Chapter 1
Stormwater Management and Planning

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1.0 Introduction

The physical and chemical characteristics of stormwater runoff change as urbanization occurs, requiring comprehensive planning and management to reduce adverse effects on receiving waters. As stormwater flows across roads, rooftops, and other hard surfaces, pollutants are picked up and then discharged to streams and lakes. Additionally, the increased frequency, flow rate, duration, and volume of stormwater discharges due to urbanization can result in the scouring of rivers and streams, degrading the physical integrity of aquatic habitats, stream function, and overall water quality (EPA 2009). This chapter provides information fundamental to effective stormwater quality management and planning, including:

- An overview of the potential adverse impacts of urban stormwater runoff.
- A summary of key regulatory requirements for stormwater management in Colorado. These regulations set the minimum requirements for stormwater quality management. It is essential that those involved with stormwater management understand these requirements that shape stormwater management decisions at the construction and post-construction stages of development and redevelopment.
- UDFCD's Four Step Process to reduce the impacts of urban runoff.
- Discussion of on-site, sub-regional, and regional stormwater management alternatives at a planning level.

UDFCD highly recommends that engineers and planners begin the development process with a clear understanding of the seriousness of stormwater quality management from regulatory and environmental perspectives, and implement a holistic planning process that incorporates water quality upfront in the overall site development process. Chapters 2 and 3 provide BMP selection tools and detailed calculation procedures based on the concepts introduced in this chapter.

2.0 Urban Stormwater Characteristics

Numerous studies conducted since the late 1970s show stormwater runoff from urban and industrial areas can be a significant source of pollution (EPA 1983; Driscoll et al. 1990; Pitt et al. 2008). Stormwater impacts can occur during both the construction and post-construction phases of development. As a result, federal, state, and local regulations have been promulgated to address stormwater quality. Although historical focus of stormwater management was either flooding or chemical water quality, more recently, the hydrologic and hydraulic (physical) changes in watersheds associated with urbanization are recognized as significant contributors to receiving water degradation. Whereas only a few runoff events per year may occur prior to development, many runoff events per year may occur after urbanization (Urbonas et al. 1989). In the absence of controls, runoff peaks and volumes increase due to urbanization. This increased runoff is environmentally harmful, causing erosion in receiving streams and generating greater pollutant loading downstream. Figure 1-1 illustrates the many physical factors associated with stormwater runoff and the responses of receiving waters.

With regard to chemical water quality, Table 1-1 identifies a variety of pollutants and sources often found in urban settings such as solids, nutrients, pathogens, dissolved oxygen demands, metals, and oils. Several national data sources are available characterizing the chemical quality of urban runoff (e.g., EPA 1983; Pitt 2004). For purposes of this manual, Denver metro area data are the primary focus. In 1983, the Denver Regional Urban Runoff Program (DRURP) conducted by the Denver Regional Council of Governments (DRCOG), provided data for nine watersheds with various land uses for 15 constituents of concern and for U.S. Environmental Protection Agency (EPA) "Priority Pollutants." In 1992, additional urban stormwater monitoring was completed by UDFCD in support of the Stormwater National Pollutant Discharge Elimination System (NPDES) Part 2 Permit Application Joint Appendix (City of Aurora et al. 1992) for the Denver area communities affected by the Phase I stormwater regulation. Table 1-2 contains a summary of the results of these monitoring efforts, followed by a discussion of key findings from the DRURP study and other research since that time.

