Prairie Trail Stormwater Guidelines

ANKENY, IOWA

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PRAIRIE TRAIL

Acknowledgments

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Table of Contents

INTRODUCTION

Introduction

The City of Ankeny acquired 1,031 acres of land from Iowa State University (ISU) in June 2005. The property had been used as a research farm since the end of World War II. During the war, portions of the site were used for munitions manufacturing and testing. The City has had an interest in the site for residential and commercial uses for a long time to foster economic development. Prior to the purchase of the land from ISU, the City prepared a Concept Plan for the site. The project area was named Prairie Trail at that time. In September 2005, the City selected DRA Properties, LLC (DRA) to purchase and develop the property.

In September 2005, Urban Design Associates, Wenk Associates, and Nilles Associates were selected by the City of Ankeny to prepare the master plan for Prairie Trail. These Stormwater Guidelines are an integral element of the master plan and have been developed to achieve three interrelated objectives: guiding community form and providing public open space and habitat while managing the community's storm runoff in a cost-effective manner.

Why are Stormwater Guidelines Important Toward a New Approach to Stormwater Management?

Urban stormwater runoff from rainfall and snowmelt — the water that runs off streets, parking lots, the Town Center, residential neighborhoods, commercial campuses, industrial sites — can adversely affect the physical, chemical and biological characteristics of streams, lakes and wetlands. Without mitigation, increased runoff volumes and peak discharges, commonly associated with urbanization, often cause degradation of stream channels through widening, deepening, accumulation of sediment deposits, significant modification to aquatic habitat, and other impacts. Elevated concentrations of substances such as gasoline and diesel fuel, oil, grease, fertilizer, heavy metals, pesticides, and pet waste can be harmful to aquatic life, native plants and wildlife and/or impair the ability of waterways to function properly.

Protecting and enhancing water quality has long been an important objective for the City of Ankeny. In planning for Prairie Trail, the City has elected to adopt a strong leadership role in advocating the use of "green infrastructure," or landscape-based approaches to stormwater management, that can reduce runoff, encourage infiltration, and simultaneously provide recreation, habitat, and aesthetic amenities that can help to define the community's quality of life.

Other factors driving the City's approach to stormwater management include:

- The new Statewide Urban Design and Specifications (SUDAS) requirements for stormwater and Iowa Stormwater Management Manual
- Increased recognition of the economic, ecological and social importance of stormwater management;
- The need to protect natural resources, including preservation of open space;
- Recognition of the public health, safety, and welfare implications of stormwater management programs and facilities;
- Growing public acceptance of alternative, "green infrastructure" approaches for protecting and improving water quality that employ landscape-based Best Management Practices (BMPs).

The Iowa Stormwater Management Manual is currently in the development stage. A technical committee has reviewed the design manual, but it does not have final approval by the SUDAS Board of Directors. The Prairie Trail Stormwater Guidelines have been developed to work in concert with the SUDAS Design Manual (www.iowasudas.org) and the Iowa Stormwater Management Manual. Ankeny approves and directs the use of SUDAS together with the Ankeny Standard Specifications. When a conflict exists between provisions, the more restrictive provision will control.

These guidelines have also been developed to work in concert with, and support other planning efforts listed in the sidebar at right. They also draw from what has been learned from other communities that have successfully adopted a "green infrastructure" approach and that have established guidelines that function well.

Related Documents

Companion documents include the following:

Storm Water Management Report
Nilles Associates
Undated

Saylor Creek Conceptual Design Plan
City of Ankeny, Iowa
Nilles Associates
September 8, 2006

Prairie Trail Master Plan
Ankeny, Iowa
Urban Design Associates
August, 2006

Precedents from Other Communities Adopting "Green Infrastructure"

A primary goal of these Guidelines is to develop a framework for managing stormwater in a manner that provides multiple benefits, while also taking into consideration the goals of the various City departments charged with implementation.

Many communities are meeting this challenge successfully, including Portland, Oregon; San Diego, California; Austin, Texas; Prince George's County, Maryland; and Philadelphia, Pennsylvania. These communities offer a number of precedent "lessons," summarized below, that have informed development of these Guidelines, to ensure that they can be implemented successfully throughout the development review process as well as in publicly-funded projects that may be sponsored by the City.

■ *Ensure an Integrated, Multi-Disciplinary Design Approach from the Outset*

Experience from other communities suggests that water quality treatment alternatives are best integrated into the early stages of site design, to be most effective. Considering water quality after the site plan has already been developed and finalized results in few effective options for treatment, or the installation of unattractive, unsafe, and unmaintainable facilities that can become public nuisances. These Guidelines emphasize interdisciplinary collaboration between landscape architects, engineers, and architects in preparation of site plans that consider water quality requirements from the initial and early stages of design.

■ *Establish an Integrated, Multi-Department Review Process*

Multiple agencies, with sometimes varying and possibly conflicting site design landscape requirements will likely be involved in the review process for public and private projects. Experience from other communities suggests that interdisciplinary design review teams that represent affected City agencies are an effective means for completing the review and resolving any conflicting requirements that may be identified.

■ *Coordinate Compatible Uses Between Parks and Water Quality Facilities*

Parks, natural areas, and open space are often viewed as opportunities for stormwater detention; however, it is critical that the uses of these areas be taken into account to ensure that conflicts are minimized or eliminated. Conflicts may relate to safety in play areas for children, mosquito concerns, and/or protection and enhancement of wildlife. These Guidelines recognize that conflicts between parks and stormwater BMPs may exist in some locations and care must be taken when selecting, designing, and maintaining BMPs in parks. Acceptance of stormwater BMPs in parks is particularly important, as is public education on the purposes of BMPs. The BMP "fact sheets" provided identify considerations to be taken when selecting BMPs.

■ *Enhance Compatibility Between Urban Design Goals and Water Quality Facilities*

Interdepartmental agreement regarding BMP design and integration into various settings is important. Templates of typical site layouts with BMPs integrated into designs of various development types are an integral component of these Guidelines. Ankeny has made a commitment to regional stormwater facilities wherever they are feasible. In some cases, on-site stormwater facilities are required due to parcel location and its proximity to the regional facilities. Conceptual locations for these regional facilities are provided elsewhere in this document.

■ *Implement Effective, Sustainable, Attractive, Multi-Purpose, Safe, and Well-Designed BMPs*

In addition to meeting the technical requirements, BMPs must also be sustainable, attractive, multi-purpose, safe, and well-designed. Ensuring that these requirements are met and BMPs are maintained on a long-term basis is critical for Ankeny to successfully minimize the impacts of stormwater runoff. Early consideration of stormwater quality requirements in the site design process can prevent water quality BMPs from being an "afterthought," which often results in poor BMP design and implementation.

■ *Employ A Varied Set of Strategies*

Structural and non-structural (such as education and management) BMP strategies can and should be used to help Ankeny improve the quality of stormwater runoff. Implementation details for structural BMPs for a variety of development types are provided to assist developers, planners, designers and engineers in selecting stormwater strategies that work in different settings.

■ *Ensure Long-term BMP Operation and Maintenance*

Even when BMPs are thoughtfully designed and properly installed, they can cease to function if not properly maintained. BMPs can be more effectively maintained when they are designed to allow easy access for inspection and maintenance and take into consideration factors such as property ownership, easements, visibility from easily accessible points, slope, vehicle access, and other factors. Clear, legal agreements assigning maintenance responsibilities and committing adequate funds for maintenance are also critical.

■ *Develop Financing and Institutional Strategies for Regional BMPs*

The concept of regional stormwater facilities is supported across the City's departments. The challenges to implementing regional BMPs lie in three key areas: 1) institutional constraints, 2) financing, and 3) maintenance. A feasibility assessment of the Prairie Trail property parcels has been prepared to identify where regional facilities are feasible. In order to take advantage of this approach, a sound financing strategy must be developed. This can be challenging, particularly in areas where development is phased over a number of years. Future work to help develop financing strategies for regional BMPs, including a discussion of institutional opportunities and constraints, is critical.

Engineering and Regulatory Basis for the Guidelines

The Guidelines have been based on Federal, State and local regulatory requirements and engineering practice and standards. Important requirements include the following:

- All development projects must address water quality in their development plans, complying with the stormwater policies and design criteria specified in the Statewide Urban Design and Specifications (SUDAS) Design Manual. Particularly critical is the four-step BMP planning process that requires:
    1. Implementing stormwater runoff reduction practices.
    2. Providing treatment for Water Quality Capture Volume (WQv).
    3. Providing for flood detention in sub-basins described in the Storm Water Management Report prepared by Nilles Associates.
    4. Implementing streambank and channel stabilization techniques for any drainageways within or adjacent to a project site.

- Under the City of Ankeny's MS4 permit, the City shall take all reasonable steps to minimize or prevent any discharge in violation of the permit that has a reasonable likelihood of adversely affecting human health or the environment. Examples of these adverse impacts can include increased pollutant loading, increased runoff rates and volumes, channel instability, modification of aquatic habitat, and increased sediment loading, both during and after construction. It is essential to recognize that, despite the best efforts to control stormwater runoff, there will be some change in receiving water characteristics due to development; therefore, a "zero impact" policy is not realistic or attainable.

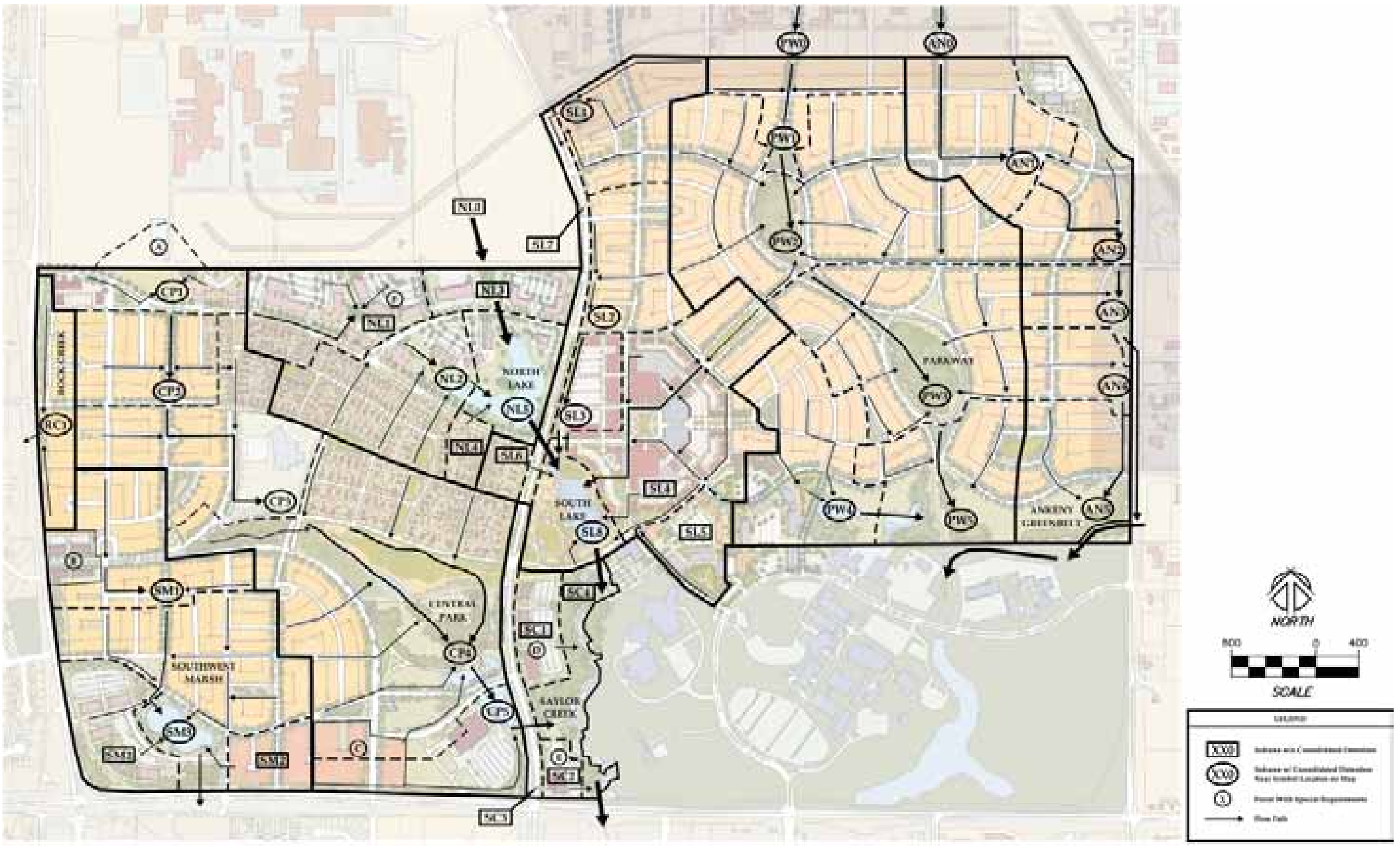
- Ankeny will continue to advocate the use of multiple BMPs, including non-structural measures, source controls, and structural BMPs, to reduce stormwater pollution. Whenever practicable, combining BMPs in "treatment train" can be very effective in reducing stormwater pollution.

- Planning for water quality must proceed hand-in-hand with drainage planning for quantity (rate and volume); these two planning efforts are inseparable. When these issues are addressed together and early in the site planning process, more efficient, economical and attractive land uses generally result.

- Ankeny will review BMPs for pubic safety, maintenance accessibility, maintainability, and documentation of maintenance requirements and schedule. Proper maintenance is fundamental to public safety and long-term effectiveness of stormwater BMPs.

- Ankeny prefers managing and treating stormwater quality on the ground surface, rather than in subsurface, vault-type treatment devices. City staff also recognize that there are cases where the use of such facilities is necessary, acceptable, or preferable. For example, this approach may be acceptable in cases of extreme space constraints that occur on smaller redevelopment sites, which are essentially completely impervious in their current condition.

- The same stormwater management practices that apply to projects in the private sector also apply to projects that are the responsibility of the City of Ankeny. When Ankeny is developing plans for these projects, stormwater management must be evaluated and suitably mitigated.



SUB-AREA DESIGN CHARACTERISTICS

WESTERN WATERSHED DISTRICTS

The following is a basic overview of sub-area characteristics and preliminary storm water management plan for the Western Watershed Districts. For additional design data please refer to the ***Prairie Trail Storm Water Master Plan Study.***

Rock Creek Watershed

Subarea RC1

10 acre watershed consisting of residential development. Storm water to be conveyed via storm sewer and enhanced swales to consolidated detention site near existing 30" storm sewer pipe under Irvinedale Drive. Detention facility shall address Water Quality and Peak Rate Management design requirements for tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate:
60,000 CF, 10 cfs.

Subarea SM3

59 acre watershed consisting of residential development as well as a naturalized park. Storm water to be conveyed via storm sewer to consolidated detention site near location shown on map. Detention facility shall address Water Quality design requirements for single family residential areas and Peak Rate Management design requirements for tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate:
720,000 CF, 83 cfs.

Southwest Marsh Watershed

Subarea SM1

33 acre watershed consisting of residential and commercial development. Storm water to be conveyed via storm sewer to consolidated detention site near location shown on map. Detention facility shall address Water Quality design requirements for single family residential areas and Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate:
210,000 CF, 61 cfs.

Subarea SM2

32 acre watershed consisting of residential and commercial development. Storm water to be conveyed via storm sewer and open conveyances to consolidated detention site within subarea SM3. Water Quality design requirements for multi-family and commercial development shall be addressed by Site Level controls.

Central Park Watershed

Subarea CP1

21 acre watershed consisting of commercial developments, a park, and off-site agricultural uses. Storm water to be conveyed via enhanced swales and storm sewer to consolidated detention site near location shown on map. Detention facility shall address Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate:
90,000 CF, 48 cfs.

Subarea CP2

34 acre watershed consisting of residential development. Storm water to be conveyed via storm sewer to consolidated detention site near location shown on map. Detention facility shall address Water Quality and Peak Rate Management design requirements for tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate:
201,000 CF, 65 cfs.

Relationship to Stormwater Management Report

The stormwater management report prepared by Nilles Associates recommends a comprehensive stormwater management strategy for peak rate flow management and water quality. Accordingly, the 100-year storm event will be conveyed as required by SUDAS. Typically this would involve designing the storm sewer to convey the 5-year flow and meeting the overland or street conveyance requirements for larger storms as set forth in SUDAS. In some cases, if the overland conveyance criteria cannot be met, larger storm sewers may be required or other flow reduction methods employed to reduce flows to manageable levels. With the exception of areas requiring on-site detention, peak rate volumes are accommodated in park and open space areas. The water quality capture volume (WQv) will be accommodated through site-level or consolidated controls. Definitions for site level and consolidated controls follows.

- **Site level controls.** Stormwater management on individual sites primarily for water quality on commercial, industrial, and medium to high-density residential properties
- **Consolidated controls.** Peak of volume reduction and water quality treatment for single-family lots will be consolidated in park and open space areas due to concerns about long-term maintenance and enforcement; peak flow and water quality capture volume can be combined.
- **Areas requiring on-site detention.** Because of existing site topography, several areas within Prairie Trail are required to provide both on-site detention and water quality treatment.

SUB-AREA DESIGN CHARACTERISTICS

WESTERN WATERSHED DISTRICTS *(continued)*

Central Park Watershed (continued)

Subarea CP3
45 acre watershed consisting of residential development, a school site and a park. Storm water to be conveyed via storm sewer and enhanced swales to consolidated detention site near location shown on map. Detention facility shall address Water Quality design requirements for single family residential areas and Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate: 370,000 CF, 97 cfs.

Subarea CP4
110 acre watershed consisting of residential development and parks. Storm water to be conveyed via storm sewer to consolidated detention site near location shown on map. Detention facility shall address Water Quality and Peak Rate Management design requirements for tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate: 620,000 CF, 140 cfs.

Subarea CP5
23 acre watershed consisting of residential and commercial development and parks. Storm water to be conveyed via storm sewer to consolidated detention site near location shown on map. Detention facility shall address Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate: 175,000 CF, 146 cfs.

CENTRAL WATERSHED DISTRICTS

North Lake Watershed

Subarea NL0
Off-site flow from 491 acre watershed consisting of residential, industrial and agricultural areas. Storm water is conveyed via open drainage to RCB culvert under existing Magazine Road. No detention is provided for this area.

Estimated 100-year existing flow rate: 1400 cfs.

Subarea NL1
33 acre watershed consisting of residential and commercial development. Storm water to be conveyed via storm sewer and enhanced swales to consolidated detention site near location shown on map. Detention facility shall address Water Quality design requirements for single family residential areas and Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate: 148,000 CF, 59 cfs.

Subarea NL2
48 acre watershed consisting of residential and commercial development. Storm water to be conveyed via storm sewer and enhanced swales to consolidated detention site near location shown on map. Detention facility shall address Water Quality design requirements for single family residential areas and Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate: 188,000 CF, 170 cfs.

Subarea NL3
15 acre watershed consisting of commercial development. Storm water to be conveyed via storm sewer and open channel to consolidated detention site within Subarea NL5 (North Lake).

Subarea NL4
6 acre watershed consisting of residential development. Storm water to be conveyed via storm sewer and enhanced swales to consolidated detention site within Subarea NL5. Runoff from this area shall be treated by selected BMPs prior to discharge to the North Lake to address Water Quality design requirements for single family residential areas as detailed in Master Plan Study.

Subarea NL5 *North Lake*
20 acre watershed consisting of commercial development and a large park. Storm water to be conveyed via storm sewer and enhanced swales to consolidated detention site (North Lake) near location shown on map. Detention facility shall address Peak Rate Management design requirements for subareas NL3, NL4, and NL5 as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate: 890,000 CF, 1429 cfs.

South Lake Watershed

Subarea SL1
27 acre watershed consisting of residential development. Storm water to be conveyed via storm sewer and enhanced swales to consolidated detention site near existing 24" storm sewer pipe under State Street. Detention facility shall address Water Quality design requirements for single family residential areas and Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate: 167,000 CF, 30 cfs.

Subarea SL2
28 acre watershed consisting of residential development. Storm water to be conveyed via storm sewer and enhanced swales to consolidated detention site along State Street frontage. Detention facility shall address Water Quality design requirements for single family residential areas and Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate:
149,000 CF, 51 cfs.

Subarea SL3
11 acre watershed consisting of commercial development. Storm water to be conveyed via storm sewer and enhanced swales to consolidated detention site along State Street frontage. Detention facility shall address Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate:
142,000 CF, 52 cfs.

Subarea SL4
57 acre watershed consisting of residential and the Town Center commercial development. Storm water to be conveyed via storm sewer and open drainage systems to consolidated detention site within Subarea SL8 (South Lake).

Subarea SL5
12 acre watershed consisting of residential and commercial development within the Campustown area. Storm water to be conveyed via storm sewer and open drainage systems to consolidated detention site within Subarea SL8 (South Lake).

Subarea SL6
8 acre watershed consisting of residential development. Storm water to be conveyed via storm sewer and enhanced swales to location near existing 30" storm sewer pipe under State Street. Address Water Quality design requirements for single family residential area within proposed greenbelt along State Street. Storm water to be conveyed via storm sewer to Subarea SL8 (South Lake).

SUB-AREA DESIGN CHARACTERISTICS

CENTRAL WATERSHED DISTRICTS *(continued)*

South Lake Watershed (continued)

Subarea SL7
11 acre watershed consisting of the State Street right-of-way. Storm water to be conveyed via storm sewer to consolidated detention site within Subarea SL8 (South Lake).

Subarea SL8 *South Lake*
25 acre watershed consisting of a large park and adjacent ROW. Storm water to be conveyed via open drainage systems to consolidated detention site (South Lake) near location shown on map. Portions of the Water Quality design requirements for Subareas SL4, SL5, SL7, and SL8 may be addressed by BMPs located where concentrated points of discharge enter the South Lake. Detention facility shall address Peak Rate Management design requirements for Subareas SL4, SL5, SL6, SL7 and SL8 as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate: 835,000 CF, 1562 cfs.

Saylor Creek Watershed

Subarea SC1
11 acre commercial development. This site is required to address Water Quality and Peak Rate Management design requirements on site as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate: 66,000 CF, 14 cfs.

Subarea SC2
5 acre commercial development. This site is required to address Water Quality and Peak Rate Management design requirements on site as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate: 28,000 CF, 7 cfs.

Subarea SC3
9 acre watershed consisting of the State Street right-of-way. This area will directly discharge to Saylor Creek through the large box culvert under Oralabor Road. There are no Water Quality or Peak Rate Management design requirements for this area.

Subarea SC4
24 acre watershed consisting of large parks, trails and open spaces. This area will directly discharge to Saylor Creek through the large box culvert under Oralabor Road. There are no Water Quality or Peak Rate Management design requirements for this area.

EASTERN WATERSHED DISTRICTS

Parkway Watershed

Subarea PW0
Off-site flow from 68 acre watershed consisting of residential and industrial areas. Storm water is conveyed via storm sewers to 36" storm sewer pipe which outlets to Prairie Trail site. Previous studies have indicated that storm sewer from this area has limted capacity (2-year developed conditions approximately), and currently limits discharge to Prairie Trail site. Should improvements to this system be made in the future, a detention basin (or other measures to reduce runoff flow rates) will be necessary to limit flows to the receiving system within Prairie Trail. A preliminary design for a detention facility has been modeled, assuming a future improved system that can adequately convey 100-year developed flows from this area to the basin either via storm sewer or overland flow.

Estimated 100-year storage capacity and release rate: 600,000 CF, 60 cfs.

Subarea PW1
22 acre watershed consisting of residential development and parks. Storm water to be conveyed via storm sewer and enhanced swales to consolidated detention site near location shown on map. Detention facility shall address Water Quality design requirements for single family residential areas and Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate: 148,000 CF, 72 cfs.

Subarea PW2
101 acre watershed consisting of residential development and parks. Storm water to be conveyed via storm sewer and enhanced swales to consolidated detention site near location shown on map. Detention facility shall address Water Quality design requirements for single family residential areas and Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate: 690,000 CF, 153 cfs.

Subarea PW3
68 acre watershed consisting of residential development and parks. Storm water to be conveyed via storm sewer and enhanced swales to consolidated detention site near location shown on map. Detention facility shall address Water Quality design requirements for single family residential areas and Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate: 884,000 CF, 118 cfs.

Subarea PW4
47 acre watershed consisting of parks, residential and commercial development. Storm water to be conveyed via storm sewer and enhanced swales to consolidated detention site near location shown on map. Detention facility shall address Water Quality design requirements for single family residential areas and Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate: 290,000 CF, 56 cfs.

Subarea PW5
43 acre watershed consisting of residential development and parks. Storm water to be conveyed via storm sewer and enhanced swales to consolidated detention site near location shown on map. Detention facility shall address Water Quality design requirements for single family residential areas and Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study. Discharge to existing stream within DMACC campus.

Estimated 100-year storage capacity and release rate: 870,000 CF, 122 cfs.

Ankeny Greenbelt Watershed

Subarea AN0
Off-site flow from 28 acre watershed consisting of residential and industrial areas. Storm water is conveyed via storm sewers to outlet to Prairie Trail site. Previous studies have indicated that storm sewer from this area has limted capacity (2-year developed conditions approximately), and currently limits discharge to Prairie Trail site. Should improvements to this system be made in the future, a detention basin (or other measures to reduce runoff flow rates) will be necessary to limit flows to the receiving system within Prairie Trail. A preliminary design for a detention facility has been modeled, assuming a future improved system that can adequately convey 100-year developed flows from this area to the basin either via storm sewer or overland flow.

Estimated 100-year storage capacity and release rate: 230,000 CF, 34 cfs.

SUB-AREA DESIGN CHARACTERISTICS

EASTERN WATERSHED DISTRICTS *(continued)*

Ankeny Greenbelt Watershed (continued)

Subarea AN1

38 acre watershed consisting of residential development. Storm water to be conveyed via storm sewer to consolidated detention site near location shown on map. Detention facility shall address Water Quality design requirements for single family residential areas and Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate:
208,000 CF, 118 cfs.

Subarea AN2

35 acre watershed consisting of residential and commercial development. Storm water to be conveyed via storm sewers and enhanced swales to consolidated detention site near location shown on map. Detention facility shall address Water Quality design requirements for single family residential areas and Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study.

Estimated 100-year storage capacity and release rate:
310,000 CF, 122 cfs.

