8. Water Quality

8.1 General

Nonpoint source pollution is a primary cause of polluted stormwater runoff and water quality impairment, and nonpoint source pollution can come from many sources. Development can concentrate and increase the amount of these nonpoint source pollutants. As stormwater runoff moves across the land surface, it has the potential to pick up and carry away both natural and human-made pollutants, depositing them into Little Rock's water resources.

In urbanizing watersheds, the potential for water quality degradation occurs because of development and other human activities. Erosion from construction sites and other disturbed areas can contribute large amounts of sediment to streams. As construction and development proceed, impervious surfaces replace the natural land cover and pollutants from human activities begin to accumulate on these surfaces. During storm events, these pollutants could be washed off into the streams. Excess stormwater also has the potential to cause discharges from sewer overflows and leaching from septic tanks. There are several other causes of potential nonpoint source pollution in urban areas that are not specifically related to wet weather events including leaking sewer pipes, sanitary sewage spills, illegal dumping of pollutants into streams or storm drains by individuals, and illicit discharge of commercial/industrial wastewater and wash waters to storm drains.

8.2 Low Impact Development

This section also provides guidance for using the natural properties and existing conditions of a site to optimize the management of stormwater using Low Impact Development (LID).

After conservation areas are delineated, development of site design should include planning to avoid future downstream stormwater impacts from the development. Planning techniques should:

- Fit the design to the terrain.
- Reduce the limits of clearing and grading.
- Locate development in less hydrologically sensitive areas.
- Utilize open space development and/or nontraditional lot designs for residential areas.
- Consider creative development design.

More details on practices that reduce the impact of development are covered below.

Conserve Natural Features and Resources

The conservation of natural features such as floodplains, higher permeability soils, and vegetation helps to retain predevelopment hydrologic functions, thus reducing runoff volumes. Impacts to natural features should be minimized by reducing the extent of construction impacts and minimize development practices that are averse to predevelopment hydrology functions. Conservation techniques include the following:

- Build upon the least permeable soils and limit construction activities to previously disturbed soils.
- Avoid mass clearing and grading and limit the clearing and grading of land to the minimum needed to construct the development and associated infrastructure.
- Avoid disturbance of vegetation and highly erodible soils on slopes and near surface waters.
- Leave undisturbed stream buffers along both sides of natural streams as covered in Section 8.5.2.
- Preserve sensitive environmental areas; historically undisturbed vegetation; and native trees as currently required in the City of Little Rock ordinances.
- Conform to watershed, conservation, and open space plans.

- Design development to fit the natural site terrain and build roadways along existing site contours wherever possible.
- Use cluster development to preserve higher permeability soils, natural streams, and natural slopes.
- Develop on previously developed sites (redevelopment or infill).

Minimize Soil Compaction

Soil compaction disturbs native soil structure, reduces soil porosity and permeability, affecting infiltration rates, and limits root growth and re-establishment of vegetation. While soil compaction is necessary within a structure footprint to provide structurally sound foundations, areas away from foundations are often excessively compacted by traffic during construction. Minimizing soil compaction can be achieved by the following methods:

- Reduce disturbance through design and construction staging practices.
- Limit areas of access for heavy equipment.
- Avoid extensive and unnecessary clearing and stockpiling of topsoil.
- Maintain existing topsoil and/or use quality topsoil during construction.
- Rapid establishment of vegetative cover in bare but otherwise undisturbed areas to minimize compaction by rainfall.
- Avoid working or driving on wet soil.
- Protect soil under tree canopies by covering with mulch or plywood to allow vehicle traffic for construction.

Reduce and Disconnect Impervious Surfaces

Reducing and disconnecting impervious surfaces increases the rainfall that infiltrates into the ground. Impervious areas may be reduced by maximizing landscaping and using pervious pavements. In addition, the number of impervious areas with direct hydraulic connections to impervious conveyances (e.g., driveways, walkways, culverts, streets, or storm drains) should be minimized. The following measures are applicable:

- Install green or blue roofs.
- Direct roof downspouts to vegetated areas, bioretention, cisterns, or planter boxes, and route runoff into vegetated swales instead of onto driveways and in gutters.
- Use porous pavements, where permitted.
- Install shared driveways that connect two or more homes, where permitted, or install residential driveways with center vegetated strips.
- Allow for shared parking in commercial areas.
- Maximize usable space, not through large building footprints but through taller buildings with more floors.
- Minimize impervious footprints.

8.3 Pollutants in Stormwater Runoff

8.3.1 Areas with High Pollution Discharge Potential

Areas with high pollutant discharge potential are areas of the urban landscape that often produce higher concentrations of certain pollutants, such as hydrocarbons or heavy metals, than are normally found in urban runoff. These areas merit special management and the use of specific pollution prevention activities and/or structural stormwater controls. Examples of areas with high pollutant discharge potential include:

- Gas / fueling stations.

- Vehicle maintenance areas.
- Vehicle washing / steam cleaning.
- Auto recycling facilities.
- Outdoor material storage areas.
- Loading and transfer areas.
- Landfills.
- Construction sites.
- Industrial sites.
- Industrial rooftops.

