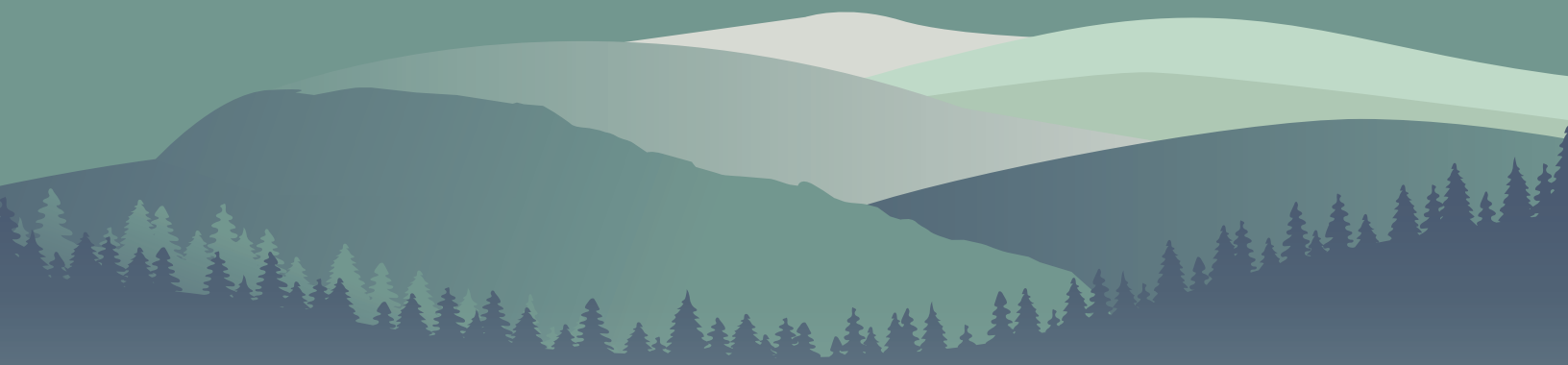
CITY OF ALCOA



CITY OF ALCOA

Stormwater Management Manual

VOLUME 1: STORMWATER DESIGN

CITY OF ALCOA, TN • STORMWATER MANAGEMENT PROGRAM
City of Alcoa Service Center
725 Universal Street, Alcoa, TN 37701

865.380.4800 • **stormwater@cityofalcoa-tn.gov**

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1.1 Overview

Volume 1: Stormwater Design is the first Volume of the C*ity of Alcoa Stormwater Management Manual*. The manual supports the stormwater management regulation established in Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code. Thus, this Volume establishes:

- design feasibility criteria, performance standards, specifications, and hydrologic methods for stormwater control measures (SCMs), including detention and retention ponds
- design specifications for vegetated buffers along streams and other waterways
- the required elements pertaining to SCMs for stormwater management plans developed for proposed developments
- forms and checklists to support the requirements of city ordinances and this manual
- encouragement and incentives to use nonstructural low impact development (LID) practices and structural LID-SCMs to reduce the volume of stormwater discharged from a development and the overall negative impacts of stormwater on communities.

1.2 Applicability and Objectives

This manual is written specifically for site design professionals (i.e., civil engineers and landscape architects) seeking to comply with City of Alcoa (City) design standards for stormwater quality. Neither the City's stormwater management ordinance nor this manual specify which SCMs are required at applicable land development. Rather, design professionals and their clients have the flexibility to choose the most effective and practical design approaches and SCMs for stormwater treatment for their development situations. However, the SCM(s) selected must be designed and constructed in keeping with the policies and specifications established in this manual.

The primary objectives of this manual are listed below.

- Support the city's stormwater management ordinance by establishing design and construction standards for post-construction stormwater quality treatment and vegetated buffers on applicable land developments in the city.
- Comply with the requirements of the State of Tennessee's National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Phase II permit (henceforth called the NPDES-MS4 permit) and Tennessee Rule 0400-40-10-.04 for post-construction stormwater quality treatment. The city is a MS4 permittee.
- Align stormwater quality and water quality buffer requirements with the city's stormwater quantity requirements and land development codes and processes.

1.3 Manual Relationship with City Ordinances, Codes, and Plans

The State of Tennessee's NPDES General Permit for Discharges from Small MS4s (Tennessee Permit No. TNS000000) requires that all permitted MS4s develop, implement, and enforce a water quality management program that reduces the discharge

of pollutants from the regulated jurisdiction. Alcoa is one of about 100 cities and counties in Tennessee that are required to obtain a permit. It is administered by the Tennessee Department of Environment and Conservation (TDEC).

Included in its many requirements are rules for post-construction/permanent stormwater management. These rules must be applied to new development and redevelopment projects that disturb one acre or more of land, or less than one acre if part of a larger common plan of development, and discharge to the permittee's MS4. Quoting directly from the 2022 permit:

"The permanent stormwater management program shall include plans review, site inspections, and a means to ensure that permanent stormwater control measures (SCMs) are adequately operated and maintained.

The permittee must develop and implement, and modify as necessary, an ordinance or other regulatory mechanism to address permanent stormwater management at new development and redevelopment projects.

Permittees shall develop and implement a set of requirements to establish, protect, and maintain permanent water quality riparian buffers to provide additional water quality treatment in riparian areas of new development and redevelopment projects that contain streams, including wetlands, ponds, and lakes."

In keeping with these requirements, the city's stormwater management ordinance stipulates that applicable developments must provide stormwater quality treatment and establish water quality buffers. This manual supports the ordinance by establishing the permit's stormwater quality design standard, prescribed rainfall depths and design storm, and water quality buffer design standards. It establishes detailed design specifications to ensure proper function of SCMs (if maintained). It also establishes requirements for the Stormwater Management Plan (SWMP), which is the stormwater quality design plan required by the city. The SWMP is submitted the required land development design plan package.

This manual is authorized by the city's ordinance. It conveys the design policies, standards, and specifications necessary to support the ordinance. Together, the ordinance and manual regulate post-construction stormwater quality and quantity, and water quality buffers within the city's jurisdiction. The requirements in this manual can be enforced by the city, consistent with the authorities and enforcement provisions of the ordinance.

1.4 How to Use This Manual

This manual does not repeat the requirements established in the stormwater management ordinance. Rather, it sets forth detailed technical information to support the ordinance in the form of planning, design, and construction policies for structural and non-structural SCMs. Table 1.1 provides a description of each chapter in this manual.

In the table, "Guidance" describes non-mandatory information aimed at enhancing a design professional's understanding of a subject or improving a design. The term "Regulatory" means the chapter contains policies and design standards and specifications that must be followed to comply with the city ordinance.

Table 1.1 Summary of Manual Chapters

Chapter and Description (Regulatory = enforceable requirements; Guidance = helpful or educational information)
Chapter 1. Introduction *(Guidance)* The introduction provides a general overview of the Manual, its applicability, objectives, use, and how it supports the city's stormwater, floodplain management, and land development requirements.
Chapter 2. The Need for Stormwater Management (Guidance) Chapter 2 provides insight into the hydrologic cycle, effects of urban runoff, and improvements in stormwater management in new developments and redevelopments.
Chapter 3. Required Stormwater Plans (Regulatory) This chapter presents policies and criteria for Pre-Development Hydrology Maps, Stormwater Management Plans (i.e., stormwater design plans), and SCM As-Built Plans.
Chapter 4. Non-Structural Low Impact Development Practices (Guidance and Regulatory) Chapter 4 provides information on the non-structural LID practices that can be used when planning and designing a development. The criteria and application of incentives for the use of low impact development practices are also established.
Chapter 5. Water Quality Buffer Design (Regulatory) Chapter 5 defines the design and plan preparation requirements for vegetated (i.e., water quality) buffers. Chapter 5 provides rules and design specifications for SCMs, pretreatment measures, and SCM components.
Chapter 6. SCM Standards, Methods, and Selection (Regulatory) Chapter 6 presents policies, criteria, and calculation methods for the design of structural water quality SCMs and SCM components presented in Chapter 7.
Chapter 7. SCM Design Specifications (Regulatory) Chapter 7 provides rules and design specifications for SCMs, pretreatment measures, and SCM components.

1.5 City Contact Information

Contact information for questions regarding the stormwater management ordinance and this manual.

City of Alcoa, TN
Stormwater Management Program
City of Alcoa Service Center
725 Universal Street, Alcoa, TN 37701
(865) 380-4800
Email: publicworks@cityofalcoa-tn.gov

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2.1 Impacts of Land Development on Water Quality

Land development changes not only the physical, but also the chemical and biological conditions of Tennessee's streams. This chapter describes the changes that occur due to development and the resulting stormwater impacts.

2.1.1 Stormwater Quality and Quantity Alterations

Our earth has a natural hydrologic cycle of water, depicted in Figure 2.1. This continuous circulation of water in the earth and its atmosphere is important because it is how water reaches the plants, animals, and humans that rely on water for life. The most important details from a stormwater perspective are described in Table 2.1.

Figure 2.1 The Natural Hydrologic Cycle ***(License: https://creativecommons.org/licenses/by/3.0/)***

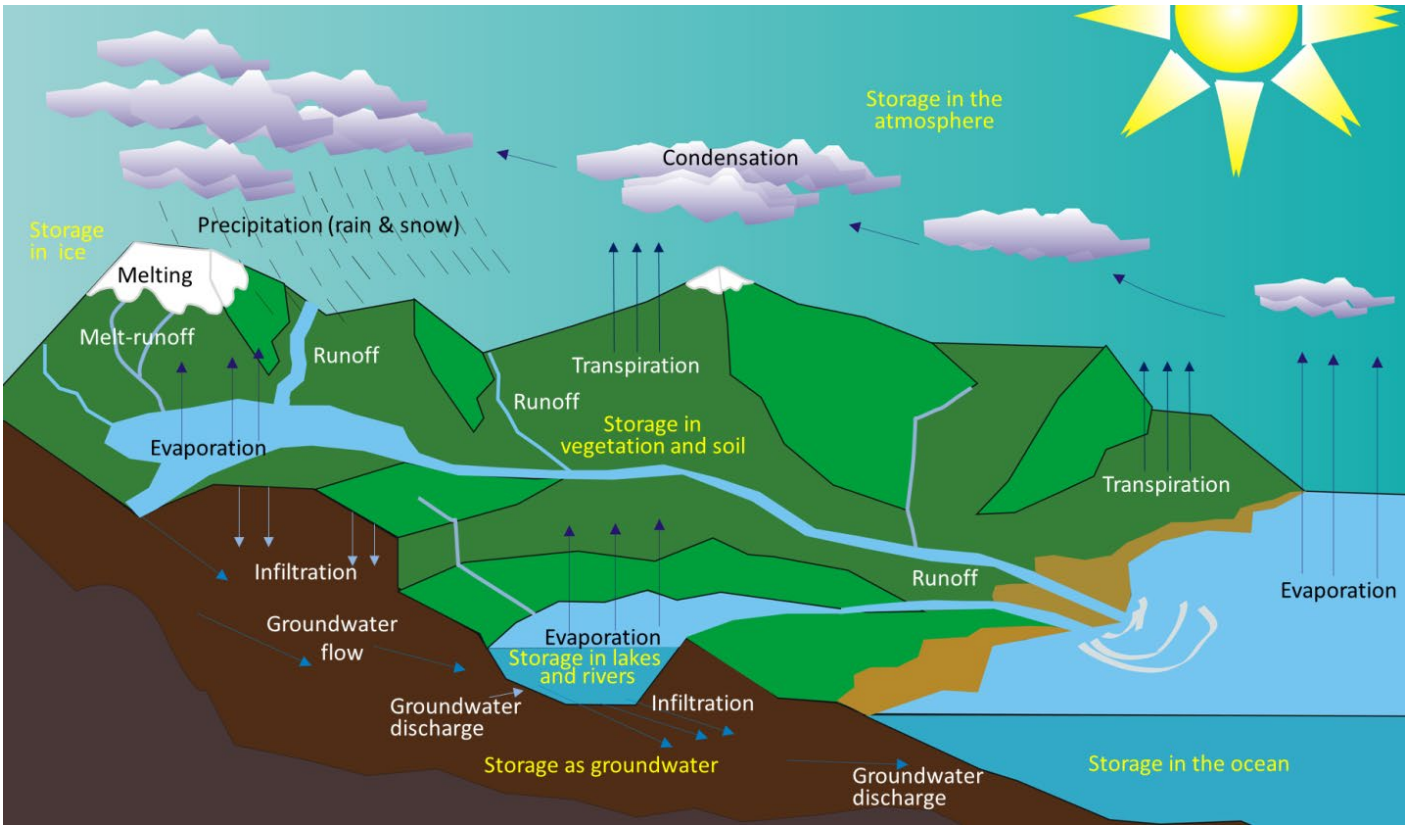


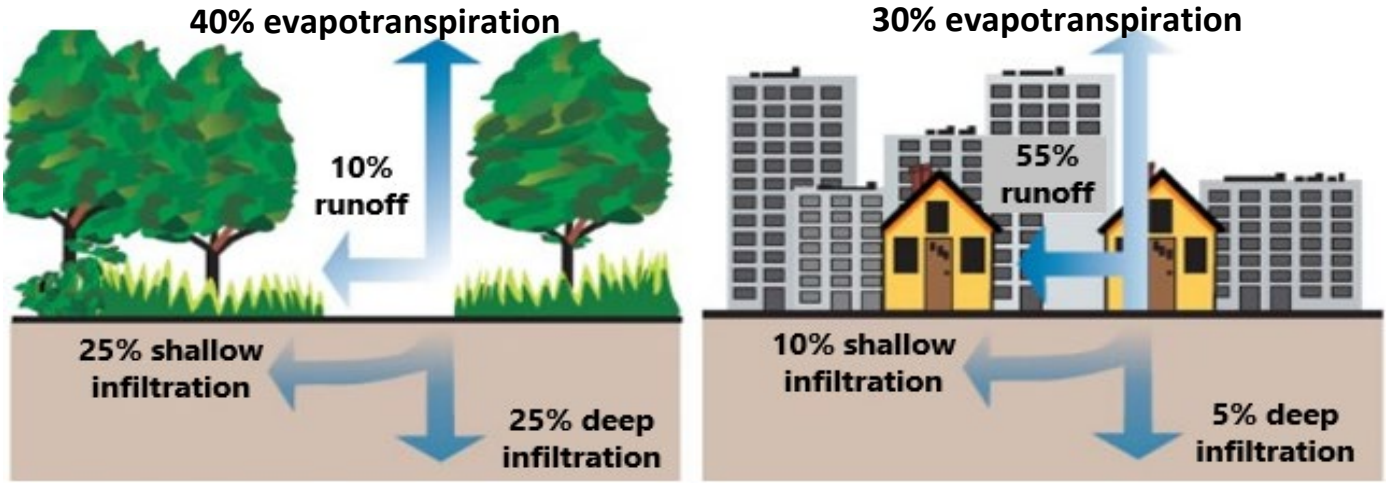
Table 2.1 Primary Hydrologic Cycle Processes *(www.noaa.gov)*

Process	Description
Evaporation	The change in the state of water from a liquid to a gas. The opposite of evaporation is condensation.
Transpiration	The evaporation of water from plants through stomata (small openings on the underside of leaves). Of the transpired water passing through a plant, only 1% is used by the plant. The remaining 99% evaporates into the atmosphere.

Process	Description
Condensation	The change in the state of water from a gas to a liquid. In the atmosphere, condensation may appear as clouds or dew. The opposite of condensation is evaporation.
Precipitation	Precipitation results when atmospheric condensation grows too large for the rising air to support, and thus falls to the earth. Precipitation can be in the form of rain, hail, snow, or sleet.
Runoff	Runoff occurs when there is excessive precipitation, and the ground cannot absorb any more water. Some runoff evaporates into the atmosphere, some percolates into the soil and is taken into plants for transpiration. The remainder flows into streams, rivers, lakes, and ultimately, the ocean.

The hydrologic cycle is disrupted and altered when land is developed. Vegetation clearing removes the vegetation that intercepts, slows, and returns rainfall to the air through evaporation and transpiration. Grading flattens hilly terrain and fills in natural depressions that slow and provide temporary storage of stormwater. The topsoil and sponge-like layers of decaying leaves and other organic materials are scraped and removed, and the soil beneath is compacted. Rainfall that once soaked into the ground now runs off the surface in greater volume and at faster velocities. The addition of impervious surfaces (building rooftops, roadways, parking lots and other surfaces) further reduces the amount of water that infiltrates into the soil and groundwater, thus reducing the amount of water that can recharge aquifers and feed streamflow during periods of dry weather. Depending on the magnitude of changes to the land surface, the volume of stormwater runoff can increase dramatically (Figure 2.2).

Figure 2.2 The Impact of Impervious Surfaces on the Hydrologic Process ***(Adapted from USEPA)***



In addition to increasing the volume of stormwater, changes due to development also accelerate the rate at which stormwater flows across the land. This acceleration is intensified by drainage systems such as gutters, stormwater conveyance systems and lined channels that are designed to quickly drain stormwater away from roadways and structures, and into local waterways.

Finally, development and urbanization affect not only the quantity of stormwater, but also its quality. Development increases both the concentration and types of pollutants carried by stormwater. As it runs over rooftops and lawns,

parking lots and industrial sites, stormwater picks up and transports a variety of pollutants to downstream waterbodies. The loss of the original topsoil and vegetation removes a valuable filtering mechanism for stormwater.

The land area that drains to the waterbody is known as its watershed. Land development and urban activities within a watershed has direct water quantity and quality impacts on downstream waterways. These impacts include changes to stream flow, changes to stream geometry, degradation of aquatic habitats, and water quality impacts.

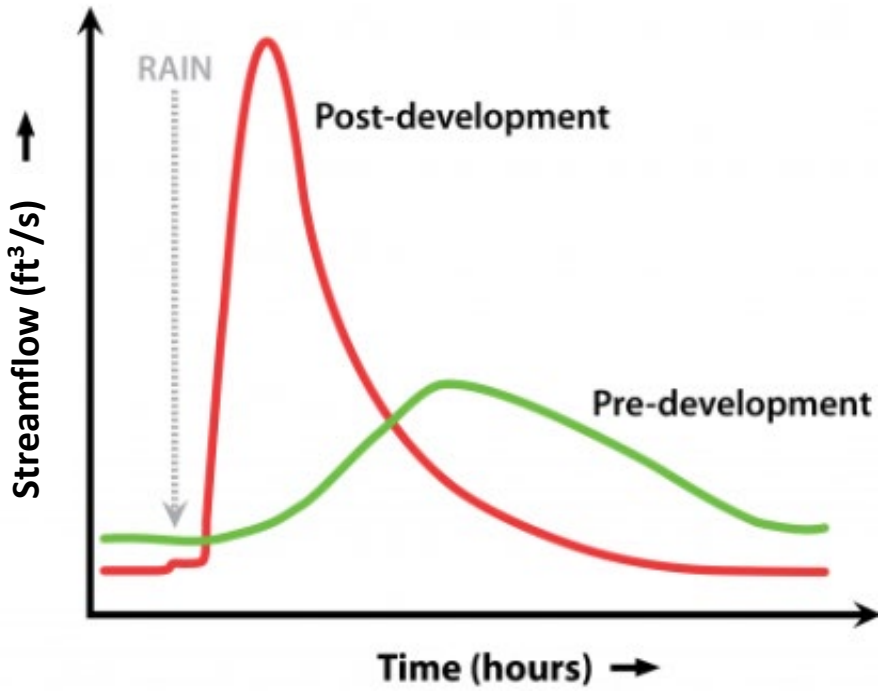
2.1.2 Changes to Stream Flow

Urban development alters the hydrology of watersheds and streams by disrupting the natural water cycle, which typically results in the negative impacts summarized below.

Increased Stormwater Volumes – Land surface changes can dramatically increase the total volume of stormwater generated.

Increased Stormwater Peak Discharges – Increased peak discharges of stormwater for a developed watershed can be two to five times higher than those for an undeveloped watershed. Streams in developed areas are often characterized as very "flashy" or "spiky" because of the increased volume of stormwater, greater peak flows, and quicker hydrologic response to storms. This translates into the sharp peak and increased size of the post-development hydrograph that site designers must mitigate through detention and retention (Figure 2.3).

Figure 2.3 Peak Discharge Differences *(Adapted from mde.state.md.us)*



Greater Stormwater Velocities – Impervious surfaces and compacted soils, as well as improvements to the drainage system such as storm drains, pipes, and ditches, increase the speed at which rainfall runs off land surfaces within a watershed.

Altered Watershed Timing – As stormwater velocities increase, it takes less time for water to run off the land and reach a stream or other waterbody.

Increased Frequency of Stream Overtopping – Increased stormwater volumes and peak flows increase the frequency and duration of bank full events, which are the primary channel forming events.

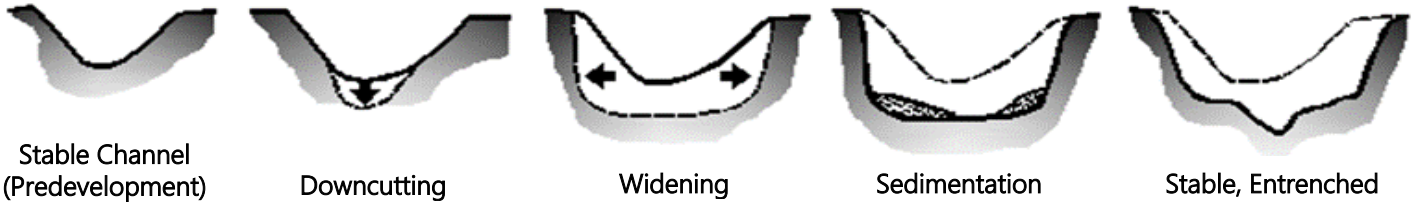
Increased Flooding – Increased stormwater volumes and peaks also increase the frequency, duration, and severity of out-of-bank flooding.

Lower Baseflows (Dry Weather Flows) – Reduced infiltration of stormwater causes streams to have less baseflow during dry weather periods and reduces the amount of rainfall recharging groundwater aquifers.

2.1.3 Changes to Stream Geometry

The changes in the volume and velocity of stormwater from developed watersheds directly affect the morphology, or physical shape and character, of creeks and streams. This is depicted graphically in Figure 2.4 and described in the paragraphs below.

Figure 2.4 Physical Stream Changes Due to Watershed Development



Stream Widening, Bank Erosion, and Streambed Changes – Stream channels widen to accommodate the increased stormwater from developed areas. Frequent small and moderate stormwater events undercut and scour the lower parts of the stream bank, causing the steeper banks to erode and collapse during larger storms. Higher flow velocities further increase stream bank erosion rates. A stream can widen to many times its original size due to post-development stormwater. Sediments accumulate in various areas of the stream, covering the channel bed, or substrate, with shifting deposits of mud, silt, and sand. The photo in Figure 2.5 is an example of bank erosion, stream widening, and changes to the streambed due to sedimentation.

Figure 2.5 Stream Changes on Pistol Creek

Stream Downcutting – Another way streams accommodate higher flows is by down-cutting the streambed. This causes instability in the stream profile, or elevation along a stream's flow path, which increases velocity and triggers further channel erosion both upstream and downstream.

Loss of Riparian Tree Canopy – As streams are gradually undercut and slump into the channel, the trees that had protected the banks are exposed at the roots. This leaves them more likely to be uprooted during major storms, further weakening the bank structure.

Changes in the Channel Bed Due to Sedimentation – Due to channel erosion and other sources upstream, sediments are deposited in the stream as sandbars and other features, covering the channel bed, or substrate, with shifting deposits of mud, silt, and sand.

Increase in the Floodplain Elevation – To accommodate the higher peak flow rate, a stream's floodplain elevation typically increases following development in a watershed due to higher peak flows. This problem is compounded by building and

filling floodplain areas, which cause flood heights to rise even further. Property and structures that had not previously been subject to flooding may now be at risk.

2.1.4 Impacts to Aquatic Habitat

Along with changes in stream hydrology and morphology, the habitat value of streams diminishes due to development in a watershed. Impacts on habitat include:

Degradation of Habitat Structure – Higher and faster flows due to development can scour channels and wash away entire biological communities. Streambank erosion and the loss of riparian vegetation reduce habitat for many fish species and other aquatic life, while sediment deposits can smother bottom-dwelling organisms and aquatic habitat.

Loss of Pool-Riffle Structure – Streams draining undeveloped watersheds often contain pools of deeper, more slowly flowing water that alternate with "riffles" or shoals of shallower, faster flowing water. These pools and riffles provide valuable habitat for fish and aquatic insects. As a result of the increased flows and sediment loads from urban watersheds, the pools and riffles disappear and are replaced with more uniform, and often shallower, streambeds that provide less varied aquatic habitat.

Decline of Abundance and Biodiversity – When there is a reduction in various habitats and habitat quality, both the number and the variety, or diversity, of organisms (wetland plants, fish, macro-invertebrates, etc.) are also reduced. Sensitive fish species and other life forms disappear and are replaced by those organisms that are better adapted to the poorer conditions. The diversity and composition of the benthic, or streambed, community are frequently used to evaluate the quality of urban streams. Aquatic insects are a useful environmental indicator as they form the base of the stream food chain.

Fish and other aquatic organisms are impacted not only by the habitat changes brought on by increased stormwater quantity but are often also adversely affected by water quality changes due to development and resultant land use activities in a watershed.

2.1.5 Water Quality Impacts

Stormwater is a major source of water quality impacts to streams, lakes, and other waterbodies. Water quality degradation in urbanizing watersheds starts when development begins. Stormwater washes sediment, pet waste, fertilizers, and other pollutants from rooftops, pavement, and landscaped areas, and erodes bare soil. These pollutants are carried in stormwater to local waterways where they can have a myriad of impacts. Common stormwater pollutants include the following:

Sediment – The single most important water quality problem in the United States is sediment dislodged from exposed soil, stream banks, and channel beds (Figure 2.6). Excessive sediment can be detrimental to aquatic life by interfering with photosynthesis, respiration, growth, and reproduction.

Nutrients – Stormwater from urban watersheds contains increased nutrients such as nitrogen and/or phosphorus compounds. In an urban setting, nutrients in stormwater primarily come from fertilizers commonly used in lawn care, and landscape materials.

Figure 2.6 Excessive Sediment in Stormwater

Pathogens – Pathogens harmful to human health consist of bacteria, protozoa, viruses, and other microscopic organisms. The sources of pathogens in urban stormwater include leaking private or public sewer lines, combined sewer overflows, malfunctioning septic tanks, and wastes from animals, pets, and birds.

Hydrocarbons – Oils, greases, and gasoline contain a wide array of hydrocarbon compounds, some of which have been shown to be carcinogenic, tumorigenic, and mutagenic in various species of fish and other lifeforms. In large quantities, oil can impact drinking water supplies and affect recreational use of water. Oil and other hydrocarbons wash off roads and parking lots, primarily due to vehicle leaks. Other sources include improper disposal of motor oil in storm drains and streams, spills at fueling stations, and restaurant grease traps.

Reduced Oxygen in Streams – Stormwater laden with lawn and landscape waste, pet waste, and other sources, delivers organic matter to local streams. While organic material is necessary for aquatic life, an overabundance of organic matter can contribute to stream impacts. The decomposition of this matter uses up dissolved oxygen (DO) in the water, which is vital for fish and other aquatic life. When combined with increased algae and weed growth due to nutrient loading, DO levels rapidly deplete causing fish kills and other stream health impacts.

Toxic Materials – Besides oils and greases, urban stormwater can contain a wide variety of other toxicants and compounds, including heavy metals like lead, zinc, copper, and cadmium, as well as organic pollutants that include pesticides, polychlorinated biphenyls (PCBs), and phenols. These contaminants are of concern because they are toxic to aquatic organisms and can bio-accumulate in the food chain, especially in area lakes where fish and other aquatic species are significant and cherished as a food source. Sources of these contaminants in urban stormwater include industrial and commercial areas, urban surfaces like rooftops and roadways, vehicles, and other machinery, improperly disposed household chemicals, landfills, hazardous waste sites, and atmospheric deposition.

Thermal Pollution – As stormwater flows over impervious surfaces, such as asphalt and concrete, it increases in temperature before reaching a stream or pond. Water temperatures are also increased due to detention and impoundments along a watercourse and fewer trees along streams to shade the water. Since warm water holds less DO than cold water, this “thermal pollution” further reduces oxygen levels in urban streams. Temperature changes can severely impact certain aquatic species, such as trout and stoneflies, which can survive only within a narrow temperature range.

Trash and Debris – Considerable quantities of trash and other debris are washed through storm drain systems and into streams and lakes. The presence of trash is an indicator of other anthropomorphic effects on water quality, stream structure, and aquatic habitat. Terrestrial and aquatic animals can be harmed when they consume or become entangled/engulfed in solid waste.

2.1.6 Impacts on Communities

The stormwater impacts of land development and gradual urbanization on local communities can be significant if not mitigated. These issues range from physical to environmental to economic, but all of them stem from two primary impacts: increased flooding and reduced water quality. Community impacts can include:

Increased Flooding – As more land development occurs without proper stormwater management, our natural and man-made infrastructure becomes more vulnerable to flooding, which is a result of the increased stormwater peak flow rates and volumes resulting from the land development (see Figure 2.7).

Figure 2.7 Flooding on Pistol Creek in Maryville in 2019

Environmental Issues – As pollutants in stormwater enter local waterways, they threaten aquatic life and drinking water supplies, can contribute to human illness, and damage tourism and recreation opportunities.

Economic Challenges – Local governments are typically charged with resolving the flooding, erosion, and environmental issues caused by increased stormwater. The financial cost to repair known issues and prevent further occurrences can sometimes be significant, competing directly against other government priorities (e.g., police, fire, schools) for funding.

Declining Property Values – Stormwater pollution affects the appearance and quality of downstream waterbodies, influencing the desirability of working, living, traveling, or owning property near the water. Furthermore, the value of property located in areas with a high potential or increasing history of flooding will also decrease.

Loss of Fisheries – Certain toxic chemicals present in streams, lakes, and rivers resulting from polluted stormwater inflows can accumulate in fish, especially in older and larger fish. When chemical concentrations are elevated in fish, they can pose health risks to people who eat them.

Reduced Drought Resiliency – Increased stormwater volumes reduces the amount of rainfall available to recharge shallow groundwater aquifers and feed freshwater rivers and streams during dry weather. Thus, streams have lower baseflow and are less able to withstand extended periods of drought.

Reduction in Quality of Life – All of the impacts listed above result in a decline in the quality of life in a community, making it a less desirable place to live, work, and play.

2.1.7 Urbanization and Stormwater in Alcoa and Surrounding Areas

The transformative shift in Alcoa, and the surrounding areas began in earnest in the late 1800s and early 1900's with the introduction of the first railroad[1] and arrival of the Aluminum Company of America. Interest in the area was primarily

[1] "History of the City of Maryville". *City of Maryville* online, December 28, 2023. https://www.maryvillegov.com/history.html

attributed to the railroad and the region's accessible rivers, utilized for hydroelectric power. The population increased during World Wars I and II to grow a workforce that could keep pace with the soaring demand for aluminum. Growth continued in the 1940's with the completion of the Hall Road Viaduct and the development of McGhee Tyson Airport[2]. In the decades that followed, the commercial expansion and the burgeoning populations of Alcoa fostered a diverse economy.

From a hydrologic standpoint, extensive mass grading to accommodate growing urban centers and their surrounding neighborhoods resulted from this growth. Native soils were lost as fill soil prevailed to support building foundations and level pavements. Vegetative land cover was replaced by impervious surfaces like rooftops, roadways, and parking lots (see Figure 2.8).

Figure 2.8 Opening of Hall Rd. Viaduct Extension, 1946

The transformation of urban areas triggered substantial changes in two key elements of the water cycle: soil, and land cover. This led to increased stormwater volumes and peak discharges, and elevated pollutant levels. These increases brought about extensive modifications in natural surface water systems. The urban areas in the region especially felt the impact, grappling with channel erosion, stream widening, and heavy sediment accumulation; and resulting in flooding in previously unaffected areas and water pollution in many local streams. Moreover, several local streams have received official designation by the State of Tennessee as impaired due to the detrimental effects of urban stormwater (TDEC, 2022).

Subsurface alterations began to be noticed as well. Land in east Tennessee is extensively underlain by soluble carbonate bedrock such as limestone. Sinkholes are very common. This karst topography combined with the higher and more concentrated volumes of stormwater resulting from land development led to increases in sinkhole flooding and new sinkhole formation (see Figure 2.9).

Figure 2.9 Sinkhole Near Foothills Mall, April 2021

A broken stormwater pipe led to formation of a sinkhole under a road near Foothills Mall in Maryville TN. Source: WATE6)

In response, the cities and private property owners sought measures to combat negative stormwater impacts. First, rules were established for stormwater management on developing properties. Regulations for stormwater detention were established in the 1990's, and rules for stormwater quality control were adopted in 2008. Additionally,

[2] "Alcoa, Tennessee". Wikipedia. Last modified September 15, 2023. https://en.wikipedia.org/wiki/Alcoa,_Tennessee

both cities became active participants in the National Flood Insurance Program (NFIP), which requires local government adherence to, and enforcement of, minimum standards for developments within and near floodplains to prevent devastating floods.

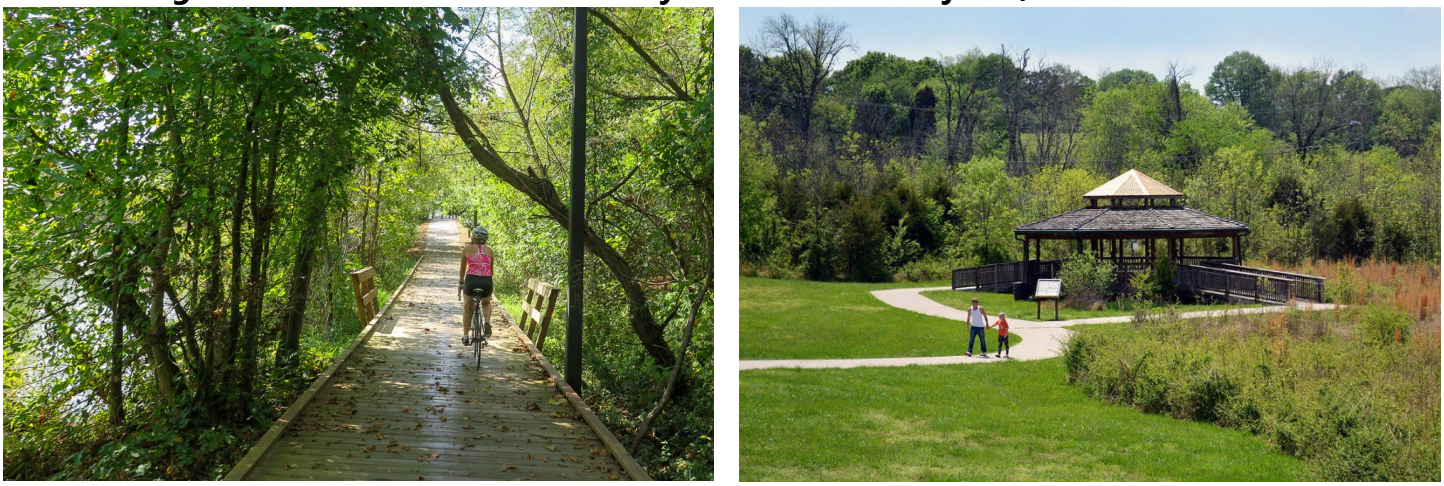
Alcoa began to analyze local streams and drainage systems, overhauling many overwhelmed natural drainage systems. Concrete reinforcement and channelization was done to accommodate the amplified flows stemming from impermeable urban surfaces. While these measures to redesign drainage systems were commonplace because of their success in swiftly diverting water from structures and roads, they can also result in hydrographs characterized by rapid fluctuations in discharge and velocity. Regrettably, in certain areas, localized flooding remains a persistent issue following heavy rainfall, as illustrated in Figure 2.10.

Both cities collaborated on a streamside greenway program in the early 2000's in the floodplains of Pistol Creek, which yielded secondary benefits in flood management for both communities. This program continues today, with greenways along much of Pistol Creek and some of its tributaries within the two jurisdictions. This LID technique provides a pervious stream buffer and limits the flooding of roadways and buildings along the greenway routes. They also provide a highly popular and attractive public amenity within both communities (see Figure 2.11).

Figure 2.10 Flooding in Alcoa

Top left:); Pistol Creek flooded near East Edison Street in Alcoa, November 2017 (The Daily Times);Top Right: Evacuation of residents on West Bell Street by Alcoa Fire Department (The Daily Times)

Figure 2.11 Pistol Creek Greenway in Alcoa and Maryville, TN



2.2 Addressing Stormwater Impacts

Across the United States, local governments address the stormwater impacts stemming from land development through a mix of solutions. First, public stormwater infrastructure improvements, called capital improvement projects, are undertaken most often to address stormwater impacts that are already being experienced as a result of existing developments. However, most of these projects are planned with consideration of the future growth in a community.

From the land development perspective, stormwater regulations are an effective tool many local governments use to keep existing stormwater problems from getting worse, or better yet, to prevent negative stormwater impacts entirely. These regulations require:

- Controlling stormwater discharges from frequent storm events to reduce pollutants discharged from a land development and prevent downstream streambank channel erosion.
- Establishing vegetated buffers along local waterways.
- Controlling stormwater from larger storms to reduce flooding on private and public properties.
- Using the most current and effective erosion prevention and sediment control (EPSC) practices during the construction phase of development
- Implementing pollution prevention practices to prevent stormwater from becoming contaminated in the first place.
- Proactively managing land development within and near local floodplains.

This manual was developed to support the post-construction stormwater quality requirements for the City of Alcoa (city). Thus, it establishes the requirements for the first two bullets listed immediately above and addresses the third and fourth bullets to a lesser degree. Table 2.2 briefly summarizes the different tools or features employed by the city and addressed in this manual for stormwater management.

Table 2.2 Summary of Stormwater Management Features in this Manual

Feature	Description
Stormwater Management Plan (SWMP)	The stormwater management plan (SWMP) is the design plan for proposed new and re-developments that indicates how stormwater quality will be addressed. The SWMP is discussed in Chapter 3.
Water Quality Volume (WQv)	The WQv is the portion of the stormwater generated from a new or re-development project that must be treated to reduce stormwater pollutants discharged from the property. WQv is fully described in Chapter 6.
Downstream Channel Protection Volume (CPv)	Local streams are susceptible to erosion and degradation due to increased flows and flow durations. Therefore, criteria are established to protect stream channels through the capture and extended detention of a specified stormwater volume. Channel protection requirements are presented in Chapter 6.
Flood Control (Detention/Retention)	The city has requirements for peak discharge control using detention or retention of stormwater. These requirements are established in the city's stormwater ordinance (see Chapter 1, Table 1.1).
Downstream Impact Analysis	The downstream impact analysis is an evaluation of the impact of stormwater detention at a new/re-development downstream of the property. The goal is to identify and prevent

(the 10% Rule)	unintended stormwater impacts of a development downstream. This analysis is fully described in Chapter 6.
Low Impact Development (LID)	LID practices are site layout and design approaches that minimize the amount of stormwater generated on a land development. The use of LID practices is not required. LID practices are addressed Chapter 4.
Stormwater Control Measures (SCMs)	SCMs are structural facilities constructed for the purpose of controlling stormwater generated by a land development. Depending on their design, SCMs can control stormwater quality and/or quantity, and provide downstream channel protection. SCMs are generally described and compared in Chapter 6. Their design specifications are provided in Chapter 7.
Water Quality Buffers	Water quality buffers are permanent strips of natural perennial vegetation adjacent to a stream, river, wetland, pond, or lake that contains dense vegetation made up of grass, shrubs, and/or trees. The purpose of a water quality buffer is to maintain existing water quality by minimizing the risk of any potential sediments, nutrients, or other pollutants reaching adjacent surface waters and to further prevent negative water quality impacts by providing canopy over adjacent waters. Buffers are addressed in Chapter 5.