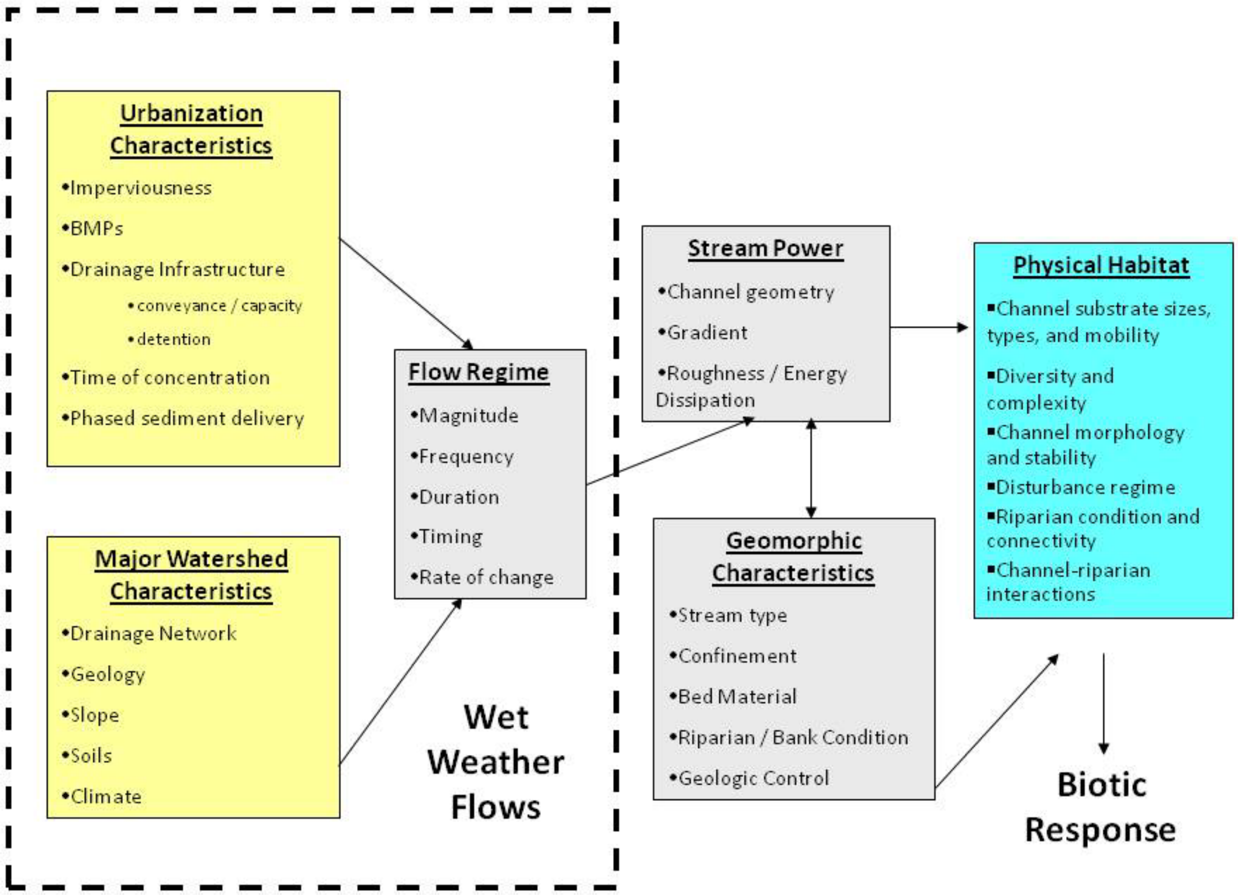

Figure 1-1. Physical effects of urbanization on streams and habitat

(Source: Roesner, L. A. and B. P. Bledsoe. 2003. *Physical Effects of Wet Weather Flows on Aquatic Habitats*. Water Environment Research Foundation: Alexandria, VA. Co-published by IA Publishing: United Kingdom.)

Table 1-1. Common urban runoff pollutant sources

(Adapted form: Horner, R.R., J.J. Skupien, E.H. Livingston and H.E. Shaver. 1994. *Fundamentals of Urban Runoff Management: Technical and Intuitional Issues*. Washington, DC: Terrene Institute and EPA.)

Pollutant Category Source	Solids	Nutrients	Pathogens	Dissolved Oxygen Demands	Metals	Oils	Synthetic Organics
Soil erosion	X	X		X	X		
Cleared vegetation	X	X		X			
Fertilizers		X	X	X			
Human waste	X	X	X	X			
Animal waste	X	X	X	X			
Vehicle fuels and fluids	X			X	X	X	X
Fuel combustion						X	
Vehicle wear	X			X	X		
Industrial and household chemicals	X	X		X	X	X	X
Industrial processes	X	X		X	X	X	X
Paints and preservatives					X	X	X
Pesticides				X	X	X	X
Stormwater facilities w/o proper maintenance[1]	X	X	X	X	X	X	X

Table 1-2. Event mean concentrations of constituents in Denver metropolitan area runoff
(based on Denver metropolitan area data collected as part of the Colorado Regulation 85 Nutrient Data Gap Analysis Report, 2013)

	Commercial			Residential			Industrial			Natural Grassland		
Analyte	n	Mean (95% CIs)	Median (95% CIs)	n	Mean (95% CIs)	Median (95% CIs)	n	Mean (95% CIs)	Median (95% CIs)	n	Mean (95% CIs)	Median (95% CIs)
Total Nitrogen (mg/L)	246	3.70 (3.33-4.06)	2.92 (2.75-3.20)	204	4.74 (4.34-5.13)	3.86 (3.59-4.40)	9	4.35 (2.58-6.12)	3.60 (1.20-5.70)	7	3.40 (1.90-4.90)	3.76 (1.49-4.11)
Total Kjeldahl Nitrogen (mg/L)	250	2.80 (2.50-3.09)	2.20 (2.03-2.40)	192	3.33 (3.00-3.66)	2.70 (2.47-3.00)	20	3.12 (2.29-3.95)	2.97 (2.01-4.2)	7	2.88 (1.56-4.21)	3.10 (1.30-3.26)
Nitrate Plus Nitrite (mg/L)	253	0.89 (0.79-0.99)	0.72 (0.63-0.78)	238	1.02 (0.91-1.12)	0.81 (0.76-0.94)	9	1.23 (0.78-1.68)	1.00 (0.30-1.60)	7	0.52 (0.23-0.80)	0.56 (0.09-0.66)
Phosphorus as P, Total (mg/L)	273	0.35 (0.29-0.42)	0.19 (0.17-0.24)	254	0.52 (0.48-0.57)	0.42 (0.38-0.46)	21	0.42 (0.27-0.58)	0.30 (0.17-0.41)	7	0.41 (0.25-0.58)	0.41 (0.21-0.53)
Phosphorus as P, Dissolved (mg/L)	192	0.13 (0.10-0.15)	0.07 (0.05-0.08)	233	0.24 (0.22-0.27)	0.19 (0.17-0.20)	9	0.34 (0.13-0.54)	0.18 (0.10-0.52)	7	0.13 (0.08-0.18)	0.15 (0.07-0.17)
Phosphorus, Ortho-P (mg/L)	136	0.15 (0.10-0.20)	0.06 (0.06-0.08)	97	0.22 (0.16-0.27)	0.15 (0.13-0.18)		NA	NA	7	0.13 (0.08-0.18)	0.12 (0.07-0.13)
TSS (mg/L)	280	219 (173-265)	85 (63-125)	270	221 (185-256)	122 (103-143)	9	502 (240-764)	370 (126-540)	7	397 (166-627)	257 (194-464)
TDS (mg/L)	9	149 (81-217)	117 (33-214)	7	146 (46-245)	95 (60-126)	9	84 (52-117)	75 (30-102)		NA	NA
COD (mg/L)	156	187 (159-215)	139 (114-162)	140	120 (105-136)	93 (80-108)		NA	NA	7	72 (51-94)	71 (42-71)
DOC (mg/L)	51	35 (24-45)	22 (17-34)	55	17 (13-21)	12 (10-14)		NA	NA	7	16 (6-27)	12 (9-12)
TOC (mg/L)	156	36 (28-44)	21 (18-27)	80	27 (23-31)	21 (18-25)	9	66 (48-84)	57 (24-82)	7	26 (11-42)	23 (13-23)
Cadmium, Total (ug/L)	147	NP	NP	119	NP	NP	9	NP	NP		NA	NA
Copper, Total (ug/L)	249	27 (20-34)	13 (12-16)	182	22 (19-25)	15 (11-20)	9	86 (31-141)	46 (39-86)	7	37 (-0.1-74)	20 (10-60)
Lead, Total (ug/L)	209	13 (10-16)	5 (5-6)	126	14 (11-17)	8 (5-10)	9	205 (3-408)	120 (63-160)		NA	NA
Zinc, Total (ug/L)	251	156 (120-192)	64 (55-80)	181	115 (99-131)	80 (68-110)	9	760 (280-1240)	520 (340-620)	7	101 (56-147)	90 (40-120)

Monitoring locations limited to Denver Metro area. 1980's lead data excluded from summary due to the phase-out of leaded gasoline.
CI = 95% confidence interval provided for mean and median values. n = number of samples. NP = Not provided due to large percentage of non-detects.