8.3.2 Stormwater Pollutant Sources

For effective stormwater management, it is important to understand the nature and sources of urban stormwater pollution. Table 8.1 summarizes the major stormwater pollutants and their effects.

Table 8.1 Summary of Urban Stormwater Pollutants

Constituents	Effects
Sediments: Total Suspended Solids (TSS), Dissolved Solids, Turbidity	Stream turbidity Habitat changes Recreation/aesthetic loss Contaminant transport Filling of lakes and reservoirs
Nutrients: Nitrate, Nitrite, Ammonia, Organic Nitrogen, Phosphate, Total Phosphorus	Algae blooms Eutrophication Ammonia and nitrate toxicity Recreation/aesthetic loss
Microbes: Total and Fecal Coliforms, Fecal Streptococci, Viruses, E.Coli, Enterocci	Ear/Intestinal infections Recreation/aesthetic loss
Organic Matter: Vegetation, Sewage, Other Oxygen Demanding Materials	Dissolved oxygen depletion Odors Fish kills
Toxic Pollutants: Heavy Metals (cadmium, copper, lead, zinc), Organics, Hydrocarbons, Pesticides/Herbicides	Human & aquatic toxicity Bioaccumulation in the food chain
Thermal Pollution	Dissolved oxygen depletion Habitat changes
Trash and debris	Recreation/aesthetic loss

8.4 Water Quality Criteria

The Total Suspended Solids (TSS) Reduction Method (TRM) focusses on the removal of 80% TSS from a selected rainfall runoff, 1.5 inches for new development and 1.3 inches for redevelopment in Little Rock. These runoff values represent the 90th and 85th percentile, respectively, of rainfall events that Little Rock experiences per year. The percentiles were calculated using rainfall records from the Little Rock airport (Adams Field) rain gage.

TSS Reduction Method (TRM)

The TSS Reduction Method follows the philosophy of removing pollutants and at least 80% of the TSS “where practicable” using a percentage removal performance goal. The approach provides treatment of the Water Quality Volume (WQ_V) from a site to reduce post-development TSS loadings by 80%, as measured on an average annual basis. This performance goal is based on the ADEQ NPDES small MS4 permit in accordance with U.S. EPA guidance.

The WQ_V is used to size stormwater control measures that work to remove pollutants from the runoff. The WQ_V is roughly equal to the runoff from the first 1.5 inches or 1.3 inches of rainfall within the catchment area. A stormwater management system designed to treat the WQ_V will treat the runoff from storm events of 1.5 inches or less, as well as the first 1.5 inches of runoff for larger storm events.

The volumetric runoff coefficient (Rv) was derived from a regression analysis performed on rainfall runoff volume data from several cities nationwide and is a shortcut method considered adequate for runoff volume calculation for the type of small storms considered in stormwater quality calculations.

The Water Quality Volume (WQv) is equal to a rainfall depth (P) of 1.5 inches (or 1.3 inches for redevelopment) multiplied by the volumetric runoff coefficient (Rv) and the site area (A), and is calculated using Equation 8.1 below:

$$\mathbf{WQ_V = \frac{PR_VA}{12}} \qquad \textbf{Eq. 8.1}$$

Where: WQv = water quality volume (ac-ft)

Rv = 0.05 + 0.009(I)
where I is the <u>percent</u> impervious cover (i.e., 50% impervious is 50 not 0.5)

A = site area (acres)

P = 1.5 inches (new development) or 1.3 inches (redevelopment)

<u>Determining the Water Quality Volume (WQ_V)</u>

- ***Measuring Impervious Area*: **The area of impervious cover shall be based on the proposed project plans and shall be independent of pre-construction conditions.
- ***Multiple Drainage Areas*:** When a development project contains or is divided into multiple drainage areas, WQ_V should be calculated and addressed separately for each drainage area.
- ***Off-site Drainage Areas:*** Off-site existing impervious areas are excluded from the calculation of the WQ_V volume.
- ***Determining the Peak Discharge for the Water Quality Storm:*** When designing off-line stormwater control measures, the peak discharge of the water quality storm (Q_{wq}) can be determined using the SCS method provided in Chapter 3. The water quality storm is equivalent to 1.5 inches (or 1.3 inches for redevelopment) of rainfall in 24 hours.
- ***Extended Detention of the Water Quality Volume:*** The water quality treatment requirement can be met by providing a 24-hour drawdown of a portion of WQ_V in a stormwater pond or wetland system. Referred to as water quality ED (extended detention), it is different than providing extended detention of the 1-year 24-hour storm for the channel protection volume (CP_V). Where used, the ED portion of the WQ_V may be included when routing the CP_V.

WQ_v can be expressed in cubic feet by multiplying by 43,560. WQ_v can also be expressed in watershed-inches as simply PR_v by removing the area (A) and the 12 from Equation 8.1.

