CHAPTER 15
STORM DRAINAGE WATER QUALITY

SECTION 1

STORMWATER QUALITY MANAGEMENT PRINCIPLES

CHAPTER 15
STORM DRAINAGE WATER QUALITY

SECTION 1
STORMWATER QUALITY MANAGEMENT PRINCIPLES

TABLE OF CONTENTS

CHAPTER 15
STORM DRAINAGE WATER QUALITY

SECTION 1
STORMWATER QUALITY MANAGEMENT PRINCIPLES

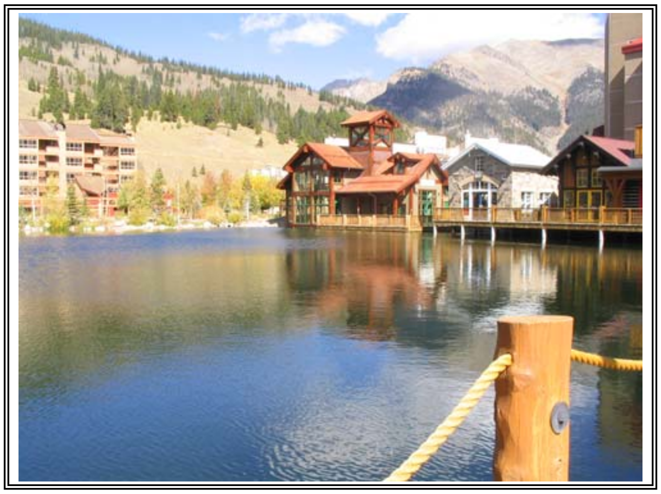
1.1 INTRODUCTION

Urban stormwater runoff from rainfall and snowmelt typically carries a variety of pollutants that can adversely affect streams, rivers and lakes unless specific measures are taken to reduce these impacts. Adverse physical impacts to streams can also result from urban runoff, even from small, frequently occurring storms. To minimize these impacts, local governments can require new development and redevelopment projects to implement measures designed to enhance the quality of stormwater runoff and to minimize the adverse physical impacts of runoff. These measures are commonly referred to as stormwater quality Best Management Practices (BMPs). BMPs should not only be designed to function properly, but should also be integrated into the overall site design, compatible with the surrounding land use and community goals, maintainable over the long term and consistent with the paramount objective of protecting public health, safety and welfare.

This section of the Statewide Manual contains general principles for effective stormwater quality management and is followed by a brief overview of specific BMPs implemented throughout the state in Section 2.

1.2 REGULATORY BACKGROUND

The 1987 amendments to the federal Clean Water Act created requirements for certain industries and urbanized areas to control pollution from stormwater runoff and to obtain National Pollutant Discharge Elimination System (NPDES) permits for stormwater discharges. In Colorado, the Colorado Department of Public Health and Environment Water Quality Control Division (WQCD) administers the stormwater program through the Colorado Discharge Permit System (CDPS). The federal and state stormwater regulations were developed in two phases. Phase I focused on medium to large municipalities (populations greater than 100,000) including Denver, Aurora, Lakewood and Colorado Springs and the Colorado Department of Transportation, as well as certain industrial facilities and large construction sites (>5 acres). The Colorado regulations were amended in 2001 to incorporate the Phase II stormwater requirements, which affected small municipalities (with populations between 10,000 and 100,000) and construction sites down to one acre (as discussed in Chapter 4). The WQCD website can be referenced for more information on Colorado's stormwater program
(http://www.cdphe.state.co.us/wq/PermitsUnit/stormwater/).



The municipal stormwater permits under the stormwater program are referred to as "municipal separate storm sewer system" (MS4) permits and are based on implementation of six minimum control measures: 1) public education and outreach on stormwater impacts; 2) public involvement/participation; 3) illicit connection and discharge detection and elimination; 4) construction site stormwater runoff control; 5) post-construction stormwater management in development/redevelopment; and 6) pollution prevention/good housekeeping for municipal operations. The post-construction stormwater management requirements apply to new development and redevelopment projects that result in land disturbance of one or more acres. Compliance with permit requirements is based on implementation and maintenance of BMPs to reduce pollutant loadings to the "maximum extent practicable."

