

APPENDIX E STRUCTURAL BEST MANAGEMENT PRACTICES

Permanent structural best management practices for new development and significant redevelopments are summarized in the following. For detailed descriptions, sizing and design criteria, and design procedures refer to Volume 3 of the UDFCD Urban Storm Criteria Manual. Specifically Chapter 03 titled BMP Planning for New Development and Significant Redevelopment and Chapter 04 Structural Best Management Practices.

Applying MDCIA to a Site

To reduce runoff peaks and volumes from urbanizing areas, a practice generally termed “*minimizing directly connected impervious areas*” (MDCIA) is utilized. Minimizing directly connected impervious area requires a basic change in land development design philosophy. This change seeks to reduce paved areas, use porous pavement and direct stormwater runoff to landscaped areas, grass buffer strips, and grass-lined swales to slow down the rate of runoff, reduce runoff volumes, attenuate peak flows, and encourage filtering and infiltration of stormwater.

Traditional land development practices have not focused on water quality enhancement. Instead, they promoted runoff from rooftops, parking lots, driveways, and roads to quickly flow to a curb and gutter and to a formalized stormwater conveyance system. This approach to drainage concentrates runoff quickly, which results in a fast responding system, increased runoff volumes, and relatively large peak runoff rates during small storms.

Minimizing DCIAs can be made an integral part of landscape and drainage planning for any development.

Drainage from rooftop collection systems can direct flow to landscaped areas, infiltration areas such as porous landscape detention and porous pavement, grassed buffer strips, and to grass swales. Instead of using solid curbing, eliminate curbing or use slotted curbing along with stabilized grass shoulders and swales. Residential driveways can be porous pavement or the runoff from them can be redirected from flowing directly into the street. Large parking lots can reduce DCIAs by using porous pavement to encourage local infiltration or storage. Roadways and other paved areas must still adhere to existing codes.

Site slopes should be capable of directing stormwater runoff by gravity in a sheet flow away from buildings, roads, and parking lots toward grass-covered or porous pavement covered areas. The runoff then needs to flow as a sheet over these porous surfaces before it reaches swales, storage, stormwater collection, and stormwater conveyance systems. As a result, in areas of high permeability soils (Hydrologic Soil Class A and B soils), the ground can provide for infiltration of large portions of surface runoff. Where less permeable soils are present, significant runoff losses can also be achieved, while the use of sand trenches with underdrains under grass swales can be used to reduce the nuisance of standing water.

Benefits of Reducing Imperviousness

- Increased infiltration and decreased rate and volume of site runoff
- Decreased *WQCV* and, in turn decreased size of required *WQCV* facilities
- Decreased peak runoff rates and volumes for downstream conveyance and detention facilities
- Reduced need for irrigation
- Less curb and gutter
- Smaller storm sewer systems
- Decreased pavement areas
- Decreased runoff rates and volumes further downstream in watershed, especially if MDCIA is used on a widespread basis

Four principles should be used when selecting structural BMPs in newly developing and redeveloping urban areas:

- **Employ Runoff Reduction Practices.** The principal behind MDCIA is twofold -- to reduce impervious areas and to route runoff from impervious surfaces over grassy areas to slow down runoff and promote infiltration. The benefits are less runoff, less stormwater pollution, and less cost for drainage infrastructure.
- **Provide Water Quality Capture Volume (WQCV).** A fundamental requirement for any site addressing stormwater quality is to provide WQCV. One or more of six types of water quality basins, each draining slowly to provide for long-term settling of sediment particles, may be selected.
- **Stabilize Drainageways.** Drainageway, natural and manmade, erosion can be a major source of sediment and associated constituents, such as phosphorus. Natural drainageways are often subject to bed and bank erosion when urbanizing areas increase the frequency, rate, and volume of runoff. It is important that drainageways adjacent to or traversing development sites be stabilized. One of three basic methods of stabilization may be selected.
- **Consider Need for Industrial and Commercial BMPs.** If a new development or significant redevelopment activity is planned for an industrial or commercial site, the need for specialized BMPs must be considered.