8.5 Water Quality Volume and Sizing

There are two primary approaches for managing stormwater runoff and addressing the water quality (and quantity-based) criteria requirements on a development site:

- The use of site design practices to reduce the amount of stormwater runoff and pollutants generated and/or provide for natural treatment and control of runoff.
- The use of stormwater control measures to provide treatment and control of stormwater runoff.

8.5.1 Site Design as the First Step in Addressing Requirements

Using the site design process to reduce stormwater runoff and pollutants should always be the first consideration of the site designer and engineer in the planning of the stormwater management system for a development.

Site design concepts can be used as both water quantity and water quality management tools and can reduce the size and cost of required structural stormwater controls. The site design approach can result in a more natural and cost-effective stormwater management system that better mimics the natural hydrologic conditions of the site and has a lower maintenance burden.

8.5.2 Stream Buffer Requirements

Natural stream channels shall be preserved as continuous systems and not segmented on a project-by-project basis because the frequent intermixing of natural and man-made systems tends to degrade the function of both. Stream buffers (also called riparian buffers) are vegetated areas along and adjacent to streams where clearing, grading, filling, building of structures, and other activities are limited or prohibited. Stream buffers act as the "right-of-way" for the stream and protect and enhance water quality and stream health in two primary ways: (1) reducing the number of pollutants entering the stream in stormwater runoff flowing overland through the vegetated buffer; and (2) preserving and enhancing stream channel stability, in-stream habitat, and the stream's natural ability to process pollutants in stream flow.

The stream buffer shall be measured from the streambank of the active channel. Buffer widths shall meet or exceed the distances specified in Table 8.2. No clearing, grading, filling, or structures are allowed in stream buffer zones other than as authorized in Sections 8.5.2.1 and 8.5.2.2.

Table 8.2. Stream Buffer Width Requirements.

Contributing Drainage Area	Stream Category	Buffer Width (ft.)	
		Streamside Zone	Outer Zone
Greater than 4 square miles	A - Large stream	50	50
1 to 4 square miles	B - Small stream	40	40
160 to 640 acres	C - Large tributary	25	25
64 to 160 acres	D - Small tributary	15	15

8.5.2.1 Streamside Zone

The structures, practices, and activities permitted in the Streamside Zone of the buffer are limited to the following:

- Stream crossings for roads, drives, trails or other pedestrian paths, and utilities.
- Utility corridors if no feasible alternative exists.
- Stormwater discharge structures in accordance with City-approved stormwater plans only
- if discharge further upland is not feasible.
- Vegetation management to maintain or improve native vegetation, including:
  a. Removal of diseased, dead, or hazard trees.
  b. Tree pruning in accordance with accepted arborist practices.
  c. Selective spraying or mechanical removal of noxious or invasive vegetation
  d. consistent with accepted best practices.
  e. Vegetation planting and seeding to improve the density, species, and diversity of native vegetation.
- Removal of trash.
- Removal of accumulated debris to maintain stream flow conveyance.
- Water quality monitoring and stream gauging.
- City-approved stream bank stabilization measures.
- Maintenance of City-approved improvements, including utilities.

The above structures, practices, and activities shall be accomplished using methods that minimize soil disturbance, clearing of vegetation, and use of motorized equipment.

8.5.2.2 Outer Zone

The structures, practices and activities permitted in the Outer Zone of the buffer are limited to the following:

- All uses permitted in the streamside zone.
- Trail corridors that are designed to minimize stream buffer impacts.
- Fences.
- Stormwater control measures in accordance with City-approved stormwater plans only if it is not feasible to locate them outside (upland) of the stream buffer.
- Managed lawns are permitted in the Outer Zone of stream categories B-D although property owners are encouraged to preserve or plant native vegetation to increase the benefits of the buffer. Existing, healthy trees must be preserved in managed lawn areas and property owners are encouraged to plant trees in managed lawn areas. Managed lawns in Outer Zones shall not be fertilized unless as recommended by a soil test. Use of pesticides/herbicides on managed lawns in Outer Zones is discouraged and if used, shall be in accordance with integrated pest management practices.

8.5.3 Structural Stormwater Control Measures

Structural stormwater controls (sometimes referred to as *structural best management practices* or *BMPs*) are constructed stormwater management facilities designed to treat stormwater runoff and/or mitigate the effects of increased stormwater runoff peak rate, volume, and velocity due to urbanization.

This Manual recommends several water quality structural stormwater controls that can be implemented to help meet the stormwater management Minimum Standards.

The recommended water quality controls are divided into three categories:

1. General application controls.
2. Limited application controls.
3. Floatables control.

These controls are targeted at 80% TSS pollution reduction. Detention structural controls are discussed in Chapter 7.

8.5.3.1 General Application Controls

General application structural controls are recommended for use with a wide variety of land uses and development types. These structural controls have a demonstrated ability to effectively treat the Water Quality Volume (WQv) and are presumed to be able to remove 80% of the total annual average TSS load in typical post-development urban runoff when designed, constructed, and maintained in accordance with recommended specifications. Several of the general application structural controls can also be designed to provide water quantity control, i.e., downstream channel protection (CPv), overbank flood protection (Qp25) and/or extreme flood protection (Qf). General application controls are the recommended stormwater management facilities for a site wherever feasible and practical.