Selected findings of DRURP include:

- Urban runoff was identified as a significant source of stormwater pollutants including sediment, fecal indicator bacteria, nutrients, organic matter, and heavy metals (e.g., lead, zinc, cadmium). Sediment loading occurred regardless of the existence of major land disturbances causing erosion. In addition, nutrients from urban runoff were identified as a concern for lakes and reservoirs.

- Very few EPA Priority Pollutants were detected in runoff samples. Organic pollutants found were particularly sparse; the most commonly occurring was a pesticide. The most significant non-priority pollutant found was 2,4-D, which is an herbicide.

- Pollutant loading was not closely related to basin imperviousness or land use. Vague relationships between event mean concentrations and imperviousness were noted, but proved statistically insignificant. Concentrations of pollutants did not vary in a predictable or anticipated pattern.

- Non-storm urban runoff (e.g., dry weather discharges such as irrigation runoff) was also identified as a source of pollutants. This was not expected and was determined indirectly in the study analysis.

In addition to these pollutants, Urbonas and Doerfer (2003) have reported that atmospheric fallout is a significant contributor to urban runoff pollution in the Denver area. Snow and ice management activities also affect the quality of urban runoff since snow and ice may be contaminated by hydrocarbons, pet waste, deicing chemicals and sand.

Although Table 1-2 indicates that constituent concentrations in urban runoff in the metro Denver area are not necessarily greater than that for natural grasslands (background) for some constituents (e.g., TSS, TDS, TKN), it is important to recognize that the table does not provide data on pollutant loads, which are the product of runoff volume and pollutant concentrations. Runoff volume from urbanized areas is much greater than that from a natural grassland; therefore, resultant differences in pollutant loads are generally greater than the difference in concentrations.

Stormwater runoff issues can be discussed in general terms for both streams and lakes; however, there are some unique effects with regard to lakes. Some of these include:

- Lakes respond to cumulative pollutant loading over time in terms of days, weeks, and longer time frames, unlike streams, which typically show effects within hours or days.

- Floating trash and shore damage are notable visible impacts of stormwater on lakes.

- Nutrient enrichment from stormwater runoff can have a significant water quality impact on lakes. This can result in the undesirable growth of algae and aquatic plants, increasing BOD and depleting dissolved oxygen.

- Lakes do not flush contaminants as quickly as streams and act as sinks for nutrients, metals, and sediments. This means that lakes take longer to recover once contaminated.

With regard to construction-phase stormwater runoff, EPA reports sediment runoff rates from construction sites can be much greater than those from agricultural lands and forestlands, contributing large quantities of sediment over a short period of time, causing physical and biological harm to receiving waters (EPA 2005). Fortunately, a variety of construction-phase and post-construction BMPs are available to help minimize the impacts of urbanization. Proper selection, design, construction and maintenance of these practices are the focus of the remainder of this manual.

Additional Resources Regarding Urban Stormwater Issues and Management

American Society of Civil Engineers and Water Environment Federation. *1992. Design and Construction of Urban Stormwater Management Systems. ASCE Manual and Reports of Engineering Practice No. 77 and WEF Manual of Practice FD-20.* Alexandria, VA: WEF.

Burton and Pitt. 2001. *Stormwater Effects Handbook: A Toolbox for Watershed Managers, Scientists, and Engineers*. Lewis Publishers. http://www.epa.gov/ednnrmrl/publications/books/handbook/index.htm

Center for Watershed Protection Website: http://www.cwp.org

Debo, T. and A. Reese. 2002. *Municipal Stormwater Management*. 2nd Edition. Boca Raton, FL: Lewis Publishers.

EPA Stormwater Program Website: http://cfpub.epa.gov/npdes/home.cfm?program_id=6

International Stormwater Best Management Practices Database: www.bmpdatabase.org

Low Impact Development (LID) Center Website: http://www.lid-stormwater.net/

National Research Council. 2008. *Urban Stormwater Management in the United States*. National Academies Press. http://www.epa.gov/npdes/pubs/nrc_stormwaterreport.pdf

Oregon State University et al. 2006. *Evaluation of Best Management Practices for Highway Runoff Control.* Transportation Research Board. NCHRP-565. http://www.trb.org/news/blurb_detail.asp?id=7184

Pitt, R., Maestre, A., and R. Morquecho. 2004. The National Stormwater Quality Database (NSQD). Version 1.1. http://unix.eng.ua.edu/~rpitt/Research/ms4/Paper/Mainms4paper.html

Shaver et al. 2007. *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*, Second Edition. EPA and North American Lake Management Society. http://www.nalms.org/Resources/PDF/Fundamentals/Fundamentals_full_manual.pdf

Water Environment Federation and American Society of Civil Engineers. 1998. *Urban Runoff Quality Management. WEF Manual of Practice No. 23 and ASCE Manual and Report on Engineering Practice No. 87.* Alexandria, VA: Water Environment Federation.

Watershed Management Institute. 1997. *Operation, Maintenance and Management of Stormwater Management Systems.* Ingleside, MD: Watershed Management Institute.

3.0 Stormwater Management Requirements under the Clean Water Act

3.1 Clean Water Act Basics

The Federal Water Pollution Control Act of 1972, as amended (33 U.S.C. 1251 et seq.) is commonly known as the Clean Water Act and establishes minimum stormwater management requirements for urbanized areas in the United States. At the federal level, the EPA is responsible for administering and enforcing the requirements of the Clean Water Act. Section 402(p) of the Clean Water Act requires urban and industrial stormwater be controlled through the NPDES permit program. Requirements affect both construction and post-construction phases of development. As a result, urban areas must meet requirements of Municipal Separate Storm Sewer System (MS4) permits, and many industries and institutions such as state departments of transportation must also meet NPDES stormwater permit requirements. MS4 permittees are required to develop a Stormwater Management Program that includes measurable goals and to implement needed stormwater management controls (i.e., BMPs). MS4 permittees are also required to assess controls and the effectiveness of their stormwater programs and to reduce the discharge of pollutants to the "maximum extent practicable." Although it is not the case for every state, the EPA has delegated Clean Water Act authority to the State of Colorado. The State must meet the minimum requirements of the federal program.