The Structural BMPs discussed below were selected based on potential effectiveness in a semiarid climate, local applicability, maintenance considerations, and cost. Not to be considered the final list, other BMPS may also be appropriate given the situation. These include manufactured devices such as water quality vaults and inlets, infiltration trenches, oil/grease separators, fabric inserts for inlets, and stream buffer setbacks.

It is recommended that discussions regarding proposed permanent structural BMPs occur early in each project between the developer's planner, engineer and City of Cañon City engineering staff.

GRASS BUFFER (GB)

Description: Grass buffer (GB) strips are uniformly graded and densely vegetated areas of turf grass. They require sheet flow to promote filtration, infiltration and settling to reduce runoff pollutants. GBs differ from grass swales as they are designed to accommodate overland sheet flow rather than concentrated or channelized flow. They can be used to remove larger sediment from runoff off impervious areas.

Whenever concentrated runoff occurs, it should be evenly distributed across the width of the buffer via a flow spreader. This may be a porous pavement strip or another type of structure to achieve uniform sheet-flow conditions. GBs can also be combined with riparian zones in treating sheet flows and in stabilizing channel banks adjacent to major drainageways and receiving waters. GBs can be interspersed with shrubs and trees to improve their aesthetics and to

***Maintenance!
All temporary and permanent
erosion and sediment control
practices shall be maintained and
repaired by the owner during the
construction phase as needed to
assure continued performance of
their intended function. All
facilities must be inspected and
replaced if necessary, following
each precipitation or snowmelt
event that results in runoff***

provide shading. Irrigation in the semi-arid climate of Colorado is required to maintain a healthy and dense grass on the GB to withstand the erosive forces of runoff from impervious areas.

Application: A GB is located adjacent to impervious areas and can be used in residential and commercial areas and along highways and roads. Because their effectiveness depends on having an evenly distributed sheet flow over their surface, the size of the contributing area, and the associated volume of runoff have to be limited. Flow can be directly accepted from a parking lot, roadway or building roof, provided the flow is distributed uniformly over the strip. GBs provide only marginal pollutant removal and require that follow-up structural BMPs be provided. They do, however, help to reduce somewhat the runoff volume from smaller storms.

GRASS SWALE (GS)

Description: A grass swale (GS) (sedimentation facility) is a densely vegetated drainageway with low-pitched sideslopes that collect and convey runoff. Design of their longitudinal slope and cross-section size, forces the flow to be slow and shallow, thereby facilitating sedimentation while limiting erosion. Berms or check dams should be installed perpendicular to the flow as needed to encourage settling and infiltration.

Application: A GS can be located to collect overland flows from areas such as parking lots, buildings, residential yards, roadways and grass buffer strips (GBs). They can be made a part of the plans to minimize a directly connected impervious area by using them as an alternative to a curb-and-gutter system. A GS is set below adjacent ground level, and runoff enters the swales over grassy banks or rundowns. The potential exists for wetland vegetation to become established if the swale experiences standing water or if there is a base flow.

POROUS PAVEMENT (PP)

Description: Porous Pavement (PP) covers a variety of stabilized surfaces that can be used for the movement and parking of vehicles (automobiles, trucks, construction equipment, light aircraft, etc.) and storage of materials and equipment. It differs from conventional pavement. It is designed to infiltrate stormwater runoff instead of shedding it off the surface. PP offers the advantage of decreasing the effective imperviousness (IA) of an urbanizing or redevelopment site, thereby reducing runoff and pollutant loads leaving the site.

PPs can be designed with and without underdrains. Whenever underdrains are used, infiltrated water will behave similarly to interflow and will surface at a much reduced rate over extended periods of time. All types of PP help to return stormwater runoff hydrology to more closely resemble pre-developed conditions. However, the actual consumptive use of water falling onto the ground is considerably less than under pre-developed conditions and for grass lawns in urban areas. The designer needs to consult with a geotechnical engineer as to the suitability of each type of PP for the loads and traffic it will support and carry, and the geologic conditions the pavement will rest upon.