There are six types of general application controls, which are summarized below. They are broken up into two categories, water quality structural controls and low impact structural controls. Detailed descriptions of the water quality structural controls along with design criteria and procedures are provided in Appendix C, Stormwater Control Measures (SCMs).

Design for all basins (extended detention, bioretention, sand filter, etc.) shall have the following design features:

A. Basins shall be designed as offline facilities, with a splitter structure used to isolate the water quality volume. The splitter box, or other City Design Review Engineer approved flow diverting approach, should be designed to covey the 100-year storm event.
B. Online facilities may be approved only with an exception from the City Design Review Engineer. Exception may only be considered if the design engineer provides justifiable reason why the facility must be online and the facility is designed to contain the 100-year storm and meet all other requirements of a detention pond as outlined in Chapter 7 of this manual for capacity, freeboard, emergency overflow, access, etc.
C. In areas where it may be difficult to treat every drainage area leaving the site, an exception may be granted by the City Design Review Engineer to provide overtreatment of drainage areas. Exception will only be considered if design engineer has made every reasonable effort to treat as much of the site as possible, detailed calculations are provided showing the amount of overtreatment being provided to cover untreated portion of the site, and a maximum of 10% of the site is left untreated and accounted for in overtreatment of other drainage areas.

Water Quality Structural Controls

Stormwater Ponds

Stormwater ponds are constructed stormwater detention basins that have a permanent pool (or micropool) of water. Runoff from each rain event is detained and treated in the pool. Pond design variants include:

- Wet Pond.
- Wet Extended Detention Pond.
- Micropool Extended Detention Pond.
- Multiple Pond Systems.

Stormwater Wetlands

Stormwater wetlands are constructed wetland systems used for stormwater management. Stormwater wetlands consist of a combination of shallow marsh areas, open water, and semi-wet areas above the permanent water surface. Wetland design variants include:

- Shallow Wetland.
- Extended Detention Shallow Wetland.
- Pond/Wetland Systems.
- Pocket Wetland.

Sand Filters

Sand filters are multi-chamber structures designed to treat stormwater runoff through filtration, using a sand bed as the primary filter media. Filtered runoff may be returned to the conveyance system or allowed to fully or partially exfiltrate into the soil. The two sand filter design variants are:

- Surface Sand Filter.
- Perimeter Sand Filter.

Low Impact Structural Controls

Bioretention Areas

Bioretention areas are shallow stormwater basins or landscaped areas that utilize engineered or amended native soils and vegetation to capture and treat stormwater runoff. Runoff may be returned to the conveyance system or allowed to fully or partially exfiltrate into the soil.

Infiltration Trenches

An infiltration trench is an excavated trench filled with stone aggregate used to capture and allow infiltration of stormwater runoff into the surrounding soils from the bottom and sides of the trench.

Enhanced Swales

Enhanced swales are vegetated open channels that are explicitly designed and constructed to capture and treat stormwater runoff within dry or wet cells formed by check dams or other means. The two types of enhanced swales are:

- Dry Swale.
- Wet Swale/Wetland Channel.

8.5.3.2 Limited Application Controls

Limited application structural controls are those that are recommended only for limited use or for special site or design conditions. Generally, these practices:

1. Cannot alone achieve the 80% TSS removal target.
2. Are intended to address specific land use constraints or conditions.
3. May have high or special maintenance requirements that may preclude their use.

Limited application controls are typically used for *water quality treatment only*. Some of these controls can be used as a pretreatment measure or in series with other structural controls to meet pollutant removal goals. Limited application structural controls should be considered primarily for commercial, industrial, or institutional developments, and not residential developments.

The following limited application controls are provided for consideration in this Manual. Each is discussed in detail with appropriate application guidance in Appendix C, Stormwater Control Measures.

<u>Filtering Practices</u>

- Organic Filter.
- Underground Sand Filter.

<u>Wetland Systems</u>

- Submerged Gravel Wetland.

<u>Hydrodynamic Devices</u>

- Gravity (Oil-Grit) Separator.

<u>Proprietary Systems</u>

- Commercial Stormwater Controls.

8.5.3.3 Floatables Control

Floatable materials can be defined as any foreign matter that may float or remain suspended in the water column. The term includes plastic, aluminum cans, wood products, bottles, and paper products.

During storm events, runoff picks up floatable litter and transports it downstream into the storm system and ultimately the receiving waterbody. Floatables control technologies are designed to reduce or eliminate the visible solid waste that is often present in stormwater runoff. See EPA's fact sheet "Combined Sewer Overflow – Floatables Control" (EPA 832-F99-008) for additional information on floatables control. There are many floatables control products, such as hydrodynamic separators, available from multiple manufacturers that utilize methods discussed below.

Example floatables control technologies include:

- Baffles.
- Screens and trash racks.
- Catch basin modifications.
- Netting.