Subarea AN3

17 acre watershed consisting of residential development. Storm water to be conveyed via storm sewer and enhanced swales to consolidated detention site near location shown on map. Detention facility shall address Water Quality design requirements for single family residential areas and Peak Rate Management design requirements for entire tributary area as detailed in Master Plan Study. Discharge to ditch within Ankeny Boulevard right-of-way near location of existing triple 15" CMP culverts beneath trail on west side of street.

Estimated 100-year storage capacity and release rate:
253,000 CF, 99 cfs.

Source: Polk County Soil Survey

The Significance of Soils and Relationship to Groundwater Levels

The soil types of Prairie Trail include loam, clay loam, silty clay loam, and at the southwest corner of the site, mucky silt loam. These soils, with the possible exception of mucky silt loam, are suitable for grass buffers and swales, which are described in detail in the implementation details portion of the guidelines. For treatment of water quality capture volumes (WQv) in infiltration type BMPs, suitable well-drained hydrologic soils Type A or B, including sandy loam, loamy sand or loam, and percolation notes described in SUDAS for these soil types will be required. Because much of the site has shallow groundwater, all infiltration type BMPs, if within 18" inches of the groundwater, will require an impermeable liner and an underdrain connected to the stormwater system or surface conveyance. Suitable on-site soils for infiltration-type BMPs are limited, engineered soils meeting textural type and percolation rates specified may be required. To verify infiltration and BMPs have been properly constructed, percolation testing will be required.

SITE DEVELOPMENT GUIDELINES

An Alternative Strategy for Stormwater Management

This section describes an alternative strategy for stormwater management on individual development sites. The strategy is to create facilities that are integrated with the landscape and hard surface elements of a site, compatible with the land use, and effective for enhancing stormwater quality and quantity (volume).

The goal of these guidelines is to implement stormwater quality Best Management Practices (BMPs) that are:

- ***Functional.*** Stormwater quality facilities must accomplish their primary function of effective stormwater quality treatment.
- ***Maintainable.*** Stormwater BMPs must be sustainable and maintainable for the long term.
- ***Attractive.*** Stormwater facilities must be compatible with the site's land use and complementary to the district's character.

Alternative strategies are a departure from conventional practices. Conventional practices dispose of stormwater quickly through a series of inlets and underground pipes that concentrate flows (thereby increasing peak runoff rates, volumes and pollutant loads), and then attempts to "solve" these problems by using detention basins at the edge of the site. These facilities are often expansive, deep basins that detract from the aesthetics of the site, are difficult to maintain, and may be only marginally effective in reducing the impacts of urban runoff.

The alternative strategies, presented in these Guidelines, seek to reduce the size of stormwater detention basins by reducing runoff volumes and distributing stormwater quality treatment throughout the site. The result is a reduction in runoff rates, volumes and pollutant loads by using porous landscape areas and porous pavements to infiltrate rainfall into the ground to better reproduce natural hydrological conditions that existed before the site was developed. Elements of this alternative strategy are catching on nationally, being promoted under the terms "low impact development" (LID - Prince George's County, 2000) and "minimizing directly connected impervious areas" (MDCIA). Regardless of the term, this approach manages runoff closest to its source and promotes infiltration.

Design Principles and Approach

The following design and stormwater quality principles provide a foundation for developing a stormwater quality strategy and are the basis for the recommendations presented in these Guidelines.

PRINCIPLE 1

Consider stormwater quality needs early in the design process.

Left to the end of site planning development, stormwater quality facilities are often "shoe-horned" into the site, resulting in forced, constrained, and limited conveyance and storage solutions. When included in the initial planning phase for a project, opportunities to integrate stormwater quality facilities into a site can be fully realized. Stormwater quality and flood control requirements are as fundamental to excellent site design as other site considerations such as building layout, grading, parking, and streets. Dealing with stormwater quality after major site plan decisions have been made is often too late in the design process and becomes reactionary rather than proactive, resulting in lost opportunities.

PRINCIPLE 2

Take advantage of the entire site when planning stormwater quality treatment.

Stormwater quality and flood detention are often sited at the low corner of the site and ignored on the remainder of the project site. With conventional methods the primary focus is to drain runoff, as quickly as possible, through inlets and storm sewers to the detention storage facility. In this "end-of-pipe" approach, all the runoff volume is concentrated at one point and designers often find it challenging to fit the required detention within the area available. This approach can lead to drainage plans resorting to the use of proprietary underground treatment devices, or deep, walled-in basins that detract from the site, are difficult to maintain, and are costly. Alternatively, spreading runoff over a larger portion of the site reduces the need for those undesirable facilities.

PRINCIPLE 3

Reduce runoff rates and volumes to more closely match natural conditions.

Prior to development, the majority of rainfall lands on pervious ground and soaks into the soil or is captured by vegetation; very little rainfall runs off and flows downstream. After development, the majority of rain falls on impervious roofs and pavement and runs off (this is a "runoff event"). Where one runoff event per year may be typical prior to development, approximately thirty runoff events per year can occur after urbanization. (Urbonas et al. 1989). Peak flows and volumes of runoff are much greater after development. This increased runoff can be environmentally harmful, causing erosion in stream systems and generating greater pollutant loading downstream.

One of the most effective stormwater quality BMPs—potentially more effective than constructing a detention basin to treat the runoff—is reducing runoff volumes to the maximum extent practicable to more closely match natural conditions. The following techniques can be used to achieve this goal:

- **Connect stormwater with the landscape and soil.** Rather than routing storm runoff from pavement to inlets, then to storm sewers to offsite pipes or concrete channels, an approach is recommended that places runoff in contact with landscape areas to slow down the stormwater and promote infiltration. Porous pavement areas also serve to reduce runoff and encourage infiltration.
- **Minimize directly connected impervious areas (MDCIA).** Low impact development promotes MDCIA – separating areas of imperviousness and directing runoff from roofs and paved areas to grass buffers, swales, and other porous landscape areas prior to being conveyed off the site. Runoff is filtered and slowed down by the vegetative cover encouraging infiltration and providing preliminary sediment removal. Even fragmenting impervious areas with small, pervious areas can have a significant impact on reducing runoff volume and improving water quality.
- **Reduce the total amount of impervious area on a site.** As less impervious areas exists on a site, less runoff from the site will occur, resulting in smaller water quality capture volume (WQv) requirements. Approaches

to reduce impervious area include using narrower street sections, and the use of porous pavement in lower traffic areas, fire access lanes, parking lanes and driveways.

- **Select treatment types that promote greater infiltration.** Porous landscape detention and porous pavements detention promote greater volume reduction than extended detention basins. Runoff tends to be absorbed into the filter media or infiltrates into underlying soils with these alternative methods.

By employing these techniques, projects can reduce the increase in runoff and related stream degradation and pollutant loading that comes with conventional development methods. In addition, some of these techniques will reduce the required water quality capture volume (WQv) and may help to create a more attractive site. Ankeny strongly encourages implementation of these runoff reduction techniques on all Prairie Trail projects to the maximum extent practicable.

PRINCIPLE 4

Integrate stormwater quality management and flood control.

Frequently occurring storms are the events that stormwater quality BMPs are designed to treat. Flooding of streets and low-lying areas can occur during less frequent, larger storms, requiring flood control detention. Both stormwater quality treatment and flood control detention goals can be accomplished on a site through a coordinated design approach.

In cases where an extended detention basin, retention pond, wetland basin, or sand filter basin is used to address stormwater quality, any of these basins can be modified to include flood control detention in addition to the water quality capture volume (WQv). This will generally increase the overall size of the basin. In these situations, all the runoff from a site, from small and large storms alike, is routed to the combined detention basin.

In a combined detention / water quality facility runoff is directed to the water quality capture volume component of the facility. Larger events spill out over the surface or through an inlet and storm sewer to a separate flood control detention basin or, may be captured in the same facility, above the water quality capture volume. An example of a combined facility is a parking lot, where water quality treatment can be provided within depressed parking lot islands, and flood control detention can take place within the parking lot itself, as long as the depth of water being detained is not too deep and drains quickly (at the historic rate). The volume of water in excess of the water quality capture volume drains out at a faster rate then that of the water quality BMP to prevent overloading of the BMP.

PRINCIPLE 5

Develop stormwater facilities that enhance the site, community, and environment.

Stormwater facilities can add interest and diversity to a site. Gardens, courtyards, plazas, rooftops, and even parking lots can be designed to treat stormwater while providing visual interest, and reinforcing urban design goals for the neighborhood and community. The integration of BMPs and associated landforms, walls, landscape, and materials can reflect the standards and patterns of a neighborhood and help to create lively, safe, and pedestrian-oriented districts.

Placement of water quality facilities is important. Avoid the placement of stormwater quality facilities along critical street frontage to discourage detrimental "gaps" in the continuity of important urban spaces. These gaps, which would create voids in a continuous building line, a highly desired outcome of new urbanist planning in town Center areas. To locate water quality facilities in these urban contexts is counter to planning principles and practices advocated by the Master Plan. The quality and appearance of stormwater quality facilities should reflect the surrounding land use type, the immediate context and the proximity of the site to important civic spaces. Aesthetics will be a more critical factor in highly visible urban commercial and office areas than at a heavy industrial site. The standard of design and construction should maintain and enhance property values without compromising function. In some cases, this means locating a facility to preserve or enhance natural resources.

PRINCIPLE 6

Design sustainable facilities that can be safely maintained.

Stormwater quality facilities must be properly and consistently maintained to function effectively and ensure long-term viability. Regular maintenance is key to public acceptance of these facilities. Typical maintenance operations to consider in designing facilities include:

- Mowing, trimming, and weed control
- Pruning of shrub and tree limbs
- Clean up of trash and debris, especially at grates and flow control structures
- Sediment removal
- Removal, replacement, and revegetation of porous landscape detention media
- Vacuuming/replacement of porous pavement and porous pavement detention media
- Structural repair

It is necessary to fully consider how BMPs will be maintained. Facility design should provide for these operations ensuring adequate access with a minimum of disturbance, disruption, and cost. Site planning should include consideration for access to BMPs by appropriate equipment, and for removal of trash, debris, and sediment on a regular basis.

PRINCIPLE 7

Design and maintain facilities with public safety in mind.

One of the highest priorities of engineers and public officials is to protect public health, safety and welfare. Stormwater quality facilities must be designed and maintained in a manner that does not pose health or safety hazards to the public. For the purpose of this discussion, public safety issues are categorized according to public access issues and mosquito/West Nile virus concerns.

Public Access and Safety

Stormwater facilities should be fully accessible and integrated into the community's parks and the landscapes of private developments. To assure the public's safety, applicable provisions of local and national building codes, and accepted principles, practices, and standards of park design must be integrated into required engineering standards and practices.

Mosquitoes and West Nile Virus

The West Nile virus first appeared in the U.S. in 1999. Since the virus is spread by mosquitoes that breed in shallow standing water, it is important to properly manage BMPs that detain or retain water to avoid creating these conditions. BMP designs that reduce the likelihood of standing shallow water should be incorporated into site designs.

According to EPA, healthy wetland BMPs and wetland ecosystems that contain fish, insects, amphibians, and birds that feed on mosquitoes are not considered uncontrolled mosquito breeding grounds (EPA 2003). Mosquito species, primarily responsible for West Nile virus, prefer to reproduce in abandoned tires, birdbaths, roof gutters, and other artificial containers that lack predators. They are also found in highly polluted environments, contaminated water, and degraded wetlands. Therefore, properly designed and managed BMPs (e.g., wetlands) should not create habitat that is suitable for mosquitoes that carry the West Nile virus (EPA 2003).

Stormwater Management Design Process

The following four-step design process has become the cornerstone of most of the community's approach to selecting and implementing BMPs that have adopted utilizing alternative stormwater approaches and BMPs in the process.

1. Reduce runoff volume to the maximum extent practicable.
2. Control residual runoff utilizing BMPs that have the necessary water quality capture volume.
3. Utilize stream channel stabilization techniques for stormwater conveyance.
4. Provide additional treatment and best available technologies if a site includes potential pollutant sources including spill containment and control and covering storage and handling areas.

These guidelines primarily address the first two steps. Information on stream channel stabilization resources can be found in the BMP Fact Sheets in this report and the Statewide Urban Design and Specifications (SUDAS) Design Manual. The following process introduces a method to address these four steps, stormwater quality and flood control requirements on a site.

1. Create attractive facilities that add value to the site.

While most designers and engineers focus on providing a functional site stormwater management system, they can plan and design a stormwater management system that also creates pleasing site amenities. Without increasing costs, effective integration of site elements and stormwater can enhance the project site.

2. Develop an initial site design.

- Identify an initial layout for lots, buildings, streets, parking, and landscape areas incorporating a general idea of proposed site grades.
- Estimate approximate impervious and pervious areas: roofs, streets, parking, sidewalks, landscaping, and open space.

3. Consider a full range of BMP alternatives.

- Determine which of the development types most closely matches the proposed development. (Note: Do not exclude BMPs or other planning criteria from other development types that may add value to the project)
- Consider the full range of alternative approaches for addressing site stormwater including runoff reduction techniques and maximizing use of BMPs throughout the site.
- Test several plan alternatives for site layout and character and strive for the optimum approach while weighing the pros and cons of each.
- Consider long-term, life-cycle costs during selection of alternative BMPs. These can be assessed by consulting references that discuss life-cycle costs of BMPs (EPA 1999; Heaney et al. 2002; Watershed Management Institute, 1997; Stormtech 2003) and by developing opinions of probable costs for construction and maintenance.
- When selecting and designing BMPs, careful consideration needs to be taken of the following: geotechnical issues, building foundations, and knowledge of BMPs and their maintenance by the owner.

4. Develop a functional distribution of landscape areas.

- Develop shallow detention basins and provide space for landscaping.
- Include sufficient area for stormwater quality treatment in concept development phase of design – approximately 5 to 10 percent of the total impervious area. These guidelines assume treatment will be incorporated into required landscape areas.
- Minimize extended detention basins.
- Maximize and distribute porous landscape detention and porous pavement detention areas throughout the site. Locate porous landscape detention adjacent to buildings, in parking lots, and throughout the site. In general, it is most effective to locate porous landscape detention in close proximity with the impervious area that it serves.

5. Maximize surface conveyance as an alternative to closed conveyance (storm pipes).

- Consider stormwater runoff conveyance. Surface conveyance is the preferred method for directing runoff to porous landscape and porous pavement detention. If shallow surface flow can be conveyed in grass swales or across porous pavement, stormwater quality will accrue and infrastructure costs reduced. In certain parts of the country, the required water quality capture volume (WQv) will be reduced if these practices are implemented.
- If runoff must be conveyed in pipes, inlets within a landscaped area are preferred over street or curb inlets. Runoff can sheet flow across vegetation and infiltrate prior to entering the storm sewer.

6. Integrate flood control detention.

- Locate flood control detention in landscape areas and in parking lots.
- Provide access for maintenance to detention facilities. Eliminate retaining walls that enclose the facility and prevent adequate access.

7. Tailor approach for specific pollutants of concern.

- Provide BMPs specifically effective for treating each pollutant.
- Illustrate estimated performance of various BMPs for pollutants.
- Refer to the International Stormwater BMP Database (www.bmpdatabase.org) for BMP performance in various settings and effluent quality that may be achieved.

How to Use the Guidelines

The Stormwater Guidelines are organized in the following three sections:

1. Development Types.

Stormwater quality treatment approaches, with tailored BMPs, have been prepared for individual development types (land use) representative of Prairie Trail. These development types are meant to serve as a guide for developers, planners, engineers, and landscape architects while developing site-specific stormwater management plans. In many cases, it will be appropriate to combine concepts from multiple development types for the most effective stormwater approach for each individual project.

2. BMP Fact Sheets.

Planning criteria for each individual stormwater quality BMP is presented on BMP Fact Sheets. The information provided includes a description of each BMP, a graphic illustration, guidance for specific site conditions/requirements, and photographic examples.

3. Implementation Details.

Detailed guidance illustrating how to integrate BMPs into site planning (e.g., parking lot islands and medians) is provided. Implementation Details are referenced to the individual Development Types and BMP Fact Sheets.

DEVELOPMENT TYPES

Guidelines for Development Types/ Parcel Specific BMPs

Guidelines for implementing stormwater quality treatment systems for representative land use types are presented in this section. The BMPs shown are tailored for the inherent program and needs of the particular development type. It is recommended that these development types be used as a general guide for developing a site stormwater quality plan for proposed projects. It may be appropriate, and it is highly recommended, to combine concepts from more than one development type to address the specific program, goals, or characteristics for each individual project. The following development types are discussed in this section:

- Light Industrial
- Town Center
- Commercial
- Campus / Office
- Single Family Residential
- Multi-Family Residential
- Attached Residential
- Parks and Natural Areas / Open Space

These Development Type Guidelines describe typical characteristics for each development type, as well as potential sites for stormwater quality treatment. Design recommendations have been developed for each that cover these four topics:

1. **Runoff Reduction:** Techniques that decrease runoff volume and reduce the Water Quality Capture Volume (WQv) requiring treatment.
2. **Water Quality Capture Volume (WQv) Treatment:** BMPs that treat the required volume of storm runoff.
3. **Flood Detention:** Methods for attenuating peak runoff from larger storm events on site.
4. **Implementation Details:** Additional details for specific portions of a site.

Within each topic, the user is directed to additional information on BMP Fact Sheets or Implementation Details following the Development Type Guidelines. Availability of this additional information is indicated by the use of blue colored, bold text (e.g., '**grass swale**' for BMP Fact Sheets). The use of red bold text (e.g., '**parking medians**' for Implementation Details). A 3-D sketch diagram shows how some of the design recommendations may be implemented on a representative site, and references additional details and photographs that further describe treatment options. These guidelines are recommendations only; the designer may choose to mix and match approaches from different development types to best meet the needs of a particular project.

DEVELOPMENT TYPES SUMMARY

	Pervious / Impervious Area Characteristics			
Development Type	**Percentage Landscape**	**Percentage Parking/Paving**	**Building Footprint**	**Parking**
Light Industrial	10 - 20%	30 -60%	40 - 60%	surface
Town Center	10 - 25%	30 -50%	25 - 50%	surface
Commercial	10 - 25%	30 -50%	25 - 50%	surface
Campus / Office	15 - 40%	10 - 30%	40 - 75%	surface
Single Family Residential	45 - 75%	5 - 10%	25 - 45%	surface
Multi-Family Residential	30 - 40%	15 - 30%	25 - 45%	surface
Attached Residential	35 - 70%	10 - 20%	25 - 45%	surface
Parks and Natural Areas/Open Space	80 - 95%	5 - 15%	0 - 10%	surface

BMP APPLICABILITY MATRIX

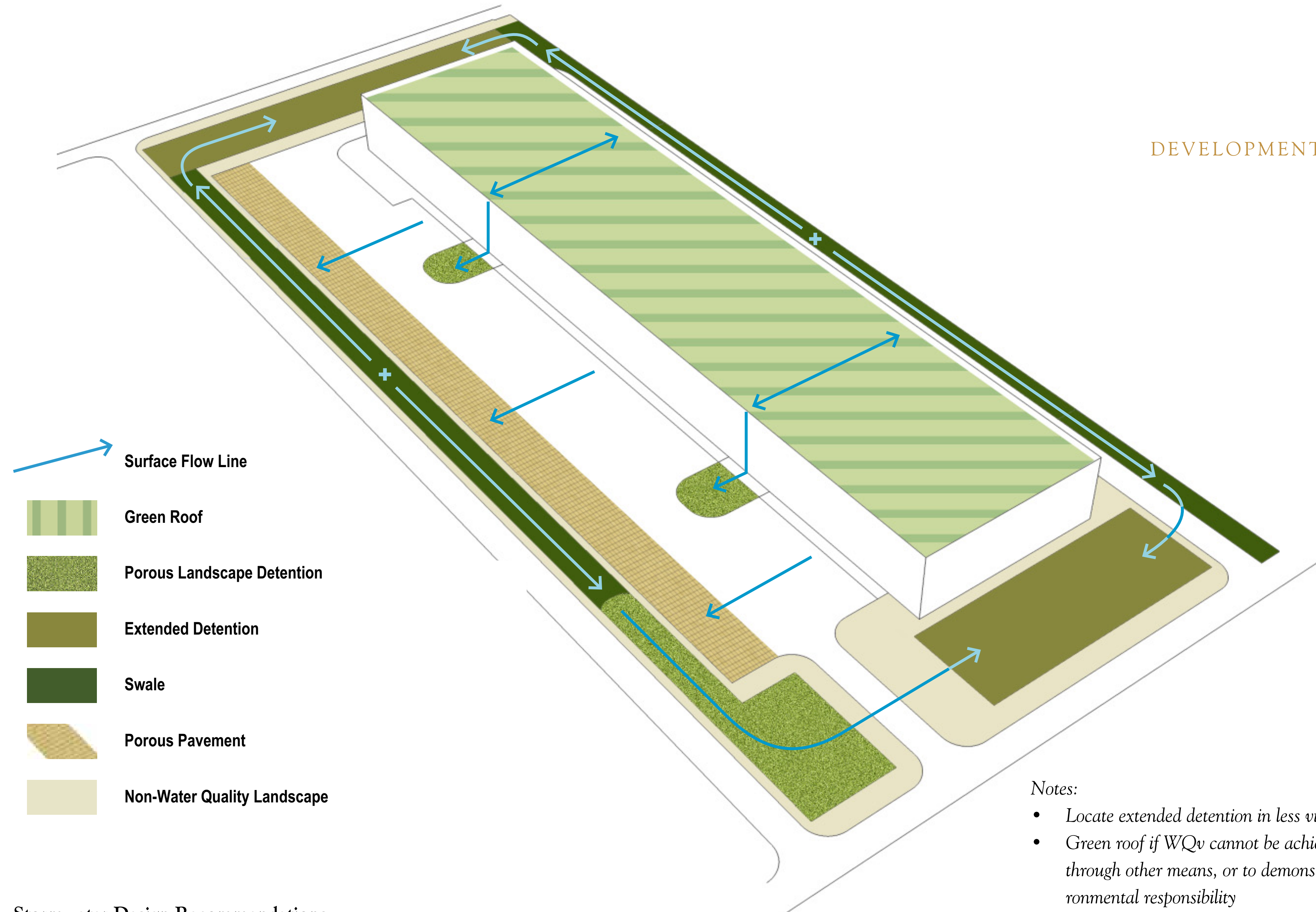
Legend: Highly applicable / Somewhat applicable / Not recommended

	Runoff Reduction		Water Quality Volume (WQv) Treatment				Possible Flood Control Detention[5]	
Development Type	Porous Pavement[1]	Grass Buffers and Swales	Porous Pavement Detention[1]	Porous Landscape Detention[2]	Dry Ponds: Extended Detention Filter Basins[3]	Wet Ponds: Constructed Wetland Basin and Retention Ponds[4]	Landscape Areas	Parking Lots
Light Industrial	Highly applicable	Highly applicable	Highly applicable	Highly applicable	Highly applicable	Somewhat applicable	Somewhat applicable	Highly applicable
Town Center	Highly applicable	Highly applicable	Highly applicable	Highly applicable	Highly applicable	Somewhat applicable	Somewhat applicable	Highly applicable
Commercial	Highly applicable	Highly applicable	Highly applicable	Highly applicable	Highly applicable	Somewhat applicable	Somewhat applicable	Highly applicable
Campus/Office	Somewhat applicable	Highly applicable	Highly applicable	Highly applicable	Somewhat applicable	Highly applicable	Highly applicable	Somewhat applicable
Single Family Residential	Somewhat applicable	Highly applicable	Somewhat applicable	Highly applicable	Not recommended	Not recommended	Somewhat applicable	Not recommended
Multi-Family Residential	Somewhat applicable	Highly applicable	Somewhat applicable	Highly applicable	Somewhat applicable	Highly applicable	Highly applicable	Not recommended
Attached Residential	Somewhat applicable	Highly applicable	Somewhat applicable	Somewhat applicable	Highly applicable	Somewhat applicable	Somewhat applicable	Not recommended
Parks and Natural Areas/Open Space	Not recommended	Highly applicable	Not recommended	Somewhat applicable	Highly applicable	Highly applicable	Highly applicable	Somewhat applicable

NOTES:

1. Porous pavement and porous pavement detention is most useful in denser development types where space for less costly BMPs is limited. It may be used in parking areas and other low-use areas where there is no likelihood of groundwater contamination. It is not recommended in parks only because less costly alternatives are available.
2. Porous landscape detention may be used in the vicinity of buildings, in parking lot islands, and in other landscape areas where there is no likelihood of groundwater contamination or geotechnical concerns. Wherever porous landscape detention is used, geotechnical issues related to building foundation drainage and expansive soils must be addressed.
3. To avoid constrained configurations of forebays, low-flow channels, and outlet structures, extended detention basins are generally recommended only for drainage areas exceeding 1.0 acre. Extended detention basins can be unsightly, and should be located in low visibility areas or screened with landscape.
4. Constructed wetland basins and retention ponds may only be used for drainage areas exceeding 2 acres that have sufficient base flow to support wetlands and permanent pools.
5. The use of underground vaults for water quality detention is discouraged.

Light Industrial



Notes:

- *Locate extended detention in less visible areas*
- *Green roof if WQv cannot be achieved through other means, or to demonstrate environmental responsibility*

Characteristics: Industrial sites consist of one or more large structures surrounded by surface parking and truck access areas. Open area is predominantly paved and accounts for up to 90 percent of the site. Sites include light manufacturing and flexible office/warehouse. This development type typically has 5-10% pervious area.

Potential Stormwater Quality Treatment Sites: Treatment occurs in islands and perimeters at surface parking. Large buildings with flat roofs are potential sites for green roofs. These sites require care to reduce the likelihood of commingling industrial chemicals with stormwater—stormwater contaminated by industrial chemicals manufactured or stored on site must be treated separately and cannot be infiltrated.

Site Planning

A. Integrate stormwater treatment, conveyance, and storage into parking islands, parking medians, and landscape areas to reduce runoff and conserve buildable land.

B. Sheet-drain large areas of paving to landscape (e.g., **grass buffers** and **swales**) to reduce runoff. Spread flows with **slotted curbs** or **level spreaders**.

C. Consolidate landscape areas (e.g., consolidate smaller **parking lot islands**) to incorporate stormwater treatment.

D. Augment landscape treatment in extensive parking areas with **porous pavement detention (PPD)** if insufficient area is available for **porous landscape detention (PLD)**.

