods. Like Vegetated Bioswales (page 69), they consist simply of a shallow channel, or swale, that conveys water down a slight gradient away from its source. As runoff travels down the swale, suspended solids and pollutants settle out, preventing them from entering stream systems.
Effectiveness	Grassed swales are most effective for dispersing the flow of stormwater across a greater area and distance. Grassed swales are not significantly effective for removal of suspended sediments or pollutants.
Advantages	• Less expensive than conventional, hard-engineering conveyance practices, in both the initial construction and maintenance phases. • Encourages infiltration.
Disadvantages	• Less effective than vegetated bioswales at filtering and reducing rates and volumes of runoff. • Swales can only treat a limited area.
Implementation Considerations	• Deep-rooted native grasses and wildflowers facilitate more effective infiltration and pollutant filtration, and a greater reduction in flow rates and volumes than conventional turfgrasses such as Kentucky bluegrass. • Mowing of grassed swales should be avoided, or should be done as infrequently as possible. • Extent of drainage area. • Planning and engineering of effective treatment train appropriate for each area. • Determine the necessary space and length to achieve stormwater management goals and water quality.

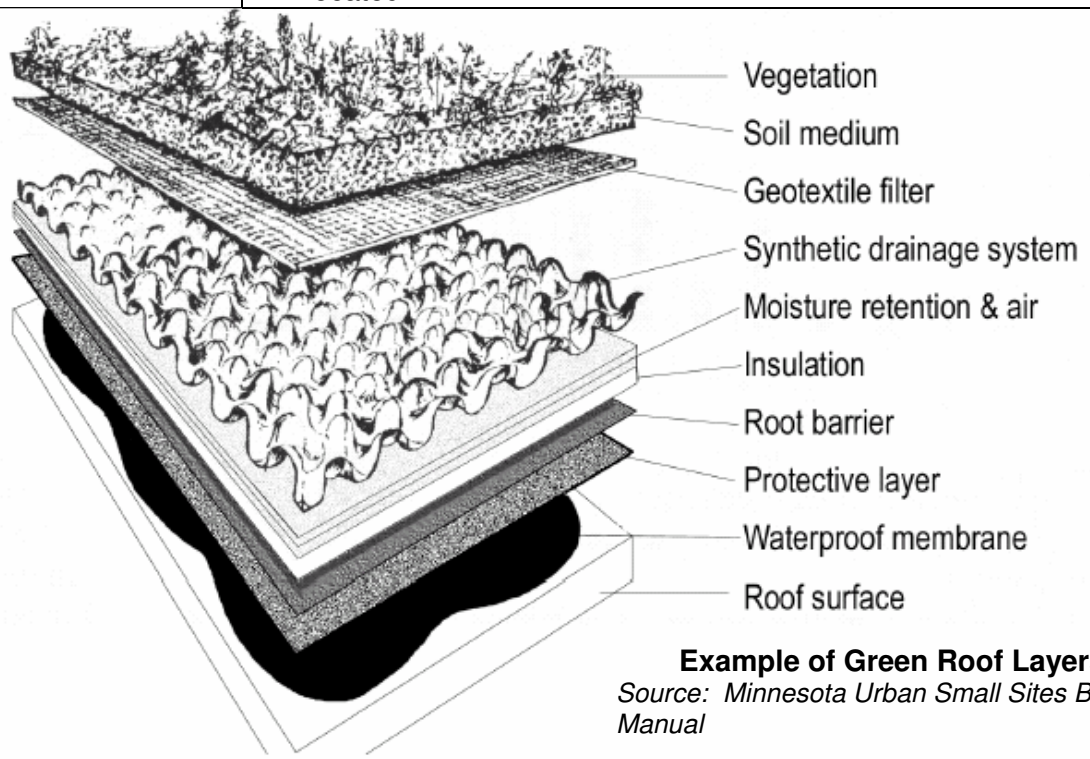
Cost	Low – less than costs for traditional hard-engineered practices. Generally, approximate costs will range from $0 to $375 per 1,000 square feet, depending on preparation and final planting (seed vs. sod).
Main Design Components	• Minimize slope (< 4:1) and depth of the swale to prevent erosion of side slopes. • Channel bottom should be relatively flat to prevent channelization that would lead to increased erosion. • Runoff should be distributed uniformly across the channel bottom at its entry point. • The bottom of the swale should be at least three feet above groundwater in order to prevent the swale bottom from remaining too wet. • The flat channel bottom should be between two and eight feet wide to ensure sufficient filtering surface for water quality treatment. • Unless existing soils are highly permeable, they should be replaced with a sand/soil mix that meets minimum permeability requirements. • An underdrain system may also be installed under the soil bed. Typically, the underdrain system is created by a gravel layer which encases a perforated pipe

3.6 Green Roof

Description	Green roofs have been used for hundreds, if not thousands of years, from sod roofs in Europe to sod houses in the Great Plains of the United States. What have changed are the materials, designs and new implementations of green roof technology. Further, a greater understanding on how green roofs function has led to using green roofs for stormwater management and building climate control. Essentially a green roof consists of placing layers of plants and rooting medium over a traditional roofing system. Green roofs are grouped into two categories: extensive and intensive. Extensive roofs are lightweight systems of manufactured root medium which typically have low plant diversity; they are more easily incorporated into conventional building construction and require little maintenance. Intensive roofs typically use a deep rooting medium such as topsoil and can incorporate a wide variety of plants but require special considerations due to higher roof loading and greater maintenance.
Effectiveness	Depending on the type of green roof used, effectiveness will vary. In most situations however, nearly all configurations will effectively reduce the volume of runoff from rooftops. If runoff is maintained through a constructed soil media, filtering capacity of sediments and pollutants may be higher than 80 percent.
Advantages	**Extensive** • Can reduce summer cooling costs. • Low maintenance. • Placement on up to 25-30° roof pitch. • Lightweight. • Suitable for retrofit. • Easier to install. • Slow stormwater runoff.

Advantages	• Aesthetically pleasing. • Provides insulation for roof. • Extends life of roof. • Reduction in impervious area for the property. **Intensive** • Greater plant diversity, better aesthetics. • Good insulation properties. • Potential access for recreation. • Slower stormwater runoff, larger detention capacity. • More amenable to wildlife. • Reduction in impervious area for the property.
Disadvantages	**Extensive** • Unattractive to some, especially in winter. • Limited plants, native species may not be possible. • No access for recreation. **Intensive** • Greater roof loads. • Expensive design and construction. • Irrigation and drainage systems necessary. • Higher maintenance than extensive roof. • Potential fire hazard during dormant season, especially with native plants.
Implementation Considerations	• Public outreach and acceptance for existing developments or communities. • Load-bearing capacity of roof structure and building. • Mechanisms to address fire hazard. • Life of the structure.
Cost	High (initial capital costs). Costs will vary depending on roof size and materials used. Low (life cycle replacement and resurfacing costs), additional cost savings through reduced summer cooling costs.

Main Design Components	• The load-bearing capacity of the underlying roof structure is critical in the design of a vegetated rooftop. Generally, greenroofs weighing more than 17 pounds per square foot saturated require consultation with a structural engineer. • Flat roofs are easiest to design and install. The maximum slope for a green roof is about 25 percent. • Follow federal and state standards for wind resistance. Since uplift pressures tend to be higher at roof corners, these areas may be considered for vegetation-free zones. • Monolithic membrane, applied as a hot liquid, provides superior waterproofing. • Protective layers are placed on top of waterproofing, including root barriers to prevent roots from damaging the waterproof layers. • A drainage system needs to be designed that will retain water for plant uptake, and retain excess water for storage. • Soil for green roofs are lighter than typical soil mixtures, generally with about 75 percent mineral matter, and 25 percent organic matter. • A range of plants are suitable for green roofs. In Lincoln, native plants offer a variety of opportunities to create effective vegetative schemes. For extensive roofs (shallow soil systems), shallow-rooted plants that can withstand heat and drought are best. • It is esential to mark the position of roof drain outlets and irrigation pipe inlets before installing protective layers so they can be easily located.



Example of Green Roof Layers.
Source: Minnesota Urban Small Sites BMP Manual

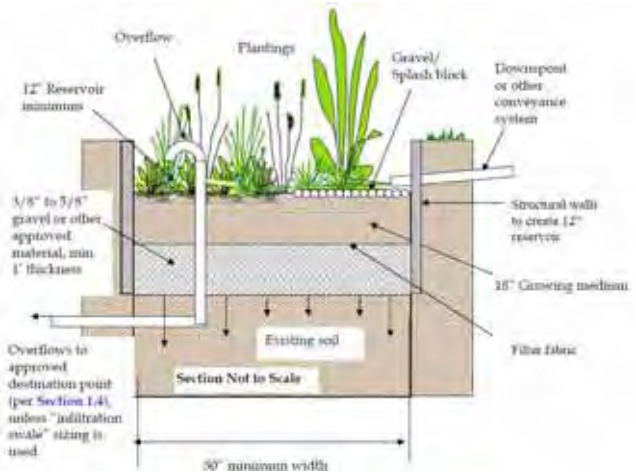
3.7 Infiltration Basin

Description	An infiltration basin is an impoundment designed to capture stormwater runoff and allowing it infiltrate into the ground over a period of a couple of days. It does not retain a permanent pool of water. Infiltration basins are typically off-line, end-of-pipe BMPs that vary is size and shape. The infiltration basins described in this section typically treat water from larger areas, from multiple lots to large parking lots, to broad areas such as neighborhoods. Infiltration basins use existing soil and vegetation to facilitate percolation of water into the ground and evapotranspiration of water through vegetation into the atmosphere. Vegetation is key to success of the infiltration basin. Deep-rooting vegetation will enhance infiltration of water while also staying well-anchored against disturbance from water or other factors. Another key element of the infiltration basin is having enough area to maintain a shallow pool that will infiltrate within 48 hours or less.
Effectiveness	Infiltration basins may remove from 10 to 90 percent of suspended solids depending on the volume of stormwater held in the basin, and how long it resides there. Removal of pollutants is dependent on the soil media and the ability to adsorb or decompose pollutant compounds. Removal of pollutants is contingent on the holding period of stormwater, which typically is substantially greater than the holding period required for reducing the peak period of storm periods.
Advantages	• Reduces peak flow rate and energy of stormwater discharges, therefore limiting downstream erosion and scouring. • Can be used for recreation when dry. • Can help to maintain baseflow of nearby streams. • Can serve as greenspace, supporting wet prairie functions and wildlife habitat. • Reduces local flooding.
Disadvantages	• Generally not prescribed for drainages greater than 10 acres. • Potential for fouling infiltration capacity of the soil if runoff is sediment-laden.

Disadvantages	• Can be considered unattractive by residents if not designed or maintained correctly.
Implementation Considerations	• Re-Vegetation: For existing unvegetated areas or for infiltration basins that require excavation, vegetation may be added. Planting in the infiltration area will improve water quality, encourage infiltration, and promote evapotranspiration. This vegetation may range from a meadow mix to more substantial woodland species. The planting plan should be sensitive to hydrologic variability anticipated in the basin, as well as to larger issues of native plants and habitat, aesthetics, and other planting objectives. The use of turf grass, which requires frequent mowing is discouraged due to soil compaction. • A grassed Infiltration Basin can be used for recreation in dry periods. Heavy machinery and vehicular traffic of any type should be avoided so as not to compact the infiltration area. • Soil infiltration tests should be conducted. For soils with poor infiltration rates, a layer of sand (6") or gravel can be placed on the bottom of the Infiltration Basin, or the soil can be amended to increase the permeability of the basin. • This BMP is not practicable in areas with high water tables. Guidelines for infiltration should be considered, including depth of water table, permeability of soils, and vegetation types.
Cost	The cost for infiltration basins are relatively low, ranging from less than $0.50 to more than $1.30 per cubic foot depending on size and existing conditions.
Main Design Components	• Uncompacted sub-grade. • Soil Infiltration Guidelines and Soil Testing Protocols apply. • Preserve existing vegetation, if possible. • Design to hold/infiltrate volume difference in 2-yr storm. • Provide stormwater overflow through engineered outlet structure. • Allow 3 ft buffer between bed bottom and seasonal high groundwater table and 2 ft buffer for rock. • When possible, place on upland soils. • The slope of the infiltration basin should be flat or less than 1 percent. • There should be at least 2 feet of freeboard between the invert out and the top of the berms. • Inlets should have erosion protection.

3.8 Infiltration Planter

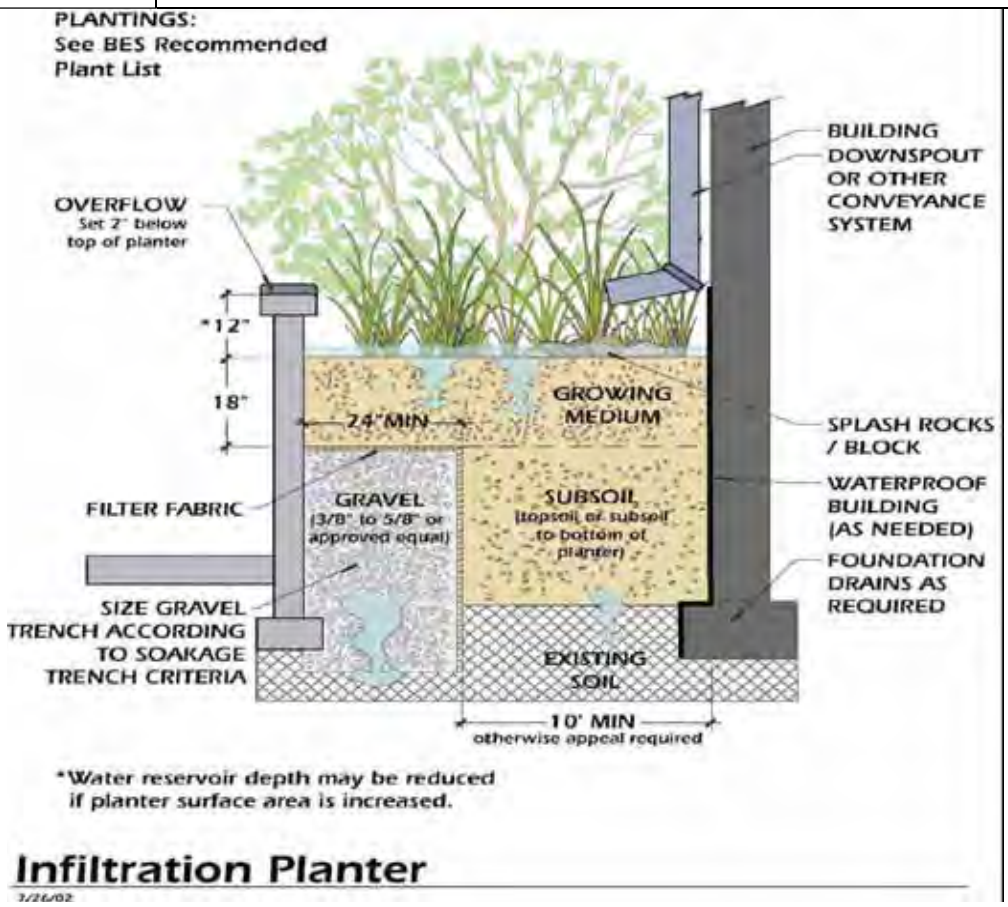
Source: City of Eugene Stormwater Management Manual



Source: City of Eugene Stormwater Management Manual

Description	Infiltration planters are raised structural planting beds that filter and infiltrate runoff from surrounding rooftops, parking lots, or sidewalks. They can be installed in a variety of sizes and styles, integrating an endless variety of plants, to suit any architectural style. Infiltration planters work well at the scale of individual residential, commercial, residential, or governmental parcel levels.
Effectiveness	Infiltration planters have limited capability to reduce significant amounts of runoff, with limitations based on the receiving area of runoff flowing to the planter, and the size of the planter itself. For runoff that enters the planter, removal of sediments and pollutants is high, often exceeding 80 percent.
Advantages	• Provides filtration of pollutants, as well as infiltration of runoff. • Reduces flow rates and volumes. • Suitable in areas with limited space. • May be used as part of a traditional landscaping plan. • Should reduce the amount of watering necessary to maintain vegetation.
Disadvantages	• Though infiltration planters will require less watering than traditional landscaping, they may require maintenance to prevent clogging of permeable medium.
Implementation Considerations	• Requires soils that allow at least two inches of infiltration per hour. • The walls of the planter should allow up to a foot of standing water to accumulate for less than twelve hours at a time. • A minimum of three feet of permeable medium (washed gravel or other aggregate) should exist between the bottom of the growing medium (topsoil) and above impermeable layers or seasonally high water table.

Cost	Overall relative costs are expected to be low, with costs dependent upon construction materials and the size of the planter. Costs on a unit basis (cubic foot) are expected to be higher than other BMPs.
Main Design Components	• Planter walls should be constructed of durable, impervious materials, but should not employ chemically treated wood that may leach chemicals into groundwater. • Planters should incorporate trees and shrubs where feasible • An overflow should be installed to divert excess water during high-flow runoff events



Source: City of Eugene Stormwater Management Manual

3.9 Infiltration Trench

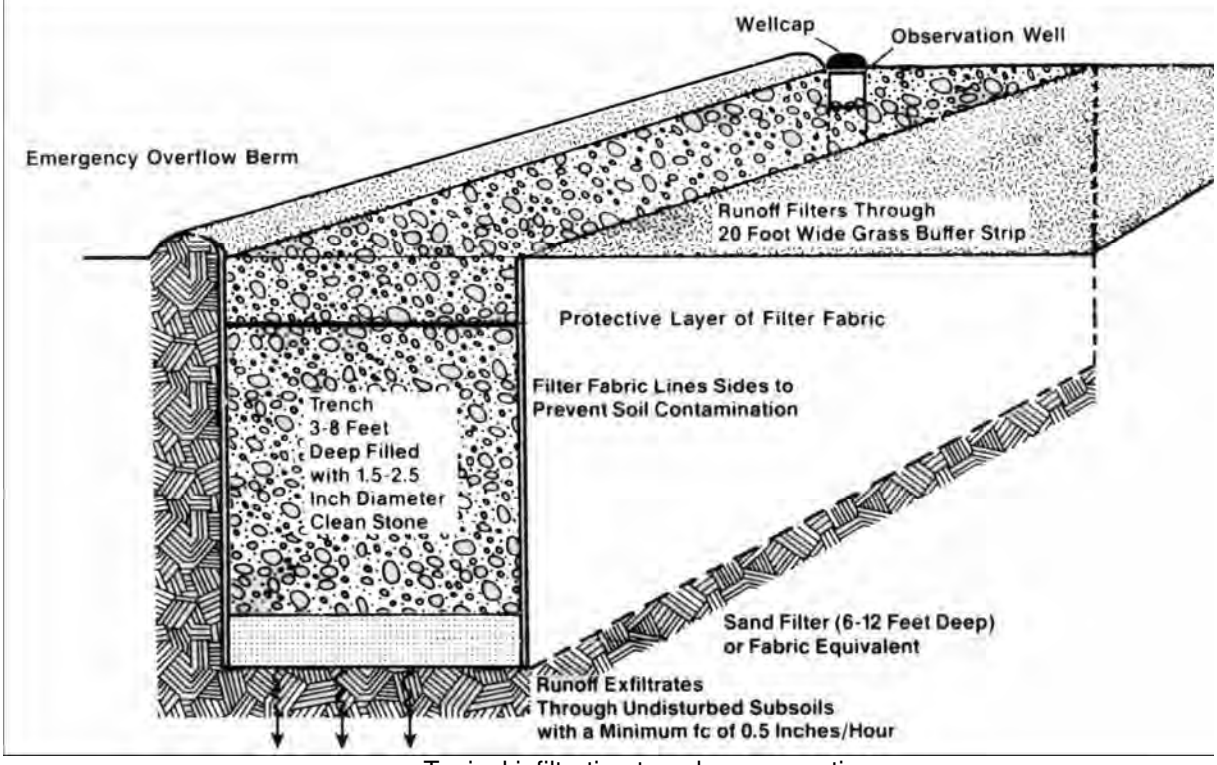
Description

Infiltration trenches are excavations that are lined with filter fabric and backfilled with aggregate. During runoff events water enters the trench where it is initially stored and then infiltrated into surrounding soil. Pollutants are filtered out as water passes through the aggregate and filter fabric, and into the soil. Infiltration trenches can treat and detain runoff for areas at the scale of residential blocks or individual commercial and governmental parcels. Their ability to remove a variety of pollutants, as well as their relatively small footprints, makes them ideally suited for applications such as parking lot island.

Infiltration trenches are most effective when applied in conjunction with other BMP types. For example, placing a vegetated filter strip around the trench decreases the amount of sediment flowing into the trench, reducing maintenance requirements and increasing the filtration efficiency.

Effectiveness	Infiltration trenches can be very effective for reducing runoff volume and for filtering sediments. Removal efficiency for pollutants can vary, but is expected to be relatively low. Infiltration trenches must be maintained as they are susceptible to clogging from fine particles.
Advantages	• Effectively removes or reduces many pollutants, including suspended solids, bacteria, and trace metals. • Reduces runoff volumes during storm events. • Increases baseflow in nearby streams.
Disadvantages	• Infiltration trenches may require periodic maintenance to prevent clogging.
Implementation Considerations	• Soils adjacent to planned trench site should be adequately permeable so as to allow infiltration • Slopes adjacent to the trench should be less than 12-15%. • Bottom of trench must be far enough from seasonally high water table to allow filtration by intermediate soil. • Trenches should not be employed where the potential is high for spills that might contaminate groundwater via the trench. • Pre-treatment practices, such as a vegetated filter strip, vegetated bioswale, or oil-grit separator are required where sediment loads from the contributing area would otherwise clog the trench, such as in parking lots and along roadsides.

Implementation Cosiderations	• Infiltration trenches in Lincoln should be constructed so a portion of the trench is below the frost line and so that ice and snow can be removed from the surface, ensuring proper functioning during cold weather. • During construction, care should be taken to avoid compacting soil surrounding the trench site, by using light equipment. • The contributing area must be stabilized before construction. Unstable areas will contribute excessive sediment to the trench, quickly clogging.
Cost	Low – approximate costs are estimate between $1.00 to $1.50 per cubic foot (USEPA, 1999)
Main Design Components	• Trenches should be excavated to a depth of approximately 3-8' and filled with washed aggregate of a diameter between approximately 1.5 to 3 inches. • The surface of the trench may be covered by aggregate, pea gravel, or vegetation. Pea gravel and vegetation both increase sediment filtering and prolong the life of the trench. If a vegetated surface is desired, it should be installed in approximately one foot of soil. • A vegetated filter strip at least 20 feet wide should be constructed upslope from the trench, to increase sediment capture and prolong the life of the trench. • Simple observation wells, constructed of PVC pipe, allow monitoring of water levels and evaluation of performance. • Flow into the trench should be evenly distributed.