2.3 References

"Alcoa, Tennessee". Wikipedia. Last modified September 15, 2023. https://en.wikipedia.org/wiki/Alcoa,_Tennessee

Fairfield (OH) Soil& Water Conservation District. (2023, December 19). *Stream Bank Stabilization.* *https://fairfieldswcd.org/stream-bank-stabilization/*

"History of the City of Maryville". City of Maryville online, December 28, 2023. https://www.maryvillegov.com/history.html

Kingsport (TN) Public Library. (2023, December 19). *David Peirce Collection, 1950-1968.* *https://www.kingsportlibrary.org/finding_aids/david-peirce-collection-kcmc-258/*

Maryland Department of the Environment. 2000. *Maryland Stormwater Design Manual, Volumes I and II.* Center for Watershed Protection (CWP), Ellicott City, MD.

National Oceanic and Atmospheric Administration (NOAA). (2023, December 19). *The Hydrologic Cycle.* *www.noaa.gov/Jetstream/atmosphere/hydro*

Tennessee Department of Environment and Conservation (TDEC). *Tennessee Final 2022 List of Impaired and Threatened Waters.* https://www.tn.gov/content/dam/tn/environment/water/watershed-planning/wr_wq_303d-2022-final.xlsx 2022

United States Environmental Protection Agency (EPA). (2023, December 19). *Urbanization – Stormwater Runoff.* *https://www.epa.gov/caddis-vol2/urbanization-stormwater-runoff#:~:text=Stormwater%20Runoff%20and%20Impervious%20Surfaces&text=Impervious%20surfaces%20associated%20with%20urbanization,associated%20contaminants)%20reach%20urban%20streams*.

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3.1 Introduction

The purpose of this chapter is to provide general information on the land development planning process, regulations, and plans as they relate to stormwater management. This chapter contains general information regarding the roles and requirements of the City of Alcoa (city) and other agencies that have a role in the development process. The reader is referred to the city or agency of interest for detailed information on development process and procedures.

3.2 Applicable Regulations

3.2.1 Stormwater Management Regulation

The policies, criteria, and guidance provided in this chapter are applicable only to stormwater management designs as required by **Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code**.

Persons responsible for the design and construction of a development or redevelopment must also comply with other relevant city ordinances, permits and regulatory mechanisms for regulations and policies that are not included in this manual. Such regulations may include, but are not limited to, zoning ordinances, minimum subdivision regulations, erosion prevention and sediment control ordinances, grading and building permits, and ordinances that regulate drainage, detention, floodplains and sinkholes, and flood damage prevention.

3.2.2 Tennessee Construction General Permit

The State of Tennessee General NPDES Permit for Discharges of Stormwater Associated with Construction Activities is henceforth referred to as the "Construction General Permit" (TNCGP). Applicable to all areas of the State of Tennessee, the TNCGP is intended to regulate the pollution prevention and the control of wastes *during* construction activities. Specific to site developments, the TNCGP emphasizes the application of best management practices (BMPs) for purposes of erosion prevention and sediment control (EPSC) and the control of other construction related materials and wastes. The TNCGP is administered by the Tennessee Department of Environment and Conservation (TDEC).

3.2.3 Aquatic Resource Alteration Permit

Persons who conduct any activity that involves construction within, and potentially the alteration of, waters of the state must obtain a state Aquatic Resource Alteration Permit (ARAP), and possibly a Federal Section 401 Certification. Examples of stream alterations that require a permit include:

- Bank Sloping; stabilization
- Channel relocation
- Water diversions or withdrawals
- Road and utility crossings
- Dredging, excavation, channel widening or straightening
- Dams, weirs, dikes, levees, or other similar structures
- Structural fill
- Flooding, excavating, draining and/or filling a wetland

ARAPs and 401 Certifications are administered by TDEC. The Section 401 Certification is required for projects involving the discharge of dredged or fill material into waters of the United States (US), or wetlands. An ARAP is required for any alteration of state waters, including wetlands that do not require a federal permit.

3.2.4 26a Permits for Shoreline Construction

The Tennessee Valley Authority (TVA) administers a permit program that governs shoreline construction along, across, or in the Tennessee River or any of its tributaries. Thus, TVA's jurisdiction for the 26a permit extends to the limits of

the Tennessee River watershed. In accordance with TVA requirements, the permit applies to construction in the 500-year floodplain or to the upper limits of TVA flowage rights, whichever is higher, for developments located along regulated rivers (tailwaters) and TVA reservoirs (e.g., Boone Lake). Along off-reservoir, unregulated streams and rivers, jurisdiction is typically applied to the limits of the 100-year floodplain. More information on the TVA 26a permit can be found at http://www.tva.gov.

3.2.5 State/Federal Water Quality Regulations

Two major regulatory programs provide the basis for the city's water quality regulations: the General Permit for Discharges from Small Municipal Separate Storm Sewer Systems (MS4s); and the Total Maximum Daily Load (TMDL) program. Both programs are administered by TDEC. For local governments subject to the MS4 permit (including the city), the TMDL program is largely implemented through permit conditions. Relevant to post-construction stormwater requirements for land developments, compliance with the permit is established through the stormwater management requirements established in Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code, which is applicable to new developments and redevelopments.

More information on MS4 permit compliance programs in Alcoa can be found on the city's website.

3.2.6 Federal Emergency Management Agency (FEMA) Floodplain Programs

The National Flood Insurance Program (NFIP) and the Community Rating System (CRS) are both initiatives managed by FEMA to address flood risk and encourage better floodplain management practices. The NFIP is managed by the FEMA and is delivered to the public by a network of more than fifty (50) insurance companies. To participate, communities must adopt and enforce local floodplain management regulations that meet or exceed NFIP standards. The CRS is a voluntary incentive program that recognizes and encourages community floodplain management practices beyond the NFIP requirements.

Flood damage prevention regulations in sub-chapter 2.21 of the city's Zoning Ordinance controls development in flood prone areas and maintains city eligibility for participation in the National Flood Insurance Program (NFIP).

3.3 The Pre-Development Hydrology Map

The Pre-Development Hydrology Map It is a layered map (or set of maps) that depicts the existing hydrologic condition of a property prior to the proposed development. For a new development, the existing condition is an undeveloped condition. For a redevelopment, the existing condition is a developed condition. Both situations have a hydrologic condition that must be understood so design professionals can develop an effective post-development stormwater management strategy. The map is prepared using available data and visual observations. Calculations and onsite tests are not required.

The primary purposes of the Pre-Development Hydrology Map are to:

- allow identification of sensitive hydrologic and topographic features (e.g., streams, sinkholes, steep slopes) so they can be avoided during development
- find opportunities for non-structural LID practices to reduce stormwater volume and peak discharges naturally
- determine and assess feasibility factors for structural SCMs.

Use of a Pre-Development Hydrology Map is a standard nonstructural LID practice aimed at minimizing stormwater volumes and maximizing natural hydrologic function after development. This practice is best performed early in the

development planning process, before the layout of roadways, driveways, and buildings is designed for a subdivision or site, and before clearing and grading. This allows design professionals to identify opportunities for inexpensive, natural LID stormwater management approaches before these areas are altered by clearing and grading.

A Pre-Development Hydrology Map is required as part of the stormwater management plan (SWMP). More information on this plan is provided in Chapter 4 (Low Impact Development Practices). A checklist for the map is provided in the Stormwater Management Plan (SWMP) checklist presented in Appendix C.

3.4 The Stormwater Management Plan (SWMP)

The Stormwater Management Plan (SWMP) is the engineering plan for the design of the onsite stormwater conveyance system, non-structural LID practices (if any), SCMs, and water quality buffers. It is required for all new and re-developments subject to the city's stormwater requirements. The SWMP is reviewed by the city for compliance with the ordinance, this manual, and any other applicable local requirements.

SWMP preparation, submittal, and adherence requirements are established in Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code. The list of required elements for the SWMP is provided in the SWMP preparation checklist located in Appendix C. Table 3.1 lists the notable sub-reports included in the SWMP. In general, sub-reports will include maps, narratives, diagrams, calculations/analyses, specifications, and certifications to show that the proposed design(s) comply with the design standards and specifications provided in stormwater management regulations and this manual.

Table 3.1 Key Sub-Reports In the SWMP

Sub-Report	Purpose
Pre-Development Hydrology Map	See description in Section 3.3 above.
Drainage System Report	Describes the proposed onsite stormwater conveyance system and how it ties into the public stormwater conveyance system.
Post-Construction Hydrology Report	Documents the proposed design for SCMs, including detention/retention basins, and water quality buffers. SCM design specifications are provided in Chapter 7. Water quality buffer design specifications are provided in Chapter 7.
SCM Vegetation Report	Describes the proposed vegetation for SCMs. For vegetated SCMs, this report must be prepared with assistance of a TN-licensed landscape architect. Vegetation design specifications and plant selection guidance are included in the SCM design specifications located in Chapter 7.
SCM Maintenance Report	Document the type and location of each SCM proposed for the development in an easy-to-read map, intended for future property owners. Also describes how the SCM designs support future maintenance.

3.5 As-Built Plan

The terms "as-built plan", "record drawing", or "as-built certification" are synonymous and often used interchangeably in the land development field. Where "as-built plan" is used, the other terms can be inferred.

As-built plans are prepared at the end of construction to document the as-constructed condition of each SCM for developments subject to an approved SWMP. The purpose of an as-built plan is to certify that the development or redevelopment was constructed in accordance with the approved SWMP, and that SCMs are clean, undamaged, and fully functional at the end of construction. As-built plans are recorded, and any restrictions or requirements shown on the as-built plan runs with the property.

As-built plan preparation and submittal requirements are established in Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code. The list of required plan elements is provided in the plan preparation checklist located in Appendix D. Several of the notable sub-plans and reports included in the SWMP are also required in the As-Built Plan, modified as necessary to document as-constructed condition.

3.6 Professional Certifications

Up to three professional certifications may be required with the SCM as-built plans. If SCMs or flood storage facilities (i.e., water quantity controls) are required on a project, certifications for each of these requirements must be completed, stamped, and signed by a Professional Engineer (PE). The PE will use as-built survey data provided to them by a Registered Land Surveyor (RLS) to complete the required certifications. By certifying the SCMs and facilities, the PE affirms that they were installed per their design plan.

Also, and separately, all projects may be required to submit an as-built plat with certifications provided by the property owner acknowledging that SCMs are installed and will be maintained in keeping with local, state, or federal regulations in clean, undamaged, and operational conditions. This certification will be recorded with the as-built plat.

3.7 Easements and Plats

Stormwater easements are a legal agreement to grant the city access to SCMs, vegetated buffers, stormwater conveyances, and related access routes from a public roadway for purposes of inspection and maintenance enforcement. The easements are required by Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code and must be shown on all land development plans. They are also shown on the plat for the development, and therefore are recorded and run with the property.

Stormwater easements are not SCM maintenance agreements. They do not assign maintenance responsibilities to the city or any other agency or person. SCM maintenance is the responsibility of the property owner. Consult Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code to ensure that stormwater easements are located, marked, and maintained in accordance with city requirements.

3.8 Bonds and Construction Securities

A performance bond or other form of construction security may be required by the city for land disturbing activities, and/or the construction of new developments and redevelopments when:

- there is a potential for stormwater to adversely impact local rights-of-way, other property, and/or streams, wetlands, ponds or lakes; or,
- an erosion prevention and sediment control plan is required; or,
- a SWMP is required; or,
- the area of grading or development drains to one or more sinkholes; or,

- the site is used for a borrow pit.

The purpose of the performance bond or security is to ensure that the responsible person(s) appropriately completes the bonded land disturbing activities and/or construction work, which have the potential to impact the public interest if performed improperly. The bond/security provides assurance to the city that it will be reimbursed should it assume the costs of corrective measures and/or work not completed by the responsible person(s) according to the required specifications and approved plans. The money can be used to cover the city's costs for SCMs and related appurtenances, the installation and maintenance of EPSC measures and EPSC corrective actions, final soil stabilization of a site, the establishment, protection, and maintenance of vegetated buffers, and the costs of as-built plan preparation and plat/plan recording.

Performance bonds are administered by the city. The dollar amount will be determined based on the information presented in the approved EPSC Plan and/or SWMP. Check Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code for more information on required bonds and construction securities.

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4.1 LID Explained

In the distant past, the design of stormwater management features for a proposed development was almost an afterthought. Areas of potential flooding were considered when laying out pavement and buildings, but the design of stormwater infrastructure was largely a product of the layout. This approach changed slightly when communities sought to reduce the rate of runoff discharging from a development. The location and approximate size of the onsite detention basin(s) needed to be identified along with the pavement/building layout, which further influenced the stormwater conveyance system design. Detention requirements can result in mixed outcomes. While flooding is prevented on properties near the new/re-development, detention basins can actually increase peak flows and exacerbate flooding further downstream. In fact, standard stormwater design approaches seek only to convey and dispose of stormwater. Thus, they often do very little to mitigate the stormwater management challenges communities experience in the present day in terms of volume and pollution.

In contrast, employing a low impact development (LID) approach to stormwater design can mitigate stormwater's negative impacts. LID includes several site design practices (herein called LID practices) that lay-out the natural and proposed man-made site elements in a way that reduces the stormwater impact. Additional LID techniques come in the form of stormwater control measures (SCMs) included in Chapter 7 (SCM Design Specifications). At the level of an individual development, the primary goals of LID are:

- Using natural hydrology as a framework for development design.
- Managing stormwater as close to the point of origin as possible, minimizing the need for large-scale runoff collection and conveyance.
- Reducing the environmental impact "footprint" of the site by preventing stormwater impacts rather than mitigating them, while retaining and enhancing the owner/developer's purpose and vision for the site.
- Utilizing simple, nonstructural methods for stormwater management that are lower cost and lower maintenance than SCMs.
- Creating a multifunctional landscape.

On a city-wide scale, LID can support community expansion and growth while minimizing the negative impacts of increased stormwater.

Reduction of adverse stormwater impacts using LID should be the first consideration of the design professional. Operationally, economically, and aesthetically, LID designs offer significant benefits over treating and controlling runoff downstream. Therefore, it is often advantageous to explore and exhaust all options for LID before considering structural stormwater controls.

This chapter provides more detail on how LID designs work, then describes several non-structural stormwater LID practices that can be used during development of layout and design. SCMs are fully described in Chapter 7 (SCM Design Specifications).

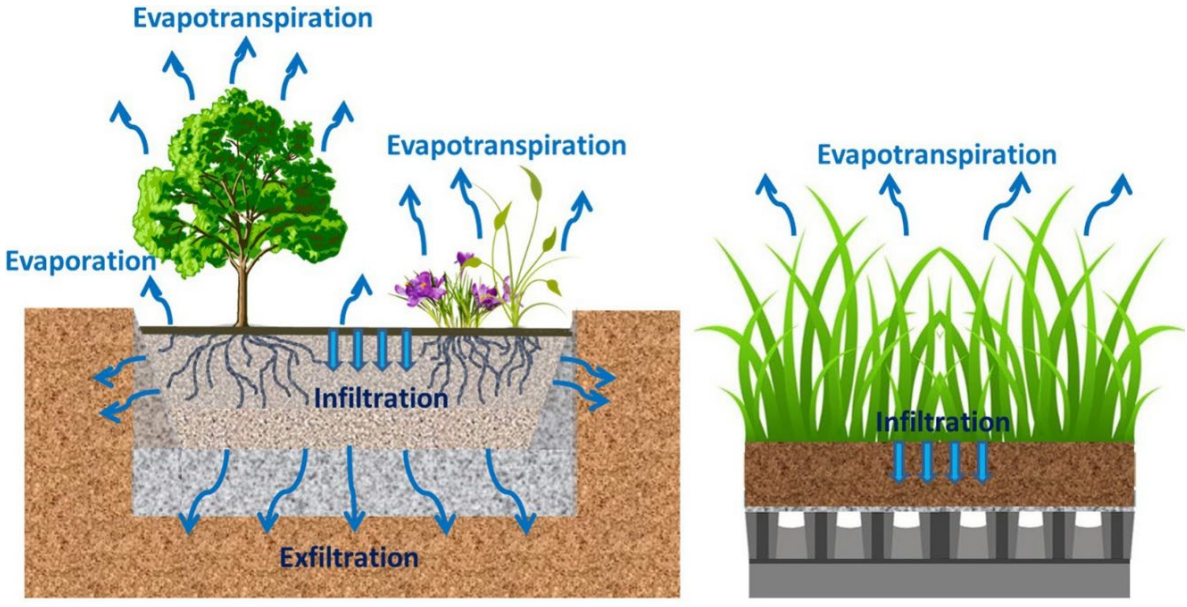
4.1.1 The Importance of Plants and Soils

As a development design approach, stormwater LID strives to mimic natural hydrology (see information on the hydrologic cycle in Chapter 2) on a developed property. Natural hydrology is dependent on water infiltration into soil, evaporation, and transpiration via plant life. Thus, designing a development with an eye toward healthy plants and uncompacted, natural soil underpins LID techniques.

Plants and soil work within a self-maintaining cycle when land disturbance is minimized, and appropriate plant diversity is maintained. The health and stormwater management capabilities of the soil affect the health and stormwater capabilities of plants, and vice versa. Well-drained and moderately well-drained soils have numerous void spaces that can store and transmit water and surface nutrients beneath the surface crust, supporting healthy plant growth both above and below ground. The nutrient filled soil also provides space and food for soil organisms. The activities and life cycles of these organisms assist in maintaining soil permeability and chemical characteristics to further support plant life. In turn, healthy plants have strong and vigorous root growth, which keeps soil permeable, aids in infiltration and subsurface nutrient delivery to soil organisms. Aboveground, leaf growth and decay cycles deliver organic matter to the ground, which migrate into the soil when it rains, thus removing rainfall and pollutants.

The role that plants and soil can play in stormwater management for urban and suburban landscapes must not be underestimated. When properly protected and managed, plants and soil can provide substantial stormwater volume reduction, even in urban developments. This is the primary premise in LID designs; maximizing, preserving, and in many cases, using healthy plants and soil in an SCM to manage stormwater generated by land development. The LID design techniques and SCMs included in this manual consider or use soil and/or vegetation to either limit or manage stormwater on a land development (see Figure 4.1).

Figure 4.1 Volume Reduction Mechanisms of Soil and Water



Bioretention Area **Green Roof**

Graphic adapted from Ebrahimian Ali et al, 2019

4.1.2 Plants and Soil as LID and SCM Design Elements

Since plants and soil are so important to LID-based designs, they must be considered by designers and municipal plan reviewers as site and stormwater design elements. This typically means understanding and considering the property's pre-development hydrology (refer to Chapter 3 and Section 4.4.3 below) as the layout of buildings and impervious surfaces are planned. For example, in-situ hydrologic soil information (e.g., A, B, C, D, and urban/fill) is useful for LID designs, as clearing, grading, and building/pavement placement can be confined to those areas with the poorest draining soils, while preserving, and possibly using, well-draining soils for stormwater management. Similar evaluations can be made for pre-development land cover (i.e., existing vegetation and impervious areas).

Plants and soil are addressed as stormwater management design elements in this manual as follows.

- The Pre-Development Hydrology Map is a portion of the Stormwater Management Plan (SWMP) that documents the existing hydrologic condition of a property prior to a proposed new development or re-development. The report includes mapping of soil and land cover (pervious vs. impervious), among other important features. The report is discussed in detail in Section 4.3 of this chapter and the report's required elements are listed in Appendix C (Stormwater Management Plan Checklist).
- The non-structural LID practices described in this chapter target the preservation of native, uncompacted soil and native, healthy, and diverse plant populations to promote wide-area infiltration and evapotranspiration. The more a site designer can use LID design approaches, the more the land development's response to rainfall will mimic a more natural hydrologic character.
- The SCMs included in Chapter 7 (SCM Design Specifications) use uncompacted soil to promote facility-level infiltration and/or biofiltration. Some also require a healthy and diverse plant cover to foster evapotranspiration. During small, frequent rain events, these SCMs can diminish the influence of impervious surfaces on the developed site. Although impervious surfaces can significantly elevate stormwater volume from pre-development levels, the utilization of SCMs effectively reduces a portion of this volume while almost entirely eliminating pollutants.

4.2 Introduction to Non-Structural LID Practices and Incentives

The reduction in stormwater volume and ideally, peak discharges, that can result from employing LID practices influences the size and cost of the onsite stormwater conveyance system and SCMs. Hence, LID practices can be viewed as both a water quantity and water quality management tool with ancillary benefits such as:

- Reduced construction & maintenance costs
- More aesthetically pleasing and naturally attractive landscape
- Open space for recreation
- Pedestrian-friendly neighborhoods
- Increased property values
- Protection of waterbodies, wetlands, wooded areas, and the habitats they provide for wildlife
- Easier compliance with wetland and other resource protection regulations

The LID design practices addressed in this chapter are listed in Table 4.1. The table groups the practices into four major categories that are described in Sections 4.3, 4.4, 4.5 and 4.6.

Table 4.1 LID Design Practices

SECTION 4.3 DESIGN COLLABORATION AND EARLY PLANNING	
4.3.2 Collaborate with multi-disciplinary design team	4.3.3 Pre-development hydrology map
SECTION 4.4 PRESERVATION OF NATURAL FEATURES AND RESOURCES	
4.4.1 Preserve stream corridors and floodplains	4.4.5 Fit the design to the terrain
4.4.2 Preserve and protect sinkholes	4.4.6 Minimize siting on porous or erodible soils
4.4.3 Preserve wooded areas and individual trees	4.4.7 Reduce limits of clearing and grading
4.4.4 Preserve undisturbed areas	
SECTION 4.5 REDUCTION OF IMPERVIOUS SURFACES	
4.5.1 Redevelopment and infill development	4.5.3 Disconnect small, paved areas
4.5.2 Reduce building and pavement footprints	4.5.4 Use permeable surfaces
SECTION 4.6 USE OF NATURAL FEATURES AND PRESERVED AREAS	
4.6.1 Use undisturbed areas and stream/shore buffers	4.6.3 Connect to parks/greenways & pocket parks
4.6.2 Use natural drainageways and vegetated swales	4.6.4 Create multi-functional landscaping

4.3 Design Collaboration and Early Planning

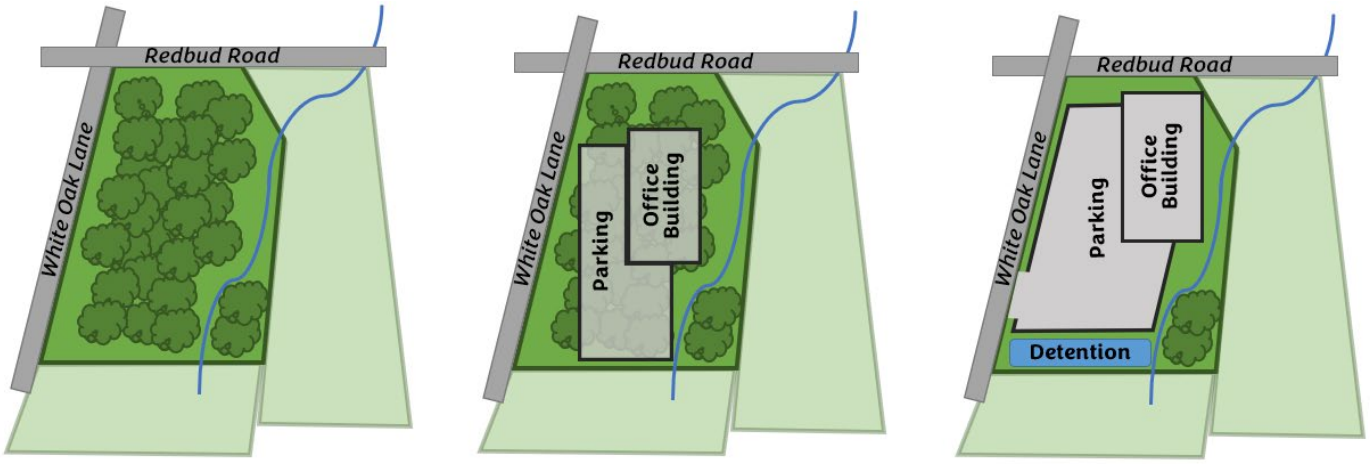
This section provides guidance for design professionals on data gathering and initial planning for land development designs. The guidance provided in this section can be used regardless of whether nonstructural LID practices are included in the proposed design.

4.3.1 Land Development Planning Process

Figure 4.2 presents a typical progression of land development design. It begins with initial consideration of a property by the developer. A general design concept takes shape with a design professional, where a basic understanding of the general number and size of buildings and parking areas, as well as their probable location (for individual sites) or street and lot locations (if subdividing). At this point, the developer understands their potential return on investment (ROI) from the property, and whether the development makes financial sense.

If the ROI is suitable for the developer, a master design is created. The lot or building and pavement configurations are refined, utility needs are understood, and the necessary clearing and grading is established. The design professional balances the developer's overall concept and city regulations in a way that can meet or exceed the expected ROI. From the stormwater perspective, it is this design that is provided to the city for approval in the form of the SWMP.

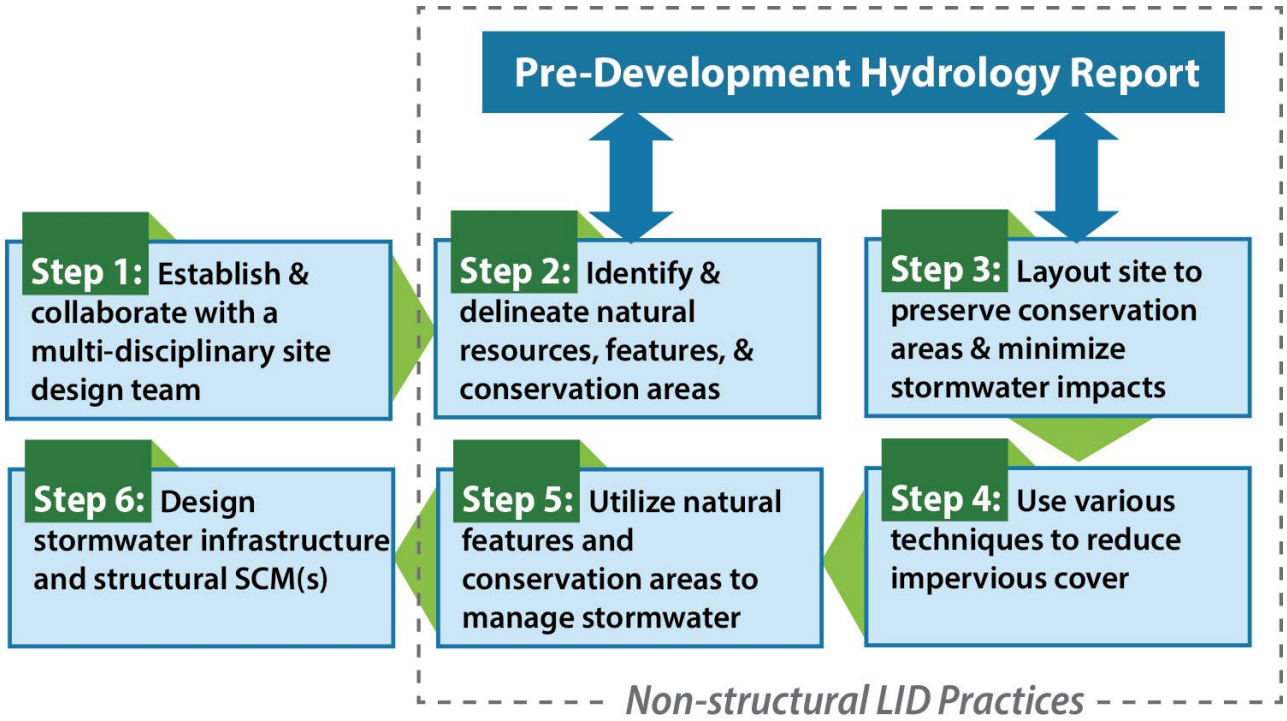
Figure 4.2 Typical Land Development Planning and Design Steps Example



Undeveloped Property | **General Design Concept** | **Master Design Plan**

This planning progression is the same when LID is considered, whether the site is originally undeveloped, as is shown in Figure 4.2, or has been previously developed. However, with LID, there are several additional steps that occur when creating the general design concept to consider LID practices, as shown in Figure 4.3.

Figure 4.3 Design Steps for LID Developments



An important concept conveyed by Figure 4.3 is that the application of non-structural LID practices ends when a designer begins the analyses and computations for SCM design. In other words, **LID planning takes place very early, before the layout of buildings, pavement, and pervious areas is established and before a site is cleared and graded**.

This allows the layout to take shape with the application of LID practices. This early planning approach is critical to the successful use of LID practices because it allows the design team to see, then preserve, restore, and/or use, a site's natural features for stormwater management. Thus, we fit the development to the site's natural hydrology rather than the other way around. In contrast, site designers who attempt to fit the existing property to a pre-conceived or "cookie-cutter" layout, or who wait to consider LID practices until after the site layout and grading plans are established, are not likely to have a high degree of success applying LID.

Most of the steps shown in Figure 4.3 are described in this chapter, as follows.

- Step 1 is addressed in Section 4.3.2.
- Step 2 is addressed in Section 4.3.3.
- Steps 3, 4, and 5 are the application of LID practices described in Section 4.4, 4.5, and 4.6. After step 5, a general concept design is well-established, and the design professional can easily move to the master design plan.
- Step 6 is the application of SCMs, which are addressed in Chapter 5 (SCM Design Specifications). The master design plan is well underway by this step.

4.3.2 Collaborate with a Multi-Disciplinary Design Team

A critical concept in Step 1 of Figure 4.3 that site designers should note is the necessity for early collaboration with a multi-disciplinary team to ensure successful LID designs. Successful LID designs demand knowledge and experience of plants and soil, which are considered design elements. As a result, stormwater designs are no longer the sole domain of the civil engineer. Rather, working with a team of skilled professionals and scientists to optimize the use of LID practices and SCMs will, ideally, improve the developers ROI. Table 4.2 presents the disciplines and relevant skills that can help ensure LID design success.

Table 4.2 Design Team Disciplines and Relevant Skills

Discipline	Skills Relevant to LID Designs
Civil Engineering	Hydrology, hydraulics, infrastructure, and utilities design, SCM design, stormwater quality and quantity control, design plan preparation
Soil Science	Soil health, profiles, texture, porosity, storage capacity, infiltration tests, borings, and restoration techniques
Landscape Architecture	Multi-functional space design, open space function and design, hydrology, landscape design and templates
Horticulture	Functional landscape planning, plant varieties and needs, native plants, plant/soil health, stream buffer restoration, and long-term plant management
Forestry	Health, preservation (or restoration), and management of wooded areas, tree selection for urban landscapes and SCMs, pest management
Ecology	Desired wildlife vs pest habitats and management, stream buffer restoration and enhancement, sensitive flora and fauna avoidance/support
Geomorphology	Stream restoration, bank stability, and stream health management in urban landscapes

When plants are included in LID designs, the city strongly suggests the inclusion of a Registered Landscape Architect or a horticulturalist because of their knowledge of soil/plant interaction, and plant diversity, succession, and landscape templates. However, expanding the team further with the skillsets in Table 4.2 can provide substantial benefits, as the team can better maximize the use of natural features for stormwater management, while possibly minimizing constructed features and their associated construction, materials, and maintenance costs. Regardless of which professionals comprise the design team, all members should be knowledgeable of, and preferably experienced in, stormwater management mechanisms and LID concepts. Local technical knowledge is preferred, especially where plant selection and maintenance are concerned.

The benefits of using a multi-disciplinary design team include the following.

- Optimization/maximization of LID practices and multi-functional SCMs
- Robust understanding of how local, state, and Federal requirements for land developments can be met creatively and aesthetically, yet cost effectively
- Robust stormwater design while potentially reducing costs for stormwater infrastructure and pavement
- Potentially reduced needs for stormwater-related maintenance by future property owners for the long-term
- Preservation or restoration of a property's natural character and aesthetic features

These benefits can have the effect of meeting or exceeding the desired ROI of the land developer, while also maximizing the value of the property for future property owners. However, to ensure success, the entire team should come together well before the general design concept is developed and remain involved with the land development through site construction. The former will provide the greatest potential for the application of LID practices. The latter will ensure the protection and proper design and construction of SCMs.

4.3.3 The Pre-Development Hydrology Map

As explained in Chapter 3 (Required Stormwater Plans), a Pre-Development Hydrology Map is a map that is required prior to full design. The map characterizes the existing hydrologic condition of a property. For a new development, the existing condition is an undeveloped condition. For a redevelopment, the existing condition is a developed condition. Both situations have a hydrologic condition that must be understood.

The Pre-Development Hydrology Map is developed for the reasons listed below, all of which can improve the developer's understanding and estimation of the site's ROI.

- Optimizing the buildings, pavement, and stormwater SCM layout while avoiding, restoring, or using natural hydrologic features for stormwater control. Hydrologic characterization identifies hydrologic or environmental issues that must be considered during site design, whether LID is strongly considered. For example, potential onsite soil contamination due to past land use may factor into the location of impervious surfaces (to eliminate infiltration in contaminated areas), if SCMs are feasible, and if soil decontamination is required.
- Identifying opportunities or limitations for LID practices and understanding SCM feasibility.
- Optimizing grading extents, construction needs and phasing, materials, and maintenance costs.
- Mapping the site hydrology and other stormwater-related factors can allow the site design team and the city's plan reviewers to identify the potential need for additional data or information to support the future design. This keeps everyone "on the same page" and facilitates a more efficient design effort and plan review process.

Creating the Pre-Development Hydrology Map is really a mapping exercise of available data. Some of the useful data to include in the map is listed below. This list is included in the Stormwater Management Plan checklist provided in Appendix C.

- ✓ Topography (2-foot intervals or closer)
- ✓ General land cover areas
- ✓ Hydrologic Soil Groups and urban fill or farmed soils
- ✓ Waterbodies, wetlands, floodplains,
- ✓ Sinkholes, seeps, springs, bogs, and swamps
- ✓ Areas of prolonged wet conditions or flooding
- ✓ Areas of ecological significance (such as endangered wildlife habitat)
- ✓ Areas of known or suspected pollutants in the soil
- ✓ Existing conservation or protected areas
- ✓ Areas of shallow bedrock, high water table, hardpan, clay lenses, or other similar subsurface conditions, if known
- ✓ Water supply, wellhead protection, or groundwater recharge areas
- ✓ Existing utility corridors, buildings, pavement, and other areas to remain
- ✓ Areas with geotechnical or structural concerns, contractive/expansive soils, etc.
- ✓ Areas of cultural, historical, or archeological significance

It is recognized that some of the data listed in the table may not be readily available, while other data can be mapped by visual inspection or using publicly available data (e.g., USGS Quadrangles, NRCS soil surveys, publicly available aerial photography, etc.). While the collection of all the data listed is encouraged to develop a well-informed stormwater management vision for the site, **performing geotechnical and environmental tests or surveys at this stage is not required**. The map can be developed using only readily available data.

Figures 4.4 and 4.5 present a rudimentary example of how a Pre-Development Hydrology Map can be used to guide a development layout. The example is for a fictional proposed redevelopment. Several LID practices and an SCM are implemented in the example, all shown on the master design plan in Figure 4.5. These are: 1) restoration and preservation of a natural water feature (the daylighted stream); 2) restoration of a stream buffer; and 3) a pervious paver parking lot. These and more LID practices are described in Sections 4.4, 4.5 and 4.6. SCM design specifications are in Chapter 7.

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Figure 4.4 Example Layers of a Pre-Development Hydrology Map for a Redevelopment

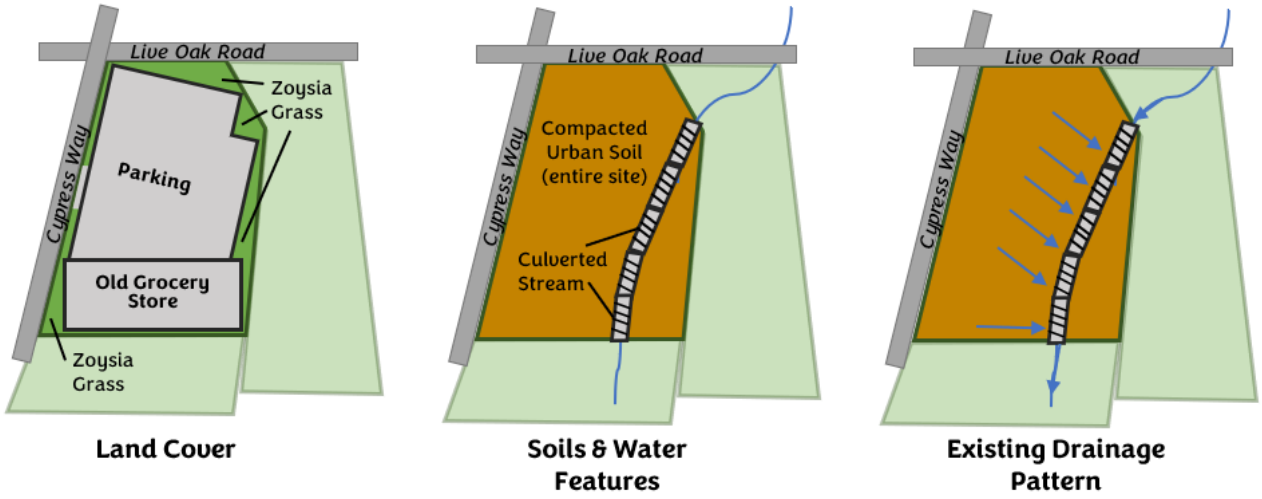
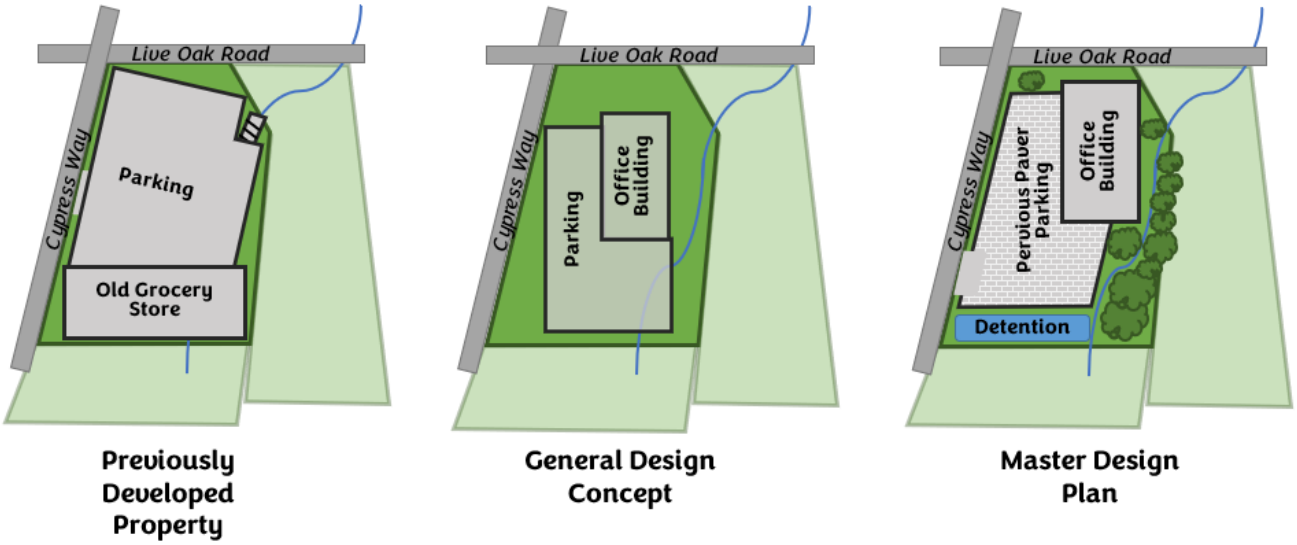


Figure 4.5 LID Design Progression Based on the Pre-Development Hydrology Map



While the Pre-Development Hydrology Map is submitted with the SWMP (i.e., after intensive stormwater design is performed), the city encourages design professionals prepare this map prior to the Pre-Submittal Meeting which is a required meeting for any development that will be considered by the Alcoa Municipal Regional Planning Commission. Bringing the map to the meeting creates an opportunity for the development's design team and city plan reviewers to discuss the potential water quality protection strategy for the proposed development, including possible LID practices. Stormwater designs will not be approved at the meeting.