What follows is a description of five types of porous pavement and defines their acronyms. These will be used throughout the remainder of this section of the Manual:

1) Modular Block Pavement (MBP)

This pavement consists of concrete block units with open surface voids laid on a gravel subgrade with open surface voids. These voids occupy at least 20% of the total surface area that are filled with sand (ASTM C-33 sand fine concrete aggregate or mortar sand) or sandy loam turf that has at least 50% sand by weight in its volume. However, unless the pavement will be watered regularly (i.e., using a sprinkler system) to keep the vegetation viable, concrete sand infill is the recommended material. An alternate application of MBP provides for a surcharge zone above its surface to detain runoff and provide storage space for the water quality capture volume (WQCV).

2) Cobblestone Block Pavement (CBP)

This pavement consists of concrete block units replicating the appearance of cobblestone that create open voids by beveling the corners of each block and/or wider spacing between the blocks. One of the commercial “cobblestone” products that meets this description is Eco-stone™ made by Pavestone Co®. These “cobblestones” are laid on a gravel subgrade. The surface area has voids that occupy at least 8% of the total surface area and are filled with sand (ASTM C-33 sand; sometimes referred to as fine concrete aggregate). The recommended use of sand for the in-fill material differs from the material recommended by the manufacturer. This change is essential for improving in water quality, especially when the installation has an underdrain.

3) Reinforced Grass Pavement (RGP)

This is a stabilized grass surface intended for use in parking lots that experience intermittent use. It has been shown to function well under wet-weather conditions and, when properly designed and installed, it will infiltrate rainwater at rates that equal or exceed the infiltration rates of NRCS Hydrologic Soil Group Type B soils. The grasses need to be mowed on a cycle that depends on the grass types and whether or not irrigation is used. Use of irrigated grasses should be considered for more actively-used parking lots.

4) Poured Porous Concrete Pavement (PCP)

This is a monolithically poured porous concrete pavement that has 15% to 21% of its volume as void ratio. These voids within the concrete are achieved by the eliminating of the fine sand aggregate from the concrete mix. They provide the flow paths for rainwater from the surface of the pavement to the base course underlying it. Because the integrity of the concrete structure may be harmed by standing water during freezing weather, the use of PCP is not recommended for use in Porous Pavement Detention installations. It is critical that sufficient aggregate base course layer is provided under the porous concrete slab to store the runoff and allow it to infiltrate slowly into the ground to be drained using an underdrain pipe system.

5) Porous Gravel Pavement (PGP)

This is a loose gravel-surface paving that is most appropriate for industrial sites and uses. Because the integrity of the gravel surface is not likely to be harmed by standing water during freezing weather, this pavement surface can also be used in Porous Pavement Detention installations. It is imperative that there is sufficient aggregate base course to store the runoff and allow it to infiltrate slowly into the ground or be slowly drained using an underdrain pipe system.

POROUS PAVEMENT DETENTION (PPD)

Description: Porous pavement detention (PPD) consists of an installation of MBP that is flat (i.e., $S_o=0.00\%$ in all directions) and is provided with a 2-inch deep surcharge zone to temporarily store the WQCV draining from an adjacent drainage area. Runoff will infiltrate into the void spaces of the gravel base course through the sand filter media and sandy loam turf. The latter is not used for the PPD facility to insure more rapid drainage of the parking surface and easy maintenance when the media needs to be replaced to maintain rapid drainage of the ponding areas. The ponded and filtered water slowly exits through an underdrain.

Application: PPD may be used in the same types of low vehicle movement zones identified for MBP with the driveways leading up to them being solid pavement.

POROUS LANDSCAPE DETENTION (PLD)—SEDIMENTATION FACILITY

Description: Porous landscape detention (PLD) consists of a low-lying vegetated area underlain by a sand bed with an underdrain pipe. A shallow surcharge zone exists above the PLD for temporary storage of the WQCV. During a storm, accumulated runoff ponds in the vegetated zone and gradually infiltrates into the underlying sand bed, filling the void spaces of the sand. The underdrain gradually dewateres the sand bed and discharges the runoff to a nearby channel, swale, or storm sewer. Like PPD, this BMP allows WQCV to be provided on a site that has little open area available for stormwater detention.