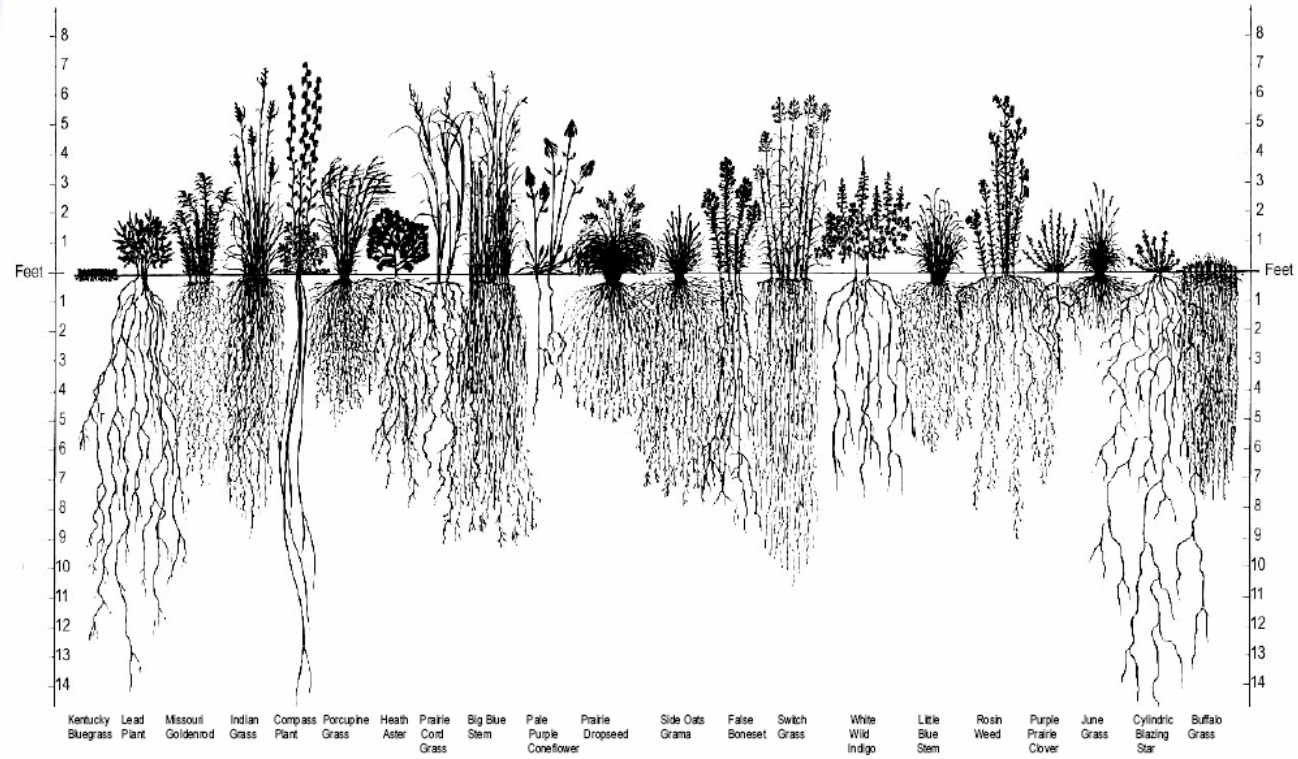


Typical infiltration trench cross section

3.10 Natural/Native Vegetation

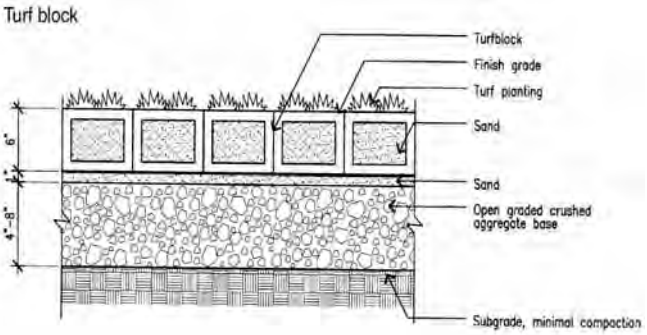
Description	"Uplands" are lands elevated above bottomlands and floodplains that are neither deepwater aquatic habitats nor special aquatic sites. They are seldom or never inundated. Prairie grasses and a few tree species typically dominate undisturbed and native landscaped uplands. The prairie grasses can include, but are not limited to, Big Bluestem, Little Bluestem, and Canada wild rye. Tree species include, but are not limited to, Hickory, Oak, and Black Locust. Undisturbed or native landscaped uplands can serve many BMP functions. They can help reduce erosion by protecting the underlying soil from splash erosion and slowing velocity of runoff. They can reduce off-site runoff by providing infiltration. They can filter sediment and other pollutants from stormwater runoff. They can also provide wildlife habitat and aesthetic values for the public. Native prairie planting, after the first two years, requires less maintenance than "tame" or domestic turf grass planting, reducing operations and maintenance costs. Native vegetation is also better suited than turf grasses for poor soils. Native grasses have deeper roots and can access more nutrients and water. Mowing and fertilizer application are not required to maintain a healthy stand of native vegetation. If controlled burning is not an option, mowing can control woody growth that may encroach on prairie plantings.
Effectiveness	Native vegetation is the core of using alternative strategies for reducing runoff volumes and pollutant transport. In uplands, native vegetation including grasses, forbs, and woody vegetation/trees, effectively slows runoff where if falls, maximizing infiltration and reducing the volume of pollutants that would otherwise be transported downstream.
Advantages	• Preserves predevelopment hydrology effectively. • Slows surface flows, promotes infiltration, and reduces erosion. • Traps sediment and sediment-bound pollutants. • Improves soil structure. • Transforms nutrients into usable forms and breaks down many pollutants.

Advantages	• Typically requires less maintenance than non-native landscaping. • Preserves wildlife habitat and provides aesthetic and recreational benefits. • Requires significantly less expense. • May increase property values.
Disadvantages	• Requires planning to maximize land available for development. • May require close maintenance until established. • May require a cover crop. • Cannot be established during winter.
Implementation Considerations	• To establish native uplands, choose plant species suited to the location. Consider moisture regimes, soils, light levels, runoff properties (pollutants, concentrated flow, and sheet flow), intended land use, and level of maintenance. Determine seeding rates considering the intended purpose of the site. Typically, an installation and management plan is appropriate. • Seedbed preparation is critical to success of plantings — do not over compact the soil. • Preserving existing upland native vegetation ultimately demands less maintenance than turf grass plantings or other landscaping, reducing operations and maintenance costs. • Minimal mowing and herbicide application is needed to maintain a healthy stand of native vegetation. • Some mechanical means may be necessary to control invasive species and preserve the health of the system. • Minimal fertilization is required. • Establishing native uplands necessitates that seeded areas be kept moist during the first weeks of establishment; mulch also may be needed. Reseeding may be necessary if the first seeding does not produce a vigorous stand.
Cost	Low – Cost will range from approximately $0.08 to $0.76 per square foot of ground depending on types of vegetation used. Lower costs come with the economy of scale from larger areas, high costs with small areas.
Main Design Components	• Seed should be applied uniformly (cyclone, drill, or hydroseeder). If feasible, broadcast seed should be covered by light raking followed by a roller. • Sod has the advantage of immediate erosion control, however native grass sod is rarely available. Native grasses can be installed as “plugs,” (i.e. young, individual grass plants).



Comparative demonstration of above- and below-ground biomass of native plants, including turf (far left).
Source: Conservation Research Institute, 1995

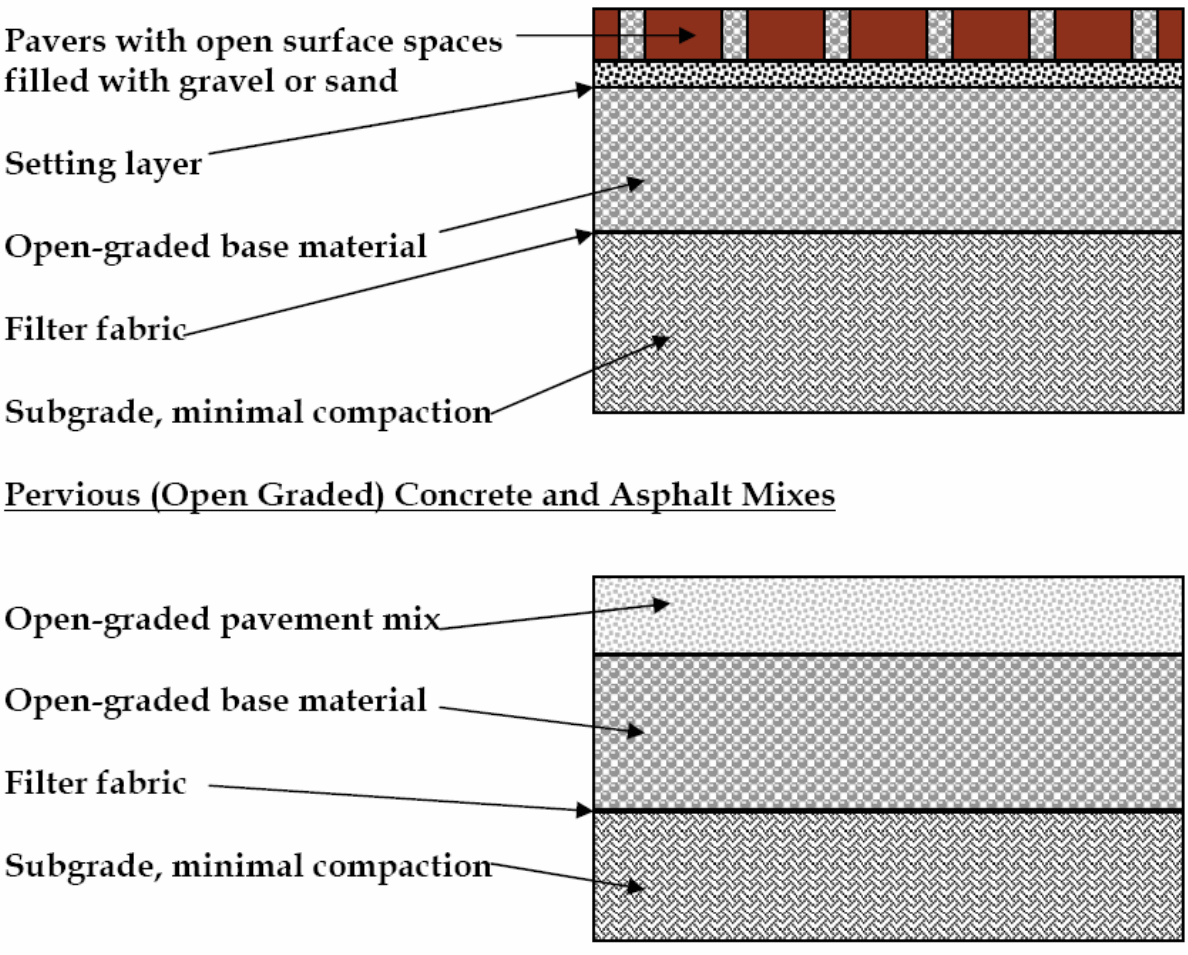
3.11 Pervious Pavement



Source: City of Eugene Stormwater Management Manual

Description	Pervious pavement allows precipitation to infiltrate by way of vertical pore spaces in the paving material. A wide variety of materials are used in the creation of pervious pavement, including brick, concrete, asphalt, plastic, rock, and gravel. A pervious pavement system may make use of porous concrete or asphalt, or it may make use of cobbles, bricks, or other evenly spaced paving units. Paving systems may even integrate vegetation within spaces in the paving units, augmenting the infiltration and filtration capacity. Studies of existing pervious pavement indicate removal rates of over 80 percent for sediment and for a number of other pollutants. Infiltration of precipitation falls where it intercepts parking lots, roads, and sidewalks reducing the volume of runoff that must be handled by stormwater management systems. Pervious pavement is suitable at a variety of scales, including individual driveways, trails, overflow parking lots, and light traffic roadways.
Effectiveness	Pervious or porous pavement, when properly maintained, has been shown to remove from 65 to 95 percent of pollutants and sediments (USEPA, 1999). Some monolithic porous pavement materials, however, have been show to clog within one- to two years. Clogging can be remediated to restore the function of the pavement material.
Advantages	• Reduces runoff volumes. • Reduces impervious surface area. • Depending on pavement system, may provide pollutant filtering.
Disadvantages	• Certain pervious pavement types have a high potential for failure unless properly designed, constructed, and maintained. Restricting pervious pavement to areas with relatively low traffic volumes and relatively light vehicles will also increase the success rate. • May require costly maintenance if pavement becomes clogged with sediment and no longer allows infiltration.

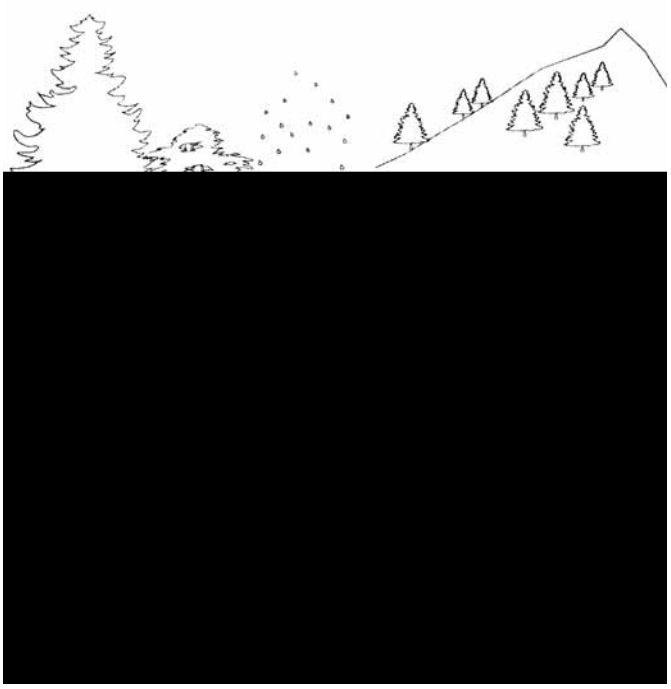
Implementation Considerations	• Excessive runoff from adjacent impervious surfaces may lead to clogging of paving systems. • Pervious pavement should not be used in sites where excessive oil, grease, or other chemical deposition may lead to groundwater contamination, such as automotive repair shops. • Given the potential for contamination by chemicals associated with automobile traffic, pervious pavement should not be employed near groundwater drinking supplies. • The type of traffic a surface receives (i.e. pedestrian, light vehicular, heavy vehicular) will determine the most suitable pavement type. • Snowplowing must be done carefully to avoid damaging the surface and paving units, and sanding and de-icing should be avoided as they will increase clogging. • Required maintenance, especially for porous concrete and asphalt paving includes vacuum sweeping to remove deposited sediment as well as washing with a high-pressure hose to remove clogs in the surface of the pavement.
Cost	Moderate – may be 2-3 times more expensive than conventional pavement.
Main Design Components	• Pavement surface must allow water to infiltrate to a permeable infiltration medium below. • An underdrain system may be required where soils beneath paving system do not allow adequate infiltration (more than two inches per hour). • Slopes should be less than 5-10% to allow infiltration rather than runoff. • Integration with other BMPs improves the effectiveness of pervious pavement. For example, placing a vegetated filter strip around the pervious pavement will reduce sediment transport to the project area, reducing the amount of maintenance required.



Source: City of Eugene Stormwater Management Manual

3.12 Rain Barrels and Cisterns

Source: Stormwater Manager's Resource Center



Source: City of Portland Code Guide

Description	A rain barrel is any above-ground container modified to receive, store, and distribute rooftop runoff for non-potable uses. Rain cisterns are similar systems designed for below-ground use, but typically provide much greater storage and more complex construction techniques. Rain barrels are ideal BMP applications for residential or small commercial sites. Both practices supply water for gardens, lawns, and flowerbeds. Homeowners with large gardens, or small businesses may want to consider installing a cistern, instead of a rain barrel, since they offer much greater storage capacity.
Effectiveness	Rainbarrels and Cisterns are effective in storing limited volumes of water from rooftops. Larger cisterns can provide effective volume reduction of runoff during storms. For example, a 0.1" rainfall event falling on a 1000 square foot roof produces about 60 gallons of runoff – more than enough to fill an average-sized 55-gallon rain barrel. These systems are not effective for removal of pollutants, and sediments may collect in the vessels that will have to be removed.
Advantages	• Reduces flow volumes, thereby reducing demands on stormwater management systems. • Provides free supply of water for non-potable uses, easing demands on potable drinking water sources. • Provides homeowners and small businesses with water for irrigation.

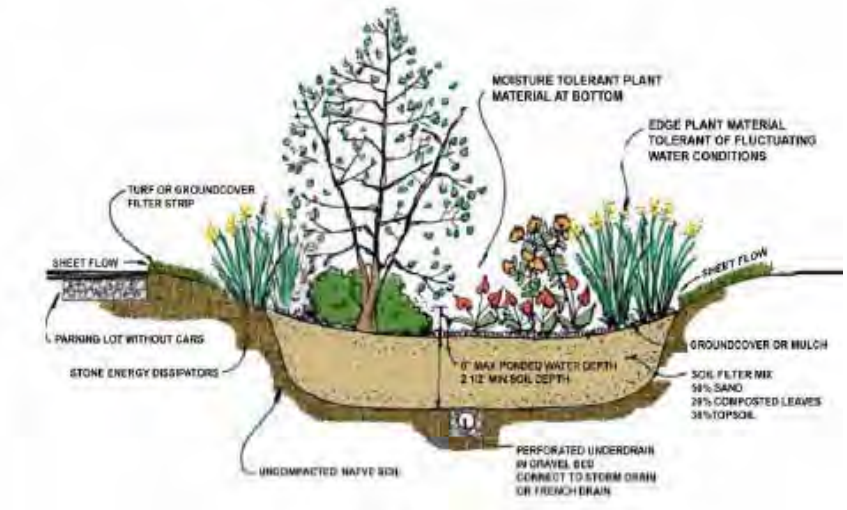
Disadvantages	• Rain barrels may not provide sufficient water in drier climates. • Rain cisterns are more expensive and require somewhat more complex design and construction.
Implementation Considerations	• Rain barrel should be sized to adequately capture runoff based on precipitation patterns in this area. • Occasional cleaning may be necessary to remove debris, such as leaves, coming off the rooftop. The barrel must also be sealed during warm months to avoid mosquito breeding, and should be drained prior to winter to prevent damage caused by freezing. • Water should be drained between rainfall events (for irrigation) to maximize effectiveness. • Rain barrels are most effective when they are designed to help meet demands for non-potable water, such as irrigation.
Cost	Low. Ready-made rain barrels range from $20 to $150. Homeowners can reduce costs by constructing their own.
Main Design Components	• Complete rain barrels can be purchased from a number of retailers, or they can be constructed relatively easily and economically. • Instructions for creating your own rain barrel can be found at Maryland Environmental Design Program Website. (http://www.dnr.state.md.us/ed/rainbarrel.html) • The main components of a rain barrel include tubing to connect the barrel to a downspout, a cover to prevent mosquitoes from entering, a faucet to allow regulated use of the captured water, and an overflow pipe to divert excess water once the barrel is filled. • The basic components of a rain cistern are much the same as with rain barrels, but with a much larger storage tank that is buried underground. This means a pump must also be installed to bring water out of the cistern.
	

3.13 Rain Garden

Description	A rain garden is a small residential depression planted with native wetland and prairie vegetation (rather than a turfgrass lawn) where sheet flow runoff collects and infiltrates. Rain gardens function similar to larger-scale bioretention areas. Typical sites for rain gardens include residential yards and community common areas.
Effectiveness	Raingardens are effective in removing from 30 to 90 percent of nutrients (such and nitrogen and phosphorus) and 80 percent of sediments as well as reducing runoff volumes.
Advantages	• Provides localized stormwater control by collecting and storing water, allowing water infiltration into the soil. • Improves water quality by filtering pollutants from stormwater. • Easy to plan and build. • Aesthetically pleasing. • Flexible to incorporate existing natural features. • Preserves natural/native vegetation. • Protects adjacent properties.
Disadvantages	• May need to irrigate to maintain vegetation during dry periods. • Requires annual maintenance to maintain vegetation and aesthetic qualities.
Implementation Considerations	• The maximum drainage area into rain gardens should be less than one acre. • The ponding depth of a rain garden is typically 4 to 6 inches. • Limit ponding in the depressional area to 3 days or less to avoid nuisance insects.

Implementation Considerations	• Line the depressional area with a mulch and organic layer in which vegetation is planted. • The mulch holds moisture and aids removal of metals. • Underneath the mulch and organic layer is the planting soil. • Place rain gardens a minimum of 10 feet away from building foundations. • Placement of the rain garden and overflow path should not interfere with adjoining property drainage patterns. • Rain gardens should not be located in areas where ponded water may create problems for surrounding vegetation or land use.
Cost	The cost of rain gardens vary and are scale dependent. On a unit basis, the cost may range from less than $2 to more than $14 per cubic foot, depending on size of the garden, vegetation used, and age of the vegetation planted. If seedling plugs are used, the cost increases. If the garden is prepared from seed, the cost is substantially less.
Main Design Components	• Ponding depths restricted to 6 inches or less. • Deep rooted perennials and trees are encouraged. • The planting soil should be a mixture of sand, loam, and clay to provide water and nutrients to the plants. • Native species that are tolerant of both wet and dry cycles are highly recommended. • Modify soil with compost to increase permeability. • Provide a drain tile system if soil permeability is a problem. • Maintenance, including mowing and weeding, is typically required two times a year.

Typical Rain Garden Cross Section *(Source: Pennsyvania Stormwater BMP Manual, 2005)*



3.14 Soil Management

Description

Soils are the primary medium of stormwater infiltration and storage. Soil management, whether by managing existing soils, or amending soil with supplemental materials to facilitate stormwater infiltration and treatment, is essential for the success of nearly all best management practices. Essentially, retaining the natural soil structure where possible is the preferred approach for soil management. Even with clay soils that may typically have low permeability, proper soil management will enhance stormwater infiltration.

Soil texture is the term applied to describe the sand, silt, and clay content of the soil. Sandier soils are more permeable and allow water to move into and through them more rapidly. Clay soils have smaller, tighter pores, and water moves into and through clayey soils more slowly.