<u>Baffles</u>

Baffles are simple floatables control devices that are typically installed at manholes or catch basins within the stormwater system. They consist of vertical steel plates or concrete beams that extend from the top of the sewer to just below the top of the regulating weir. During an overflow event, floatables are retained by the baffles while water passes under the baffles, over the regulator, and into the receiving water body. When the flow recedes below the bottom of the baffle, floatable material is deposited in the bottom of the catch basin and then can be removed. An example of a typical baffle in a CSO regulator can be found in Appendix C, Figure C-18.

<u>Screens and Trash Racks</u>

Screens and Trash Racks consist of a series of vertical and horizontal bars or wires that trap floatables while allowing water to pass through the openings between the bars or wires. Screens can be installed at select points within a stormwater system to capture floatables and prevent their discharge into natural waterbodies. Screens used for floatable control include mechanically cleaned permanent screens, static screens, traveling screens, or drum screens. Screens can also be divided into three categories according to the size of floatable material they are designed to capture.

These are:

- Bar screens (> 1-inch openings).
- Coarse screens (0.19 – 1-inch openings).
- Fine screens (0.004 - 0.19-inch openings).

The screens most commonly used in stormwater systems are trash racks (a type of bar screen primarily used as an end-of-pipe control) and coarse screens. See EPA's fact sheet "Screens" (EPA 832-F99-027) for additional information on screens for floatable control.

Catch Basin Modifications

Catch basins are surface-level inlets to the sewer system that are often used to allow runoff from streets and lawns to enter the storm system. These basins are often modified to prevent floatables from entering the system. Inlet grates installed at the top of the catch basins reduce the amount of street litter and debris that enters the catch basin. If floatables enter the basin through these grates, they can be collected in colander-like structures called trash buckets installed in the basin beneath the grate. These structures retain floatables while letting water flow through to the downstream system. Other catch basin modifications, such as hoods and submerged outlets, alter outlet pipe conditions and keep floatables from entering the storm system. Hoods are vertical cast iron baffles installed in catch basins. Submerged outlets are located below the elevation of the storm system and are connected by a riser pipe. A typical modified catch basin with hood is presented in Appendix C, Figure C-19.

Netting

Two types of netting systems can be used to collect floatables in a storm system: in-line netting, and floating units.

In-line netting can be installed at strategic locations throughout the storm system. The nets would be installed in underground concrete vaults containing one or more nylon mesh bags and a metal frame and guide system to support the nets. The mesh netting is sized according to the volume and types of floatables targeted for capture. The stormwater flow carries the floatables into the nets for capture. Bags are replaced after every storm event.

Floating units consist of an in-water containment area that funnels stormwater flow through a series of large nylon mesh nets. Mesh size depends on the volume and type of floatables expected at the site. This system is passive and relies on the energy of the overflow to carry the floatables to the nets. However, nets must be located some distance from the outfall (often 15 meters [50 feet] or more) to allow floatables entrained in the turbulent stormwater flow to rise to the flow surface and be captured. The nets are single use, and after an overflow, the nets are typically removed and taken to a disposal area. Additional information on one type of floating unit, the TrashTrap™ system, is provided in a separate fact sheet (EPA 832-F-99-024).

8.5.3.4 Structural Stormwater Control Pollutant Removal Capabilities

General and limited application structural stormwater controls are intended to provide water quality treatment for stormwater runoff. Though each of these structural controls provides pollutant removal capabilities, the relative capabilities vary between structural control practices and different pollutant types.

Pollutant removal capabilities for a given structural stormwater control practice are based on several factors including the physical, chemical and/or biological processes that take place in the structural control and the design and sizing of the facility. In addition, pollutant removal efficiencies for the same structural control type and facility design can vary widely depending on the tributary land use and area, incoming pollutant concentration, rainfall pattern, time of year, maintenance frequency and numerous other factors.

Table 8.3 provides design removal efficiencies for each of the general and limited application control practices. It should be noted that these values are *conservative* average pollutant reduction percentages for design purposes derived from sampling data, modeling, and professional judgment. A structural control design may be capable of exceeding these performances, however the values in the table are generally reasonable values that can be assumed to be achieved when the structural control is sized, designed, constructed, and maintained in accordance with recommended specifications in this Manual.

Where the pollutant removal capabilities of an individual structural stormwater control are not deemed sufficient for a given site application, additional controls may be used in series in a "treatment train" approach. More detail on using structural stormwater controls in series are provided in the next section.

For additional information and data on the range of pollutant removal capabilities for various structural stormwater controls, refer to the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org, the National Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org, or EPA's fact sheet "Combined Sewer Overflow" (EPA 832-F99-008).

Table 8.3 Design Pollutant Removal Efficiencies for Structural Stormwater Controls

Structural Control	Total Suspended Solids	Total Phosphorus	Total Nitrogen	Fecal Coliform	Metal
General Application Structural Controls					
Stormwater Ponds	80	50	30	70*	50
Stormwater Wetlands	80	40	30	70*	50
Bioretention Areas	80	60	50	---	80
Sand Filters	80	50	25	40	50
Infiltration Trench	80	60	60	90	90
Enhanced Dry Swale	80	50	50	---	40
Enhanced Wet Swale	80	25	40	---	20
Limited Application Structural Controls					
Organic Filter	80	60	40	50	75
Underground Sand Filter	80	50	25	40	50
Submerged Gravel Wetland	80	50	20	70	50
Gravity (Oil-Grit) Separator	40	5	5	---	---
Proprietary Systems	***	***	***	***	***

*	If no resident waterfowl population present.
***	The performance of specific proprietary commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data.
---	Insufficient data to provide design removal efficiency.