3.2 Colorado's Stormwater Permitting Program

The Colorado Water Quality Control Act (25-8-101 et seq., CRS 1973, as amended) established the Colorado Water Quality Control Commission (CWQCC) within the Colorado Department of Public Health and Environment (CDPHE) to develop water quality regulations and standards, classifications of state waters for designated uses, and water quality control regulations. The Act also established the Colorado Water Quality Control Division (CWQCD) to administer and enforce the Act and administer the discharge permit system, among other responsibilities. Violations of the Act are subject to significant monetary penalties, as well as criminal prosecution in some cases.

Colorado's stormwater management regulations have been implemented in two phases and are included in *Regulation No. 61 Colorado Discharge Permit System (CDPS) Regulations* (CWQCC 2009). After the 1990 EPA "Phase I" stormwater regulation became effective, Colorado was required to develop a stormwater program that covered specific types of industries and storm sewer systems for municipalities with populations of more than 100,000. Phase I affected Denver, Aurora, Lakewood, Colorado Springs, and the Colorado Department of Transportation (CDOT). Phase 1 requirements included inventory of stormwater outfalls, monitoring and development of municipal stormwater management requirements, as well as other requirements. Construction activities disturbing five or more acres of land were required to obtain construction stormwater discharge permits.

Phase II of Colorado's stormwater program was finalized in March 2001, establishing additional stormwater permitting requirements. Two major changes included regulation of small municipalities (≥ 10,000 and <100,000 population) in urbanized areas and requiring construction permits for sites disturbing one acre or more. The Phase II regulation resulted in a large number of new permit holders including MS4 permits for almost all of the metro Denver area communities. MS4 permit holders are required to develop, implement, and enforce a CDPS Stormwater Management Program designed to reduce the discharge of pollutants from the MS4 to the maximum extent practicable, to protect water quality, and to satisfy the appropriate water quality requirements of the Colorado Water Quality Control Act (25-8-101 et seq., C.R.S.) and the Colorado Discharge Permit Regulations (Regulation 61).

The CWQCD administers and enforces the requirements of the CDPS stormwater program, generally including these general permit categories:

- **Municipal**: CDPS General Permit for Stormwater Discharges Associated with Municipal Separate Storm Sewer Systems (MS4s) (Permit No. COR-090000). The CWQCD has issued three municipal general permits:

  1. A permit for MS4s within the Cherry Creek Reservoir Basin,

  2. A permit for other MS4s statewide, and

  3. A permit specifically for non-standard MS4s. (Non-standard MS4s are publicly owned systems for facilities that are similar to a municipality, such as military bases and large education, hospital or prison complexes.)

- **Construction**: CDPS General Permit for Stormwater Discharges Associated with Construction Activity (Permit No. COR-030000).

- **Industrial**: CDPS General Permits are available for light industry, heavy industry, metal mining, sand and gravel, coal mining and the recycling industries.

The Phase II municipal MS4 permits require implementation of six minimum control measures (MCM):

1. Public education and outreach on stormwater impacts

2. Public involvement/participation

3. Illicit connections and discharge detection and elimination

4. Construction site stormwater management

5. Post-construction stormwater management in new development and redevelopment

6. Pollution prevention/good housekeeping for municipal operations

This manual provides guidance to address some of the requirements for measures 4, 5, and 6.

Resources for More Information on Colorado's Stormwater Regulations

CDPHE Stormwater Permitting Website: www.colorado.gov/pacific/cdphe/wqcd

See the CDPHE Regulation No. 61 Colorado Discharge Permit System Regulations and Colorado's Stormwater Program Fact Sheet both located on this website.

Common Stormwater Management Terms

Best Management Practice (BMP): A device, practice, or method for removing, reducing, retarding, or preventing targeted stormwater runoff constituents, pollutants, and contaminants from reaching receiving waters. (Some entities use the terms "Stormwater Control Measure," "Stormwater Control," or "Management Practice.")

Low Impact Development (LID): LID is a comprehensive land planning and engineering design approach to managing stormwater runoff with the goal of mimicking the pre-development hydrologic regime. LID emphasizes conservation of natural features and use of engineered, on-site, small-scale hydrologic controls that infiltrate, filter, store, evaporate, and detain runoff close to its source. The terms Green Infrastructure and Better Site Design are sometimes used interchangeably with LID.

LID Practice: LID practices are the individual techniques implemented as part of overall LID development or integrated into traditional development, including practices such as bioretention, green roofs, permeable pavements and other infiltration-oriented practices.

Minimizing Directly Connected Impervious Area (MDCIA): MDCIA includes a variety of runoff reduction strategies based on reducing impervious areas and routing runoff from impervious surfaces over grassy areas to slow runoff and promote infiltration. The concept of MDCIA has been recommended by UDFCD as a key technique for reducing runoff peaks and volumes following urbanization. MDCIA is a key component of LID.

Maximum Extent Practicable (MEP): MS4 permit holders are required to implement stormwater programs to reduce pollutant loading to the maximum extent practicable. This narrative standard does not currently include numeric effluent limits.

Municipal Separate Storm Sewer System (MS4): A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) owned or operated by an MS4 permittee and designed or used for collecting or conveying stormwater.

Nonpoint Source: Any source of pollution that is not considered a "point source.” This includes anthropogenic and natural background sources.

Point Source: Any discernible, confined and discrete conveyance from which pollutants are or may be discharged. Representative sources of pollution subject to regulation under the NPDES program include wastewater treatment facilities, most municipal stormwater discharges, industrial dischargers, and concentrated animal feeding operations. This term does not include agricultural stormwater discharges and return flows from irrigated agriculture.

Water Quality Capture Volume (WQCV): This volume represents runoff from frequent storm events such as the 80th percentile storm. The volume varies depending on local rainfall data. Within the UDFCD boundary, the WQCV is based on runoff from 0.6 inches of precipitation.

Excess Urban Runoff Volume (EURV): EURV represents the difference between the developed and pre-developed runoff volume for the range of storms that produce runoff from pervious land surfaces (generally greater than the 2-year event). The EURV is relatively constant for a given imperviousness over a wide range of storm events.

Full Spectrum Detention: This practice utilizes capture and slow release of the EURV. UDFCD found this method to better replicate historic peak discharges for the full range of storm events compared to multi-stage detention practices.