E. Direct **roof runoff** to **porous landscape detention** to reduce and treat runoff.

F. When the site is contiguous with open space buffers, consolidate treatment and detention, and integrate native plantings to extend normal qualities of the adjacent open space.

G. Route runoff from high sediment areas through sediment traps prior to routing through treatment to minimize long-term maintenance.

Stormwater Design Recommendations

Runoff Reduction

1. **Grass buffer** as an integral component of **parking islands, medians** and **buffers**.
2. **Grass swale** as an integral component of parking and perimeter landscaping.
3. **Porous pavement** in low traffic areas including portions of parking lots.

WQv Treatment

4. **Porous landscape detention** in **parking islands, medians** and **landscape buffers** creating landscape amenities.
5. **Porous pavement detention** in low traffic areas such as parking (e.g., close to buildings and perimeter areas) and emergency access drives.
6. **Detention basins** including extended detention for remainder of treatment needed (not provided by PLD, PPD, and sand filters), **constructed wetlands** and retention ponds. **Sand filter detention basins** can be located along roof perimeters for water quality treatment in areas with very low landscape/open space.
7. Storage cover, manufacturing and loading areas, spill containment and prevention of groundwater contamination.

Flood Detention / Conveyance

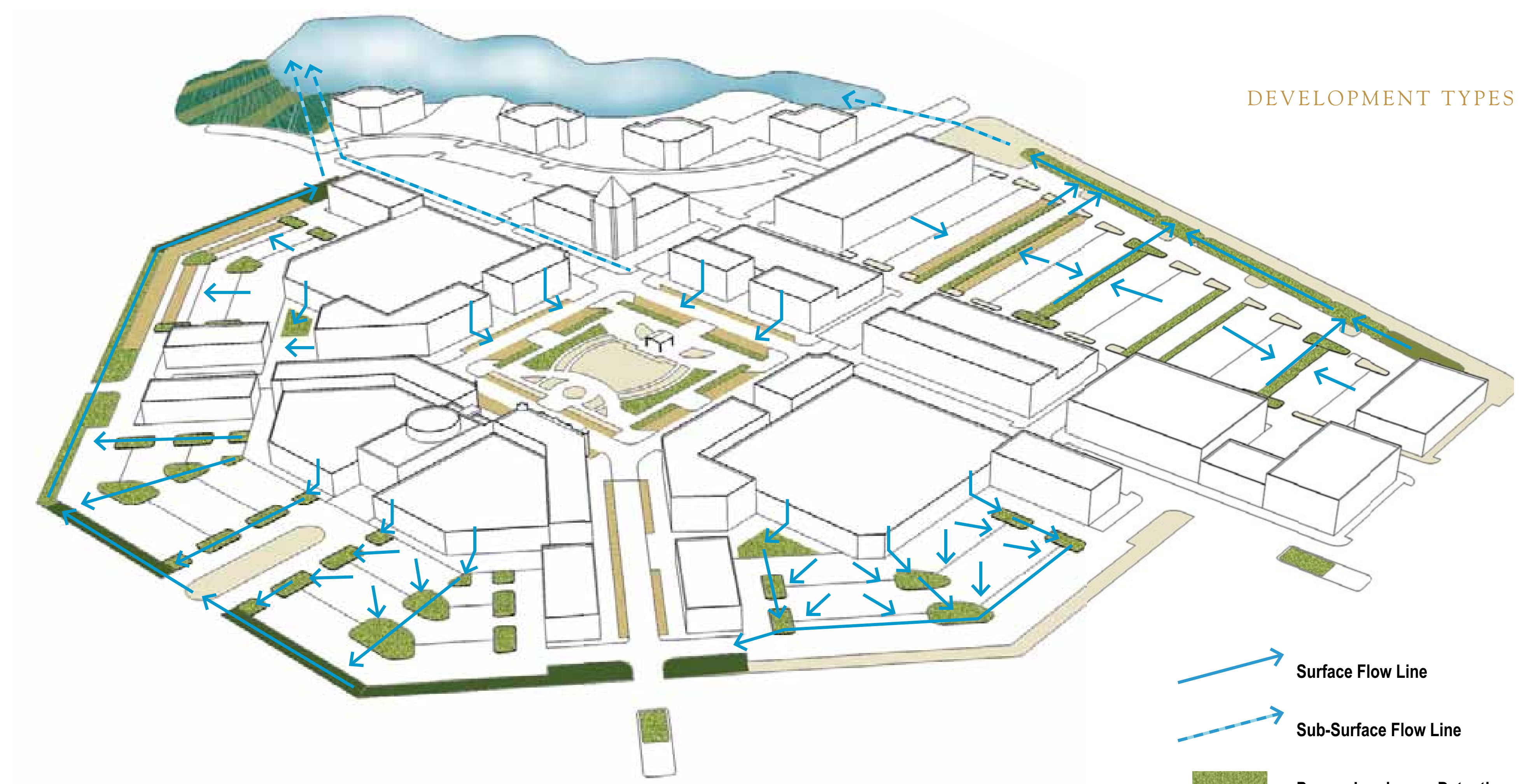
8. Provide flood detention within **parking areas** without creating a hazard at loading areas.

***NOTE:** Words in **blue bold** appear in the BMP Fact Sheet section of this report. Words in **red bold** appear in the Implementation Detail section of this report.

Town Center

Characteristics: The Town Center consists of interconnected, large retail buildings bordering a town square. The complex is surrounded by large surface parking lots and pad retail sited at the edge of the town center. This development type typically has 10-20% pervious area.

Potential Stormwater Quality Treatment Sites: Treatment occurs in islands, buffers, and medians at surface parking lots, lawns, plazas, courtyards, and gardens. Because of the proximity of Saylor Creek park area, consolidated treatment and detention should be considered as alternate or supplemental to on-site treatment and detention. Parking areas can be designed to both treat the WQv and to store flood volumes for the runoff they generate. Greater area is available for runoff reduction and treatment landscapes when parking requirements are combined for multiple buildings.



Site Planning

A. Minimize building setbacks / consolidate landscape areas to allow incorporation of larger, more efficient stormwater facilities into landscape areas.

B. Orient landscape buffers to treat WQv and to provide conveyance detention.

C. Integrate stormwater treatment, conveyance and storage into **parking islands**, **parking medians** and **landscape areas** to reduce runoff and conserve buildable land.

D. Consider consolidating detention and the WQv and developing a multi-functional "natural edge" along the proposed pond in the Saylor Creek park.

Notes:

- *Alternative to on-site treatment of WQv is sub-basin treatment at the edge of Saylor Creek Pond at the pipe out fall.*
- *Treat all upstream flows for WQv prior to reaching Town Center.*
- *Surface sand filters are unsightly and discouraged/ prohibited.*
- *Consider green roofs and rooftop sand filters for flow reduction.*

Stormwater Design Recommendations

Runoff Reduction

1. **Grass buffer** as an integral component of **parking islands, medians** and **landscape areas.**
2. **Grass swale** as an integral component of parking and perimeter landscaping.
3. **Porous pavement** in low traffic areas including portions of parking lots.

WQv Treatment

4. **Porous landscape detention** in **parking islands, medians** and **landscape buffers.**
5. **Porous pavement detention** in low traffic areas such as parking and emergency access drives.
6. **Detention-type BMPs** including **extended detention basins, constructed wetlands** and retention ponds in low visibility perimeters.
7. **Green roof** or **sand filter basins** on buildings and parking structures.

Flood Detention / Conveyance

8. Design **parking areas** and landscapes to accommodate their own treatment and flood detention requirements. Include shallow parking depressions of less than nine inches in parking lots to detain flood volumes. Consider consolidation detention in the adjacent park.

***NOTE:** Words in **blue bold** appear in the BMP Fact Sheet section of this report. Words in **red bold** appear in the Implementation Detail section of this report.

Commercial

Characteristics: Commercial sites consist of small to large floor plate, single-story structures organized by automobile circulation and parking. Landscape areas are typically limited to buffers, parking islands, and building entries. Certain building types, such as pad restaurants, may have more extensive patios, gardens and landscape buffers. This development type typically has 10-25% pervious area.

Potential Stormwater Quality Treatment Sites: Treatment occurs in islands, buffers, and medians in surface parking lots, courtyards, and building perimeter landscape areas. Parking areas can be designed to both treat the WQv and store flood volumes for the runoff they generate.

Site Planning

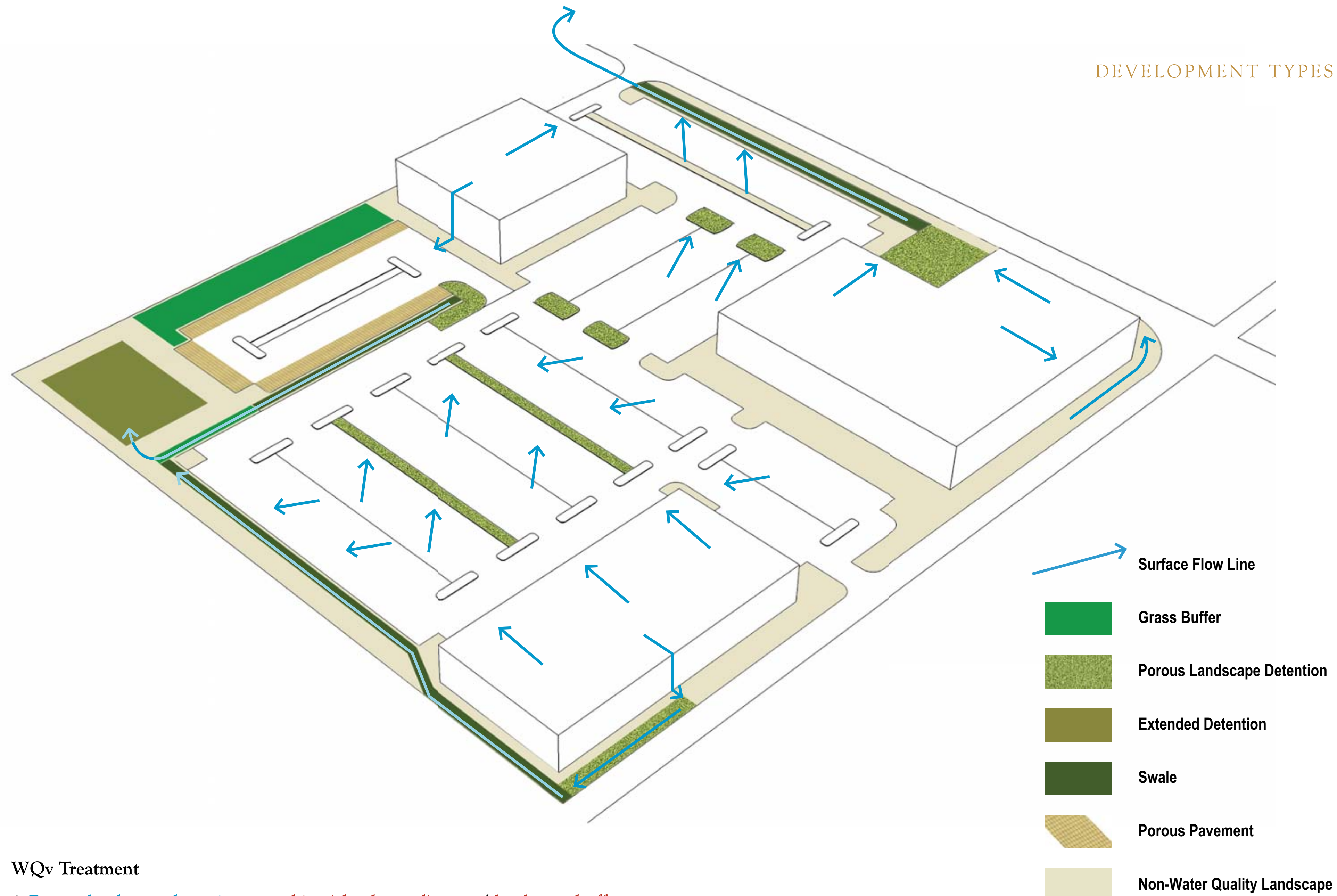
A. Minimize building setbacks / consolidate landscape areas to allow incorporation of stormwater facilities into larger landscape areas.

B. Integrate stormwater treatment, conveyance, and storage into **parking islands**, **parking medians** and **landscape areas** to reduce runoff and conserve buildable land. Utilize shallow (9" maximum depth) ponding in perimeter parking areas to minimize detention, if required, in landscape areas.

Stormwater Design Recommendations

Runoff Reduction

1. **Grass buffer** as an integral component of **parking islands, medians** and **landscape areas.**
2. **Grass swale** as an integral component of parking and perimeter landscaping.
3. **Porous pavement** in low traffic areas including portions of parking lots.



WQv Treatment

4. **Porous landscape detention** in **parking islands, medians** and **landscape buffers.**
5. **Porous pavement detention** in low traffic areas such as parking and emergency access drives.
6. **Detention basins** including **extended basins, sand filter basins, constructed wetlands** and retention ponds.
7. **Green roof** on buildings.

Flood Detention / Conveyance

8. Design **parking areas** and landscapes to accommodate their own treatment and flood detention requirements. Include shallow parking depressions of less than nine inches in parking lots to detain flood volumes.

***NOTE:** Words in **blue bold** appear in the BMP Fact Sheet section of this report. Words in **red bold** appear in the Implementation Detail section of this report.

Campus / Office

Characteristics: A campus site consists of multiple buildings with a related purpose or function, organized around pedestrian-oriented spaces. Emphasis on automobile circulation and parking can vary considerably. This development type typically has 15-40% pervious area.

Potential Stormwater Quality Treatment Sites: Runoff reduction techniques, infiltration techniques, and WQv detention options can be integrated into the landscape to create site amenities where space permits. Strategies shown in the Multi-Family Residential or Commercial Development Types are also appropriate for confined spaces on campuses, including treatment in gardens, plazas, islands, and buffers at surface parking and roofs.

Site Planning

A. Integrate stormwater treatment, conveyance, and storage into landscape areas, parking islands, and parking medians to reduce runoff and conserve buildable land.

B. Consolidate landscape areas (e.g., consolidate smaller parking lot islands) to incorporate stormwater treatment.

C. Orient parking containing treatment areas to avoid conflicts with pedestrian access patterns.

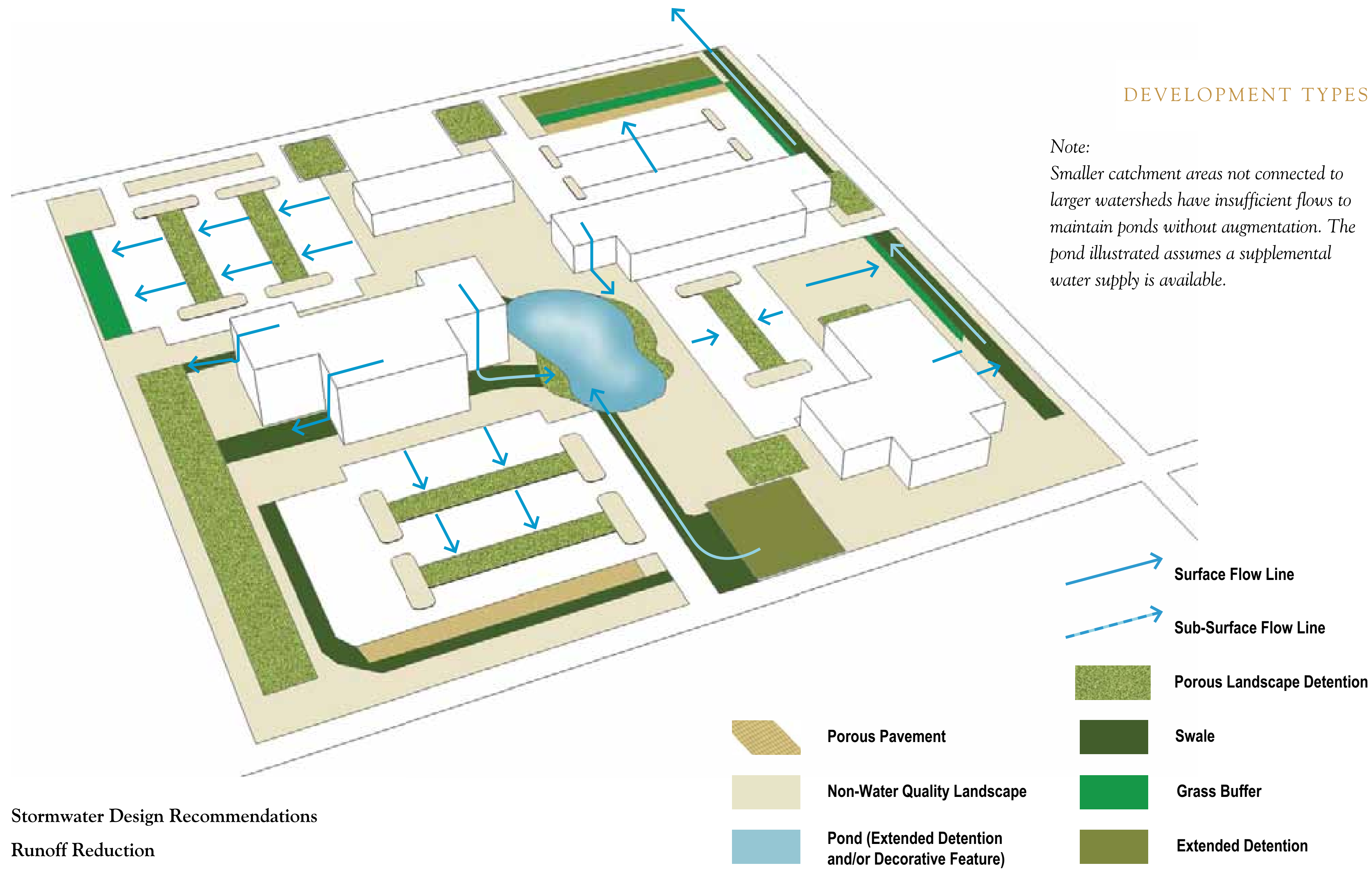
D. Drain roofs, walks, and drives to **porous landscape detention** to reduce and treat runoff. Locate **grass swales** to treatment areas to preserve usable interior open space.

E. Break up extensive parking areas with **porous pavement detention** and **porous landscape detention.**

F. Sheet-drain large areas of paving to landscape (e.g., **grass buffers** and **swales**) to reduce runoff.

G. Disperse runoff in parking lots with **slotted curbs** or **level spreaders** and direct to adjacent **grass buffers** and **swales**.

Note:
Smaller catchment areas not connected to larger watersheds have insufficient flows to maintain ponds without augmentation. The pond illustrated assumes a supplemental water supply is available.



Stormwater Design Recommendations

Runoff Reduction

1. **Grass buffer** as an integral component of **parking islands, medians and buffers**.
2. **Grass swale** as an integral component of parking and perimeter landscaping.

WQv Treatment

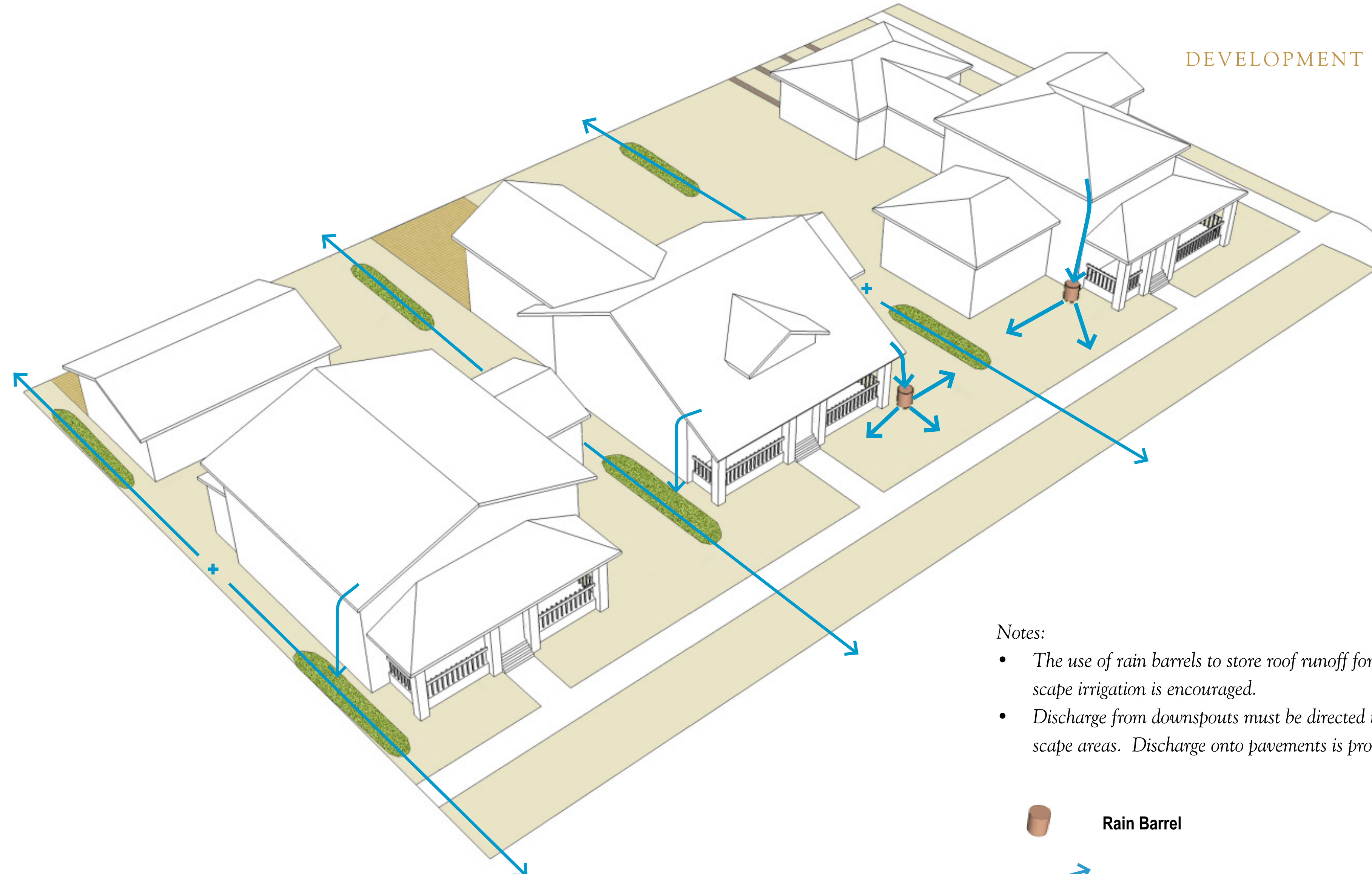
3. **Porous landscape detention** in **parking islands, medians and landscape buffers** creating landscape amenities.
4. **Porous pavement detention** in pedestrian areas and low traffic areas such as parking (e.g., close to buildings and perimeter areas) and emergency access drives.
5. **Detention basins** including **extended detention** in low visibility areas, wetlands and retention ponds.
6. **Constructed wetland basins** and retention ponds can be developed as landscape amenities.

Flood Detention / Conveyance

8. Combine stormwater quality treatment with flood control in **detention basins** and or retention ponds; route at WQv and turf areas through treatment prior to discharge into permanent pool.

***NOTE:** Words in **blue bold** appear in the BMP Fact Sheet section of this report. Words in **red bold** appear in the Implementation Detail section of this report.

Single Family Residential



Characteristics: The Residential development type is characterized by single-family homes lining a roadway. Typical development patterns include small landscape areas in the front and back of each structure. This development type typically has a pervious area of 45-75%.

Potential Stormwater Quality Treatment Sites: The focus in this development type is on reducing runoff from homes. Yards and gardens surrounding each structure or group of structures receive runoff from roofs as well as paved walks and drives.

Stormwater Design Recommendations

Runoff Reduction

1. Drain roofs to **grass buffers** and **grass swales** in gardens and yards.
2. Drain driveways, walks, and patios to adjacent **grass buffers** either directly or through slot drains at property lines or manor or large estate lots if swales allow surface conveyance, or across porous pavement on smaller lots. Provide sufficient slope and/or a ledge between the pavement and the landscape to accommodate future thatch buildup on lawns.
3. Construct driveways and parking aprons using **porous pavement**; minimize driveway pavement by limiting paving to "wheel tracks"

Flood Detention / Conveyance

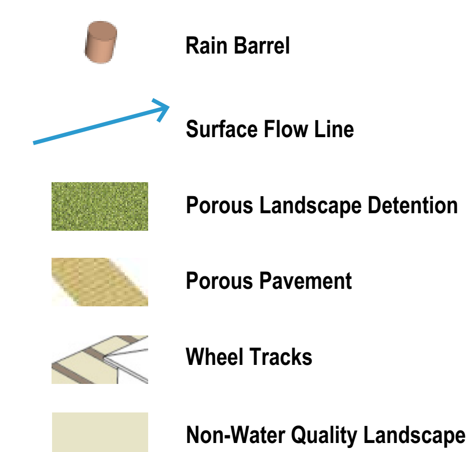
4. No detention is required on individual lots.

Implementation Details

5. Drain roofs to adjacent **porous landscape detention** and turf areas to reduce run-off. Avoid storing water on foundation soils at the building perimeter.
6. Design gardens and planting beds to accommodate and thrive on runoff from roofs and paving; incorporate "rain barrels" to temporarily store runoff for distribution on maintained landscapes.
7. Direct runoff from large storms to roadside swales, curb pans, and alleys as applicable.