Even if a community or industry is not regulated under an MS4 or industrial stormwater permit, it may be required or choose to implement BMPs to reduce pollutant loading to streams, rivers or lakes that do not attain Colorado stream standards and that are listed on the Colorado "303(d) list" and subject to the Total Maximum Daily Load (TMDL) process under the federal Clean Water Act. A TMDL is an estimate of the greatest amount of a specific pollutant that a water body or stream segment can receive without violating water quality standards. This amount includes a margin of safety, waste load allocation (for point sources) and a load allocation (for non-point sources and natural background). The TMDL process is a method of analyzing pollution sources and allocating responsibility among those sources. For stormwater and nonpoint sources of pollution, BMPs are used to reduce pollutant loading.

1.3 GENERAL CRITERIA

Local government criteria for managing stormwater quality post-construction should include the following requirements:

1. New development and significant redevelopment projects should provide specific measures to enhance the water quality of storm-generated runoff from the fully developed project site in accordance with criteria adopted by the local government.
2. Facilities designed to provide detention of storm-generated runoff for drainage and flood control purposes should be required to provide water quality enhancement through the use of a timed release water quality outlet structure or an approved alternative. Water quality facilities that provide runoff storage volume for a "water quality capture volume" (WQCV) (ASCE/WEF 1998 and UDFCD 1999) should be required or encouraged, as opposed to "flow through" treatment devices without storage volume because of the benefits that storage provides in terms of mitigation of physical impacts of urbanization, in addition to pollutant removal.

3. Timed release water quality outlet structures should be designed to treat a portion of the runoff identified as the WQCV. Drain times of 12 to 48 hours, depending on the type of BMP selected, are recommended by many of the most common technical references and criteria manuals.
4. Sites that are not required to provide detention of storm runoff for drainage and flood control purposes may still need to detain for water quality purposes.

1.4 MINIMUM TECHNICAL STANDARDS

The minimum technical requirements for design, implementation and maintenance of stormwater BMPs should be adopted or developed by local governments. Many communities along Colorado's Front Range have adopted the *Urban Storm Drainage Criteria Manual, Volume 3-Best Management Practices*, issued by UDFCD (1999), or adapted the manual to fit local constraints. A four-step process is recommended to minimize adverse water quality and receiving water impacts:

1. Reduce post-development site runoff volume to the maximum extent practicable. Implement measures that minimize directly connected impervious area and promote infiltration of runoff. These techniques incorporate many "low impact development" and "better site design" concepts that are increasingly recognized nationally. (Note: infiltration practices are highly dependent on the underlying soils. While infiltration practices are advantageous from the standpoint of runoff reduction, they may not be advisable in areas with expansive or low permeability soils.)
2. Control the remaining (residual) runoff through BMPs that treat the necessary WQCV.
3. Implement stream channel stabilization techniques for drainageways on or adjacent to the site, as needed to minimize channel impacts from site runoff.
4. If a site includes significant potential pollutant sources (e.g., gas stations, loading facilities, industrial sites), provide additional treatment, including covering of storage/handling areas, spill containment and control, and other best available technologies.

1.5 DESIGN PRINCIPLES AND PROCESS

Guiding principles[1] for integrating stormwater quality measures into the overall design of new development or redevelopment include the following practices:

1. Consider stormwater quality needs early in the design process. When included in the initial planning for a project,

[1] The principles and process included in Section 1.5 and the BMP descriptions included in Section 2.0 are adapted directly from the *Denver Water Quality Management Plan,* prepared by Wright Water Engineers, Wenk Associates, Muller Engineering, Matrix Design Group and Smith Environmental in 2004. This plan should be referenced for more detail on these topics.

stormwater quality facilities can be better integrated into the overall site, rather than being "shoe-horned" into the site.