Soil structure is the term applied to the arrangement of soil components – the sand, silt, and clay, as well as organic matter, into secondary units, or aggregates. Soil structure may be more important than soil texture, as soil structure more effectively describes the soil's capability to infiltrate and move water through the profile. "Good" soil structure usually describes soil that is friable, or easily broken into smaller pieces, and that has a combination of large and small pores. This soil will typically be high in organic matter and allow plant roots to grow freely and water to move rapidly into the soil. Even clay soils can have good soil structure and provide an optimal medium for stormwater management BMPs.

Soil Amendments

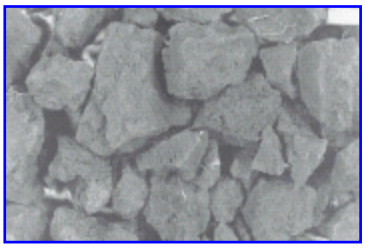
The clayey soils in Southeast Nebraska can limit stormwater infiltration, especially soils in developed areas. Where soils have little topsoil and are predominantly clay or fine silt, soil amendments may be necessary to "open up" the soil with greater macroporosity and better soil structure. Soil amendments typically include manure or compost, plant materials, or chemicals that will help aggregate soil particles. When soil amendments are added to existing soils, they need to be thoroughly mixed and integrated into the soil. Soil amendments can also be added to sandy soils to increase water holding capacity and its ability to support plants.

Effectiveness	Proper soil management is essential for nearly all stormwater BMPs. Soil that provides adequate infiltration will filter more than 90 percent of pollutants, 100 percent of sediments, and substantially reduce surface runoff. Soil management is most effective with native vegetation cover to stabilize soils and reduce erosion.
Advantages	• Retaining native or natural soils on a site allows for more rapid and successful plant establishment. Plants in soils with good structure and high organic matter will survive climate extremes better than plants in "poor" soils. • Retaining topsoil maximizes rainwater infiltration and storage capacity. One foot of topsoil can store more than one-inch of precipitation. • Soils high in organic matter filter pollutants and break down organic compounds. • Organic matter in soils hold more water, acting like a sponge. The water is released as needed for plant use. • Organic matter in soils hold and provide nutrients for plant growth. • Soils with good structure and high organic matter are more stable.
Disadvantages	• Re-building soils with good porosity and structure can be expensive. • If improperly managed, soils high in clay may not support stormwater infiltration or good plant growth. • Development may require removing topsoil, grading, and then replacing the topsoil. • To much heavy equipment on soils may compact them, resulting in poor BMP performance. • Soil amended with other materials must be carefully mixed to assure uniformity.
Implementation Considerations	• Local soils and soil conditions should be examined before site construction begins. • Soil tests should be completed to determine if the physical and chemical properties are adequate for absorbing rainwater or supporting vegetation. • BMP goals (infiltration, detention, biotreatment) should be established prior to determining what appropriate soil characteristics are desired. • Avoid stripping topsoil from construction sites if possible. • Maximize soil porosity and organic content where possible.
Cost	Low cost if native soil is used, medium to high if soil is re-engineered. Cost will vary substantially depending on existing soil and vegetation conditions, and amendments that may need to be added.

Main Design Components	• Depth of soil. • Clay content. • Soil permeability, organic content, infiltration rate. • Subsoil consistency, depending on performance criteria of BMP. • Effective homogenization of soils to assure effective porosity, texture, and particle distribution.

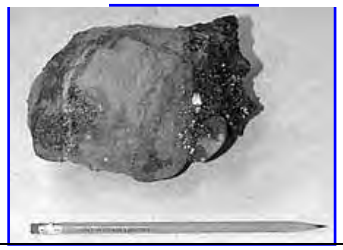
Examples of Typical Soil Structure

Granular Structure

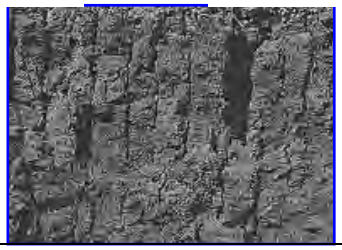


Blocky Structure

Platy Structure

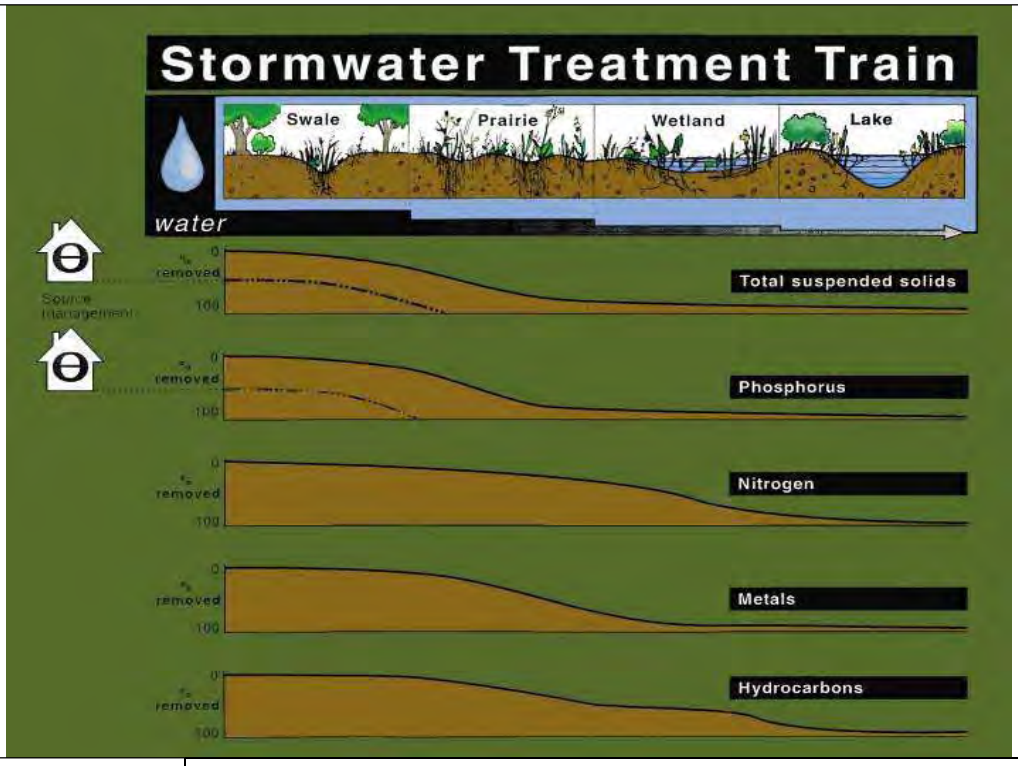


Massive Structure



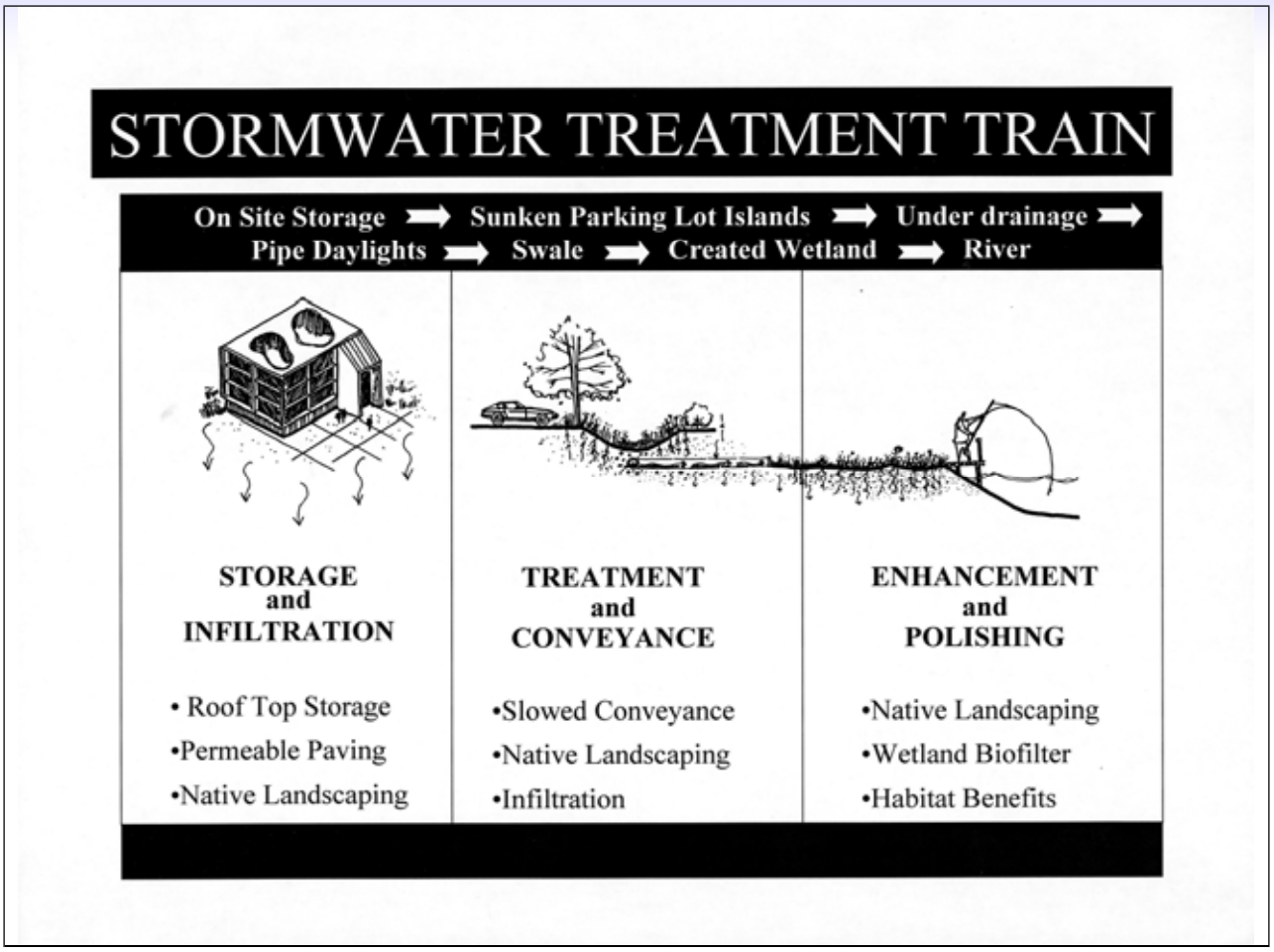
Prismatic Structure

3.15 Stormwater Treatment Train

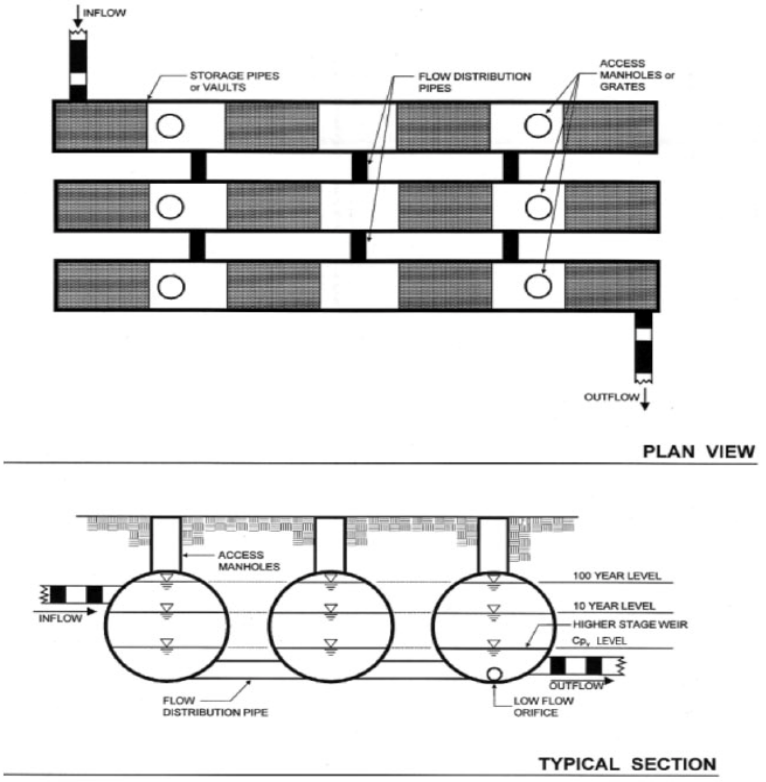


Description	The Stormwater Treatment Train (STT) represents an ecological approach to stormwater management and has proven effective and versatile in its various applications. The STT was designed with sequential components that contribute to the treatment of stormwater before it leaves the site. The components of the Stormwater Treatment Train system were designed to treat stormwater runoff for water quality benefits and to reduce stormwater runoff peaks and volumes. Based on hydrologic modeling and published information on BMP effectiveness, the STT approach can be expected to reduce surface runoff volumes by 65 percent and reduce solids, nutrients, and heavy metals loads by 85 percent to 100 percent. Source controls (upstream from the initial swale component) minimize the impacts of the development even further. This alternative approach to stormwater management not only has the potential to reduce infrastructure costs, but it also reduces maintenance costs. As described above, native plants are adapted to the environment, and do not need extensive watering, chemical treatment, mowing, and replanting that non-native species demand. In addition, there is also a substantial benefit to downstream neighbors. By treating stormwater where it falls on the land, responsible landowners are reducing their contribution to downstream flooding and sedimentation.
Effectiveness	The STT incorporates a number of BMPs with varying effectiveness for removing particulates and pollutants while also reducing runoff volume.

Advantages	• Provides effective stormwater flood control by slowing down runoff and storing water, including water infiltration into the soil. • Improves water quality by filtering pollutants from stormwater (oils, greases, metals, and sediments that can be picked up from paved surfaces). • Reduces erosion. • Flexible to incorporate existing natural features and/or introduced stormwater control features. • Provides open space that can be used for recreation and aesthetic value. • Preserves natural/native vegetation and provides habitat for wildlife. • Protects adjacent properties. • Improves property values.
Disadvantages	• May require more space than is available. • Requires planning and stakeholder acceptance.
Implementation Considerations	• Public outreach and acceptance for existing developments or communities. • Affect on long-term stormwater management infrastructure. • Demonstration of improved property values and cost of development with implementation of the Stormwater Treatment Train. • Planning and engineering of effective treatment train appropriate for each area. • Determine the necessary space and length to achieve stormwater management goals and water quality.
Cost	Variable, depending on best management practices and extent of the treatment system. Overall cost is less, however, than stormwater collection and conveyance systems for a similar area.
Main Design Components	Not applicable.


STORMWATER TREATMENT TRAIN
On Site Storage
Sunken Parking Lot Islands
Under drainage
Pipe Daylights
Swale
Created Wetland
River
STORAGE and INFILTRATION
• Roof Top Storage
•Permeable Paving
•Native Landscaping
TREATMENT and CONVEYANCE
•Slowed Conveyance
•Native Landscaping
•Infiltration
ENHANCEMENT and POLISHING
•Native Landscaping
•Wetland Biofilter
•Habitat Benefits

3.16 Subsurface Storage

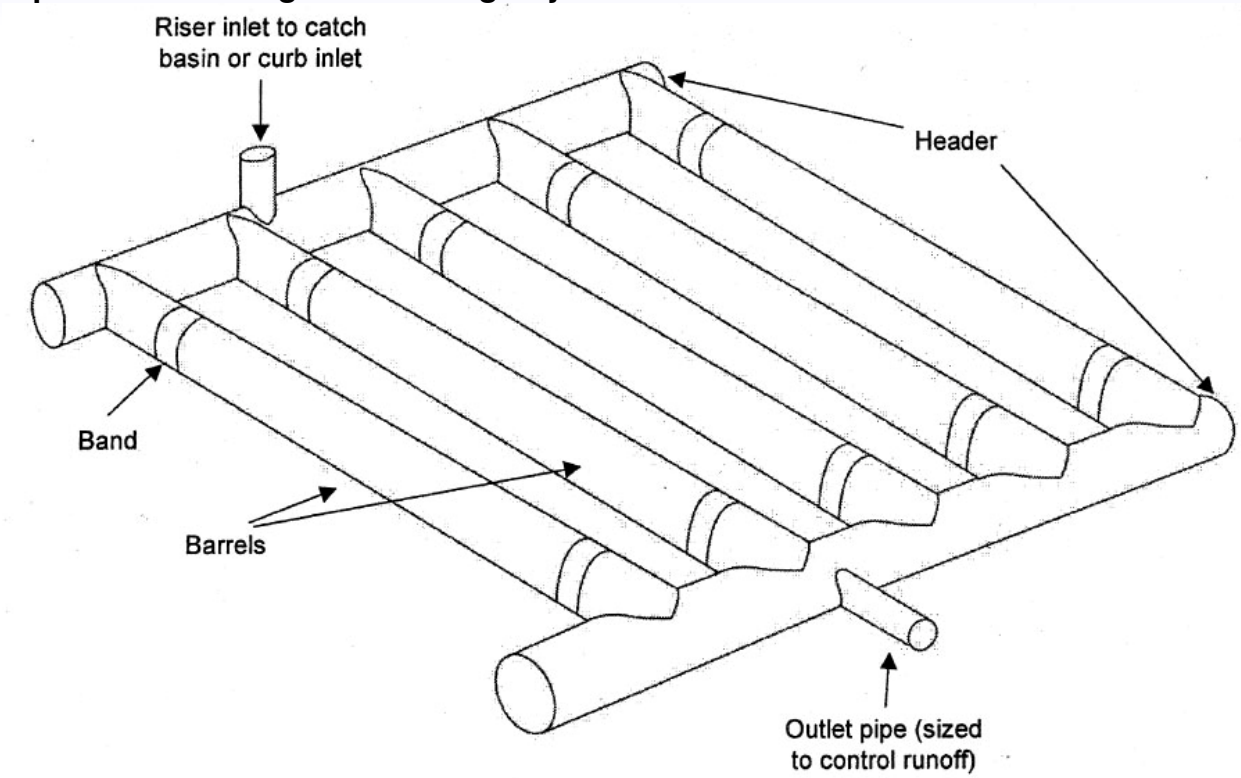


Source: Vermont Stormwater Management Manual

Description	In relatively dense urban areas where a large percentage of the landscape may already be developed, subsurface facilities may be the most practical way to achieve substantial flow volume and rate reductions. Although costs for constructing subsurface storage practices may be high, it may be the most economical way to detain stormwater in urban settings where land values are high. There are a number of types of subsurface storage available. In the simplest system, oversized pipes replace standard pipes in a storm drain, providing temporary storage of water. More storage can be achieved by using a series of interconnected pipes or a single large storage vault. Since these systems offer little or no water quality enhancement when used on their own, they should be coupled with other BMPs in a Stormwater Treatment Train™ to achieve water pollution control objectives. Certain measures, such as sand filters or sediment traps will reduce the amount of maintenance required to keep subsurface storage systems functioning properly.
Effectiveness	Subsurface storage is effective for reducing stormwater runoff, however little reduction of sediments or pollutants occurs without supplemental means to filter stormwater.

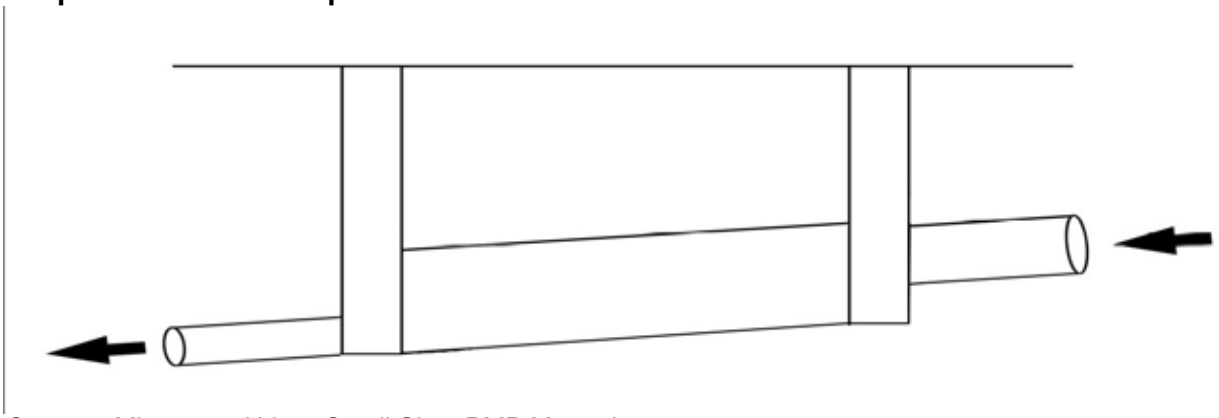
Advantages	• Provides substantial storage in areas with limited or no land left undeveloped. • Can be constructed under parking lots or other surfaces, allowing multiple uses for land. • Subsurface storage facilities can be constructed relatively quickly and are quite durable once constructed. • Safer than above-ground storage such as ponds, since residents will not have access to them. • Water captured in subsurface storage can be used for non-potable uses on-site, such as toilet flushing, irrigation, or evaporative air-conditioning.
Disadvantages	• Does not provide water quality benefits, unless other measures, such as oil/grit separators, sand filters, or water quality inlets, are integrated into the design. • May be relatively expensive to implement. • Requires removal of existing surface. • May require more excavation than aboveground storage facilities. • Maintenance may be more difficult than for aboveground storage.
Implementation Considerations	• The size and shape of the available site will determine the correct system. Large continuous areas are more suited to large vault-type systems, while more linear, angular sites are better suited for pipe-based system. • Plastic pipes used in storage may float upward if water table is too high. • Construction materials are influenced by the usable depth and size of the site. Sites requiring more shallow construction should use concrete, since corrugated steel and plastic must be surrounded by more fill.
Cost	Variable – depends primarily on amount of storage required and material used for storage structure, but may average around $400 per cubic yard of maximum instantaneous storage volume.
Main Design Components	• May consist of a simple storage pipe or chambers, or a more complex network of inlets, pipes, chambers, joints, outlets, and access points. • All underground storage must have, at a minimum, an inlet structure, an outlet structure, and an access point, such as a manhole, to the chamber. • HDPE or corrugated metal pipes are more economical, and easier to install, but require greater fill for stabilization and support.