Notes:

- *The use of rain barrels to store roof runoff for landscape irrigation is encouraged.*
- *Discharge from downspouts must be directed to landscape areas. Discharge onto pavements is prohibited.*

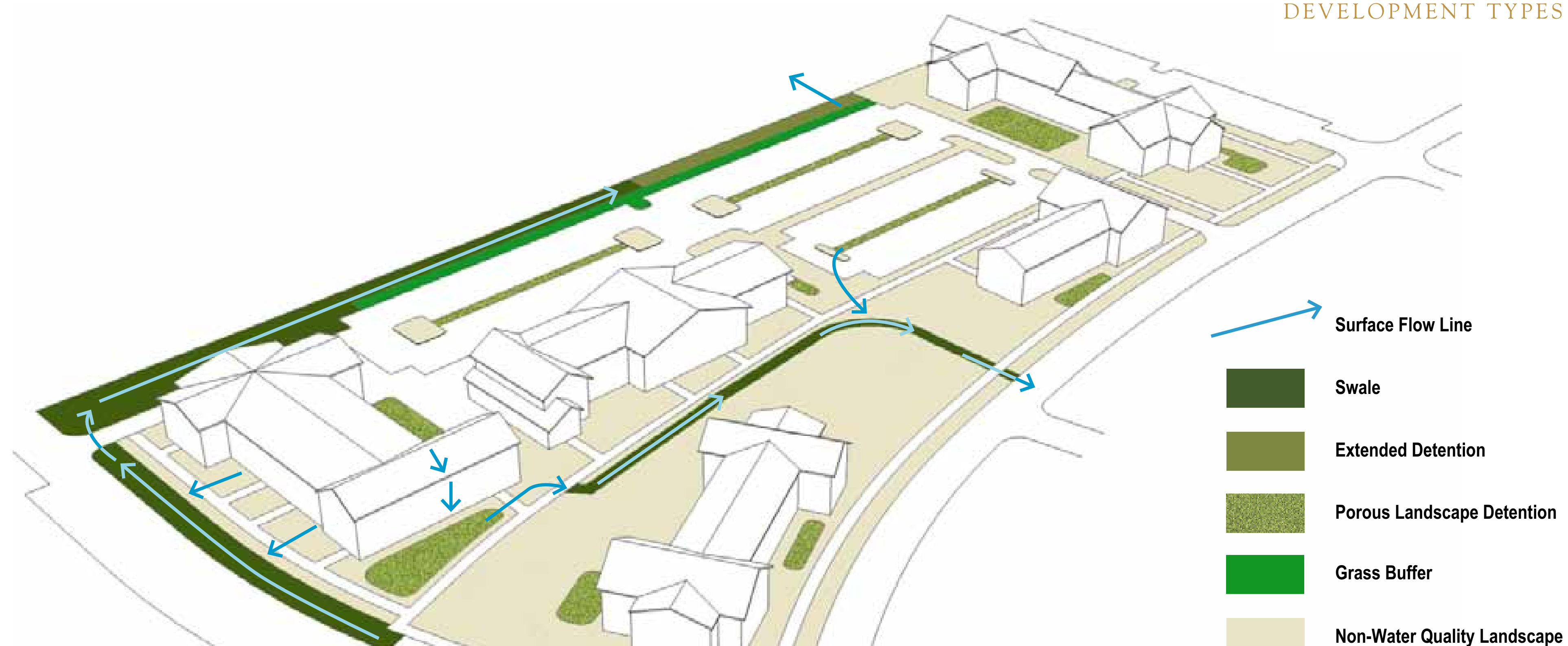


***NOTE:** Words in **blue bold** appear in the BMP Fact Sheet section of this report. Words in **red bold** appear in the Implementation Detail section of this report.

Multi-Family Residential

Characteristics: Multi-family residential sites consist of multiple residential structures organized primarily by automobile circulation and parking with pedestrian-oriented spaces and walkways. Commonly this development pattern includes extensive parking areas that can account for more than half the site. Emphasis on automobile circulation and parking can vary considerably. This development type typically has a pervious area of 30-40%.

Potential Stormwater Quality Treatment Sites: Runoff reduction techniques, infiltration techniques, and WQv detention options should be integrated into the landscape to create site amenities where space allows. Stormwater treatment can occur in surface parking lot islands, medians, landscape buffers, lawns, courtyards, and gardens. Parking areas treat both WQv and flood storage for the runoff they generate. Stormwater treatment strategies for confined spaces include treatment in gardens, courtyards, parking islands, and landscape buffers.



Notes:

- *Slope parking and driveways to landscape buffer/ PLD.*
- *Expansive soils- line and underdrain to storm sewer when required.*
- *If extended detention is used, locate in low visibility areas.*
- *On-site detention may be required. Refer to the Sub-Area Design Characteristics section in the Introduction of this report to identify sub-watersheds requiring on-site detention.*

Site Planning

A. Consolidate landscape areas to allow incorporation of stormwater facilities.

B. Integrate stormwater treatment, conveyance, and storage into **parking islands**, **parking medians** and **landscape areas** to reduce runoff and conserve buildable land.

C. Sheet-drain large areas of paving to landscape (e.g., **grass buffers** and **swales**) to reduce runoff. Spread flows with **slotted curbs** or **level spreaders**.

D. Drain roofs, walks and drives to **porous landscape detention** to reduce and treat runoff.

E. When the site is contiguous with open space buffers, consider integrating consolidated treatment and storage adjacent to the park/open space.

F. When it is not possible to utilize consolidated district detention, incorporate flood detention into the site as an amenity and **landscape buffer** to treat WQv and flood detention.

Stormwater Design Recommendations

Runoff Reduction

1. **Grass buffer** as an integral component of **parking islands, medians, landscape buffers**, courtyards and plazas.
2. **Grass swale** as an integral component of parking and perimeter landscaping.
3. **Level spreaders** to disperse concentrated flows into turf and landscape areas.

WQv Treatment

4. **Porous landscape detention** in **parking islands, medians** and **landscape buffers**.
5. **Detention basins** including **extended detention, sand filter basins, constructed wetlands** and retention ponds.

Flood Detention / Conveyance

6. Direct roof runoff to **porous landscape detention**.
7. Design **parking areas** and **landscape buffers** to accommodate their own treatment and flood detention requirements. Include shallow paving depressions of less than nine inches in parking lots to detain flood volumes.
8. Combine stormwater quality treatment with flood control in **detention basins** when flood storage is not directed to consolidated district detention facilities.
9. Locate residential structures at an elevation to accommodate the 100-year storm event.

***NOTE:** Words in **blue bold** appear in the BMP Fact Sheet section of this report. Words in **red bold** appear in the Implementation Detail section of this report.

Attached Residential

Characteristics: Attached residential units consist of linked, multi-story units. Driveways and parking is dispersed throughout the project in small lots with garages, courtyard gardens; small parks and perimeter landscape buffers are typical.

Potential Stormwater Quality Treatment Sites: Runoff reduction techniques, infiltration techniques, and WQv detention options should be integrated into the landscape to create site amenities where space allows. Stormwater treatment can occur at surface parking edges, landscape buffers, lawns, small parks, and gardens. Parking areas can be designed to treat both WQv and flood storage, if required, for the runoff they generate.

Site Planning

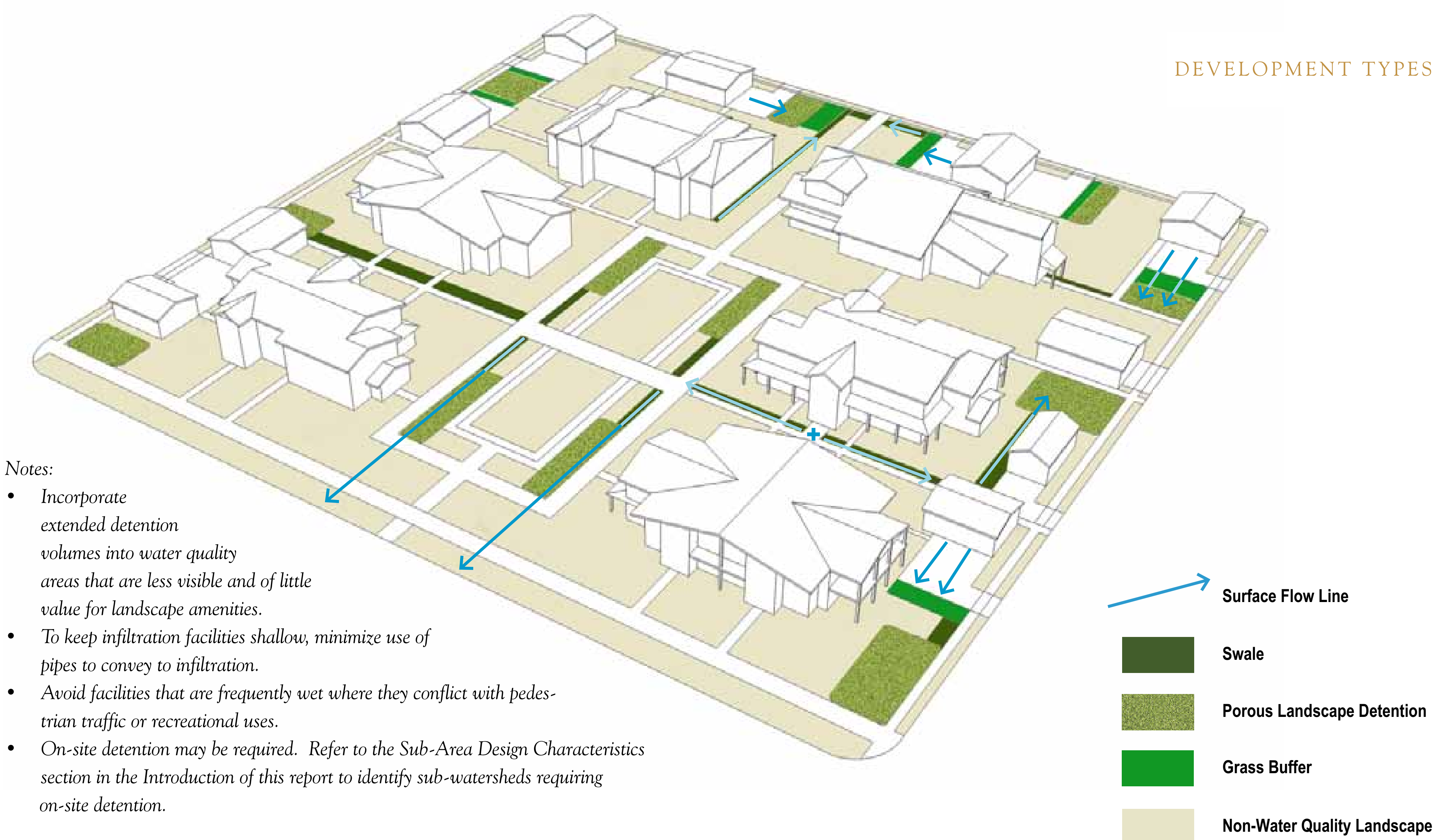
A. Consolidate landscape areas to allow incorporation of stormwater facilities

B. Sheet-drain large areas of paving to landscape (e.g., **grass buffers** and **swales**) to reduce runoff. Spread flows with **slotted curbs** or **level spreaders**.

D. Drain roofs, walks, and drives to **porous landscape detention** to reduce and treat runoff.

E. When the site is contiguous with open space buffers, develop plantings that create a smooth transition between the site and open space; consider joint/integrated detention if required.

F. When it isn't beneficial to utilize consolidated detention, incorporate flood detention into the site as an integral part of WQv.



Notes:

- *Incorporate extended detention volumes into water quality areas that are less visible and of little value for landscape amenities.*
- *To keep infiltration facilities shallow, minimize use of pipes to convey to infiltration.*
- *Avoid facilities that are frequently wet where they conflict with pedestrian traffic or recreational uses.*
- *On-site detention may be required. Refer to the Sub-Area Design Characteristics section in the Introduction of this report to identify sub-watersheds requiring on-site detention.*

Stormwater Design Recommendations

Runoff Reduction

1. **Grass buffer** as an integral component of **landscape buffers**, courtyards and plazas.
2. **Grass swale** as an integral component of parking and perimeter landscaping.

WQv Treatment

3. **Porous landscape detention** in small parks, lawn gardens, and **landscape buffers**.
4. **Detention basins** including **extended detention, sand filter basins, constructed wetlands** and retention ponds are acceptable in low visibility areas.

Flood Detention / Conveyance

5. Direct **roof** runoff to **porous landscape detention**.
6. Design **parking areas** and landscapes to accommodate their own treatment and flood detention requirements. Include shallow paving depressions of less than nine inches in parking lots to detain flood volumes, if required.
7. Combine stormwater quality treatment with flood control in **detention basins** when flood storage is not directed to consolidated detention facilities.

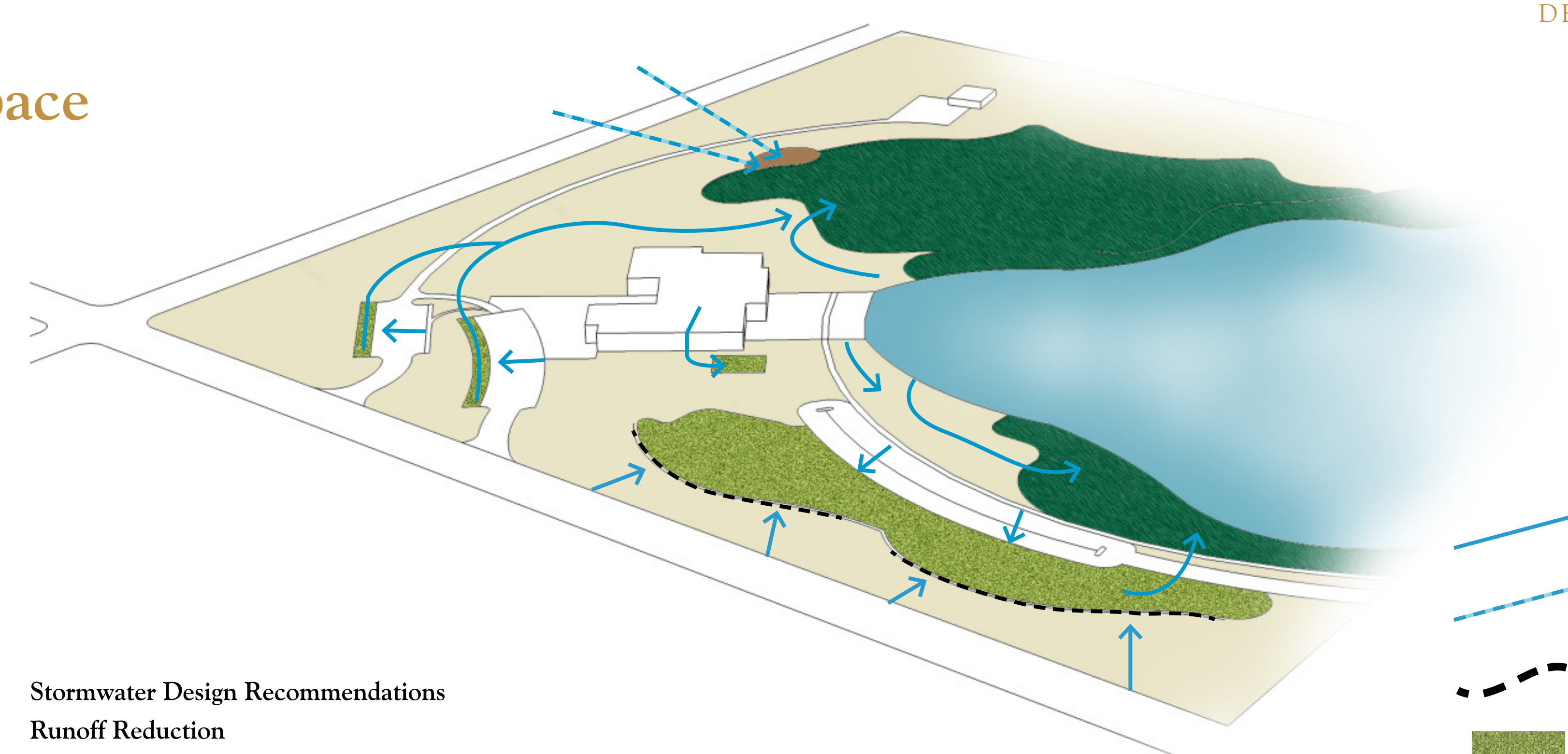
***NOTE:** Words in **blue bold** appear in the BMP Fact Sheet section of this report. Words in **red bold** appear in the Implementation Detail section of this report.

Parks and Natural Areas / Open Space

Characteristics: Due to the minimal amount of impervious area in parks, supplemental efforts to reduce runoff from on-site sources are rarely required. Parks and open spaces in Prairie Trail will serve as some of the primary locations for consolidated treatment and detention. These guidelines assume that detention and treatment will be an integral part of the parks recreational program, and be fully accessible to park users. The incorporation of treatment and storage assumes significant portions of the parks will be of a more naturalized character. Parks with high intensity uses adjacent to the Town Center may have significant areas of surface parking or paved area runoff requiring treatment.

Potential Stormwater Quality Treatment Sites: The public nature of park spaces create an opportunity for reducing and treating consolidated runoff in regional facilities. Locate treatment and storage to support the use and character of each park and adjacent development. For example, wetland treatment can serve to screen large parking areas, or to provide a buffer between residential and heavily used and programmed park facilities.

Site Design:
A. Direct all sheet flows from pavements, buildings, and turf areas through **porous landscape detention**, or related treatment prior to discharge into ponds and streams.
B. Consolidated detention and treatment should be located to accommodate traditional park uses.
C. Continuously link naturalized treatment, storage, and conveyance to Saylor Creek to promote wildlife habitat; develop a diverse range of native landscape types to accommodate a broad range of wildlife species.
D. Locate **treatment wetlands** and **porous landscape detention** to allow visual surveillance of actively used park areas from adjacent areas. Integrate trails and maintenance access. Make routes visible from roadways and adjacent development.
E. Comply with pond edge design guidelines for constructed **wetland basins**.
F. Provide sediment traps and cleanouts where stormwater pipes daylight.
G. Route runoff from turf areas through **treatment wetlands** and **landscape buffers** rather than direct discharge into ponds.



Note:
To minimize flow of nutrients into ponds, route surface flows from fertilized turf areas through treatment wetland rather than direct discharge into ponds.

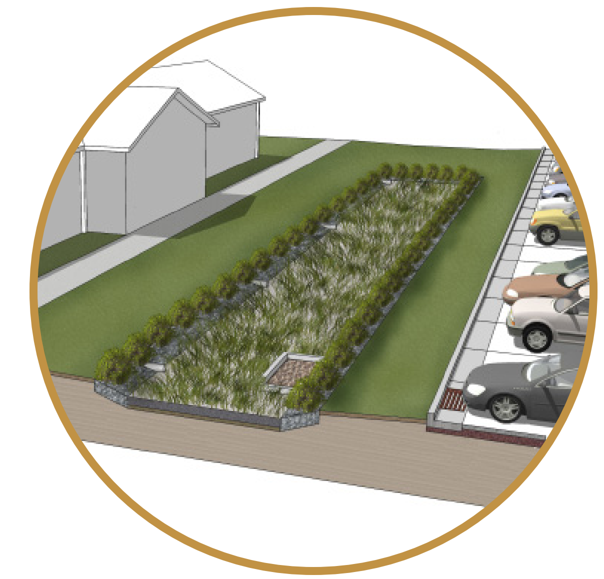
Stormwater Design Recommendations
Runoff Reduction
1. Sheet-drain parking and paving to **grass buffers** and **grass swales**, native landscapes, or treatment and detention.
2. Drain roofs to **grass buffers**, **grass swales**, and **porous landscape detention**.
3. Develop multi-purpose trails, maintenance routes, and parking areas to minimize directly connected impervious areas. Avoid concentrating runoff from roadways and parking lots by allowing runoff from those areas to sheet drain over landscape areas.
4. Use **porous pavement** to the maximum extent practicable for parking areas, patios, trails, etc.

WQv Treatment
5. Treat runoff from parking lots and roadways using **porous landscape detention** and **porous pavement detention** where practicable.
6. Incorporate regional stormwater quality treatment as part of **extended detention basins**, **constructed wetlands**, and retention ponds. Construct all facilities as site amenities, with WQv surcharges two feet or less to support diverse ecology. Minimize use of retention ponds as primary treatment for WQv to maintain a higher level of water quality in the permanent pool.
7. Do not vegetate WQv facilities with regularly mown turf.
8. Implement source control BMPs through proper pesticide, herbicide, fertilizer and other chemical use.

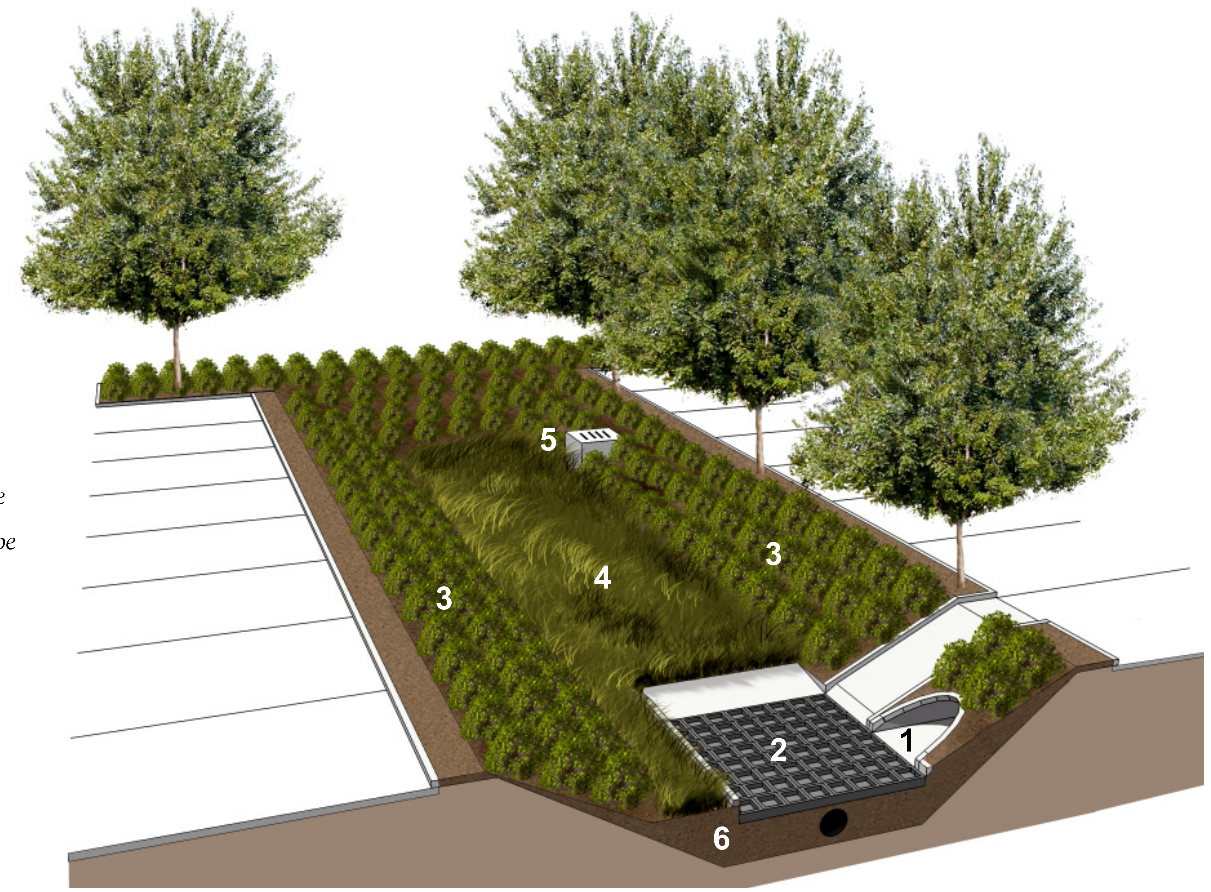
Flood Detention / Conveyance
9. Avoid locating regularly mown turf grass areas below the five-year storm level in retention ponds, or as determined by parks department or entity maintaining turf areas.
Implementation Details
10. Direct runoff from parking to adjacent landscape areas.
11. Parks present a tremendous opportunity to include ecologically diverse plant communities in larger treatment areas. Coordinate the design of ponds and **constructed wetlands** with goals for the creation of habitat types determined in the park design process.

***NOTE:** Words in **blue bold** appear in the BMP Fact Sheet section of this report. Words in **red bold** appear in the Implementation Detail section of this report.

BMP FACT SHEETS



Extended Detention Basins (EDB)



1 Inlet: *Dissipate energy at outfalls to prevent erosion and trap larger sediment.*

2 Sediment Trap: *Provide forebay and equipment access to allow regular maintenance; provide pervious hard bottom and access ramp to allow equipment access.*

3 Side Slopes: *3:1 max.; 4:1 or flatter preferred to maintain stable slope.*

4 Vegetation: *Native mesic prairie, wetland grasses, or forbes are preferred in the bottom to facilitate infiltration. To minimize landscape damage during maintenance, avoid locating trees, shrubs, and related ornamental plantings on basin bottom where significant sediment deposition is anticipated.*

5 Outlet/Overflow: *Located outlet in less visible or screened areas; build into basin slope to reduce visibility. On the larger facilities, locate micro-pool, trash rack, and emergency spillway in less visible areas.*

6 Infiltration Matrix: *Comply with soils and underdrain requirements if EDB will incorporate infiltration BMP's. Acceptable soils include Groups A and B, soil texture class sand to loam.*

Naturalized Retention Ponds can be used for regional extended detention. Treatment of the WQv upstream is encouraged to maintain better water quality in the permanent pool.

The above photo is an example of including a wide range of plant materials that screen and enhance the basin, located in a low visibility area of the site.

Function: To provide for Water Quality Capture Volume (WQv) and Flood Control

Detention basins for stormwater quality include the following two types, each capturing the WQv and slowly releasing it to provide long-term settling.

1. Extended detention basin
2. Sand filter extended detention basin - use is discouraged except in low visibility areas
3. Constructed wetlands
4. Retention ponds

These basins are generally intended to serve watershed areas greater than one acre, with areas less than one acre served by WQv facilities such as porous landscape detention and porous pavement detention. Constructed wetland basins and retention ponds are only suitable if the local hydrology will support viable wetlands or a permanent pool. Flood control detention may be designed in a surcharge zone above any of the water quality detention basins identified above.

Typical Applications: Watershed areas typically greater than one acre, generally located in landscape areas that are of moderate to low visibility. Use in high visibility areas where image is important could detract from the project image.

Operation and Maintenance Considerations: Access to the basin by sediment clean out equipment is required. Provide an all-weather driving surface designed to accommodate appropriate maintenance equipment to the bottom of the basin near the pre-sedimentation forebay and outlet works.

Sediment Trap

Concrete tracks allow loader access for sediment removal; permeable center of the bottom provides for infiltration. Stormwater outfall daylights between the ramps into the foreground. See diagram on page 31 for an overview of the combined detention and PLD.

Retention Pond

Frequent storms are contained within concrete edge; 100-year storm by the turf slopes around pond.

Maintained Landscape Extended Detention

Gravel in the frequently flooded portions of this new grass detention basin is difficult to maintain once vegetation moves into deposited sediment. Use of riparian or wetland grasses would be a better long-term solution. Trees on the banks of the basin might help it to blend with the surrounding neighborhood landscape. The outlet structure would be less conspicuous if placed into the slope on the far end of the basin.