Application: A PLD can be located in just about any of the open areas of a site. It is ideally suited for small installations such as: Parking lot islands, Street medians, Roadside swale features, and Site entrance or buffer features

EXTENDED DETENTION BASIN (EDB)—SEDIMENTATION FACILITY

Description: An extended detention basin (EDB) is a sedimentation basin designed to totally drain dry sometime after stormwater runoff ends. It is an adaptation of a detention basin used for flood control. The primary difference is in the outlet design. The EDB uses a much smaller outlet that extends the emptying time of the more frequently occurring runoff events to facilitate pollutant removal. The EDB's drain time for the brim-full water quality capture volume (i.e., time to fully evacuate the design capture volume) of 40 hours is recommended to remove a significant portion of fine particulate pollutants found in urban stormwater runoff. Soluble pollutant removal can be somewhat enhanced by providing a small wetland marsh or ponding area in the basin's bottom to promote biological uptake. The basins are considered to be "dry" because they are designed not to have a significant permanent pool of water remaining between storm runoff events. However, EDB may develop wetland vegetation and sometimes shallow pools in the bottom portions of the facilities.

Application: An EDB can be used to enhance stormwater runoff quality and reduce peak stormwater runoff rates. If these basins are constructed early in the development cycle, they can also be used to trap sediment from construction activities within the tributary drainage area. The accumulated sediment, however, will need to be removed after upstream land disturbances cease and before the basin is placed into final long-term use. Also, an EDB can sometimes be retrofitted into existing flood control detention basins.

SAND FILTER EXTENDED DETENTION BASIN (SFB)

Description: A sand filter extended detention basin (SFB) is a stormwater filter that consists of a runoff storage zone underlain by a sand bed with an underdrain system. During a storm, accumulated runoff ponds in the surcharge zone and gradually infiltrates into the underlying sand bed, filling the void spaces of the sand. The underdrain gradually dewateres the sand bed and discharges the runoff to a nearby channel, swale, or storm sewer.

Application: A SFB is generally suited to onsite configurations where there is no base flow and is put in operation when the upstream catchment no longer has construction or grading/landscaping activities.

CONSTRUCTED WETLANDS BASIN (CWB)—SEDIMENTATION FACILITY

Description: A constructed wetlands basin (CWB) is a shallow retention pond (RP), which requires a perennial base flow to permit the growth of rushes, willows, cattails, and reeds to slow down runoff and allow time for sedimentation, filtering, and biological uptake. It is a sedimentation basin and a form of a treatment plant.

Application: A CWB can be used as a follow-up structural BMP in a watershed, or as a stand-alone onsite facility if the owner provides sufficient water to sustain the wetland. Flood control storage can be provided above the CWB's water quality capture volume (WQCV) pool to act as a multiuse facility. CWB requires a net influx of water to maintain its vegetation and microorganisms. A complete seasonal water budget analysis is necessary to ensure the adequacy of the base flow.

RETENTION POND (RP)—SEDIMENTATION FACILITY

Description: A Retention Pond (RP) is a sedimentation facility and a form of a treatment plant that has a permanent pool of water that is replaced with stormwater, in part or in total, during storm runoff events. In addition, a temporary detention volume is provided above this permanent pool to capture storm runoff and enhance sedimentation. RPs are similar to EDBs because they are designed to capture in total, as a surcharge to the pond, runoff from frequently occurring storms. However, RP differs from extended detention basins (EDBs) because the influent water mixes with the permanent pool water as it rises above the permanent pool level. The surcharge captured volume above the permanent pool is then released over 12 hours. RP requires a dry-weather base flow to maintain the permanent pool. They can be very effective in removing pollutants, and, under the proper conditions, can satisfy multiple objectives.

Application: A RP can be used to improve the quality of urban runoff from roads, parking lots, residential neighborhoods, commercial areas, and industrial sites and is generally used as regional or follow-up treatment because of the base-flow requirements. It can be used as an onsite BMP if the owner provides sufficient water to keep the pond full between storms. A RP works well in conjunction with other BMPs, such as upstream onsite source controls and downstream filter basins or wetland channels.