Pipe-Based Underground Storage System



Source: EPA, Storm Water Technology Fact Sheet: On-Site Underground Retention/Detention

Simplified Oversized Pipe Section



Source: Minnesota Urban Small Sites BMP Manual

3.17 Urban Forest

Lincoln's Wilderness Park

Description	Trees clean the air and water, provide protection from the wind, improve the view from our homes, and create green space that provides recreational and educational opportunities. Trees along streams cool the water, provide food for stream organisms, add structure to the stream channel, and stabilize streambanks. While sod and other ground cover hold topsoil in place, tree roots penetrate deep and spread out anchoring large blocks of soil. Densely-planted trees and shrubs can do additional duty by keeping bikes, foot traffic, and motor vehicles off slopes and fragile soils that are prone to wind and water erosion.
Effectiveness	Trees intercept rainfall, reducing its velocity and impact by holding a substantial portion of the rain in the canopy. In one study, a 32-foot tall tree intercepting rainfall reduced stormwater runoff by 327 gallons. Trees and shrubs planted in bioswales, wetlands, and riparian forest buffers can filter out contaminants as they slow and capture stormwater runoff.
Advantages	• Trees improve soil erosion and sediment control. • Trees provide excellent streambank stabilization. • Create green space for riparian zones, and utilization for recreation. • Require minimal or no maintenance. • Trees provide food, shelter, nesting, and travel corridors for wildlife. • Trees provide many additional environmental values including noise reduction, temperature modification, and aesthetic benefits. • Trees resist environmental extremes. • Improve value of property.

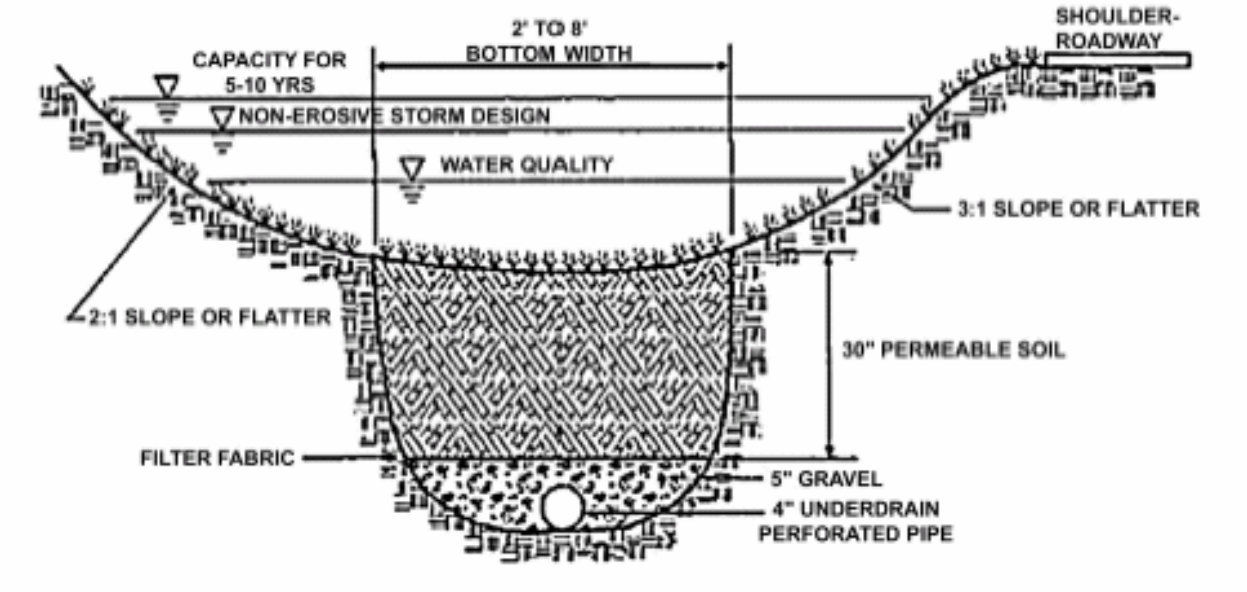
Disadvantages	• Slow growth, therefore benefits are not immediately realized. • May require substantial space if many trees are desired.
Implementation Considerations	• Green spaces should be designed with a variety of plant species to guard against major losses from insects and disease and help diversify the urban landscape. • Species should be chosen that are indigenous to the area and will tolerate climatic extremes. • Surrounding environment, including soils, hydrology, and land-use, should be considered in picking the types of trees used and where they will be planted. • Surrounding vegetation should not out-compete young trees.
Cost	Low if seedlings or young trees are planted, high if more mature trees are planted.
Main Design Components	• If buildings will be nearby future tree canopy height and extension must be considered. • Depth of soil. • Surface and subsurface hydrology. (How much water will support the tree?) • When possible, design developments around stands of existing trees; avoid complete clearing, and replant trees.

Lincoln's Wilderness Park

3.18 Vegetated Bioswale

Description	Vegetated swales are basically a filter strip located along a gentle ditch known as a "swale". Drainage swales that are planted with native vegetation are commonly called bioswales. Swales have gently sloping sides and are used to convey the overland flow of stormwater down a subtle gradient. Swales accomplish many of the same functions provided by filter strips (slowing and cleaning water, encouraging infiltration, etc.), while also providing directed conveyance. This conveyance function is particularly important when managing concentrated flows and during severe storm events when stormwater needs to be directed to a destination, such as a wetland. Swales should be designed with native species for the reasons described above, and can be augmented with check dams and other techniques to maximize their effectiveness at managing stormwater.
Effectiveness	Vegetated bioswales are effective in slowing stormwater and reducing significant amounts of runoff. Removal of sediments and pollutants is high, ranging from 20 to 40 percent, but removal rates have been reported to exceed 80 percent (USEPA, 1999).
Advantages	• Provides effective stormwater flood control by slowing down runoff and storing water, including water infiltration into the soil. • Improves water quality by filtering pollutants from stormwater (oils, greases, metals, and sediments that can be picked up from paved surfaces). • Can be used as a system by itself or in conjunction with other Best Management Practices. • Easy to plan and build. • Reduces erosion. • Flexible to incorporate existing natural features. • Preserves natural/native vegetation and provides habitat for wildlife.

Advantages	• Protects adjacent properties. • Although periodic cleaning may be required, swales should never need to be replaced, in contrast to conventional stormwater systems.
Disadvantages	• May require planning and stakeholder acceptance depending on location. • Requires proper sloping. • Not the fastest conveyance method—carefully design and place swales to minimize risk of flooding. • Swales can only treat a limited area.
Implementation Considerations	• Public outreach and acceptance for existing developments or communities. • Extent of drainage area. • Demonstration of improved property values and cost of development with implementation of the Stormwater Treatment Train. • Planning and engineering of effective treatment train appropriate for each area. • Determine the necessary space and length to achieve stormwater management goals and water quality.
Cost	Low. Roadside swales in residential settings achieve substantial documented cost savings over conventional curb and gutter and stormwater systems. In a suburban example in Chicago, a savings of about $800 per residence was estimated. Generally, costs may range from less than $0.10 to as much as $0.50 per cubic foot.
Main Design Components	• Individual swales should be designed to treat relatively small, flat drainage areas. If swales use slopes steeper than four percent, or if they treat areas larger than 5 acres, the flow velocity may be too great for effective treatment and erosion could occur. • Unless existing soils are highly permeable, they are replaced with a sand/soil mix that meets minimum permeability requirements. An underdrain system may also be installed under the soil bed. Typically, the underdrain system is created by a gravel layer which encases a perforated pipe. • The bottom of the swale should be at least three feet above groundwater in order to prevent the swale bottom from remaining too wet. • The swale should have trapezoidal or parabolic cross section with relatively flat side slopes (less than 3:1). • The flat channel bottom should be between two and eight feet wide to ensure sufficient filtering surface for water quality treatment.



Typical cross section of a parabolic vegetated swale

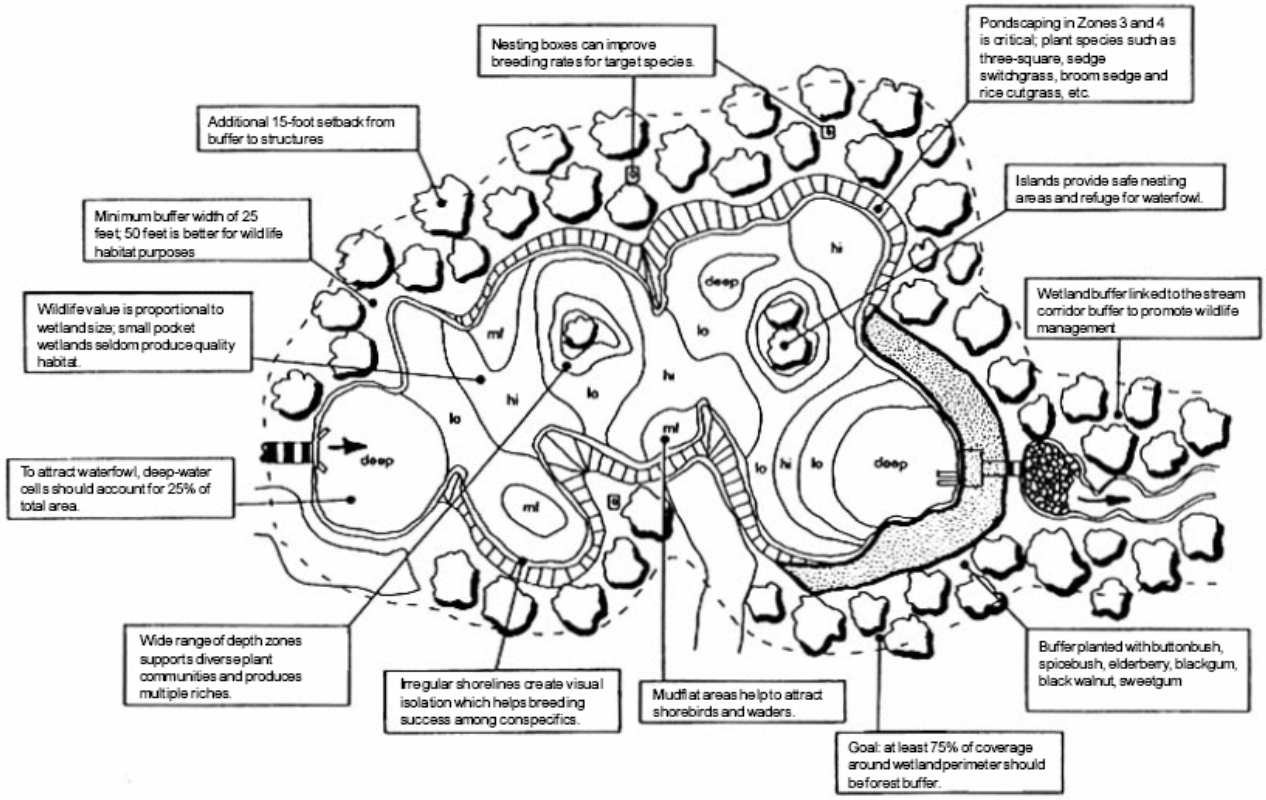
3.19 Wetland

Urban Wetland, First Street, South of Cornhusker Highway, Lincoln

Description	Stormwater wetlands are shallow marsh systems planted with emergent vegetation that are designed to treat stormwater runoff. While they are one of the best BMPs for pollutant removal, stormwater wetlands can also mitigate peak rates and even reduce runoff volume to a certain degree. They also can provide considerable aesthetic and wildlife benefits. Wetlands use a relatively large amount of space and require an adequate source of inflow to maintain the permanent water surface. Like detention basins and wet ponds, stormwater wetlands may be used in connection with other BMP components, such as forebays and micropools.
Effectiveness	Properly designed wetlands can remove significant amounts of nitrogen and phosphorus, suspended solids, and other pollutants from urban environments. The relative amounts of pollutant and suspended solid removal is similar to other BMPs, however, with removal rates ranging from 40 to 80 percent. Wetlands are very effective for reducing runoff volume and velocity.
Advantages	• Improvements in downstream water quality. • Settlement of particulates. • Removal of pollutants. • Flood attenuation and reduction of peak discharge. • Enhancement of biological diversity and wildlife habitat in urban areas. • Aesthetic enhancement and valuable addition to community green space. • Relatively low maintenance costs.

Disadvantages	• May be difficult to maintain vegetation under a variety of flow conditions. • May require larger land requirements than other BMPs. • Pollutant removal efficiencies may be low until vegetation is established. • Relatively high construction costs. • If not designed properly, wetlands may not receive favorable community attention.
Implementation Considerations	• Site must have adequate water flow and appropriate underlying soils. • Baseflow must be sufficient to maintain a shallow pool in the wetland. • Underlying soils should allow only allow small infiltration losses.
Cost	The costs of constructed wetlands are estimated to range from $0.75 to $1.60 per cubic foot. Costs will vary based on plant selection and density of plantings, and if plantings are from live stems or from seed.
Main Design Components	• Sediment forebays are recommended to decrease the velocity and sediment loading to the wetland. • The wetland design should include a buffer to separate the wetland from surrounding land. • Above-ground berms or marsh wedges should be placed at approximately 50 foot intervals to increase the dry weather flow path within the wetland. • Before the outlet, a four- to six-foot micropool should be included in the design to prevent the outlet from clogging. The micropool should hold at least 10 percent of the total treatment volume. • The outlet from the micropool should be at least one foot below the normal pool surface. • Install a bottom drain pipe with inverted elbow to prevent sediment clogging in order to drain the wetland in case of emergencies or for routine maintenance. • As the wetland-to-watershed ratio increases, the average runoff residence time increases and the effectiveness of the wetland for pollutant removal also increases. • The stormwater wetland's effectiveness for removing pollutants depends on the residence time of water in the wetland. • Vegetation can be established by allowing volunteer vegetation to become established, or, from planting nursery stock.

Main Design Components	• Give priority to species that have already been used successfully in constructed wetlands. • Lincoln has unique saline wetlands that are home to the threatened and endangered Salt Creek Tiger Beetle at some locations. Special care must be taken when designing wetlands near or around these sensitive environments.



4. LOW IMPACT DEVELOPMENT

The following readings provide published information about the benefits and economics of low impact development (LID). LID commonly incorporates nearly all of the BMPs described in this guidance manual as a standard of practice and measurement, achieving not only environmental benefits, but economic benefits for developers and builders, for residents and commercial property owners, and municipal governments as well.

4.1 Seven Benefits of Low Impact Development

Effective. Research has demonstrated LID to be a simple, practical, and universally applicable approach for treating urban runoff. By reproducing predevelopment hydrology, LID effectively reduces runoff and pollutant loads. Researchers have shown the practices to be successful at removing common urban pollutants including nutrients, metals, and sediment. Furthermore, since many LID practices infiltrate runoff into groundwater, they help to maintain lower surface water temperatures. LID improves environmental quality, protects public health, and provides a multitude of benefits to the community.

Economical. Because of its emphasis on natural processes and micro-scale management practices, LID is often less costly than conventional stormwater controls. LID practices can be cheaper to construct and maintain and have a longer life cycle cost than centralized stormwater strategies. The need to build and maintain stormwater ponds and other conventional treatment practices will be reduced and in some cases eliminated. Developers benefit by spending less on pavement, curbs, gutters, piping, and inlet structures. LID creates a desirable product that often sells faster and at a higher price than equivalent conventional developments.

Flexible. Working at a small scale allows volume and water quality control to be tailored to specific site characteristics. Since pollutants vary across land uses and from site to site, the ability to customize stormwater management techniques and degree of treatment is a significant advantage over conventional management methods. Almost every site and every building can apply some level of LID and integrated management practices that contribute to the improvement of urban and suburban water quality.

Adds value to the landscape. It makes efficient use of land for stormwater management and therefore interferes less than conventional techniques with other uses of the site. It promotes less disturbance of the landscape and conservation of natural features, thereby enhancing the aesthetic value of a property and thus its desirability to home buyers, property users, and commercial customers. Developers may even realize greater lot yields when applying LID techniques. Other benefits include habitat enhancement, flood control, improved recreational opportunities, drought impact prevention, and urban heat island effect reduction.

Achieves multiple objectives. Practitioners can integrate LID into other urban infrastructure components and save money. Lot level LID applications and integrated stormwater management practices combine to provide substantial reductions in peak flows and improvements in water quality.

Follows a systems approach. LID integrates numerous strategies, each performing different stormwater management functions, to maximize effectiveness and save money. By emulating natural systems and functions, LID offers a simple and effective approach to watershed sensitive development.

Makes sense. New environmental regulations geared toward protecting water quality and stabilizing our now degraded streams, rivers, lakes, and estuaries are encouraging a broader thinking than centralized stormwater management. Developers and local governments continue to find that LID saves them money, contributes to public relations and marketing benefits, and improves regulatory expediencies. LID connects people, ecological systems, and economic interests in a desirable way.

4.2 Low Impact Development (LID) Practices for Storm Water Management

Water quality concerns have intensified, and storm water management practices have come under scrutiny, as development occurs on an increasing percentage of the available land area in the United States. With more stringent design requirements, costs for traditional collection and conveyance systems have risen sharply. Organizations from community groups, regional watershed authorities, and state and federal agencies have become involved in this issue. Subsequent changes in storm water regulations could strongly impact builders and communities as more new regulations and practices are implemented. Low Impact Development (LID) techniques can offer developers a more cost effective way to address storm water management through site design modifications and "Best Management Practices" (BMPs). These strategies allow land to be developed in an environmentally responsible manner, and create a more "Hydrologically Functional" landscape.

Low Impact Development (LID)

Low Impact Development is an ecologically friendly approach to site development and storm water management that aims to mitigate development impacts to land, water, and air. The approach emphasizes the integration of site design and planning techniques that conserve the natural systems and hydrologic functions of a site.

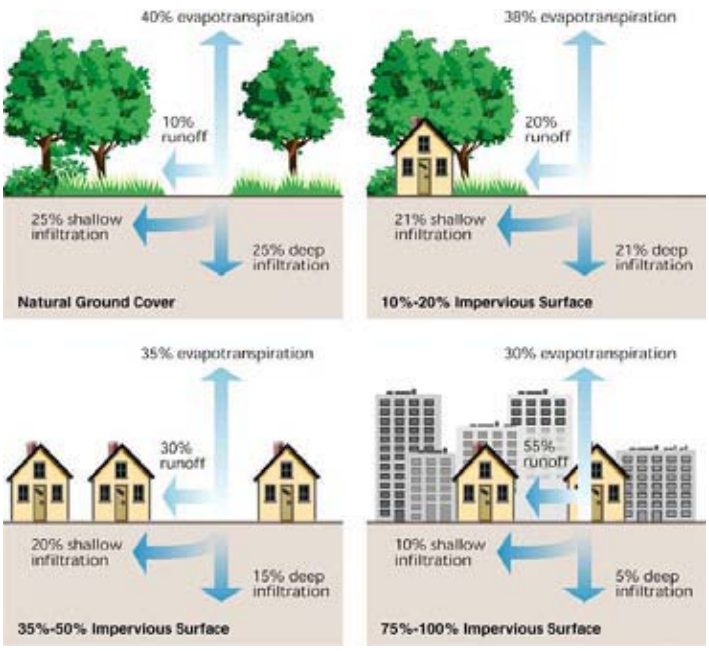
Low Impact Development (LID) strategies strive to allow natural infiltration to occur as close as possible to the original area of rainfall. By engineering terrain, vegetation, and soil features to perform this function, costly conveyance systems can be avoided, and the landscape can retain more of its natural hydrological function. Low Impact Development practices dovetail with "green" building practices that incorporate environmental considerations into all phases of the development process. Builders can often use green building and LID to lower actual development costs. (Although most effective when implemented on a community-wide basis, using LID practices on a smaller scale, i.e., on individual lots, can also have an impact).

Pollution from stormwater runoff can also be a major concern, especially in urban areas. Rainwater washing across streets and sidewalks can pick up spilled oil, detergents, solvents, de-icing salt, pesticides, fertilizer, and bacteria from pet waste. Storm water drains do not typically channel water to treatment facilities, but carry runoff directly into streams, rivers, and lakes. Most surface pollutants are collected during the first one-half inch of rainfall in any "storm event". This is the period when the majority of pathogens, sediment, waste and debris are picked up by flow across lawns and roadways. Carried untreated into streams and waterways, these materials become "non-point source pollutants" which can increase algae content, reduce aquatic life, and require additional costly treatment to make the water potable for downstream water systems. LID design principles can be used as buffers to filter these pollutants before they reach aquifers. For traditional conveyance systems, specially designed catchbasins may be designed to perform a "first flush" filtering function using various technologies for collection of sediment and contaminants. Some units are designed to retrofit existing storm water inlets.

Manufacturers include AquaShield, Stormtreat Systems, Inc, Stormceptor, and Stormwater Management Co.

Effects of Runoff

In 1998, a report on Stream Corridor Restoration was produced by the Federal Interagency Stream Restoration Working Group (FISRWG) documenting the impact of human activities on the stream systems forming the backbone of watersheds throughout the United States. This group represents 15 Federal agencies from the Departments of Agriculture, Commerce, Interior, Defense, Housing and Urban Development (HUD), Environmental Protection Agency (EPA), Federal Emergency Management Agency (FEMA), and Tennessee Valley Authority (TVA). The following illustration from the report shows how development affects water infiltration into soils and runoff.



Less developed land areas allow a larger portion of storm water to seep gradually into soils, remove contaminants, replenish soil moisture, and recharge groundwater aquifers. As areas become developed, a much larger percentage of rainwater hits impervious surfaces including roofs, sidewalks, parking lots, driveways, and streets, and must be controlled through storm water management techniques. Traditional approaches have focused on collection and conveyance to prevent property damage. Local building code requirements often require developers to take an "end of pipe" approach, using gutters and piping systems to carry rainwater into ponds or detention basins. As new requirements have attempted to address water quality, erosion, flow volume, and other problems created by common conveyance methods, the cost and complexity of these engineered systems has increased.

History

On September 21-23, 2004 the first national Low Impact Development (LID) Conference, called *Putting the LID on Stormwater Management*, took place in College Park, Maryland. It highlighted innovative LID techniques designed to minimize the effect of development on watersheds. Presenters of over 85 papers provided insight into a variety of Low Impact Development projects conducted nationwide.

During the Conference's closing session, *Future Vision of LID and Storm Water Management*, a panel of experts reflected upon the current state of LID and the direction in

which LID is headed. One common theme was that LID is a concept where residential developers, local public planners, engineers, citizens, and environmental groups all can support the idea of using water as a resource, reducing stream erosion, and pretreating storm water before it enters waterways and recharges groundwater aquifers.

LID should be more than just new storm water technologies for single lots. LID should be about looking at water resources in a holistic, watershed-based manner, and effectively managing such resources. Such an approach involves conserving water inside and outside a house, using decentralized storm water management BMPs for single lots and larger-scale developments, and identifying the best ways to handle wastewater.