3.2.1 Construction Site Stormwater Runoff Control

Under the Construction Program, permittees are required to develop, implement, and enforce a pollutant control program to reduce pollutants in stormwater runoff to their MS4 from construction activities that result in land disturbance of one or more acres. MS4 permittees frequently extend this requirement to smaller areas of disturbance if the total site acreage is one acre or larger or if it drains to an environmentally sensitive area. See Chapter 7 for detailed information on construction BMPs.

3.2.2 Post-construction Stormwater Management

Under the post-construction stormwater management in new development and redevelopment provisions, the MS4 General Permit (CWQCD 2008) requires the permittee to develop, implement, and enforce a program to address stormwater runoff from new development and redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale, that discharge into the MS4. The program must ensure controls are in place that would prevent or minimize water quality impacts. See Chapter 4, Treatment BMPs and Chapter 5, Source Control BMPs, for detailed information on post-construction BMPs.

> **Redevelopment**
>
> The EPA Stormwater Phase 2 Final Rule Fact Sheet 2.7 states that redevelopment projects alter the footprint of an existing site or building in such a way that that there is a disturbance of equal to or greater than one acre of land.
>
> This means that a "roadway rehabilitation" project, for example, where pavement is removed and replaced with essentially the same footprint would not be considered "redevelopment", whereas a "roadway widening project", where additional pavement (or other alterations to the footprint, pervious or impervious) equal to or in excess of one acre would be considered "redevelopment".

Although MS4 general permits have historically focused on water quality, it is noteworthy that there has been increased emphasis on reducing stormwater runoff volumes through use of Low Impact Development (LID) techniques. For example, MS4 permit language for some Phase I municipalities has also included the following:

> Implement and document strategies which include the use of structural and/or non-structural BMPs appropriate for the community, that address the discharge of pollutants from new development and redevelopment projects, or that follow principles of low-impact development to mimic natural (i.e., pre-development) hydrologic conditions at sites to minimize the discharge of pollutants and prevent or minimize adverse in-channel impacts associated with increased imperviousness (City and County of Denver 2008 MS4 permit).

Similarly, at the national level, the Energy Independence and Security Act of 2007 (Pub.L. 110-140) includes Section 438, Storm Water Runoff Requirements for Federal Development Projects. This section requires:

> …any sponsor of any development or redevelopment project involving a federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow.

Finally, in October 2009, EPA issued a notice in the Federal Register (Federal Register Vol. 74, No. 209, 56191-56193) expressing its intent to implement new comprehensive stormwater regulations for new developments and redevelopments by 2012. EPA intends to propose requirements, including design or performance standards, for stormwater discharges from, at a minimum, newly developed and redeveloped sites. In the notice, EPA cites the National Research Council (2008) recommendations that "EPA address stormwater discharges from impervious land cover and promote practices that harvest, infiltrate and evapotranspirate stormwater to reduce or prevent it from being discharged, which is critical to reducing the volume and pollutant loading to our nation's waters."

Although it is important to be aware of increased regulatory emphasis on volume control, it is also noteworthy that UDFCD guidance has recommended volume reduction as the first step in urban stormwater quality management since the initial release of the USDCM Volume 3, in 1992. Chapter 2 of this manual provides the designer with additional tools to encourage site designs that better incorporate volume reduction, based on site-specific conditions.

3.2.3 Pollution Prevention/Good Housekeeping

Under the Pollution Prevention/Good Housekeeping requirements, permittees are required to develop and implement an operation and maintenance/training program with the ultimate goal of preventing or reducing pollutant runoff from municipal operations. Chapter 5 provides information on source controls and non-structural BMPs that can be used in support of some of these requirements. Stormwater managers must also be aware that non-stormwater discharges to MS4s are not allowed, with the exception of certain conditions specified in the MS4 permit.

3.3 Total Maximum Daily Loads and Stormwater Management

Section 303(d) of the Clean Water Act requires states to develop a list of water bodies that are not attaining water quality standards for their designated uses, and to identify relative priorities for addressing the impaired water bodies. States must then develop Total Maximum Daily Loads (TMDLs) to assign allowable pollutant loads to various sources to enable the water body to meet the designated uses established for that water body. (For more information about the TMDL program, see http://www.epa.gov/owow/tmdl.) Implementation plans to achieve the loads specified under TMDLs commonly rely on BMPs to reduce pollutant loads associated with stormwater sources.

In the context of this manual, it is important for designers, planners and other stormwater professionals to understand TMDLs because TMDL provisions can directly affect stormwater permit requirements and BMP selection and design. EPA provides this basic description of TMDLs:

> A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that load among the various sources of that pollutant. Pollutant sources are characterized as either regulated stormwater, sometimes called "point sources" that receive a waste load allocation (WLA), or nonpoint sources that receive a load allocation (LA). Point sources include all sources subject to regulation under the NPDES program (e.g., wastewater treatment facilities, most municipal stormwater discharges and concentrated animal feeding operations). Nonpoint sources include all remaining sources of the pollutant, as well as anthropogenic and natural background sources. TMDLs must also account for seasonal variations in water quality, and include a margin of safety (MOS) to account for uncertainty in predicting how well pollutant reductions will result in meeting water quality standards.

The TMDL calculation is:

$$\text{TMDL} = \Sigma\text{WLA} + \Sigma\text{LA} + \text{MOS} \qquad \text{Equation 1-1}$$

Where:

ΣWLA = the sum of waste load allocations (point sources),

ΣLA = the sum of load allocations (nonpoint sources and background)

MOS = the margin of safety.

Although states are primarily responsible for developing TMDLs, EPA is required to review and approve or disapprove TMDLs. EPA has developed a basic "TMDL Review Checklist" with the minimum recommended elements that should be present in a TMDL document.

Once EPA approves a TMDL, there are varying degrees of impact to communities involved in the process, generally differentiated among whether point sources or non-point sources of pollution are identified in the TMDL. Permitted stormwater discharges are considered point sources. Essentially, this means that wastewater or stormwater permit requirements consistent with waste load allocations must be implemented and are enforceable under the Clean Water Act through NPDES permits.