2. Take advantage of the entire site when planning for stormwater quality treatment. Spreading runoff control measures or strategies over a larger portion of the site can help to reduce undesirable treatment strategies that detract from a site or are difficult to maintain.
3. Reduce runoff rates and volumes to the maximum extent practicable to more closely match natural conditions by placing stormwater in contact with the landscape, minimizing directly connected impervious areas, reducing the amount of impervious area (e.g., replace low-use or emergency access paved areas with porous pavement) and selecting treatment techniques that promote infiltration.
4. Integrate stormwater quality management and flood control, when practical.
5. Design attractive stormwater quality facilities that enhance the site, community, and environment. Consider surrounding land use type, context, prominence of the facility's location on the site, and proximity of the site to civic spaces.
6. Design sustainable facilities that can be safely maintained. Provide adequate maintenance access with a minimum disturbance, disruption, and cost. Consider how facilities will be maintained and what equipment will be necessary.
7. Design and maintain facilities with public safety in mind. Consider minimizing perimeter wall heights, providing railing adjacent to vertical drops of 30 inches or more, and ensuring basin edges are designed with gradually sloping banks. Walled-in or steeply sloped, remote basins should be avoided. Lighting may also be needed.

The following design process outlines an approach for integrating these seven principles into the four minimum technical criteria presented in Section 1.4.

1. Develop an initial site design. This should include a rough layout of lots, buildings, streets, parking, and landscape areas with a general idea of proposed site grades and an estimate of approximate areas associated with roofs, streets, walks, parking lots, and landscaping or open space.
2. Consider the full range of BMP alternatives, including techniques to reduce runoff and distribute BMPs throughout the site. Reduce runoff volume to the maximum extent practicable by implementing practices that minimize directly connected impervious area and promote infiltration. Test the influence of several alternatives on the overall character and layout of the site, weigh pros and cons of each, and progress towards an optimum approach. Consider long-term or life-cycle costs in the selection of alternative BMPs. When selecting and designing BMPs that rely on infiltration, the designer needs to consider geotechnical and foundation issues, the ability of the property owner to understand and properly maintain these facilities, long-term infiltration capability, and assurance of adequate funding to maintain the infiltration facilities.
3. Pursue a functional distribution of landscape areas. Consider these principles:
   - Keep detention basins shallow and consider providing some space for tree and shrub plantings around their perimeter in areas that do not restrict maintenance access.
   - Reserve an initial area about 5 to 15 percent of the size of the impervious area for stormwater quality treatment. This area may be reduced in later stages of design.

- Minimize exclusive reliance on extended detention basins (primarily for aesthetic and land use reasons). When included, locate them near a low-lying area of the site away from pedestrian corridors and gathering places.
- Distribute landscaped areas/grass buffers, porous landscape and porous pavement areas throughout the site. Locate porous landscape detention in close proximity to the impervious area being served.

4. Consider surface conveyance as an alternative to pipes. Conveying flows on the surface is the best method for conveying runoff to porous landscape and porous pavement detention because it allows the facilities to be shallow. If flow can be conveyed on the surface in grass swales or in strips of modular block porous pavement, additional stormwater quality benefits will accrue and the required WQCV will be reduced. If runoff must be conveyed under the surface in a pipe, area inlets within a landscaped area may be considered as an alternative to street or curb inlets if soil conditions are appropriate, since this gives runoff a chance to sheet flow through vegetation and infiltrate prior to entering the storm sewer. The basin or channel receiving these flows must be deep enough to allow the pipe to drain.
5. Integrate stormwater quality and flood control detention. Identify flood control detention requirements, water quality treatment requirements and opportunities to integrate these functions into multi-purpose facilities.
6. Tailor approach to the specific pollutants of concern. If downstream receiving waters are threatened by specific stormwater constituents, such as lakes threatened by excessive phosphorus loading leading to eutrophication, provide BMPs that are particularly effective at addressing that pollutant.