8.5.4 Stormwater Treatment Trains

A stormwater "treatment train" is an integrated planning and design approach with components that work together to limit the adverse impacts of urban development on downstream waters and riparian areas. When considered comprehensively a treatment train consists of all the design concepts and nonstructural and structural controls that work together to attain water quality and quantity goals. This is illustrated in Figure 8.1.

Figure 8.1. Generalized stormwater treatment train.

Runoff and Load Generation – The initial part of the “train” is located at the source of runoff and pollutant load generation and consists of better site design and pollution prevention practices that reduce runoff and stormwater pollutants.

Pretreatment – The next step in the treatment train consists of pretreatment measures. These measures typically do not provide sufficient pollutant removal to meet the 80% TSS reduction goal but do provide calculable water quality benefits that may be applied towards meeting the WQ_v treatment requirement. These measures include:

- The use of stormwater better site design practices to reduce the water quality volume (WQ_v).
- Limited application structural controls that provide pretreatment.
- Pretreatment facilities such as sediment forebays on general application structural controls.

Primary Treatment and/or Quantity Control – The last step is primary water quality treatment and/or quantity (channel protection, overbank flood protection, and/or extreme flood protection) control. This is achieved through the use of:

- General application structural controls.
- Limited application structural controls.
- Detention structural controls.

Use of Multiple Structural Controls in Series

Many combinations of structural controls in series may exist for a site. Figure 8.2 provides several hypothetical examples of how the stormwater sizing criteria may be addressed by using structural stormwater controls.

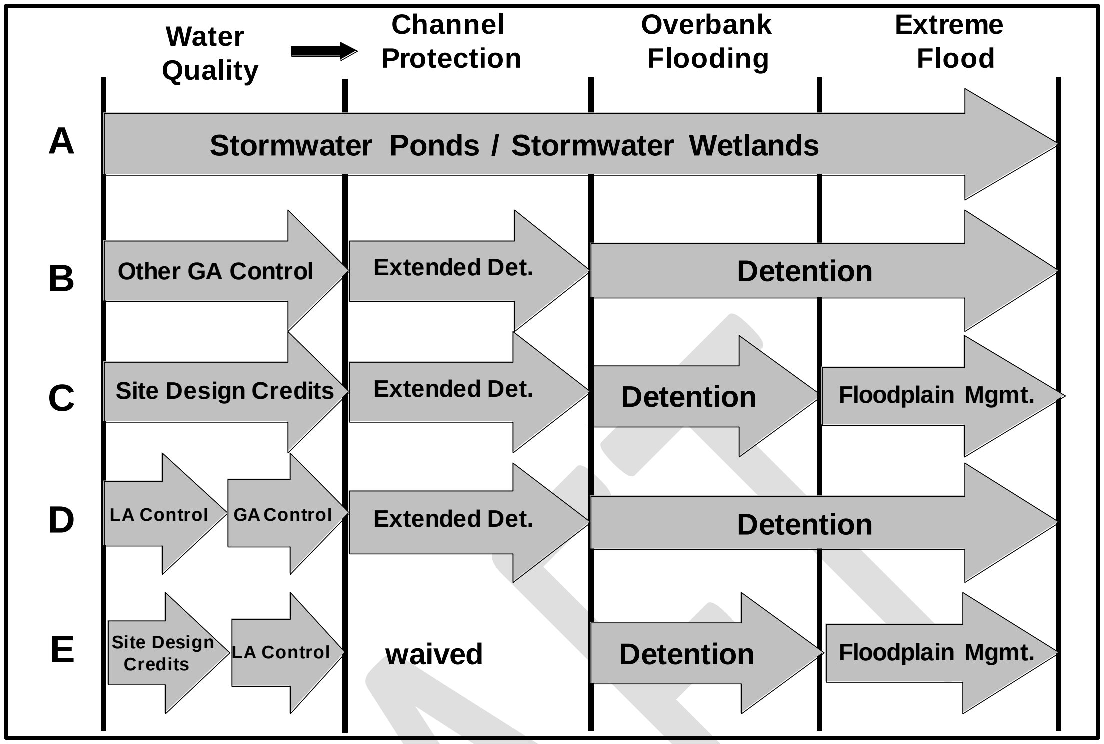

Figure 8.2. Examples of structural controls used in series.