The objectives for discussing the Pre-Development Hydrology Map with city staff include:

- review of the information provided in the report (and the master design plan if already determined)
- discussion of potential limitations for application of SCMs
- discussion of preliminary strategies and concerns for site clearing, grading, and construction

- discussion of preliminary design strategies for erosion and sediment control, road geometry and layout, SCMs, water quality buffers, the use of LID practices, and LID or SCMs incentives (see Section 4.7 below).
- determination of how the technical guidelines and criteria presented in this manual should be applied to the site.

4.4 Preservation of Natural Features and Resources

After creation of the Pre-Development Hydrology Map to characterize the existing hydrology of the property (see Chapter 3), the layout of the future land development can begin to take shape. The preservation of natural features and resources is integral to hydrologic mimicry and therefore critical to the success of LID designs. These LID practices target preservation of native, uncompacted soils and vegetated open spaces, ideally in areas or ways that provide value to the property beyond hydrologic mimicry. For example, a preserved wooded areas can provide infiltration and evapotranspiration, but also reduces the cost of clearing and grading, provides a woodsy, natural landscape aesthetic, and may even provide amenity areas, such as walking trails or picnic areas.

Natural area preservation LID-BMPs are described in Sections 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6 and 4.4.7.

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4.4.1 Preserve Stream Corridors and Floodplains

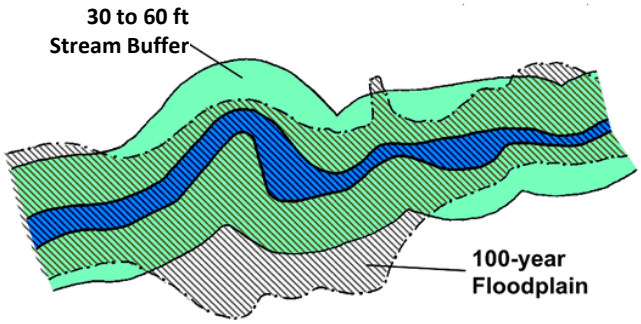
Preserve Stream Corridors & Floodplains	LID Design Practice
Description: Stream corridors and floodplains can be critical to water quality. They also provide infiltration, filtration, and evapotranspiration of stormwater, and habitat, shade, and bank stability. Identify, delineate, and avoid land development in stream corridors and floodplains as much as possible. If such areas are already disturbed, consider restoration to a more natural condition.	**Key Benefits:** • Preserves pre-development hydrology • Provides bank stability, shade, and habitat • Limits stormwater volumes and peak flows • Provides undeveloped land for flooding • Reduces clearing and grading • Provides natural character and aesthetic features

Planning and Design Activities:

Perennial and ephemeral streams are easy to recognize on land that has yet to be developed. However, taking notice of drainageways on properties that have already been developed is important, too, as these linear features may have been a natural stream prior to land development and could benefit from restoration to a more natural form. Providing a wooded buffer for streams and natural drainageways can manage stormwater, act as a stream "right of way" during floods and sustain the integrity of the watershed and stream ecosystem.

- TDEC requires vegetated buffers along streams during and after construction. Consult buffer requirements in The Alcoa Municipal Code, Title 16, titled *Streets, Sidewalks, Drainage and Erosion Control*.
- Regardless of a stream's regulatory status, a 60-foot or wider undisturbed buffer is preferred for stormwater filtration and infiltration, streambank stability, shade, and a supportive environment for both aquatic and bankside flora and fauna.
- Ideally, stream buffers should be heavily wooded and left undisturbed. Restore vegetation by planting native trees and preventing encroachments.
- Ideally, avoid any clearing, grading, and development in floodplains and leave them undisturbed. This prevents having to deal with regulations pertaining to development in floodplains and avoids, to some degree, the code conflicts that sometimes occur between floodplain rules and stream corridor rules (see Figure 4.6).
- Where development in floodplain areas cannot be avoided, minimize the placement of impervious areas in the floodplain and comply with the city's floodplain regulations located in the zoning ordinance.

Figure 4.6 Floodplain Boundaries in Relation to a Stream Buffer



Stream floodplains and stream buffers are two different features. Floodplains are low-lying flat lands that border streams and rivers providing storage and conveyance of the excess flows. Floodplain boundaries are determined for flood events using mathematical models. In contrast, a stream buffer is an undisturbed streamside corridor set aside for purposes of water quality, streambank stability, and habitat preservation. Depending on the site topography, the 100-year floodplain boundary may be inside or outside of a stream buffer. (ARC, 2016)

4.4.2 Preserve and Protect Sinkholes

Preserve and Protect Sinkholes	LID Design Practice
Description: Sinkhole preservation and protection preserves pre-development hydrology and can be critical to flood prevention. Identify, delineate, and avoid sinkholes as much as possible. Also avoid discharge of sediment and waste to sinkholes.	**Key Benefits:** • Preserves pre-development hydrology • Protects sinkhole throats • Reduces clearing and grading • Provides natural character and aesthetic features

Planning and Design Activities:

Karst areas are generally defined as terrain underlain by soluble carbonate rock, where the topography is chiefly formed by dissolving of the rock. The land may be characterized by sinkholes, sinking stream, closed depressions, subterranean drainage, and caves (Monroe, 1970). In karst areas, surface and ground waters are highly interconnected, and often constitute a single, dynamic flow system (Taylor and Greene, 2008). Thus, it follows that alteration of that system can have significant consequences.

Figure 4.7 Sinkhole Formation in East Tennessee

A giant sinkhole causes the closing of a section of Topside Road in south Knox County on July 23, 1996. (Source: Margaret Bentlage/Knoxville News Sentinel Archives)

Karst topography is common in east Tennessee. This is true in Alcoa, as city staff routinely interact with developers, construction contractors, residents, and businesses on sinkhole avoidance and repair. Often, new sinkhole formation is caused by the change in natural hydrology as a result of land development (see Figure 4.7). Guidance on sinkhole preservation and protection are as follows:

- Follow the city's requirements in the stormwater management regulation in The Alcoa Municipal Code, Title 16, titled *Streets, Sidewalks, Drainage and Erosion Control*. Ideally, avoid clearing, grading, and development in sinkholes and leave them undisturbed.
- Delineate sinkholes at their highest contour (i.e., the "lip" elevation) before site layout. Mark this elevation onsite with high visibility fencing before clearing and grading begin to prevent entry.
- Protect sinkhole capacity and throat (even if not visible) during construction using erosion prevention and sediment control (EPSC) measures. Discharges of sediment and waste to sinkholes can reduce the surface capacity of sinkholes and clog the sinkhole throats.
- Implement as many nonstructural LID practices described in this chapter as possible to limit the increase in stormwater volume caused by the proposed development. Large, concentrated volumes of stormwater are significant contributors to sinkhole formation in karst areas.
- It may be necessary to place an impermeable liner beneath onsite SCMs to avoid sinkhole dropouts due to storage of concentrated water.
- If possible, direct stormwater runoff from impervious areas of the development to the nearest public stormwater conveyance system.

4.4.3 Preserve Wooded Areas and Individual Trees

Preserve Wooded Areas and Individual Trees	LID Design Practice
Description: Wooded areas that coincide with other natural features are key areas to preserve. They provide infiltration, filtration, and evapotranspiration of stormwater, as well as habitat, shade, and tranquility. For previously developed properties without many trees, use reforestation techniques to create new wooded areas (see below).	**Key Benefits:** • Preserves pre-development hydrology • Limits stormwater volumes and peak discharges • Reduces clearing and grading • Provides shade, habitat, natural character, and improved air quality • May increase the value of the property after development

Planning and Design Activities – Existing Tree Protection

The following activities should be done to preserve wooded areas and mature trees.

- On the Pre-Development Hydrology Map (see Section 4.3.3), delineate the boundaries of wooded areas and mark the locations of individual mature trees. Take special note of wooded areas or multiple mature trees that coincide with other features or resources, such as stream corridors and floodplains, native and well-draining soils, and endangered species habitats. These coincidental areas should be more highly valued for post-construction preservation because they can provide an enhanced stormwater or environmental function.
- Once the site layout is better determined, individual, healthy, mature trees (not located in a wooded area) that are not located where buildings or pavement is planned should be preserved and integrated into the post-construction landscape.

Figure 4.8 Mature Tree Protection

Protection for mature trees during construction must extend to the dripline. (Source: City of Calgary AB)

- Clearly identify trees and wooded areas to be preserved, specifying measures to protect these features during and after construction on the SWMP and erosion prevention and sediment control (EPSC) plan. See Table 4.3.

Table 4.3 Protection Measures for Existing Wooded Areas and Mature Trees

Protection During Construction (SWMP and EPSC Plan Guidelines)	**Protection After Construction** (Site Design Guidelines)
For individual trees, install high visibility fencing around the root zone, extending at least to the canopy drip line. For wooded areas, install fencing around the area along the drip line edge of the area.	Do not direct roadway runoff to the tree. The dripline area under an existing, mature tree is not suitable for use as a stormwater SCM. This may cause localized flooding and stress or kill the tree being preserved.
In the fenced area, do not: • allow vehicles or heavy equipment	Do not change the grade of the site near the tree(s) root zones. Within the drip line, avoid exposing the roots or

Protection During Construction (SWMP and EPSC Plan Guidelines)	Protection After Construction (Site Design Guidelines)
• wash equipment or dump chemicals • store construction materials or chemicals • allow erosion or sediment discharges	covering them with extra soil. Either of these will stress or kill the tree.
Minimize foot traffic in fenced areas. If unavoidable, build boardwalks or lay sheets of plywood to limit compaction.	For trees preserved near impervious areas, consider using permeable pavers near the tree to allow rainwater to percolate into the soil and provide water to tree roots. Bypass flood flows from the pavers.
Water preserved trees as needed to ensure their health during construction.	If drainage patterns change, ensure preserved trees will have a source of water for their root zones.

Planning and Design Activities – Reforestation

- On the Pre-Development Hydrology Map (see Section 4.3.3), delineate areas where reforestation can provide maximum benefit and where trees have a good chance of survival.
- Areas that provide maximum benefit are those where other natural features or resources are present, such as floodplains and native well-draining soils. These areas are highly valued for preservation and reforestation because they can provide an enhanced stormwater function.
- Urban environments are challenging for tree health and survival. Consider soil contaminants, high temperatures, high winds, compacted soil, poor drainage, and confined areas for root expansion as challenges to tree life.

Figure 4.10 Example of Urban Reforestation

Urban forest in Chattanooga TN. (Trees for Energy Conservation)

- Once the site layout is better determined, designate locations where immature trees can be planted. Remember, a single tree or group of trees planted primarily for landscape aesthetic IS NOT a stormwater control measure. If stormwater treatment is needed by these trees, design the appropriate SCM that includes trees (e.g., bioretention area, urban bioretention, or manufactured treatment devices (MTDs). Design specifications for all of these SCMs are provided in Chapter 7.
- For a planned reforestation area, collaborate with a forester to develop the reforestation design, select the appropriate tree species (native is preferred), and oversee tree installation. The forester should remain involved for at least two growing seasons after the reforestation area has been planted.
- For individual trees, a forester or landscape architect should be included in the design to determine appropriate tree placement, species, installation, and maintenance.
- On EPSC and SWMP plans, clearly identify the location of tree installation and reforestation areas. Specify protection measures during and after construction per the guidance of the forester or landscape architect.

4.4.4 Preserve Undisturbed Areas

Preserve Undisturbed Areas	LID Design Practice
Description: Undisturbed areas are areas that have not yet been developed, graded, or compacted. They can be excellent areas for infiltration, filtration, and evapotranspiration because they have native soil and deep-rooted vegetation. The best areas for preservation are those with well-draining soils.	**Key Benefits:** • Preserves pre-development hydrology • Limits runoff volumes and peak discharges • Reduces clearing and grading • Provides natural character

Undisturbed areas are hard to find in urban and suburban settings. They do exist, even if they are only on small pockets of land on a property that is largely developed. These areas can be highly valuable from a stormwater management perspective, even if they are not considered "buildable" land. In east Tennessee, it is not uncommon to find low-lying or even "swampy" areas. Many of these features already play a strong role in mimicking the natural hydrology of a property, often by flushing stormwater from pervious areas through and off the property. However, for stormwater management, the most valuable undisturbed areas are those located along stream corridors or where native, well-draining soils lie. Leaving these areas undisturbed can protect local streams, reduce stormwater runoff, and sustain the integrity of the watershed and stream ecosystems.

Figure 4.11 Example of Protection Sign

Source: City of Columbia, MO

Planning and Design Activities:

- On the Pre-Development Hydrology Map (see Section 4.3.3), delineate existing undisturbed areas, especially areas along stream corridors and where native, well-drained soils exist.
- Develop the site layout, preserving the specially noted areas first. Once the site layout is better determined, allow any remaining undisturbed areas to remain, avoiding clearing and grading if possible. A more natural landscape for the future development can allow these areas to blend into the aesthetic.
- Collaborate with a forester or horticulturalist if any of these areas require vegetation enhancement. Ensure this is done in a way that will not compact the underlying native soils. Avoid using heavy equipment and vehicles in the area during enhancement installations.
- Clearly identify the location of undisturbed areas that will be preserved on EPSC and SWMP plans. Specify and install protection measures during construction to avoid accidental clearing or grading, encroachments, erosion of the areas, or sediment discharges into the areas.
- For post-construction, install signs that educate landscapers and/or the public as to the function and maintenance (or lack thereof) of these areas and the importance of leaving them undisturbed.

4.4.5 Fit the Design to the Terrain

Fit the Design to the Terrain	LID Design Practice
Description: The layout of buildings, roads/streets, utilities, and other site infrastructure should conform to the existing topography and natural features of the land as much as possible. Streams, natural drainage ways, steep slopes, wetlands, and other features should be preserved by designing road layouts around them. Lots/buildings should utilize natural grading and drainage systems.	**Key Benefits:** • Preserves the natural hydrology and drainageways of a site • Reduces the need for clearing and grading • Provides a natural framework for site layout, design, and stormwater management

Figure 4.12 Comparison of Traditional Site Layout and "Fit to the Terrain" Layout

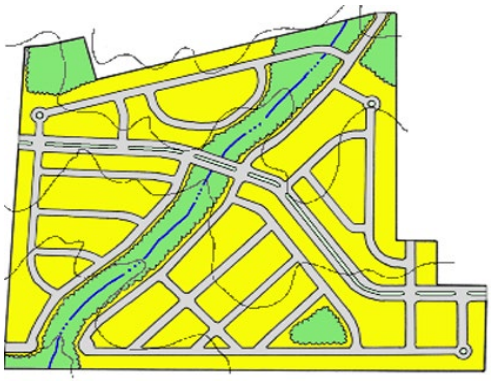
Planning and Design Activities:

Site designers should perform the following activities to implement this LID design practice.

Left: A traditional residential layout means wide scale clearing and grading, loss of stream buffers, and development in floodplains. Right: The "Fit to Terrain" layout provides the same number of lots, but reduces clearing and grading, provides sufficient buffer for stream health, and avoids development in the floodplain. Adapted from: ARC, 2016.

- Lay out the site to conform or "fit" the natural landforms and topography of the property, minimizing grading as much as possible. This preserves the natural hydrology and features on the site, and reduces clearing plants and grading native, uncompacted soil. Avoid floodplains and low-lying areas.
- Roadway patterns should match the terrain, following natural contours. This provides buildable areas while reducing stormwater infrastructure (i.e., bridges and culverts). Consider viable access points for parking areas and buildings, avoiding steep slopes.
- In areas that slope, the major axis of buildings should be oriented parallel to existing contours.

Figure 4.13 Fluid Grid Street Pattern



(Source: ARC, 2016)

4.4.6 Minimize Siting on Porous or Erodible Soils

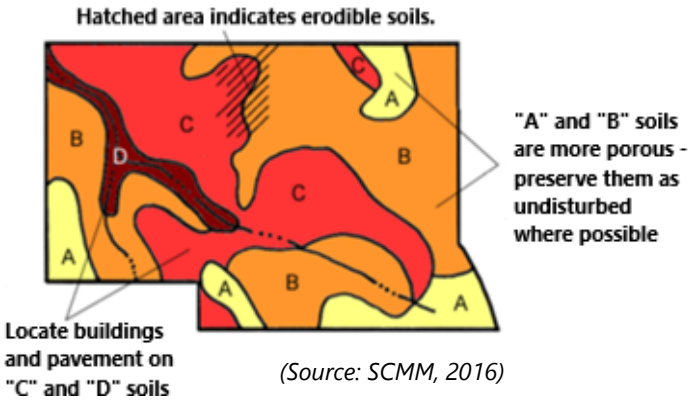
Minimize Siting on Porous or Erodible Soils	LID Design Practice
Description: Native, porous soils such as sand and sand mixes provide natural opportunities for stormwater infiltration. These areas should be preserved to support hydrologic mimicry after land development, and as potential options for the management of runoff from developed areas of the property. Unstable or easily erodible soils must be avoided altogether due to their greater erosion potential.	**Key Benefits:** • Preserves the natural hydrology of a site • Provides areas for natural runoff reduction and structural LID-SCMs without underdrains • Reduces the need for clearing and grading • Reduces needs for erosion prevention and sediment control

Discussion:

See Figure 4.14. Soils with maximum permeabilities (hydrologic soil group A and B soils such as sands and sandy loams) allow for the most infiltration of stormwater into the subsoil. These areas should be conserved as much as possible and incorporated into undisturbed natural or planned open space areas. Conversely, buildings and other impervious surfaces should be located on those portions of the site with the least permeable soils (hydrologic soil groups C and D).

Development on highly erodible or unstable soils should be avoided for land disturbing activities and buildings to prevent erosion and sedimentation problems as well as potential future structural problems.

Figure 4.14 Example Soil Map



(Source: SCMM, 2016)

Planning and Design Activities:

The following activities should be done to minimize development on porous and erodible soils.

- A Tennessee licensed soil scientist should be consulted for this exercise, as they can easily identify highly porous and highly erodible soil. They can also identify other soils of concern, such as those with high shrink-swell potential.
- On the Pre-Development Hydrology Map (see Section 4.3.3), delineate areas of native soils that have maximum permeabilities (typically hydrologic soil groups A and B).
- Also delineate areas of highly erodible soils. The United States Department of Agriculture (USDA) National Resource Conservation Service (NRCS) prepares lists of highly erodible soils, called the Highly Erodible Land (HEL) Soil List for each state. It can be found online (enter "USDA-NRCS HEL Soil List" into search bar). See Figure 4.14.
- Develop the site layout, preserving areas of porous and erodible soils first. Once the site layout is better determined, allow any areas that are left to remain undisturbed, if possible.
- Clearly identify the location of areas that will be preserved as "undisturbed" on EPSC and SWMP plans. Specify and install protection measures during construction to avoid accidental clearing or grading, encroachments, erosion of the areas, or sediment discharges into the areas. If these areas will be disturbed for landscape purposes, avoid the removal of topsoil and the use of vehicles and heavy equipment.

4.4.7 Reduce Limits of Clearing and Grading

Reduce Limits of Clearing and Grading	LID Design Practice
Description: Clearing and grading should be limited to the minimum amount needed for the development and road access. Site foot-printing should be used to disturb the smallest possible land area on a site.	**Key Benefits:** • Preserves the natural hydrology & drainageways • Reduces clearing and grading costs • Provides shade, habitat, and improved air quality • Provides natural character and aesthetic features

Planning and Design Activities:

Minimal disturbance methods should be used to limit the amount of clearing and grading that takes place on a development site, preserving more of the undisturbed vegetation and natural hydrology of a site. Methods that support minimum disturbance are as follows.

- Establish a limit of disturbance (LOD) based on maximum disturbance zone radii/lengths. These maximum distances should reflect reasonable construction techniques and equipment needs together with the physical situation of the development site such as streams, shoreline, or soils. LOD distances may vary by type of development, size of lot or site, and by the specific development feature involved.
- Map all the LODs to identify the smallest possible land area on a site which requires clearing or land disturbance. This is called "site footprinting", examples of which are illustrated in Figure 4.15.
- Using the LID design practice called "Fit the Design to the Terrain" (Section 4.4.5 above) is especially well-suited to limiting the limits of clearing and grading.
- Identify the location of areas that will be preserved versus those that can be cleared and graded on EPSC and SWMPs. Specify and install protection measures during construction to avoid accidental clearing or grading, encroachments, erosion of the areas, or sediment discharges into the areas.
- Consider the specification and use of special procedures or equipment which will reduce land disturbance. For example, the use of compact machinery when grubbing, grading, loading, or hauling in close proximity to preserved areas can help construction site personnel better navigate these areas and avoid accidental encroachments.

Figure 4.15 Examples of Mass Grading and Site Footprinting

Left: Mass grading removes or compacts native soil and greatly reduces the potential for LID practices. (Source: Reed Contracting) Right: An example of site footprinting, confined to the roadway, ROW, and a portion of the home sites. (Source: Specialty Grading)

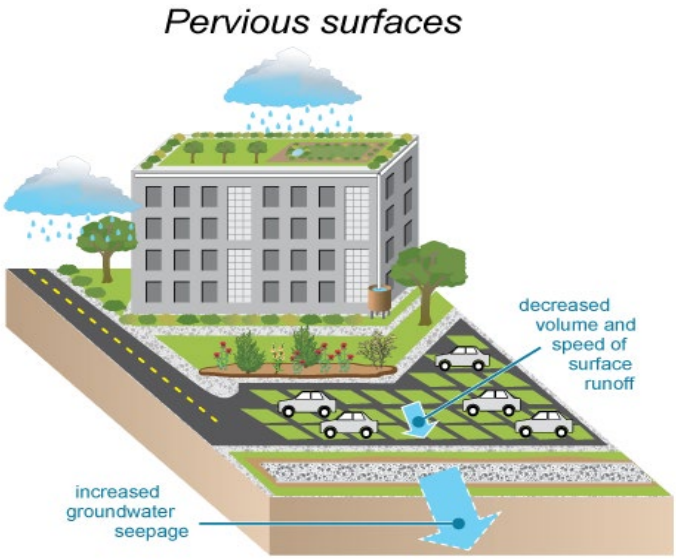
4.5 Reduction of Impervious Surfaces

As the future land development layout takes shape, utilizing LID design practices to preserve natural features (refer to Section 4.4), site designers can explore methods to potentially minimize impervious surfaces such as rooftops and pavements in the development (refer to Figure 4.16). LID design practices outlined in Sections 4.5.1, 4.5.2, and 4.5.3, along with SCMs detailed in Chapter 7, offer various methods to diminish impervious surfaces.

Unlike other LID design practices, the ability of site designers to reduce the amount of imperviousness on a site is limited by local land development codes for streets, driveways, and parking lots. Local rules for minimum street widths, lane and ROW requirements, parking lot minimums, and pavement surfaces are all in play and must be followed. To the degree possible, the policies and guidance provided in this manual do not conflict with the city's land development regulations.

Figure 4.16 Stormwater Impacts from Impervious Surfaces and Pervious Surfaces *(Adapted: Chesapeake & Atlantic Coastal Bys Trust Fund, 2013; Graphic: Integration and Application Network & Univ. of Maryland Center for Env. Science)*

Impervious surfaces (roads, roofs, parking areas) increase the volume, speed, and temperature of runoff. This fast surge of water erodes stream banks and beds, reduces infiltration, and delivers warm, polluted flows into local streams and lakes.



Pervious surfaces (green space, trees, and pervious pavement) decrease the volume and speed of runoff. Water seeps into the ground, or filters through vegetation, delivering cleaner and cooler water into local streams and lakes.

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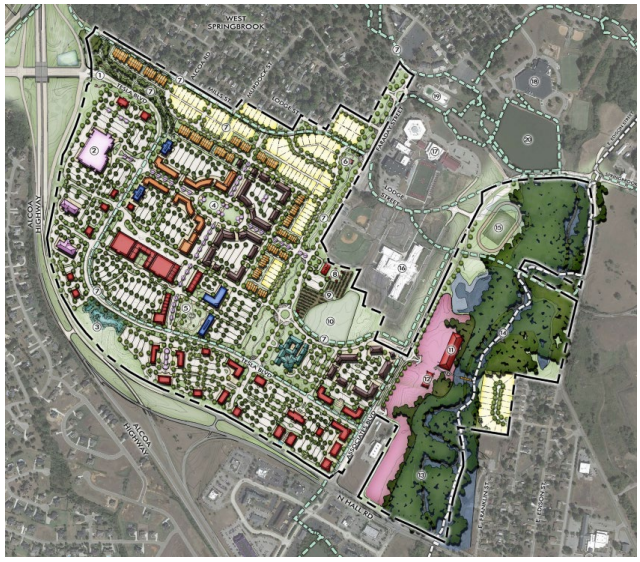
4.5.1 Redevelopment and Infill Development

Redevelopment and Infill Development	LID Design Practice
Description: Redevelopment and infill strategies effectively minimize impervious surfaces compared to similar developments in suburban or rural regions. These practices align with LID principles, capitalizing on existing supportive infrastructure like roads and sewers, thereby reducing the necessity for additional construction to service the property	**Key Benefits:** When contrasted with new developments, redevelopment and infill projects offer: • Community saves costs by using existing infrastructure and services; developers cut expenses through minimized clearing/ grading • Often does not increase (and may decrease) impervious surface area (redevelopment only)

Redevelopment creates new buildings/pavement on a previously developed lot. Infill developments occur on vacant land within an existing community, enclosed by other developed properties. The term "infill" illustrates that the existing area is mostly built-out and the new development is "filling in" the gaps. Redevelopment and infill development can include the following.

- Demolish existing buildings (and pavement) on a lot, creating a new site layout for a development in the same place
- Build single-family or multi-family homes on vacant lots in an existing neighborhood, or build commercial or industrial properties on vacant parcels in an established commercial/industrial area
- Subdivide a lot or property within an existing established area into two or more lots and develop the newly created lots
- Revitalize a neighborhood or urban area using a mix of repurposed existing properties, demolition and redevelopment, and infill development on vacant lots

Figure 4.17 Former Alcoa West Planned Redevelopment *(City of Alcoa)*



Planning and Design Activities:

- Consult real estate agents, local agencies, or the city to find potential properties for re- or infill development. Departments that may be able to help are those involved with planning and zoning, neighborhood development, and historic development.
- Develop a Pre-Development Hydrology Map (see Section 4.3.3). Even in areas already developed, there may be opportunities to use LID practices to restore hydrologic features. Examples include daylighting a previously culverted stream or reducing existing pavement in favor of a small green space.
- Work with existing topography, street and sidewalk layouts, and utilities to design building and parking areas. In some areas, zoning overlays, historic districts, or special design rules may exist and will need to be followed.

4.5.2 Reduce Building and Pavement Footprints

Reduce Building and Pavement Footprints	LID Design Practice
Description: Finding reasonable ways to limit the size of buildings and pavement on a development is an obvious approach to employ when seeking natural hydrologic mimicry. Less impervious surface means less land disturbance, lower runoff volumes, and lower peak discharges. It also can provide significant stormwater benefits (see right) and, in some cases, reduce construction costs.	**Key Benefits:** • Preserves the natural hydrology of a site • Facilitates greater use of preservation-focused nonstructural LID-SCMs • Reduces the need for clearing and grading • Reduces the size and cost of site infrastructure

Planning and Design Activities:

The following activities should be done for impervious area reductions.

- Use the Pre-Development Hydrology Map (see Section 4.3.3) and the natural preservation LID design practices (see Sections 4.4.1 to 4.4.7) to optimize locations and sizes for buildings and pavement.
- Consider the following design approaches (where feasible and allowed by locally adopted land development rules) to reduce impervious surfaces.
- Redevelop existing or choose to infill properties instead of developing green space (see Section 4.5.1)
- Use shared driveways and parking with other properties in the same area (Figure 4.18)
- Employ designs favoring shared driveways or single-lane roads in residential neighborhoods/lots. (Figure 4.19)
- Minimize the amount of parking to only that required by the city.
- Use porous or permeable surfaces for parking where feasible (see Section 4.5.4 and Chapter 7)
- Increase the vertical density for parking and buildings, instead of the impervious footprint (i.e., build upward instead of outward)

Figure 4.18 Example Shared Parking Plan
(Source: City of Falls Church, VA)

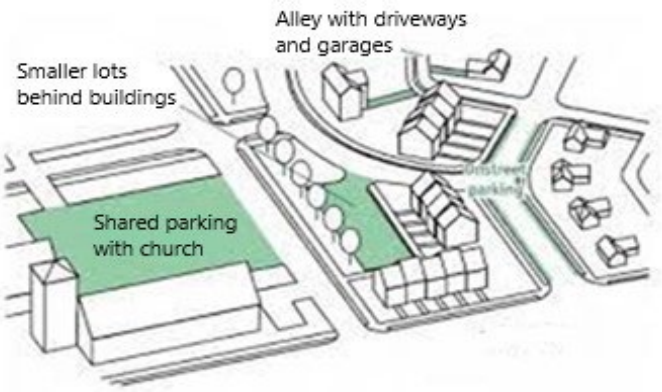


Figure 4.19 Example Single Lane Road Layout *(Adapted from: ProBuilder.com)*

4.5.3 Disconnect Paved Areas

Disconnect Small Paved Areas	LID Design Practice
Description: Pavement disconnection is a technique that allows stormwater from small storms to discharge in vegetated areas that allow for infiltration, filtration, and increased time of concentration. This approach is generally applicable to small or narrow pavement areas, such as driveways, sidewalks, trails, and patios.	**Key Benefits:** • Cost conscious stormwater quality method for small, paved areas • Can provide stormwater attenuation for driveways and entrance ways that may be difficult to include in onsite treatment SCMs

Planning and Design Activities:

During site layout, seek small areas of pavement that can be disconnected to discharge to pervious areas (such as a driveway into the property from the main roadway). Inadvertent impacts must be considered. Follow the minimum requirements stated below. This practice is not suitable for large, paved areas, or those along streams or other potentially erosive or sensitive areas.

- Pavement disconnection must meet the following minimum requirements.
- The maximum contributing flow path of the impervious pavement being disconnected is 50 feet.
- The length and width of overland flow over the vegetated pervious area must be greater than, or equal to, the length and width of the contributing flow path over the impervious area.
- The overland flow must be sheet flow into and over the vegetated pervious area.
- The soil of the vegetated pervious area must be well-drained or moderately well-drained. For native soils, this is typically hydrologic soil group A or B. For pervious areas that have been disturbed, soil restoration to eliminate compaction and improve soil permeability is allowed. Consult a Tennessee licensed Soil Scientist, Registered Landscape Architect, or agricultural extension for guidance on soil restoration.
- The slopes for impervious and vegetated areas must be less than 5%.
- No more than 1,000 ft2 of pavement may discharge to the pervious area at a single location.
- Permanent erosion prevention measures, such as a gravel strip is required where discharges may concentrate. Conversely, non-concentrated discharges along pavement edges (see Figure 4.20) do not necessitate permanent erosion control measures. Instead, focus on installing vegetation and stabilizing the area until it becomes well-established.

Figure 4.20 Example of Pavement Disconnection *(Source: Philadelphia Water Department)*

4.5.4 Use Permeable Pavement Systems

Use Permeable Pavement Systems	SCM
Description: Permeable pavement allows rainwater to percolate into the base layer below the concrete or paver. When used instead of impervious pavement, these surfaces can mimic the natural hydrology of the area it covers (Figure 4.21). With proper design, these surfaces can manage stormwater from other areas.	**Key Benefits:** • Mimics natural hydrology during small storms • Provides a multi-functional surface useful for both transportation and stormwater management • Can provide an upscale and unique aesthetic • May reduce the size of stormwater infrastructure

Planning and Design Activities:

The following considerations are important when contemplating the use of permeable pavement systems.

- Consider the use of permeable pavements in parking areas and low-use/light-load driving areas. Some paver systems may be suitable for higher use/higher load areas. Consult local vendors for more information on paver types, use, and load criteria.
- Pervious/permeable surfaces are suitable and encouraged for use as driveway surfaces on single-family residential (SFR) lots. However, they cannot be claimed as an SCM for compliance with stormwater management rules in the cities of Mayville or Alcoa when used in this manner. This is due to difficulties inherent in oversight of regulated stormwater SCMs on SFR properties. These surfaces can be used in residential common areas, such as amenity area parking lots.
- Permeable pavement systems must be designed in keeping with the use and load specifications for the material being used and the design specifications provided in Chapter 7, Section 7.6.
- Permeable pavement systems are highly versatile in terms of color and design (Figure 4.22).

Figure 4.21 Pervious Concrete

(Source: National Ready Mixed Concrete Association)

Figure 4.22 Examples of Design Versatility of Permeable Pavement Systems

Sources: Left, Bay Area Pervious Concrete; Middle, multiple pervious surfaces shown, source unknown; Right, City of Auburn AL

4.6 Use of Natural Features and Preserved Areas

After the development layout is created, design professionals should look at the natural areas and resources that will be preserved (or restored) for stormwater management purposes, as described in the sections that follow.

- Section 46.1 Use Undisturbed Areas and Stream/Shore Buffers for infiltration from small impervious areas, as filters for overland flow, or areas where other SCMs can be located.
- Section 4.6.2 Use Natural Drainageways and Vegetated Swales to convey stormwater through the property.
- Section 4.6.3 Connect to Parks/Greenways and Provide Pocket Parks to enhance onsite green spaces by connecting them to public use areas or create hydrologically mimicking amenities within the development.
- Section 4.6.4 Create Multi-Functional Spaces describes how some non-structural LID practices and SCMs can function beyond stormwater management. An example includes recreational fields that double as stormwater detention ponds or emergency flood storage areas

Figure 4.23 Examples of "Use of Natural Features and Preserved Areas" LID Design Practices

(Top left) Green way connection to a multi-family residential development provides public amenity to residents, City of Sacramento, CA; (Right): A pocket park in Allentown, PA, Land Collective; (Bottom) Detention basin used as recreational fields in Great Falls, MT. Picture on left shows the basin when dry and the one on the right shows it after a storm event. TDH Engineering.

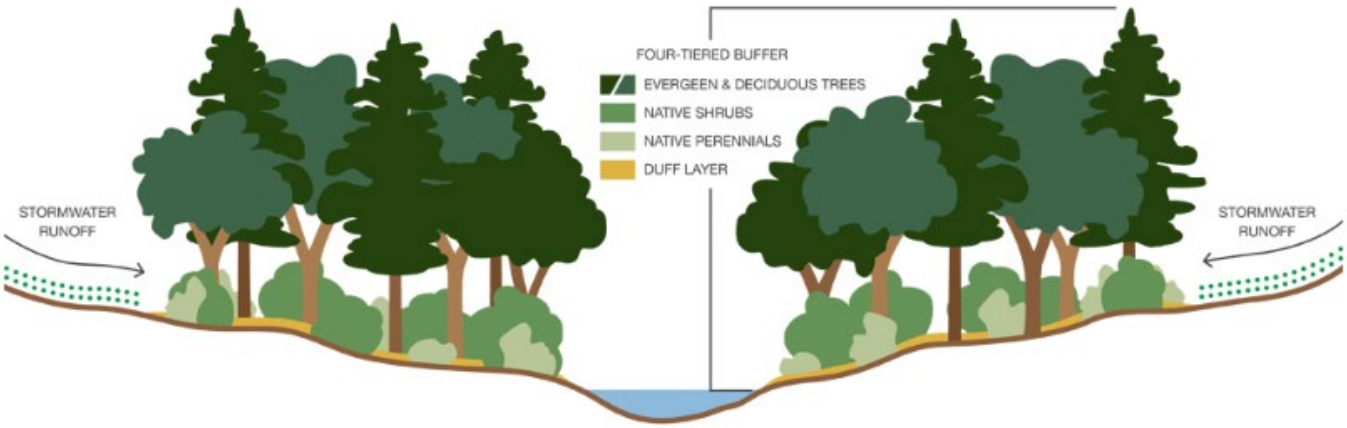
4.6.1 Use of Undisturbed Areas and Stream Buffers

Use Undisturbed Areas and Stream/Shore Buffers	LID Design Practice
Description: With proper design, preserved stream buffers and other undisturbed areas on a development can provide areas for natural infiltration and filtration of stormwater runoff.	**Key Benefits:** • Provides multiple environmental benefits (stormwater and stream stability, shading, etc.) • May reduce the size of stormwater infrastructure

Planning and Design Activities:

- Select only those natural areas that will remain preserved and undisturbed for the life of the development. If there is a chance of disturbance in the future (e.g., due to the construction of the next phase of a development), the area cannot be used to accept and treat surface runoff.
- Do not disturb the preserved area during clearing, grading, and development construction and adhere to city restrictions on stream buffers during and after construction (see buffer requirements in The Alcoa Municipal Code, Title 16, titled *Streets, Sidewalks, Drainage and Erosion Control* and Chapter 5 of this manual). If already disturbed, soil restoration is required to eliminate compaction and improve soil permeability. Consult a Tennessee licensed Soil Scientist, Registered Landscape Architect, or local agricultural extension for guidance. Furthermore, the area should undergo restoration to foster the growth of dense, healthy, and diverse vegetation over time. Managed turf is not acceptable vegetation for these areas. See Figure 4.24 for an example of stream buffer plant design and diversity.
- This LID practice is suitable only for small impervious areas that can safely be discharged to the preserved area as sheet flow. Criteria are as follows.
- The maximum contributing flow path of the impervious pavement is 50 feet. The length and width of overland flow over the preserved area must be greater than, or equal to, the length and width of the contributing flow path over the impervious area.
- The slopes of the impervious area must be less than 5%.
- No more than 1,000 ft^2 of pavement may discharge to the preserved area at a single location.

Figure 4.24 Graphic Showing Vegetation in a Tiered Stream Buffer *(Source: The LID Certification ™ System)*



4.6.2 Use Natural Drainageways and Vegetated Swales

Use Natural Drainageways and Vegetated Swales	LID Design Practice
Description: Preserved natural drainageways, constructed grass channels, and vegetated swales can provide an inexpensive means for stormwater conveyance within the boundaries of the land development. They are less hydraulically efficient than curb and gutter, pipes, and lined channels, resulting in longer travel times, which reduces pollutants and temperatures and lowers peak discharges.	**Key Benefits:** • Slows, filters, and cools stormwater, especially for small, frequent storm events • Can be combined with other LID design practices to enhance hydrologic mimicry • Provides natural character • Lower construction and maintenance costs

Planning and Design Activities:

Stormwater must discharge to the drainageway or swale in a non-erosive manner. Where discharges to the feature are concentrated/channelized flow, energy dissipation must be provided (refer to Chapter 7, Section 7.14).

A vegetated swale is not considered an SCM for water quality treatment. It can be used for pretreatment or simply as a stormwater conveyance feature. However, if water quality treatment is needed, consider the use of a dry enhanced swale SCM (Chapter 7, Sections 7.3) instead of a vegetated swale. Dry enhanced swales can provide both water quality treatment and stormwater conveyance.

Figure 4.25 Vegetated Swale Examples

Source: WAYPOINT Property Inspection, LLC

Source: Ft. Wayne, IN

Vegetated swales shall be designed as follows:

- A vegetated swale must be designed to accommodate flows up to the 25-year, 24-hour design storm without eroding.
- The maximum flow velocity is 1.0 ft/s.
- The bottom width shall be a maximum of 6 feet. If a larger channel is needed to accommodate onsite flows, a compound cross-section (i.e., a benched channel) is required.
- Swale side slopes shall be 3:1 (horizontal : vertical) or flatter.
- The swale should be entirely vegetated with dense, deep-rooted plants that can withstand occasional inundation and water flows. Managed turf is suitable, but tall, dense, non-woody plants are preferred. Areas of bare soil or non-vegetated ground cover (e.g., mulch, river rock, etc.) are not permitted.

4.6.3 Connect to Parks/Greenways and Provide Pocket Parks

Connect to Parks/Greenways & Provide Pocket Parks	LID Design Practice
Description: Preserve open space and enhance development amenities by connecting private land developments with city greenways or creating privately-owned "pocket parks" within a development.	**Key Benefits:** • Mimics natural hydrology during small storms • Provides multi-functional spaces, useful as both landscape features and amenities • Can improve property aesthetic and value

Planning and Design Activities – Park/Greenway Connections:

Alcoa has a strong greenway and park program to provide amenities to local residents and businesses. Properties in close proximity to these areas have ready access to a larger green space for recreation, picnicking, or exercise. The following considerations are important when connecting to a park.