Naturalized Extended Detention

While attractive, the density of shrubs in the bottom of this basin may complicate maintenance. Native grasses that can easily be mowed on occasion in dry periods would be a better choice; sediment removal would only require re-seeding rather than re-planting.

Extended Detention Basins (EDB) (*continued*)

Landscape Considerations: Design basins as a site amenity; otherwise, locate in an unobtrusive part of the site. Exclude recreation facilities, bluegrass, and cobble from the bottom of the facility subject to frequent prolonged inundation. The shaping of the detention basin should focus on creating a subtle, attractive facility. Constructed wetland detention basins can create habitat and wildlife amenities while providing additional stormwater quality benefits.

Retaining Walls: Attempt to design without the use of retaining walls, to improve aesthetics and allow easy maintenance access. If walls are unavoidable, plan at least one side of the basin perimeter without retaining walls to allow access. Walls over 30 inches in height require handrails, or designed in accordance with the current Uniform Building Code. Locate walls away so as to be less visible from heavily used areas as possible.

Outlets: Outlets must control the design release rates and be provided with micro-pools, oversized trash racks, and emergency spillways. Outlets that are flush with the vegetated side slope are less visually obtrusive.

Relative Cost: Low, except for ultra-urban, where cost is high.

Porous Landscape Detention (PLD)

1 Inlet: *Curb inlet and roof drains supply water to porous landscape detention. Sheet flow from parking lot over a grass buffer would be more cost effective and would allow reduced area requirement for the PLD.*

2 Sediment Trap: *Include a defined entrapment to remove sediments from paved areas.*

3 Slopes: *Relatively flat bottom with a 6-12 inch deep WQv zone (six inches recommended). Side slopes maximum 3:1 slope. (Slopes conveying significant sheet flow should be shallower.)*

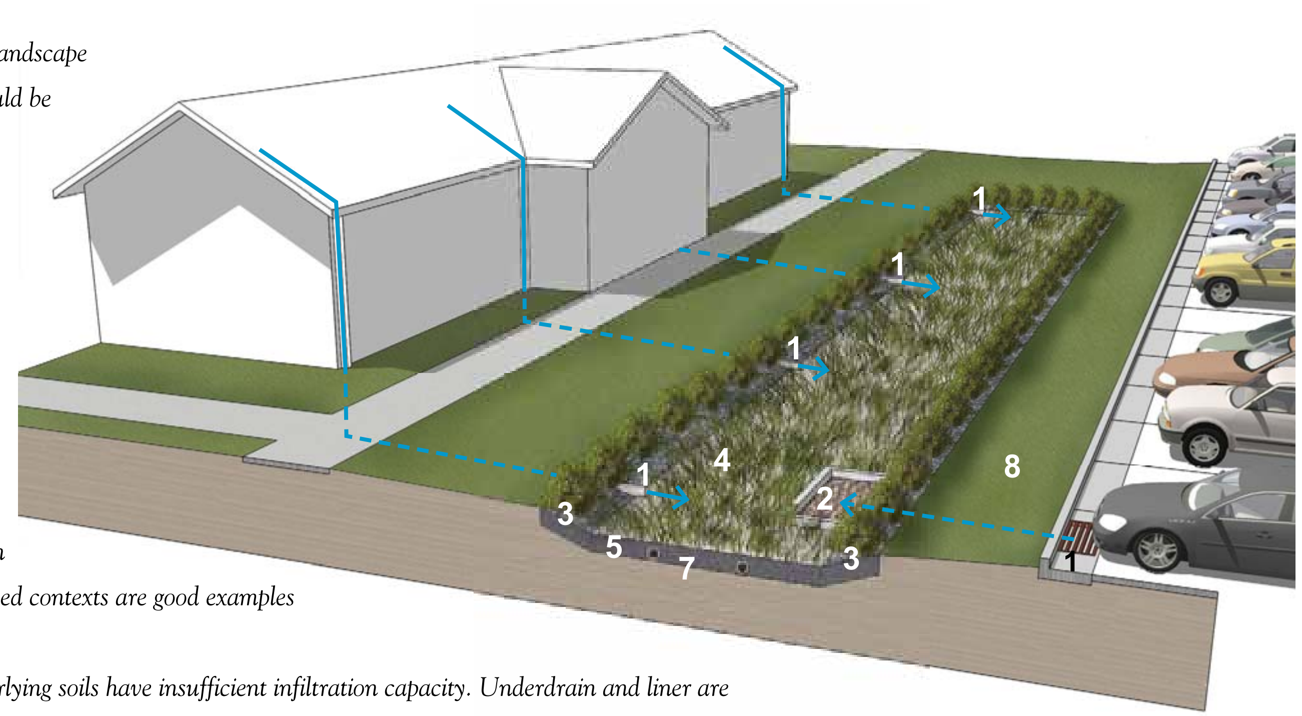
4 Vegetation: *Varies depending on context. Native mesic prairie in natural settings, ornamental plantings that can tolerate wide variations in soil moisture in more highly developed contexts are good examples of proper planting.*

5 Underdrain/Liner: *Underdrain is required when underlying soils have insufficient infiltration capacity. Underdrain and liner are recommended where geotechnical concerns exist.*

6 Outlet/Overflow: *Provide overflow above WQv for larger storm events. (Not shown in sketch)*

7 Infiltration Matrix: *Provide in accordance with design requirements shown in Soils, Implementation Details.*

8 Adjacent Areas: *When possible, eliminate curbs or daylight roof drains and sheet drain parking, roads and roofs across grass buffer to enhance treatment.*



The landscape area in the center of the photo is a PLD. It can be incorporated into small spaces between buildings like these planters in this residential courtyard. Source: Murase Associates; City of Portland, Department of Environmental Services

This larger PLD in a medium density neighborhood gives identity to the community. Native mesic prairie shown can tolerate wet and dry periods. The sediment trap shown filled with water following a storm event in this photo, is shown on page 49 in more detail.

This PLD treats runoff from the parking area to the right of the photo. The small pocket wetland compliments the natural qualities of the stream corridor to the left, and provides an enhanced experience for trail users.

Function: To provide for Water Quality Capture Volume (WQv)

Porous landscape detention is a depressed landscape area with hydrologic soils Type A or B (sand to loam) that promotes filtration and infiltration of runoff. Also, a PLD (if not underdrained) greatly reduces runoff volume, which reduces flooding and erosion in downstream receiving waters.

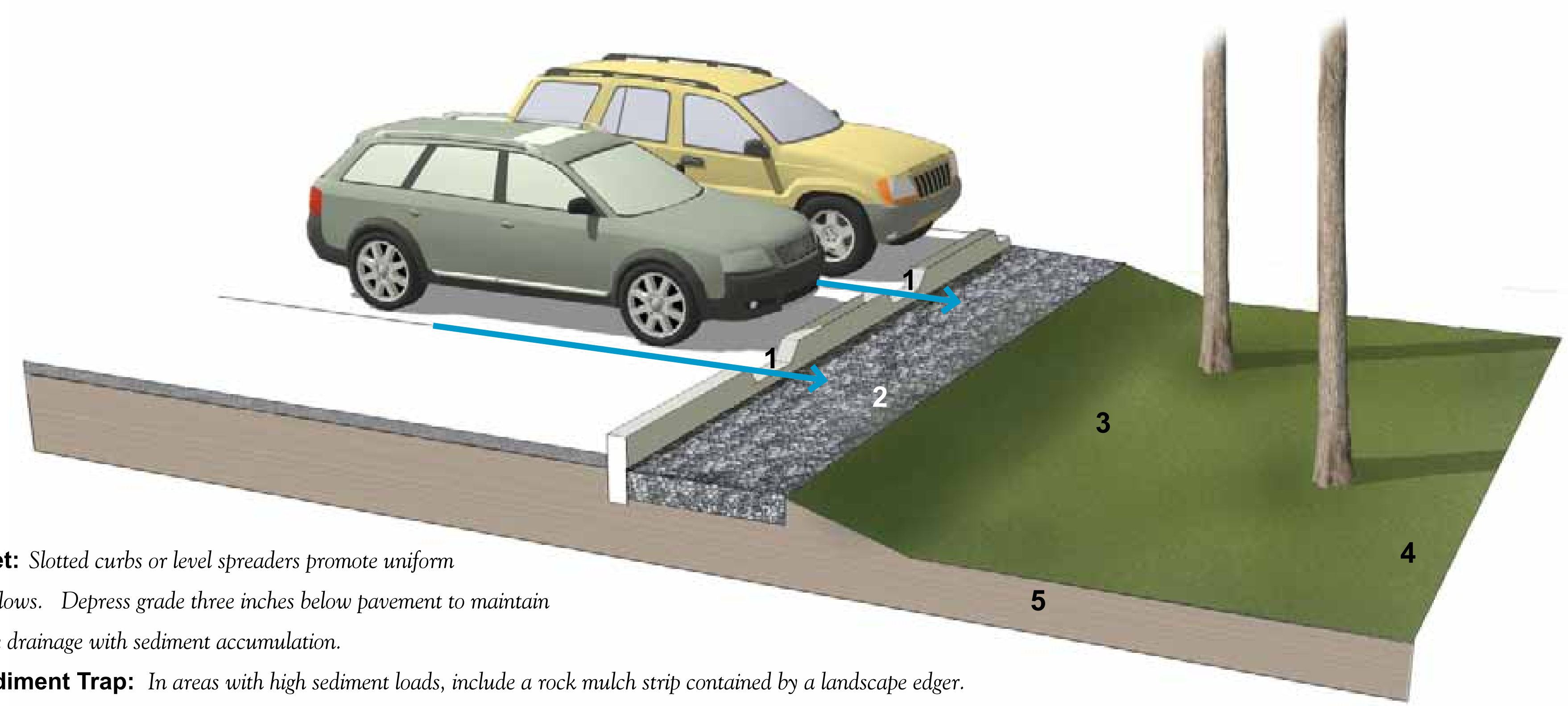
Typical Applications: Parking islands, medians, and landscape buffers, courtyards, and planters. Geotechnical and foundation issues must be carefully considered when locating porous landscape detention facilities and designing underdrains and linings.

Operation and Maintenance Considerations: Sediment build-up may require periodic removal of sediments and plants when clogging reduces infiltration capacity to unacceptable levels. Access to facility must be provided to enable maintenance operations. Plant materials in areas prone to sediment build-up should be limited to grasses and groundcovers tolerant of periodic wet-dry cycles.

Landscape Considerations: A wide variety of plant types are possible, ranging from native grasses, groundcovers, flowers, and shrubs. Turf grass is discouraged because of the difficulty of maintenance. Trees should not be included in porous landscape detention areas (roots make maintenance difficult). Dense shrub plantings may become difficult to maintain, and should be limited to edges not prone to sediment build-up. Rock mulches (especially in high sediment areas) are discouraged because they limit the available pervious surface and are difficult to remove sediment from. The use of long fiber shredded wood mulch is encouraged because of a higher level of perviousness.

Relative Cost: Moderate to high

Grass Buffer



1 Inlet: *Slotted curbs or level spreaders promote uniform storm flows. Depress grade three inches below pavement to maintain positive drainage with sediment accumulation.*

2 Sediment Trap: *In areas with high sediment loads, include a rock mulch strip contained by a landscape edger.*

3 Vegetation: *Irrigated dense turf or native grasses—may include other dense groundcovers. Provide positive slope to allow gradual deposition of sediment while maintaining positive drainage.*

4 Outlet/Overflow: *Drain to a grass swale or a depression with inlet and storm sewer. Buffers may also sheet flow over pavement. Direct to treatment area.*

5 Infiltration Matrix: *Native soils*

The native grasses of the buffer in this park reduce runoff from the alley, neighborhood, and irrigated turf, reducing pollutants and protecting the adjacent drainageway.

One-foot-wide mulch along this curbless road at an industrial facility traps sediment from runoff before it enters the swale below. It can be replaced easily when clogged. An edger between the mulch and adjacent landscape would help contain the mulch and create a cleaner edge.

Stormwater flows directly from the road across the grass buffer planted with turf and trees into a grass covered sand filter treatment in a residential parkway. This example would function better and require less frequent sediment removal if the turf edge was below pavement as shown in detail above.

Function: Runoff Reduction

A grass buffer is a gently sloped turf area designed to disperse runoff over a broad area, promote infiltration, remove large sediment, and reduce the volume of runoff entering treatment facilities.

Typical Applications: Landscape edges and transitions to paved areas, roads, parking lots, and residential lawns.

Operation and Maintenance Considerations: Turf should be approximately three inches lower than adjacent paving to provide positive drainage even when a moderate amount of sediment and thatch has accumulated. When used adjacent to parking lots, consider slotted curbs, other vehicular controls, or reinforced turf at the edge of the pavement to reduce wheel rutting and compaction of the buffer. Avoid heavy use of fertilizers that will undermine stormwater quality goals. Direct sheet flows (unconcentrated flows) to grass buffers to reduce erosion.

Landscape Considerations: Select turf or native grasses appropriate to the surrounding landscape. When groundwater is close to the surface, use wetland grasses that can tolerate inundation. Dense groundcovers with fibrous root systems may also be considered. Slope bluegrass buffers at a 2% minimum slope, and native grasses or shrub-planted buffers may be sloped slightly less, but require at least a 1% minimum slope.

Relative Cost: Low

Conveyance/Infiltration Swale

1 Inlet: *Slotted curbs or curbless streets allow for sheet flows into the swale; slopes serve as grass buffers. Control sediment and erosion at inlets and wherever flows concentrate. Provide for positive drainage with sediment accumulation.*

2 Sediment Trap: *Depress landscape edge; provide gravel filter if large volumes of sediment are anticipated in sheet flow conditions. Provide sediment trap at pipe outfalls to dissipate energy and to allow easier sediment removal. Locate sediment trap above low flow conveyance to minimize re-mobilization of sediments.*

3 Slopes: *Longitudinal slope should be shallow (0.5%+/-) Check structures may be required; side slopes 3:1 max., 4:1 or flatter preferred.*

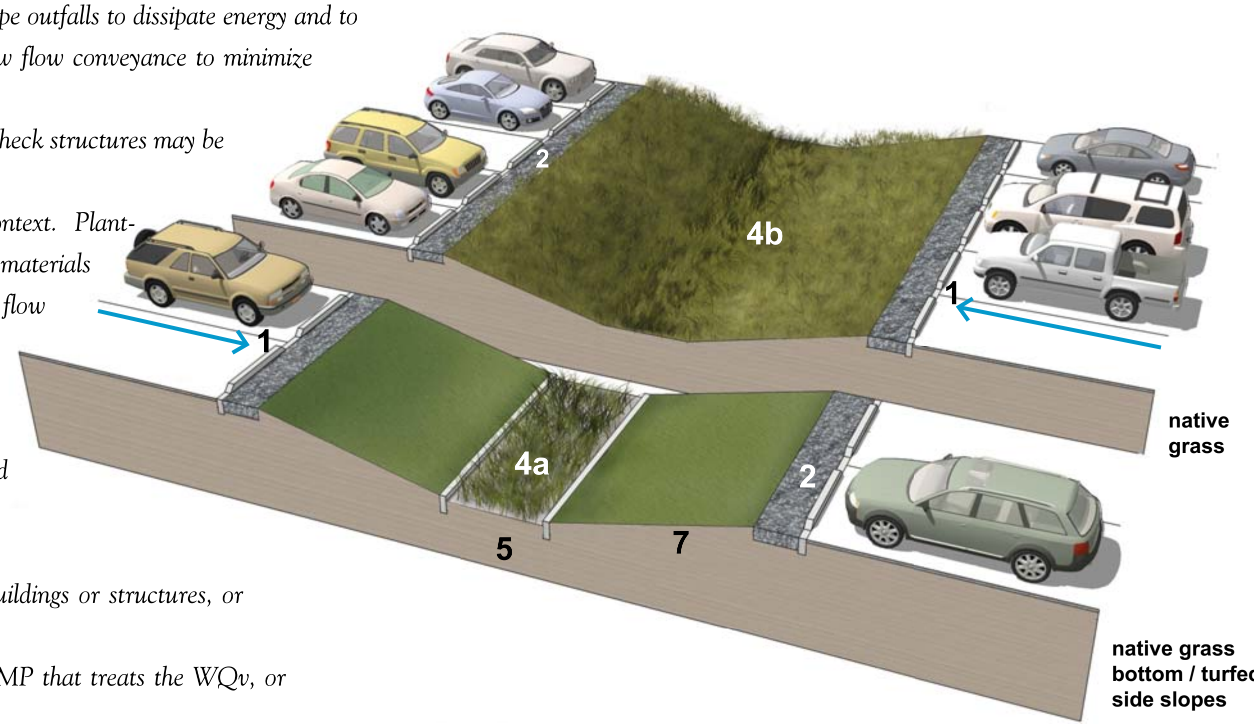
4 Vegetation: *Plantings vary depending on surrounding context. Plantings in channel bottom facilitate biological uptake. Select plant materials appropriate for wet and dry cycles, and that can withstand storm flow velocities.*

- **a** *Native grasses minimize maintenance; mowing edge that defines a low flow channel is encouraged to minimize maintenance of adjacent maintained landscapes.*
- **b** *Native grasses require minimal maintenance.*

5 Underdrain/Liner: *Not required unless proximity to buildings or structures, or geotechnical requirements dictate.*

6 Outlet/Overflow: *Flows are typically delivered to a BMP that treats the WQv, or convey runoff from a WQv facility. (Not shown on sketch)*

7 Infiltration Matrix: *Consists of native soils*



(Far Left)

This swale in a depressed parking median removes coarse sediment while conveying flows to an extended detention basin. Note the flush curb that provides a clean edge to the asphalt and allows sheet flows into the swale. This example has minimal bio-uptake value.

(Left)

A swale between this industrial building and the entry drive collects runoff from downspouts and pavement then conveys it below the road to an adjacent stormwater quality treatment area. Shallow side slopes blend with surrounding landscape and allow easy maintenance. Vegetation provides bio-uptake.

Wet Swales, as described in SUDAS, must be constructed according to requirements for porous landscape detention as described in this document.

Dry Swales, as described in SUDAS, must be constructed according to requirements for constructed wetland basins.

Function: Runoff Reduction and on-site or consolidated conveyance

A grass swale is a gently depressed grass-lined or planted channel that conveys stormwater slowly, promoting infiltration and sediment removal.

Typical Applications: A surface flow conveyance in lieu of a storm sewer. Incorporate along curbless streets or to capture flow from grass buffers, or to convey flows to and from porous landscape detention. Piped flow can be diverted into a grass swale if pipe outlet provides energy dissipation (level spreader or riprap reinforcement).

Operation and Maintenance Considerations: In locations where routine mowing is planned, provide an underdrain. Avoid mowing following extended periods of precipitation. Maintain mowable side slopes.

Landscape Considerations: Native Grass or mulched plantings provide a stable surface for storm flows, grasses require regular mowing, which may be difficult when wet. Consider using native grasses that require less frequent mowing. Woody plant material in the swale bottom should be avoided as it may trap trash and debris and become difficult to maintain; allow adequate space along the flow-line to periodically remove sediment and debris. In the swale bottom avoid using turf grasses that require frequent mowing, as maintenance will be difficult when soils in swale are wet.

Relative Cost: Low

Porous Pavements

1 Ponding Depth: *2" maximum*

2 Slopes: *Flat*

3 Underdrain/Liner: *Infiltration without liner provides maximum benefits. Underdrain will be required when underlying soils have insufficient infiltration capacity and where geo-technical concerns exist. Porous pavement shall not be used if a likelihood of groundwater contamination exists due to the handling of chemicals or petroleum products.*

4 Inlet: *(not shown) For porous pavement detention, outlet drainage generally enters by surface flow or roof drains*

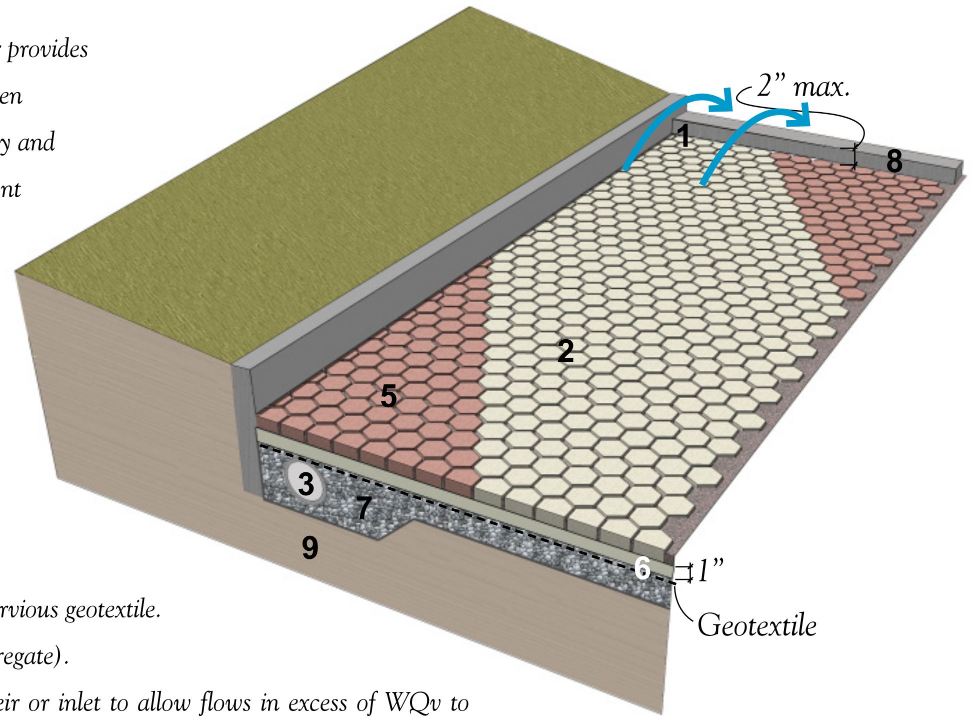
5 Pavers: *Install per manufacturer's directions when using proprietary products.*

6 Filter Layer: *1" thick sand layer on top of pervious geotextile.*

7 Storage Matrix: *Crushed gravel (course aggregate).*

8 Outlet / Overflow: *Provide an overflow weir or inlet to allow flows in excess of WQv to proceed to flood detention areas.*

9 Subgrade Soils: *Ponding depth to accommodate WQv.*



Modular block porous pavement in this small parking lot allows water from the adjacent building, as well as the parking lot itself to infiltrate.

Reinforced Grass Pavement stabilized by plastic rings is used for an occasional driving and parking surface outside this stadium. (Rings are located throughout turf area.) This surface cannot be plowed for snow removal. Source: www.invisiblestructures.com

Poured-in-place concrete porous pavement can be substituted for standard asphalt or concrete pavement.

Function: WQv treatment.
(Porous pavements can also be implemented without gravel sub-layer as runoff reduction techniques.)

Porous pavements include any pavement that allows vehicular traffic while also allowing stormwater to penetrate though the pavement and infiltrate. SUDAS mentions three different pavements as suitable for water quality treatment, including Modular porous pavement systems, Pervious concrete, and Porous asphalt. These are all pavements that provide water quality treatment (and reduce site impervious area) by allowing water to percolate through the pavement where it is then stored in a gravel reservoir until it infiltrates into the native soils. In cases where infiltration is not possible due to expansive soils or other geotechnical concerns, theses systems may be underdrained. (Note: In an underdrained system, the design must incorporate a sand filter layer to remove most of the fine particulate pollutants for the water column before the water reaches the underdrains.).

Other porous pavements include Reinforced grass pavement, which is a vegetated pavement that supports very limited vehicular use. This type of surface is generally used to eliminate the need for additional pavement for infrequent access needs, such as fire lanes, maintenance access, etc. This is not generally used as a BMP for water quality treatment, and will not be discussed here in detail.

The SUDAS Guidelines identify porous pavement as a viable alternative for water quality treatment, but recommend that these be used in specific situations where installation, maintenance, and sediment loads be tightly controlled. Following are keys to successful implementation of porous pavement systems:

- Proper function depends on high quality workmanship and maintenance requirements— maintain high quality control;
- There is a high failure rate if sediment loads are high (particularly from uncontrolled off-site sources)— assess your site carefully;
- These systems can be more expensive than other approaches, and are best suited for dense development with limited space for water quality treatment.

Of the pavement types mentioned, the modular systems are currently the most common. They also are the most maintainable over the long term, as the sand filter layer can be placed at the top of the system, allowing removal and replacement of the filter medium if clogging occurs. They also avoid the problems of freeze / thaw damage that the pervious concrete and porous asphalt systems can be prone to.

Typical Applications: Generally not recommended for high volume vehicular traffic areas. Best located in more remote areas of a parking lot, where periodic ponding (usually no more than 2" in depth) can be tolerated. Consider using porous pavement to collect runoff and intercept surface drainage, particularly where swales are not practical (i.e. at edges of driveways, and near building entrances.)

Landscape Considerations: N/A

Operations and Maintenance: Void spaces can become clogged over time and require periodic maintenance (vacuum removal of sedimentation) to re-establish infiltration capacity.

Relative Cost: High

Constructed Wetland Basin (CWB)

Function: Site WQv and Flood Control

A constructed wetland basin is a shallow pond, fed by a perennial base flow or ground water, which permits the growth of rushes, cattails, and other emergent wetland vegetation, and is designed to slow down runoff and allow time for sedimentation, filtering, and biological uptake. It is a sedimentation basin and a form of treatment plant. Well-designed and implemented CWBs are site amenities, providing aesthetic and habitat value in addition to water quality treatment functions.

A CWB differs from natural wetlands as they are completely man-made, and are built to enhance stormwater quality. Flood control storage can be provided above the water quality capture volume (WQv) pool, allowing it to act as a multi-use facility. Sedimentation forebays that collect coarse sediment are recommended for CWBs to reduce the amount of maintenance required to the wetland pool. Forebays should be approximately 5% to 10% of the WQv, and should have a hard driving surface on the bottom to allow sediment removal by mechanized equipment. The side slopes of the main wetland basin should not exceed 4:1 (5:1 is preferable).

Requirements: In addition to a perennial base flow, CWBs require low permeability soils to allow wetland plants to thrive. A relatively flat site is also required, as the longitudinal slope of the basin must be essentially flat.