Details

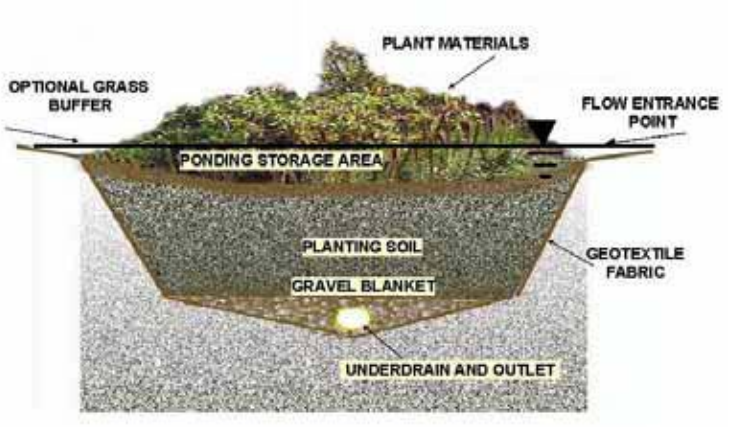
Low Impact Design Strategies:

Strategies fall under the two broad categories of **practices** and **site design**. The most common concepts are summarized below:

Practices:

Basic LID strategy for handling runoff is to: 1) reduce the volume of runoff and 2) decentralize flows. This is usually best accomplished by creating a series of smaller retention/detention areas that allow localized filtration rather than carrying runoff to a remote collection area. For the practices noted below, special attention should be paid to the composition of existing soils, as well as new soils or amended soils used, and underlying topography. For instance, a locale with karst topography may react differently to introduction of LID practices than a site that does not have underground channels. Common methods include:

- **Bio-retention cells** typically consist of grass buffers, sand beds, a ponding area for excess runoff storage, organic layers, planting soil and vegetation. Their purpose is to provide a storage area, away from buildings and roadways, where storm water collects and filters into the soil. Permanent ponds can be incorporated into the cell design as landscaping features. Temporary storage areas without ponds may be called **detention cells**. Bioretention areas have also been called **rain gardens** since they are typically landscaped with native plants and grasses, selected according to their moisture requirements and ability to tolerate pollutants. Annual maintenance of bioretention cells must be planned in order to replace mulching materials, remove accumulated silt, or revitalize soils as required.



- **Grass swales** function as alternatives to curb and gutter systems, usually along residential streets or highways. They use grasses or other vegetation to reduce runoff velocity and allow filtration, while high volume flows are channeled away safely. Features like plantings and checkdams may be incorporated to further reduce water velocity and encourage filtration. Walkways are either separated from roadways by swales, or relocated to other areas. In areas where salts are commonly used for winter de-icing, careful attention must be paid to selecting plant species which are salt tolerant.

- **Filter strips** can be designed as landscape features within parking lots or other areas, to collect flow from large impervious surfaces. They may direct water into vegetated detention areas or special sand filters that capture pollutants and gradually discharge water over a period of time.

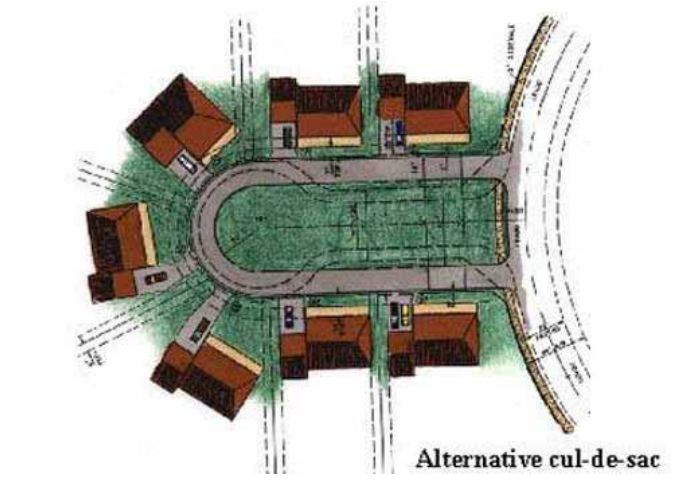
- **Disconnected impervious areas** direct water flows collected from structures, driveways, or street sections, into separate localized detention cells instead of combining it in drainpipes with other runoff. Disconnecting the flow limits the velocity and overall amount of conveyed water that must be handled by end-of-pipe facilities.

- **Cistern collection systems** can be designed to store rainwater for dry-period irrigation rather than channeling it to streams. Smaller tanks that collect residential roof drainage are often called "**rain barrels**" and may be installed by individual homeowners. Some collection systems are designed to be installed directly under permeable pavement areas, allowing maximum water storage capacity while eliminating the need for gravel beds.

Site Design:

Decreasing Impervious Surfaces can be a simple strategy to avoid problems from storm water runoff and water table depletion, by reducing surfaces that prevent natural filtration. Methods may include:

- **Reducing Roadway Surfaces** can retain more permeable land area. In some cases, planners have reduced pavement needs by up to 40% by using longer, undulating roads that create more available lot frontage, instead of wide shorter streets with more intersections. Other options may include shared driveways, "flag" lots with reduced street frontage, landscaped detention islands within cul-de-sacs, or alternate designs for turn-around areas.

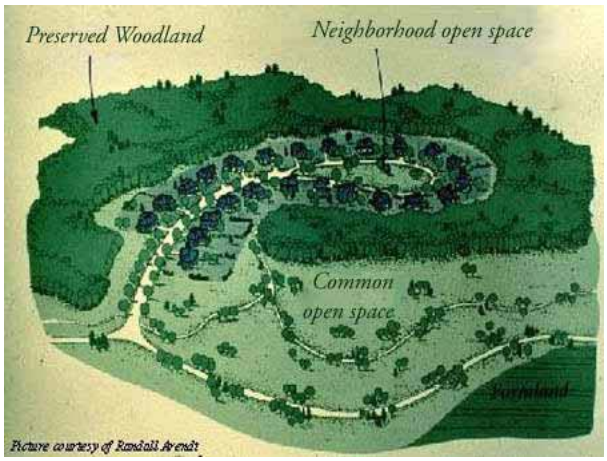

Alternative cul-de-sac

- **Permeable Pavement Surfaces** can be constructed from a variety of materials, including traditional asphalt and concrete, gravel or pavers. Permeable roadway or parking areas allow water to flow through, replenishing soil areas directly beneath. However, the sub-base underneath permeable pavements must be engineered to accommodate temporary water storage and filtration. In many cases, permeable surfaces can reduce or eliminate the need for traditional storm water structures.

- **Vegetative Roof Systems** create a lightweight, permeable vegetative surface on an impervious roof area. Moss, grass, herbs, wildflowers, and native plants can be used, creating an aesthetically pleasing roof landscape. The systems start with a high strength rubber membrane placed over the base roof structure. Various layers above the rubber may contain insulation, filter and drainage media, separation fabrics, lightweight growth media, vegetation, and wind erosion fabric. Some systems even incorporate rainbarrel runoff collection, pumping, and irrigation equipment. These systems are more costly than standard roofs, and have not been used on a large scale for residential development in the U.S.

Planning site layout and grading to natural land contours can minimize grading costs and retain a greater percentage of the land's natural hydrology. Contours which function as filtration basins can be retained or enhanced, and incorporated into the landscaping design.

- **Natural Resource Preservation and Xeriscaping** can be used to minimize the need for irrigation systems and enhance property values. Riparian, or stream bank, areas are particularly crucial to water quality, and in most areas, subject to Federal or State regulations. Preserving existing wooded areas, mature trees, and natural terrain, can give new developments a premium "mature landscape" appearance and provide residents with additional recreational amenities. Both of these features can improve marketability. Xeriscaping refers to landscaping with plants native to area climate and soil conditions. These plants thrive naturally, requiring less maintenance and irrigation than most hybrid or imported varieties.



- **Clustering Homes** on slightly smaller lot areas can allow more preserved open space to be used for recreation, visual aesthetics, and wildlife habitat. Clustering can reduce infrastructure costs to the builder, since fewer feet of pipe, cable, and pavement are needed, and maintenance costs are reduced for homeowners. Builders in many areas have been able to charge

a premium price for "view lots" facing undisturbed natural vistas, or pond areas that also function as bioretention cells.

Installation

Low Impact Development requires more precise engineering for soil characteristics, filtration rates, water tables, native vegetation, and other site features. Participation of environmental consultants and planners is critical from the earliest planning phases for residential development.

Benefits

In addition to the practice just making good sense, LID techniques can offer many benefits to a variety of stakeholders.

Developers

- Reduce land clearing and grading costs
- Potentially reduce infrastructure costs (streets, curbs, gutters, sidewalks)
- Reduce storm water management costs
- Potentially reduce impact fees and increase lot yield
- Increase lot and community marketability

Municipalities

- Protect regional flora and fauna
- Balance growth needs with environmental protection
- Reduces municipal infrastructure and utility maintenance costs (streets, curbs, gutters, sidewalks, storm sewer)
- Increase collaborative public/private partnerships

Environment

- Preserve integrity of ecological and biological systems
- Protect site and regional water quality by reducing sediment, nutrient, and toxic loads to water bodies
- Reduce impacts to local terrestrial and aquatic plants and animals
- Preserve trees and natural vegetation

Costs

Cost benefits to builders and developers utilizing LID strategies can be significant. According to the Center for Watershed Protection, traditional curbs, gutters, storm drain inlets, piping and detention basins can cost two to three times more than engineered grass swales and other techniques to handle roadway runoff. Other LID strategies can have similar impact. Choosing permeable pavement for a parking area may remove the need for a catchbasin and conveyance piping. Small distributed filtration areas on individual lots can reduce site requirements for larger detention ponds that take up valuable land area.

Dissatisfied with a conventional land plan, a developer in central Arkansas contacted Tyne and Associates in North Little Rock AR, who specializes in environmentally sensitive land

development. The resulting design for the Gap Creek community was showcased in the Spring/Summer 2000 issue of Land Development Magazine along with the following cost information:

A Comparison of Two Different Land Plans for Gap Creek Community

PROJECTED RESULTS FROM TOTAL DEVELOPMENT		
Total Site	**Conventional Plan**	**Revised Green Plan**
Lot Yield	358	375
Linear Feet - Street	21,770	21,125
Linear Feet - Collector Street	7,360	0
Linear Feet - Drainage Pipe	10,098	6,733
Drainage Sections (Inlets, Boxes, Headwalls)	103	79
Estimated Total Cost	$4.6 million	$3.9 million

ACTUAL RESULTS FROM PHASE ONE		
Total Site (engineer estimate)	**Conventional Plan**	**Revised Green Plan**
Lot Yield	63	72
Total Cost	$1,028,544	828,523
Cost Per Lot	$16,326	$11,507

BENEFITS FROM LOW-IMPACT DEVELOPMENT	
General Benefit	**Specific Benefit**
Higher Lot Yield	17 additional lots
Higher Lot Value	$3,000 more per lot than competition
Lower Cost per Lot	$4,800 less per lot
Enhanced Marketability	80% of lots sold in the first year
Added Amenities	23.5 acres of green space/parks
Recognition	National, state, and professional group recognition
TOTAL ECONOMIC BENEFIT	More than $2.2 million in savings

This development was also cited in an NAHB Research Center report, published in July 2001, called *Environmentally Green... Economically Green, Tools for a Green Land Development Program.* The report provides a wealth of information and sources on Low-Impact and Sustainable Development practices.

Limitations

Not all sites can effectively utilize LID techniques. Soil permeability, slope, and water table characteristics may limit the potential for local infiltration. Urban areas and locations with existing high contaminant levels may be precluded from using LID filtration techniques.

Many existing local codes, zoning regulations, parking requirements and street standards were developed prior to the emergence of water quality and storm water management concerns, and may prohibit or inhibit implementing LID practices.

Established practices can be difficult to modify, although cost factors may help drive change. Additionally, there may be negative perceptions among homebuyers. Even though many buyers welcome naturalistic features proscribed by LID, others may prefer large flat lots with wide curbed streets. While traffic studies have not borne out the theory, some consumers perceive curbs to be a safety feature for pedestrians. Others fear that the lack of conventional storm water systems will result in basement flooding or structural damage.

Code/Regulatory

Statutes mandating the implementation of storm water management plans include: The Clean Water Act (Wetlands, Section 404; Storm water, Section 402), the National Pollutant Discharge Elimination System (NPDES) regulations, and in some cases, State Pollutant Discharge Elimination Systems (SPDES). State, local, or subdivision codes and zoning requirements may dictate designs or systems which are sometimes not consistent with current LID strategies. Especially in largely developed areas, however, the trend is for land-use or water-basin management authorities to mandate more stringent storm water management planning and practices.

Source: Toolbase Services, NAHB Research Center, 400 Prince George's Boulevard, Upper Marlboro, MD 20774

4.3 Applying an Ecological Systems Approach in Urban Landscapes

URBAN LANDSCAPING

Applying an Ecological Systems Approach in Urban Landscapes

by Steve Apfelbaum and Jack Broughton, Applied Ecological Services, Inc.

"***CHICAGO*** Wilderness", the title of a new, rapidly growing conservation movement in the Chicago metropolitan area, would seem to be an oxymoron. If there is "wilderness" in Chicago, most people have missed it.

But in fact, there once was a vast wilderness in and surrounding the Chicago regions, and in fact, people do miss it! In the northeastern Illinois region, people miss the wild, natural and open spaces so much that the region has become one of our nation's hottest hotbeds for native landscaping and ecological restoration.

They miss it because Chicago presents a typical urbanizing landscape in which the ecological systems we once called wilderness have been replaced by a dominant "ecological system" that can fairly be called a biological desert. We call this dominant system of urban sprawl, lawn.

In the U.S., we've converted 30 million acres into lawns, which are landscapes by German definition "in the absence of trees". We don't usually look at lawns as ecological systems, but if we did, we'd see these systems are dominated by non-native plant and animal species. Kentucky bluegrass is from Europe and Asia. So are the common earthworms. So are dandelions and most other weeds.

We've placed many of these lawn systems in urban landscapes on glacial till clay soils, compacted by earthmovers during development so that we've essentially created millions of acres of low-permeable lawnscape that is hydrologically not unlike that of an impervious asphalt parking lot.

In urbanizing areas, we've surrounded ourselves with these non-native ecological systems which support few species. And to many people — even to people who don't consciously think about it — these lawnscapes are uninspiring. They're especially uninspiring compared to the diverse plant and wildlife species in the many native restorations springing up in the Chicago region.

In contrast to our biologically barren and high maintenance lawns, native ecological systems, such as wetlands, upland prairie or oak savanna are immensely diverse, productive systems. At one time, the marshy Chicago region produced immense flocks of whooping cranes, sand hill cranes, huge flights of ducks and geese, and biological diversity we can only imagine today.

You can get a small sense of this unbelievable productivity by visiting remnants of the wilderness, such as one particularly high, dry hill prairie near Elgin that has survived because its soils were too rocky and dry for agriculture. Historically, when these types of prairies were blended with a mesic prairie featuring deeper, more well developed soil systems, the prairies supported 550 to 650 species of native vascular plants, perhaps thousands of associated insect species, and untold numbers of micro-fauna and micro-flora, bacteria and fungi. A lawn might have 10-15 plant species and far fewer associated organisms.

Tallgrass savanna areas in urban environments.

Complex Native Ecosystems are Highly Integrated

From wetlands to oak savanna, our pre-settlement native systems were seamlessly blended together on gradients of hydrology, topography, soil types and soil nutrition. The blended systems were also impacted by an area's fire history, grazing ungulates, insect infestation and a variety of gradients that intersected on the landscape on an immense scale.

The interrelationships between systems is demonstrated in projects today where disturbances in upland grassland systems create erosion and sedimentation that degrades wet prairie and wetland systems at lower elevations. This can occur when there has been ineffective thinking about the relationship between the developed landscape and natural wetland areas.

What we do on the uplands drastically affects lowland environments. A coffee-colored river flowing into a lake system with algae blooms and large sediment swirls is characteristic of the landscapes we see through most of the upper Midwest today, while historically, our waters ran clear and at a much slower rate.

Hydrology, hydraulics, chemistry, biology and ecology must all be considered if we're to see the true picture of how we impact integrated natural systems at the boundaries where human and natural activities are also integrated.

Conservation Development - Another Oxymoron?

In November, the Wall Street Journal published a survey which showed what home buyers are looking for in today's urbanizing developments. At the top of the list was Natural, Open Space. Second was Walking and Biking Paths. Gardens with Native Plants came in third. Wilderness Areas was fifth, and Interesting Little Parks was eighth. Ninth and tenth were Tennis Courts and Golf Courses.

These rankings show that the need for "Conservation Development" is more compelling now than ever. People feel the need to interact with their natural environment, and conservation developments can help fulfill that internal desire.

Prairie Crossing in Grayslake, IL, is one of the best examples of a Conservation Development, in which an ecological approach to planning considered the needs of the natural areas equal to and integrated with the needs of developed space.

Held up as a national example of conservation development, Prairie Crossings is a 667-acre development that preserves 70% of its acreage as open space and allows only 30% of its land for residential and commercial development.

In the development, 175 acres of prairie and 18 acres of wetland were designed as a basic element for stormwater management, and greenway trails are looped throughout the property. Housing is clustered, and surrounding the clustered housing are prairie swale systems that passively filter water as it flows through 175 acres of prairie and ultimately into 18 acres of wetlands and 27 acres of lake.

By replicating the historic prairie to wetland ecosystem gradient, we've predicted that the majority of contaminants associated with urban land use can be bio-filtered and assimilated within the prairie swales before reaching the wetlands and lake.

Housing is clustered, and surrounding the clustered housing are prairie swale systems that passively filter water as it flows through 175 acres of prairie and ultimately into 18 acres of wetlands and 27 acres of lake.

We wanted a healthy wetland system and healthy lake system and the delivery of high quality water to these systems was an important precursor to that performance-based outcome. In addition, because of the native vegetation and natural swale and wetland design, we've predicted a 60% reduction in peak stormwater discharge from storm events from this system, compared to the previous agricultural land use.

A young ecologist.

Because of the healthy, integrated ecological systems created at Prairie Crossing and the appeal of "living with nature", the walk-in rate at the sales office is substantially higher than conventional developments in the local area. Nature and quality-of-life aspirations are some of the products Prairie Crossings is offering. An in the urban areas, these products are selling.

Traditional Neighborhood Developments Integrated with the Ecological Approach

Because of the growing need to integrate human developments harmoniously with natural systems, Applied Ecological Services, Inc. (AES), Brodhead, WI, and Land Planning Services, Inc., St. Charles, IL, are planning to create a series of model projects that would illustrate how the concepts of conservation development can be integrated with traditional neighborhood development (TND). The model projects will be designed to show how, in urbanizing areas, an ecologically sound TND can fulfill the desires of a growing marketplace, in large part by preserving and restoring the health and integrity of nearby natural areas.

In a Traditional Neighborhood Development, houses are clustered closely together, with wide front porches, sidewalks, large curbside shade trees, narrow streets,

garages built in back, mixed housing types for mixed income levels, lots of public parks and open space, a corner grocery store - in short, a neighborhood as opposed to a suburb.

The TND offers the small-town or neighborhood environment that fits well with the needs of people looking for connections with other people as well s the natural world. The integration of ecological systems with the TND environment is expected to broaden the interest in "conservation development" begun by Prairie Crossing.

A Swamp in the Middle of Town?

Attempts to naturalize urban sites based on ecological function often lead to the creation of wetlands which were far more prevalent historically than they are today. In some areas, this will be a controversial decision, and controversy can sometimes prevent these projects from getting on the ground.

For this reason, it is crucial to involve people from all walks of life in the process of urban ecosystems restoration. Not only can local people provide support for a restoration project, but they can also contribute observations about the site, its historic land use, its ecological functions, etc.

In the urban Chicago area, the Otter Creek Wetland Park, developed by Land and Water Resources, Inc. (LWR), Rosemont, IL, stands as the finest example of how to restore a healthy, functioning wetland ecosystem within urban boundaries while gaining appreciation for an improved quality of life from local area residents.

At Otter Creek, LWR developed the first private wetland mitigation bank in the U.S. by restoring a 56-acre farm field to its historic wetlands condition. Since its creation in the early 90s, wetland mitigation credits have been sold to fund the project, and the restored property has contributed to passive recreational uses as a popular public park under ownership of the St. Charles, IL, Park District.

Project team members LWR, Christopher B. Burke Engineering and AES designed the site as a passive recreation park by creating landscapes of prairies, wetlands, and riparian ecological systems. The park and design were keyed to use by school groups for outdoor and environmental education. Consequently, viewing areas, a trail system, and a special bridge to allow access for student projects - including stream water sampling opportunities - were integrated with the project plan.

Today, when student sampling shows the stream water to be clearer and cleaner than when it had been ditched to remove water quickly from the cropland, perhaps a young ecologist will recognize the biofiltration benefits of the upland swales.

And, perhaps, she will make a new discovery — one that will improve our restoration efforts in the future. One that shows us again, with new insight, how integrated our natural ecosystems are, and how connected our human systems can be with functional natural systems. **L&W**

For more information, contact Steve Apfelbaum, Applied Ecological Services, Inc., (608)897-8641, fax (608)897-8486, e-mail: AppliedEco@Brodnet.com

4.4 Impacts of Development Type on Runoff Volume and Infiltration Performance

Kent Brander, Katherine E. Owen, and Kenneth W. Potter[1]

ABSTRACT

Development type has emerged as an important focal point for addressing a wide range of social, cultural, and environmental concerns related to urban growth. Concurrently, infiltration is gaining recognition as an important stormwater mitigation strategy. In this study, four development types (conventional curvilinear, urban cluster, coving, and new urbanism) were modeled both with and without infiltration practices, in order to determine their relative effects on urban runoff. Modeling was performed with an expanded version of the NRCS Curve Number method, which was modified to permit evaluation of infiltration practices. Model results indicate that urban cluster developments produce the smallest volume of runoff due to the large portion of land kept in a natural condition. Additionally, significant reductions in runoff can be achieved in all four development types if infiltration practices treat many impervious surfaces; and as more infiltration practices are implemented, the differences in runoff between development types diminish. With a strategic combination of site layout and infiltration design, any development type can reduce hydrologic impacts, allowing developers to consider other factors, such as convenience, marketability, community needs, and aesthetics.