If the MS4 permittee discharges into a waterbody with an approved TMDL that includes a pollutant-specific waste load allocation under the TMDL, then the CWQCD can amend the permit to include specific requirements related to that TMDL. For example, the permit may be amended to require specific BMPs, and compliance schedules to implement the BMPs may be required. Numeric effluent limits may also be incorporated under these provisions. TMDLs can have substantive effects on MS4 permit requirements. As an example, the City and County of Denver's MS4 permit has additional requirements to control *E. coli* related to the *E. coli* TMDL approved for the South Platte River (Segment 14). Information on 303(d) listings and priorities for TMDL development can be obtained from the EPA and CWQCC websites (http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/index.cfm and www.colorado.gov/pacific/cdphe/impaired-waters).

EPA's Recommended TMDL Checklist
(http://www.epa.gov/owow/tmdl/overviewoftmdl.html)

- Identification of Waterbody, Pollutant of Concern, Pollutant Sources, and Priority Ranking
- Applicable Water Quality Standard & Numeric Water Quality Target[1]
- Loading Capacity[1]
- Load Allocations and Waste Load Allocations[1]
- Margin of Safety[1]
- Consideration of Seasonal Variation[1]
- Reasonable Assurance for Point Sources/Non-point Sources
- Monitoring Plan to Track TMDL Effectiveness
- Implementation Plan
- Public Participation

[1] Legally required components under 40 C.F.R. Part 130

4.0 Four Step Process to Minimize Adverse Impacts of Urbanization

UDFCD has long recommended a Four Step Process for receiving water protection that focuses on reducing runoff volumes, treating the water quality capture volume (WQCV), stabilizing streams, and implementing long-term source controls. The Four Step Process pertains to management of smaller, frequently occurring events, as opposed to larger storms for which drainage and flood control infrastructure are sized. Implementation of these four steps helps to achieve stormwater permit requirements described in Section 3. Added benefits of implementing the complete process can include improved site aesthetics through functional landscaping features that also provide water quality benefits. Additionally, runoff reduction can decrease required storage volumes, thus increasing developable land. An overview of the Four Step Process follows, with Chapters 2 and 3 providing BMP selection tools and quantitative procedures for completing these steps.

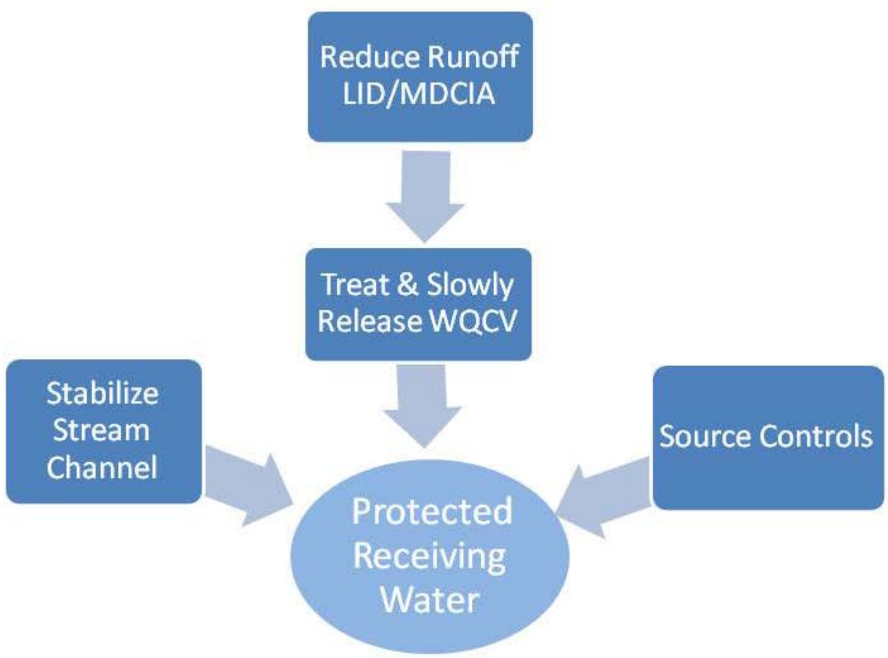

Figure 1-2. The four step process for stormwater quality management

4.1 Step 1. Employ Runoff Reduction Practices

To reduce runoff peaks, volumes, and pollutant loads from urbanizing areas, implement LID strategies, including MDCIA. For every site, look for opportunities to route runoff through vegetated areas, where possible by sheet flow. LID practices reduce unnecessary impervious areas and route runoff from impervious surfaces over permeable areas to slow runoff (increase time of concentration) and promote infiltration. When LID/MDCIA techniques are implemented throughout a development, the effective imperviousness is reduced, thereby potentially reducing sizing requirements for downstream facilities.

Differences between LID and Conventional Stormwater Quality Management

Low Impact Development (LID) is a comprehensive land planning and engineering design approach to managing stormwater runoff with a goal of replicating the pre-development hydrologic regime of urban and developing watersheds. Given the increased regulatory emphasis on LID, volume reduction and mimicking pre-development hydrology, questions may arise related to the differences between conventional stormwater management and LID. For example, Volume 3 has always emphasized MDCIA as the first step in stormwater quality planning and has provided guidance on LID techniques such as grass swales, grass buffers, permeable pavement systems, bioretention, and pollution prevention (pollutant source controls). Although these practices are all key components of LID, LID is not limited to a set of practices targeted at promoting infiltration. Key components of LID, in addition to individual BMPs, include practices such as:

- An overall site planning approach that promotes conservation design at both the watershed and site levels. This approach to development seeks to "fit" a proposed development to the site, integrating the development with natural features and protecting the site's natural resources. This includes practices such as preservation of natural areas including open space, wetlands, soils with high infiltration potential, and stream buffers. Minimizing unnecessary site disturbances (e.g., grading, compaction) is also emphasized.
- A site design philosophy that emphasizes multiple controls distributed throughout a development, as opposed to a central treatment facility.
- The use of swales and open vegetated conveyances, as opposed to curb and gutter systems.
- Volume reduction as a key hydrologic objective, as opposed to peak flow reduction being the primary hydrologic objective. Volume reduction is emphasized not only to reduce pollutant loading and peak flows, but also to move toward hydrologic regimes with flow durations and frequencies closer to the natural hydrologic regime.

Even with LID practices in place, most sites will also require centralized flood control facilities. In some cases, site constraints may limit the extent to which LID techniques can be implemented, whereas in other cases, developers and engineers may have significant opportunities to integrate LID techniques that may be overlooked due to the routine nature and familiarity of conventional approaches. This manual provides design criteria and guidance for both LID and conventional stormwater quality management, and provides additional facility sizing credits for implementing Step 1, Volume Reduction, in a more robust manner.