- Comply with local requirements for the connection of private land to a public park or greenway.
- Although green space within the land development is preferred from a stormwater management perspective, a park/greenway connection does not have to involve a park-like setting. It can simply consist of a connection via a pedestrian/bike path, trail, or street/parking access.
- Consider the use of signs to identify where the public park/greenway end and private property begins.

Planning and Design Activities– Private Pocket Parks:

A pocket park is a small outdoor space, usually no more than ¼ of an acre, located in an urban or suburban area for people to gather, relax, and enjoy the outdoors (Figure 4.26). They are amenities for the owners/users of the property where they are located. Successful pocket parks are accessible, engaging, and sociable spaces.

- Good locations for pocket parks are small open spaces that are left after the site layout and disturbance areas are known. They can also be integrated with an SCM, such as a bioretention area.
- Pocket parks should be accessible on foot and by bicycle. Parking areas are not usually included.
- Consult a Landscape Architect for park location selection, design, and vegetation.

Figure 4.26 A Pocket Park in Baltimore, MD with an Integrated Bioretention SCM

4.6.4 Provide Multifunctional Landscaping

Provide Multi-Functional Landscaping	LID Design Practice
Description: Some SCMs can serve other functions on a land development. Identifying and taking advantage of these opportunities may save land, since two necessary functions occupy the same space. It can also reduce both construction and maintenance costs and provide additional value to the property for future property owners.	**Key Benefits:** • Provides multi-functional spaces, useful for stormwater management and other functions • May reduce costs for SCM construction and maintenance • May reduce the size of stormwater infrastructure

Discussion:

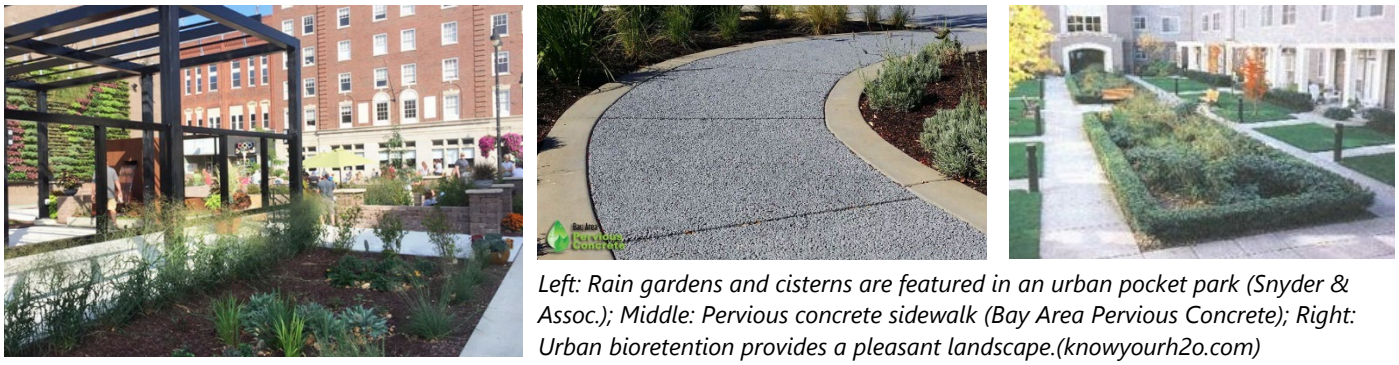
Some non-structural LID practices can function beyond stormwater management. Examples include:

LID practices and SCMs can meet both stormwater rules and land development landscape requirements	Urban bioretention SCM that doubles as a landscaped parking lot island
Recreational fields that double as stormwater detention ponds or emergency flood storage areas	Permeable/pervious surfaces provide both stormwater control and parking/drive surfaces
Pedestrian walking trail constructed within preserved natural space or along preserved stream corridors	LID practices that double as a pocket park

Planning and Design Activities:

- The city places the responsibility for the inspection and maintenance of all SCMs on the property owner. This must be kept in mind when designing a multi-functional space. The SCM should be designed to protect the stormwater functionality and accessibility for inspection and maintenance.
- SCM vegetation should not conflict with the city's landscape requirements for developments.
- SCM protection is especially important when it provides functions to property users beyond stormwater management. Protection measures can be active (such as a physical fence) or passive (such as a walkway that direct pedestrians around or between SCMs). Often, they can be integrated into the SCM design. Consult the SCM design specifications in Chapter 7 for more information.

Figure 4.27 Examples of Multi-Functional LID Design Practices and SCMs



Left: Rain gardens and cisterns are featured in an urban pocket park (Snyder & Assoc.); Middle: Pervious concrete sidewalk (Bay Area Pervious Concrete); Right: Urban bioretention provides a pleasant landscape.(knowyourh2o.com)

4.7 References

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition.* Atlanta Regional Commission, 2016.

City of Birmingham AL. *Post-Construction Stormwater Design Manual.* March 2019.

Ebrahimian Ali, Bridget Wadzuk, and Robert Traver. *Evapotranspiration in green stormwater infrastructure systems.* Department of Civil and Environmental Engineering, Villanova University, Villanova PA. June 27, 2019.

Monroe, W.H., *A glossary of karst terminology: US Geological Survey Water Supply Paper 1899*, 26p., 1970

Philadelphia Water Department. *Philadelphia Stormwater Management Guidance Manual*, Version 3.2. October 2020.

Taylor, C.J., and Greene, E.A., 2008, *Hydrogeologic characterization and methods used in the investigation of karst hydrology*, in Rosenberry, D.O., and LaBaugh, J.W., eds., *Field techniques for estimating water fluxes between surface water and groundwater: U.S. Geological Survey Techniques and Methods 4-D2*, Ch. 3, p. 71–114

USEPA Low Impact Development Center. Low Impact Development (LID). A Literature Review. EPA-841-B-00-005, October 2000.

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5.1 Introduction

A water quality buffer, also called a "riparian buffer" is a use-restricted, permanent strip of dense, perennial vegetation located along the shoreline of a natural waterbody (see Figure 5.1). The area of dense vegetation protects the adjacent waterbody from polluted stormwater by infiltrating ponded stormwater and filtering overland stormwater flow. The vegetation provides shade and stabilizes the streambanks and shoreline, which in turn provides a myriad of benefits, as follows.

Figure 5.1 Riparian Buffer on a Suburban Stream

Source: PlanOKC Development Guide, 2024

- Reduces the potential for bank/shoreline erosion and associated property damage
- Reduces sediment pollution caused by eroding banks/shorelines
- Reduces the potential for property damage when the waterbody experiences flooding
- Provides habitat for aquatic flora/fauna and shoreline wildlife
- Supports the chemical, physical, and biological integrity of the waterbody
- Minimizes public investment in waterbody restoration, stormwater management, and public water resource endeavors (Reynolds, 1999)

The Tennessee Department of Environment and Conservation (TDEC) Rule 0400-40-10 requires small Municipal Separate Storm Sewer Systems (MS4s) to implement and enforce requirements to establish, protect, and maintain permanent vegetated buffers at applicable land developments. The City of Alcoa's (city) stormwater ordinance, Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code, set forth the foundational requirements for buffer establishment in applicable new developments and redevelopments, and for protection and maintenance of all platted buffers. The regulation also places restrictions on uses of, and materials and activities in, a platted buffer. Lastly, the regulation refers to this manual for technical design specifications regarding buffer width and vegetation.

This chapter provides city policies and guidance for the design and management of vegetated buffers, to support the buffer requirements in Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code.

5.2 Buffer Width

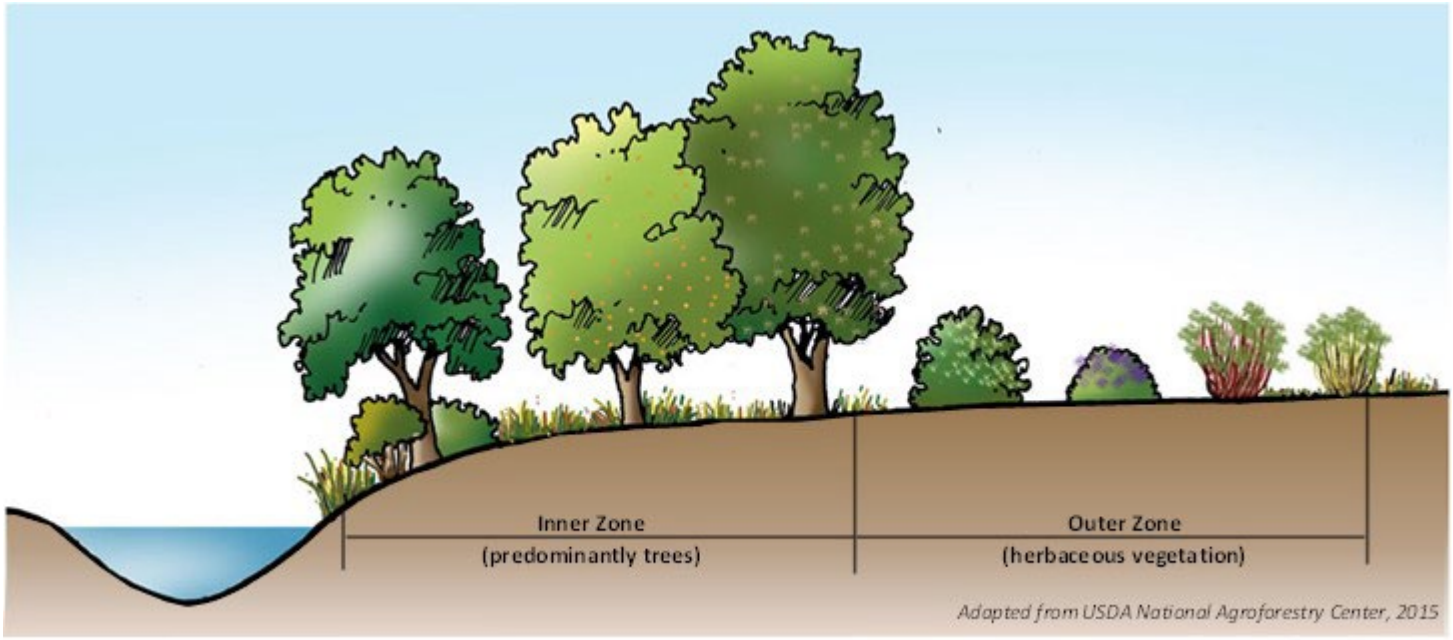
The required minimum buffer widths in terms of the minimum width at any location along a buffer and a minimum average width are shown in Table 5.1. The minimum width establishes the "inner zone" of the buffer, located

adjacent to the buffered waterbody. Buffer width averaging is applied to the variable width "outer zone" located adjacent to, but upland of, the inner zone (see Figure 5.2). The width of the outer zone can vary, as long as the minimum (or a larger) average width is maintained along the length of the buffer. This method provides flexibility to accommodate developed areas located near the buffered waterbody. Regardless, property owners and design professionals are encouraged to establish buffers beyond the minimum width requirements included herein to further protect local water resources.

Table 5.1 Water Quality Buffer Widths

Waterbody Characterization	Minimum Width (ft)	Minimum Average Width (ft)
Waters with available parameters for siltation and habitat alteration or unassessed waters	15	30
Waters with unavailable parameters for siltation and habitat alteration or Exceptional Tennessee Waters	30	60

Figure 5.2 Water Quality Buffer Zones



Policies and guidance for buffer width measurement and averaging are as follows.

1. For streams, the buffer width shall be measured perpendicular to the top-of-bank of the active, natural stream channel. If the bank is not clearly defined, the width shall be measured perpendicular to the centerline.
2. For ponds and lakes, the buffer width shall be measured perpendicular landward from the topographic contour that defines the normal pool elevation.
3. For wetlands, buffer width shall be measured perpendicular from the outermost edge of the wetland as determined by the United States Army Corps of Engineers (USACE), the Natural Resources Conservation Service (NRCS), or TDEC.
4. The width of the inner zone of the vegetated buffer shall not be less than the minimum width identified in Table 5.1, except in the locations of approved stream crossings and utility corridors.
5. Buffer width averaging can be applied in the outer zone to accommodate the development design provided the actual average width of the buffer equals or exceeds the average width identified in Table 5.1.
6. The average width is determined for the total length of streambank or shoreline located within the boundaries of the property to be developed, including the areas where stream crossings and utility corridors occur. If the development encompasses both sides of a stream, buffer width averaging can be used on both sides of the stream but must be applied independently.
7. Buffers on adjoining properties cannot be included in buffer averaging computations, even if the developing and adjacent properties are owned by the same person(s).
8. Paths and trails may be included in a water quality buffer. When included, they must be shown in the SWMP. The use of pervious materials for paths and trails is preferred. When comprised of impervious materials, the width of the buffer zone within which the path or trail is located shall be increased by the width of the path or trail. The also means the total width of the buffer will increase by the same width.
9. Design requirements for stream crossings and utility corridors within a vegetated buffer are as follows:
    a. There shall be at least 1000 linear feet between stream crossings and at least 400 linear feet between access areas for utilities.
    b. Crossings/corridors shall be no more than 15 degrees deviation to perpendicular to the waterbody bank/shoreline to minimize clearing within the vegetated buffer. Allow sufficient room for installation and maintenance access.
    c. The area of these features shall be the minimum width needed to allow for maintenance access and installation.

Examples of buffer width averaging for a vegetated buffer on a stream designated by TDEC as having unavailable parameters for siltation are shown in Figures 5.3 and 5.4.

Figure 5.3 Example of Buffer Width Averaging in a Residential Development

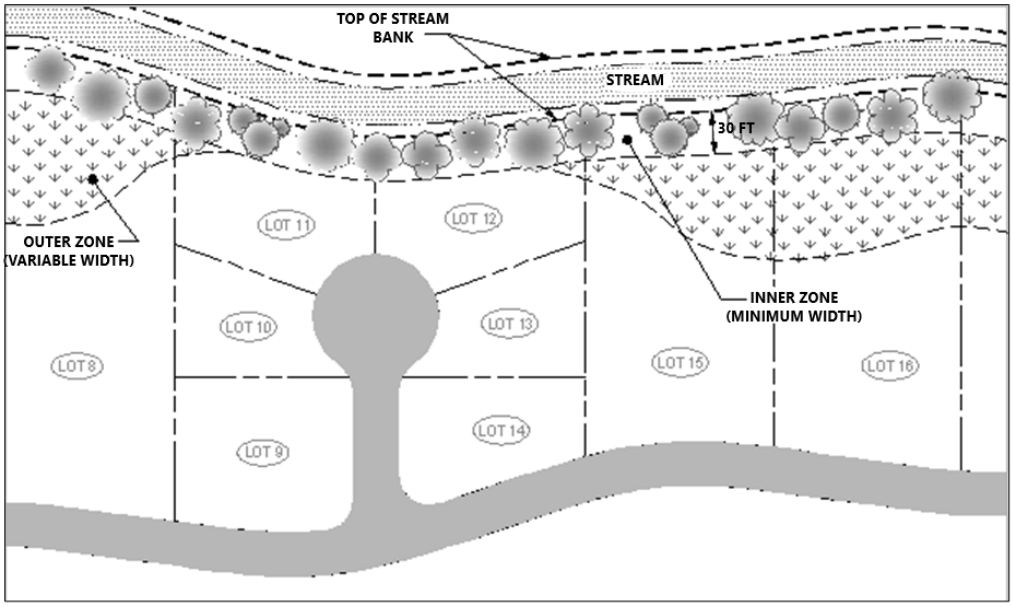
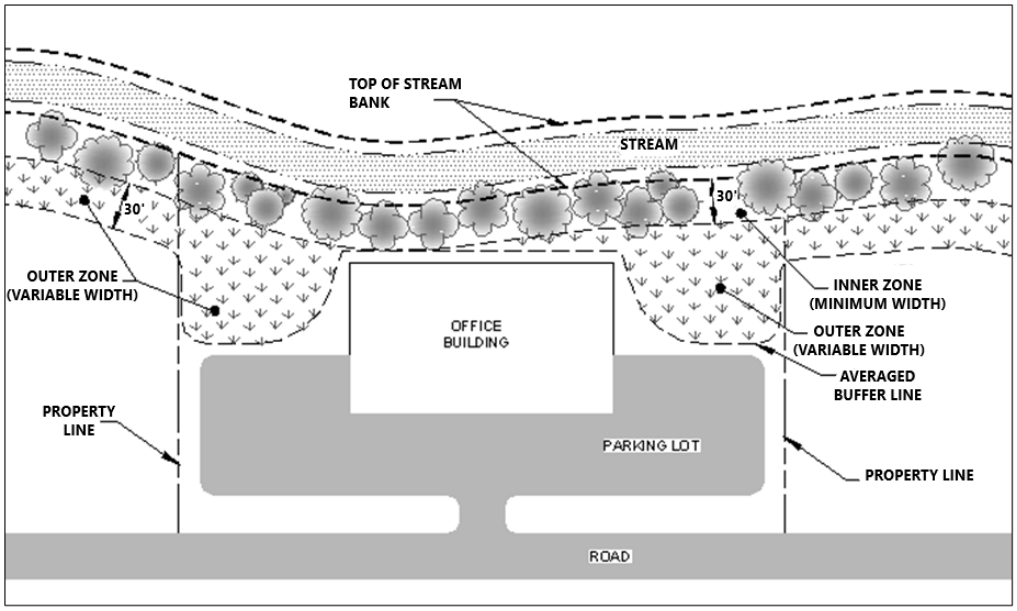


Figure 5.4 Example of Buffer Width Averaging in a Commercial Development



5.3 Buffer Vegetation

Vegetation within water quality buffers is critical to their effectiveness in removing pollutants from overland flows and providing habitat and shade along the bank or shore. Ideally, all water quality buffers would be comprised of a dense, undisturbed stand of trees with native, understory vegetation including immature trees, shrubs, and grasses. However, this ideal is not always desired by property owners in urban and suburban areas. Thus, the minimum requirements and guidance for buffer vegetation provide flexibility for a more

"landscaped" buffer. Regardless, property owners are encouraged to avoid buffers that require significant landscape maintenance and allow vegetation within them to grow as undisturbed, natural areas.

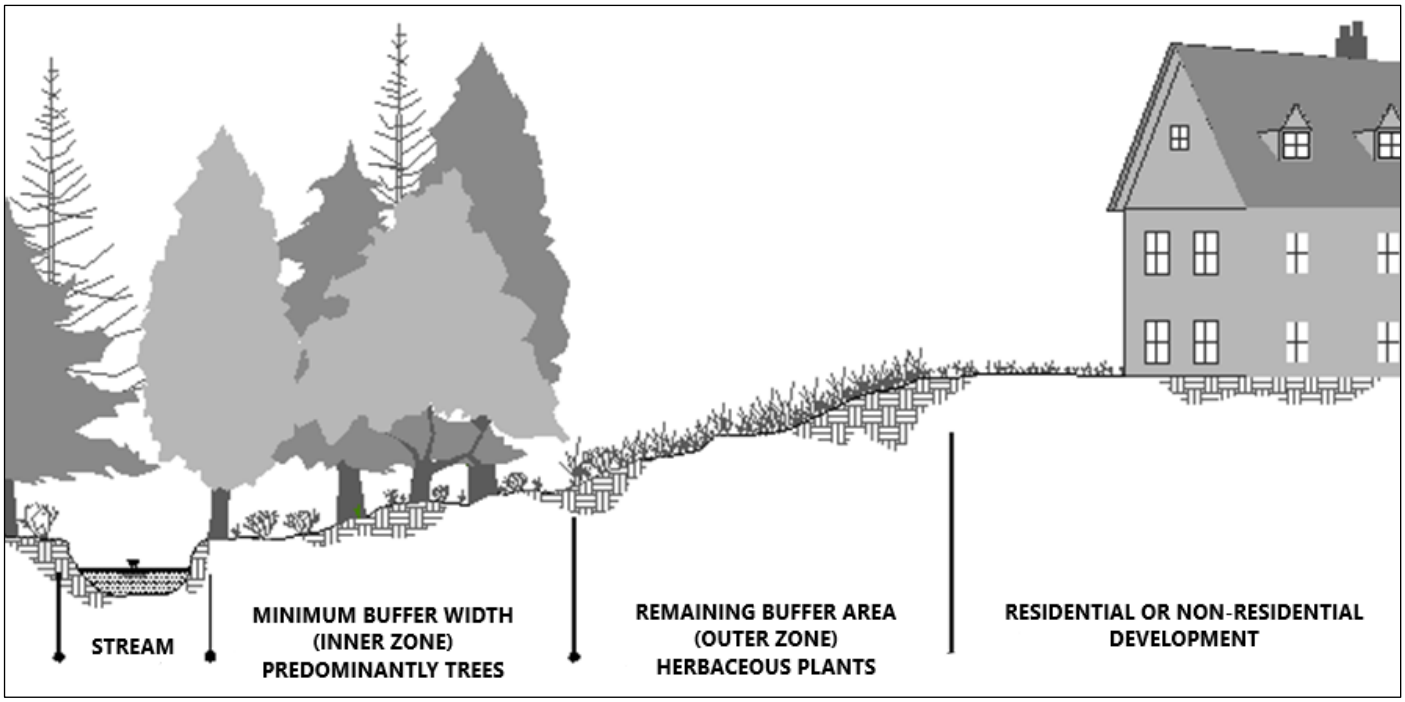
5.3.1 Minimum Standards and Vegetation Growth Policies

The minimum vegetation standard for a vegetated buffer is established below, along with additional vegetation policies and guidance.

1. The predominant vegetation within the minimum buffer width (inner zone) shall be trees. The predominant vegetation in the remaining buffer (outer zone) shall be herbaceous plants (i.e., vascular plants that have little to no persistent woody stems above ground, such as grass). The herbaceous plants provide ground cover for erosion control and stormwater filtration. This standard is depicted in Figure 5.5.
    a. Areas of bare soil and erosion are not allowed at any location in the water quality buffer.
    b. Mulch in any form is discouraged in a water quality buffer except when used as a temporary erosion prevention measure. Vegetation, such as grass and similar plant ground covers, is preferred as a permanent soil stabilization method. When mulch is used, natural wood bark mulches must be used. Crumb rubber and mulches consisting of semi-synthetic or fully synthetic materials are prohibited due to their potential impacts on stormwater quality.
    c. Non-vegetated ground covers (impervious surfaces, pavers, etc.) are prohibited, except when shown on an approved stormwater management plan (SWMP) or with prior approval by the city.
    d. The introduction of invasive plant species and plants considered as nuisance, non-native (also termed "exotic") is prohibited in and near the buffer. Bush honeysuckles, privet, English ivy, kudzu, and mimosa (silk) trees are examples of undesirable plant species that are commonly found along streams in east Tennessee. Native plant species are preferred throughout the buffer. See Section 5.3.2 (below) for resources pertaining to desirable native and undesirable non-native plant species.
2. Water quality buffers that do not do not meet the vegetation standards established in policies 1 through 4 above can be established by the property owner through the removal of undesirable vegetation and installation of trees and herbaceous vegetation. In fact, buffer vegetation enhancement may be required by the city if the existing vegetation within the buffer is unlikely to meet the above standards through natural growth. For new developments or redevelopments, buffer vegetation enhancement must be shown in the SWMP, to include:
    a. the extent of the buffer zone(s),
    b. existing vegetation to remain,
    c. vegetation to be installed, and
    d. best management practices for erosion prevention and sediment control during buffer restoration.

3. Buffer vegetation enhancement activities shall be performed in accordance with any and all applicable local, State, and Federal permits. The property owner is responsible for obtaining such permits.

Figure 5.5 Minimum Vegetation Standards by Buffer Zone



5.3.2 Additional Guidance

More detailed guidance and information on buffer vegetation enhancement, including appropriate species and plant installation techniques, can be found in the resources listed below.

- The Tennessee Department of Environment and Conservation (TDEC) Riparian Buffers webpage: TDEC Riparian Buffers
- TDEC's Tennessee Urban Riparian Buffer Handbook
- Tennessee Valley Authority (TVA) Shoreline Stabilization webpage: TVA Shoreline Stabilization
- Tennessee Invasive Plant Council website: https://www.tnipc.org/

5.4 Signs and Markers

Permanent signs or boundary markers may be required by the city to ensure that adjacent property owners are aware of the buffer's presence. Design professionals will be advised during the plan review process if signs are required. When required, signs/markers must be replaced when they are unreadable or have been removed or destroyed. Contact city staff to obtain the signs.

The following general policies shall apply to buffer boundary markers.

1. Locate signs/markers denoting the presence of a vegetated buffer on the lot lines at their intersection with the landward edge of the buffer, and at other locations which will approximately delineate the outer zone boundary with the remainder of the development (i.e., where it changes direction, etc.). For single lot site developments, signs/markers, shall be posted every 100 feet along the buffer boundary. For subdivisions where multiple lots are located along the buffer, it is recommended that a buffer boundary marker be located at the intersection of every other lot line with the landward edge of the buffer.
2. Buffer signs/markers should be brightly colored and mounted at least 3 feet above the service to ensure their visibility and avoid damage. The post must extend below the ground surface at least 12 to 18 inches.
3. At a minimum, signs/markers shall include the statement "Water Quality Buffer" at a reasonable font sized to allow reading from a distance of 10 feet. Additional information, such as "Do Not Mow" or educational messaging may be included.

Figure 5.6 Vegetated Buffer Sign Template used in Nashville-Davidson Co., TN

5.5 Level Spreaders

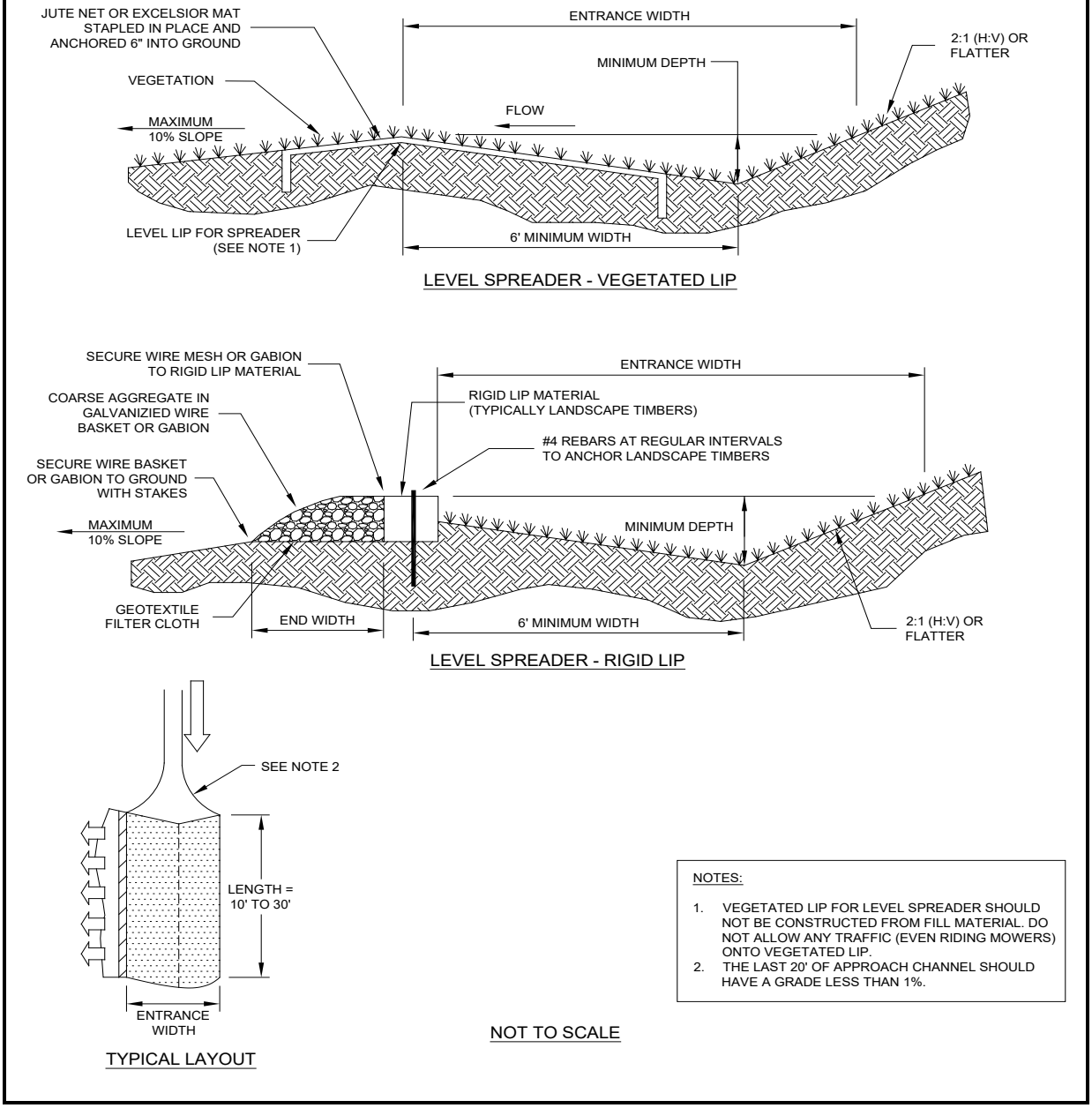
5.5.1 Additional Guidance

Level spreaders are structures that are designed to dissipate energy of concentrated flow and distribute it as sheet flow over a large surface area. For water quality buffers, they are used to maintain the function of buffers by transitioning concentrated flows of stormwater runoff into sheet flow. Water quality buffers are most effective for pollutant removal when shallow sheet flow is discharged to them. A shallow, sheet flow has a high surface contact area, increasing infiltration and the effectiveness of filtration. In contrast, concentrated flow can cause erosion in the buffer area, and limits the effectiveness of plants to filter out pollutants. Thus, the process of transitioning concentrated flows of stormwater into sheet flow is essential to maintaining the function and effectiveness of buffers that will receive stormwater runoff from adjacent areas.

An engineering detail of a typical level spreader is shown in Figure 5.7.

Figure 5.7 Detail of a Level Spreader Design

Source: City of Knoxville Land Development Manual, January 2001



Level spreader primary applications:

- to disperse shallow concentrated or channelized stormwater runoff from impervious areas or upstream stormwater outfalls to a water quality SCM, such as a filter strip, water quality or other buffer, or other vegetated area; or,
- for land draining to vegetated buffers that has more than a three percent (3%) slope: or,

- for outlet diversion (i.e., the release of small volumes of concentrated flow from diversions when conditions are suitable).

Level spreader design elements:

- A pipe, ditch, or swale through which concentrated flow enters the spreader;
- An energy dissipator that slows the water;
- A level lip provided by the construction of a berm, concrete chute, or other permanent material or a shallow linear trench. The purpose of this component is to distribute runoff perpendicularly over the lip or through the trench at the same depth for the entire length of the spreader.

5.5.2 Design Standards

Level spreaders are difficult to construct properly, and therefore a high degree of care is needed to construct the spreader lip completely level. A spreader lip that slopes to one side or has notches or depressions along its length will result in concentrated flow discharging over the lip, defeating the purpose of the spreader. Improperly designed level spreaders can reduce the filtering effectiveness of filter strips and buffer areas to remove trash, debris, and heavy sediments from stormwater. Also, they increase the potential for erosion in vegetated areas to which the level spreader discharges.

All level spreaders shall conform to the design standards listed below.

For impervious surface runoff applications:

1. The capacity for the level spreader is determined in the design of the structural SCM or vegetated buffer to which it discharges. Design guidance for structural SCMs is presented in Chapter 7.
2. The spreader shall run linearly along the entire length of the SCM to which it discharges or along the stream/wetland/pond. In most cases, the spreader will be the same width as the contributing impervious surface. The ends of the spreader shall be tied into higher ground to prevent flow around the spreader.

For all level spreader applications:

1. The capacity of the level spreader shall be determined using the peak flow from the 1-year, 24-hour storm. The drainage area shall be restricted so that maximum flows into the spreader will not exceed 30 cfs.
2. The minimum depth shall be 6-inches and the minimum width shall be 6 feet for the lower side slope.
3. Side slopes shall be 2:1 (horizontal to vertical) or flatter.
4. The grade of the spreader shall be 0%.
5. The appropriate length, width, and depth of spreader should be selected from Table 5.2.

Table 5.2 Level Spreader Dimensions by Design Flow

Design Flow (cfs)	Minimum Entrance Width (ft)	Minimum Depth (ft)	Minimum End Width (ft)	Minimum Length (ft)
0-10	10	0.5	3	10
10-20	16	0.6	3	20
20-30	24	0.7	3	30

6. It will be necessary to construct a 20-foot transition section in the diversion channel (formed by the diversion berms) so the width of the channel will smoothly meet the width of the spreader to ensure uniform outflow.
7. The last 20 feet of the diversion channel shall provide a smooth transition from the channel grade to the level spreader and where possible, shall be less than or equal to 1%.
8. The receiving area below the level spreader shall be protected from harm during construction. Minor disturbed areas shall be stabilized with vegetative measures. A temporary stormwater diversion may be necessary until the vegetation on the level spreader has fully stabilized.
9. Level spreaders must blend smoothly into the downstream receiving area without any sharp drops or irregularities, to avoid channelization, turbulence, and hydraulic jumps.
10. Level spreaders shall be constructed on undisturbed soil where possible. If fill is used, it shall be constructed of material compacted to 95% of standard proctor test levels for that area not considered the seedbed.
11. Immediately after level spreader construction, seed and mulch the entire disturbed area of the spreader.
12. The level spreader lip shall be protected with erosion resistant material to prevent erosion and allow vegetation to be established.

5.6 References

Reynolds, Ward. 1999. *Guidelines for Vegetated Riparian Buffers and Buffer Ordinances.* Office of Coastal Resource Management. Charleston, SC.

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6.1 Introduction

This chapter represents performance standards, calculation methods, and supporting policies for the design and selection of the stormwater control measures (SCMs) presented in Chapter 7 (SCM Design Specifications). The design criteria target stormwater pollutants, downstream channel erosion, and flooding.

6.2 Water Quality Management

6.2.1 Background

The city is subject to the State of Tennessee's National Pollution Discharge Elimination System (NPDES) Permit for small Municipal Separate Storm Sewer Systems (MS4). The permit requires the implementation of a stormwater quality management program that reduces the discharge of pollutants in stormwater. Included among the many permit requirements are permanent (post-construction) stormwater standards for new development and redevelopment projects. These standards require the design, construction, and maintenance of stormwater control measures (SCMs) to meet a performance standard of 80% total suspended solids (TSS) removal.

As required by the NPDES-MS4 permit, Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code similarly establishes the requirement for stormwater quality treatment for new developments and redevelopments. This section provides the policies and guidance to support the ordinances, as well as requirements for stormwater quantity (flood control) design.

6.2.2 Design Standard and General Policies

The water quality design standard and associated policies for stormwater quality treatment are set forth below.

1. **Stormwater Quality Treatment (WQv) Standard.** Stormwater control measures (SCMs) shall be designed to achieve a minimum treatment of 80% TSS removal from the required water quality volume (WQv) for their contributing drainage area. Compliance with the stormwater quality treatment standard is achieved through the design and construction of the SCM(s) in keeping with Table 6.1 and the policies and specifications in this manual.

   Table 6.1 is read by row, with each row equating to 80% TSS removal. SCMs are grouped (Columns 1 and 3) by their stormwater treatment mechanism(s) (Column 2). Each SCM tier is assigned a minimum WQv (Column 4) that equates to 80% TSS removal. Thus, an SCM must be designed and constructed to treat the minimum WQv for its tier to achieve 80% TSS removal. For example, if a bioretention area with an underdrain (a Tier 2 SCM) is selected for stormwater quality treatment for a drainage area within a development, it must be designed and constructed to treat the runoff volume generated from the first 1.25 inches of the 1-yr, 24-hr storm for that drainage area to meet the stormwater quality treatment standard.

Table 6.1 SCM Treatment Table

Column 1	Column 2	Column 3	Column 4
SCM Tier	**SCM Treatment Mechanism(s)**	**Available SCMs** *(design configuration)*	**Minimum WQv** *(for 80% TSS Removal[1])*
Tier 1	Stormwater harvest and reuse	Green Roof	The runoff volume generated from the first **1-inch** of the 1-yr, 24-hr storm[2]
Tier 2	Biologically active filtration with an underdrain	Bioretention Area Biofiltration MTDs[3] Dry Enhanced Swale Urban Bioretention	The runoff volume generated from the first **1.25 inches** of the 1-yr, 24-hr storm[2]
Tier 3	Sand or gravel filtration, settling	Dry Extended Detention (ED) Basin Filtration MTDs[3] Permeable Pavement System Sand Filter (all types) Stormwater Wetland Underground Detention Basin Wet Detention (all types)	The runoff volume generated from the first **2.5 inches** of the 1-yr, 24-hr storm[2] or, 75% of the total runoff volume from the 1-yr, 24-hr storm[2] (whichever is less)
Tier 4	Pollutant/stormwater separation	Hydrodynamic Separation MTDs[3]	Maximum runoff generated from the 1-yr, 24-hr storm[2]

1 – In addition to treating the required WQv, SCM designs must follow the design specifications provided in Chapter 7 of this manual to be approved by the city.
2 – The water quality treatment design storm is the 1-year, 24-hour storm event for the development location, as defined by the National Oceanic and Atmospheric Administration (NOAA) Precipitation-Frequency Atlas of the United States.
3 – MTD is an acronym for Manufactured Treatment Device.

2. **SCM Drainage Area (A) Composition.** The SCM drainage area (A) must include all areas that drain stormwater to the SCM, inclusive of different land cover types (pervious and impervious) within the area.

   Ideally, the area draining to the SCM would be composed entirely of impervious surfaces (e.g., rooftop and/or pavement). This situation is the most efficient and effective use of the SCM. However, it is not always feasible to separate stormwater flows from different land covers within a single drainage area. For example, stormwater generated from a residential subdivision is often a mix of runoff from residential lawns and landscapes, rooftops, driveways, sidewalks, and streets. In this situation, it is difficult to separate stormwater discharges by their land cover sources. Thus, the WQv is determined to be inclusive of all land cover types that will discharge stormwater to the SCM.

3. **Interior SCMs.** An SCM drainage area may include one or more interior SCMs that serve small, distinct areas located inside a larger drainage area. For example, the drainage area to a dry extended detention (ED) basin may include interior SCMs (such as a permeable pavement system or green roof, and areas discharging to cisterns). The drainage areas for these interior SCMs shall not be excluded from the larger SCMs Drainage Area (A) in Equation 6.1. However, the volume managed by interior SCMs (typically this will be the WQv for their own, interior drainage areas) can be used to reduce of the larger SCM's WQv using policies defined for treatment trains (see Section 6.2.4 below).

4. **WQv Routing.** The WQv (and any other post-development condition discharges that will flow through the SCM) must be routed at appropriately small time intervals, no longer than 3 minutes, through SCMs using either hand calculations or computer models that are widely accepted among engineering professionals to ascertain whether the SCM as designed can manage expected flows.

6.2.3 Determining the WQv

The following pages describe two different approaches to determine WQv to size SCMs that are not manufactured treatment devices (MTDs). Site design professionals can choose the approach best suited to their needs. Water quality sizing methods for MTDs are provided in Chapter 7, Section 7.6 (Manufactured Treatment Device).

Approach 1 - The Simple Method

The Simple Method is a technology-based approach to determining WQv which converts a rainfall volume to a runoff coefficient for the purpose of calculating pollutant loads (Schueler, 1987). The method is expressed in Equation 6.1. Supporting policies and guidance are provided below the equation.

Equation 6.1

$$WQv = \frac{P \; x \; Rv \; x \; A}{12}$$

where:

WQv = water quality volume for the SCM drainage area (acre-feet)

P = water quality design rainfall depth for the selected SCM (inches). *(see Column 4 in Table 6.1)*

Rv = volumetric runoff coefficient, *Rv = 0.05 + 0.0092*I*
where I is the percent impervious cover of the SCM's drainage area; when I = 100%, then Rv = 0.97;
(see policies 2 and 3 in Section 6.2.2 above and Section 6.2.6 to determine I)

A = SCM drainage area (acres); *(see policies 2 and 3 in Section 6.2.2 above)*

Approach 2 - The Runoff Hydrograph Method

This approach is grounded in the development of a runoff hydrograph, using:

- NRCS[1] hydrologic methodology
- the SCM drainage area
- rainfall intensity and depth information; and,
- the required water quality design rainfall depth for the selected SCM from Table 6.1.