KEY WORDS: Infiltration, Urban Planning, Hydrologic Modeling, Runoff, Bioretention, Stormwater Management

INTRODUCTION

The introduction of impervious surfaces greatly increases the volume of storm runoff. Traditional stormwater management, which relies heavily on the use of detention ponds, controls the rate of storm runoff, but not the volume. The excess runoff can increase downstream flooding in streams and lakes and cause channel erosion and stream habitat degradation, even when detention practices are used (Lakatos and Krupp, 1982; Ferguson, 1991; Booth and Jackson, 1997). In addition, most of the water that runs off impervious surfaces would have, under natural circumstances, infiltrated into the ground, recharging groundwater. This loss of recharge, especially when coupled with excess groundwater pumping, can deplete groundwater supplies and reduce beneficial groundwater flow to wetlands, streams, and lakes (Simmons and Reynolds, 1982).

Infiltration of stormwater is a proven method for mitigating excess storm runoff. For example, since the 1930's, over 2000 infiltration basins have been constructed on Long Island to restore groundwater conditions; tests of these basins by Aronson and Seaburn (1974) indicated that over 90% of these basins were performing as designed. However, large-scale infiltration basins have serious disadvantages that limit their effectiveness in many locations. One problem is the difficulty of finding sites that have favorable soils and sufficient depths to groundwater. Infiltration basins also have a tendency to clog when fine-grained soils are present in the contributing watershed. For example, Lindsey et al. (1992) found that only 27% of infiltration ponds inspected in Maryland in 1986 and 1990 were working in both years.

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An alternative infiltration strategy is directing of runoff from impervious surfaces to nearby pervious surfaces and depressions, particularly those modified for increased permeability. This approach, which we refer to as on-site infiltration, has several advantages. First, it can be implemented at higher elevations in the watershed where, generally, soils are more permeable and the water table is further below the surface. On-site infiltration practices can also be much smaller than typical infiltration basins, making it easier to find a suitable location. Finally, local practices can be matched to the quality of water draining from a particular site. For example, infiltration of relatively unpolluted roof drainage can be carried out with much less water quality treatment than would be required prior to infiltration of runoff from a parking lot.

In this paper a simple spreadsheet model, based largely on the NRCS curve number runoff equation, is used to evaluate the potential benefits of on-site infiltration practices in the context of four types of development: conventional curvilinear, urban cluster, coving, and new urbanism. (This classification of development types is taken from SEWRPC, 2001).

PREVIOUS RESEARCH

The most common hydrologic models used to compute runoff hydrographs and to design stormwater control structures were not originally developed to model infiltration practices. Investigators of such practices have therefore either modified existing models or developed new ones suitable to the task.

Moglen (2000) modified the NRCS runoff method to account for the effects of directing runoff from impervious surfaces to pervious surfaces. Holman-Dodds, et al., (2003) used Moglen's approach to compare runoff from a hypothetical area under natural conditions with runoff from the same area under developed conditions, considering both conventional and infiltration-based stormwater management practices. They found that infiltration practices are most beneficial in relatively permeable soils and for small, common rain events. Sample, et al., (2001) modified NRCS runoff curve numbers to account for infiltration practices. Using a rainfall-runoff model developed for research purposes and based on the NRCS runoff method, they found the optimal mix of management practices for a hypothetical development.

Huber (2001) modified the Stormwater Management Model (SWMM) to account for runoff that is directed from one surface to another. This enables evaluation of vegetative buffer areas and spreading from an impervious surface to a pervious surface.

CH2M Hill (2001) used HSPF and the Santa Barbara Urban Hydrograph (SBUH) to evaluate the potential benefits of various practices including bioretention, soil amendments, reduced building footprints, and grass swales, in the context of two proposed developments in Pierce County, Washington. They found that low impact developments could produce a post-development hydrologic regime much closer to the natural regime than conventional developments.

Kronvater, et al., (2001) developed a new continuous hydrologic model for evaluating stormwater conditions in developed areas. This model includes options for modeling the performance of infiltration trenches and the disposition of runoff routed from impervious surfaces to pervious ones. In an application of the model to a development in Israel, they found that infiltration practices could

increase annual infiltration by 5-50%, depending on soil conditions, annual rainfall, and size of the practices.

DESCRIPTION OF THE MODEL, IP

Modification of widely used models to permit evaluation of infiltration practices is an important tool for low-impact stormwater design. Infiltration Patch (IP), a spreadsheet-based model developed for this study, utilizes and expands upon the curve number method outlined in NRCS Technical Report 55 (TR-55) by adding the capability to model infiltration practices. IP has the same capability as TR-55 to compute event runoff volumes, peak flows, and hydrographs from given precipitation events for small, urbanizing watersheds with known soil type, antecedent moisture conditions, and land use characteristics. Additionally, IP calculates the average annual runoff volume for the site, based on a geographically specific rainfall record. IP is not a continuous model, as it does not simulate ongoing changes in soil moisture conditions, and it also fails to account for the seasonal variations of frozen ground and snowmelt. In order to calculate average annual runoff volumes, the long-term precipitation record from thawed seasons is split into discrete, independent 24-hour events. All results from this study apply to Madison, Wisconsin, where the model was created, for the April 15th to October 15th time period. The average annual runoff from a site is important as an indicator of how much water is added to or taken away from the regional surface water or groundwater systems.

Two calculation procedures are included in IP that characterize general strategies for increasing the amount of infiltration at a site: spreading runoff from an impervious or less pervious surface over a more pervious surface, and using lot-scale infiltration basins (e.g., raingardens) to collect and infiltrate stormwater. Model characterization of these infiltration-enhancing processes may be used to represent a variety of specific structures that exist in the field.

In IP, the user divides the area under consideration into several land cover categories commonly found in residential neighborhoods (rooftop, driveway, street, lawn, raingarden, and high-permeability enhanced or undisturbed areas). The amount of runoff from each of these surfaces is computed separately, using the equations from TR-55, and the runoff can then be treated by one of the infiltration strategies described above. Looking at the entire site, the user determines the total amount of each type of land cover with runoff treated by either strategy. The original results from TR-55 are then modified to reflect the effects of the infiltration treatments.

Spreading Methodology

The user may choose to direct runoff from less-pervious to more-pervious surfaces. For example, the user can dictate that runoff from 30% of the total rooftop area will spread over 15% of the lawn area, or that runoff from 50% of the driveway area will spread over 40% of the enhanced area. Using the procedure Moglen (2000) created, the volume of runoff from the shedding surface is determined, and then added to the precipitation for the receiving surface. The runoff from the receiving surface is then computed using the adjusted precipitation value.

Raingarden Methodology

The user can also include raingarden area as part of any run of the IP model. A raingarden in IP is modeled as a depression with vertical sides, the bottom of which is a high-permeability engineered soil layer overlying the natural subsoil. The user enters the total raingarden area, raingarden

depression depth, engineered soil layer thickness, engineered soil infiltration rate, engineered soil porosity, engineered soil field capacity, and natural subsoil infiltration rate.

Inflow to the raingarden is represented by a runoff hydrograph computed using the SCS type II rainfall distribution and NRCS runoff calculation equations. This hydrograph (divided into 1-minute time steps) is routed through the raingarden basin, where during each interval water may infiltrate, overflow, remain in the raingarden depression, or be stored as soil moisture in the engineered soil layer. Infiltration rates into the two soil layers are controlled by the minimum of the available water and the corresponding constant infiltration rate. If water remains in the depression 48 hours after the beginning of the event, IP will return a warning message indicating that standing water could oversaturate and kill raingarden plants.

ANALYSIS OF DEVELOPMENT TYPES AND INFILTRATION PRACTICES

Four development types were considered: conventional curvilinear, urban cluster, coving, and new urbanism. Development characteristics were taken from the Land Division Control Guide, Planning Guide Number 1, (SEWRPC, 2001) as reproduced in Table 1. These characteristics were augmented by data collected from a conventional curvilinear development and new urbanism development located in Middleton, Wisconsin to obtain specific geometric elements.

Figure 1 illustrates the four development types. Conventional curvilinear, the most common development type in the United States, is easily identifiable by the cul-de-sacs, large lots, and minimal open space. Urban cluster developments are designed to protect environmentally sensitive areas by maximizing undisturbed open space and by creating small lots. Coving developments offer an estate-like feel by providing large lots, setbacks, and minimal streets. New urbanism developments typically consist of a large public common area and smaller lots. In an effort to encourage neighbor interaction and walking, garages are moved to alleys and therefore total street area is higher than in other development types.

Several factors affect runoff variations among different development types. First, if no infiltration practices are in place, the development layout, land cover distribution, and soil type determine the runoff volume. For example, development types such as urban cluster and new urbanism that emphasize communal open space rather than larger individual lot sizes produce less runoff, because open space has a lower curve number than lawns (In our analysis we assume that communal green space left open is not subject to grading, which allows the area to retain close-to-natural infiltration characteristics.) If local infiltration practices are used, other factors become important. Primarily, soil type and texture control infiltration rates and runoff curve numbers. In addition, it is important from a practical standpoint to consider how much space is conveniently available on each lot for infiltration practices. People who have already sacrificed a larger lot for additional open space may not be willing to give up what little yard space they do have in order to install a raingarden, and by this measure, the small lots associated with urban cluster and new urbanism developments leave less opportunity for lot-scale infiltration.

Infiltration Practices

Numerous combinations of infiltration practices were modeled within the context of the four development types under consideration. Individual practices are described in Table 2, and the constituent practices of the ten most representative and significant development scenarios

evaluated in this study are identified in Table 3. Neither of these tables is an exhaustive list of the practices or scenarios that may be modeled with IP.

The hydrologic effects of variations in soil type and precipitation were evaluated along with the effects of infiltration strategies, again within the context of the four development types. As indicated in Table 4, the three hydrologic soil types and textures modeled were group A (loamy sand), B (silt loam), and C (silty clay loam). The three precipitation scenarios modeled were the 1-year 24-hour event, the 100-year 24-hour event, and a long-term (many-event) analysis from which average annual hydrologic budget components were computed. These precipitation scenarios were selected for their applicability to key stormwater management issues. First, the 1-year 24-hour storm (2.4" for Madison, Wisconsin) is an important storm with respect to water quality. Second, many communities calculate detention storage from the 100-year 24-hour (6") storm. For this or other large storms, IP can be used to determine the reduction in detention requirements effected by the use of infiltration practices. Finally, the long-term analysis (19.88" of precipitation for April 15 to October 15) and subsequent computation of average annual runoff allows for comparison of the overall water budgets resulting from different scenarios. Most rain events in a year are small enough that infiltration practices can reduce their associated runoff to zero; the long-term calculations account for the cumulative effect of reducing or eliminating runoff from these many small events, an effect that is not detected when analysis is limited to infrequent large events.

RESULTS

Figures 2a to 2i presents the runoff depth for each infiltration practice scenario, precipitation scenario, and soil type, in context of the four development types under consideration. Several conclusions can be drawn from the model results presented in the above figures. The following remarks highlight key observations.

- *Infiltration practices can significantly reduce runoff in any development type*

Although runoff is not reduced to predevelopment levels in any of the development types (Scenario 10), infiltration practices can significantly reduce runoff in all of them. With the most aggressive infiltration combination used in this study, runoff from the 100-year 24-hour storm in a conventional curvilinear development atop A soils is reduced by 60% (Scenario 9) as compared to the development with no infiltration practices (Scenario 1).

- *Hydrologic Group A soils are most sensitive to infiltration practices*

Hydrologic Group A soils are the most sensitive to infiltration practices and achieve the highest percent runoff reduction of all soil groups from infiltration practices. For example, all developments atop A soils achieve a minimum runoff reduction of 47% for the 100-year 24-hour storm from the case when many infiltration practices are used (Scenario 9), as compared to the case in which no infiltration practices are used (Scenario 1). Comparatively, the corresponding reduction in the case of C soils is at most 21%.

- *It is better to do numerous infiltration practices, rather than a few "very good" practices*

Results from IP suggest that it is more effective to treat more impervious areas than to treat fewer areas to a higher level. For example, if a developer were to install only very well constructed

raingardens to treat rooftop water and did no other infiltration practices, runoff would still be significantly higher than the scenario with multiple practices. This is apparent in the difference in runoff between Scenario 3 and Scenario 9.

- *Raingardens boost recharge more than spreading onto lawns*

In all cases, raingardens are more effective in reducing runoff than spreading runoff onto lawns (Scenario 2 vs. Scenario 3). Additionally, Dussaillant (2002) showed that raingardens concentrate water and maximize recharge, due in part the resulting reduction in evapotranspiration.

- *Infiltration practices are most effective for small storms*

These results confirm the conclusion made by Holman-Dodds, et al. (2003) that infiltration practices are most effective for small storms. Because an average year is mainly comprised of very small precipitation events, runoff from most daily events can be eliminated via infiltration. Runoff for all developments atop B soils is reduced by at least 85% for an average year when many infiltration practices are used (Scenario 9), as compared to the case in which no infiltration practices are used (Scenario 1). By way of contrast, the analogous reduction in the case of the 100-year 24-hour storm is at most 32%.

- *Spreading runoff over a compacted lawn is not very effective*

The effectiveness of the runoff-spreading strategy depends to a large extent on how a given pervious area has been treated. In particular, lawns compacted during construction are significantly less effective infiltration areas than uncompacted lawns (Scenario 5 vs. Scenario 6 and Scenario 7 vs. Scenario 8). In order to maximize infiltration on lawns, compaction must be either avoided during construction, or reversed following construction by deep tilling with compost or other accepted methods.

- *The urban cluster development type produces the least runoff due to the large area left in its natural condition*

Urban cluster produces the least runoff of all the development types under consideration, because much of the site is left in its natural state. Consequently, even if a developer decides not to implement any infiltration practices, benefits could still be attained by including significant undisturbed open area in the site design.

- *Differences in runoff between development types diminish as more infiltration practices are implemented*

For example, if no infiltration practices are implemented (Scenario 1), the difference between conventional curvilinear and urban cluster for the average year for Hydrologic Group B soils is nearly 0.9”, whereas the difference between these two development types for the most aggressive infiltration combination (Scenario 9) is only 0.1”.

CONCLUSION

Concern about the consequences of land development with regard to surface water and groundwater volume has motivated studies on the hydrologic effects of site design and on-site

infiltration practices. In this study, a model based on an expanded version of the NRCS curve number method was developed and used to assess how infiltration practices and development type affect the amount of runoff from a site. Four prevalent development types (conventional curvilinear, urban cluster, coving, and new urbanism), with and without various infiltration practices, were analyzed within multiple hydrologic soil group and precipitation contexts. While infiltration practices reduce runoff, they are not a substitute for conveyance and detention and should be used in combination with these traditional techniques. The urban cluster development type produced the least amount of runoff due to the large percentage of total land area left uncompacted. Model results indicated that significant reductions in runoff can be achieved in any development if infiltration practices treat many impervious surfaces; and that as more infiltration practices are implemented, the differences in runoff between development types diminish. With a strategic combination of site layout and infiltration design, any development type can reduce hydrologic impacts, allowing developers to consider other factors, such as convenience, marketability, community needs, and aesthetics.

ACKNOWLEDGMENTS

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Table 1: Comparative Analysis of Subdivision Designs

	Subdivision Type			
	Conventional Curvilinear	Urban Cluster	Coving	New Urbanism
Lot Information				
Number of Lots	160	160	160	160
Average Lot Size (sq. ft.)	17002	6028	16517	7325
Average Lot Width (ft.)	95	60	81	62
Average Lot Depth (ft.)	179	101	204	118
Average Rooftop Area (sq. ft.)*	2200	2200	2200	2200
Average Front Yard Setback from Right-of-way (ft.)*	30	17	50	17
Average Driveway Width (ft.)*	20	20	20	20
Average Driveway Length if Connected to Street (ft.)*	43	30	63	30
Average Driveway Length if Connected to Alley (ft.)*	N/A	N/A	N/A	12
Percent of Site Area within Lots	77.0	27.3	74.8	33.2
Street Information				
Total Street Length (ft.)	10363	10730	9865	17154
Street Right-of-Way Width (ft.)*	66	66	66	66
Street Width (ft.)*	40	40	40	40
Alley Width (ft.)*	N/A	N/A	N/A	14
Sidewalk Width (ft.)	4	4	4	4
Percent of Site Area within Street Right-of-Way	18.1	15.8	15.3	20.7
Open Space Information				
Percent of Site Area within Open Space	4.9	57.2	9.9	46.1

*These assumptions were based on Northlake Development, a conventional curvilinear development, and Middleton Hills, a new urbanism development, both located in Middleton, Wisconsin. All other data directly from Land Division Control Guide (Southeast Wisconsin Regional Planning Commission, 2001).

Table 2: Infiltration Practices Used in Modeling

Practice	**Comments**
Spreading rooftop runoff over lawns	Downspouts are set to drain onto pervious lawn area rather than to impervious surfaces connected to the drainage network. 100% of rooftop area is treated in this manner.
Improving the infiltration capacity of lawns	Minimizing damage through careful construction or reversing effects of soil compaction by tilling in compost can increase the curve number and infiltration of lawns. The curve number of the lawn improves to 49 for A group soils, 69 for B group soils, and 79 for C group soils.
Directing rooftop runoff into raingardens	Due to limited lawns in urban cluster and new urbanism developments, raingarden sizes are kept at 10% of the rooftop area. Raingarden sizes are set at 30% of the rooftop area for the conventional curvilinear and coving developments, which contain larger average lot sizes.
Spreading driveway and sidewalk runoff over lawns	Driveways and sidewalks are designed to shed runoff onto adjacent pervious area.
Reducing street width	Street width for all developments is reduced to 32'.
Directing street runoff into grass swales	Curb-and-gutter networks are either eliminated or slotted to permit drainage into pervious, vegetated drainage swales.
Directing street runoff into raingardens	A series of raingardens are placed between the street and sidewalks to collect runoff from the streets. These raingardens are sized at 10% of the street area.

Table 3: Evaluated Combinations of Infiltration Practices

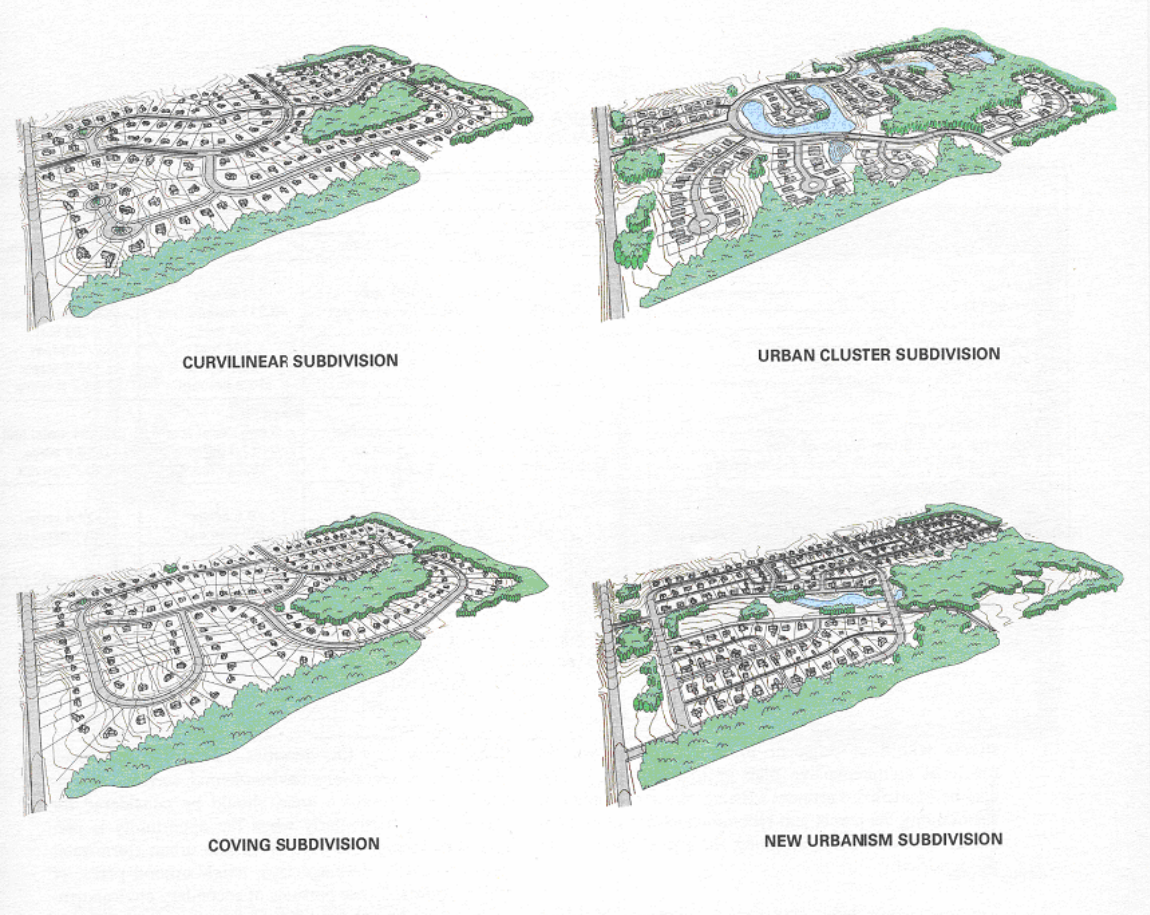
Infiltration Practices	**Scenarios**									
	1	2	3	4	5	6	7	8	9	10
No Infiltration	X									
Spread Roof to Lawn		X		X	X	X				
Improve Lawn				X	X		X		X	
Raingarden (10% or 30% of roof)			X				X	X	X	
Spread Driveway to Lawn					X	X	X	X	X	
Reduce Street Width					X	X	X	X	X	
Grass Swales					X	X	X	X		
Raingarden (10% of street)									X	
Predevelopment										X

Table 4: Comparative Analysis of Soil Groups

	Hydrologic Soil Group		
	A	B	C
Undisturbed Enhanced Open Area Curve Number	30	58	71
Compacted Lawn in Poor Condition Curve Number	68	79	86
Rooftop Curve Number	98	98	98
Driveway Curve Number	98	98	98
Street Curve Number	98	98	98
Soil Texture	Loamy Sand	Silt Loam	Silty Clay Loam
Natural Subsoil Infiltration Rate (in/hr)**	1.2	0.26	0.04