1.6 MAINTENANCE

In order for stormwater BMPs to be effective, proper maintenance is essential. Maintenance includes both routinely scheduled activities, as well as non-routine repairs that may be required after heavy storm events or as a result of other unforeseen problems. Arrangements for BMP maintenance are the responsibility of the entity owning the BMP and must be conducted over the entire lifespan of the BMP. In recent years, mosquito-transmitted diseases such as West Nile virus have been of concern in Colorado. Proper maintenance is necessary to prevent conditions that are conducive to mosquito breeding.

For communities with MS4 permits, enforcement of BMP maintenance is required. In addition to adequate local government staffing to conduct inspections of permanent BMPs, local governments can implement a variety of mechanisms to ensure maintenance such as: 1) agreements establishing legally binding BMP maintenance requirements and responsibilities; 2) permit obligations specifying BMP maintenance requirements; or 3) municipal legislative action or rulemaking authority regarding maintenance. Examples of some of the specific requirements suggested for legal agreements by the Watershed Management Institute (1997) include:

- General Assurances: Identify requirements for proper operation and maintenance, conditions for modification of facilities, dedicated easements, binding covenants, operation and maintenance plans, and inspection requirements.
- Warranty Period: Require the original developer to be responsible for maintenance and operation during a defined short-term period, and identify the entity responsible for long-term operation. The party responsible for long-term maintenance must have appropriate legal authority to own, operate, maintain, and raise funds to complete needed maintenance.
- Proof of Legal Authority: Require that the entity meet certain conditions verifying its legal authority to ensure maintenance.
- Conditions for Phased Projects: Clearly specify how maintenance responsibilities are allocated over the long-term for a project that is phased in over time.
- Remedies: Clearly define remedies in the event that inspections determine that the facility is not being properly maintained.

In the event that subsurface BMPs are implemented, maintenance is particularly critical because these facilities tend to be “out-of-site, out-of-mind.”

CHAPTER 15
STORM DRAINAGE WATER QUALITY

SECTION 2

BEST MANAGEMENT PRACTICES

CHAPTER 15
STORM DRAINAGE WATER QUALITY

SECTION 2
BEST MANAGEMENT PRACTICES

TABLE OF CONTENTS

CHAPTER 15
STORM DRAINAGE WATER QUALITY

SECTION 2
BEST MANAGEMENT PRACTICES

2.1 INTRODUCTION

Although many different BMPs may be capable of improving water quality at a given development site, factors related to the development type, aesthetics, surrounding land use, long-term sustainability, cost, maintenance and other factors should be considered when selecting stormwater quality BMPs to determine the most suitable combination of BMPs for a particular site.

This section of the Statewide Manual contains a brief overview of various types of BMPs that can be considered for a site. The BMPs are categorized into three general types: 1) overall site design practices that reduce impacts of development; 2) traditional structural BMPs (e.g., detention basins, grass swales), and 3) non-structural practices or source controls (e.g., fertilizer and pesticide application and handling, spill prevention). This highly condensed summary provides basic information on various BMPs; however, appropriate local, regional, or national design manuals should be referenced for complete design guidance. In addition to storm drainage criteria manuals developed by local governments that specify design criteria, the following manuals and websites are particularly helpful and should be referenced for more detail:

- *Urban Storm Drainage Criteria Manual, Volume 3-Best Management Practices* (UDFCD 1999) (www.udfcd.org)
- *Denver Water Quality Management Plan* (WWE et al. 2004)
- *Urban Runoff Quality Management*, *Water Environment Federation Manual of Practice No. 23 and American Society of Civil Engineers Manual and Report on Engineering Practice No. 87* (WEF and ASCE 1998)
- *Design and Construction of Urban Stormwater Management Systems, ASCE Manual and Reports of Engineering Practice No. 77 and WEF Manual of Practice FD-20.* (ASCE and WEF 1992)
- *Green Industry Best Management Practices for the Conservation and Protection of Water Resources in Colorado* (GreenCO and WWE 2004) (www.greenco.org)
- Low Impact Development website (www.lowimpactdevelopment.org/)
- EPA Stormwater website (www.epa/gov/npdes/stormwater)

2.2 IMPLEMENTATION OF BMPs IN COLORADO

In Colorado, engineers, planners, developers and local governments face many challenges in implementing BMPs and should carefully consider factors such as:

- Widely varying statewide climatic conditions, ranging from heavy snowfall in mountain areas to the dry eastern plains, that may require adaptation to commonly used BMP designs.

- Significant variation in community development patterns and objectives, ranging from low density rural areas to ultra-urban conditions in Denver, as well as variation in the regulatory requirements among local governments.
- Water rights constraints under the prior appropriation doctrine that must be taken into consideration in BMP selection and design.
- Needed assurance of adequate water supply for BMPs with a permanent pool (e.g., constructed wetland) or that may require irrigation (e.g., grass swale).
- Topographic conditions such as clay soils and landslide areas that must be carefully considered in BMP designs, particularly BMPs that are infiltration-oriented.
- Significant variation in hydrologic conditions such as long duration, low intensity conditions from snowmelt to high peak intensity, short duration flows from thunderstorms.
- Prevalence of high-quality streams that have significant recreational use and tourism values and that host sensitive aquatic life, necessitating effective implementation of BMPs to protect receiving waters.
- Runoff management challenges posed by the prevalence of steep slopes.
- Increased maintenance requirements posed by road sanding for public safety during the winter in many areas.

In addition to these factors, those designing and implementing BMPs should always be sure that appropriate local, state and federal permits are obtained that are relevant to a particular development site. Chapter 4 addresses several of the common permits that should be considered.

2.3 SITE DESIGN PRACTICES

Throughout the country, increased recognition is being given to the importance of up-front land planning to reduce impacts of development. These types of strategies are referred to by a variety of terms such as “Low Impact Development” (LID), “Green Development,” “Smart Growth,” and “Better Site Design,” to name a few. Regardless of the terminology used, the basic strategy is to mimic a site's predevelopment hydrology to reduce impacts to receiving waters and to work with the natural environment to the extent practicable. The concept of minimizing directly connected impervious area is a key component of these strategies.

LID is an integrated approach that uses design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source for the purpose of mimicking the site’s predevelopment hydrology. Instead of conveying and treating stormwater in facilities located at the bottom of drainage areas, LID addresses stormwater through small, landscape features located at the lot level. Examples of LID “integrated management practices” include bioretention, permeable pavers, tree box planters, rain gardens, and disconnected downspouts.

Green Development or Smart Growth strategies consider factors beyond the immediate development and redevelopment area, helping to minimize urban sprawl and its impacts, while recognizing the interconnectedness of the natural environment to development. Communities throughout the country have also moved toward these types of developments (see http://www.sustainable.doe.gov/greendev/ for examples). Zoning ordinances and municipal planning strategies are key components of Smart Growth and Green Development strategies and require cooperation across local government departments and regional agencies.

2.4 STRUCTURAL BMP TYPES

Structural BMPs include a variety of practices that can be designed and constructed to treat stormwater runoff. A brief overview of practices commonly used in Colorado follows. Design criteria for these practices can be obtained from local governments or from regional agencies such as UDFCD. Highlights of various BMPs are provided below based on the *Denver Water Quality Management Plan* (WWE et al. 2004) and the *Urban Storm Drainage Criteria Manual—Volume 3, Best Management Practices* (UDFCD 1999). A "treatment train" approach that incorporates a combination of BMPs is recommended.