The development of a runoff hydrograph is a laborious process not normally done by hand. Thus, this discussion of the Runoff Hydrograph Method is limited to an overview of its basic steps. Design professionals will likely use hydrology software adherent to the hydrologic parameters and methods described below to apply the method.

Step 1. Obtain the rainfall intensity and depth for the 1-year, 24-hour storm at the location of the proposed development from the most recent version of the NOAA *Precipitation-Frequency Atlas of the United* States.

Step 2. Determine the SCM drainage area (A) based on policies 2 and 3 in Section 6.2.2 above.

[1] NRCS is the acronym for National Resource Conservation Service (NRCS), formerly called the Soil Conservation Service

Step 3. Use NRCS TR-55 hydrologic methods to determine the Curve Number (CN), Time of Concentration (Tc), and any other site-specific parameters to develop a hydrograph for the SCM drainage area (A).

Step 4. Develop the hydrograph for the SCM drainage area (A) using the site-specific rainfall information obtained in Step 1 and site-specific data determined in Steps 2 and 3.

Step 5. Find the point on the hydrograph when the required rainfall depth (P) from Table 6.1 (Column 4) is reached on the hydrograph. This point is identified as Tp. This step is often done using tabular hydrograph data; linear interpolation along the rising or falling limb of the hydrograph may be necessary.

For example, if the selected SCM is a bioretention area with an underdrain (a Tier 2 SCM in Table 6.1), the design professional would determine when the first 1.25 inches (per Column 4) is reached on the hydrograph.

Step 6. WQv is determined by calculating the area under the hydrograph from its start to Tp. WQv is equal to the runoff volume for the water quality design rainfall.

Step 7. Determine the maximum flow rate water quality design rainfall (Q_{wq}) as prescribed in Section 6.2.5.

For Tier 3 SCMs, the design professional has the option of determining the WQv using Steps 1 through 7 described above or setting WQv equal to 75% of the total runoff volume under the hydrograph for the 1-year, 24-hour storm event using Steps 1 through 4. In this option, the total rainfall depth for the 1-year, 24-hour storm at the development location (provided by the NOAA Atlas reference) must be used to generate the hydrograph.

Figure 6.1 presents a runoff hydrograph for a fictitious development, presuming a Tier 3 SCM is selected, and the design professional chooses to size the WQv using the water quality design rainfall of 2.5 inches. In the figure, linear interpolation of the rainfall data generated by the hydrologic modeling software (see the inset) is performed to determine that the first 2.5 inches of rainfall occurs at 12.4 hours (Tp = 12.4 hrs). Thus, the area under the hydrograph up to 12.4 hours is the water quality volume (WQv). This area is shown in orange. The Tier 3 SCM, such as a sand filter, would be sized for WQv = 6,323 ft^3.

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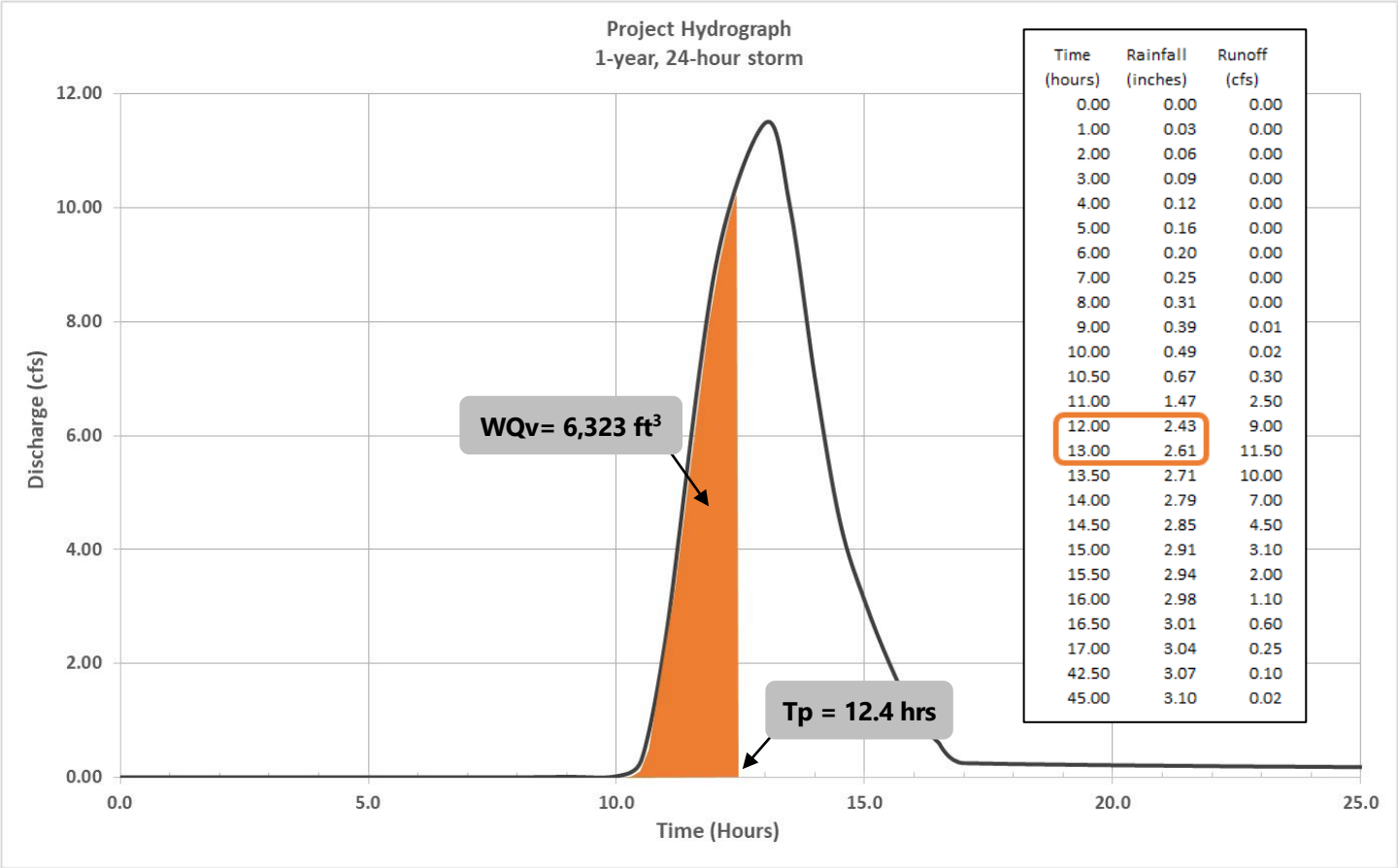
Figure 6.1 Runoff Hydrograph Showing WQv Determination



Time (hours)	Rainfall (inches)	Runoff (cfs)
0.00	0.00	0.00
1.00	0.03	0.00
2.00	0.06	0.00
3.00	0.09	0.00
4.00	0.12	0.00
5.00	0.16	0.00
6.00	0.20	0.00
7.00	0.25	0.00
8.00	0.31	0.00
9.00	0.39	0.01
10.00	0.49	0.02
10.50	0.67	0.30
11.00	1.47	2.50
12.00	2.43	9.00
13.00	2.61	11.50
13.50	2.71	10.00
14.00	2.79	7.00
14.50	2.85	4.50
15.00	2.91	3.10
15.50	2.94	2.00
16.00	2.98	1.10
16.50	3.01	0.60
17.00	3.04	0.25
42.50	3.07	0.10
45.00	3.10	0.02

6.2.4 Treatment Trains

When the SCM selected for stormwater quality treatment does not have the capacity to treat the entire WQv for its drainage area as required by Table 6.1, the design professional has two choices.

1. A different SCM can be selected, provided it has the capacity to treat its entire WQv.
2. Another SCM is designed and constructed upstream or downstream of the selected SCM in a treatment train approach.

A treatment train is formed when two SCMs are placed in series (i.e., an upstream SCM discharges to a downstream SCM). Treatment train designs shall adhere to the following policies.

1. **Treatment Trains using MTDs.** Treatment trains that include an MTD shall be designed in accordance with policies set forth in found in Chapter 7 Section 7.6 of this Manual.
2. **Treatment Trains without MTDs.** When MTDs are not included in a treatment train, the higher Tier SCM must always be placed upstream of the lower Tier SCM. For example, a Tier 2 SCM must always be placed upstream of a Tier 3 SCM in a treatment train.

The WQv from the upstream SCM may be subtracted from the WQv of the downstream SCM to determine the design treatment volume for the downstream SCM. Equation 6.2 is used to determine the design treatment volume for the downstream SCM. Example 6.1 illustrates this policy.

Equation 6.2

$$Tv_{ds} = WQv_{ds} - Tv_{us}$$

where:

Tv_{ds} = the design volume of the downstream SCM (acre-feet)

WQv_{ds} = the WQv of the downstream SCM (acre-feet) *(see Equation 6.1)*

Tv_{us} = the design volume of the upstream SCM (acre-feet)

Example 6.1 Volume Calculation for a Treatment Train using Tier 2 and 3 SCMs

A site designer is designing SCMs for a proposed small commercial development in Alcoa, TN. The development has a total area of 2 acres, all of which is impervious and located within a single drainage area. The designer wants to use a dry enhanced swale to convey stormwater from the impervious area to a traditional detention basin. They calculate the required WQv.

Step 1: Calculate the WQv for the dry enhanced swale as prescribed by Table 6.1 (a Tier 2 SCM, P = 1.25 inches). The site designer decides to use the Simple Method to calculate WQv.

WQv = (P x Rv x A) ÷ 12; where Rv = 0.97 for a 100% impervious drainage area
WQv = (1.25 inches x 0.97 x 2.0 acres) ÷ 12
WQv = 0.20 ac-ft

When the designer begins the preliminary design, they determine the swale will not have sufficient capacity to treat its required WQv. The swale has capacity for just 0.15 ac-ft, leaving 0.05 ac-ft of the required WQv left untreated.

The designer decides to modify the detention basin design into a dry extended detention (ED) basin, which is a Group 3 SCM. Two design options are available: 1) the swale can discharge to the ED basin in a treatment train, thus reducing the required treatment volume for the ED basin by the 0.15 ac-ft treated in the swale; or, 2) the swale can be eliminated from the design and the ED basin sized to treat the entire WQv for a Group 3 SCM.

The designer opts to include the swale, thus creating a treatment train to meet the 80% TSS removal standard. The required treatment volume for the ED basin is then calculated as follows.

Step 2: Using the Simple Method again, calculate the WQv for the ED basin as prescribed by Table 6.2 (a Group 3 SCM, where P = 2.5 inches).

WQv = (2.5 inches x 0.97 x 2.0 acres) ÷ 12
WQv = 0.40 ac-ft

Step 3: Since the swale and dry ED basin are in a treatment train, calculate the design treatment volume (Tv_{ds}) for the ED basin.

$Tv_{ds} = WQv_{ds} - Tv_{us}$
$Tv_{ds} = 0.40$ ac-ft – 0.15 ac-ft
$Tv_{ds} = 0.25$ ac-ft

Thus, the water quality portion of the dry ED basin must be designed for a treatment volume 0.25 ac-ft. Together, the dry enhanced swale (upstream SCM) and dry ED basin (downstream SCM) meet the 80% TSS removal standard.

6.2.5 Calculating the Water Quality Peak Discharge

The peak rate of discharge for the water quality design storm (Q_{wq}), also called the water quality peak discharge, is needed to size SCM components, such as inlets and flow splitters, especially for offline SCMs. More traditional peak discharge calculation methods are not appropriate for this application for a variety of reasons. First, the use of more traditional methods, such as the Rational Method would require the choosing of an arbitrary design storm event that will differ from required water quality rainfall depths established in Table 6.1. Further, conventional NRCS methods have been found to underestimate the rate of runoff for rainfall events of less than two inches. This discrepancy in estimating discharge rates can lead to situations where a significant amount of runoff bypasses the SCM due to an inadequately sized diversion structure and leads to the design of undersized bypass channels.

The method employed to calculate the water quality peak discharge uses the volumetric runoff coefficient, Rv, to find the depth of stormwater for the water quality rainfall. The Simplified NRCS TR-55 Peak Runoff Rate Estimation technique (USDA, 1986) is then used to find a unit peak discharge that is combined with the runoff depth to find a peak runoff rate. The procedure to determine Q_{wq} follows.

Step 1. Equation 6.3 is used to determine the water quality volume (in inches), Q_{wv}.

Equation 6.3

$$Q_{wv} = PRv$$

where:

Q_{wv} = water quality volume (inches)

P = water quality design rainfall depth for the SCM (inches)
(see Column 4 in Table 6.1)

Step 2. Equation 6.4 is used with Qwv to determine the synthetic curve number (CN).

Equation 6.4

$$CN = \frac{1000}{[10 + 5P + 10Q_{wv} - 10(Q_{wv}^2 + 1.25Q_{wv}P)^{0.5}]}$$

where:

CN = synthetic curve number

Step 3. Determine the Time of Concentration (Tc) for the SCM drainage area, and the initial abstraction (Ia) from Table 6.2, then compute the ratio Ia/P.

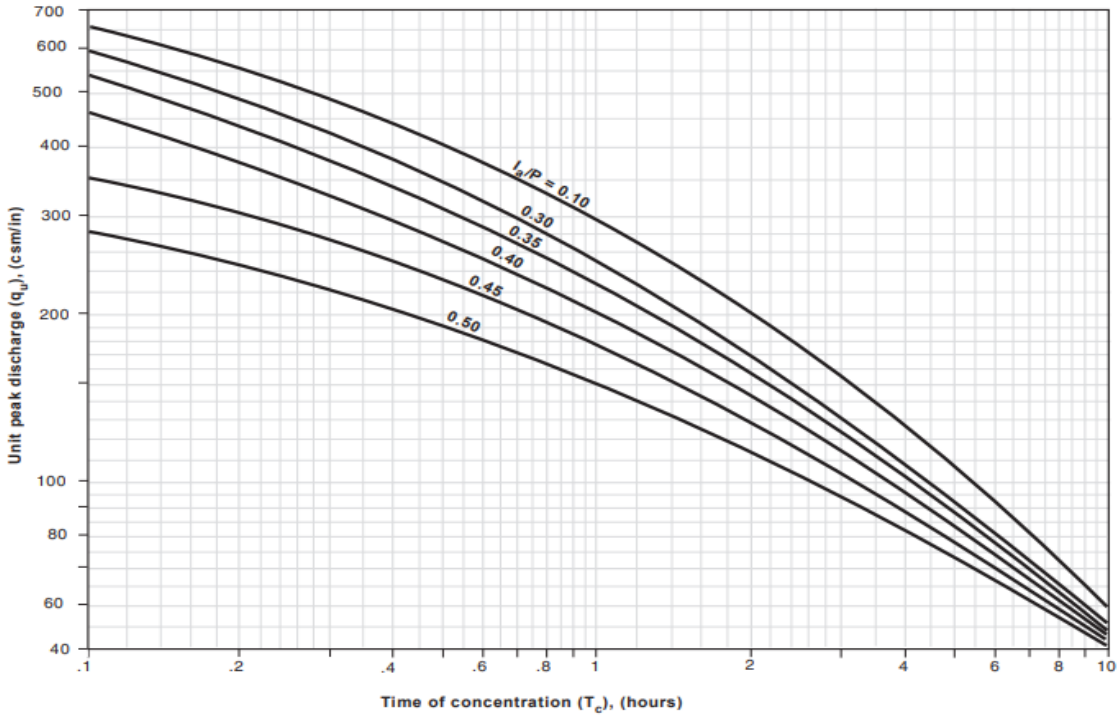
Step 4. Tc is used with the ratio Ia/P in Figure 6.2 to obtain the unit peak discharge, qu. If the ratio Ia/P lies outside the range shown in the figure, use the limiting values.

Table 6.2 Initial Abstraction (I_a) for Runoff Curve Numbers *(Source: NRCS, TR-55, June 1986)*

Curve Number	I_a (in)	Curve Number	I_a (in)	Curve Number	I_a (in)
40	3.000	60	1.333	80	0.500
41	2.878	61	1.279	81	0.469
42	2.762	62	1.226	82	0.439
43	2.651	63	1.175	83	0.410
44	2.545	64	1.125	84	0.381
45	2.444	65	1.077	85	0.353
46	2.348	66	1.030	86	0.326
47	2.255	67	0.985	87	0.299
48	2.167	68	0.941	88	0.273
49	2.082	69	0.899	89	0.247
50	2.000	70	0.857	90	0.222
51	1.922	71	0.817	91	0.198
52	1.846	72	0.778	92	0.174
53	1.774	73	0.740	93	0.151
54	1.704	74	0.703	94	0.128
55	1.636	75	0.667	95	0.105
56	1.571	76	0.632	96	0.083
57	1.509	77	0.597	97	0.062
58	1.448	78	0.564	98	0.041
59	1.390	79	0.532	-	-

Figure 6.2 SCS Type III Unit Peak Discharge Graph *(Source: NRCS, TR-55, June 1986)*

Step 5. The water quality peak discharge (Q_{wq}) is then determined using Equation 6.5.



Equation 6.5

$$Q_{wq} = q_u * A * Q_{wv}$$

where:

Q_{wq} = water quality peak discharge (cfs)

q_u = unit peak discharge (csm/in)

Note: csm/in = cfs per mi^2 of drainage area per inch of runoff

A = SCM drainage area (mi^2)

Q_{wv} = water quality volume (inches)

Example 6.2 illustrates calculation of the water quality peak flow.

Example 6.2. Calculation of the Water Quality Peak Flow, Q_{wq}

Find Q_{wq} for a 50-acre site, with 18 impervious acres. The Time of Concentration (Tc) is determined to 0.35 hours. The proposed SCM is a dry extended detention (ED) basin

Step 0: Compute volumetric runoff coefficient, Rv. See variables under Equation 6.1.
Rv = 0.05+(0.0092)(I) = 0.05+[0.0092(18acres/50acres)(100)] = 0.38*

Step 1: Compute the water quality volume in inches, Q_{wv} using Equation 6.3. From Table 6.1, P = 2.5 inches for a Tier 3 SCM.
Q_{wv} = PRv = 2.5(0.38) = 0.95 inches

Step 2: Compute the synthetic curve number for the drainage area.
$CN = 1000/\{10 + 5(2.5) + 10(0.95) – 10[(0.95)^2 + 1.25(0.95)(2.5)]^{0.5}\} = 81$

Step 3: Using the CN and Table 6.2, find I_a and calculate determine I_a/P. Then, Figure 6.1 to determine q_u.
I_a = 0.469, from Table 6.2
I_a/P = 0.1876
$q_u \approx 450$ csm/in Note: csm/in = cfs per mi^2 of drainage area per inch of runoff

Step 5: Calculate Q_{wq} using Equation 6.5.
Q_{wq} = 450 (cfs/mi^2)/in)(50 acres/640 acre/mi2)(0.95 inches) = 33.40 cfs.

6.2.6 Calculating the Percent Impervious (I)

Impervious areas are defined as impermeable surfaces which prevent the percolation of water into the soil. Impervious surfaces include, but are not limited to, rooftops and paved surfaces such as walkways, sidewalks, parking areas and driveways, patios, pool decks, and athletic courts, and packed gravel or soil. The impervious area must be determined using the following methods.

Impervious Area Calculations for Site Plans and Planned Unit Developments. Equation 6.6 is used to calculate the percent impervious area (I) for SCM drainage areas on site plans and planned unit developments.

The total impervious surface in the SCM drainage area (I_A) shall be determined from the footprints for all impervious areas as defined above. The footprint for all impervious surfaces in the proposed development and the calculation of I_A be shown in the stormwater management plan (SWMP).

For downstream SCMs in a treatment train, do not exclude the area addressed by an upstream SCM when determining I_A and the SCM drainage area (A). Volumetric credit is given for these areas by subtracting the volume managed by the

upstream SCM from the WQv calculated for the downstream SCM. For more information see the treatment train policies established in Section 6.2.4.

Equation 6.6

$$I = \frac{I_A}{A} X\ 100\%$$

where:

I = percent impervious area (%)

I_A = total impervious surface area in the SCM drainage area

A = SCM drainage area (acres)

Subdivision designs may not include the layout and sizes of all impervious surfaces. Instead, the design professional may only be able to determine the actual impervious area of subdivision roadways. Determination of I_A for these developments shall be made as established in the policy below.

Impervious Area Calculations for Subdivision Developments. For situations where the impervious area is to be determined, use Table 6.3 to estimate the percent impervious cover (I). The estimates included in the table are taken from land cover descriptions and average percent impervious area estimates from Technical Release 55 (NRCS, 1986).

Table 6.3 Percent Impervious Area Values *(Source: NRCS, TR-55, June 1986)*

Land Cover Description	Average Percent Impervious Area (I)
Commercial and business or similar	85
Industrial	72
Residential[1], average lot size 1/8 acre or less (town houses)	65
Residential[1], average lot size 1/4 acre	38
Residential[1], average lot size 1/3 acre	30
Residential[1], average lot size 1/2 acre	25
Residential[1], average lot size 3/4 acre	22.5[2]
Residential[1], average lot size 1 acre	20
Residential[1], average lot size 2 acres	12

1 – Includes residential lots and streets. Impervious surface area in common areas (rooftops, parking areas, athletic courts, pool decks, etc.) must be determined based design plans in Equation 6.6.

2 – The % impervious value is interpolated from SCS data

It is understood that residential subdivision lot sizes will not fall cleanly into one of the categories listed in the table, but rather fall between two lot size categories. The design professional has two options, as follows. (1) If the overall lot size variability is minor, round up to the higher lot size. A rounded-up estimate will account for future on-lot improvements that add impervious surfaces over time (e.g., driveway expansions, room additions, patio additions, etc.). (2) Determine an overall average lot size using an area-weighting technique.

Example 6.3 includes the calculation of the % impervious value for a residential subdivision having variable lot sizes.

Example 6.3. Calculation of the Percent Impervious Area (I) for a Residential Subdivision

A site design engineer is preparing a SWMP for a proposed residential development. The subdivision has a total area of 31 acres and will include 52 residential lots ranging in area from approximately ¼ acre to no greater than 1 acre (as shown in the table below). Three (3) acres will be preserved as an undisturbed forested vegetated buffer located along a stream that crosses the property, and therefore, there is no impervious coverage within these three acres. Another three (3) acres will be utilized for a recreational common area which includes a community pool, tennis courts and an associated parking lot.

Due to local topography on the site, the subdivision drains to two separate dry ED basins, herein called SCM A and SCM B. Twelve acres, including the 3-acre vegetated buffer and 3-acre common area, drains to SCM A. The other 19 acres drains to SCM B. Table 6.1 provides lot size, area, and impervious data for the proposed subdivision.

Determine the % impervious area for each SCM drainage area.

Table A provides lot size, area, and impervious data for the proposed subdivision.

Table A

Column 1	Column 2	Column 3	Column 4
Lot Size	**Number of Lots in Size Range**	**Sub-total Area of Lots in Size Range**	**% Impervious** *(from Table 6.3)*
DRAINAGE AREA A (area draining to SCM A)			
approx. ⅓ acre	0	0 acres	30
approx. ½ acre	0	0 acres	25
approx. ¾ acre	2	1.3 acres	22.5
approx. 1 acre	5	4.7 acres	20
Drainage Area A Totals	**7 lots**	**6.0 acres**	--
DRAINAGE AREA B (area draining to SCM B)			
approx. ⅓ acre	21	6.6 acres	30
approx. ½ acre	16	7.3 acres	25
approx. ¾ acre	7	4.3 acres	22.5
approx. 1 acre	1	0.8 acres	20
Drainage Area B Totals	**45 lots**	**19.0 acres**	--

Example 6.3. continued

Since the site will be served by two separate dry ED basins, it is best to determine the impervious area for each basin's drainage area, rather than the overall impervious area for the site. For ease in calculation, the site design engineer decided not to interpolate impervious area values, preferring to group lots into approximate lot sizes that correspond to Table 6.3.

Step 1: Determine the total impervious area for the portion of each drainage area that is covered by residential lots and associated subdivision roads ($I_{A\ residential\ areas}$). This is done by multiplying the sub-total area of each lot size range (column 3 from Table A) by the corresponding % impervious in that lot size range (column 4 from Table A). Results of this calculation are shown in Table B.

Thus, the portions of the site where residential lots are located are covered by impervious surfaces as follows:

Drainage Area A impervious area from residential lots ($I_{A\ residential\ areas}$ A)= 1.23 acres
Drainage Area B impervious area from residential areas ($I_{A\ residential\ areas}$ B) = 4.99 acres

Table B

Lot Size	Sub-total Area of Lots in Size Range	% Impervious (from Table 6.2)	Sub-total Impervious Area
DRAINAGE AREA A (area draining to SCM A)			
approx. ⅓ acre	0 acres	30	0 x 0.30 = 0 ac
approx. ½ acre	0 acres	25	0 x 0.25 = 0 ac
approx. ¾ acre	1.3 acres	22.5	1.3 x 0.225 = 0.29 ac
approx. 1 acre	4.7 acres	20	4.7 x 0.20 = 0.94 ac
Drainage Area A Totals	**6.0 acres**	--	**1.23 acres**
DRAINAGE AREA B (area draining to SCM B)			
approx. ⅓ acre	6.6 acres	30	6.6 x 0.30 = 1.98 ac
approx. ½ acre	7.3 acres	25	7.5 x 0.25 = 1.88 ac
approx. ¾ acre	4.3 acres	22.5	4.3 x 0.225 = 0.97 ac
approx. 1 acre	0.8 acres	20	0.8 x 0.20 = 0.16 ac
Drainage Area B Totals	**19.0 acres**	--	**4.99 acres**

Step 2: Determine the impervious area of the common areas located in Drainage Area A using building and pavement footprints shown on design plans. Table C shows the results of this exercise.

Example 6.3. continued

Table C	
Area Description	**Impervious Area**
Community pool (includes pool, surrounding deck, maintenance building and sidewalk from parking lot)	0.8 acres
Tennis court (includes two courts, surrounding paved areas, and sidewalk from parking lot)	1.2 acres
Common area driveways and parking lot	0.7 acres
Total $I_{A\ common\ areas}$	**2.7 acres**

Thus, 2.7 acres of the 3-acre common area, located in Drainage Area A, is covered by impervious surfaces.

Step 3: Calculate the % impervious area (I) for each drainage area of the site using Equation 6.6. Because the vegetated buffer is entirely pervious, it is not considered in the calculation.

For Area A:

A = total area of Drainage Area A = 12 acres

$I_A = [(I_{A\ residential\ areas\ A} + I_{A\ common\ areas}) \div A] \times 100\%$

$I_A = [(1.23\ acres + 2.7\ acres) \div 12\ acres] \times 100\%$

$I_A = [3.9\ acres \div 12\ acres] \times 100\%$

I_A = 32.8% = the percent impervious area of Drainage Area A

For Area B:

A = total area of Drainage Area B = 19 acres

$I_B = (I_{B\ residential\ areas\ B} \div A) \times 100\%$

$I_B = (4.99\ acres \div 19\ acres) \times 100\%$

I_B = 26.3% = the percent impervious area of Drainage Area B

6.2.7 Reducing the WQv

The WQv is proportional to impervious area. So, the amount of stormwater requiring treatment increases as impervious area increases. In other words, the more you pave, the more you treat. Therefore, to reduce the amount of stormwater that must be treated, the developer must find ways to reduce site imperviousness. Reductions in imperviousness are beneficial from a stormwater quality management standpoint. They also can be beneficial from a flood control perspective. Decreases in impervious area equate to a lower volumetric runoff coefficient (Rv), a lower Curve Number (CN), and in some cases, a higher Time of Concentration (Tc). In turn, this will lead to lower post-development peak discharges and stormwater volumes. It follows then that SCMs, detention basins, and stormwater conveyance systems can also be reduced, potentially lowering the cost of stormwater management construction and maintenance.

In order to reduce the WQv for a development site, site designers are encouraged to use low impact development (LID) practices during the site planning and design process (see Chapter 4, Non-Structural Low Impact Development Practices). LID practices focus on impervious area reductions, green space protection, and stormwater-efficient site layout techniques with the goal of limiting the amount of stormwater and pollutants that are generated from a development after its construction.

The use of the LID practices described in Chapter 4 is strongly encouraged, but not mandatory.

6.2.8 Water Balance Calculations

Water balance calculations can help to determine if a drainage area is large enough or has the right characteristics to support a permanent pool of water during average or extreme conditions. When in doubt, water balance calculations are advisable for retention pond and wetland design.

The details of a rigorous water balance are beyond the scope of this manual. However, a simplified procedure is described herein that will provide an estimate of pool viability and point to the need for more rigorous analysis. Water balance can also be used to help establish planting zones in a wetland design.

6.2.8.1 Basic Equations

Water balance is defined as the change in volume of the permanent pool resulting from the total inflow minus the total outflow (actual or potential). Equation 6.7 presents this calculation.

Equation 6.7

$$\Delta V = \sum I - \sum O$$

where:

- Δ = delta or "change in"
- V = basin volume (acre-feet)
- Σ = "the sum of"
- I = Inflows (acre-feet)
- O = Outflows (acre-feet)

The inflows consist of rainfall, runoff and baseflow into the basin. The outflows consist of infiltration, evaporation, evapotranspiration, and surface overflow out of the basin or wetland. Equation 6.7 can be expanded to reflect these factors, as shown in Equation 6.8. Key variables are discussed in detail after the equation.

Equation 6.8

$$\Delta V = PA + R_O + Bf - ID - EA - EtA - Of$$

where:

- P = precipitation (feet)
- A = basin area (acres)
- RO = runoff (acre-feet)
- Bf = baseflow (acre-feet)
- I = infiltration (acre-feet/day)
- D = number of days in a given month
- E = evaporation (feet)
- Et = evapotranspiration (feet)
- Of = overflow (acre-feet)

Rainfall (P): Average monthly rainfall values can be obtained from the National Weather Service (NWS) Climate information portal (https://www.weather.gov/wrh/climate). Monthly values are commonly used for water balance calculations of values over a season. Rainfall is then the direct amount that falls on the basin surface for the period in question. When multiplied by the basin surface area (in acres) it becomes acre-feet of volume. Table 6.4 presents the NWS average monthly rainfall values that can be used for the city based on a 30-year period of record.

Table 6.4 Average Precipitation (inches)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alcoa/ Maryville	4.93	5.18	5.31	5.36	4.56	4.41	5.52	3.97	4.04	3.09	4.35	5.64

Source: NOAA Climate Data Online (https://www.ncei.noaa.gov/cdo-web/), Maryville Station US1TNBT0026 from 1991 to 2020

Runoff (R_O): Runoff is equivalent to the rainfall for the period times the "efficiency" of the watershed, which is equal to the ratio of runoff to rainfall (Q/P). In lieu of gage information, Q/P can be estimated one of several ways. The best method would be to perform long-term simulation modeling using rainfall records and a watershed model.

Equation 6.9 gives a ratio of runoff to rainfall volume for a particular storm. If it can be assumed that the average storm that produces runoff has a similar ratio, then the Rv value can serve as the ratio of rainfall to runoff. Not all storms produce runoff in an urban setting. Typical initial losses (often called "initial abstractions") are normally taken between 0.1 and 0.2 inches. In a water balance calculation, a factor of 0.9 should be applied to the calculated Rv value to account for storms that produce no runoff. Equation 6.10 reflects this approach. Total runoff volume is then simply the product of runoff depth (Q) times the drainage area (A) to the basin, as shown in Equation 6.9.

Equation 6.9

$$R_O = QA$$

where:

R_O = total runoff volume (cubic feet)
Q = runoff depth (feet)
A = basin area (square feet)

Equation 6.10

$$Q = 0.9PRv$$

where:

P = precipitation (feet)
Rv = volumetric runoff coefficient (from Equation 6.1)

Baseflow (Bf): Most water quality basins and wetlands have little, if any, baseflow, as they are rarely placed across perennial streams. If so placed, baseflow must be estimated from observation or through theoretical estimates. Methods of estimation and baseflow separation can be found in most hydrology textbooks.

Infiltration (I): Infiltration is a very complex subject and cannot be covered in detail here. The amount of infiltration depends on soils, water table depth, rock layers, surface disturbance, the presence or absence of a liner in the basin, and other factors. The infiltration rate is governed by the Darcy equation, shown in Equation 6.11.

Equation 6.11

$$I = Ak_hG_h$$

where:

I = infiltration (acre-feet per day)
A = cross-sectional area through which the water infiltrates (acres)
k_h = saturated hydraulic conductivity or infiltration rate (feet per day)
G_h = hydraulic gradient (also, pressure head/distance)

G_h can be set equal to 1.0 for basin bottoms and 0.5 for basin sides steeper than about 4:1. The infiltration rate can be established through infiltration tests [see Appendix E (Policies for Soil Borings and Infiltration Tests)]. Table 6.5 can be used for initial estimation of the saturated hydraulic conductivity.

Table 6.5 Saturated Hydraulic Conductivity *(Source: Ferguson and Debo, 1990)*

Material	Hydraulic Conductivity (k_h)	
	Inches/hour	feet/day
ASTM Crushed Stone No. 3	50,000	100,000
ASTM Crushed Stone No. 4	40,000	80,000
ASTM Crushed Stone No. 5	25,000	50,000
ASTM Crushed Stone No. 6	15,000	30,000
Sand	8.27	16.54
Loamy sand	2.41	4.82
Sandy loam	1.02	2.04
Loam	0.52	1.04
Silt loam	0.27	0.54
Sandy clay loam	0.17	0.34
Clay loam	0.09	0.18
Silty clay loam	0.06	0.12
Sandy clay	0.05	0.10
Silty clay	0.04	0.08
Clay	0.02	0.04

Evaporation (E): Evaporation is from an open lake water surface. Evaporation rates are dependent on differences in vapor pressure, which, in turn, depend on temperature, wind, atmospheric pressure, water purity, and shape and depth of the basin. It is estimated or measured in a number of ways, which can be found in most hydrology textbooks. Pan evaporation methods are also used.

Table 6.6 presents pan evaporation rate distributions for a typical 12-month period based on pan evaporation information from one station in Knoxville, TN, based on a NOAA assessment done in 1982. The assessment determined the average annual free water surface (FWS) evaporation in the Knoxville area (denoted as "Knoxville WB Airport" in the NOAA report) is 50.61 inches (NOAA, June 1982). FWS evaporation differs from lake evaporation for larger and deeper lakes but can be used as an estimate of it for the type of structural water quality basins and wetlands being designed in east Tennessee. This total annual estimate can be distributed in accordance with the percentages presented in Table 6.6.

Table 6.6 Pan Evaporation Rates – Monthly Distribution *(Source: NOAA, June 1982)*

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2.9%	3.8%	7.1%	10.5%	13.1%	13.1%	13.3%	12.4%	9.8%	6.7%	4.2%	3.1%

Evapotranspiration (Et): Evapotranspiration consists of the combination of evaporation and transpiration by plants. The estimation of Et for crops is well documented and has become standard practice. However, the estimating methods for wetlands are not documented, nor are there consistent studies to assist the designer in estimating the wetland plant demand on water volumes. Literature values for various places in the United States vary around the free water surface lake

evaporation values. Estimating Et only becomes important when wetlands are being designed and emergent vegetation covers a significant portion of the basin surface. In these cases, conservative estimates of lake evaporation should be compared to crop based Et estimates, and a decision made. Crop-based Et estimates can be obtained from typical hydrology textbooks or from the web sites mentioned above. A value of zero shall be assumed for Et unless the wetland design dictates otherwise.

Overflow (Of): Overflow is considered as excess runoff. In water balance design, Of is either not considered since the concern is for average precipitation values or is considered lost for all volumes above the maximum basin storage. Obviously, for long-term simulations of rainfall-runoff, large storms would play an important part in basin design.

6.3 Channel Protection

The section provides the channel protection standard and establishes the methods to be used for channel protection design. The objective of the standard is to prevent the erosive channel-forming flows that occur during high frequency storms. This purpose is accomplished by extended detention of the 1-year 24-hour design storm to at least 24-hours.

6.3.1 Design Standard and Associated Policies

Channel protection design standard and associated policies are set forth below.

1. **Channel Protection (CPv) standard.** The runoff volume from the 1-year frequency, 24-hour duration storm event, herein called the channel protection volume (CPv), shall be detained for no less than a 24-hour period, up to a maximum of 48 hours. This standard shall be applied at each drainage area in the development.
2. **CPv standard waivers.** Waivers are as follows.
   - A CPv waiver may be granted when post-development discharge from the drainage area for the 1-year, 24-hour storm is less than 2.0 cfs.
   - A CPv waiver may be granted when the drainage area discharges directly to a large stream, river, natural wetland, or lake, where the reduction in small storm flows will not have an impact on stream bank or channel integrity.
3. **CPv credit for Tier 1 and 2 SCMs.** The WQv managed by Tiers 1 and 2 SCMs (see Column 4 in Table 6.1) can be credited to the required CPv in sizing the CPv control facility. Use Equation 6.12 to determine the design CPv.

   Note: If a Tier 3 SCM is being used to manage the WQv and CPv, the credited CPv (CPv_{design} in Equation 6.12) cannot be less than the WQv for the Tier 3 SCM.

Equation 6.12

$$CPv_{design} = CPv_{1yr} - WQv$$

where:

CPv_{design} = design channel protection volume (acre-feet)
CPv_{1yr} = channel protection volume for the 1-yr, 24-hr storm (acre-feet)
WQv = water quality volume for the Tier 1 or Tier 2 SCM (acre-feet)

4. **Alternative approaches.** The city may approve designs for alternative approaches to protect downstream channels in lieu of controlling the CPv, provided that sufficient hydrologic and hydraulic analysis shows that the alternative approach will offer adequate channel protection from erosion. Said analysis shall be provided to the city for approval with, or prior to, submittal of the SWMP.

6.3.2 Method

The Simplified SCS Peak Runoff Rate Calculation approach can be used for estimation of the channel protection volume (CPv) prior to storage design. **This method shall not be used for standard detention design.** Instead, see Section 6.4 (Storage Design) in this chapter.

The Simplified SCS Peak Runoff Rate Calculation approach must be modified to determine the volume for a 1-year frequency, 24-hour duration design storm event. The calculation procedure is as follows.

Step 1. Obtain the rainfall depth (P, in inches) for the 1-year, 24-hour storm at the location of the proposed development from the most recent NOAA Precipitation-Frequency Atlas of the United States.

Step 2. Estimate the NRCS curve number (CN) for the drainage area. The CN is used to determine the initial abstraction (I_a) from Table 6.2, and the ratio I_a/P is computed.

Step 3. The accumulated runoff (Q_d, inches) can then be calculated using the NRCS method Equations 6.12a, b, and c.

Equations 6.12a, b, and c

$$Q_d = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad I_a = 0.2S \qquad S = \frac{100}{CN} - 10$$

where:

Q_d = accumulated runoff (inches)
P = rainfall depth for the 1-yr, 24-hr storm (inches)
I_a = initial abstraction (inches)
S = storage (potential maximum retention after runoff begins (inches)
CN = NRCS curve number

Step 4. Compute the drainage area Time of Concentration (Tc) for the post-development land use using NRCS methods.

Step 5. Use Tc with the ratio I_a/P to obtain the unit peak discharge, q_u, from Figure 6.2 for the Type III rainfall distribution. If the ratio I_a/P lies outside the range shown in the figure, either use the limiting values or use another peak discharge method.

Step 6. Knowing q_u and T (extended detention time, minimum of 24 hours and maximum of 48 hours); the q_o/q_i ratio (peak outflow discharge/peak inflow discharge) can be estimated from Figure 6.3.