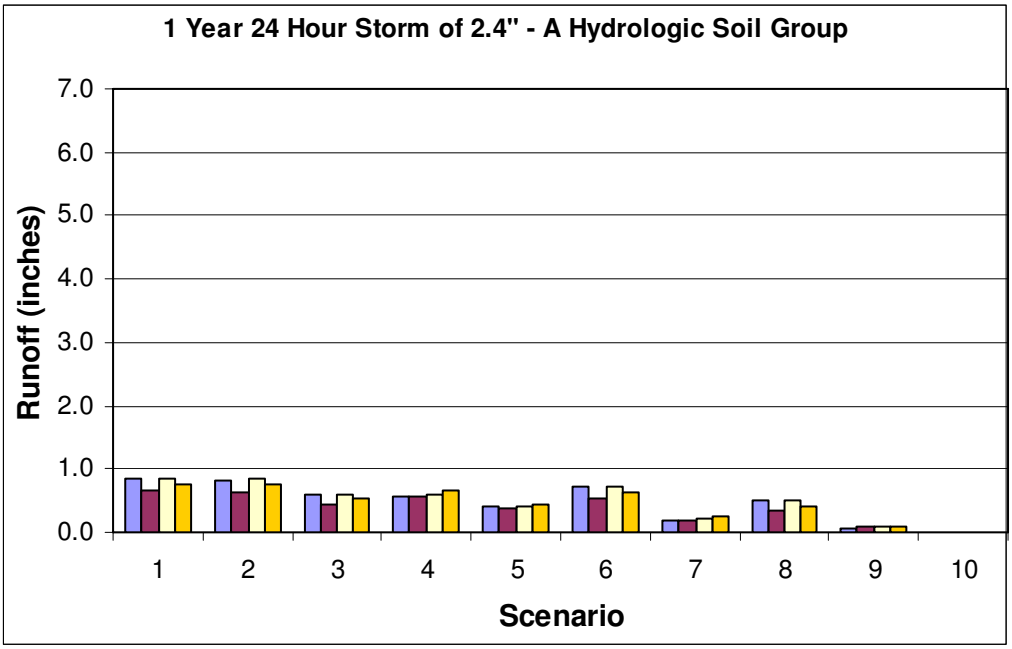
**From Rawls, Brakenseik & Miller (1987)

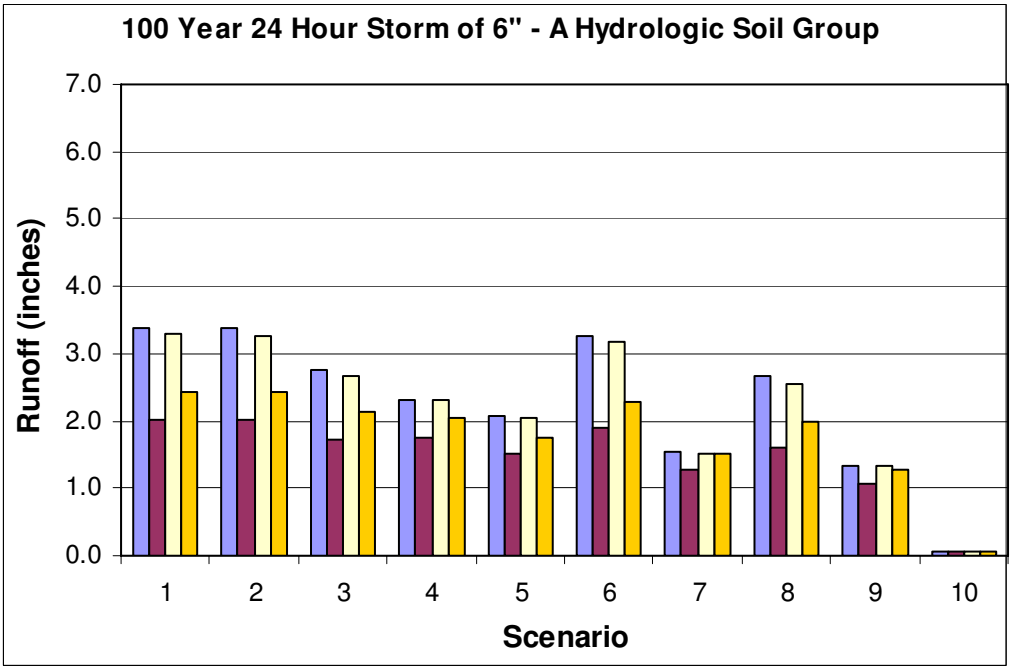
Figure 1 Oblique Aerial View of Four Subdivision Designs

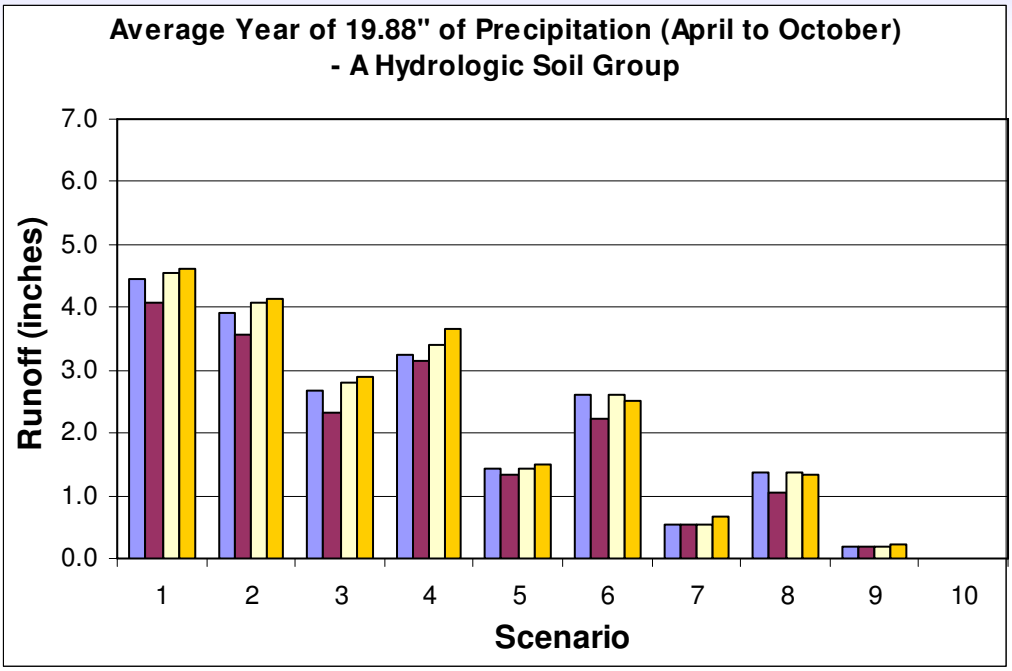


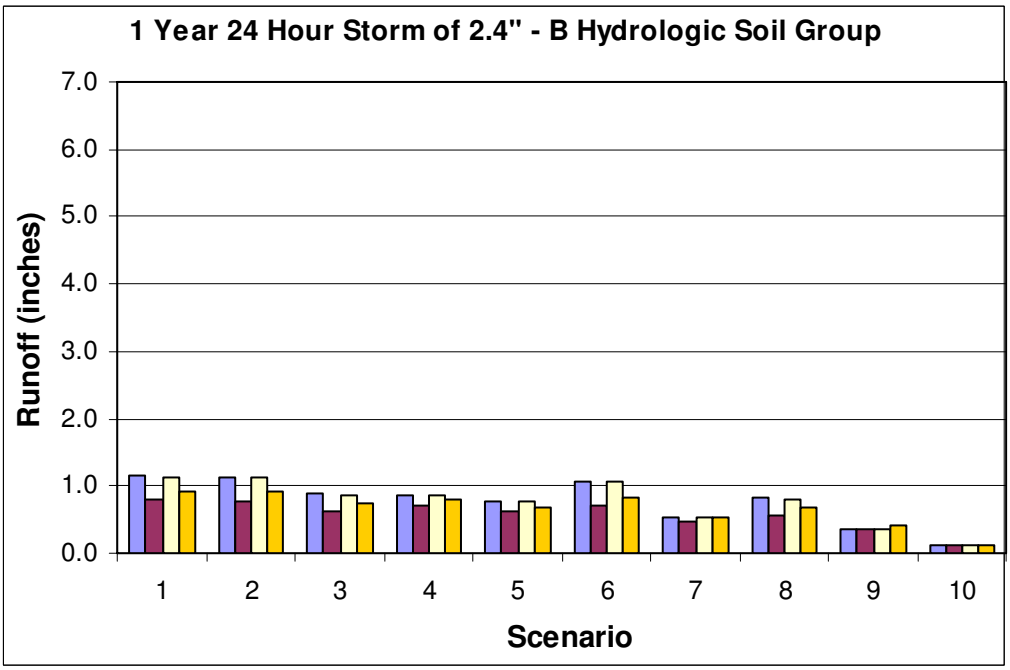
From Land Division Control Guide (Southeast Wisconsin Regional Planning Commission, 2001).

Figure 2a-i Runoff Depth for Infiltration Practices, Precipitation, and Soil Group Scenario Combinations for the Four Development Types






Average Year of 19.88" of Precipitation (April to October)
- A Hydrologic Soil Group
Runoff (inches)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1
2
3
4
5
6
7
8
9
10
Scenario


1 Year 24 Hour Storm of 2.4" - B Hydrologic Soil Group
Runoff (inches)
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6.0
5.0
4.0
3.0
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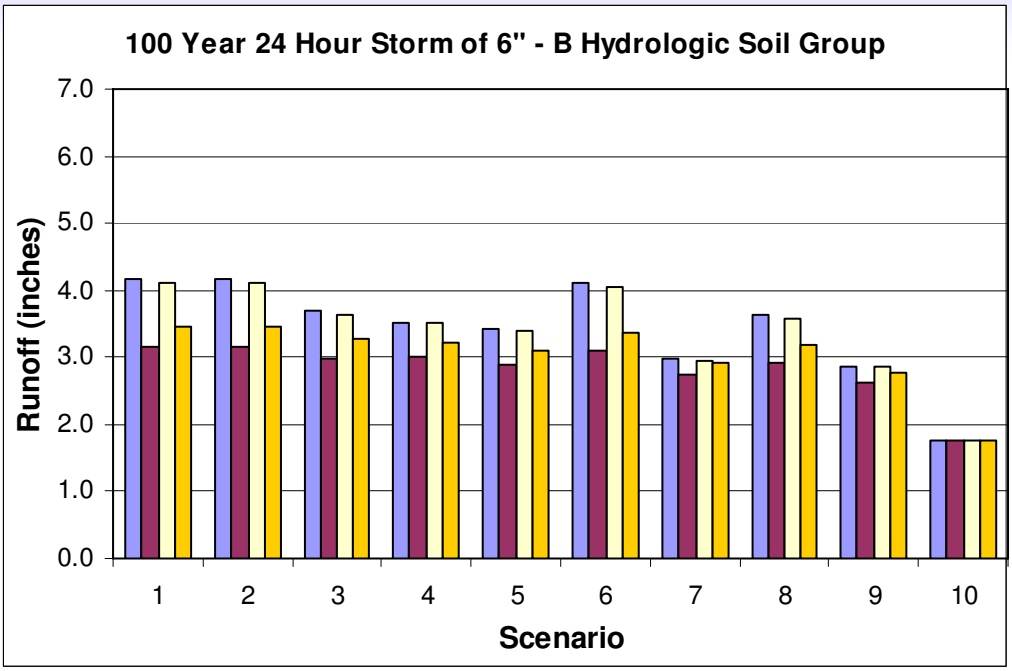
1.0
0.0
1
2
3
4
5
6
7
8
9
10
Scenario


100 Year 24 Hour Storm of 6" - B Hydrologic Soil Group
Runoff (inches)
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5.0
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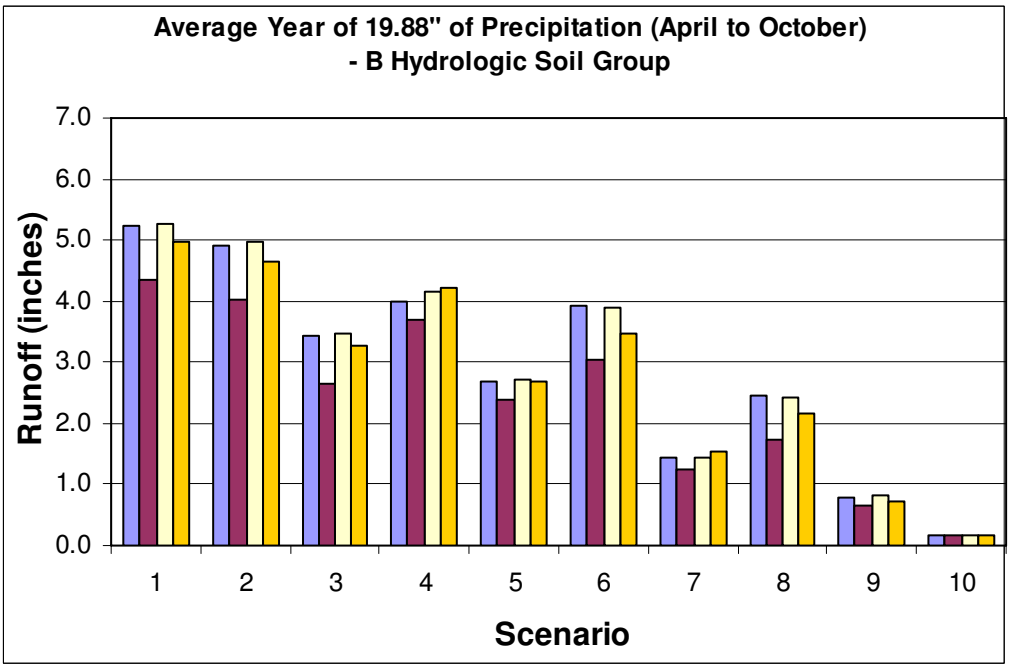
1
2
3
4
5
6
7
8
9
10
Scenario


Average Year of 19.88" of Precipitation (April to October)
- B Hydrologic Soil Group
Runoff (inches)
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6.0
5.0
4.0
3.0
2.0
1.0
0.0
1
2
3
4
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6
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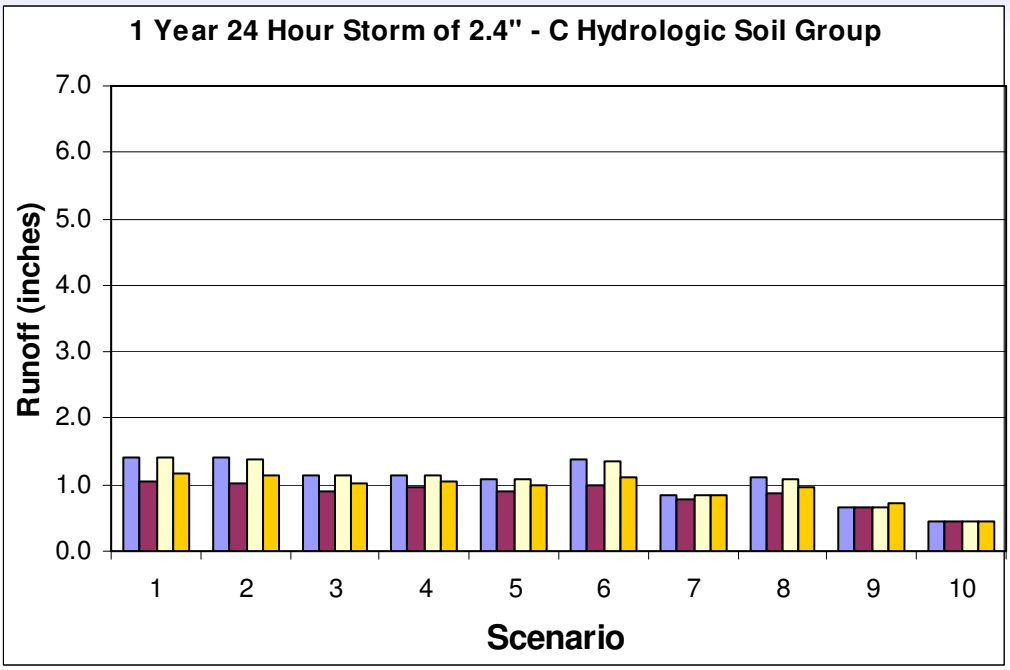
8
9
10
Scenario


1 Year 24 Hour Storm of 2.4" - C Hydrologic Soil Group
Runoff (inches)
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5.0
4.0
3.0
2.0
1.0
0.0
1
2
3
4
5
6
7
8
9
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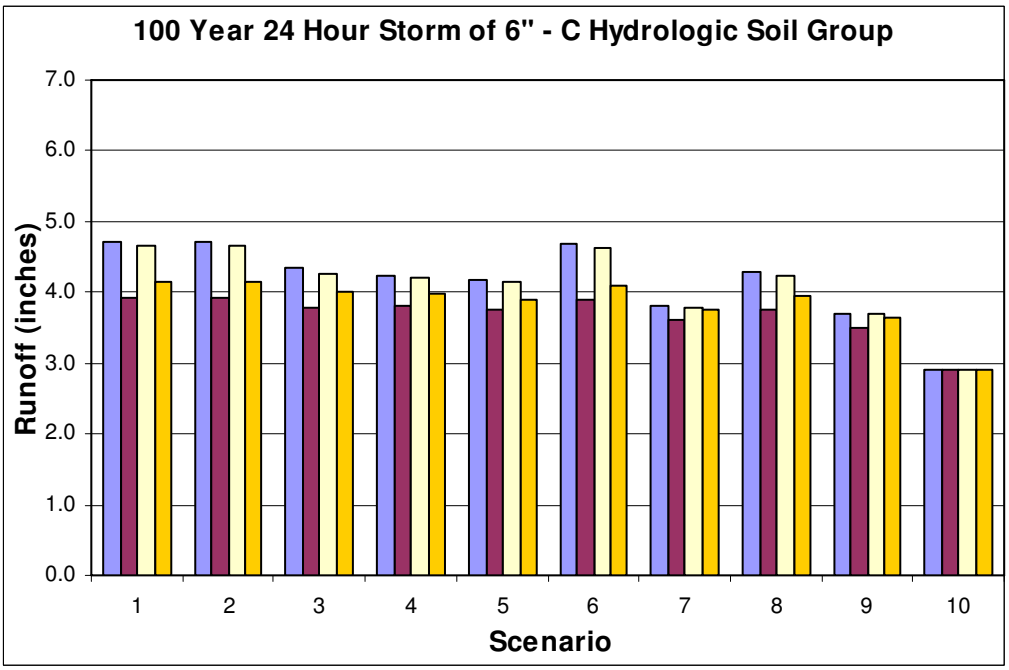
Scenario


100 Year 24 Hour Storm of 6" - C Hydrologic Soil Group
Runoff (inches)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
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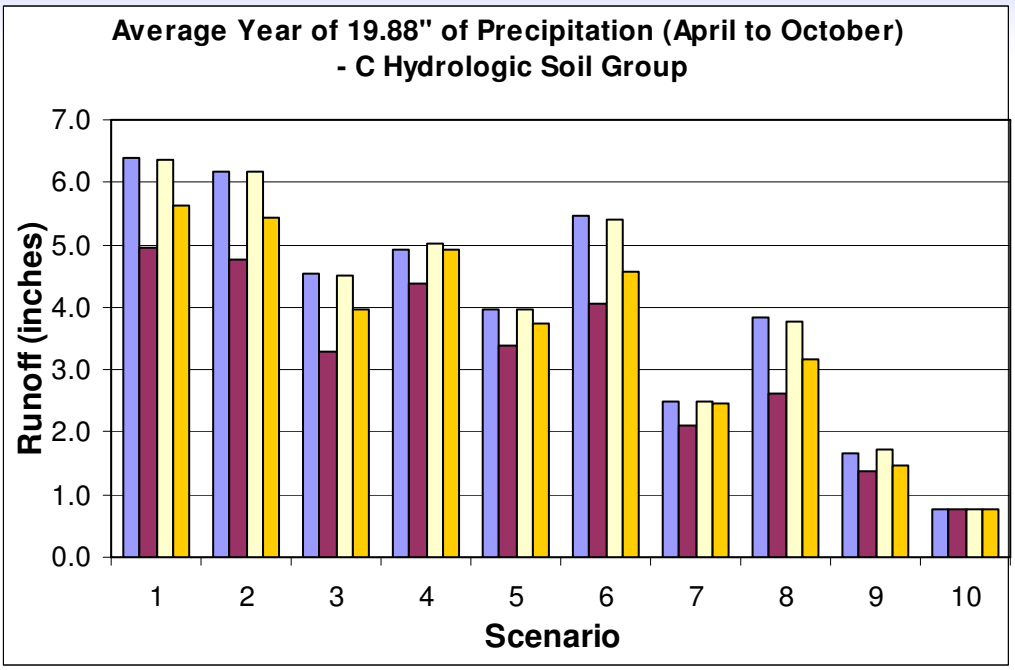
Scenario


Average Year of 19.88" of Precipitation (April to October)
- C Hydrologic Soil Group
Runoff (inches)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
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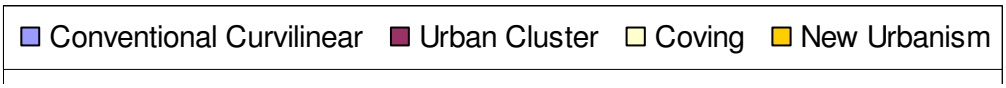
10
Scenario

Legend:


Conventional Curvilinear
Urban Cluster
Coving
New Urbanism

4.5 Using Native Plants to Improve Water Quality

Once viewed as obstacles and land planning headaches, natural systems are now being recognized as a solution to water resource management problems. Using natural systems instead of trying to avoid or eliminate them has proven to be a low-cost Best Management Practice (BMP) in land development and watershed restoration projects. Incorporating native plant materials into water management projects can improve water quality, provide additional and improved wildlife habitat, and, because they are optimally adapted to local conditions, minimize maintenance. The six projects described below are in place in southeastern Pennsylvania, functioning successfully, and easily adaptable for a variety of regulatory and non-regulatory projects.

The regulatory (reactive) issues focus mainly on stormwater management. Natural systems BMPs can be integrated into the National Pollution Discharge Elimination System (NPDES- II), Stormwater Management ACT 167 Planning Program, and Municipal Separate Storm Sewer Systems (MS4). The following two paragraphs from the Pennsylvania Comprehensive Stormwater Management Policy illustrate the thrust of the regulatory focus.