2.4.1 GRASS BUFFERS

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 after a moderate amount of sediment and thatch has accumulated. When used adjacent to parking lots, consider slotted curb, other vehicular controls, or reinforced turf at the edge of the pavement to reduce wheel rutting of the buffer. Avoid heavy use of fertilizers that will undermine stormwater quality goals. Provide sheet flows (unconcentrated flows) to grass buffers to reduce erosion.

Landscape Considerations: Select turf or native grasses appropriate to the surrounding landscape. Supplemental irrigation is necessary to establish and maintain turf and should be applied based on water requirements of the selected plant species. When groundwater is close to the surface, use wetland grasses that can tolerate inundation. Dense groundcovers with fibrous root systems may also be considered.

Considerations for Mountain Developments: Snow storage from plowing operations on grass buffer areas tends to smother vegetation from the sand in plowed snow. If practical, store snow upgradient of grass buffers and use the buffer to filter runoff as the snow melts. On steep slopes, grass buffers may not be the best BMP because of the tendency of runoff to concentrate over shorter distances on steep slopes.

2.4.2 GRASS SWALES

A grass swale is a gently depressed, turf-lined channel that slowly conveys stormwater, promoting infiltration.

Typical Applications: Use as a flow conveyance facility in lieu of a storm sewer. Use along curbless streets or to capture flow from grass buffers.

Operation and Maintenance Considerations: In locations where routine mowing is planned, provide an underdrain, turf reinforcement, or rock mulch and avoid mowing following extended periods of precipitation. Mow side slopes, as needed.

Landscape Considerations: Irrigated turfgrass provides a stable surface for storm flows, but requires regular mowing, which may be difficult when wet. Consider using native grasses that require less frequent mowing. Woody plant material should be avoided because it may trap trash and debris and become difficult to maintain.

Considerations for Mountain Developments: Grass swales may not be practical in the mountain areas subject to significant road sanding. Even without grass, roadside ditches can provide water quality benefits by promoting infiltration. Use check dams in roadside ditches to slow runoff and encourage infiltration. Because of heavy sediment load to ditches in road sanding areas, regular maintenance is particularly important.

2.4.3 POROUS PAVEMENT

Both porous pavement and porous pavement detention consist of paver blocks or other reinforcement with sufficient void space to allow stormwater to percolate. Porous pavement detention is flat and includes a shallow storage area above the surface for the water quality capture volume (WQCV). Typical types of porous pavement used in Colorado include:

1. Modular Block Porous Pavement
2. Cobblestone Block Porous Pavement
3. Reinforced Grass Pavement
4. Poured Porous Concrete Pavement
5. Porous Gravel Pavement

Of these types, modular block porous pavement and porous gravel pavement may be used in porous pavement detention installations. Experience along the Front Range indicates that properly designed, constructed and maintained porous pavement can be highly effective at reducing runoff volume.

Typical Applications: Use reinforced grass pavement or planted modular block porous pavement in landscape areas used for maintenance access, in infrequently used overflow parking lots, and adjacent to curbless streets where wheel rutting is a concern. In higher traffic and parking areas, use cobblestone block porous pavement or poured porous concrete pavement. Porous gravel pavement may be considered for industrial land uses where there is little likelihood of groundwater contamination.

Operation and Maintenance Considerations: Void spaces can become clogged over time and require periodic maintenance to re-establish infiltration capacity. Blocks planted with turf cannot easily be plowed.

Landscape Considerations: Turf grown in pavers is particularly susceptible to drought, and must be irrigated. Consider irrigation head locations when establishing vehicle routes. Vehicles tend to compact soils, making vegetation growth difficult. Consider cobblestone block porous pavement or poured porous concrete pavement for paved pedestrian areas and walkways to reduce tripping hazards.