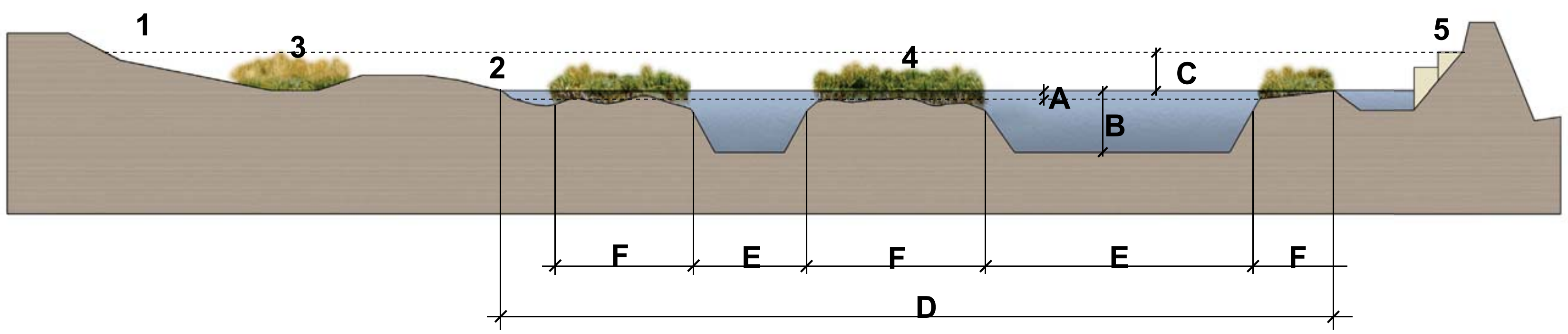
Typical Applications: Land uses which incorporate significant open space areas large enough to create wetlands without creating conflicts between other uses. Generally recommended for larger drainage basins / catchment areas. SUDAS describes four different types of CWBs. Use in Prairie Trail will primarily be in areas where consolidated stormwater controls are planned. Recommended uses of different types include the following:

- **Shallow Marsh, Pond/Wetland, Extended Detention Wetland**

  Integrate into longer public park and open space areas along Saylor Creek and its eastern tributary where stream base flows can supplement runoff volumes.

- **Pocket Wetland**

  Develop in areas of high groundwater, areas adjacent to natural open space and where a more naturalized landscape character is desired on private development.



1 Inlet: *Dissipate energy at inlets to prevent erosion and sediment re-suspension. (Not in Sketch)*

2 Slopes: *Sideslopes are generally 4:1 or flatter for safety and maintenance. Provide a safety bench slope at 10:1 to a depth of 18" below normal water level for ponds.*

3 Sediment Trap: *Sediment forebay to remove larger sediment particles and to be easily accessible for maintenance.*

4 Vegetation: *Should consist of native grasses, rushes, willows, cattails, and reeds.*

5 Outlet/Overflow: *Provide micropool, outlet structure, and overflow weir designed to withstand necessary flow velocities.*

6 Infiltration Matrix: *Infiltration through pond areas is not appropriate; requires soils with low permeability. In areas with permeable soils, an impervious liner may be necessary to retain water.*

A *6"- 18" min./max. water depth in areas other than designated open water*

B *6" min. depth recommended in open water areas*

C *Extended detention volume: 50% of the WQv, maximum water surface no more than 3" above permanent pool.*

D *Total extent of water surface area, with hydrologic group C&D (silt loam to clay) soils.*

E *20 -70% of total water surface area (***D***) needs to be open water at least 30" deep, and broken into multiple areas.*

F *Treatment wetlands range in depth from 6"- 30" min./max.*

Created wetlands adjacent to the creek provide areas for filtration of stormwater as well as habitat.

Sediment removal from a forebay.

Constructed Wetland Basin (CWB) (*continued*)

Operation and Maintenance Considerations: Since a CWB is a sedimentation pond, design must account for capacity and maintenance. It is recommended that the facility be oversized by a minimum of 25% of the WQv to increase the amount of time between major maintenance requirements. A stable-surfaced access route should be provided to the forebay. Along with routine maintenance, occasional mucking out will be required when sediment accumulations become too large and modify the proportion of open water to deep and shallow marsh areas.

Design Considerations: The facility needs to be designed so that sediment that collects in the CWB does not get flushed out in large storm events.

1. The surcharge for the WQv in the pond cannot be higher than 2' above the permanent water surface elevation. (100-year flood detention elevations can be higher)
2. Without a continuous dry-weather base flow, salts and algae can concentrate in the water column and be released into the receiving water in higher levels at the beginning of a storm event as they are washed out.
3. The volume of the permanent wetland pool should be no less than 75% of the WQv.
4. Recommended basin shape should have a length to width ratio between 2:1 and 4:1. Preferred shape is 3:1.

Relative Cost: Moderate (not considering land value)

Stream Channel Stabilization

Sites that encompass or are adjacent to major drainageways need to preserve and enhance natural stream functions, provide adequate flood capacity, and protect the channel from degradation. SUDAS provides design criteria for major drainage improvements and constructed wetland channels. "Soft" stream restoration techniques utilizing channel shaping and riparian vegetation, as well as appropriately designed grade control structures, are favored over more structural approaches to help enhance water quality and aesthetics.

Healthy streams and drainageways, if managed well, provide a number of important functions and values, including the following listed at the right:

(left) *Goldsmith Gulch (Denver) prior to stabilization. Increased volumes destabilized the channel, resulting in "head cutting".*
(below) *Goldsmith Gulch following stabilization and reconstruction. A series of check structures have flattened the gradient of the low flow channel, slowing the velocity of small storm events and creating a stable channel. Lowering the velocity of frequent storms allows the establishment of wetland and riparian vegetation, which can withstand damage from larger storms.*

- Conveyance of baseflow and storm runoff;
- Moderation of flood velocities and associated erosion;
- Attenuation of peak flows though channel storage;
- Support of riparian and wetland vegetation;
- Creation of habitat for wildlife and aquatic species;
- Infiltration and groundwater recharge;
- Enhancement of water quality;
- Reduction of ongoing maintenance requirements;
- Corridors for trails and open space;
- Aesthetic amenities;
- Enhancement of adjacent property values and improved quality of life.

Degradation of drainageways from increased urban runoff creates adverse water quality impacts by mobilizing significant quantities of sediment and associated pollutants and conveying them to downstream receiving waters. Stream degradation is best prevented before it begins. If significant erosion has already occurred, mitigation and repair must take place utilizing appropriate stabilization improvements and taking into account the root causes, including increased base flows and peak flows. In addition to providing adequate flood conveyance and channel stabilization, these improvements should provide all of the benefits listed above that are associated with healthy stream systems.

While the water quality treatment BMPs discussed in this volume are key components in the strategy to protect our waterways, even more important is the maintenance of a stable and healthy drainage network. In addition to the value that streams and stream corridors provide to communities for recreation, aesthetics, and property values, healthy streams and ponds can provide a significant water quality benefit, while deteriorating streams can contribute significantly to water pollution problems. Degradation of streams and ponds from the effects of urbanization is inevitable, however, unless there are very strict controls on runoff volumes, proactive protection of existing drainageways, and a forward thinking approach to the design of new channels.
The increased runoff volumes and peak flows that come with urbanization increase stream velocity and energy, causing channels to erode. Depending on the nature of the existing channel, erosion can occur downwardly ("head cutting") or horizontally (bank erosion). Both types of erosion often result in steep vertical bank that are prone to constant degradation due to the lack of vegetation that can establish itself on the constantly moving and failing banks.

Although the sediment introduced into the stream system by channel erosion is from a "natural' source (the stream bank or bed), this sediment can have major detrimental effects on the water quality of streams and ponds. Not only is the sediment itself a problem for fish, macroinvertibrates and other creatures that live in the streams and ponds, but also the sediment carries with it nutrients and other potentially detrimental compounds that contribute to the pollution of steam flows and the eutrophication of

(right)
Grange Hall Creek (Denver) prior to stabilization.
(far right)
Grange Hall Creek check structure installed to prevent head cutting. The shotcrete structure is terraced for safety; materials blend into the natural setting. Vegetation upstream of the structure illustrates how revegetation is possible when velocities are reduced and head cutting controlled.

Stream Channel Stabilization *(continued)*

ponds. Although often ignored by typical development water quality measures, eroding channels can dwarf the sediment and pollutant loads contributed by the development itself.

With proper management, maintenance, and design, urban streams can withstand the effects of development and be valuable community amenities. Following are recommended drainageway management and design objectives.

Establish Stable Channel Slope

Drainageway channels must have a longitudinal slope gradient that is stable and sustainable given the anticipated post-development flows. Recommended slopes depend on channel geometry, peak flows, soil types, base flows, and even sediment load, but for small to medium sized drainageways with a vegetative bottom, a range of 0.3% to 0.6% is recommended. (This must be verified using engineering criteria.) For existing streams that become receiving waters for runoff from new development with gradients exceeding the estimated "stable" slope, the effective slope of the channel must be reduced through the use of grade control or drop structures. Without an effective "flattening" of the channel gradient, downward cutting of the stream bed ("head cutting") will occur. This downward erosion may also create tall exposed cut banks. The grade control issues must be addressed before the bank stabilization can be addressed.

Create Compound Channel Sections with Active Flood Plains

Many erosion problems occur in channelized urban streams due to the concentration of flows in an incised channel during larger storm events. These deep flows tend to have higher velocities (and more erosion potential) than shallower flows due to the relative lack of roughness in the channel. In many natural streams flood flows overflow the base flow channel and spread out over the larger flood plan, thereby reducing velocity, dropping sediment, and preventing erosion. A new channel should have a compound design, with a defined base flow channel, and a wider flood plain that contains the larger flood events. The baseflow channel should be sized to accommodate smaller storms, ideally the 2-year event, while larger flows should overflow onto the overbanks, in as wide a floodplain as possible.

If channel sections and gradients are properly designed, the stabilization of the low flow channel can be accomplished using bio-engineering techniques and simple revegetation. Natural processes will cause some changes (and temporary, localized erosion) in the stream corridor, but in general, a well designed, stable stream will require less maintenance than a channelized stream, and can often be self-healing. Hard armoring (riprap, etc.) may be needed at bridge abutments, storm drain outfalls, and areas where minor bank erosion cannot be tolerated.

Implement Pro-active Stabilization Techniques for Existing Drainages

Increased runoff from development will immediately alter channel morphology. Delay in stabilizing the natural drainage system receiving the runoff will cause significant cost increases. Down cutting in the channel can be prevented by the installation of check structures and drop structures before erosion begins. Providing overbank areas where larger flood events can overflow into will also relieve erosional pressures on the drainageway. Proactive planting of vegetation to reinforce channel banks is also recommended, however, vegetation alone will not protect a channel that has been completely pushed out of its stable equilibrium by urbanization impacts.

(right)
Willow Creek (Denver) before stabilization; the result of lateral channel movement and head cutting.
(middle)
Willow Creek during stabilization. A number of bio-engineering techniques including bio-logs, brush layering, and wrapped soil lifts (shown in photo) were used to stabilize banks.
(far right)
The project area during planting establishment.
NOTE: *Construction details for this project can be viewed in Denver's Urban Drainage and Flood Control District Drainage Criteria Manual, Vol. 2; www.udfcd.org*

Subsurface Treatment Devices

Over the last decade, many proprietary stormwater BMPs have been developed; many of these are subsurface, vault-type treatment devices. Examples of these devices include Stormcepter™, Vortechnics™, Bay Saver™, and Storm Filter™. As a class of treatment technologies, these devices have proven to be controversial for the following reasons:

- In many cases, the performance claims are unsubstantiated.
- When manufacturers provide "performance data", it is often obtained without independent third parties and lacks appropriate quality assurance and quality control procedures.
- Many of these treatment devices are normally located below ground surface and tend to be "out-of-sight, out-of-mind". Therefore, they do not receive regular attention, maintenance or proper, periodic performance monitoring.
- Maintenance access is often poor or non-existent.
- Effectiveness can be typically limited to the removal of larger-sized pollutants. Dissolved pollutant removal and the removal of very small solids is typically very sporadic if it occurs at all.
- Few of these devices control stormwater volume. Consequently, they can easily fail to address the leading cause of receiving stream degradation from urban stormwater discharges—increased frequency, magnitude and duration of runoff.
- Anaerobic (absence of dissolved oxygen) conditions in bottom sediments are more likely to develop in underground devices. This condition can release pollutants that were bound to the sediment and cause bad odors.
- For all of these reasons, managing stormwater quality on the ground surface, using various BMPs presented in these Guidelines, is recommended. Under most circumstances, it should be feasible to manage the modest water quality capture volume (WQv) on the ground surface, without having to utilize subsurface, proprietary devices. Nevertheless, there are some cases where the use of such facilities is necessary due to extreme space constraints in smaller redevelopment sites. The use of such devices must comply with the following restrictions prior to receiving authorization for the use of such devices.
- Provide evidence that WQv cannot be managed on the ground surface through capture, extended detention, filtration and/or infiltration and the reason(s) for the use of subsurface proprietary device as the best choice for the site, considering factors such as initial installation, maintenance, and ability to assure long-term function.
- The proprietary device must provide volume control and be sized for the WQv based on a drain time of no less than six hours.
- Independent, unbiased test data for the device, along with demonstration of effectiveness, must be provided. Performance data should be gathered in general accordance with the recommendations of the International Stormwater BMP Database (www.bmpdatabase.org).
- A binding, long-term maintenance plan, including demonstration of adequate funding for such maintenance, must be provided.
- Performance of these devices has been shown to often deteriorate over time without proper maintenance. The applicant must either annually submit proof of maintenance or must gather monitoring data to demonstrate that pollutant removals are not declining over an extended period of time (i.e., no less than five years). It is the responsibility of the applicant to submit a monitoring plan for review and approval.

Other Alternative Technologies

In keeping with the above policy statement on subsurface stormwater treatment, other alternative technology can be proposed for consideration with the following information submitted for reference:

- Description of technology including size, capital costs, design life, installation process and costs, and operating and maintenance requirements and costs.
- Data on effectiveness including lab testing and prior testing, pollutant removal rates, operational details on any existing installations, and monitoring information.
- Additional information including articles from peer-review, scientific or engineering journals, approvals or permits from other authorities, and references from other installations.

Industrial Source Controls

An important component of any stormwater management strategy involves BMPs to prevent pollution by controlling it at its source. Examples include covering of storage/handling facilities and spill containment and control for sites that handle potential industrial or commercial contaminants.

IMPLEMENTATION DETAILS

Roofs

Runoff from roof surfaces contains urban pollutants primarily from atmospheric fallout. This runoff water requires treatment prior to off-site conveyance. Although roof drains have often been tied directly to storm sewers, this practice is no longer acceptable. Several approaches to treating roof runoff are discussed below. For all of these treatment options, it is essential that the building foundation be protected from moisture. When properly designed, these features can remove pollutants and provide aesthetic appeal. Concepts for PLDs should be considered as part of building concepts. Roof drain types will influence the range of options for BMPs and their location on the site. The illustration (lower right) describes alternative approaches and related constraints.

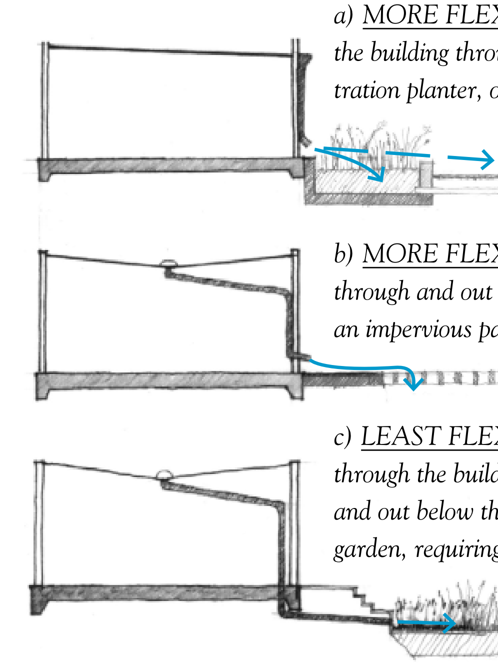
Primary approaches for treating roof runoff at ground level include:

1. Downspouts and scuppers at the building perimeter may be drained to a contained porous landscape detention facility or a porous pavement detention facility located adjacent to the structure. These closed systems drain away from building foundations.
2. Internal roof drain piping may be routed to an exterior wall and daylighted above grade to a contained porous landscape detention or porous pavement detention facility located adjacent to the structure.
3. Internal roof drain piping may be routed under the first floor and directed to a contained below-grade porous landscape detention or other BMP adjacent to the structure. Although not as desirable as daylighting above grade, this is a viable technique in constrained sites. In this case, BMPs must be located down-slope from the building or in a sunken planter.
4. Internal drains may also be conveyed below grade in a pipe to a porous landscape detention area, extended detention basin, or other treatment BMP at the low end of site.

GARDEN SUPPORTED BY ROOF RUNOFF
Runoff drains through a spout from the roof to a splash basin behind the curved walls and to a rain garden on the left. Drought tolerant native and non-native plants can withstand wet and dry cycles.

PLANTER GARDEN SUPPORTED BY ROOF RUNOFF
Runoff drains to an infiltration planter that is lined to prevent building damage. Overflows drain to adjacent grass swales, plants were selected to accommodate wet and dry cycles.

DOWNSPOUT
Rooftop runoff from urban housing splashes into rain gardens set in buried concrete pipe adjacent to the building, and then flows on a concrete pan out of the basin.



a) MORE FLEXIBLE Runoff drains outside the building through a downspout to an infiltration planter, or PLD.

b) MORE FLEXIBLE Runoff drains through and out the side of the building over an impervious pavement to porous pavement.

c) LEAST FLEXIBLE Runoff drains through the building, down through the slab, and out below the foundation to a stormwater garden, requiring significant grade differential between building finish floor and the BMP.

ROOF DRAINAGE
Architectural detailing of roof drainage will affect the options for design of BMPs.

INDUSTRIAL FACILITY "LIVING ROOF"
This 10-acre Ford Motor Company facility in Dearborn, Michigan, has a green roof planted with sedum groundcover.
Source: http://www.ford.com

ROOF GARDEN
Roof garden plantings reduce the amount of runoff from this urban building in Chicago with soils that absorb water and plantings that increase evapotranspiration.
Source: http://www.roofmeadow.com/

BURIED PARKING
This garage provides both park space and water quality treatment.

Green Roofs

A green roof – a building roof or parking structure covered with soil and vegetation – reduces the impervious area of a site and provides filtering and stormwater quality treatment of rain falling on the roof. This concept requires careful planning, design, construction, and maintenance. Many proprietary green roof systems are available on the market. These roofs have the potential to provide significant runoff reduction and stormwater quality enhancement for a site, particularly when the roof area is large. Access for maintenance must be considered. This technique works particularly well when the structure is underground and at least a portion of the roof is at-grade.

Elements of green and treatment roofs include:

- Roof structure that supports soils, vegetation and live loads associated with rainfall, snow, people, and equipment
- Waterproof membrane
- Root barrier
- Drainage layer

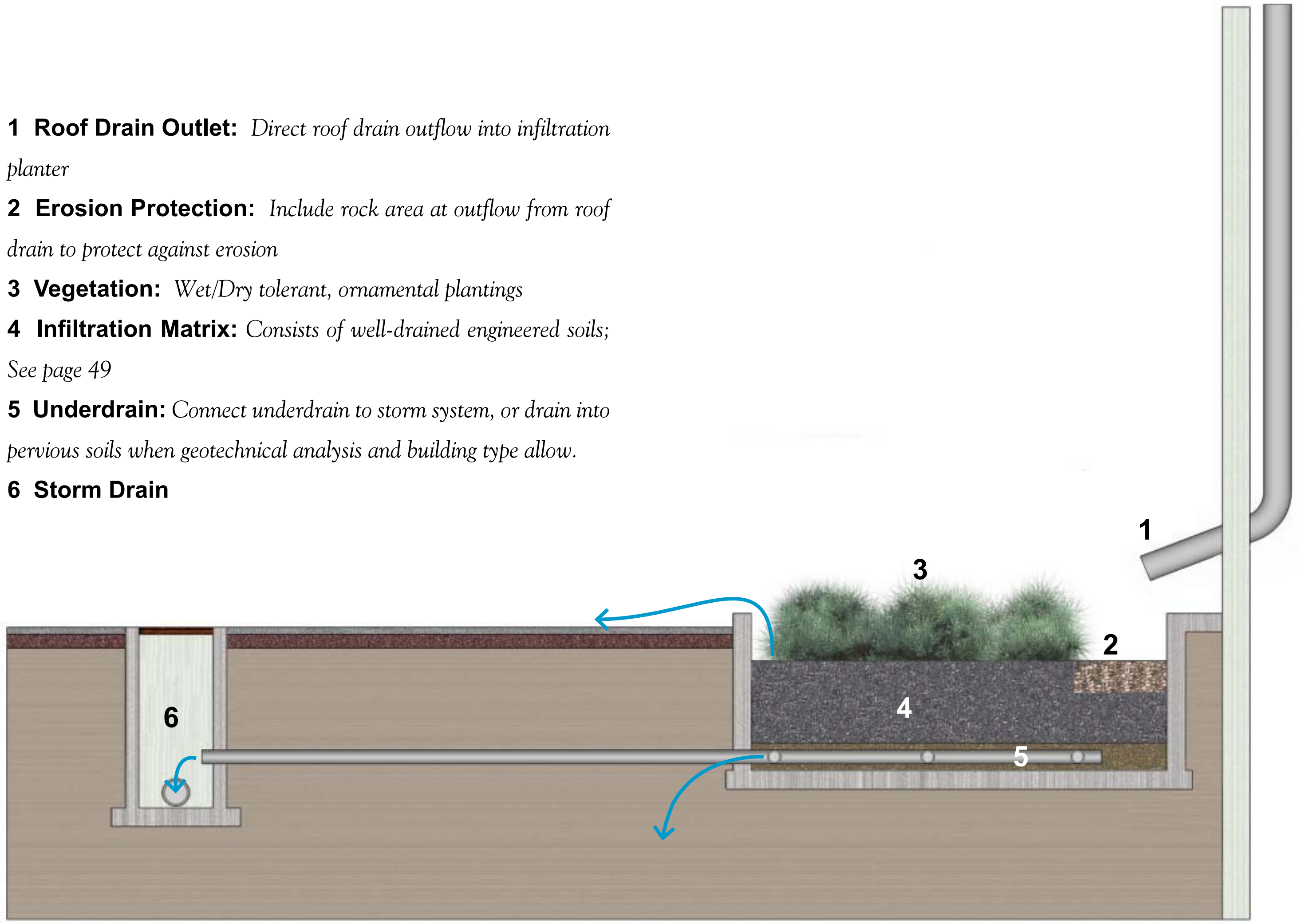
Soil, or growth medium, for treatment roofs includes a porous landscape detention or porous pavement detention type soil.

- Irrigation and plant materials. Native/naturalized, drought-tolerant grasses, perennials, and shrubs are preferred for roof plantings.

Maintenance for green roofs vary depending on the specific application. For living roofs, with little access (i.e. an industrial building) maintenance would be limited to monitoring and replacement of dead plantings, if required. If the roof is used as a park or garden, as in the case of buried parking, maintenance would be as required for a typical at-grade facility. Supplemental irrigation may be required depending on use, soil type and depth, plant types, and root system.

Infiltration Planters

Porous landscape detention can be implemented within planter boxes adjacent to buildings to treat roof runoff. Incorporating the standard porous landscape detention design into a planter box allows treatment to occur in constrained spaces while providing a landscape amenity. It is critical to consider soil types and ensure that building foundations are protected from subsurface water. The planter should be designed to dissipate energy from the downspout or water source, and a means to convey larger storm events to the storm system must be developed.



ROOF DRAIN INFILTRATION PLANTER SKETCH

Any basin adjacent to a building must be completely separated from the building to address geotechnical concerns. Create a stable system that accounts for foundation differential movement by following the recommendations of a structural engineer and including adequate foundation drainage.

ROOF DRAIN INFILTRATION PLANTER

This infiltration planter accepts roof run-off, seen in the foreground, as well as runoff from adjacent parking, in a series of three interconnected infiltration planters. Storm volumes exceeding the capacity of the planters spill into the parking area.

Parking Medians and Islands

Parking lots contribute significant pollutant loading to urban runoff. Typical drainage approaches include inlets and storm sewers that capture runoff and convey it to perimeter detention basins. Although this facilitates efficient drainage, runoff volumes are not reduced and the resulting detention basins are often forced into constrained "holes in the ground" that are difficult to maintain and add little value to a site. This method is also not an efficient use of land, as the ability of the parking lot to provide flood detention is not taken advantage of.

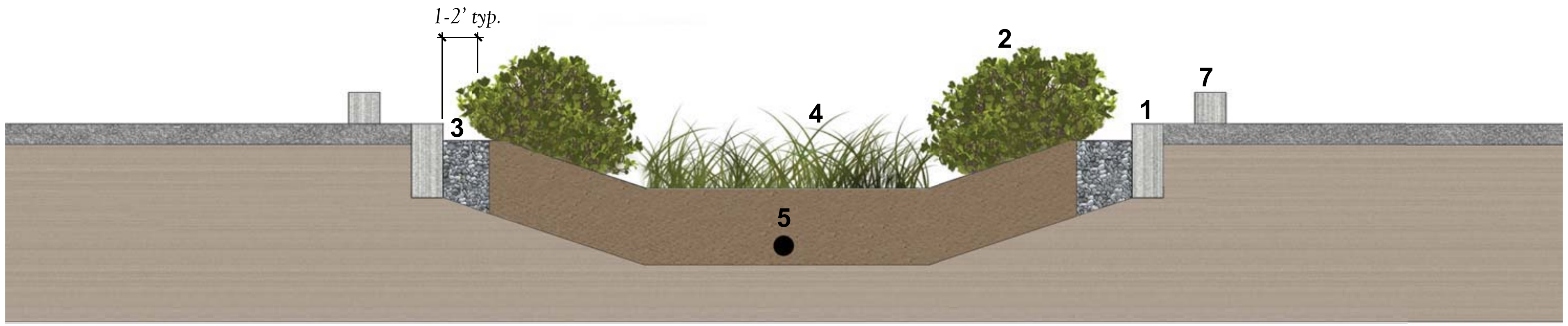
The following techniques for parking medians, parking islands, and shallow parking lot detention incorporate both stormwater quality treatment into parking areas to reduce or eliminate detention volumes required elsewhere.