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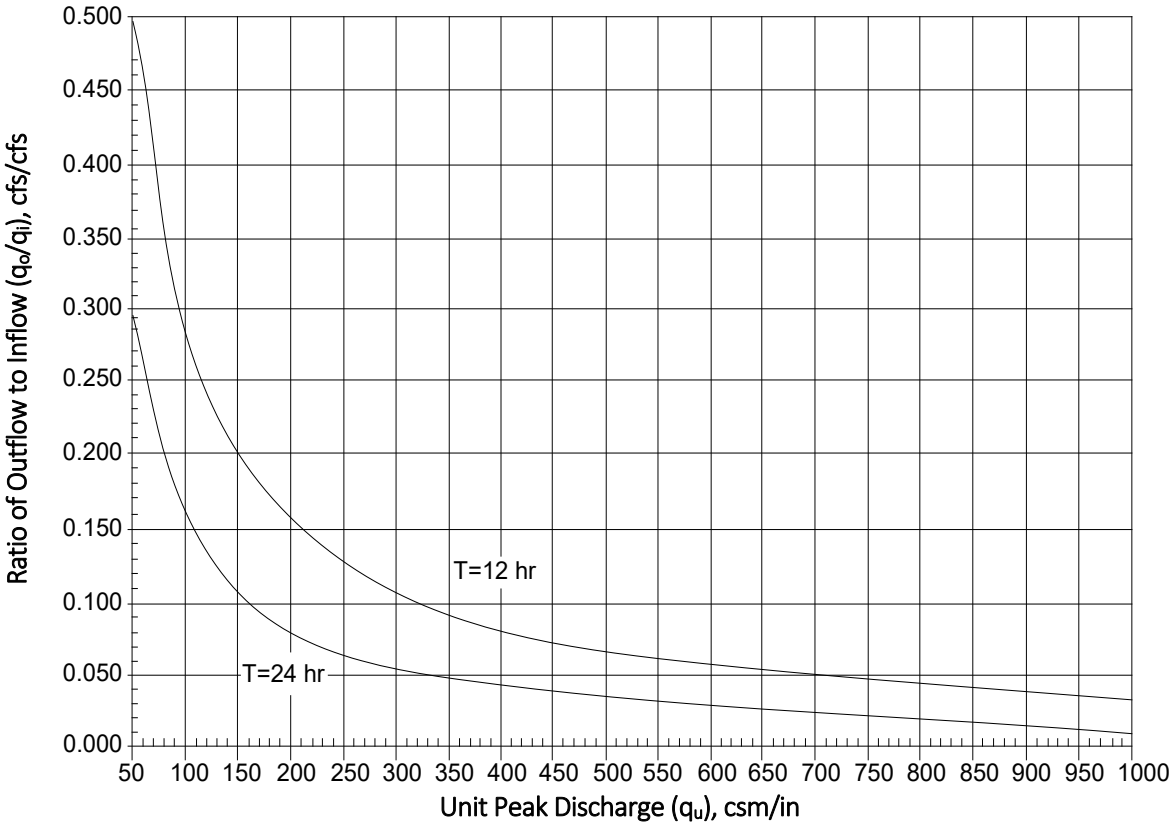
Figure 6.3 Detention Time vs. Discharge Rations *(Source: MDE, 1998)*



Step 7. V_s/V_r is then determined using the NRCS detention basin routing formula of Equation 6.13 or using Figure 6.4. (Note: the equation is suspect when q_o/q_i approaches its limits of 0.1 and 0.8.

The plotted curves in Figure 6.4 are based on the four NRCS developed 24-hour synthetic rainfall distributions (Types I, IA, II, and III). A rainfall distribution is used to describe what portion of the total rainfall depth falls during each portion of the total storm duration. The curves in the figure were created from available National Weather Service duration-frequency data and local storm data for various regions in the United States. Types I and IA represent the Pacific maritime climate (wet winters and dry summers), while Type II represents Gulf of Mexico and Atlantic coastal area rainfalls where tropical storms cause large 24-hour rainfall amounts). Of the four distributions, Type IA is the least intense and Type II is the most intense short duration rainfall. The Type II rainfall distribution applies to all of Tennessee. (TDOT, 2007)

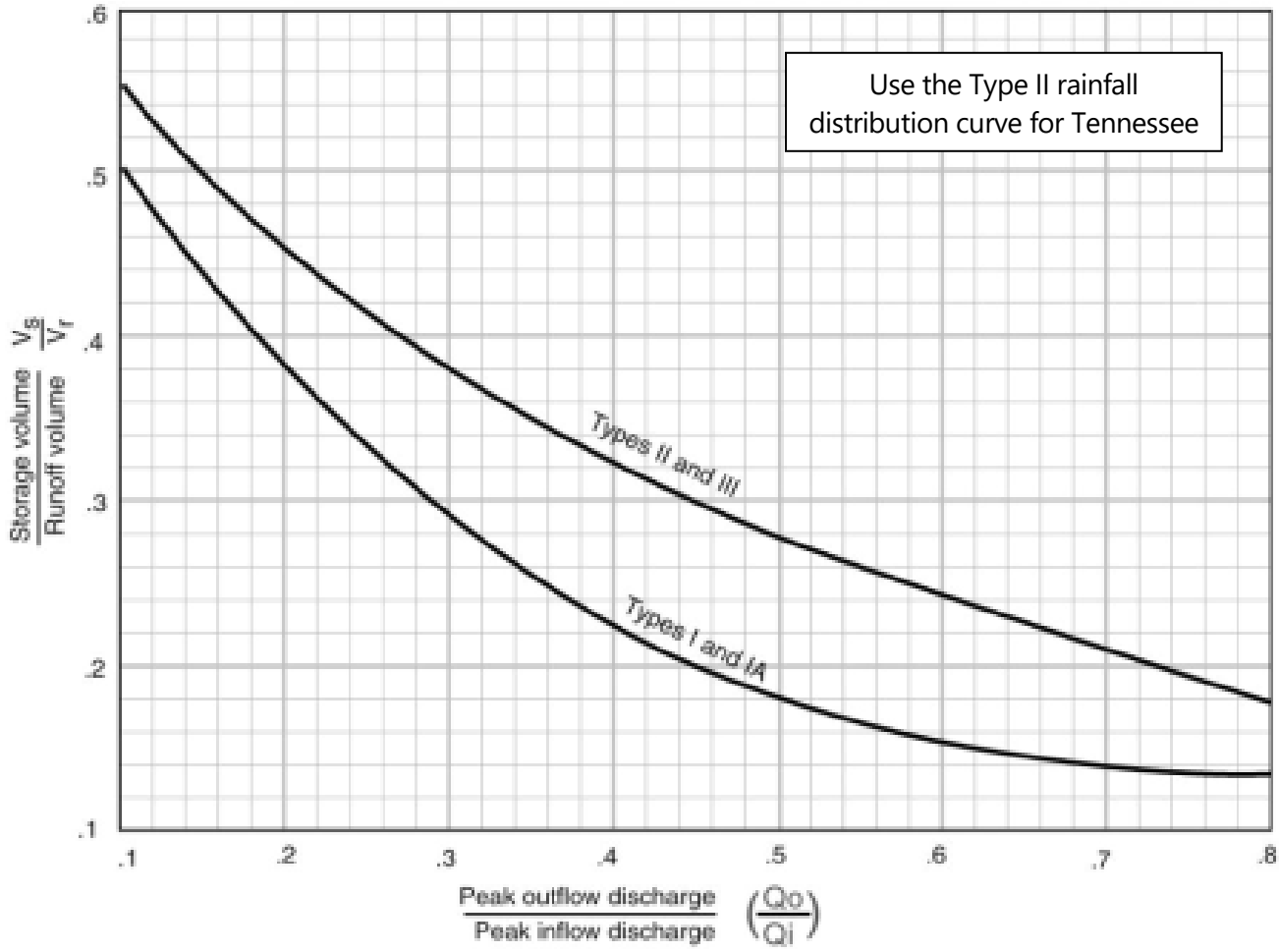
$$\frac{V_s}{V_r} = 0.682 - 1.43\left(\frac{q_o}{q_i}\right) + 1.64\left(\frac{q_o}{q_i}\right)^2 - 0.804\left(\frac{q_o}{q_i}\right)^3$$

Equation 6.13

where:

V_s = required storage volume (acre-feet)
V_r = runoff volume (acre-feet)
q_o = peak outflow discharge (cfs)
q_i = peak inflow discharge (cfs)

Figure 6.4 Approx. Detention Basin Routing for Basin Rainfall Types *(Source: USDA TR-55, 1986)*



Step 8. The required storage volume (Vs) can then be calculated using Equation 6.14.

Equation 6.14

$$V_s = \frac{\left(\frac{V_s}{V_r}\right) Q_d A}{12}$$

where:

Q_d = the post-development runoff depth for the design storm (inches)

A = total drainage area

Step 9. Vs must be incorporated into the SCM design, and the 1-year 24-hour storm routed through the SCM. Adjust the design accordingly. The Vs is adequate when the 1-year 24-hour design storm (or design volume as allowed by Section 6.3.1) is detained for at least 24 hours and no more than 48-hours. The release period is a brim drawdown time, beginning at the time of peak storage of the CPv until the entire calculated volume drains out of the basin. For more information see Section 6.5.8 (Extended Detention Outlets for WQv and CPv) below.

Example 6.4 illustrates the estimation of CPv.

Example 6.4 Estimation of CPv

Estimate the CPv necessary for a 50-acre wooded watershed, which will be developed as follows:

1-Forest land - good cover (hydrologic soil group B) = 10 ac
2-Forest land - good cover (hydrologic soil group C) = 10 ac
3-Residential with 1/3 acre lots (hydrologic soil group B) = 20 ac
4-Industrial development (hydrological soil group C) = 10 ac

Other data include the following:

Total impervious area = 18 acres
% of pond and swamp area = 0

Step 1 *Determine the rainfall depth (P) for the 1-year 24-hour design storm for development location. For this example, the 1-year, 24 hour rainfall = 2.04 inches = P*

Step 2 *Determine the weighted runoff coefficient as in the table below.*

Dev. #	Area (ac)	% Total	CN	Composite CN[1]
1	10	20	55	11
2	10	20	70	14
3	20	40	72	28.8
4	10	20	91	18.2
Total	50	100	-	72

*1 – Composite CN = % Total * CN/100*

Step 3 *Calculate I_a/P for CN= 72,*
I_a = 0.778 (Table 6.2)
$I_a/P = (0.778/2.5) = 0.31$

Step 4 *Calculate Q_d for 1-year 24-hour storm using SCS Equation 6.12a*
$Q_d = (2.5-0.778)^2/(2.5-0.778+5*0.778) = 0.53$ inches

Step 5 *Calculate Tc.*
Utilizing standard methods for overland, shallow concentrated and channel flow:
Tc = 0.35 hours (assumed)

Step 6 *Use Tc with the ratio I_a/P to obtain the unit peak discharge, q_u, from Figure 6.2 for the Type III rainfall distribution. From the figure, q_u = 390 csm/in*

Example 6.4 Continued

Step 7 *Estimate channel protection volume (CPv = V_s)*
Knowing q_u (1-year) = 390 csm/in from Step 6 and T (extended detention time of 24 hours), find q_o/q_i from Figure 6.3.
q_o/q_i = 0.040

Step 8 *Estimate storage/runoff using Equation 6.13,*
$V_s/V_r = 0.682 - 1.43(q_o/q_i) + 1.64(q_o/q_i)^2 – 0.804(q_o/q_i)^3$
$V_s/V_r = 0.682 - 1.43(0.040) + 1.64(0.040)^2 – 0.804(0.040)^3 = 0.63$

Step 9 *The necessary detention volume is then calculated using Equation 6.14.*
$CPv = V_s \approx (V_s/V_r)*Q_d*A/12 = (0.63)(0.53)(50)/12 \approx 1.39$ ac-ft

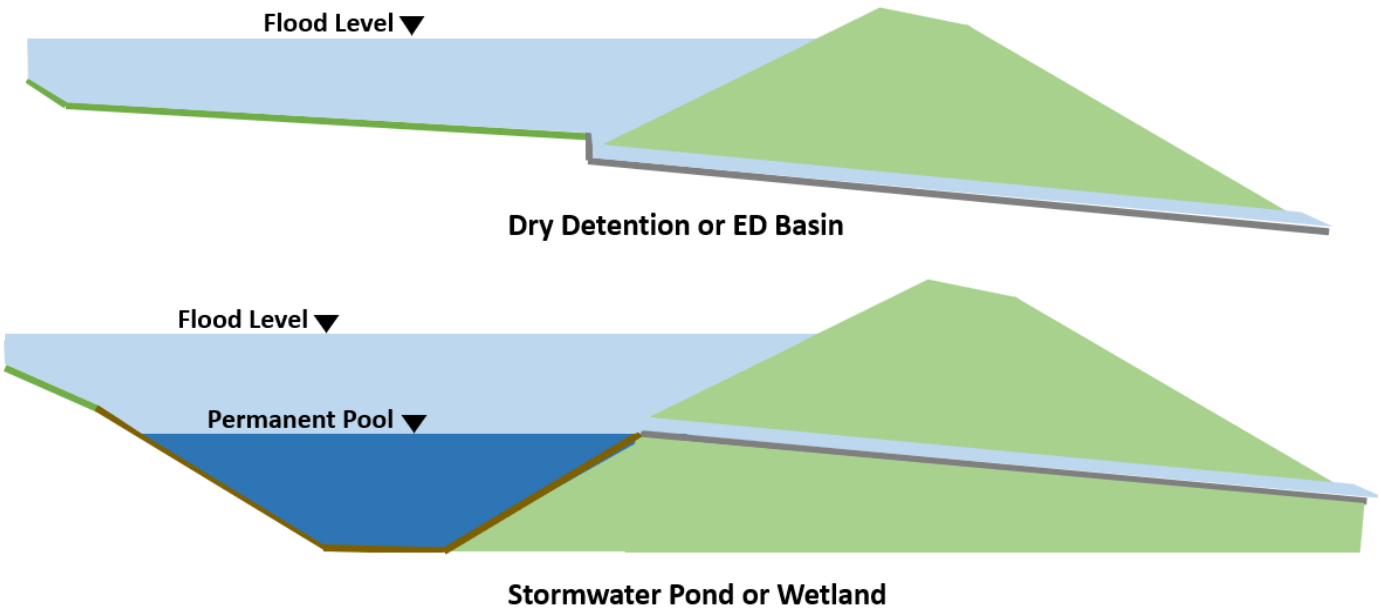
6.4 Storage Design

For many years, local governments have required detention or retention storage of stormwater to attenuate post-construction peak discharges for purposes of drainage and flood control. Stormwater quality and channel protection standards also include storage controls through extended detention of stormwater to allow pollutant settling (in some Tier 3 SCMs) and extended peak discharge moderation (channel protection designs). This section provides policies and guidance on stormwater storage design.

6.4.1 Storage Types and Design Configurations

Storage types are depicted in Figure 6.5 and described after the figure.

Figure 6.5 Detention Storage Types *(Adapted form ARC, 2016)*



Detention storage, also called "standard or conventional detention", is used to detain stormwater runoff from a developed property for a short period of time and release it at a specified peak discharge. Typical detention design standards require release of post-construction peak discharges that match (or are less than) pre-development peak discharges for a suite of design storms (see Figure 6.6). The storage area is designed to drain completely after the design storm(s) have passed.

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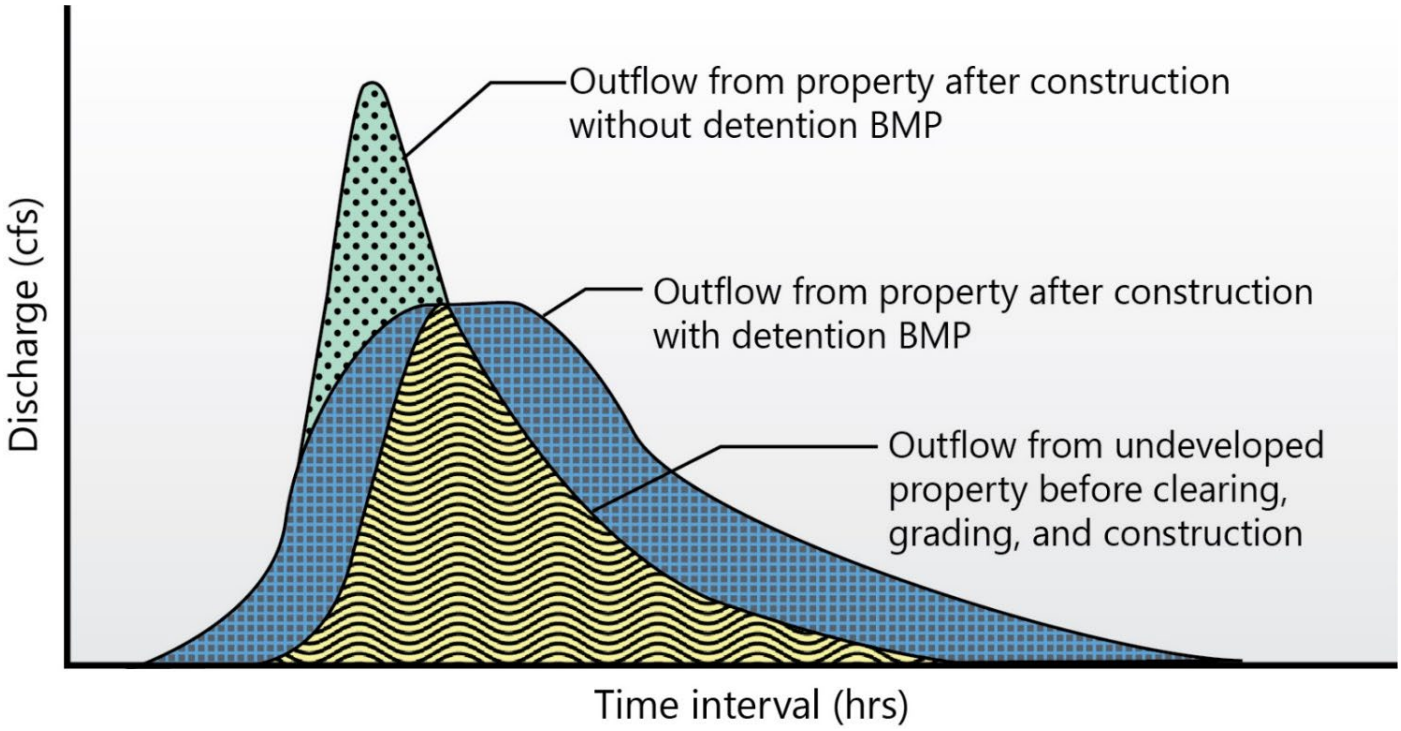
Figure 6.6 Example of Peak Flow Control by a Standard Detention Basin *(Source: City of Topeka, 2021)*



Extended detention (ED) storage is used to detain stormwater runoff for a longer period of time than conventional detention storage. ED storage designs typically focus on volume control, rather than designing for a specific peak discharge, and are designed to drain completely within a specified time period (usually 24 to 72 hours). ED storage is the approach employed to meet the channel protection standard (see Section 6.3), and one of the treatment mechanisms for Tier 3 SCMs for stormwater quality treatment. It is not uncommon to see a "stacked" detention design where a traditional detention storage area is designed above a smaller ED storage area within the same detention basin. A multi-stage outlet is designed to meet both storage types. Stacked designs can be used in dry ED basins, underground detention, wet basins, and stormwater wetlands. Permeable pavement systems can also be designed this way, although this is not common.

Tier 2 SCMs, such as bioretention areas and dry swales with underdrains, detain stormwater to some degree as an ancillary outcome of their biofiltration treatment mechanisms. However, these SCMs are not typically designed for detention or ED storage purposes.

Retention storage has a permanent pool of water but can still be designed to detain and discharge water at specific rates and time periods when the permanent pool elevation is exceeded. Wet basins and stormwater wetlands are an example of retention storage. Standard detention and/or ED storage can also be designed above retained permanent pool.

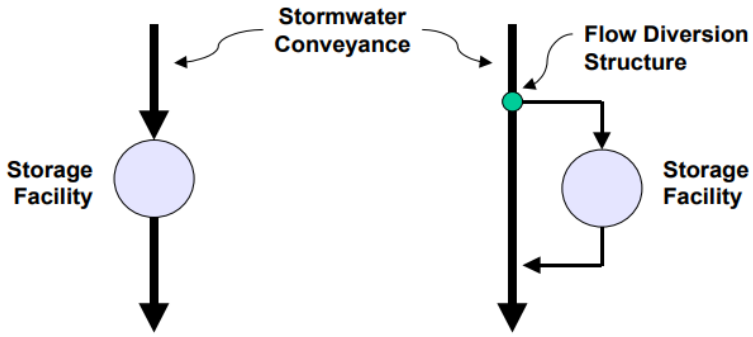
Stormwater storage can also be online or offline (see Figure 6.7). Online storage is located within the main flow path, receiving flows directly from an onsite stormwater conveyance system. Online storage can also receive flows directly from a stream, but this design

configuration requires significant engineering analysis and authorization/permits from local, State, and (sometimes) Federal agencies. In contrast, offline storage receives water that is diverted from an onsite conveyance system using a flow splitter or other diversion structure.

6.4.2 Detention Design Standard and Methods

For many years, local governments have required detention or retention storage of stormwater to attenuate post-construction peak discharges for purposes of drainage and flood control. Detention and retention can be provided by dry detention basins, wet basins, and stormwater wetlands. The following standards and policies apply to all detention/retention storage facilities. Additional design specifications for SCMs that provide detention/retention are established in Chapter 7.

Figure 6.7 Online and Offline Storage (Source: ARC, 2016)



Standard:	The post-development peak discharge shall be less than or equal to the pre-development peak discharge for the 2, 5, 10, 25, and 100-year, 24-hour storm events
Spillway & Freeboard:	Spillway: The emergency spillway shall be 0.1 feet above the water surface elevation (WSEL) for the 100-year, 24-hour storm event. Freeboard: The top of the berm shall be a minimum of (1) foot above the WSEL for the 100-year, 24-hour storm event. If inclusion of an emergency spillway is not possible (this is rare), a minimum of two (2) feet of freeboard above the top of the berm shall be provided. The berm shall be designed to allow safe passage of floodwaters without damage, should it be overtopped.
Method(s):	NRCS (formerly SCS) methods must be used for detention and retention SCM and outlet structure designs.

6.5 Storage Facility Orifice and Outlet Structures

This section is primarily taken from the Georgia Stormwater Management Manual, 2016 Edition.

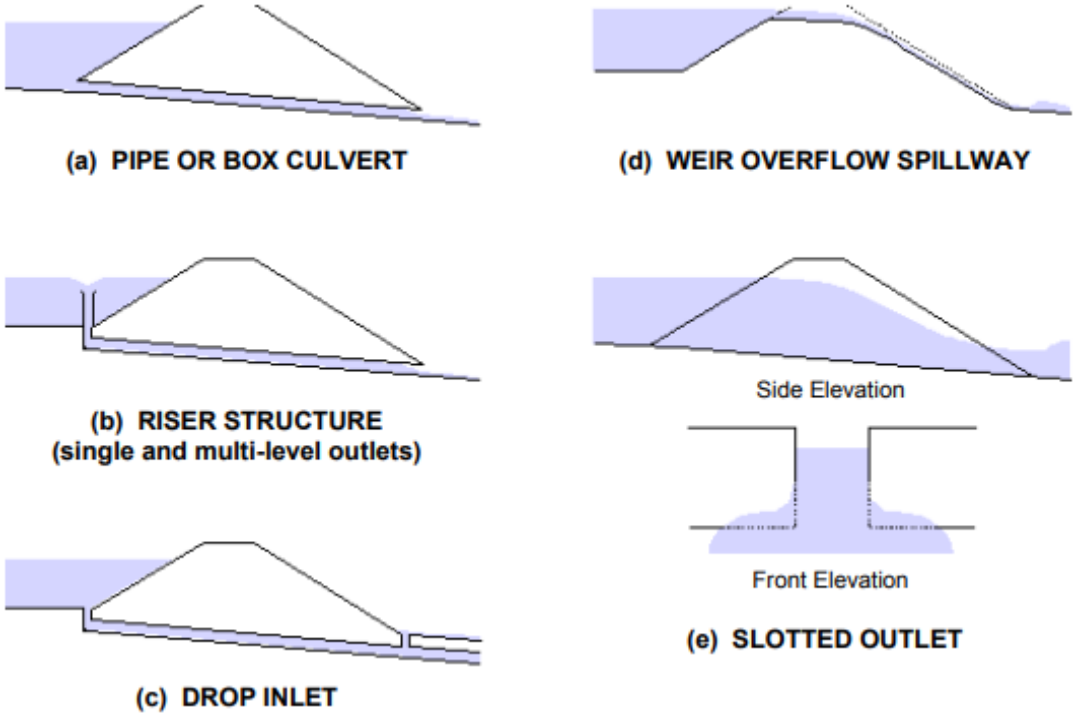
This section provides an overview of hydraulics and design for the most common outlet structure types for stormwater storage facilities, shown in Figure 6.8. The design engineer is referred to an appropriate hydraulics text for additional information on outlet structures not contained in this section.

Each outlet type has a different design purpose and application.

WQv and CPv flows are normally handled with smaller, more protected outlet structures such as reverse slope pipes, hooded orifices, orifices located within screened pipes or risers, perforated plates or risers, and V-notch weirs.

The larger flood and drainage control flows are typically handled through a riser with different sized openings, through an overflow at the top of a riser (drop inlet structure), or a flow over a broad crested weir or spillway through the embankment. Overflow weirs can also be of different heights and configurations to handle control of multiple design flows.

Figure 6.8 Common Outlet Types for Storage Facilities (Source: ARC, 2016)



6.5.1 Orifices

An orifice is a circular or rectangular opening of a prescribed shape and size. The flow rate depends on the height of the water above the opening and the size and edge treatment of the orifice. For a single orifice, the discharge is determined using the standard orifice equation (Equation 6.15). See also Figure 6.9.

Equation 6.15

$$Q = CA(2gH)^{0.5}$$

where:

Q = orifice flow rate (or discharge) (cfs)

C = discharge coefficient (see Table 6.7)

A = cross-section area of orifice or pipe (ft^2)

g = acceleration due to gravity (32.2 ft/s^2)

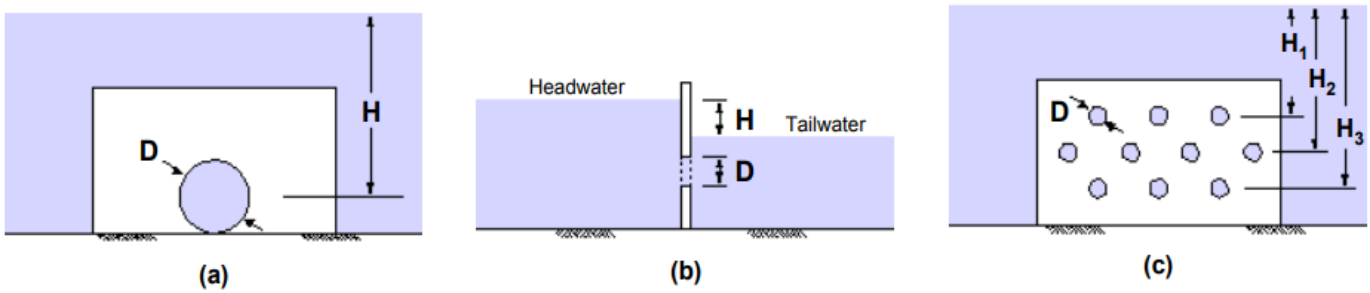
D = diameter of orifice or pipe (ft), used for cross-section area (A) calculation above (see Figure 6.9)

H = effective head on the orifice, from its center to the upstream (headwater) surface elevation (ft); if the orifice is submerged, H is the difference in the headwater and tailwater surface elevations (see Figure 6.9)

Table 6.7 Orifice Discharge Coefficient (C)

Orifice Description	Discharge Coefficient (C)
Orifice material is thinner than its diameter, with sharp or squared edges	0.6
Orifice material is thicker than its diameter, with sharp or squared edges	0.8
Orifice material is thicker than its diameter, with rounded edges	0.92

Figure 6.9 Orifice Parameters *(Source: ARC, 2016)*



When multiple orifices in a perforated orifice plate are used but with different effective heads (H), as shown in Figure 6.9. sum the flow through the individual orifices for the combined flow. If the orifices are the same size and have the same discharge coefficient (C) and effective head (H), the total flow can be determined my multiplying Q for a single orifice by the number of openings. Figure 6.10 is a schematic of an orifice plate outlet structure for a wet ED basin. The design pool elevations and flow control mechanisms are shown.

For rectangular slots, the slot height is normally 2-inches with variable width. Only one column of rectangular slots is allowed.

Figure 6.10 Schematic of Orifice Plate Outlet Structure *(Adapted from ARC, 2016)*

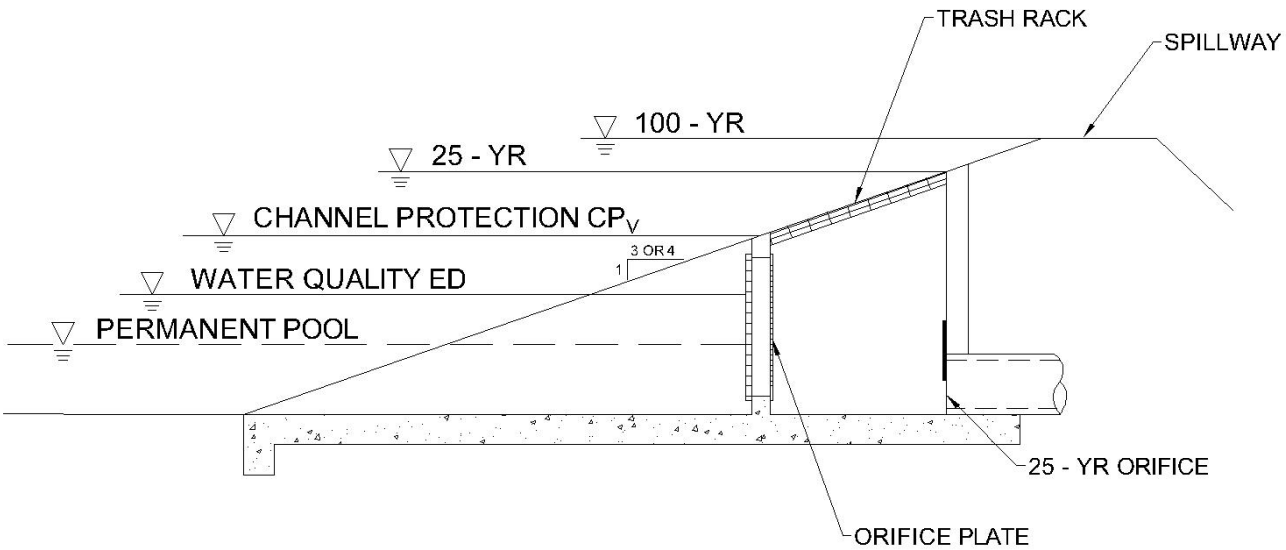


Table 6.8 presents the standardized dimensions for orifice plates with circular perforations.

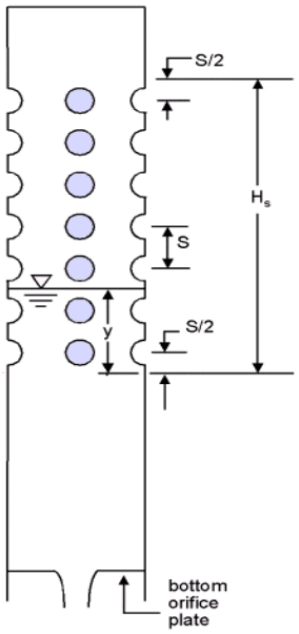
Table 6.8 Standardized Dimensions for Orifice Plates with Circular Perforations *(UDFCD, 2013)*

Hole Diameter (inches)	Min. Column Hole Centerline Spacing (inches)	Flow Area per Row (in^2) *(Number of columns refers to parallel columns of holes.)*		
		1 column	2 columns	3 columns
1/4	1	0.05	0.1	0.15
5/16	2	0.08	0.15	0.23
3/8	2	0.11	0.22	0.33
7/16	2	0.15	0.3	0.45
1/2	2	0.2	0.4	0.6
9/16	3	0.25	0.5	0.75
5/8	3	0.31	0.62	0.93
11/16	3	0.37	0.74	1.11
3/4	3	0.44	0.88	1.32
13/16	3	0.52	1.04	1.56
7/8	3	0.6	1.2	1.8
15/16	3	0.69	1.38	2.07
1	4	0.79	1.58	2.37
1-1/16	4	0.89	1.78	2.61
1 1/8	4	0.99	1.98	2.97
1 3/16	4	1.11	2.22	3.33
1 1/4	4	1.23	2.46	3.69
1 5/16	4	1.35	2.7	4.05
1 3/8	4	1.48	2.96	4.44
1 7/16	4	1.62	3.24	4.86
1 1/2	4	1.77	3.54	5.31
1 9/16	4	1.92	3.84	5.76
1 5/8	4	2.07	4.14	6.21
1 11/16	4	2.24	4.48	6.72
1 3/4	4	2.41	4.82	7.23
1 13/16	4	2.58	5.16	7.74
1 7/8	4	2.76	5.52	8.28
1 15/16	4	2.95	5.9	8.85
2	4	3.14	6.28	9.42
The vertical spacing between hole centerlines is always 4-inches.				
Minimum steel plate thickness		1/4 inches	5/16 inches	3/8 inches

6.5.2 Perforated Risers

A perforated riser is shown in Figure 6.11. In this type of outlet structure, an orifice plate at the bottom of the riser, or in the outlet pipe just downstream from the elbow at the bottom of the riser, controls the flow. It is important that the perforations in the riser convey more flow than the orifice plate so as not to become the control. Use the shortcut formula in Equation 6.16 to estimate the total flow capacity of the perforated section.

Figure 6.11 Perforated Riser *(Source: ARC, 2016)*



Equation 6.16

$$Q = C_P \frac{2A_P}{3H_s}\sqrt{2g}H^{3}/_{2}$$

where:

Q = discharge (cfs)
C_P = discharge coefficient (normally 0.61)
A_p = cross-sectional area of all the holes (ft^2)
H_s = distance from S/2 below the lowest row of holes to S/2 above the top row (Figure 6.11)
H = elevation head differential (ft)

6.5.3 Pipes and Culverts

Discharge pipes or culverts are often used as outlet structures for storage facilities. The design of these pipes can be for single or multi-stage discharges. A reverse slope underwater pipe is often used for WQv and CPv outlets.

Pipes smaller than 12 inches in diameter may be analyzed as a submerged orifice as long as Elevation Head Differential divided by the Diameter of Orifice (H/D) is greater than 1.5. Note: For low flow conditions when stormwater begins to flow through the pipe, weir flow controls. As the stage increases, the flow will transition to orifice flow. Pipes greater than 12 inches in diameter should be analyzed as a discharge pipe with headwater and tailwater effects considered. The outlet hydraulics for pipe flow can be determined from outlet control culvert design nomographs and procedures.

Equation 6.17 is a general pipe flow equation that is derived through the use of the Bernoulli and continuity principles.

Equation 6.17

$$Q = a\left[\frac{2gH}{1 + k_m + k_pL}\right]0.5$$

where:

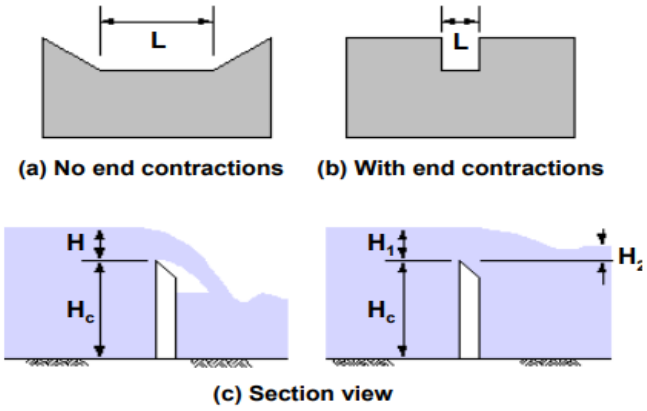
Q = discharge (cfs)
a = pipe cross-sectional area (ft^2)
g = acceleration of gravity (32.2 ft/s)
H = elevation head differential (ft)
k_m = coefficient of minor losses (use 1.0)
k_p = pipe friction coefficient = $5087n^2/D^{4/3}$
n = manning's number
D = diameter of pipe (ft)
L = pipe length (ft)

6.5.4 Sharp-Crested Weirs

A sharp-crested weir has an overflow portion with a sharp, thin, leading (upstream) edge such that water springs clear of the weir as it flows over it. If the sides of the weir also cause the flow of water to contract, the weir is called an end-contracted, sharp-crested weir. Weir configurations with no end contractions and with two end contractions are shown in Figures 6.12(a) and (b). The figure also shows dimension parameters used in the discharge equations.

Equation 6.18 is the discharge equation for a sharp-crested weir without end-contractions (Chow, 1959).

Figure 6.12 \Sharp Crested Weirs *(Source: ARC, 2016)*



Equation 6.18

$$Q = \left[3.27 + 0.4\left(\frac{H}{H_C}\right)\right] LH^{1.5}$$

where:

Q = discharge (cfs)
H = head above weir crest excluding velocity head (ft)
H_c = height of weir crest above channel bottom (ft)
L = horizontal weir length (ft)

Equation 6.19 is the discharge equation for a sharp-crested weir with two end contractions (Chow, 1959). The parameters are the same as defined for Equation 6.18.

Equation 6.19

$$Q = \left[3.27 + 0.4\left(\frac{H}{H_C}\right)\right] (L - 0.2H)H^{1.5}$$

A sharp-crested weir will be affected by submergence when the tailwater rises above the weir crest elevation, reducing the discharge over the weir. Equation 6.20 is the discharge equation for a submerged sharp-crested weir (Brater and King, 1976).

Equation 6.20

$$Q = Q_f \left[1 - \left(\frac{H_2}{H_1}\right)^{1.5}\right]^{0.385}$$

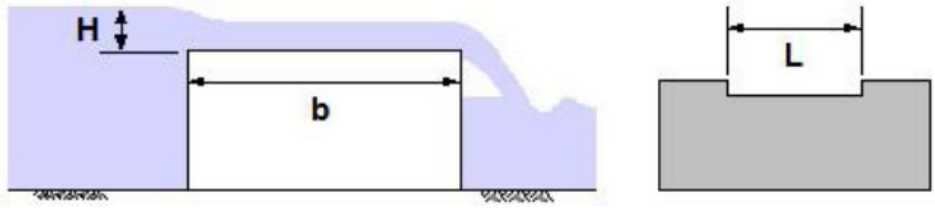
where:

Q = submerged flow (cfs)
Q_f = free flow (cfs)
H_1 = upstream head above crest (ft)
H_2 = downstream head above crest (ft)

6.5.5 Broad-Crested Weirs

A weir in the form of a relatively long raised channel control crest section is a broad-crested weir (see Figure 6.13). The flow control section can have different shapes, such as triangular or circular. True broad-crested weir flow occurs when upstream head above the crest is between the limits of about 1/20 and 1/2 the crest length in the direction of flow. For example, a thick wall or a flat stop log can act like a sharp-crested weir when the approach head is large enough that the flow springs from the upstream corner.

Figure 6.13 Broad-Crested Weir (Source: ARC, 2016)



If upstream head is small enough relative to the top profile length, the stop log can act like a broad-crested weir (USBR, 1997).

Equation 6.21 is the discharge equation for a broad-crested weir (Brater and King, 1976).