Considerations for Mountain Developments: Durability (given freeze-thaw cycles), plugging of pores from excessive sediment accumulation and maintenance are factors to consider for applications in mountainous areas. Technical literature demonstrates that porous pavement technologies can be effective in cold climates when appropriate consideration is given to these and other factors. One potential advantage of porous pavements with void space beneath the pervious surface is accelerated melting of accumulated ice and snow.

2.4.4 POROUS LANDSCAPE DETENTION

Porous landscape detention is a depressed landscape area with suitable soil that promotes filtration and infiltration of runoff.

Typical Applications: Parking islands, medians and buffers, courtyards, planters, and green roofs. Excellent on sites with minimal space for detention where landscape and stormwater quality can be combined. Geotechnical and foundation issues must be carefully considered when selecting and locating porous landscape detention facilities and designing underdrains and linings.

Operation and Maintenance Considerations: Growing medium will have to be removed and replaced periodically to maintain performance when clogging reduces infiltration capacity to unacceptable levels. Access to facility must be provided to enable maintenance operations.

Landscape Considerations: A wide variety of plant types is possible, ranging from irrigated bluegrass turf to native grasses, groundcovers, flowers, and shrubs. Trees should not be included in porous landscape detention areas because the infiltration matrix needs to be replaced periodically; however, trees may be included in oversized porous landscape detention, or outside of porous landscape detention. Dense shrub plantings may become difficult to maintain and must be removed for major maintenance requiring removal of growing medium. If planted with trees, a three-foot radius around each tree should not include underdrains or be counted as porous landscape detention volume. Consider stonework or pedestrian-oriented pavers within the installation. Consider the use of a non-floatable mulch as a water-retaining element of the BMP.

Considerations for Mountain Developments: Porous landscape detention has been successfully implemented in mountain areas in Colorado, including Summit County. Sediment accumulation and potential for soil media plugging are increased if porous landscape detention is used for storage of snow removed from impervious areas, and frequent maintenance should be anticipated for porous landscape detention areas that are adjacent to impervious areas that are sanded. Use of a thick layer of mulch that is removed and replaced seasonally is one approach to reducing plugging of the underlying media. Underdrains are advisable in many mountainous areas due to soils with poor infiltration capacity and/or concerns with slope stability due to excessive infiltration of water.

CHAPTER 15
STORM DRAINAGE
WATER QUALITY

SECTION 2
BEST
MANAGEMENT
PRACTICES

2.4.5 DETENTION BASIN

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

1. Extended detention basin
2. Sand filter extended detention basin
3. Constructed wetland basin
4. Retention pond

These basins are generally intended to serve watershed areas greater than one acre, with areas less than one acre served by WQCV 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, and if water rights issues are considered and addressed. Flood control detention may be designed in a surcharge zone above any of the water quality detention basins identified above. See Chapter 13 for additional considerations related to retention ponds.

Typical Applications: Watershed areas typically greater than one acre, generally located in landscape areas.

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

Landscape Considerations: Locate basins along major roads when consistent with zoning and urban design requirements, and when the basin can be designed 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, which is 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, but 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 designed in accordance with the International Building Code. Locate walls away from main view points to and from the site.

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.

Considerations for Mountain Developments: Two critical components of detention basin designs in mountain areas are the forebay and the outlet structure. Forebays are important due to high sediment loads from road and parking lot sanding, steep slopes and prevalence of erosive soils. A well-designed forebay will trap coarse particulate matter in a well-defined and easy to maintain area near the pond inlet(s), improving maintainability of the pond and reducing the potential of heavy sediment loads to smother vegetation on the pond bottom. The potential for clogging from freezing is a key consideration for outlet design, and standard designs used on the Front Range may be problematic. Local governments and agencies such as the Northwest Colorado Council of Governments can provide design guidance based on many years of experience with outlets clogged by ice. The ability to maintain the outlet to remove ice or to prevent the buildup of ice is critical in the spring before runoff and rainstorms.