Referring to Figure 8.2 by line letter:

A. Two general application (GA) structural controls, *stormwater ponds* and *stormwater wetlands*, can be used to meet the unified stormwater sizing criteria in a single facility.
B. The other general application structural controls (*bioretention, sand filters, infiltration trench and enhanced swale*) are typically used in combination with detention controls to meet the unified stormwater sizing criteria. The detention facilities are located downstream from the water quality controls either on-site or combined into a regional or neighborhood facility.
C. Line C represents a special case where an environmentally sensitive large lot subdivision has been developed that can be designed to waive the water quality treatment requirement altogether. However, detention controls may still be required for downstream channel protection, overbank flood protection and extreme flood protection.
D. Where a limited application (LA) structural control does not meet the 80% TSS removal criteria, another downstream structural control must be added. For example, areas with high pollutant loading potential may be fit or retrofit with devices adjacent to parking or service areas designed to remove petroleum hydrocarbons. These devices may also serve as pre-treatment devices removing the coarser fraction of sediment. One or more downstream structural controls is then used to meet the full 80% TSS removal goal, as well as water quantity control.

The combinations of structural stormwater controls are limited only by the need to employ measures of proven effectiveness and meet local regulatory and physical site requirements. Figure 8.3 illustrates the application of the treatment train concept for a large shopping mall site.

In this case, runoff from rooftops and parking lots drains to a depressed parking lot, perimeter grass channels, and bioretention areas. Slotted curbs are used at the entrances to these swales to better distribute the flow and to settle out the very coarse particles at the parking lot edge for removal. Runoff is then conveyed to a wet ED pond for additional pollutant removal and channel protection.

Calculation of Pollutant Removal for Structural Controls in Series

For two or more structural stormwater controls used in combination, it is important to have an estimate of the pollutant removal efficiency of the treatment train. Pollutant removal rates for structural controls in series are not additive. For pollutants in particulate form, the actual removal rate (expressed in terms of percentage of pollution removed) varies directly with the pollution concentration and sediment size distribution of runoff entering a facility.

For example, a stormwater pond facility will have a much higher pollutant removal percentage for very turbid runoff than for clearer water. When two stormwater ponds are placed in series, the second pond will treat an incoming particulate pollutant load differently from the first pond. The upstream pond captures the easily removed larger sediment sizes, passing on an outflow with a lower concentration of TSS but with a higher proportion of finer particle sizes. Hence, the removal capability of the second pond for TSS is considerably less than the first pond. Recent findings suggest that the second pond in series can provide as little as half the removal efficiency of the upstream pond.