Key LID techniques include:

- **Conserve Existing Amenities**: During the planning phase of development, identify portions of the site that add value and should be protected or improved. Such areas may include mature trees, stream corridors, wetlands, and Type A/B soils with higher infiltration rates. In order for this step to provide meaningful benefits over the long-term, natural areas must be protected from compaction during the construction phase. Consider temporary construction fence for this purpose. In areas where disturbance cannot practically be avoided, rototilling and soil amendments should be integrated to restore the infiltration capacity of areas that will be restored with vegetation.
- **Minimize Impacts**: Consider how the site lends itself to the desired development. In some cases, creative site layout can reduce the extent of paved areas, thereby saving on initial capital cost of pavement and then saving on pavement maintenance, repair, and replacement over time. Minimize

imperviousness, including constructing streets, driveways, sidewalks and parking lot aisles to the minimum widths necessary, while still providing for parking, snow management, public safety and fire access. When soils vary over the site, concentrate new impervious areas over Type C and D soils, while preserving Type A and B soils for landscape areas and other permeable surfaces. Maintaining natural drainage patterns, implementing sheet flow (as opposed to concentrated flow), and increasing the number and lengths of flow paths will all reduce the impact of the development.

Permeable pavement techniques and green roofs are common LID practices that may reduce the effects of paved areas and roofs:

- **Permeable Pavement**: The use of various permeable pavement techniques as alternatives to paved areas can significantly reduce site imperviousness.

- **Green Roofs**: Green roofs can be used to decrease imperviousness associated with buildings and structures. Benefits of green roofs vary based on design of the roof. Research is underway to assess the effectiveness of green roofs in Colorado's semi-arid climate.

▪ **Minimize Directly Connected Impervious Areas (MDCIA)**: Impervious areas should drain to pervious areas. Use non-hardened drainage conveyances where appropriate. Route downspouts across pervious areas, and incorporate vegetation in areas that generate and convey runoff. Three key BMPs include:

- **Grass Buffers**: Sheet flow over a grass buffer slows runoff and encourages infiltration, reducing effects of the impervious area.

- **Grass Swales**: Like grass buffers, use of grass swales instead of storm sewers slows runoff and promotes infiltration, also reducing the effects of imperviousness.

- **Bioretention (rain gardens)**: The use of distributed on-site vegetated features such as rain gardens can help maintain natural drainage patterns by allowing more infiltration onsite. Bioretention can also treat the WQCV, as described in the Four Step Process.

Photograph 1-1. **Permeable Pavement**. Permeable pavement consists of a permeable pavement layer underlain by gravel and sand layers in most cases. Uses include parking lots and low traffic areas, to accommodate vehicles while facilitating stormwater infiltration near its source.

Photograph 1-2. Grass Buffer. This roadway provides sheet flow to a grass buffer. The grass buffer provides filtration, infiltration, and settling to reduce runoff pollutants.

Photograph 1-3. Grass Swale. This densely vegetated grass swale is designed with channel geometry that forces the flow to be slow and shallow, facilitating sedimentation while limiting

Historically, this critical volume reduction step has often been overlooked by planners and engineers, instead going straight to WQCV requirements, despite WQCV reductions allowed based on MDCIA. Chapter 3 extends reductions to larger events and provides a broader range of reductions to WQCV sizing requirements than were previously recommended by UDFCD, depending on the extent to which Step 1 has been implemented. Developers should anticipate more stringent requirements from local governments to implement runoff reduction/MDCIA/LID measures (in addition to WQCV capture), given changes in state and federal stormwater regulations. In addition to benefiting the environment through reduced hydrologic and water quality impacts, volume reduction measures can also have the added economic benefit to the developer of increasing the area of developable land by reducing required detention volumes and potentially reducing both capital and maintenance costs.

Practical Tips for Volume Reduction and Better Integration of Water Quality Facilities
(Adapted from: Denver Water Quality Management Plan, WWE et al. 2004)

- **Consider stormwater quality needs early in the development process.** When left to the end of the site development process, stormwater quality facilities will often be shoe-horned into the site, resulting in few options. When included in the initial planning for a project, opportunities to integrate stormwater quality facilities into a site can be fully realized. Dealing with stormwater quality after major site plan decisions have been made is too late and often makes implementation of LID designs impractical.

- **Take advantage of the entire site when planning for stormwater quality treatment.** Stormwater quality and flood detention is often dealt with only at the low corner of the site, and ignored on the remainder of the site. The focus is on draining runoff quickly through inlets and storm sewers to the detention facility. In this "end-of-pipe" approach, all the runoff volume is concentrated at one point and designers often find it difficult to fit the required detention into the space provided. This can lead to use of underground BMPs that can be difficult to maintain or deep, walled-in basins that detract from a site and are also difficult to maintain. Treating runoff over a larger portion of the site reduces the need for big corner basins and allows implementation of LID principles.

- **Place stormwater in contact with the landscape and soil**. Avoid routing storm runoff from pavement to inlets to storm sewers to offsite pipes or concrete channels. The recommended approach places runoff in contact with landscape areas to slow down the stormwater and promote infiltration. Permeable pavement areas also serve to reduce runoff and encourage infiltration.

- **Minimize unnecessary imperviousness, while maintaining functionality and safety.** Smaller street sections or permeable pavement in fire access lanes, parking lanes, overflow parking, and driveways will reduce the total site imperviousness.

- **Select treatment areas that promote greater infiltration.** Bioretention, permeable pavements, and sand filters promote greater volume reduction than extended detention basins, since runoff tends to be absorbed into the filter media or infiltrate into underlying soils. As such, they are more efficient at reducing runoff volume and can be sized for smaller treatment volumes than extended detention basins.

4.2 Step 2. Implement BMPs That Provide a Water Quality Capture Volume with Slow Release

After runoff has been minimized, the remaining runoff should be treated through capture and slow release of the WQCV. WQCV facilities may provide both water quality and volume reduction benefits, depending on the BMP selected. This manual provides design guidance for BMPs providing treatment of the WQCV, including permeable pavement systems with subsurface storage, bioretention, extended detention basins, sand filters, constructed wetland ponds, and retention ponds. Green roofs and some underground BMPs may also provide the WQCV, depending on the design characteristics. Chapter 3 provides background information on the development of the WQCV for the Denver metropolitan area as well as a step-by-step procedure to calculate the WQCV.