2.4.6 CONSTRUCTED WETLANDS

For sites with sufficient water to support wetlands, detention facilities can be developed as a constructed wetland basin. The treatment wetland in the bottom of the basin utilizes physical, chemical, and biological processes in the water, soil, root zones, and vegetation to provide additional treatment of stormwater. Design guidance for treatment wetlands can be found in the *Urban Storm Drainage Criteria Manual Volume 3*. In mountain areas, the considerations listed for detention basins in Section 2.3.6 also apply to constructed wetlands.

CHAPTER 15
STORM DRAINAGE
WATER QUALITY

SECTION 2
BEST
MANAGEMENT
PRACTICES

2.4.7 UNDERGROUND FACILITIES/PROPRIETARY DEVICES

Over the last decade, many proprietary stormwater BMPs have been developed; many of these are subsurface, vault-type treatment devices. Treatment of stormwater in underground vault-type devices is generally discouraged due to long-term maintenance concerns with such devices that are often "out-of-sight, out-of-mind." In cases where space constraints do not allow above-ground treatment, a variety of proprietary stormwater devices are available. These devices are best suited to removal of coarse-grained material or as pre-treatment devices for other BMPs.

In mountain areas with heavy sediment loads from sanding, maintenance of these facilities can be particularly burdensome. These devices should be allowed only when no viable volume-based surface treatment BMP can be engineered.

2.5 SOURCE CONTROLS

Pollution source controls, also commonly referred to as non-structural BMPs, are a key component of any effective stormwater management strategy and should be integrated into plans for all development types. This type of BMPs can generally be described as a variety of practices intended to prevent or limit the entry of pollutants into stormwater runoff. In contrast to structural BMPs, source controls do not normally involve construction, but instead focus on measures to minimize pollution at its source, thereby reducing the amount of pollutants that need to be removed by downstream structural BMPs. Most source controls depend on behavioral change, which in turn depends on public education. Non-structural approaches are particularly important in areas that have already been developed and are a key strategy in reducing pollution when new structural controls are not an option due to cost or space constraints.

Many non-structural and structural practices are interrelated, but for purposes of an overview, non-structural/source control BMPs have been grouped into the following general categories:

- Public Outreach and Education—Examples include educating citizens and business owners about topics such as automotive product disposal; good housekeeping practices at commercial, restaurant and retail sites; construction site training; industrial good housekeeping practices; inlet stenciling activities; proper pesticide/herbicide use; and educational programs at schools.
- Illicit Discharge and Detection Programs—This involves identification, detection and prevention of illicit discharges to storm sewers. This BMP relies on other non-structural BMPs such as public education and proper waste disposal programs. Examples of illicit discharges include illegal dumping, accidental chemical spills and illicit connections of sanitary sewers to storm sewers.
- Source Controls—Examples include minimizing exposure of pollutants to stormwater at facilities such as automobile maintenance sites, salvage facilities and service stations; commercial, restaurant and retail sites; construction sites; farming and agricultural sites; and industrial sites. Activities at such sites requiring particular attention include outside materials storage, above ground storage tanks, loading and unloading areas, vehicle washing, fueling, outside manufacturing, etc.

- Recycling/Waste Disposal Programs—Examples include household toxics collection and recycling programs and leaf and landscaping waste collection.
- Good Housekeeping Practices/Spill Prevention and Response—Examples include developing spill prevention measures, identifying spill areas, implementing material handling procedures, and spill plan development.
- Municipal Maintenance Practices—Examples include catch basin cleaning; maintenance of structural BMPs; parking lot and street sweeping; road and street pavement repair, sealing, overlay, etc.; road salting and sanding; roadside ditch cleaning and restoring.
- Land Use Planning and Management (Programmatic) Strategies—Examples include new development planning procedures; procedures for site planning at construction sites; protective covenants; riparian buffer zone setbacks; Low Impact Development, Green Development, and Smart Growth development strategies, as discussed in Section 2.3.