The State Engineer administers all waters within the state under constitutional provisions. In Colorado, surface water is any water in any form that flows on the land surface. This includes rivers and streams, intermittent creeks or springs, irrigation canals and ditches, rainfall and snow. Water projects now involve a complex process of planning, permitting, and engineering to prove that unappropriated water is available for use. If the water court approves a conditional decree, the project must be carried on with due diligence until its completion. Otherwise, the water right is forfeited. In Colorado, water rights are considered a private property right. Water rights can be sold or inherited and prices may vary according to supply and demand. The consumptively used portion of a water right may be transferred to another area or use with approval of the water court, with the stipulation that other water rights are not injured.

CONSTRUCTED WETLANDS CHANNEL (CWC)—SEDIMENTATION FACILITY

Description: Constructed wetland-bottomed channels takes advantage of dense natural vegetation (rushes, willows, cattails, and reeds) to slow down runoff and allow time for settling out sediment and biological uptake. It is another form of a sedimentation facility and a treatment plant.

Constructed wetlands differ from "natural" wetlands as they are artificial and are built to enhance stormwater quality. Sometimes small wetlands that exist along ephemeral drainageways on Colorado's high plains may be enlarged and incorporated into the constructed wetland system. Such action, however, requires the approval of federal and state regulators.

Application: Wetland bottom channels can be used in the following two ways:

- A wetland can be established in a totally man-made channel and can act as a conveyance system and water quality enhancement facility. This design can be used along wide and gently sloping channels.
- A wetland bottom channel can be located downstream of a stormwater detention facility (water quality and/or flood control) where a large portion of the sediment load can be removed. The wetland channel then receives stormwater and base flows as they drain from the detention facility, provides water quality enhancement, and at the same time conveys it downstream. This application of a wetland channel is recommended upstream of receiving waters and within lesser (i.e., ephemeral) receiving waters, thereby delivering better quality water to the more significant receiving water system.

A CWC requires a net influx of water to maintain their vegetation and microorganisms. A complete water budget analysis is necessary to ensure the adequacy of the base flow.

COVERING OF STORAGE/HANDLING AREAS

Description: Covering of areas for storage and for handling facilities associated with potential industrial or commercial pollutants, such as salt piles, oil products, pesticides, fertilizers, etc. will reduce the likelihood of storm water contamination and will prevent loss of material from wind or rainfall erosion. Coverings can be permanent or temporary and consist of tarpaulins, plastic sheeting, roofing, enclosed structures, or any other device that prevent precipitation and wind from spreading possible contamination.

Application: Covering is appropriate for areas where solids (gravel, salt, compost, building materials, etc.) or liquids (oil, gas, tar, etc.) are stored, prepared, or transferred.

SPILL CONTAINMENT AND CONTROL

Description: Spill containment within industrial and some commercial sites consists of berming and gates that allow for the control of spilled material. Berming consists of temporary or permanent curbs or dikes that surround a potential spill site preventing spilled material from entering surface waters or storm sewer systems. The berm may be made concrete, earthen material, metal, synthetic liners, or any material that will safely contain the spill. A potential spill site is one that allows the storage or transfer of potential spill material. Spill material is that which is not allowed into surface waters or storm sewer systems according to local, state, or federal regulations. Spill control devices include valves, slide gates, or any other device which can contain material when required and then release the spilled material in a controlled fashion.

Erosion Control Criteria
Areas used for storage of chemicals, petroleum-based products and waste materials, including solid and liquid waste, shall be designed to prevent discharge of these materials in the runoff from a construction site

Application: Two methods of berming can be used: 1) containment berming that contains an entire spill and 2) curbing that routes spill material to a collection basin. Containment berming should be of sufficient size to safely contain a spill from the largest storage tank, rail car, tank truck, or other containment device located inside the possible spill area. A small collection basin should be provided for removal of storm water and leaked material.

Curbing is used to route spill material to a large collection basin. The curb should be of sufficient size to safely route a spill from the largest storage tank, rail car, tank truck, or other containment device located inside the possible spill area. A containment device must be provided to safely store the spilled material until removal is possible.

If the capacity of the containment berming or the collection basin are exceeded, a spill control device must be used. The spill control device ideally would convey flow into a portable containment device for removal of the material. However, if material is escaping the berming area through the spill control device, two available means of controlling a spill are to use sorbent (adsorption and absorption through chemical processes) or gelling agents (physically or chemically gel the spill material; solidification eventually occurs).