4.3 Step 3. Stabilize Streams

During and following development, natural streams are often subject to bed and bank erosion due to increases in frequency, duration, rate, and volume of runoff. Although Steps 1 and 2 help to minimize these effects, some degree of stream stabilization is required. Many streams within UDFCD boundaries are included in major drainageway or outfall systems plans, identifying needed channel stabilization measures. These measures not only protect infrastructure such as utilities, roads and trails, but are also important to control sediment loading from erosion of the channel itself, which can be a significant source of sediment and associated constituents, such as phosphorus, metals and other naturally occurring constituents. If stream stabilization is implemented early in the development process, it is far more likely that natural stream characteristics can be maintained with the addition of grade control to accommodate future development. Targeted fortification of a relatively stable stream is typically much less costly than repairing an unraveled channel. The *Open Channels* chapter in Volume 1 of this manual provides guidance on stream stabilization.

4.4 Step 4. Implement Site Specific and Other Source Control BMPs

Site specific needs such as material storage or other site operations require consideration of targeted source control BMPs. This is often the case for new development or significant redevelopment of an industrial or commercial site. Chapter 5 includes information on source control practices such as covering storage/handling areas and spill containment and control.

5.0 Onsite, Subregional and Regional Stormwater Management

Whereas flood control is best handled on a regional basis, stormwater quality is best managed as a resource and distributed throughout the site.

Stormwater quality BMPs should be implemented as close to the source as practicable. This results in smaller BMPs (in parallel or in series) that are distributed throughout a site rather than the "end of pipe" alternative. Whereas flood control is best handled on a regional basis, stormwater quality is best managed when stormwater is viewed as a resource and distributed throughout the site. When the watershed of a BMP is so big that a base flow is present, this both limits the type of BMP appropriate for use and complicates the design. The treatment provided by a regional BMP will also vary when base flows differ from that assumed during design.

Although not preferred, WQCV facilities may be implemented regionally (serving a major drainageway with a drainage area between 130 acres and one square mile) or subregionally (serving two or more development parcels with a total drainage area less than 130 acres). Drainage master plans should be consulted to determine if regional or subregional facilities are already planned or in place for new developments or redevelopments. Life-cycle costs of onsite, subregional, and regional facilities, including long-term maintenance responsibilities, should be part of the decision-making process when selecting the combinations of facilities and channel improvements needed to serve a development or redevelopment. Potential benefits of regional/subregional facilities include consolidated maintenance efforts, economies of scale for larger facilities as opposed to multiple onsite WQCV facilities, simplified long-term adequate assurances for operation and maintenance for public facilities, and potential integration with flood control facilities. Additionally, regional storage-based facilities may be beneficial in areas where onsite BMPs are not feasible due to geotechnical or land use constraints or when retrofitting an existing flood control facility in a fully developed watershed.

One of the most common challenges regarding regional facilities relates to the timing of funding for construction of the facilities. Often, regional facilities are funded by revenues collected from new development activities. New developments (and revenues) are required to fund construction of the water quality facility, but the water quality facility is needed upfront to provide protection for new development. This timing problem can be solved by constructing onsite water quality facilities for new development that occur before a regional facility is in place. These onsite BMPs are temporary in that they can be converted to developable land once the regional facility is constructed. Another option is to build a smaller interim regional facility that can be expanded with future development.

When regional water quality facilities are selected, BMPs are still required onsite to address water quality and channel stability for the reach of the drainageway upstream of the regional facility. In accordance with MS4 permits and regulations, BMPs must be implemented prior to discharges to a State Water from areas of "New Development and Significant Redevelopment." Therefore, if a regional BMP is utilized downstream of a discharge from a development into a State Water, additional BMPs are required to protect the State Water between the development site and the regional facility. However, these BMPs may not have to be as extensive as would normally be required, as long as they are adequate to protect the State Water upstream of the regional BMP. Although the CWQCD does not require onsite WQCV per se, MS4 permits contain conditions that require BMPs be implemented to the Maximum Extent Practicable to prevent "pollution of the receiving waters in excess of the pollution permitted by an applicable water quality standard or applicable antidegradation requirement." Additional requirements may also apply in the case of streams with TMDLs. As a result, MS4 permit holders must have a program in place that requires developers to provide adequate onsite measures so that the MS4 permit holder remains in compliance with their permit and meets the conditions of current regulations.

State Waters

State Waters are any and all surface and subsurface waters which are contained in or flow in or through this State, but does not include waters in sewage systems, waters in treatment works of disposal systems, waters in potable water distribution systems, and all water withdrawn for use until use and treatment have been completed (from Regulation 61, Colorado Discharge Permit System Regulations).

When a regional or subregional facility is selected to treat the WQCV for a development, the remaining three steps in the Four Step Process should still be implemented. For example, minimizing runoff volumes on the developed property by disconnecting impervious area and infiltrating runoff onsite (Step 1) can potentially reduce regional WQCV requirements, conveyance system costs, and costs of the regional/subregional facility. Stream stabilization requirements (Step 3) must still be evaluated and implemented, particularly if identified in a master drainage plan. Finally, specific source controls (Step 4 BMPs) such as materials coverage should be implemented onsite, even if a regional/subregional facility is provided downstream. Although UDFCD does not specify minimum onsite treatment requirements when regional/subregional facilities are used, some local governments (e.g., Arapahoe County) have specific requirements related to the minimum measures that must be implemented to minimize directly connected impervious area.

Chapter 2 provides a BMP selection tool to help planners and engineers determine whether onsite, subregional or regional strategies are best suited to the given watershed conditions.

6.0 Conclusion

Urban stormwater runoff can have a variety of chemical, biological, and physical effects on receiving waters. As a result, local governments must comply with federal, state and local requirements to minimize adverse impacts both during and following construction. UDFCD criteria are based on a Four Step Process focused on reducing runoff volumes, treating the remaining WQCV, stabilizing receiving drainageways and providing targeted source controls for post-construction operations at a site. Stormwater management requirements and objectives should be considered early in the site development process, taking into account a variety of factors, including the effectiveness of the BMP, long-term maintenance requirements, cost and a variety of site-specific conditions. The remainder of this manual provides guidance for selecting, designing, constructing and maintaining stormwater BMPs.

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