> Unmanaged or poorly managed stormwater can result in stream bank scour, stream destabilization, sedimentation, loss of groundwater recharge, loss of base flow, localized flooding, habitat modification and water quality and quantity impairment. Conversely, properly managed stormwater through properly constructed and maintained best management practices (BMPs) can remove pollutants, facilitate ground water recharge through retention and infiltration, provide base flow for surface water and maintain the stability and the environmental integrity of waterways and wetlands. To provide long-term protection and sustainability of ground and surface water resources, stormwater should be managed at the source or origin as an environmental resource to be protected rather than as a waste to be quickly discharged and moved downstream.
>
> Fundamentally, the goals of the policy are to improve and sustain ground and surface water quality and quantity through the use of planning practices and BMPs that minimize the generation of stormwater runoff, provide ground water recharge and minimize the adverse effects of stormwater discharges on ground and surface water resources. This policy also supports the fulfillment of the state's obligation

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USING NATIVE PLANTS TO

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under 25 Pa. Code Section 93.4a to protect and maintain exiting uses and the level of water quality necessary to protect those uses in all surface waters and to protect and maintain water quality in special protection waters. Special protection waters are Pennsylvania's highest quality surface waters and include Exceptional Value (EV) and High Quality (HQ) waters.

The non-regulatory (proactive) use of natural systems is being implemented on a community watershed basis through Pennsylvania's Growing Greener program. Growing Greener encourages the identification and remediation of non-point source pollution by local residents, farmers, schools, and municipalities. The BMP projects described here, all of which use native plants, were initiated at the community watershed level and, in some cases, were completed with the help of community volunteers.

1. **Regional Water-Quality Management.** A six-acre municipal water-quality facility filters runoff from upstream agricultural fields and provides uptake for phosphorus and nitrogen. A forebay provides a three-year maintenance for sediment being transported through the system, which is maintained by the municipality. The filtration area is immediately adjacent to active sports fields and a rails-to-trails network and is surrounded by mixed-use residential properties. The facility supports a diverse wildlife population including migrating waterfowl, wading birds, amphibians, and reptiles while aiding in stormwater management for the watershed. Plantings, installed by community volunteers, include soft stem bulrush, bur reed, duck potato, yellow and blue iris, pickerelweed, rice cut grass, black willow, button bush, swamp rose, silky dogwood, arrowwood, and chokeberry. (Lititz Run, Warwick Township, Lancaster County)

Lititz Run, Warwick Township, Lancaster County

Pocopson Township, - Chester County

2. **Infiltration/Stormwater Management.** Collaboration between the architect and planner produced an innovative solution to stormwater management at minimal costs. A no-gutter roof system flows directly into a created wetland basin, eliminating the need for pipes and gutters. Wetland plantings include broadleaf cattail, soft rush, and mixed sedges. (Pocopson Township, Chester County)

3. **Stormwater Management/Aesthetics/Maintenance**. A low-lying area adjacent to a community walking trail and park was difficult to maintain. Designers converted the area to a wetland, which now filters runoff before it enters Cocalico Creek and provides an aesthetic component to a public area through the use of aquatic and aquatic emergent plants, wildflowers, and flowering shrubs. Community volunteers helped install the wetland. Plantings include duck potato, bur reed, soft stem bulrush, soft rush, woolgrass, buttonbush, silky and red osier dogwoods, arrowwood, and an assorted wildflower meadow mix. (Cocalico Creek, Ephrata Borough, Lancaster County)

Cocalico Creek Borough, Lancaster County

IMPROVE WATER QUALITY

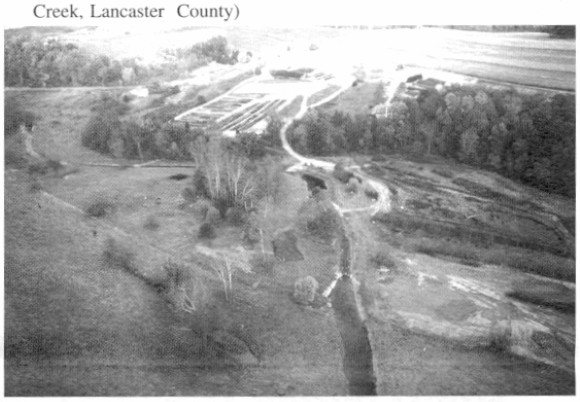
Lititz Run, Millport Conservancy - Warwick Township, Lancaster County

4. **Riparian Buffer.** Riparian (streamside) buffers provide bank stability, shading to reduce water temperatures, wildlife corridors, nutrient uptake, and organic material for the stream. State and federal governments are aggressively promoting riparian buffers as a BMP. The federal program for farmers, Conservation Reserve Enhancement Program (CREP), compensates agricultural landowners for converting marginal streamside pastures into riparian corridors. The corridors also provide a sense of structure to the landscape. The six-year-old buffer shown here consists of black willow, sycamore, red maple, black gum, river birch, black and red chokeberry, winterberry, and poplars. (Lititz Run, Millport Conservancy - Warwick Township, Lancaster County)

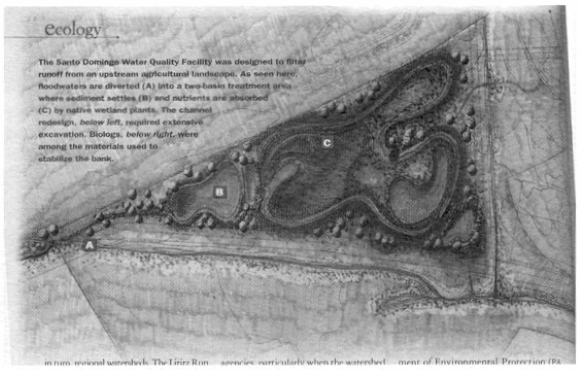
Downingtown Middle School, Downingtown, Chester County

5. **Schools.** Teachers are using a designed wetland area built adjacent to their school as an outdoor classroom for environmental studies. The project is consistent with recent Pennsylvania Education Curriculum Standards for Ecology and Environment. Emergent wetland plantings include soft stem bulrush, soft rush, lurid sedge, dark green bulrush, and woolgrass. (Downingtown Middle School, Downingtown, Chester County)

6. **Natural Channel Design.** A stream relocation project included the creation of 10 acres of wetlands. The stream channel was overwide, shallow, and unable to transport sediment. As a result, the streambanks contributed over 1,500 tons of eroded sediments to the water channel per year. The restoration project connected the channel to the active floodplain to reduce erosion significantly, increase and improve aquatic wildlife habitat, and transport sediment. The former channel was used to create wetlands. Plantings include live transplants of silky dogwood, black willow, and arrowwood. Additional riparian buffer plants include sycamore, red maple, green ash, river birch, pin oak, and black gum. (Octoraro Creek, Lancaster County)



Octoraro Creek, Lancaster County



Mark Gutshall is President of LandStudies, Inc. and founder of Octoraro Native Plant Nurseries. LandStudies was responsible for all of the design-build projects shown above.

4.6 Prairie Restorations: What to Expect and Why

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Foreword

Within the first year of a prairie planting we receive calls asking "Where's the prairie, all I see are weeds?" Because of the methods of prairie restoration site selections, site preparation, site maintenance, and the growth habit of prairie plants, a large number of weeds are present in the initial establishment phase of the prairie planting. Hopefully, the following narrative will help to explain the process involved in prairie restoration and what should be expected from your prairie planting.

Year One

Site Preparation

In most cases, agricultural fields, old pastures, and fallow fields are selected for prairie plantings. This is not surprising, since historically these areas were probably once prairie or savanna and were converted to farm fields because of their excellent soils.

In preparing a prairie planting, the same farm practices and equipment a farmer uses to prepare his field are also employed in prairie site preparation. Depending on the situation, it may be necessary to apply herbicides to kill weedy vegetation, or may involve disking, tilling, and recontouring. However, these practices are extremely conductive to the establishment of non-native weeds. The farmer is able to apply selective herbicides to control most weeds. The prairie restorationist is limited in this regard, since the herbicides are also lethal to many prairie plants.

The combination of good soil, and years and years of agricultural practice allows for thousands (sometimes hundred of thousands) of weed seeds to build up in the soil. Prairie site preparation methods provide an excellent habitat for these weeds to survive and grow.

Plant Strategy

Most prairie plantings occur in spring and the initial flush of vegetation appears to be nothing but weeds. Most weed seeds will germinate in the spring immediately after the site has been prepared. Don't panic, this is supposed to happen. Exposure of the soil during site preparation has allowed for the germination of many species. Weeds associated with agricultural fields and prairie plantings are annuals (they germinate, grow, set seed, and die in one growing season). On the other hand most prairie plants are biennials (require two growing seasons to flower and perennials (continue to grow year after year from below ground organs).

Since annual plants have very little time to grow and set seed, they typically germinate early in spring, grow rapidly and tall, and produce a large number of seeds. Biennials typically form a low growing rosette the first year and flower during the second year. Perennials, since they depend on below ground structures for a large part of their existence invest in large amount of energy to root production.

Thus, annuals allocate most of their nutrients to stems, leaves, and seed and become the most conspicuous plants in the first year. Perennials, on the other hand, may be quite abundant, but since they have allocated most of their nutrients to growing roots, they are not always evident. A qualified consultant or trained ecologist can identify these small prairie perennials among the many weeds. These two contrasting plant strategies (think of it as the fable of the tortoise and the hare; we all know who eventually wins) of rapid vs. slow growth results in what many people describe as just a field of weeds. Again, don't panic, be patient. The perennial prairie plants are present.

Site Maintenance

During the first growing season, mowing at a height of six inches when the vegetation reaches about one foot is recommended. This is detrimental to the weeds and prevents them from producing seeds. However, the perennials are too small to be injured by a six-inch mowing. No watering or fertilizing is recommended this benefits the weedy species. Native perennials are adapted to the natural conditions and require no watering or fertilizer.

Year Two

All the seeds of the weedy annuals that germinated in year one have died, and if proper maintenance was done, the number of weed seeds in the soil has been greatly diminished. The perennials, with their well-established root system, now can begin to allocate a greater portion of their nutrient reserves to above ground plant parts. What one begins to observe is called succession. Succession is the process by which plant community replaces another plant community. In this case, it is the beginning of the perennial prairie species replacement of the weed community. Remember, this is not an all or none process, some weed species can persist for years. Prairie plants with their increased production of above ground structures and their superior below ground (root) system gradually out-compete and replace the weeds. Expect some prairie plants to flower in year two.

Site Maintenance

Since soil disturbance is essential for the weeds to continue to survive, it is recommended that weeds not be pulled out by roots. The area vacated by a weed by such an act leaves a small area of disturbed soil from which many seeds in the soil can emerge.

Fire is an integral part in the maintenance of a healthy native prairie. Fires have maintained native prairies for thousands of years. By investing a large portion of their nutrients to an under ground structure, they can endure most, if not all, prairie fires. Weedy annuals are afforded no such protection and can not cope with repeated fires. Again, be patient, one initial fire will not rid your prairie planting of all weeds. Burning is best accomplished in early spring or late fall.

Year Three and Four and Beyond

Burning may be required; if there is sufficient above ground dried fuel, for several consecutive years. Generally after year four, the prairie plants are well on their way and it may be necessary to burn only every two or three-years. Years three and four should become increasingly colorful as more and more of the prairie plants reach sufficient size (vigor) to flower.

Some additional questions that might be raised concerning a prairie restoration site:

1) Will there be a time when all the weeds have been replaced? No, even minor soil disturbances such as those created by ant mounds and animal tracks provide sufficient habitat for some weeds to establish.

2) Is it harmful to have some weeds? No, as long as weeds are kept to manageable levels they will not present a problem. In fact, some weeds are quite attractive when they flower.

3) Are there alternative options to burning? Not really, the prairie plants are adapted to fire, which concentrates nutrients and blackens the surface, which warms the soil in spring allowing prairie plants to begin growth early.

4) All weedy species annuals? No, some weedy species such as bluegrass are perennials. These species are not as easily removed or replaced through succession, competition, mowing or fire. While they might not be eliminated for a number of years, they can be reduced to minor components within the prairie landscape.

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ATTACHMENT A

EXAMPLE BMP SELECTION MATRIX

Minnesota Urban Small Sites **BMP** Manual. Section 2
www.metrocouncil.org/environment/ Watershed/BMP/CH2_Selecting.pdf

Stormwater Treatment BMP Selection Matrix[1]

This section outlines a process for selecting the best stormwater treatment BMP or group of BMPs for a small site and provides factors to consider for their placement. The three-step process described below should be used to select which BMPs can best meet predetermined pollutant removal targets. This process guides the designer through three steps that progressively screen:

- Stormwater Treatment Suitability
- Physical Feasibility Factors
- Community and Environmental Factors

The Three-Step Process

Step ❶ Stormwater Treatment Suitability

Use the stormwater treatment matrix to answer the following question:

Can the BMP meet the stormwater rate, volume, and water quality treatment requirements mandated by local regulations at the site or are a combination of BMPs needed?

In this step, designers can screen the BMP list using the Step 1 matrix to determine if a particular BMP can meet the rate, volume, and water quality requirements they have identified. At the end of this step, the designer can reduce the BMP options to a manageable number and determine if a single BMP or a group of BMPs are needed to meet stormwater sizing criteria at the site.

Step ❷ Physical Feasibility Factors

Use the stormwater treatment matrix to answer the following question:

Are there any physical constraints at the project site that may restrict or preclude the use of a particular BMP?

In this step, the designer screens the BMP list using Step 2 matrix to determine if the soils, water table, drainage area, slope or head conditions present at their development site might limit the use of a particular BMP. In addition, the second matrix indicates whether a BMP is capable of treating hotspot runoff and provides comparative indexes on land consumption.

Step ❸ Community and Environmental Factors

Use the stormwater treatment matrix to answer the following question:

Do the remaining BMPs have any important community or environmental benefits or drawbacks that might influence the selection process?

In this step, the third matrix is used to compare the 16 stormwater treatment BMP options with regard to maintenance, community acceptance, habitat and cost.

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[1]Adapted from the *Maryland Stormwater Design Manual*, Maryland Department of the Environment.

Step ❶ Stormwater Treatment Suitability Matrix

Runoff Hydrology

Rate Control

The matrix indicates the relative capacity of the BMP to provide rate control. If a particular BMP cannot meet the full rate control requirement it should not be necessarily eliminated from consideration, but it is an indication that more than one practice may be needed at a site (e.g., a bioretention area and a downstream stormwater wetland).

Volume Reduction

The matrix indicates the relative effectiveness in reducing the volume of stormwater runoff. Again, the fact that a particular BMP cannot fully meet the requirement does not necessarily mean that it should be eliminated from consideration, but rather is a reminder that more than one practice may be needed at a site.

Water Quality

The four columns under the Water Quality heading are (1) TSS - Total Suspended Solids, (2) P & N - Phosphorus and Nitrogen, (3) Metals, and (4) Fecal Coliform. These columns indicate a particular BMP's expected benefits for each of the four constituents. A "primary" in a column indicates that this is a primary benefit of the BMP. A "secondary" indicates the BMP has some benefit but it is not the intended or primary benefit. A "minor" indicates there is little or no benefit using this BMP to control this constituent. It should be understood that a "primary" rating under the TSS column, for example, for wet vaults and a "primary" rating of TSS for an infiltration basin does not mean that the benefit or performance is the same or even similar. Rather it means that TSS removal is a primary benefit of each of these BMPs. It is not a comparison of BMP performance to one another.

Step ❶ Stormwater Treatment Suitability Matrix

BMP Family	BMP List	RUNOFF HYDROLOGY		WATER QUALITY BENEFIT			
		Rate Control	Volume Reduction	TSS	P & N	Metals	Fecal Coliform
Retention	Wet Pond	High	Low	Primary	Secondary	Secondary	Secondary
	Extended Storage Pond	High	Low	Primary	Secondary	Secondary	Secondary
	Wet Vaults	Medium	Low	Primary	Secondary	Secondary	Minor
Detention	Dry Pond	High	Low[1]	Secondary	Minor	Minor	Minor
	Oversized Pipes	High	Low	Minor	Minor	Minor	Minor
	Oil Grid/Separator	Low	Low	Secondary	Minor	Minor	Minor
	Dry Swale	Medium	Low[1]	Primary	Secondary	Primary	Minor
Infiltration	On-Lot Infiltration	Medium	High	Primary	Primary	Primary	Secondary
	Infiltration Basin	Medium	High	Primary	Primary	Primary	Secondary
	Infiltration Trench	Medium	High	Primary	Primary	Primary	Secondary
Wetland	Stormwater Wetland	High	Medium	Primary	Secondary	Secondary	Primary
	Wet Swale	Low	Low	Primary	Secondary	Secondary	Minor
Filtration	Surface Sand Filters	Low	Low[1]	Primary	Secondary	Primary	Secondary
	Underground Filters	Low	Low	Primary	Secondary	Primary	Secondary
	Bioretention	Medium	Medium	Primary	Primary	Primary	Secondary
	Filter Strips	Medium	Medium	Secondary	Minor	Minor	Minor

[1]Mayprovide some volume reduction depending on permeability of native soil.

Step ❷ Physical Feasibility Factors Matrix

At this point, the designer has narrowed down the BMP list to a manageable size and can evaluate the remaining options given the actual physical conditions at a site. The six primary factors are:

Soils

The key soils evaluation factors are based on an initial investigation of the Natural Resources Conservation Service (NRCS) hydrologic soils groups at the site. Note that more detailed geotechnical tests are usually required for infiltration feasibility and during design to confirm permeability and other factors.

Water Table

This column indicates the recommended minimum depth to the seasonally high water table from the bottom or floor of a BMP. The designer should check to see that local regulations do not require further restrictions, primarily with respect to infiltration and runoff from hot spots.

Drainage Area

This column indicates whether or not the BMP is considered suitable for small sites of 5 acres or less. The restrictions indicated for ponds and sometimes wetlands should not be considered inflexible limits and may be increased or decreased depending on water availability (baseflow or groundwater).

Head

This column provides an estimate of the elevation difference needed at a site (from the inflow to the outflow) to allow for gravity operation within the practice.

Area Requirements

This comparative index expresses the typical space or area requirements for the BMP. A "low" indicates that the BMP consumes a relatively small amount of land, whereas a "high" indicates the BMP may consume a relatively high fraction of land at a site. This factor is included in this early screening stage because many BMPs are severely constrained by land consumption.

The Ability to Accept Hotspot Runoff

This last column examines the capability of a BMP to treat runoff from hotspots. Hot spots are sites that produce exceptionally contaminated stormwater from surfaces such as vehicle salvage yards or industrial sites. A BMP that receives hotspot runoff may have design restrictions as noted, in addition to Local and State restrictions.

This does not imply that a single BMP would be adequate to treat an entire small site. Typically several BMPs, either the same type or different, will be required to adequately treat the runoff from a small site.

Step ❷ Physical Feasibility Factors Matrix

BMP Family	BMP List	Soil Considerations	Water Table[1]	Suitable for Site ≤ 5 acres	Head (feet)	Area Require-ments	Accepts Hotspot Runoff
Retention	Wet Pond	"A" soils may require pond liner	3 feet if hotspot or aquifer	Limited[4]	3 – 8	High	Varies[2]
	Extended Storage Pond	"B" soils may require testing		Limited	4 – 8	High	Varies[2]
	Wet Vaults	NA	NA	Yes	4 – 8	Low	Yes
Detention	Dry Pond	"A" soils may require pond liner "B" soils may require testing	3 feet if hotspot or aquifer	Yes	3 – 8	High	Varies[2]
	Oversized Pipes	NA	NA	Yes	5 – 10	Low	Yes
	Oil Grit/Separator	NA	NA	Yes	4 – 8	Low	Yes
	Dry Swale	Any soil type	3 feet	Yes	3 – 5	Med.	Yes[3]
Infiltration	On-Lot Infiltration	"A" and "B" soils preferred "C" soil difficult "D" soil not recommended	3 feet	Yes	1	Med.	No
	Infiltration Basin		3 feet	Yes	3 – 5	High	No
	Infiltration Trench		3 feet	Yes	2 – 4	Med.	No
Wetland	Stormwater Wetland	Any soil type if below water table	NA	Limited	2 – 6	High	Varies[2]
	Wet Swale	Any soil type if below water table	Below water table	Yes	3 – 5	Med.	No
Filtration	Surface Sand Filters	Any soil type	3 feet or 0 feet with liner	Yes	2 – 4	High	Yes[3]
	Underground Filters	NA	NA	Yes	4 – 8	Low	Yes
	Bioretention	Planting soil	3 feet	Yes	3 – 5	High	Yes[3]
	Filter Strips	Any soil type	3 feet	Yes	1	Med.	Yes

1 Recommended minimum elevation above water table. Check with state and local regulations.

2 Varies depending on type and concentration of contaminants in the runoff and depth to the water table.

3 Yes, but only if bottom of facility includes an impermeable liner that prevents infiltration of highly contaminated water into the groundwater.

4 Suitable only if a consistent source of water (such as groundwater) is available or if the pond is constructed with a liner or in clay soils.

Step ❸ Community and Environmental Factors Matrix

Maintenance

This column in the matrix assesses the relative maintenance effort needed for a BMP in terms of three criteria: frequency of inspection, scheduled maintenance and chronic maintenance problems (such as clogging). It should be noted that all BMPs require routine inspection and maintenance.

The amount of maintenance required is also a function of proper BMP selection, design, and construction. For this column, it was assumed that these steps were all completed properly.

Community Acceptance

This column in the matrix assesses community acceptance, as measured by three factors: market and preference surveys, reported nuisance problems, and visual orientation (e.g., is it prominently located or is it in a discreet underground location). It should be noted that a low rank can often be improved by a better landscaping plan.

Construction Cost

The BMPs are ranked according to their relative construction cost per impervious acre treated as determined from cost surveys and local experience.

Wildlife Habitat

BMPs are evaluated on their ability to provide wildlife or wetland habitat, assuming that an effort is made to landscape them appropriately. Objective criteria include size, water features, wetland features and vegetative cover of the BMP and its buffer.

Step ❸ Community and Environmental Factors Matrix

BMP Family	BMP List	Maintenance	Community Acceptance	Cost (Relative to Drainage Area)	Wildlife Habitat
Retention	Wet Pond	Low	High	Low	Medium
	Extended Storage Pond	Low	Medium	Low	Medium
	Wet Vaults	High	High	High	None
Detention	Dry Pond	Medium	Medium	Low	Low
	Oversized Pipes	Low	High	High	None
	Oil Grit/Separator	High	High	High	None
	Dry Swale	Medium	High	Medium	Low
Infiltration	On-Lot Infiltration	Medium	Medium	Low	Medium
	Infiltration Basin	Medium	Medium	Medium	Medium
	Infiltration Trench	Medium	Medium	Medium	None
Wetland	Stormwater Wetland	Low	High	Medium	High
	Wet Swale	Medium	High	Low	Medium
Filtration	Surface Sand Filters	Medium	Medium	High	Low
	Underground Filters	High	High	High	None
	Bioretention	Medium	Medium	Medium	Medium
	Filter Strips	Low	High	Low	Medium