Equation 6.21

$$Q = CLH^{0.5}$$

where:

Q = discharge (cfs)
C = broad-crested weir coefficient (see Table 6.9)
L = weir length perpendicular to flow (ft)
H = head above weir crest (see Figure 6.13)

Table 6.9 Broad-Crested Weir Coefficient (C) Values *(Source: Brater and King, 1976)*

Measured Head (H)*	Weir Crest Breadth (b) in Feet										
In feet	0.50	0.75	1.00	1.50	2.00	2.50	3.00	4.00	5.00	10.00	15.00
0.2	2.80	2.75	2.69	2.62	2.54	2.48	2.44	2.38	2.34	2.49	2.68
0.4	2.92	2.80	2.72	2.64	2.61	2.60	2.58	2.54	2.50	2.56	2.70
0.6	3.08	2.89	2.75	2.64	2.61	2.60	2.68	2.69	2.70	2.70	2.70
0.8	3.30	3.04	2.85	2.68	2.60	2.60	2.67	2.68	2.68	2.69	2.64
1.0	3.32	3.14	2.98	2.75	2.66	2.64	2.65	2.67	2.68	2.68	2.63
1.2	3.32	3.20	3.08	2.86	2.70	2.65	2.64	2.67	2.66	2.69	2.64
1.4	3.32	3.26	3.20	2.92	2.77	2.68	2.64	2.65	2.65	2.67	2.64
1.6	3.32	3.29	3.28	3.07	2.89	2.75	2.68	2.66	2.65	2.64	2.63
1.8	3.32	3.32	3.31	3.07	2.88	2.74	2.68	2.66	2.65	2.64	2.63
2.0	3.32	3.31	3.30	3.03	2.85	2.75	2.27	2.68	2.62	2.64	2.63
2.5	3.32	3.32	3.31	3.28	3.07	2.89	2.81	2.72	2.67	2.64	2.63
3.0	3.32	3.32	3.32	3.32	3.20	3.05	2.92	3.75	2.66	2.64	2.63
3.5	3.32	3.32	3.32	3.32	3.32	3.19	2.97	2.76	2.68	2.64	2.63
4.0	3.32	3.32	3.32	3.32	3.32	3.32	3.07	2.79	2.70	2.64	2.63
4.5	3.32	3.32	3.32	3.32	3.32	3.32	3.32	2.88	2.74	2.64	2.63

Measured Head (H)*	Weir Crest Breadth (b) in Feet										
In feet	0.50	0.75	1.00	1.50	2.00	2.50	3.00	4.00	5.00	10.00	15.00
5.0	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.07	2.79	2.64	2.63
5.5	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	2.88	2.64	2.63

6.5.6 V-Notch Weirs

The configuration of a v-notch weir is obvious from its name (see Figure 6.14). Equation 6.22 is the discharge equation for a v-notch weir (Brater and King, 1976).

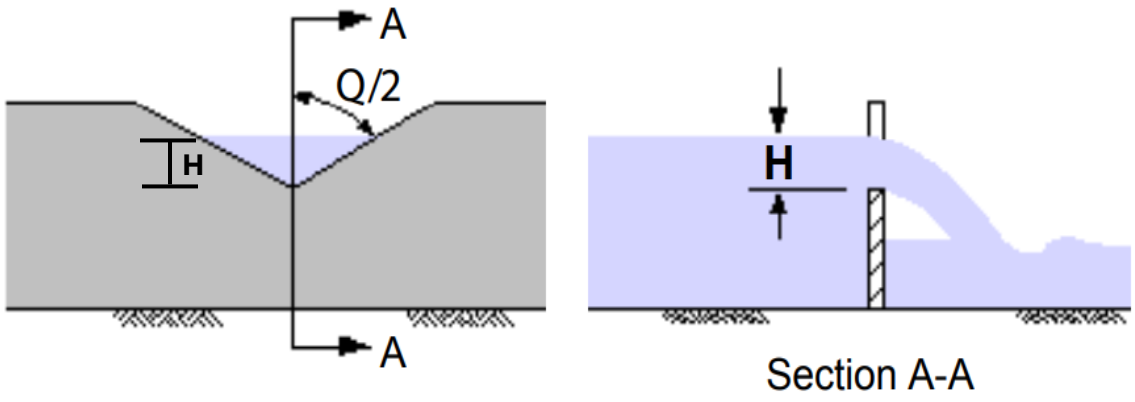
Equation 6.22

$$Q = 2.5 \tan\left(\frac{\Theta}{2}\right) H^{2.5}$$

where:

Q = discharge (cfs)
Θ = angle of v-notch (degrees)
H = head above weir crest (see Figure 6.14)

Figure 6.14 V-Notch Weir *(ARC, 2016)*



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6.5.7 Proportional Weirs

Equations 6.23 and 6.24 are the design equations for proportional weirs (Sandvik, 1985). See Figure 6.15 for dimensions a, b, H, x, and y). The equation is used to calculate the design discharge from the variables in Figure 6.15.

Equation 6.23

$$Q = 4.97a^{0.5}b\left(H - \frac{a}{3}\right)$$

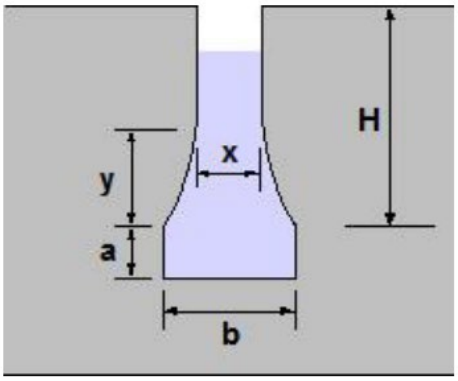
Equation 6.24

$$\frac{x}{b} = 1 - \left(\frac{1}{3.17}\right)\left(arctan\left(\frac{y}{a}\right)^{0.5}\right)$$

where:

Q = discharge (cfs)

Figure 6.15 Proportional Weir Dimensions *(ARC, 2016)*



6.5.8 Extended Detention Outlets (for WQv and CPv Designs)

Extended detention outlet design is required for SCMs that use extended detention storage for stormwater quality (WQv) and/or channel protection (CPv) control. The SCMs that are typically employed for extended detention are listed below.

- Standard dry detention basins
- Dry ED basins
- Underground detention basins
- Permeable pavement systems
- Stormwater wetlands
- Submerged stormwater wetlands
- Water quality (wet) basins

Experience shows that a 48-hour drawdown requirement can yield a small extended detention outlet orifice diameter for small drainage areas. Small orifices and discharge pipes can easily be buried by inflows of sediment and debris, and therefore are difficult to maintain. The policies below must be followed.

- The minimum orifice diameter is 1-inch. Use the minimum 24-hour drawdown period for orifice calculations if 48-hours yields unreasonable results.
- To prevent clogging, orifices that have a diameter of 8-inches or less must be protected by a rock filter/debris cage.
- The use of filter fabric is not allowed for orifice protection.

Related to orifice policies, detention basins used for peak discharge control (i.e., flood control) require selection of an outlet (or series of outlets) that will limit the post-development peak flow for a design storm to the pre-development peak flow(s) for the same design storm(s). The outlet design is easily determined, and routing procedures used to determine if flood control design standards are met. However, the outlet control hydraulics for extended detention is different, since volume and the time required for water to exit the storage facility must be considered.

In an SCM that employs extended detention, the storage volume is detained and released over a minimum of 24 hours and maximum of 48 hours. The release period is a brim drawdown time, beginning at the time of peak storage of the water quality volume until the entire calculated volume drains out of the basin. This assumes that the brim volume is present in the basin prior to any discharge. In reality, however, water is flowing out of the basin prior to the full or brim volume being reached. Therefore, the extended detention outlet can be sized using either of the following methods.

Approach 1 - Maximum Hydraulic Head With Routing

This method uses the maximum hydraulic head associated with the storage volume and maximum flow. The orifice size needed to achieve the required drawdown time is determined, then the volume is routed through the basin to verify the actual storage volume used and the drawdown time.

A wet ED pond sized for the required WQv will be used here to illustrate the sizing procedure for an extended-detention orifice. The same procedure is appropriate for CPv outlet design. Given the following information, calculate the required orifice size for stormwater water quality (WQv) design.

Given: Water Quality Volume (WQv) = 0.76 ac ft = 33,106 ft^3
Maximum Hydraulic Head (H_{max}) = 5.0 ft (from stage vs. storage data)

Since this is a Tier 3 SCM that will control the entire WQv for its drainage area, the drawdown (extended detention) requirement is a minimum of 24 to a maximum of 48 hours.

Step 1. Determine the maximum discharge resulting from the 48-hour drawdown requirement. It is calculated by dividing the WQv by the required time to find the average discharge, and then multiplying by two to obtain the maximum discharge.

Q_{avg} = 33,106 ft^3/(48 hr)(3,600 s/hr) = 0.19 cfs
Q_{max} = 2 * Q_{avg} = 2 * 0.19 = 0.38 cfs

Step 2. Determine the required orifice diameter using the Equation 6.15 (the orifice equation) and Q_{max} and H_{max}. From Table 6.7, the discharge coefficient (C) is 0.6.

$Q = CA(2gH)^{0.5}$, or $A = Q / C(2gH)^{0.5}$
$A = 0.38 \text{ cfs} / 0.6[(2)(32.2 \text{ ft/s})(5.0 \text{ ft})]^{0.5} = 0.035 \text{ ft}^3$

This result makes it clear that the orifice and pipe diameter will be unreasonably small given the 48-hour drawdown requirement. Steps 1 and 2 are recalculated using a 24-hour drawdown requirement, yielding A = 0.071 ft^3. Proceed to Step 3 with the 24-hour drawdown results.

Step 3. Determine pipe diameter from:

$A = 3.14r^2 = 3.14d^2/4$, then $d = (4A/3.14)^{0.5}$
$D = [4(0.071 \text{ ft}^3)/3.14]^{0.5} = 0.30 \text{ ft} = 3.61 \text{ in}$

Use a 3.6-inch diameter water quality orifice.

Step 4. Route the water quality volume through the water quality orifice to verify the drawdown time and the maximum hydraulic head elevation. In the case of this example, the routing effect will result in the actual drawdown time being less than the calculated 24 hours. Judgment should be used to determine whether the orifice size should be reduced to achieve the required 24 hours or if the actual time achieved will provide adequate pollutant removal. See also the orifice policies at the beginning of this section of the manual.

Approach 2 - Average Hydraulic Head and Average Discharge

Again, a wet ED pond sized for the required water quality volume will be used here to illustrate this approach for sizing an extended-detention orifice.

Given: Water Quality Volume (WQv) = 0.76 ac ft = 33,106 ft^3
Maximum Hydraulic Head (H_{max}) = 5.0 ft (from stage vs. storage data)

Since this is a Tier 3 SCM that will control the entire WQv for its drainage area, the drawdown (extended detention) requirement is a minimum of 24 to a maximum of 48 hours.

In this example, our experience in designing extended detention outlets tells us to size using a 24-hour drawdown period to avoid an overly small orifice diameter.

Step 1. Determine the average release rate to release the WQv over a 24-hour time period.

Q_{avg} = 33,106 ft^3/(24 hr)(3,600 s/hr) = 0.38 cfs

Step 2. Determine the required orifice diameter using the Equation 6.15 (the orifice equation) and the average head on the orifice (H_{avg} = 2.5 feet):

$Q = CA(2gH)^{0.5}$, or $A = Q / C(2gH)^{0.5}$
$A = 0.38 \text{ cfs} / 0.6[(2)(32.2 \text{ ft/s})(2.5 \text{ ft})]^{0.5} = 0.05 \text{ ft}^3$

Step 3. Determine pipe diameter from

$A = 3.14r^2 = 3.14d^2/4$, then $d = (4A/3.14)^{0.5}$
$D = [4(0.05 \text{ ft}^3)/3.14]^{0.5} = 0.252$ ft = 3.03 in; so, use a 3-inch diameter water quality orifice.

6.5.9 Combination Outlet Structures/Multi-Stage Outlets

Combinations of orifices , weirs, and pipes can be used to provide multi-stage outlet control for different control volumes and peak discharges within a storage facility. In general, there are two types of combination outlets: shared outlet control structures and separate outlet control structures. A shared outlet control is typically a number of individual outlet orifices, weirs, or drops at different elevations on a riser pipe or box which all discharge to a common larger conduit or pipe. The multi-stage plate in Figure 6.10 is an example of shared outlet control.

Separate outlet controls are less common. They may consist of several pipe or culvert outlets at different levels in the storage facility that are either discharged separately or combined to discharge at a single location.

A combination outlet such as a multiple orifice plate system or multi-stage riser is often used to provide adequate hydraulic outlet controls for the different design requirements (e.g., WQv, CPv, and flood control). They are most commonly used in detention basins (all configurations) and stormwater wetlands (all configurations). Separate openings or devices at different elevations are used to control the rate of discharge from a facility during multiple design storms. Figure 6.16 shows an example of a multi-stage riser for a wet extended detention basin.

A design professional may be creative to provide the most economical and hydraulically efficient outlet design possible in designing a multi-stage outlet. Many iterative routings are usually required to arrive at a minimum structure size and storage volume that provides proper control. The stage-discharge table or rating curve is a composite of the different outlets that are used for different elevations within the multi-stage riser (Figure 6.17).

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Figure 6.16 Schematic of a Multi-Stage Riser
(ARC, 2016)

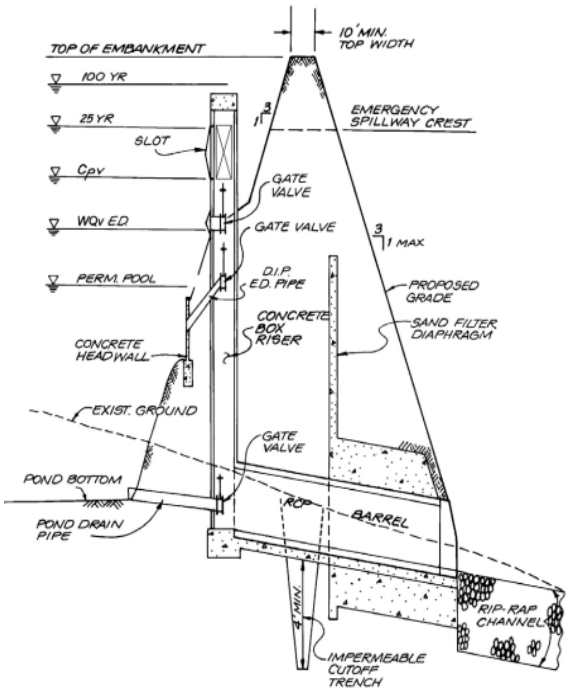
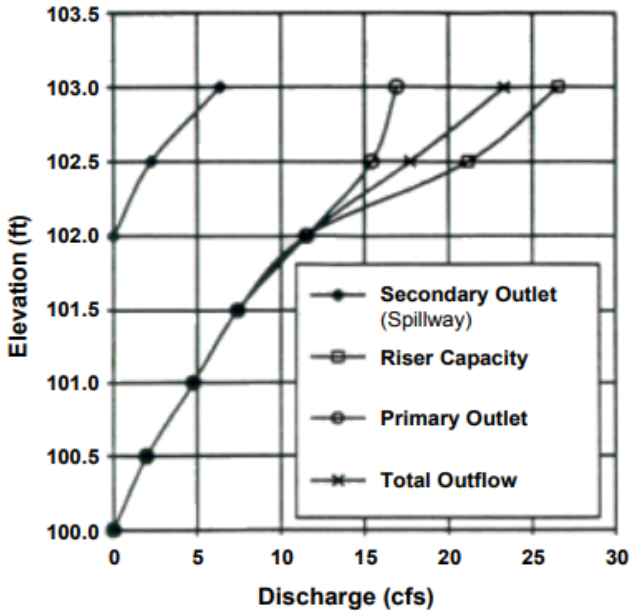


Figure 6.17 Composite Stage-Discharge Curve
(ARC, 2016)



Design Procedure

The steps for design of a multi-stage outlet are below. Note: If an SCM will not control one or more of the required storage volumes, then that step in the procedure is skipped.

Step 1. **Determine Stormwater Volumes**. Determine the WQv and/or CPv, and the flood control volumes needed for peak discharge control of the required design storms.

Step 2. **Develop Stage-Storage Curve.** Develop the stage-storage curve for the SCM using the site geometry and topography. Sufficient storage must be provided for the control volumes determined in Step 1.

Step 3. **Design WQv and/or CPv Outlets.** If the storage facility will manage both the WQv and CPv in a stacked orifice configuration, design the extended detention orifices for both volumes (see Section 6.2 for WQv determination and Section 6.5.8 for extended detention outlet sizing). The total stage-discharge curve at this point will include both the WQv orifice and CPv orifice.

If the design is for a storage facility that will provide only CPv control without WQv control, design the extended detention orifice for the CPv (see Section 6.3 for CPv determination and Section 6.5.8 for extended detention outlet sizing). The total stage-discharge curve at this point will be only for the CPv orifice.

Regardless of WQv/CPv orifice configuration, if the SCM will be designed to have a permanent pool, a portion of the storage volume for WQv (or CPv, or both) will be above the elevation of the permanent pool. The outlet can be protected using either a reverse slope pipe, a hooded protection device, or another acceptable method. See also orifice protection policies established in Section 6.5.8.

Step 4. **Design Flood Control Outlets.** The flood control volumes are added above the WQv/CPv storage. Establish the maximum water surface elevation for each design storm using the stage-storage curve and subtract the WQv (or CPv, or both) elevation to find the maximum head for the design storm. Select an outlet type and calculate the initial size and geometry based on maintaining the pre-development peak discharge rate (Qp) for the design storm. Develop a stage-discharge curve for the combined sent of outlets (WQv, CPv, and Qp).

Step 4 is repeated for peak flow attenuation of all required design storms.

Step 5. **Check Outlet Structure Performance.** Perform a hydraulic analysis of the multi-stage outlet structure using reservoir routing to ensure that all outlets will function as designed. Several iterations may be required to calibrate and optimize the hydraulics and outlets that are used. Also, the structure should operate without excessive surging, noise, vibration, or vortex action at any stage. This usually requires that the structure have a larger cross-sectional area than the outlet conduit.

Step 6.

The hydraulic analysis of the design must consider the hydraulic changes that will occur as depth of storage changes for the different design storms. As the water passes over the rim of a riser, the riser acts as a weir. However, when the water surface reaches a certain height over the rim of a riser, the riser will begin to act as a submerged orifice. Flow diagrams depicting these situations are provided in Figure 6.18. The designer must compute the elevation at which this transition from riser weir flow control to riser orifice flow control takes place for an outlet where this change in hydraulic conditions will occur. Also note in Figure 6.18 that as the elevation of the water increases further, the control can change from barrel inlet flow control to barrel pipe flow control.

Figure 6.18 Riser Flow Diagrams

(Source: VDCR, 1999)

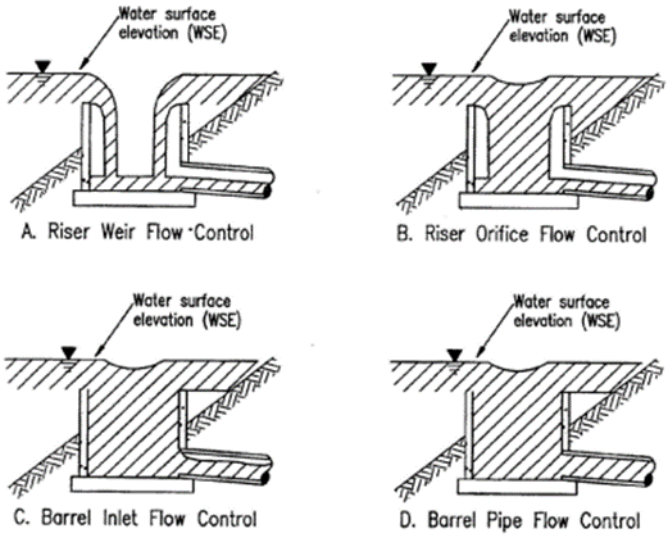


Figure 6.19 shows another condition where weir flow can change to orifice flow, which must be considered in the hydraulics of the rating curve as different design conditions result in changing water surface elevations.

Step 7. **Size the Emergency Spillway.** An emergency spillway is required for all surface detention, retention, and wetland storage areas. It provides a degree of safety to prevent overtopping of an embankment if the primary outlet structure or principal spillway becomes clogged or otherwise fails. The spillway shall be 0.1 foot above the WSEL for the 100-year, 24-hour event. See Section 6.5.10 for guidance on emergency spillway design. Route the 100-year storm through the outlet devices and emergency spillway to ensure the hydraulics of the storage area will operate as designed.

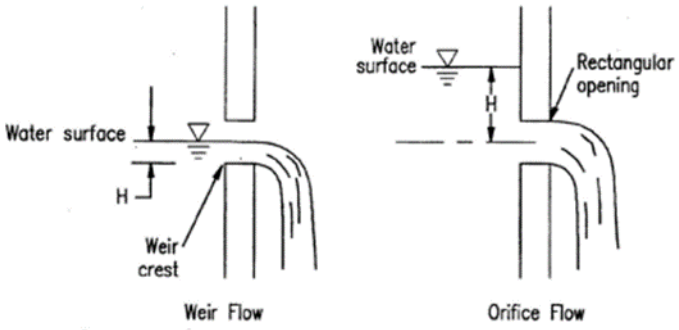
The top of the berm shall be a minimum of one foot above the WSEL for the 100-year, 24-hour storm event.

Step 8. **Design the Outlet Protection.** Design necessary outlet protection and energy dissipation devices to avoid outlet clogging and erosion problems downstream from the outlet and spillway. A rock filter cage must be provided for orifices that have a diameter of 8-inches or less.

Step 9. **Perform Buoyancy Calculations.** Floatation of the outlet structure and its components will occur when its weight is less than or equal to the buoyant force exerted by the water. Thus, confirmation that the outlet structure will not float is required. Perform buoyance calculations for the structure, including its footing.

Figure 6.19 Weir and Orifice Flow

(Source: VDCR, 1999)



Step 10. **Provide Seepage Control.** Seepage control should be provided for the outflow pipe or culvert through an embankment using anti-seep collars.

6.5.10 Emergency Spillways

Emergency spillway designs are open channels, usually trapezoidal in cross section, and consist of an inlet channel, a control section, and an exit channel (see Figure 6.20). The emergency spillway is proportioned to pass flows in excess of the design flood (typically the 100-year flood or greater) without allowing excessive velocities and without overtopping of the embankment. Flow in the emergency spillway is open channel. Normally, it is assumed that critical depth occurs at the control section.

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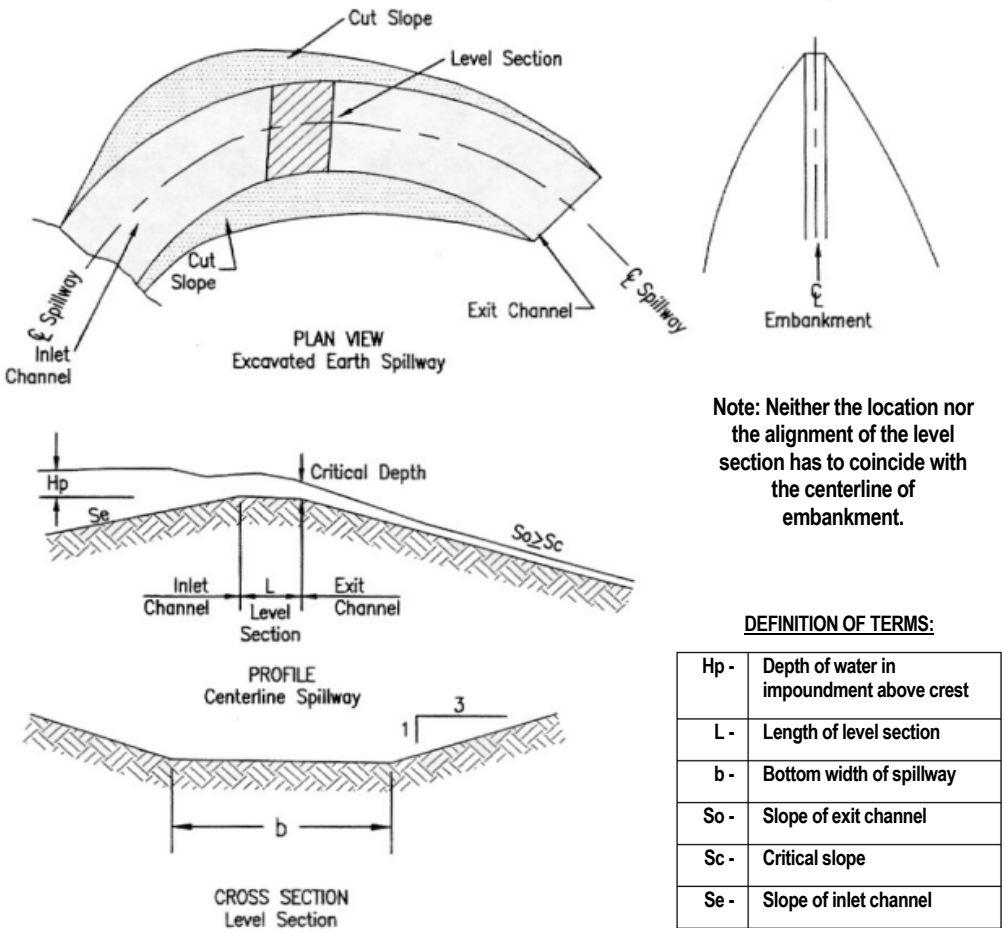
Figure 6.20 Emergency Spillways *(VDCR, 1999)*



Note: Neither the location nor the alignment of the level section has to coincide with the centerline of embankment.

DEFINITION OF TERMS:

Hp -	**Depth of water in impoundment above crest**
L -	**Length of level section**
b -	**Bottom width of spillway**
So -	**Slope of exit channel**
Sc -	**Critical slope**
Se -	**Slope of inlet channel**

6.6 SCM Selection and Feasibility

This section provides requirements and supporting guidance for the selection of SCMs to meet the County's stormwater management standards. There are many factors to consider when selecting one or more SCMs for a drainage area, which are presented comparatively in this section. Table 6.10 presents SCM feasibility based on land-use characteristics. Table 6.11 presents physical and other (non-physical) feasibility factors. All of the information provided in these tables are described in greater detail in the individual SCM design specifications provided in Chapter 7 Sections 7.1 through 7.13.

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Table 6.10 SCM Selection Based on Land Use

SCM Name	*Land Use of Project or Areas Within a Project*								
	Com-mercial	Indus-trial	Parking Lots	Roadways		Parks & Open Space	Residential		
				Shoulder & Medians	Travel-Ways		SFR Individual Lots	SFR Common Area	Multi-Family Res.
Bioretention (Rain Garden)	●	○	●	●	✖	●	✖	●	●
Detention Basin (Standard & ED)	●	○	●	●	✖	●	✖	●	●
Dry Enhanced Swale	●	○	●	●	✖	●	✖	●	●
Gravity (Oil-Grit) Separator	●	●	●	○	✖	○	✖	○	○
Green Roof	●	●	●	✖	✖	●	✖	●	●
LID-MTDs (Tiers 1 & 2)	●	●	●	○	✖	●	✖	●	●
Filtration MTDs (Tiers 3)	○	●	○	○	✖	○	✖	●	●
Hydrodynamic MTDs (Tiers 4)	●	○	●	✖	✖	○	✖	●	●
Permeable Pavement Systems (all types)	●	○	●	●	●	●	✖	●	●
Sand Filter (all types)	●	●	●	●	✖	●	✖	○	○
Stormwater Wetland	●	●	○	●	✖	●	✖	○	○
Underground Detention	●	●	●	○	○	●	✖	●	●
Urban Bioretention	●	○	✖	●	✖	✖	✖	●	●
Wet Detention	●	●	●	○	✖	●	✖	●	●
Wet Enhanced Swale	●	●	●	●	✖	●	✖	○	○

● = Generally, well-suited for this application with proper protection and regular maintenance.

○ = Generally, not well-suited for this application due to feasibility, protection, or maintenance concerns. Check design specification in Chapter 7.

✖ = Not allowed for this application without prior city approval.

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Table 6.11 SCM Feasibility Table

	Stormwater Management Capability			Physical and Hydrologic Design Factors											Cost Constraints	
												Minimum Setbacks				
SCM Name	Water Quality (WQv)	Channel Protection (CPv)	Detention/Retention (Peak Flow) Control	Plants Req'd	Includes Under-drain	Max. Drainage Area	Approx. Space Required (% of max. drainage area)	Max. Slope of Drainage Area	Ideal Slope of Drainage Area	Min. Head (Elev. Differ-ence)	Min. Depth to Water Table	Building Foundations	Water Supply Wells	Water Supply Reservoirs	Const. Cost	Maint. Burden
Bioretention	Yes	No	Minor	Yes	Always	5 acres	3 - 5%	20%	5%	3 ft	2 ft	20' and 30'	-	-	Med.	Med. / High
Dry Detention Basin	Yes	Yes	Yes	Yes	Never	25 acres	2 - 3%	15%	-	Varies	2 ft	see zoning ord.	see zoning ord.	see zoning ord.	Low	Low / Med.
Dry Enhanced Swale	Yes	No	Minor	Yes	Always	5 acres	5%	5%	-	3 - 5 ft	2 ft	10' and 30'	-	-	Med.	Low / Med.
Gravity (oil-grit) Separator	Yes	No	No	N/A	Always	5 acres	Minor	6%	-	4 ft	2 ft	10'	100'	200'	High	Med. / High
MTDs	Yes	No	No	Depends on MTD	Always	Varies	Varies	Varies	Varies	Varies	Varies	10'	100'	200'	Varies	Varies
Permeable Pavement System	Yes	Yes	Yes	N/A	Always	5 acres	100%	15%	5%	2 - 4 ft	2 ft	15'	100'	200'	High	Med. / Med.
Sand Filter	Yes	Yes	No	No	Always	Varies	Varies	6%	-	Varies	Varies	10'	100-250'	See TDEC	Med. /High	Varies / High
Stormwater Wetland	Yes	Yes	Yes	Yes	Never	Varies	3 – 5%	8%	-	3 - 5 ft	-	10'	100'	See TDEC	Med.	Low / Low
Underground ED Basin	No	Yes	Yes	No	Never	25 acres	-	15%	-	4 – 8 ft	2 ft	-	50-250'	See TDEC	High	Med. / High
Urban Bioretention	Yes	No	No	Yes	Always	2,500 ft^2	5%	6%	0 – 3%	2 ft	2 ft	0-10'	100'	400'	Med.	Med. / Med.
Wet Detention	Yes	Yes	Yes	Yes	Never	Varies	2 – 3%	15%	-	6 – 8 ft	2 – 4ft	15'	100'	See TDEC	Med.	Med. / Low
Wet Enhanced Swale	Yes	No	No	Yes	Never	5 acres	10 - 20%	5 %	-	1 ft	-	10' and 30'	100'	200'	Med.	Med. / Low

6.7 References

Allred-Coonrod, J.E., 1991, Safety Grates in Open Channels, MS Prof. Paper. University of New Mexico, Albuquerque.

American Society of Civil Engineers, 1985, Stormwater Detention Outlet Control Structures, Task Committee on the Design of Outlet Control Structures, ASCE, New Your, N.Y.

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition.* Atlanta Regional Commission, 2016.

Brater, Ernist F., Horace W. King. 1976. *Handbook of Hydraulics*. 6th ed. NY: McGraw Hill Book Co.

Chow, C. N. 1959. *Open Channel Hydraulics*. New York: McGraw Hill Book Company.

City of Topeka, Kansas. *Stormwater BMP Design Handbook, January 2021 Version*.

Ferguson, B. and Debo, Thomas. *On-Site Stormwater Management*. 1990.

Knox County, Tennessee. Knox County Stormwater Management Manual Volume 2, Technical Guidance. 2006.

Maryland Department of the Environment. 2000. *Maryland Stormwater Design Manual, Volumes I & II.* Online. Accessed February 2024. Center for Watershed Protection (CWP), Ellicott City, MD.

Metcalf & Eddy, Inc., 1972, Wastewater Engineering, McGraw Hill, New York.

National Oceanic and Atmospheric Administration (NOAA). *Evaporation Atlas for the Contiguous 48 United States*. NOAA Technical Report NWS 34, Washington DC, 1982.

Pitt, Robert. *Small Storm Hydrology*. Unpublished report. Department of Civil Engineering, University of Alabama at Birmingham, 1994.

Sandvik, A. 1985. *Proportional Weirs for Stormwater Pond Outlets*. Civil Engineering, March 1985, ASCE pp. 54-56.

Schueler, Thomas R., July 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMP's,* Department of Environmental Programs Metropolitan Washington Council of Governments, Metropolitan Information Center, Washington, DC.

Tennessee Department of Transportation (TDOT). 2007. *TDOT Design Division Drainage Manual. Chapter VIII Stormwater Storage Facilities*. March 15, 2007.

Urban Drainage and Flood Control District (UDFCD). 1999. *Criteria Manual*. Denver, CO.

UDFC. *Urban Storm Drainage Criteria Manual Volume 3*. August 2013. Urban Drainage Flood Control District. Mile High Flood District. Lakewood Colorado.

U.S. Army Corps of Engineers, 1988. *Hydraulic Design Criteria (HDC),* USAE Waterways Experiment Station, Vicksburg, MS.

U.S. Bureau of Reclamation (USBR) , 1978. *Design of Small Canal Structures.*

U.S. Department of Agriculture, Natural Resource Conservation Service, Engineering Division. 1986. *Urban Hydrology for Small Watersheds. Technical Release 55.* Natural Resource Conservation Service (NRCS).

Virginia Department of Conservation and Recreation. *Virginia Stormwater Management Handbook, First Edition*, 1999.

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7.1 BIORETENTION AREA design specifications

Water Quality Volume (WQv) Rainfall
Tier 2 Design 1.25 inches

OTHER SCM ATTRIBUTES *(cost scale is $-low, $$-medium, $$$-high)*	
Channel Protection Volume (CPv)	**No**
Detention / Retention Control	**Minor**
Small Onsite Drainage Control	**Limited**
Typical SCM Footprint Size *(percent of contributing drainage area)*	**3 to 5%**
Construction Cost	**$$**
Operation & Maintenance Cost *(when properly maintained)*	**$**

PROJECT SUITABILITY				
Industrial	**Commercial**	**Residential** *(common areas only)*	**Pollutant Hotspots**	**Private Roadways** *(requires HOA)*
✓	✓	✓	✗	✓

Legend: ✓ **High** ✓ **Limited** ✗ **None**

OVERVIEW

Bioretention areas are structural stormwater control measures (SCMs) with vegetated, shallow depressions used to capture and filter stormwater runoff through an engineered soil mix. Filtered water then enters an underdrain, which discharges the water to the onsite stormwater conveyance system. This SCM is becoming more popular because of its versatility in location, configuration, size, and landscape.

ADVANTAGES/BENEFITS

- Reduces pollutant discharges
- May address small, onsite drainage issues
- Enhances site aesthetics and habitat availability

DISADVANTAGES/LIMITATIONS

- Not often suitable for detention
- Highly sensitive to poor construction sediment control practices; cannot be used as a sediment trap/basin during construction
- Operate SCM only after the drainage area is permanently stabilized

LOCATION, SIZING, & COMPONENTS

- An underdrain is required for all applications
- Not appropriate for slopes greater than 20%
- The impervious surface area draining to the bioretention area cannot exceed 20 times the SCM's surface area
- Minimum 2-foot separation from seasonally high-water table
- Runoff pretreatment is required at all inlets
- Energy dissipation is required at all inlets
- Minimum required distance from the edge of buildings to the edge of a bioretention area ranges from 20 to 30 feet

LONG-TERM PROTECTION

- Primary concerns are plant damage and soil compaction
- Protect from entry by vehicles and heavy equipment
- Suitable for a wide variety of protective designs

LONG-TERM MAINTENANCE

- Primary routine maintenance activities will be cleaning and plant care (e.g., weeding, pruning, mulching, leaf and landscape debris removal, plant replacement)
- Consider permanent signs to dissuade entry and use of SCM as a pet relief area if SCM is near a pedestrian area
- Select plants that can withstand occasional short-term inundation
- Provide trash cans and pet waste stations in the drainage area

7.1.1 General Description

Bioretention areas (sometimes called "rain gardens") are SCMs that allow the water quality treatment volume (WQv) to soak into a shallow, landscaped basins filled with vegetation and an engineered soil mix. The soil mix and subsurface design of the SCM creates a biofilter for captured stormwater. Some bioretention areas are designed to allow exfiltration of the biofiltered water into the native soils below the SCM. When this design configuration is not feasible, the biofiltered water flows into an underdrain connected to the onsite stormwater drainage system.

Typically, bioretention areas without underdrains are not feasible in east Tennessee due to the prevalence of karst terrain (areas underlain by soluble carbonate bedrock). In these areas, concentrated infiltration into the in-situ soil can easily cause sinkhole formation. The location of sinkhole formation cannot be easily predicted. This phenomenon is a significant concern in Maryville and Alcoa, where sinkhole formation is a frequent occurrence. Thus, underdrains are required for all bioretention areas to reduce the possibility of sinkhole formation.

7.1.2 Design Applications

The requirement for an underdrain should not detract from the selection of a bioretention area for development sites. In fact, bioretention areas are highly versatile SCMs appropriate for numerous applications. They can be used for all soil types since runoff will remain in the bioretention area until it discharges to the stormwater system via the underdrain. The most important design factor to consider when designing this SCM is the scale at which it will be applied. There are few limits on bioretention area geometry which means they can be sized to fit into tight site layouts. Bioretention areas are often used at commercial, institutional, and residential sites in spaces that are traditionally pervious and landscaped, such as parking lot islands and buffer areas (see Figure 7.1.1). With proper design and maintenance, this SCM can also be used in highly impervious or space-constrained high traffic areas.

Figure 7.1.1 Examples of Bioretention Area Applications

Location and photo source: (Top left) Sacramento State Campus, Sacramento State Office of Water Programs; (top right) location unknown, The Nature Conservancy; (bottom right) Metro Water Services parking lot in Nashville TN; (bottom left) University of Tennessee Gardens, Univ. of TN campus in Knoxville,

Typical locations for bioretention areas include the following:

Parking lot islands. Bioretention areas can be sited as linear features (between parking space rows) or within parking lot islands. Flow into the bioretention areas is achieved with sheet flow over flush pavement edges (with the SCM) or through curb cuts if curbing around these areas is required by the City parking lot design requirements. Curb cuts are more prone to blockage, clogging and erosion and thus have a minimum opening width of 18 inches. For flush pavement edges between rows of parking stalls, curb blocks are highly recommended to prevent inadvertent vehicle entry into the SCM. An apron of dense turf or cobbles around the edge of the area functions as a filter strip to provide pretreatment.

Parking lot edge. Small parking lots can be graded so that flows reach a flush pavement edge or curb cut before reaching catch basins or storm drain inlets. The turf at the edge of the parking lot functions as a filter strip to provide pre-treatment for the bioretention practice. The depression for the bioretention area is located in the pervious area adjacent to the parking lot.

Courtyards. Stormwater collected in a storm drain system or roof leaders can be directed to courtyards or other pervious areas on site where bioretention can be installed.

Unused pervious areas on a site. Bioretention areas can be applied in unused pervious areas on a site to provide both stormwater management and landscaping. Storm flows can be redirected from a storm drainpipe to discharge into the area.

Dry Extended Detention (ED) basin. A bioretention area can be located on an upper shelf of an extended detention basin, after the sediment forebay, in order to boost treatment. A bypass or diverter must be implemented to send large flows directly into the ED basin. See Section 7.2 (Dry Detention Basins) for more information on design of a dry ED basin.

Retrofitting. Numerous options are available to retrofit bioretention areas in the urban landscape. These are described more fully in Section 7.11 (Urban Bioretention).

7.1.3 SCM Suitability

Use Table 7.1.1 to determine if a bioretention area is suitable for the application being considered.