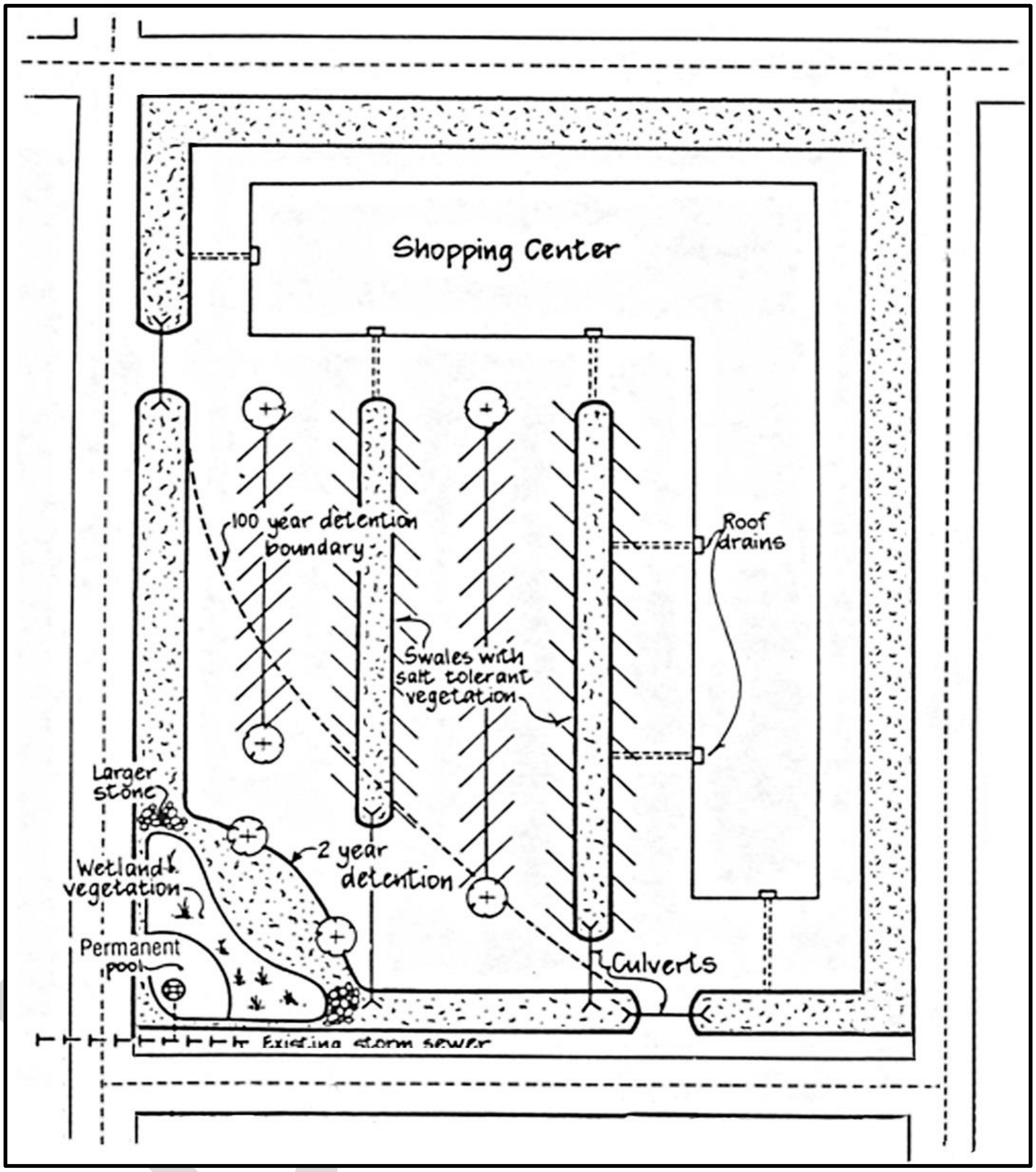

Figure 8.3. Example of treatment train of commercial development.

To estimate the pollutant removal rate of structural controls in series, a method is used in which the removal efficiency of a downstream structural control is reduced to account for the pollutant removal of the upstream control(s). The following steps are used to determine the pollutant removal:

- For each drainage area, list the structural controls in order, upstream to downstream, along with their expected average pollutant removal rates from Table 8.3 for the pollutants of concern.
- For any general application structural control located downstream from another general application control or a limited application structural control that has TSS removal rates equivalent to 80%, the designer should use 50% of the normal pollutant removal rate for the second control in series. For a general application structural control located downstream from a

limited application structural control that cannot achieve the 80% TSS reduction goal the designer should use 75% of the normal pollutant removal rate for the second control in series.

- For example, if a general application structural control has an 80% TSS removal rate, then a 40% (0.5 x 80%) TSS removal rate would be assumed for this control if it were placed downstream from another general application control in the treatment train. If it were placed downstream from a limited application structural control that cannot achieve the 80% TSS reduction goal a 60% (0.75 x 80%) TSS removal rate would be assumed. This rule should always be used with caution depending on the actual pollutant of concern and with allowance for differences among structural control pollutant removal rates for different pollutants. Actual data from similar situations should be used where available.
- For cases where a limited application control is located upstream from a general application control in the treatment train, the downstream general application structural control is given full credit for removal of pollutants.
- Apply the following equation for calculation of approximate total accumulated pollution removal for controls in series:
- **Final Pollutant Removal = (Total load * Control1 removal rate) + (Remaining load * Control2 removal rate) + removal for other Controls in series.**

Example 8.1

TSS is the pollutant of concern, and a commercial gravity (oil/grit) separator is inserted that has a 40% sediment removal rate. A stormwater pond is designed at the site outlet. What is the total TSS removal rate? The following information is given:

Control 1 (Commercial Device) = 40% TSS removal

Control 2 (Stormwater Pond 1) = 70% TSS removal (use 1.0 x design removal rate)

Then applying the controls in order and working in terms of “units” of TSS starting at 100 units:

For Control 1: 100 units of TSS * 40% removal rate = 40 units removed

100 units - 40 units removed = 60 units of TSS remaining

For Control 2: 60 units of TSS * 70% removal rate = 42 units removed

60 units - 42 units removed = 18 units of TSS remaining

For the treatment train in total = 100 units TSS – 18 units TSS remaining = **82% removal**

8.6 Water Quality SCM Maintenance

Each water quality BMP installed on a site requires regular maintenance to ensure that it functions properly. A BMP-specific maintenance agreement for each development site is required. The maintenance agreement consists of the following:

1. An Inspection and Maintenance Agreement signed by the developer or BMP owner.
2. A long-term maintenance plan written by the engineer or site designer that includes a description of the stormwater system and its components, inspection priorities and schedule for each component, and BMP schematics for each BMP. The plan should also include requirements for the proper disposal of any materials removed from the BMP during maintenance.

3. A drawing of easements on a plat or a system location map to enable the City to locate BMPs as needed.

The maintenance agreement and its attachments must be submitted for review by the City with the site plans. After the plans and the agreement are approved, the property owner shall record the maintenance agreement and its attachments with the register of deeds. The property owner, under the maintenance agreement, shall be responsible for inspecting and maintaining the BMPs and for turning in inspection reports annually to show that the facilities have been inspected and maintained.

8.7 References

- Drainage Criteria Manual | Fayetteville, AR - Official Website (fayetteville-ar.gov)
- Managing Stormwater in Your Community: A Guide for Building an Effective Post-Construction Program (epa.gov)
- Combined Sewer Overflow Technology Fact Sheet: Floatables Control (epa.gov)
- NIPC, 2000
- Assessing and Monitoring Floatable Debris (epa.gov)
- Flood-Control-and-Water-Quality-Protection-Manual-April-2022 (springfieldmo.gov)
- Sweeney and Newbold, 2014