Parking Medians

Landscape medians between rows of cars can break up large expanses of pavement and provide a location for trees, plantings, and turfgrass. Instead of raised medians with curbs, medians can be constructed as shallow depressions and protected with wheel stops or slotted curbs. A standard porous landscape detention design can be incorporated into the median. These medians are designed to have a flat longitudinal grade so that the WQv can have a level water surface (an average depth of 6 inches is recommended). Adjacent pavement should have a cross slope to drain runoff to the porous landscape detention. An overflow inlet is provided in the porous landscape detention to control larger flood events and any porous landscape detention underdrains also tie into this inlet.

Medians can be included in every parking bay or in select bays. If medians are oriented parallel with the flow of pedestrian traffic, access across the median does not present a significant design issue. When pedestrian access crosses the median, include intermittent walkways clearly designated by railings, tall shrubs, or mini-bridges. When trees are planted in the median, include a minimum 6-foot square planting area without underdrains that is not included in porous landscape detention volume calculations, and use a tree root barrier to keep roots out of porous landscape areas. Medians can also function as grass buffer and grass swales to convey runoff to treatment areas.

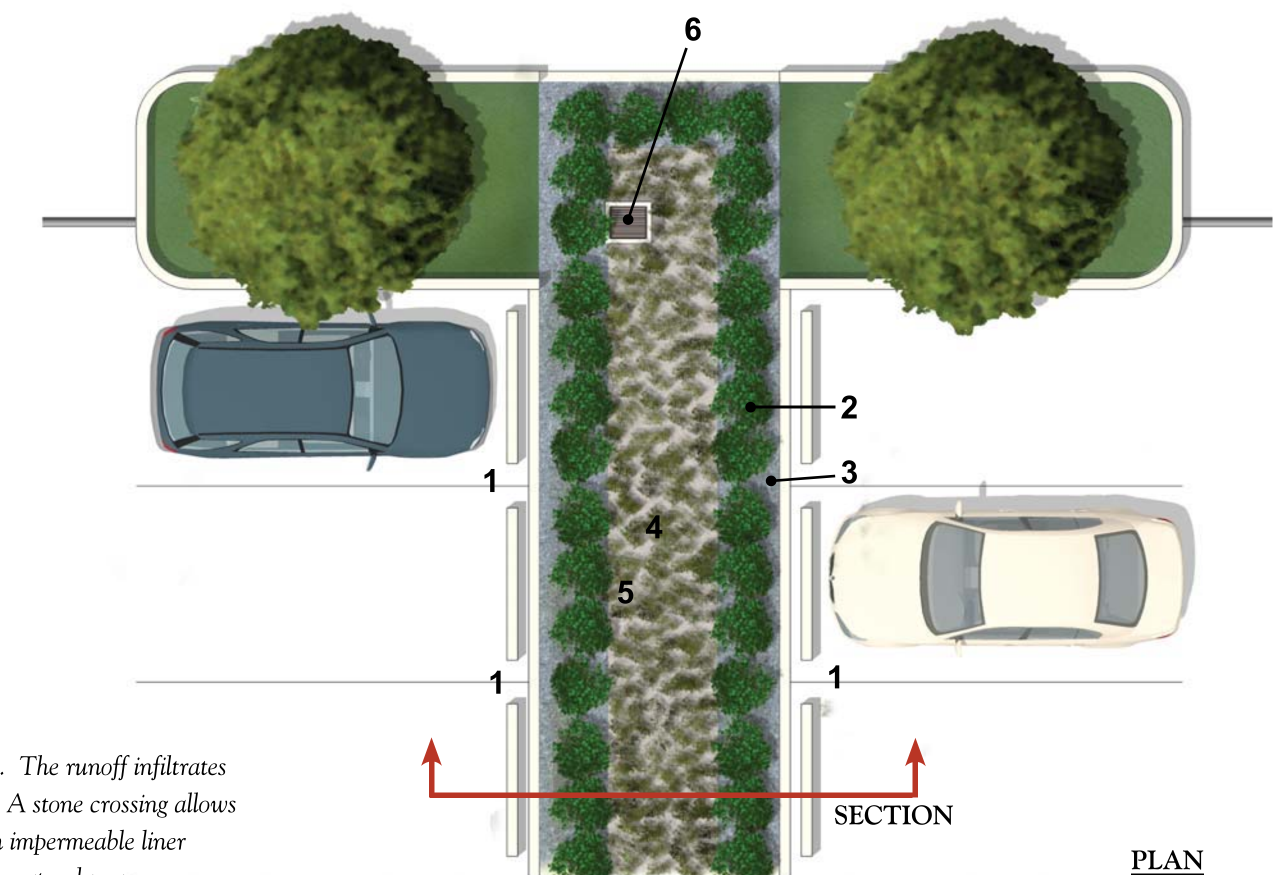
POROUS LANDSCAPE DETENTION IN PARKING MEDIAN/DISPERSED STORM FLOW



SECTION

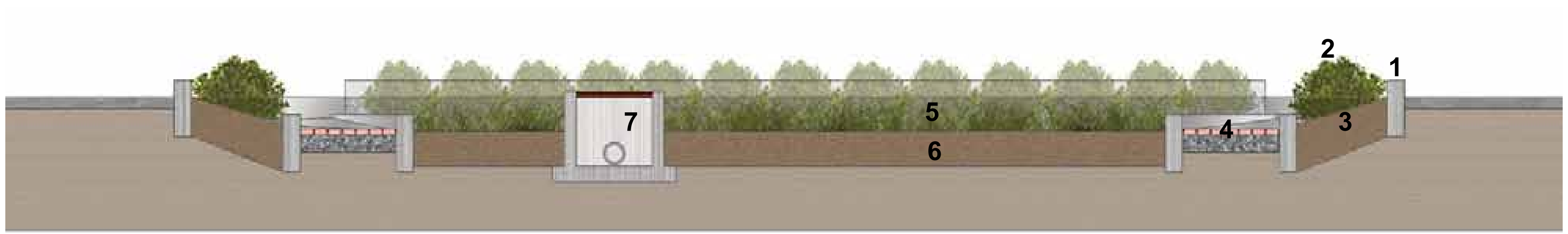
1 Inlet: *Curb flush to pavement; depress mulch three inches below curb in median to provide for sediment accumulation*
2 Planting: *Wet/Dry tolerant, ornamental plantings*
3 Sediment Trap: *Gravel mulch collects sediments before accumulating at the bottom of the median*
4 Planting: *Native grasses allow for periodic sediment removal and replacement*
5 Infiltration Matrix: *Consists of well-drained engineered or hydrologic soils Type A; Subdrain if required by geotechnical engineers*
6 Outlet/Overflow: *Provide overflow above WQv for large storm event; sheet flow overland to storm drain*
7 Curb Stop: *Median needs to be protected from vehicular traffic. Curb stops or slotted curbs allow drainage to flow into median with minimal concentration of flow*

A narrow median strip receives runoff from two bays of parking. The runoff infiltrates and supports the native grasses, shrubs, and trees planted there. A stone crossing allows pedestrians to cross the median without trampling plantings. An impermeable liner extending three feet below each curb protects the pavement from water damage.



PLAN

PARKING ISLAND SKETCH/CONCENTRATED STORM FLOW



SECTION

1 Inlet: *Curb is flush at the corners to allow stormwater flow into basin*

2 Planting: *Wet/Dry tolerant, ornamental plantings*

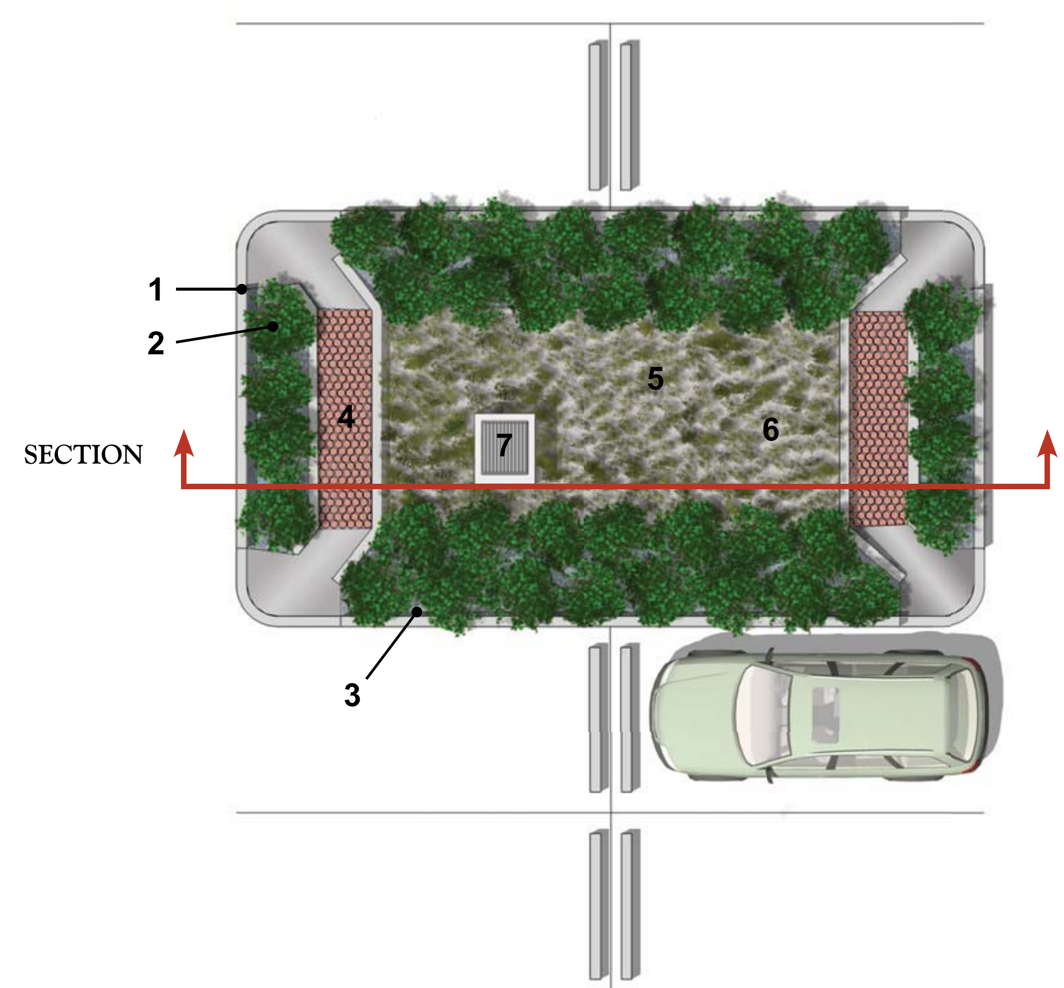
3 Slopes: *Slopes no greater than 3:1*

4 Sediment Trap: *Porous paving / gravel mulch sedimentation trap*

5 Planting: *Native mesic grasses, permeable mulch in smaller islands*

6 Infiltration Matrix: *Consists of well-drained hydrologic soils Type A and B*

7 Outlet/Overflow: *Provide overflow or surface flow path above WQv for larger storm events*



PLAN

Parking Medians and Islands

(Continued)

Parking Islands

Parking Islands, much like medians, can provide water quality treatment within a parking lot. They are best located at approximately 100-foot intervals, and need to be oversized to accomplish a meaningful water quality function.

In-Street Infiltration PLD

1 Inlet: *Curb cut diverts surface flows*

2 Sediment Trap: *Concrete run-down and basin with pervious bottom traps larger sediment*

3 Slopes: *Shallow (3:1) slopes with 6-12" deep WQv*

4 Vegetation: *As recommended for PLD; limit planting to side slopes and install pervious mulch in areas where significant sediment loads are anticipated*

5 Underdrain/Liner: *As recommended for PLD, pg. 31*

6 Outlet/Overflow: *Larger volumes are conveyed in the street to storm system*

7 Infiltration Matrix: *As recommended for PLD, pg. 31*

Existing city street, prior to installation of PLD Source: City of Portland, Department of Environmental Services

Following installation of PLD Source: City of Portland, Department of Environmental Services

Detail of PLD. Curb cuts divert smaller storm flows to infiltrate into PLD. Larger flows divert to the stormwater system when the PLD fills. Source: City of Portland, Department of Environmental Services

Function: Runoff reduction, WQv. An in-street PLD expands the potential options for runoff reduction and treatment of the WQv in densely developed development types.

Typical Applications: Use In-street PLD's in areas like the Town Center when adjacent landscape areas cannot be used as a PLD, or consolidated detention and treatment is not possible. May be used as a "traffic calming" strategy to slow traffic in residential areas.

Operation and Maintenance Considerations: Sediment build-up may require periodic removal of sediments and plants when clogging reduces infiltration capacity to unacceptable levels. Access to the facility must be provided to enable maintenance operations. Plant materials in PLDs prone to sediment build-up should be limited to those tolerant of periodic wet-dry cycles that can be easily replaced following periodic sediment removal.

Landscape Considerations: Use only low, groundcover type plantings to maintain site distances at intersections. A wide variety of plant types are possible, ranging from native grasses, groundcovers, flowers, and shrubs. Turf grass is discouraged because of the difficulty of maintenance. Trees should not be included in porous landscape detention areas (roots make maintenance difficult). Dense shrub plantings may become difficult to maintain, and should be limited to edges not prone to sediment build-up. Rock mulches (especially in high sediment areas) are discouraged because they limit the available pervious surface and make sediment removal difficult. The use of long fiber shredded wood mulch is encouraged because they provide a higher level of perviousness.

Relative Cost: Medium to high.

Drop and Check Structures

Drop structures and check structures are grade control structures that dissipate a stream's energy. Drop structures generally traverse the entire stream corridor, while check structures are designed to only dissipate energy in the low flow channel. These structures effectively "flatten" a stream's profile, thereby reducing flow velocities and erosion. In the real of urban channels, where drainage corridors are limited in width, and the increased runoff caused by development increases the potential for stream erosion, drop structures are a basic tool for channel design. Successful drop and check structures achieve the following:

- Integrate with and enhance surrounding environment
- Accommodate public use
- Are safe (no sharp protrusions, 30" maximum vertical drop in any one step)
- Allow migration of fish and macroinvertibrates

Each of the structures illustrated have buried cut-off walls and rip-rap or other armoring at the top and toe of the structure to maintain structural stability. Terraces, baffles, and plunge pools serve to dissipate energy of storm flows. In all of these examples except for the soil cement structure, buried rip-rap provides additional protection in large storm events.

POURED-IN-PLACE CHECK STRUCTURE

This is a modified form of a baffle chute structure designed to minimize vertical hazards. Although the structure is appropriate for its setting, the concrete low flow channel and vertical drops of the low flow channel provide no habitat value. The photo on the bottom shows the structure during a minor storm event.

SLOPED GROUTED RIP-RAP DROP STRUCTURE

This structure extends from the vertical wall on the right to a wall out of the photo on the left. Plantings are in grouted rip-rap basins. Rip-rap lining of the plunge pool at the base of the structure is buried to diminish the visual mass of the structure. The stepped low flow is a preferred design, allowing movement of fish and macro invertebrates. Terraced side slopes allow safe pedestrian access to the waters edge.

SCULPTED SHOTCRETE CHECK STRUCTURE

The small, stepped drops and pools allow movement of fish and macro invertebrates, and allow safe pedestrian water access.

SOIL CEMENT DROP STRUCTURE

The structure blends into its natural prairie setting. Small terraces created by the layered installation of soil cement makes it safe. Aquatic habitat value is limited because low flows are piped through the structure.

Stormwater Distribution

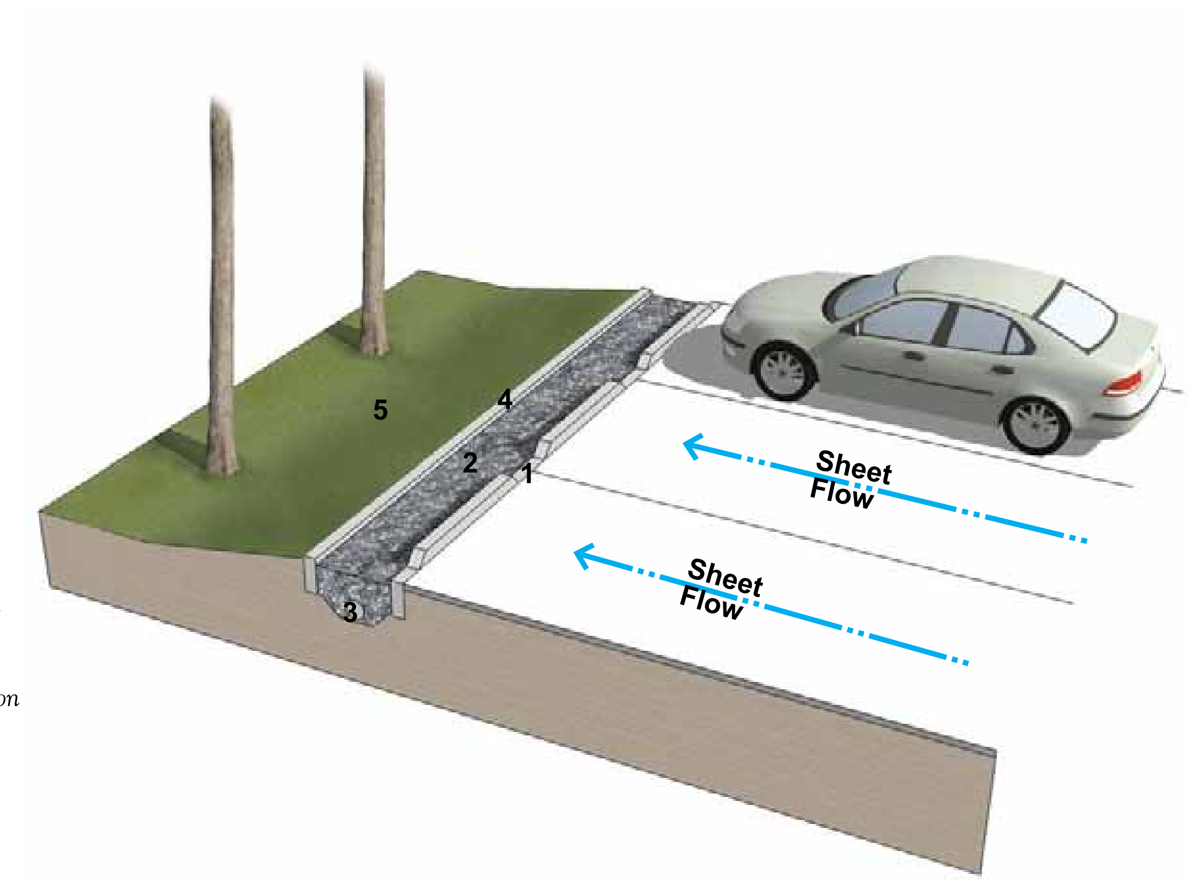
Many of the BMPs included in these Guidelines require concentrated flows to be dispersed to function efficiently. Ideally, flows will sheet-drain to the BMP. A flush curb allows sheet flows to drain to the BMP landscape. However, both the pavement edge and the BMP landscape require protection from cars, which can be achieved by wheel-stops, shrubs, or railings. When sheet-draining runoff is not possible, slotted curbs can minimize the amount of concentration and level spreaders can evenly distribute concentrated flows.

CURB LEVEL SPREADER SKETCH

Suggested use:
Sheet flows

- *Sedimentation collection*
- *De-concentration of flows*

1 Inlet: *Slotted curb or curbless design protects sediment trap*
2 Sediment Trap: *Gravel mulch collects sediment buildup and contains irrigation runoff*
3 Underdrain: *Underdrain pipe surrounded in gravel conveys excess amounts of water to storm sewer in impervious soils*
4 Outlet: *Level spreader / secondary curb must be nearly flat to evenly disburse storm flows*
5 Plantings: *Turf areas with highly permeable soils promote infiltration*

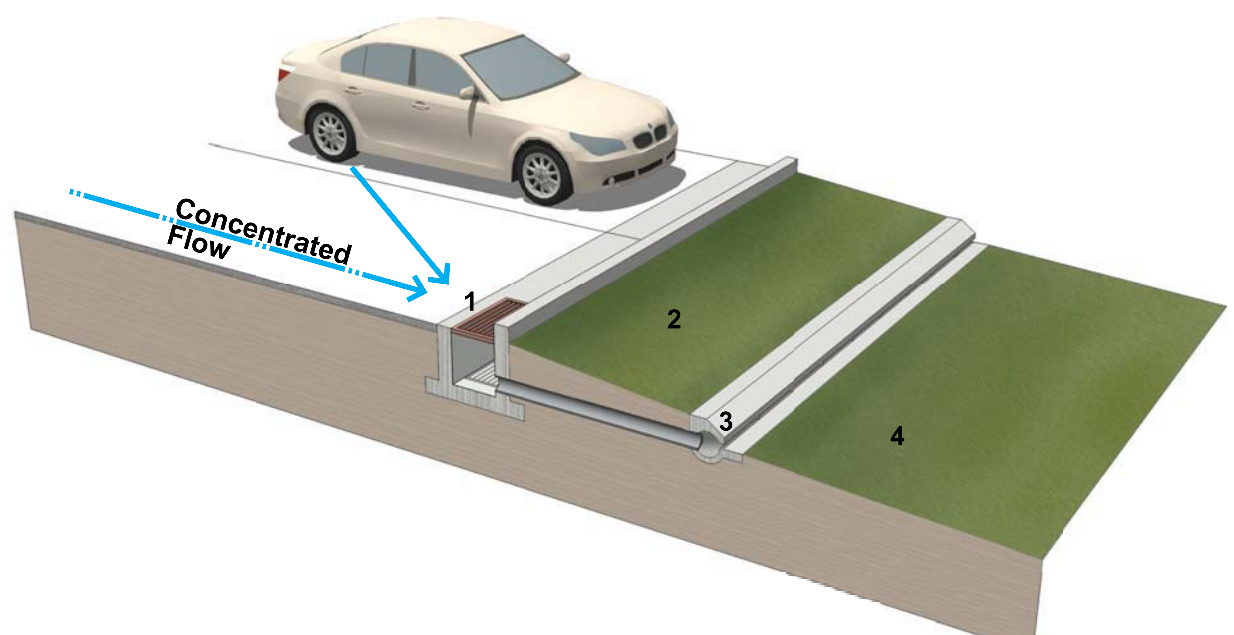


PIPE LEVEL SPREADER
A horizontal slotted pipe "level spreader" below the curb evenly distributes storm flows to avoid standing water and disperse concentrated flows.

PIPE LEVEL SPREADER SKETCH

Suggested use:
Dispersal of concentrated flows

1 Inlet: *Standard drop inlet*
2 Slopes: *Side slope not to exceed 3:1 slopes*
3 Outlet: *Corrugated slotted metal pipe level spreader must be level to evenly disperse storm flows*
4 Planting: *Turf areas with slopes 2% or greater*



SLOTTED CURB SPREADER
The slotted curb in this parking lot area has depressions between each parking space to allow runoff to flow to the interior landscape area without concentrating.

Sediment Removal

Planning for sediment capture and periodic sediment removal is essential to ensure the long-term sustainability of stormwater BMPs. Particular attention to sediment control is necessary where waterborne sediments in stormwater reach slower velocities and tend to settle out, and in areas adjacent to parking lots and roadways where winter use of sand creates heavy sediment loads. Sediment removal areas are an early step in the treatment train for stormwater, removing large sediments and trash from the runoff. A wide range of sizes and configurations for these areas is possible, from small rock mulch beds to large sediment basins accessible by heavy equipment. Sediment traps at pipe outlets need to be designed to dissipate the energy of storm flows sufficiently to allow sediment to drop out and not become re-suspended. All types of sediment traps need to include access for maintenance equipment.

SMALL STORMWATER PIPE SEDIMENT TRAP

This sediment basin also functions as a level spreader which disperses flows to the PLD on the right. The ramps, which have a small pipe outfalling between them, extend the length of the trap as concrete tracks allowing access by a Bobcat for sediment removal. Infiltration occurs in pervious soils between the tracks.

Soils

Soil characteristics are important to BMP performance because of their ability to 1) trap pollutants and 2) support vegetation that traps pollutants. Runoff that flows across and through the upper part of the soil profile comes in contact with the physical, chemical, and biological components of the soil. The organic material in the soil binds and removes phosphorous, metals, and salts.

BMPs included in these Guidelines employ vegetation as an integral component in treating stormwater runoff. The medium in which the vegetation grows is critical to the growth and long-term health of that vegetation.

Grass buffers, grass swales, and porous landscape detention BMPs use native soils when possible. The characteristics of these soils, including texture, impermeable soil layers, salinity, and the quantity of organic matter, are all key considerations in making plant selections. Soils tests should be completed to determine soil characteristics and the type of soil amendments needed to support the desired plant types. For example, three to five cubic yards of organic matter per 1000 square feet incorporated into the top layers of soil is typically required for turfgrass planted in swales. Porous landscape detention requires hydrologic soils Type A or B, sandy loam, sand, loam, or an engineered soil. The soil must allow stormwater to infiltrate while still holding enough fine material and organics with nutrients and moisture to support vegetation and provide some adsorption capacity. If engineered soils are required, the following two mixes at the right are excellent options as optimal infiltration and growing media.

SAND-PEAT MIX		
75% sand as defined below, and 25% sphagnum peat		
Textural class/USDA Designation	**Size in mm**	**Percent of total weight**
Gravel	>2 mm	Less than 5%
Sand	0.05-2 mm	95-100%
Silt	0.002-0.05 mm	Less than 5%
Clay	<0.002 mm	Less than 5%

SANDY LOAM MIX		
100% sandy loam as defined below		
Textural class/USDA Designation	**Size in mm**	**Percent of total weight**
Gravel	>2 mm	Less than 5%
Sand	0.05-2 mm	70-80%
Silt	0.002-0.05 mm	15-20%
Clay	<0.002 mm	Less than 5%

SEDIMENT POND

This on-line pond collects large volumes of sediment from a small urbanized watershed. Creek flows can be redirected and the pond can be drained to allow access by large equipment.

Planting

BASIN PLANTINGS
Plant trees and shrubs on the side slopes of basins rather than in the wet bottom area.

DETENTION BASIN
WET MEADOW OR MESIC PRAIRIE
Wetland grasses planted in the bottom of this detention basin remove nutrients and pollutants from stormwater runoff, require minimal maintenance, and can be easily replaced if sediments must be removed.

RUSHES IN A
STORMWATER GARDEN
Rushes can withstand up to six months of drought and two months of inundation after establishment.

APPROPRIATE PLANTING OF PLD
This mix of drought and inundation tolerant plantings requires minimal maintenance. Trees are at the edge of the PLD.
Source: City of Portland, Department of Environmental Services

When selecting plants for use in stormwater quality BMPs, select plants that can survive under the site conditions, perform the desired water quality function, are appropriate to the site context, and can be supported with a realistic maintenance schedule. Key aspects of each of these factors are described below.

1. *Plants that survive.*

While typical plant choice considerations including site soils, slope, aspect, and exposure apply equally to BMPs, the most significant environmental consideration is water. Plants in BMPs are subject to inundation, prolonged localized saturation, and drought, so they must be selected to thrive in these widely varying conditions. In more refined settings plants may require irrigation for establishment, and during periods of drought.

Consider the typical amount of saturation in a BMP, site-specific conditions and typical periods of inundation when selecting appropriate plantings.

BMP SITE-SPECIFIC CONDITIONS		
Wet	**Variable**	**Dry**
Detention pond basin bottoms	Porous landscape detention bottoms	Grass Buffers
Swale bottoms	Pond and basin margins	Upper slopes of ponds
Wherever irrigation flows concentrate		Side slopes of swales and porous landscape detention

TYPICAL BMP INUNDATION PERIODS	
BMP	**Inundation Period**
Porous landscape detention	6 hours
Extended detention basins	40 hours
Retention ponds	Permanent: 12 hours in zone above pool
Constructed wetland basins	Permanent: 24 hours in zone above pool

Soil considerations include texture, compaction, nutrients, permeability of subgrade, salinity, and the quantity of organic matter. For porous landscape detention, employ hydrologic soils Type A or B, or engineered soils to achieve required permeability.

Planting *(Continued)*

STORMWATER GARDEN
The colorful plantings in this stormwater garden provide an attractive feature at the building entrance.

2. Plants that perform the desired stormwater quality function.

Plants are an integral aspect of most of the BMPs, performing a wide range of functions that improve the quality of stormwater runoff. Runoff typically enters a BMP with some velocity. One function of the plants is to slow down quick flowing water to minimize erosion both within the BMP and downstream of it. The above ground portions of a plant can reduce the velocity of runoff. Grasses, shrubs, or groundcovers with stiff stems can filter sheet flows. Root systems serve to stabilize the soil with fibrous roots systems providing greater soil stability. These issues are more critical on the sloping portions of BMPs than in flat or gently sloping bottoms.

Most common pollutants in urban runoff are actually excess nutrients. Many plants can thrive in BMPs while removing the very nutrients that can cause problems downstream. Plants also remove other pollutants from runoff, particularly wetland species that are included in basin micropools and wetlands. Slower and more evenly spread-out flows will greatly improve the treatment effects of vegetation.

GRASS OVER SAND FILTER
The grass over this sand filter can serve as an informal play area during most of the year.

TREES IN GRASS BUFFER
Trees in this grass buffer serve to both screen and shade the adjacent parking.

3. Plants that are appropriate to the context.

Many BMPs can perform multiple functions. In addition to providing stormwater quality functions, plants in BMPs can also provide shade and screening for parking lots, color and texture at building entrances, or grassy fields in park areas. These additional characteristics of plants selected for BMPs can help create a successfully pleasing landscape.

4. Plants that can be supported with a realistic maintenance schedule.

All plants require some degree of ongoing maintenance. Ensure that the plantings can be cared for within a project budget and schedule, as well as in perpetuity.

Weed control in BMPs must be considered both with regard to the overall structure of the BMP, as well as access for maintenance (e.g., removal of weeds, trash, and sediment). These areas are intended to treat stormwater quality, therefore selecting plants that require herbicides is not recommended.

Mulch can provide an effective barrier against weeds. Rock mulch has greater stability than organic mulches, which float and can wash out of the system. Sedimentation on top of mulch, and subsequent plant growth in the sediments, should be considered.

In choosing mulch, consider that it may be necessary to mow these areas after several years of operation.

Planting strategy can have a tremendous impact on the requirements for maintenance (e.g., weed control). Masses of dense shrubs or groundcover can often out-compete weeds without appearing overgrown, while more intricate planting patterns with many different plant species require larger spaces between plants that often become subject to invasion of weeds. It is also critical to consider ultimate plant size and growth rate, and important to select plants that can be trimmed or mowed easily.

GLOSSARY

Basin: A hydrologic unit consisting of a part of the surface of the earth covered by a drainage system consisting of a surface stream or body of impounded surface water plus all tributaries.

Best Available Technology Economically Achievable (BAT): Technology-based standard established by the Clean Water Act (CWA) as the most appropriate means available on a national basis for controlling the direct discharge of toxic and non-conventional pollutants to navigable waters. BAT effluent limitation guidelines, in general, represent the best existing performance of treatment technologies that are economically achievable within an industrial point source category or subcategory.

Best Available Technology/Best Control Technology (BAT/BCT): A level of technology based on the very best (state-of-the-art) control and treatment measures that have been developed or are capable of being developed and that are economically achievable within the appropriate industrial category.

Best Conventional Pollutant Control Technology (BCT): Technology-based standard for discharges from existing industrial point sources of conventional pollutants including BOD, TSS, fecal coliform, pH, oil, and grease. The BCT is established in light of a two-part "cost reasonableness" test which compares the cost for an industry to reduce its pollutant discharge with the cost to a POTW for similar levels of reduction of a pollutant loading. The second test examines the cost-effectiveness of additional industrial treatment beyond BPT. EPA must find limits which are reasonable under both tests before establishing them as BCT.

Best Management Practices (BMPs): Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the United States. BMPs also include but are not limited to treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or wastewater disposal, or drainage from raw material storage.

Biofilter: Dense vegetation designed to filter stormwater runoff as it passes through. (Also see definition of Grass Buffer and Grass Swale.)

Bioretention: Also known as Rain Garden, Biofilter and a LID BMP. On-lot retention of stormwater through the use of vegetated depressions engineered to collect, store, and infiltrate runoff.

Buffer Strip: Strips of grass or other erosion resistant vegetation located between a waterway and an area of more intensive land use. (Also see definition of Grass Buffer.)

Buffer Zone: A designated transitional area around a stream, lake, or wetland left in a natural, usually vegetated state so as to protect the waterbody from runoff pollution. Development is often restricted or prohibited in a buffer zone.

Catch Basin: An entryway to the storm drain system, usually located at a street corner.

Channel Stabilization: Erosion prevention and stabilization of velocity distribution in channel using jetties, drops, revetments, structural linings, vegetation, and other measures.

Clean Water Act: Legislation that provides statutory authority for the NPDES program; Public law 92-500; 33 U.S.C. 1251 et seq. Also known as the Federal Water Pollution Control Act.

Cluster Development: Buildings concentrated in specific areas to minimize infrastructure and development costs while achieving the allowable density. This approach allows the preservation of natural open space for recreation, common open space, and preservation of environmentally sensitive features.

Combined Detention Basin: A detention basin that performs both water quality and flood control functions.

Constructed Wetland Basin: A constructed wetland basin is appropriate for large catchments and is a shallow retention pond which requires a perennial supply of water to permit the growth of rushes, willows, cattails, and reeds. It treats runoff by slowing it down to allow time for settling and biological uptake.

Cubic Feet Per Second (cfs): A rate of flow that is equal to a volume of water one foot high and one foot wide flowing a distance of one foot in one second. One "cfs" is equal to 7.48 gallons of water flowing each second. As an example, if a car's gas tank is 2 feet by 1 foot by 1 foot (2 cubic feet), then gas flowing at a rate of 1 cubic foot/second would fill the tank in two seconds.

Culvert: A short, closed (covered) conduit or pipe that passes stormwater runoff under an embankment, usually a roadway.

Design Storm: A rainfall event of specific size, intensity, and return frequency (e.g., the 1-year storm) that is used to calculate runoff volume and peak discharge rate.

Detention: The storage and slow release of stormwater from an excavated pond, enclosed depression, or tank. Detention is used for pollutant removal, stormwater storage, and peak flow reduction. Both wet and dry detention methods can be applied.

Effective Imperviousness: The total imperviousness of a site is the weighted average of individual areas of like imperviousness. For instance, paved streets (and parking lots) have an imperviousness of 100 percent; drives and walks have an imperviousness of 96 percent; roofs have an imperviousness of 90 percent; and lawn areas have an imperviousness of 0 percent. The total imperviousness of a site can be determined taking an area-weighted average of the imperviousness of the street, walk, roof, and lawn areas.

End-of-Pipe System: Any device and/or treatment system applied to stormwater, combined wastewater, municipal wastewater and/or industrial wastewater at the outlet of a collection system prior to a receiving water body. The majority of wastewater treatment systems including sanitary and combined wastewater treatment plants and many stormwater treatment schemes such as detention basins are end-of-pipe systems.

Erosion: When land is diminished or worn away due to wind, water, or glacial ice. Often the eroded debris (silt or sediment) becomes a pollutant via stormwater runoff. Erosion occurs naturally, but can be intensified by land clearing activities that remove established vegetation such as farming, development, road building, and timber harvesting.

Event Mean Concentration (EMC): A method for characterizing pollutant concentrations in a receiving water from a runoff event often chosen for its practicality. The value is determined by compositing (in proportion to flow rate) a set of samples, taken at various points in time during a runoff event, into a single sample for analysis.

Extended Detention Basin: An extended detention basin is appropriate for larger sites and is designed to totally empty out sometime after stormwater runoff ends. The extended basin uses a much smaller outlet than a flood control detention basin which extends the emptying time for the more frequently occurring runoff events to facilitate pollutant removal.

Filter Strip: Grassed strips situated along roads or parking areas that remove pollutants from runoff as it passes through, allowing some infiltration and reduction of velocity.

First Flush: The condition, often occurring in storm-sewer discharges, in which a disproportionately high pollutant load is carried in the first portion of the discharge or overflow.

Flow Control Structure: A structure, such as an outlet of a detention basin, that is designed to produce a specific rate of runoff in the outflow of a stormwater management facility, generally with the intent of reducing peak runoff rates from developed areas, and, for treatment BMPs, to provide an extended drain time for settling of particulates.

Forebay: Storage space located near a stormwater BMP inlet that serves to trap incoming coarse sediments before they accumulate in the main treatment area.

Geographic Information System (GIS): A database of digital information and data on land-use, land cover, ecological characteristics, and other geographic attributes that can be overlaid, statistically analyzed, mathematically manipulated, and graphically displayed using maps, charts, and graphs.

Grading: Stripping, excavating, filling and/or stockpiling soil to shape land area for development or other purposes.

Grass Buffer: Uniformly graded and densely vegetated area of turf grass. This BMP requires sheet flow to promote filtration, infiltration, and settling to reduce runoff pollutants.

Grass Swale: Densely vegetated drainageway with low-pitched side slopes that collects and slowly conveys runoff. Design of longitudinal slope and cross-section size forces the flow to be slow and shallow, thereby facilitating sedimentation while limiting erosion.

Green Roof: A vegetated roof that can be used to treat precipitation and/or provide detention. Green roofs require an engineered structure that can support soils, vegetation and loads associated with rainfall, snow, people and equipment. Key components include a waterproof membrane, root barrier, drainage layer, soil/growing medium, irrigation system and plants.

Greenway: A linear open space or corridor composed of native vegetation. Greenways can be used to create connected networks of open space that include traditional parks and natural areas.

Hot Spot: Area where land use or activities generate highly contaminated runoff with concentrations of pollutants in excess of those typically found in stormwater.

Hydrodynamic Structure: An engineered structure using gravitational separation and/or hydraulic flow to separate sediments and oils from stormwater runoff.

Hydrology: The science addressing the properties, distribution, and circulation of water across the landscape, through the ground, and in the atmosphere.

Illicit Connection: Any discharge to a municipal separate storm sewer that is not composed entirely of stormwater and is not authorized by an NPDES permit, with some exceptions (e.g., discharges due to fire-fighting activities).

Integrated Management Practice (IMP): A Low Impact Development (LID) practice or combination of practices that are the most effective and practicable (including technological, economic, and institutional considerations) means of controlling the predevelopment site hydrology.

Impervious Area: A hard surface area (e.g., parking lot or rooftop) that prevents or retards the entry of water into the soil, thus causing water to run off the surface in greater quantities and at an increased rate of flow.

Infill Development: Development of vacant lots or enhancement of existing urban properties.

Infiltration: The process or rate at which water percolates from the land surface into the ground. Infiltration is also a general category of BMP designed to collect runoff and allow it to flow through the ground for treatment.

Inlet: An entrance into a ditch, storm sewer, or other waterway.

In-Line Storage: The use of a portion of the volume of a storm sewer or drain, combined sewer and/or interceptor sewer system that is not being used to transport combined wastewater or stormwater to accommodate the storage of additional stormwater runoff or combined wastewater. This term also applies to a storage facility, such as a tank, basin, or other reservoir, which is connected to a sewer system in such a way that all flow in the system passes through the storage facility. In the latter usage, inline storage is differentiated from offline storage which is connected in such a way that excess flow can be diverted to the storage facility, but normal flows bypass the facility. (Also see Off-Line Storage.)

Integrated Pest Management (IPM): The practice of using biological, chemical, cultural, and physical measures to manage pests while minimizing or eliminating the use of chemical pesticides.

Level Spreader: An outlet designed to convert concentrated runoff to sheet flow and disperse it uniformly across a slope, thereby preventing/minimizing erosion.

Low Impact Development: The integration of a site's ecological and environmental goals and requirements into all phases of urban planning and design from the individual residential lot level to the entire watershed. Also see Smart Growth, Minimizing Directly Connected Impervious Area, Sustainable Urban Drainage Systems.

Macroinvertebrate: An organism is visible without magnification and that lacks a backbone. Examples include snails, worms, fly larvae, and crayfish.

Media Filter: A filter containing sand, compost, sand peat, or perlite and zeolite designed to filter constituents (particulates, oil, bacteria, or dissolved metals) out of stormwater runoff as it passes through the filter. (Also see Sand Filter Extended Detention Basin.)

Micropool: A smaller permanent pool incorporated into the design of larger stormwater ponds to avoid resuspension of particles and minimize impacts to adjacent natural features.

Milligrams Per Liter (mg/L): A unit of concentration of a constituent in water or wastewater. It represents 0.001 gram of a constituent in 1 liter of water and is approximately equal to one part per million (PPM).

Minimizing Directly Connected Impervious Areas (MDCIA): A variety of runoff reduction strategies based on reducing impervious areas and routing runoff from impervious surfaces over grassy areas to slow down runoff and promote infiltration. The benefits are less runoff, less stormwater pollution, and less cost for drainage infrastructure. Also see Smart Growth and Low Impact Development.

Modular Block Porous Pavement: Modular block porous pavement consists of open void concrete slab units underlain with gravel. The surface voids are filled with sand. This BMP is intended to be used in low traffic areas to accommodate vehicles while facilitating stormwater infiltration near its source. A variation of this BMP is termed stabilized-grass porous pavement, consisting of plastic rings affixed to filter fabric underlain with gravel. The surface voids are filled with sand and grass sod or seed.

Municipal Stormwater Permit: An NPDES permit issued to municipalities to regulate discharges from municipal separate storm sewers for compliance with EPA regulations.

National Pollutant Discharge Elimination System (NPDES): The national program under Section 402 of the Clean Water Act for regulation of discharges of pollutants from point sources to waters of the United States. Discharges are illegal unless authorized by an NPDES permit.

NPDES: National Pollutant Discharge Elimination System, as described above.

Non-Point Source (NPS) Pollution: Pollution discharged over a wide land area, not from one specific location. These are forms of diffuse pollution caused by sediment, nutrients, organic and toxic substances originating from land-use activities and carried to lakes and streams by surface runoff. Non-point source pollution is contamination that occurs when rainwater, snowmelt, or irrigation washes off plowed fields, city streets, or suburban backyards. As this runoff moves across the land surface, it picks up soil particles and pollutants, such as nutrients and pesticides.

Non-Structural BMPs: Stormwater runoff treatment techniques which use natural measures to reduce pollution levels, and do not require extensive construction efforts and/or promote pollutant reduction by eliminating the pollutant source.

Off-Line: A management system designed to control a storm event by diverting a percentage of stormwater events from a stream or storm drainage system.

Oil/Water Separator: A device installed (usually at the entrance to a drain) which removes oil and grease from water entering the drain.

On-Line: A management system designed to control stormwater in its original stream or drainage channel.

Open Space: Land set aside for public or private use within a development that is not built upon.

Open-Channel Flow: Fluid flow where the bottom and sides of the flow are confined by solid surfaces and the upper surface is in contact with the atmosphere and is at atmospheric pressure. Open-channel flow occurs in rivers, streams, canals, channels, swales, and ditches, and in pipes, sewers, and culverts that are less than completely full.

Outfall: The point where wastewater or drainage discharges from a sewer pipe, ditch, or other conveyance to a receiving body of water.

Peak Flow: The maximum instantaneous discharge of a stream or river at a given location. It usually occurs at or near the time of maximum stage.

Peak Runoff Rate: The highest actual or predicted flow rate (measured in cubic feet per second) for runoff from a site.

Permeability: The ability of a material to allow the passage of a liquid, such as water through rocks or soil. Permeable materials, such as gravel and sand, allow water to move quickly through them, whereas impermeable material, such as clay, does not allow water to flow freely.

Point Source Pollutant: Pollutants from a single, identifiable source such as a factory, refinery, or place of business.

Pollutant: Dredged spoil, dirt, slurry, solid waste, incinerator residue, sewage, sewage sludge, garbage, trash, chemical waste, biological nutrient, biological material, radioactive material, heat, wrecked or discarded equipment, rock, sand, or any industrial, municipal or agriculture waste.

Pollutant Load: The quantity of pollutants carried in stormwater.

Porous Landscape Detention: Porous landscape detention consists of a low lying vegetated area underlain by a sand bed with an underdrain. A shallow surcharge zone exists above the porous landscape detention for temporary storage of the WQv. This BMP allows small amounts of WQv to be provided on parking lots or adjacent to buildings without requiring the set-aside of significant developable land areas. Also see Rain Garden.

Porous Pavement and Pavers: Alternatives to conventional asphalt that utilize a variety of porous media, often supported by a structural matrix, concrete grid, or modular pavement, which allow water to percolate though to a sub-base for gradual infiltration. See definition for Modular Block Porous Pavement.

Porous Pavement Detention: Porous pavement detention consists of modular block porous pavement that is installed flat and is provided with a two-inch-deep detention zone above its surface to temporarily store the WQv from the tributary drainage area including its own surface. Runoff infiltrates the void spaces of the gravel base course through the sand filter and slowly exits through an underdrain.

Rain Garden: See bioretention and porous landscape detention.

Receiving Waters: Natural or man-made water systems into which materials are discharged.

Restoration: Human activity that results in the return of an ecosystem to a close approximation of its condition prior to disturbance.

Retention Pond: A BMP consisting of a permanent pool of water designed to treat runoff by detaining water long enough for settling, filtering, and biological uptake. Wet ponds may also be designed to have an aesthetic and/or recreational value. These BMPs have a permanent pool of water that is replaced with stormwater, in part or in total, during storm runoff events. In addition, a temporary extended detention volume is provided above this permanent pool to capture storm runoff and enhance sedimentation. It requires a perennial supply of water to maintain the pool. A retention pond is appropriate for larger catchments.

Retrofit: The creation or modification of a stormwater management practice, usually in a developed area, that improves or combines treatment with existing stormwater infrastructure.

Riparian Area: Vegetated ecosystems along a waterbody through which energy, materials, and water pass. Riparian areas characteristically have a high water table and are subject to periodic flooding.

Riparian Zone: The border or banks of a stream. Although this term is sometimes used interchangeably with flood plain, the riparian zone is generally regarded as relatively narrow compared to a flood plain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river flood plain.

Runoff Reduction Practices: Strategies to reduce runoff peaks and volumes from urbanizing areas, employing a practice generally termed “minimizing directly connected impervious areas” (MDCIA).

Runoff: Water from rain, melted snow, or irrigation that flows over the land surface.

Sand Filter Extended Detention Basin: A sand filter extended detention basin consists of a sand bed and underdrain system. Above the vegetated sand bed is an extended detention basin sized to capture the WQv. A sand filter extended detention basin provides pollutant removal through settling and filtering and is generally suited to off-line, on-site configurations where there is no base flow and the sediment load is relatively low.

Sanitary Sewer: A system of underground pipes that carries sanitary waste or process wastewater to a treatment plant.

Scupper: An opening in a wall through which water can drain (i.e., from the roof of a building or a landscape area)

Sediment: Soil, sand, and materials washed from land into water, usually after rain. Sediment can destroy fish-nesting areas, clog animal habitats, and cloud water so that sunlight does not reach aquatic plants.

Sheet Flow: The portion of precipitation that moves initially as overland flow in very shallow depths before eventually reaching a stream channel.
Slope: Angle of land measured in horizontal distance necessary for the land to fall or rise one foot, expressed by horizontal distance in feet to one vertical foot.
Slotted Curbs: Curbs with slots or cut-out areas that allow stormwater to flow away from the curbed pavement into an adjacent landscape or turf area. These can reduce excessive concentration of flows and associated erosion problems.

Smart Growth: Development that uses a variety of strategies to enhance existing communities and protect community character in a way that is compatible with the natural environment, as well as attracts economic development. It encourages more town-oriented, transit-focused, and pedestrian-friendly new development while restoring vitality to existing developed areas. Also see Low Impact Development.

Source Control: A method of abating storm-generated or CSO pollution at the upstream, upland source where the pollutants originate and/or accumulate.

Spill Prevention Control and Countermeasure Plan (SPCC): A plan prepared by a facility to minimize the likelihood of a spill and to expedite control and cleanup activities should a spill occur.

Storage Capacity: The volume of fluid that can be stored in a system. For storm drainage and sewerage systems, storage capacity refers to the volume available for the temporary storage of excess storm flow or wastewater flow in a pipe, channel, basin, tank, or other facility, or in the system as a whole.

Storm Drain: A slotted opening leading to an underground pipe or an open ditch from carrying surface runoff.

Storm Sewer: A sewer that carries intercepted surface runoff, street wash, and other wash waters, or drainage, but excludes domestic sewage and industrial wastes except for unauthorized cross-connections.

Stormwater Facilities: Systems such as watercourses, constructed channels, storm drains, culverts, and detention/retention facilities that are used for the conveyance and/or storage of stormwater runoff.

Stormwater Management: Functions associated with planning, designing, constructing, maintaining, financing, and regulating the facilities (both constructed and natural) that collect, store, control, and/or convey stormwater.

Stormwater Ponds: A land depression or impoundment created for the detention or retention of stormwater runoff. See definition for Retention Pond and Extended Detention Basin.

Stormwater Quality Detention: The temporary storage of stormwater to provide stormwater quality treatment through the settlement of suspended solids.

Stormwater Quantity Detention: The temporary storage of stormwater on a site to provide downstream flood control through the reduction of the runoff rate to pre-development levels.

Stormwater: Precipitation that accumulates in natural and/or constructed storage and stormwater systems during and immediately following a storm event.

Streetscaping: Physical amenities added to the roadway and intersections, including lighting, trees, landscaping, art, surface textures and colors, and street furniture.

Structural BMPs: Devices that are constructed to provide temporary storage and treatment of stormwater runoff.

Sustainable Urban Drainage Systems (SUDS): A series of techniques that are designed to manage surface water runoff as close to the source as possible in a more sustainable manner than traditional drainage systems. Typical techniques include porous surfacing, permeable paving systems, infiltration/attenuation trenches and swales. Also see Low Impact Development, Smart Growth, and Minimizing Directly Connected Impervious Area.

Surface Conveyance: A means of conducting stormwater runoff above ground rather than in underground pipes, usually involving curb and gutter, concrete V-pan, or channel.
Surface Water: Water that remains on the surface of the ground, including rivers, lakes, reservoirs, streams, wetlands, impoundments, seas, estuaries, etc.

Suspended Sediment: Very fine soil particles that remain in suspension in water for a considerable period of time without contact with the solid fluid boundary at or near the bottom. They are maintained in suspension by the upward components of turbulent currents.

Sustainable Development: Development that meets the needs of the present without compromising the ability of the future to meet its own needs. Also: Development that maximizes efficiency and functionality of systems while minimizing the consumption of precious resources.

Swale: See definition of Grass Swale.

Technology-Based Effluent Limit: Permit limit for a pollutant that is based on the capability of a treatment method to reduce the pollutant to a certain concentration.

Total Maximum Daily Load (TMDL): The maximum allowable loading of a pollutant that a designated water body can assimilate and still meet numeric and narrative water quality standards. TMDLs were established by the 1972 Clean Water Act. Section 303(d) of the US Water Quality Act requires states to identify water bodies that do not meet federal water quality standards. In 1996 the states developed (with EPA approval) a list of water bodies that failed to meet section 303(d) standards. These are the focus of TMDLs. Allocation of named pollutants is on percentage basis.

Trash Rack: Grill, grate or other device installed at the intake of a channel, pipe, drain, or spillway for the purpose of preventing oversized debris from entering the structure.

Treatment Roof: A green roof that provides stormwater quality treatment.

Treatment Train: Best Management Practices that work together in series to provide stormwater quality treatment.

Treatment Volume: The volume of stormwater runoff from a site requiring stormwater quality treatment.

Underdrain: A perforated pipe, typically 4-6" in diameter placed longitudinally at the invert of a bioretention facility for the purposes of achieving a desired discharge rate.

Urban Design: Involves the social, economic, functional, environmental, and aesthetic objectives that result in the plan or structure of a city, in whole or in part.

Water Quality Capture Volume (WQv): The quantity of stormwater runoff that must be treated in stormwater quality BMPs. This volume is equivalent to the runoff from an 80th percentile storm, meaning that 80 percent of the most frequently occurring storms are fully captured and treated and larger events are partially treated. In simple terms, this quantity is about half of the runoff from a 2-year storm.

Watershed: That geographical area which drains to a specified point on a water course, usually a confluence of streams or rivers (also known as drainage area, catchment, or river basin).

Wet Pond: See definition of Retention Pond.

Wet Weather Flows: Water entering storm drains during rainstorms.

Wetlands: Areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

Zero-Lot-Line Development: A development option in which side yard restrictions are reduced and the building abuts a side lot line. Overall unit-lot densities are therefore increased. Zero-lot-line development can result in increased protection of natural resources, as well as reduction in requirements for roads and sidewalks.