Table 7.1.1 Bioretention Suitability Factors

Factor	Suitability
Stormwater Quality Treatment	Bioretention areas designed in keeping with the specifications established herein will satisfy the City's stormwater quality treatment standards.
Channel Protection	It may be possible to size a bioretention area to provide channel protection (extended detention of the 1-year, 24-hour storm) for smaller sites. However, this is unnecessary for bioretention areas that discharge to another control that is designed to provide channel protection (like a detention basin). For larger sites or where the WQv is diverted to the bioretention area (an offline design configuration), channel protection must be provided by another control, such as a dry extended detention basin.
Detention	Bioretention areas are generally not suitable for peak discharge (detention) control, even for small design storms (the 2-year event). The bioretention area must be designed to bypass these flows. Bioretention areas can be helpful in addressing small, limited, onsite drainage issues when designed with additional storage capacity for volumes higher than the WQv. This is done by providing

<table>
<tr><th>Factor</th><th>Suitability</th></tr>
<tr><td></td><td>additional internal water storage. See Section 7.15 (Underdrain and Internal Water Storage Design) for more information.</td></tr>
<tr><td>Pollutant Treatment Capability</td><td>Bioretention areas can be used to address following common stormwater pollutants[1]:
<table>
<tr><th>Total Suspended Solids (TSS)</th><th>Total Phosphorus (TP)</th><th>Total Nitrogen (TN)</th><th>Fecal Bacteria[1]</th><th>Metals*</th></tr>
<tr><td>85%</td><td>80%</td><td>60%</td><td>90%</td><td>95%</td></tr>
</table>
*Cadmium, copper, lead, and zinc</td></tr>
<tr><td>Treatment of Waste and Other Pollutants</td><td>Bioretention areas shall not be used to treat the following pollutants:
Construction sediment/waste
Landscape storage or waste
Sewage, pet, and livestock waste
Medical waste
Household & commercial wastes
Hazardous wastes
Gasoline, motor oils, greases, and other petroleum-based products
Fats, oils & grease (from food preparation)
Pesticides, fertilizers, herbicides
Other byproducts and waste materials expected, based on the property's land use</td></tr>
<tr><td>Suitability by Land Use</td><td>Privately owned bioretention SCMs are not allowed in the public right-of-way.
General suitability criteria by land-use type are as follows. See Chapter 6 (SCM Standards, Methods, and Selection) for more information.
<table>
<tr><th>Commercial</th><th>Industrial</th><th>Private Roadways</th><th>Single Family Residential</th><th>Multi-Family Residential</th></tr>
<tr><td>Yes</td><td>Limited</td><td>Yes</td><td colspan="2">Common Areas Only</td></tr>
</table></td></tr>
</table>

7.1.4 SCM Location Requirements

Location constraints for bioretention areas are provided in Table 7.1.2.

Table 7.1.2 Bioretention Area Location Requirements

Physical Element	Requirement

SCM Setbacks	Minimum setbacks, measured from the edge of the bioretention area, are as follows:
	• At least 5 feet down gradient from underground utility lines
	• Building foundations:
	  ○ Offline configuration: 20 feet from a building's foundation, if positioned downslope of the building and no closer than 30 feet from buildings that are downslope
	  ○ Online configuration: Safe bypass of the 1-year storm and above is required in an online configuration. The distance of the edge of the SCM from a building's foundation shall be determined based on the expected extent of flooding around the SCM for the 100-year event

[1] Source: *Georgia Stormwater Management Manual, Volume 2 Technical Handbook, 2016 Edition.*

	Since the bioretention area design specified in this document includes underdrains and impermeable liners, the potential for negative impacts on subsurface water supplies and septic systems is minimal. Adhere to City specified minimum setbacks.
Flow Avoidance	Bioretention areas shall not be located where it will receive continuous or dry weather inflows from springs, seeps, sump pumps, wash stations, or other sources.
Utility Avoidance	Bioretention areas shall not be located above underground dry utility lines (electric, cable, and telephone), water/wastewater infrastructure, and existing storm drainage infrastructure. Design professionals must consult the local utility to determine the horizontal and vertical clearance required between SCMs and dry and wet utility lines.

7.1.5 Design Requirements

The criteria provided in Tables 7.1.3 and 7.1.4 shall be considered minimum standards and specifications for the design of bioretention areas and their contributing drainage areas. Some of the specifications are shown in Figure 7.1.2 which is provided as an example of a properly designed bioretention area. The figure shows an upturned underdrain configuration. Other acceptable underdrain configurations are provided in Section 7.15 (Underdrain and IWS Design).

Figure 7.1.2 Schematic of a Bioretention Area with an Upturned Elbow Underdrain

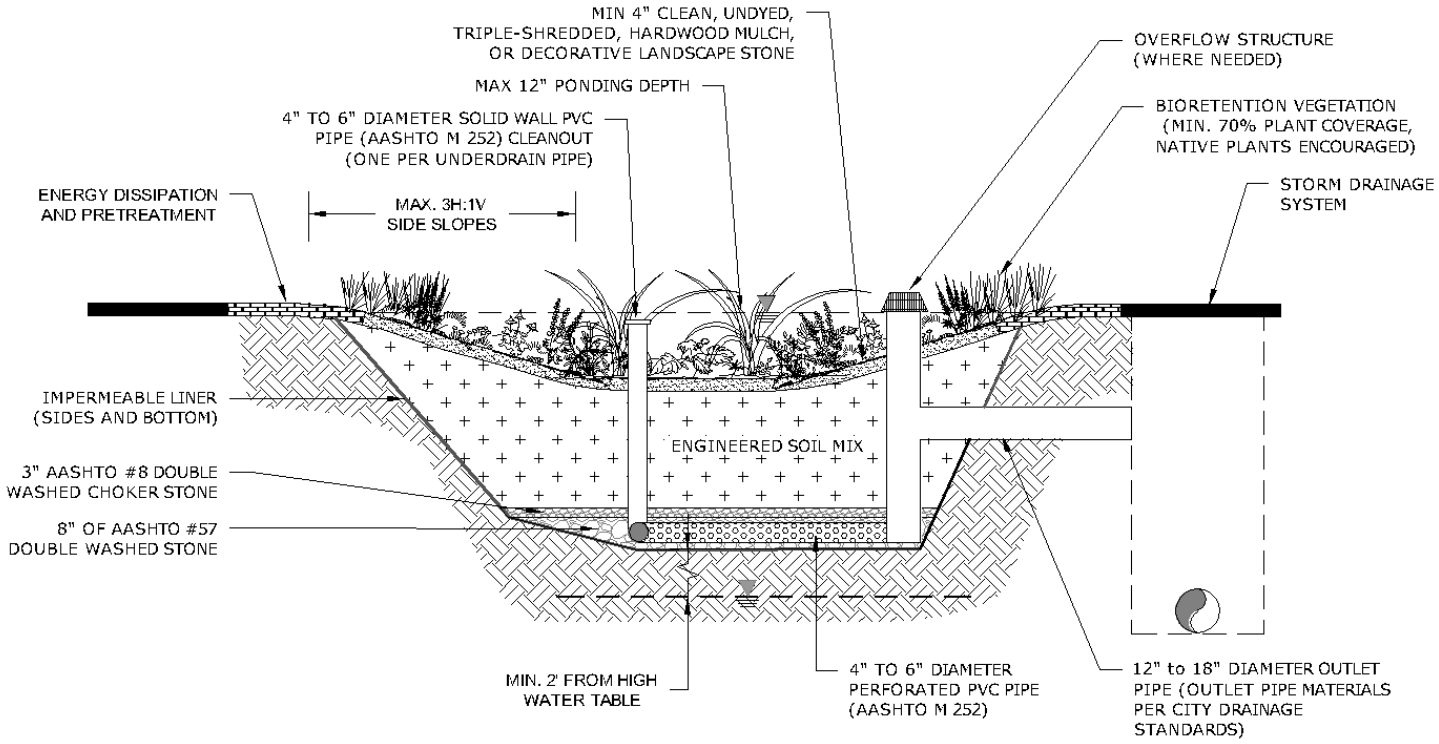


Table 7.1.3 Design Specifications for the Contributing Drainage Area

Design Element	Specification(s)
Drainage Area	Maximum contributing drainage area (CDA) = 5 acres; 0.5 to 2.0 acres is preferred. • Contributing drainage areas greater than 5 acres can be divided into multiple areas, each drainage area draining to a separate bioretention area or another SCM.
Slope	Maximum slope = 20%; 5% is preferred. • Energy dissipation techniques upstream of the inlets must be used for CDA slopes greater than 5% to ensure WQv flow will not bypass the inlets and have a maximum inflow velocity of 5 ft/sec. Terracing or inlet controls may be used to slow runoff velocities. Bioretention areas are not allowed in areas where slopes exceed 20%.
Controls for Waste & Other Pollutants	Appropriate controls shall be included in the design of the contributing drainage area to the SCM to address any Wastes and Other Pollutants (see Table 7.1.1 above) that are expected on the property after construction. Use the proposed land use as a guide to determine appropriate controls. Examples of such controls include, but are not limited to, dumpsters, trash cans, covered materials/waste storage areas, covered materials transfer areas, oil and grease waste controls, and pet waste stations.

Table 7.1.4 Design Specifications for the Bioretention Area

Design Element	Specification(s)
Water Quality Volume (WQv)	The water quality rainfall depth (P) for determination of WQv = 1.25 inches Acceptable methods to determine WQv are presented in Chapter 6 (SCM Standards, Methods, and Selection). Bioretention areas that cannot treat the entire WQv for its contributing drainage area must be used in a treatment train or exchanged with an alternate SCM that can treat the entire WQv.
Use in a Water Quality Treatment Train	If the bioretention area cannot manage the entire WQv for its contributing drainage area, it must be placed in a treatment train with another SCM. See Chapter 6, Section 6.2.4 for treatment train policies and calculations.
Offline and Online Design Configuration	An offline configuration is the preferred design configuration for bioretention area applications as they are designed and constructed away from the main flow path for the drainage area, thus avoiding large flood flows. A flow splitter, diversion structure, or other means is used upstream of the bioretention area's inlets to redirect the bioretention area's design volume (typically this will be the WQv) from the main flow path to the SCM while still allowing larger flows to remain in the main flow path. The structure shall include a low-flow orifice, weir, or other hydraulic structure, sized to pass the peak discharge of the design volume (typically this will be the water quality peak discharge, Q_{wq}) to the bioretention area. Chapter 6 (SCM Standards, Methods, and Selection) provides the method required for diversion structure sizing. An online configuration is designed and constructed so the main flow path for the drainage area passes through the bioretention area. This creates a high potential for frequent sediment deposition in the engineered soil mix and corresponding need for remedial maintenance. Thus, an online bioretention area is permissible only for drainage areas that are 100% impervious and have low potential for sediment and debris loads, such as drainage from a small building rooftop.

Design Element	Specification(s)
	Regardless of design configuration (offline or online), bioretention areas shall always be located upstream of other SCMs (e.g., detention basins designed for flood control, SCMs in a water quality treatment train, etc.). Flow regulators (flow splitters and diversion structures) shall be designed in keeping with Section 7.16 (Overflow Structures).
Maintenance Access and Easement	A maintenance easement shall be provided to the bioretention from a driveway, public or private road. It shall be designed as follows: • a minimum width of 15 feet • a maximum slope of no more than 15% • the access route in the easement shall be free of permanently affixed obstructions (e.g., trees, pools, fences without gates, permanent signs, etc.) and appropriately stabilized to withstand maintenance equipment and vehicles • to the extent feasible, allow vehicles to turn around. The entire bioretention area, including inlets, pretreatment devices, the storage area. embankments, and outlet structure) shall be included in the easement and shall be accessible from the easement's drive path.
Inlets and Energy Dissipation	Maximum stormwater entry velocity = 5 ft/sec • Stormwater shall enter the bioretention area as sheet or shallow concentrated flow. Energy dissipation measures, such as vegetated buffer strips or rock aprons shall be provided. These measures may also provide stormwater pretreatment.
Pretreatment	Pretreatment is required immediately at each inlet to remove gross solids, trash, and sediment from stormwater prior to flowing into the main treatment area. • Vegetated filter strips and gentle side slopes of dense grass are suitable pretreatment measures for lateral non-concentrated inflows. Rock aprons or other methods may be preferred for more concentrated inflows. Pretreatment options and design specifications are provided in Section 7.14 (Inlets, Pretreatment, and Energy Dissipation Devices). • Swales that will receive direct concentrated stormwater may require a 6-inch drop to a pea gravel diaphragm flow spreader at the upstream end of the control to slow and spread runoff entering the swale. • Consider screens, grates, baffles, or other pretreatment measures for debris capture in areas where high amounts of floatables (litter, trash, etc.) are expected.
Surface Area and Geometry	Recommended surface area = 3% to 5% of the CDA Stormwater flowing into the bioretention area must be distributed evenly across its entire surface area. Ensure the planting bed/engineered soil mix are not bypassed or short-circuited (e.g., for example, inlets or curb cuts that are very close to outlet structures, or incoming flow is diverted immediately to the underdrain)
Side Slopes	Side slopes = 1:1 or flatter, except when one or more vertical side walls are necessary. • For bioretention areas near pavement or in space-constrained areas, a drop curb design or a precast structure can be used to create a stable, vertical side wall. Safety precautions, such as railing, fencing, walls, grates, etc. shall be included in the design for vertical drops exceeding 6 inches. If three vertical sides or greater are needed, design professionals must use the design specification for urban bioretention [Section 7.11 (Urban Bioretention)].

Design Element	Specification(s)
Ponding Depth	Maximum surface ponding depth = 12 inches
Minimum Depth to Water Table	Minimum separation distance (bottom of excavation to seasonally high-water table) = 2 feet Soil borings shall be used to determine the seasonally high-water table. See Appendix E (Policies for Soil Borings and Infiltration Tests) for soil boring requirements.
Minimum Hydraulic Head	Minimum hydraulic head = 3 feet The hydraulic head is the difference in the inflow elevation, including the design ponding depth, to the outflow elevation at the underdrain invert elevation or bottom of SCM at its downstream end.
Drawdown Time	The WQv shall fully discharge from the underdrain within 48 hours.
Overflow Structure	An overflow structure that safely passes runoff that exceeds the design volume (typically this will be the WQv) must be included in the design to prevent overfilling the SCM and flooding in adjacent areas. Small, offline bioretention areas may be excepted from this requirement depending on situation. • The overflow inlet is typically a yard drain catch basin (with suitable debris/trash rack), though any number of conventional systems could be used. It must be set at the maximum ponding elevation (i.e., no more than 12 inches above the mulch layer). • The overflow structure shall bypass the underdrain and discharge to the outlet pipe/channel for the bioretention area (e.g., typically an onsite stormwater conveyance system or stabilized watercourse). Discharges to a channel must be non-erosive (maximum of 5 ft/sec). See additional guidance in Section 7.16 (Overflow Structures) and requirements for bypass/overflow structures in the online configuration row of this table (below).
The remaining rows specify the subsurface layers of the SCM, starting at the bottom	
In-situ Soil	Limit the excavation to the width and depth specified in the design. The bottom and sidewalls shall be uniform with no voids. Trim all large roots on the sides and bottom of the excavation before the liner is placed.
Liner Layer(s)	An impermeable liner shall be installed on the sides and bottom of the bioretention area to separate the SCM layers from the in-situ soil.
Bottom Stone Layer	Bottom stone layer = 8-inch layer of AASHTO #57 stone (double washed)
Underdrain & Internal Water Storage (IWS)	Minimum depth of internal water storage = 12 inches (see Figure 7.1.2). The underdrain and internal water storage area shall be designed in accordance with Section 7.15 (Underdrain and Internal Water Storage Design).
Stone Choker Layer	Stone choker layer = 3-inch layer of double washed AASHTO #8 stone or double washed AASHTO #89 pea gravel, placed above the underdrain
Engineered Soil Mix Layer	Minimum depth of the engineered soil mix layer = 18 inches; beyond this minimum, the design depth is determined by the design volume (typically this will be the WQv), the geometry of the bioretention area, and plant needs for establishment and long-term root growth. The engineered soil mix shall be a homogenous mix and meet the standards in the following two tables to provide adequate infiltration, nutrient uptake, and plant support.

<table>
<tr><th>Design Element</th><th>Specification(s)</th></tr>
<tr><td></td><td>
<table>
<tr><th>Material</th><th>Specification</th><th>Recommended Test Method</th></tr>
<tr><td>Medium to coarse washed sand:</td><td>70-85%
Particle size: 0.050 to 2.0 mm</td><td rowspan="2">AASHTO T88 Standard Method of Test for Particle Size Analysis of Soils</td></tr>
<tr><td>Clean, fine soil:</td><td>Silt + clay 10 to 20%, with clay content less than 10%
Clay particle size: < 0.002 mm
Silt particle size: 0.002 to 0.050 mm</td></tr>
<tr><td>Organic Matter</td><td>5 to 8%
*Animal or poultry manure, at any stage of composition, shall not be used for organic matter content</td><td>AASHTO T194 Standard Method of Test for Determination of Organic Matter in Soils</td></tr>
</table>
<table>
<tr><th>Parameter</th><th>Specification</th></tr>
<tr><td>pH</td><td>5.5 to 7.5</td></tr>
<tr><td>Magnesium</td><td>Minimum 32 parts per million (ppm)</td></tr>
<tr><td>Phosphorus* (as phosphate $P_2 0_5$)</td><td>Maximum 60 ppm as plant available phosphorus</td></tr>
<tr><td>Potassium ($K_2 0$)</td><td>Minimum 78 ppm</td></tr>
<tr><td>Soluble Salts</td><td>Maximum 500 ppm</td></tr>
</table>
The volume of engineered soil mix specified and placed shall be based on 110% of the required volume for the SCM to account for settling just after mix placement in the SCM.
Assume an infiltration rate of 2 inches per hour for the engineered soil mix when determining the ponding depth and media depth.
</td></tr>
<tr><td>Mulch Layer</td><td>
Place mulch after plants are installed.
Depth of mulch layer = 3 to 4 inches
Mulch shall be clean, undyed, triple-shredded, hardwood mulch, free of weeds and debris.
The following materials are PROHIBITED for use as a mulch layer.

Shredded pine bark (will float and clog outlets and downstream stormwater systems)
Un-composted bark mulch, lawn and landscape clippings, and immature composted materials (will alter oxygen and nitrogen content of underlying soil)
Rubber mulch or “crumb rubber” (can release pollutants and clog outlets and downstream stormwater systems)

Plastic sheeting of any kind, as it can disintegrate from sun exposure
</td></tr>
<tr><td>Planting Bed</td><td>See Section 7.1.7 of this design specification, titled Vegetation Design Requirements, for planting bed standards.</td></tr>
</table>

7.1.6 Design Procedure

Table 7.1.5 provides the design procedure for a bioretention area.

Table 7.1.5 Design Procedure

Step	Design Activity
Step 1	**Evaluate bioretention area feasibility.** Use the feasibility criteria provided in Tables 7.1.1 and 7.1.2 to determine if a bioretention area is feasible for the selected location on the land development site. Consider especially whether it is appropriate for the proposed development based on the intended land use of the property, the maintenance burden, and assumptions or knowledge of how the property owner(s) will care for the bioretention area after construction (e.g., self-maintenance, property/facilities management maintenance, landscape contractor). If possible, include the property owner(s) in SCM selection since they will be responsible for maintenance. If a bioretention area is determined to be feasible and appropriate for the proposed development, create a rough layout of its dimensions, taking into consideration existing trees, utility lines, and other obstructions to ascertain if it will fit into the desired space, given its general design requirements.
Step 2	**Determine the goals and primary function of the bioretention area.** Consider whether the intention is to: • Comply with the City's stormwater quality requirements (i.e., treat the WQv, provide channel protection, etc.). • Include additional storage capacity for a higher level of stormwater quality treatment or to address a small onsite drainage issue. • Enhance landscape and provide aesthetic qualities.
Step 3	**Calculate the design storage volume (DSv) for the contributing drainage area**. Typically, the DSv = WQv, unless the bioretention area cannot manage the entire WQv or will be used to control a volume larger than the WQv. Use one of the calculation methods explained in Chapter 6 (SCM Standards, Methods, and Selection) to calculate WQv.
Step 4	**Determine the minimum surface area of the bioretention area.** The minimum required surface area of the bioretention area is determined using Darcy's Law equation. $$A_f = \frac{(DSv)(d_f)}{[(k)(h_f + d_f)(t_f)}$$ *where:* A_f = surface area of the ponding area (ft^2) DSv = design storage volume (typically this will be the water quality treatment volume) (ft^3) d_f = planting media depth (ft) k = coefficient of permeability of planting media (ft/day) *(use 0.5 ft/day engineered soil mix)* h_f = average height of water ponding above bioretention bed (ft) t_f = planting media design drain time (days*) (Use two days)*
Step 5	**Check for adequate capacity to manage the entire WQv storm.** Route the hydrograph of the water quality storm event through the bioretention area to ensure it captures the entire WQv, even when the WQv includes the peak flow of the water quality storm event.
Step 6	**Size the overflow structure and any flow regulators. (for OFFLINE bioretention areas only).**

Step	Design Activity
	Use Section 7.16 (Overflow Structures) for requirements.
Step 7	**Design the underdrain.** See Section 7.15 (Underdrain and Internal Water Storage Design) for requirements.
Step 8	**Design the pretreatment measures.** See Section 7.14 (Inlets, Pretreatment, and Energy Dissipation Devices)
Step 9	**Design the vegetation, mulch layer, and protection measures.** The vegetation design shall be in accordance with the vegetation design requirements provided in Table 7.1.6. Use guidance found in Section 7.1.8 (below) to design protection measures.

7.1.7 Vegetation Design Requirements

Plants are critical to bioretention area performance and function. Plants filter and transpire stormwater, providing both pollutant removal and runoff volume reduction. They maintain soil health by preventing erosion and providing organic matter for nutrient replenishment. Further, they function as habitat for surface and subsurface fauna that help keep the soil loose and permeable for stormwater infiltration. Additionally, the plants are the primary visual attribute of the bioretention area and should enhance the landscaping of the property.

The importance of plants to bioretention area function means they, like any SCM component, have design, installation, and maintenance specifications. Much of the design and maintenance of a bioretention area centers on plant coverage and replacement. Table 7.1.6 provides the vegetation specifications for bioretention areas.

Table 7.1.6 Vegetation Design Specifications

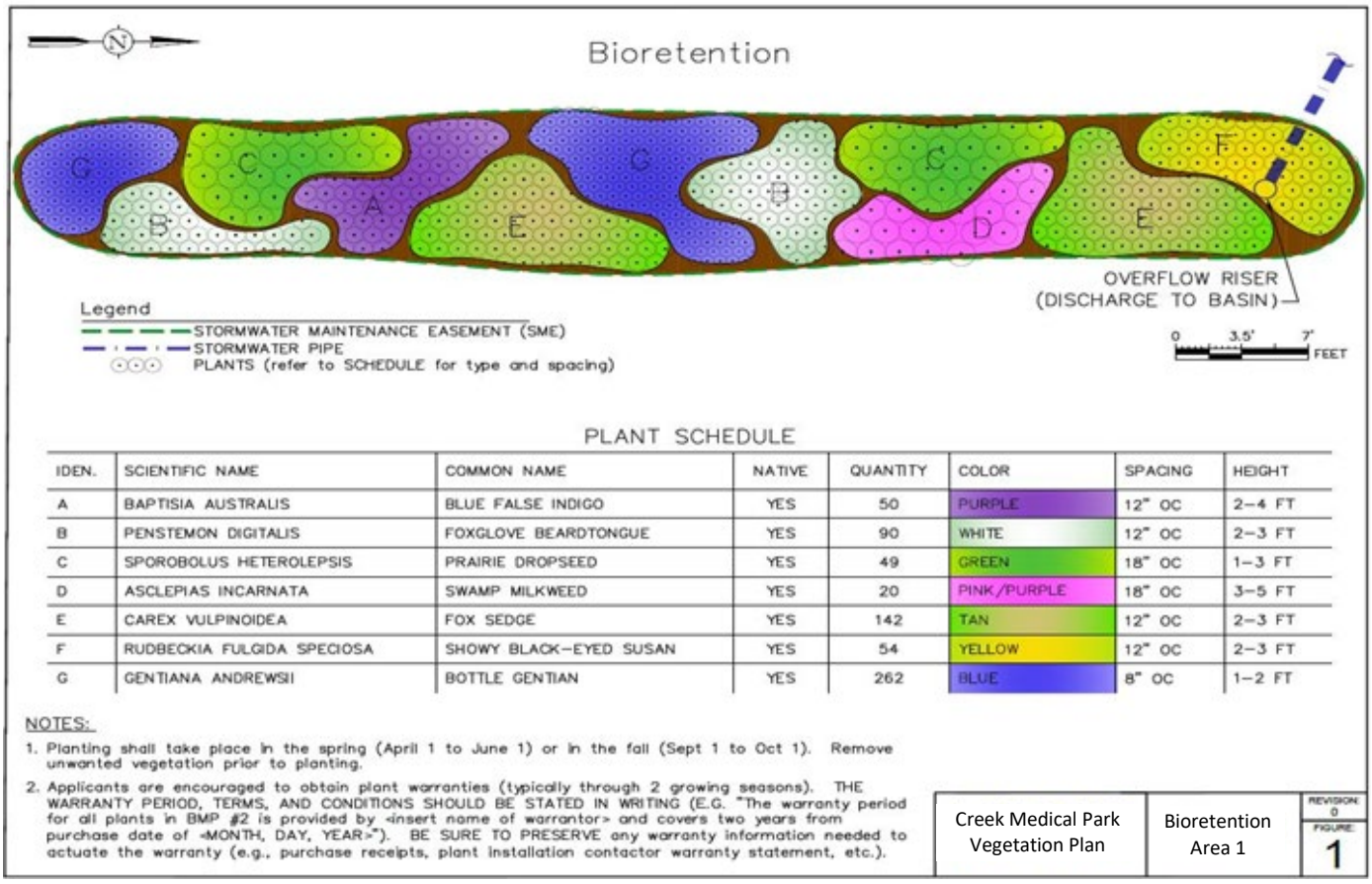
Vegetation Design Element	Specification(s)
Minimum Coverage	A minimum of 70% of the bioretention surface area must be covered by vegetation, predominately grasses, flowering plants, and/or shrubs, as indicated in the "Plant Selection" row of this table. Remaining areas must be covered by mulch (see Table 7.1.4), native ground cover, or decorative landscape stone having a size large enough to withstand the maximum inflow velocity of 5 ft/sec. The minimum coverage requirement must be achieved within the first two growing seasons (March through November) after installation, and then maintained thereafter. Areas of bare soil are not allowed in bioretention areas. Soil must be covered by plants or mulch. Trees are not allowed in bioretention areas to avoid damage to the underdrain and subsurface layers.
Plant Survival	Plant replacement is required when the minimum coverage goal of 70% is not achieved.
Plant Selection	Select plants for the bioretention area that will tolerate cycles of drought and inundation, as both conditions will occur. Salt tolerant plants should be selected for bioretention areas that will receive drainage from areas treated for ice in winter. • Non-native, flowering annuals are often not well suited to such conditions, and thus can require a lot of care. For guidance on appropriate plant species, consult a plant and landscape expert, such as a landscape architect, local nursery, or Master Gardener from the Tennessee Extension Master Gardener program. (https://mastergardener.tennessee.edu/) • Native plant species better suited to local hydrologic conditions are recommended.

Vegetation Design Element	Specification(s)
	• Plants suitable for United States Department of Agriculture Plant Hardiness Zoned 7b are recommended. Consider future maintenance needs of vegetation when designing the bioretention area. The level of plant care needed to maintain the landscape should influence plant selection.
Plant Location	Woody vegetation shall not be located at points of stormwater inflow. Energy dissipation measures, such as a rock apron, are preferred.

Compliance with the vegetation standards set forth in Table 7.1.6 shall be shown in a vegetation plan that is included with the stormwater management plan (SWMP). An example of a vegetation plan for a bioretention area is provided in Figure 7.1.3. Plan preparation requirements are below.

- The plan must be prepared by a professional qualified in landscape design by their education or experience.
- The plan shall include one or more labeled plans/details (to scale) showing the plants to be installed, their numbers, and locations. Plan notes showing a plant schedule and installation instructions are encouraged. This additional information allows both the plant installer at the time of construction, as well as the person(s) responsible for maintenance of the SCM after construction, to understand the original vegetation design and its compliance with the minimum standards.
- Landscaped SCMs may not be recognized under the City's codes as property landscaping. Therefore, additional requirements for property landscaping may apply.

Figure 7.1.3 Example of a Bioretention Area Vegetation Plan



PLANT SCHEDULE

IDEN.	SCIENTIFIC NAME	COMMON NAME	NATIVE	QUANTITY	COLOR	SPACING	HEIGHT
A	BAPTISIA AUSTRALIS	BLUE FALSE INDIGO	YES	50	PURPLE	12" OC	2–4 FT
B	PENSTEMON DIGITALIS	FOXGLOVE BEARDTONGUE	YES	90	WHITE	12" OC	2–3 FT
C	SPOROBOLUS HETEROLEPSIS	PRAIRIE DROPSEED	YES	49	GREEN	18" OC	1–3 FT
D	ASCLEPIAS INCARNATA	SWAMP MILKWEED	YES	20	PINK/PURPLE	18" OC	3–5 FT
E	CAREX VULPINOIDEA	FOX SEDGE	YES	142	TAN	12" OC	2–3 FT
F	RUDBECKIA FULGIDA SPECIOSA	SHOWY BLACK-EYED SUSAN	YES	54	YELLOW	12" OC	2–3 FT
G	GENTIANA ANDREWSII	BOTTLE GENTIAN	YES	262	BLUE	8" OC	1–2 FT

NOTES:
1. Planting shall take place in the spring (April 1 to June 1) or in the fall (Sept 1 to Oct 1). Remove unwanted vegetation prior to planting.
2. Applicants are encouraged to obtain plant warranties (typically through 2 growing seasons). THE WARRANTY PERIOD, TERMS, AND CONDITIONS SHOULD BE STATED IN WRITING (E.G. "The warranty period for all plants in BMP #2 is provided by <insert name of warrantor> and covers two years from purchase date of <MONTH, DAY, YEAR>"). BE SURE TO PRESERVE any warranty information needed to actuate the warranty (e.g., purchase receipts, plant installation contactor warranty statement, etc.).

Creek Medical Park Vegetation Plan	Bioretention Area 1	REVISION: 0 FIGURE: 1

7.1.8 Protection Design Guidance

SCMs designed for stormwater quality purposes must be maintained in keeping with the approved SCM design for the life of the land development. **Design professionals can assist property owners with this requirement by including protective features in and around SCMs to limit the potential for damage by external factors**. Often, the landscape and impervious features around an SCM can be tailored to its specific needs, and therefore used to protect its critical components.

For bioretention areas, protection is especially important for the planting bed. Encroachments by vehicles, heavy equipment, and pedestrians can damage plants, compact the engineered soil mix, damage the overflow structure, and potentially deform or crush the underdrain. However, bioretention areas are especially well-suited to a variety of protection methods that can enhance the property's landscape aesthetic or impervious surface function. Protection methods that work well are listed in Table 7.1.7. Examples of bioretention protection are shown in Figure 7.1.4.

Table 7.1.7 Bioretention Protection Measures*

Passive Protection Measures	Active Protection Measures
• Natural fencing around the perimeter (e.g., dense, woody, or prickly shrubs or tall grass) • Driveways, sidewalks, or walkways around the SCM • Pedestrian benches on the perimeter • Geometry/sizing to allow maintenance without vehicles/equipment entering the bioretention area	• Decorative fencing • Curbs or curb blocks • Hardscaping (cobble, boulder, or block edging; block walls; etc.) • Educational or directive (e.g., no pets) signs • Pet waste stations and trash cans near the SCM

** The list presented in the table is not exhaustive. There may be other possible protection measures.*

Figure 7.1.4 Examples of Protective Landscaping

Top Left: Pathways along and through a bioretention area guide pedestrians around plants (City of Philadelphia, PA Water Dept); Top Right: Concrete curbing around a parking lot bioretention area keeps vehicles and people out while allowing stormwater in (Sacramento State University); Bottom Left: Bioretention area sign erected before a bioretention area is planted (source unknown).Top Right: Decorative fencing, benches, and signage protect this bioretention area (City of Oak Ridge, TN);

7.1.9 Site Preparation and Land Disturbance Requirements

The following information is provided to support proper and effective construction and protection of bioretention areas during land disturbance activities and site construction. Mandatory requirements are identified using "shall" or "must." All other statements can be regarded as non-mandatory guidance. **Site preparation and land disturbance practices described in this section shall be shown on Erosion Prevention and Sediment Control (EPSC) plan for the proposed land development.** Table 7.1.8 provides requirements for site preparation and land disturbance practices for land developments with bioretention areas.

Table 7.1.8 Site Preparation and Land Disturbance Requirements for Bioretention Areas

SCM Type	Policy
Bioretention Area	Construction phasing and sequencing are critical to the success of bioretention areas. Thus, the following requirements apply: • Site construction shall be sequenced such that the bioretention area is installed after the area draining to it has been fully and permanently stabilized. • Construction vehicle and equipment parking, thoroughfares, roadways, parking, and wash-off areas shall not be located where bioretention areas will be located. • Bioretention SCMs that have a drainage area less than two (2) acres may be used as sediment traps (NOT SEDIMENT BASINS) during construction. When the bioretention area is to be used as a sediment trap, the following requirements shall apply: (1) The maximum excavation depth of the trap must be at least one (1) foot higher than the post-construction (final) invert (bottom of the bioretention area). (2) Conversion of the temporary sediment trap to a permanent bioretention area shall include trap dewatering, sediment removal, and permanent stabilization.

Figures 7.1.5 and 7.1.6 provide examples of good site preparation and land disturbance practices, and results of poor practices, respectively.

Figure 7.1.5 Examples of Good Site Preparation and Land Disturbance Practices

Left: A future bioretention area is protected during construction (adapted from a photo by North Carolina State University Extension); Middle: erosion prevention and sediment control measures surround this newly installed bioretention area until construction in the area surrounding it is fully completed. (University of Cincinnati's Clermont College, the Water Environment Foundation); Right: Inlets are blocked to prevent inflows of stormwater during construction of a bioretention area. Note that all surrounding areas are fully stabilized. (Source: Montgomery County, MD Department of Environmental Protection)

Figure 7.1.6 Results of Poor Land Disturbance Practices During Bioretention Area Construction

Left: Improper sequencing and poor erosion prevention and sediment control measures destroyed this bioretention area before it could ever start functioning (Source: Cuyahoga Soil & Water Conservation District); Right: Failed bioretention area due to poor land disturbance and construction (Source: City of Ballard, WA)

7.1.10 Installation Requirements

The information in Table 7.1.9 provides a typical construction sequence to properly install bioretention areas. These steps may be modified to reflect different applications or site conditions. **Installation practices shall be shown in the approved erosion prevention and sediment control plan and stormwater management plan, as appropriate for the proposed land development.** Table 7.1.8 provides requirements for site preparation and land disturbance practices for land developments with bioretention areas.

Table 7.1.9 Installation Steps

Step	Requirement
Step 1	The installation site shall be checked for existing utilities prior to construction. Construction of the bioretention area shall be performed only after the area draining to it has been fully stabilized to prevent sediment discharges. Where this requirement cannot be met, a temporary bypass shall be designed to prevent stormwater discharge to the bioretention area until its drainage area is fully stable. It may be necessary to block certain curb or other inlets while it is being constructed. Supervision during construction is required to ensure the bioretention area is constructed/installed in accordance with the approved EPSC and SWMP plans. The design professional or a designee under their supervision must inspect the bioretention area at critical stages of construction. Examples of critical stages of construction include protection zone and erosion prevention and sediment control measure installation, excavation, underdrain installation, and final inspection. This ensures that the contractor's interpretation of the plan is consistent with the design professional's intentions and allows the design professional to certify (in the as-built plan) that the bioretention area is built in keeping with the permitted plan.
Step 2	Construction sites can have many different contractors responsible for different portions of the site or aspects of construction. Therefore, subtle differences in site grading, drainage, and paving elevations from those identified in the design, or relative to different areas/aspects of construction, can affect the hydraulics of the proposed bioretention area. The following practices should be done prior to construction to ensure the approved design is still valid: • During the preconstruction meeting, review and confirm that the actual boundaries of the bioretention area's contributing drainage area and inlet elevations conform with the approved design.

Step	Requirement
	• Any changes that result from the preconstruction meeting must be shown as a revision to the SWMP and resubmitted to the City for approval. This includes changes to material certifications for aggregate, engineered soil mix, and liners if not approved prior to the preconstruction meeting.
Step 3	Install protection and erosion prevention and sediment control measures as indicated in Table 7.1.7 above. Special protection measures, such as erosion control fabrics, may be necessary to protect vulnerable side slopes from erosion during the construction.
Step 4	Pretreatment measures shall be excavated first and then sealed to trap sediments prior to installation of the main treatment area.
Step 5	Excavate the bioretention area to its appropriate design depth and dimensions. Excavators or backhoes, if used, must be located on the sides of the bioretention area and have adequate reach inside the footprint for full excavation. For excavation of large bioretention areas, use a cell construction approach where the area is split into 500- to 1,000-square foot temporary cells with a 10- to 15-foot earth bridge in between. This allows cell excavation from the sides.
Step 6	Install the impermeable liner on the sides and bottom of the bioretention area (with a 6-inch overlap). Place the required depth of stone on the bottom, install the perforated underdrain pipe and its required stone jacket, and add the stone choker layer.
Step 7	Apply the engineered soil mix in 12-inch lifts until the desired top elevation of the bioretention area is achieved. Wait a few days to check for settlement and add additional engineered soil mix as needed to achieve the design elevation. DO NOT allow vehicles and heavy equipment in the engineered soil mix as they will cause compaction. Note: The batch receipt confirming the source of the engineered soil mix must be included with the As-Built Plan.
Step 8	Install temporary irrigation measures, if needed, to ensure plants will be watered during the remainder of site construction. If coir or jute matting will be used, the matting will need to be installed prior to planting (Step 9), and holes or slits will have to be cut in the matting to install the plants.
Step 9	Install plants as shown in the vegetation plan (see Section 7.1.7 and Table 7.1.6).
Step 10	Place the surface cover (i.e., mulch, river stone, or turf).
Step 11	Erosion prevention and sediment control devices can be removed from the inlets once the bioretention area's side slopes have good vegetative stability and the drainage area is fully and permanently stabilized. If the area draining to the bioretention cell includes newly installed asphalt, the erosion prevention and sediment control devices at inlets should remain in place for at least three storm events after asphalt installation. A substantial amount of fine particles and grit are discharged from newly installed asphalt during the first several storms that produce runoff after installation. Maintenance will be required to remove the particles and grit if erosion prevention and sediment control devices are removed too early.
Step 12	Maintain the bioretention area in keeping with Section 7.1.11 below. Prepare the As-Built Plan and submit to the City for review and approval with the engineer's as-built certification before a final Certificate of Occupancy can be obtained.

Step	Requirement
	Advise the landowner (i.e., the person(s) taking ownership of the property immediately after its development) of the presence of the bioretention area and provide them with a copy of the property's As-Built Plan and SCM location map. The plan must clearly show the location of the bioretention area on the property and list the activities (and their frequencies) necessary for its proper maintenance.

Figure 7.1.7 Examples of Good Installation Practices for Bioretention

Using hand tools instead of heavy equipment for small bioretention areas can ensure their successful operation after construction. (Far left source: Chesapeake Stormwater Network; Near left source: Courtesy of Stormwater Facilities, www.stormwaterfacilities.com)

7.1.11 SCM Maintenance on an Active Construction Site

Once an SCM is installed, its maintenance is regulated by Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code. Further, SCMs must pass a final inspection prior to construction termination. This inspection will be performed to ensure they are constructed in accordance with the approved SWMP, undamaged, and free of sediment and debris. Thus, SCM maintenance is good practice to ensure construction termination goes smoothly. Relevant policies are as follows:

- The property owner is responsible for SCM maintenance. If the property is still an active construction site, these responsibilities may fall to the land disturbance permittee until the project receives final approval from the City and/or a Certificate of Occupancy.
- Property owners may have others, such as a site contractor or landscaping company, maintain the bioretention area on their behalf. However, the City will hold the property owner responsible for ensuring it is maintained in proper operating condition (i.e., as designed and constructed) regardless of who performs maintenance activities.
- Maintenance activities, which include ensuring proper operation of the SCM as designed and required SCM inspections, must begin immediately following installation of the bioretention area.
- Maintenance activities shall be performed in keeping with the *SCM Inspection and Maintenance Manual*. Additional guidance on maintenance of newly installed bioretention areas located on active construction sites is provided in Table 7.1.10.

Table 7.1.10 Maintenance Activities for Newly Installed Bioretention Areas

Area or Component	Post-Installation Maintenance Requirement
Contributing Drainage Area	Keep the contributing drainage area clean. Sweep trash, debris, and sediment frequently so that it does not wash in the basin during a rain event.

Area or Component	Post-Installation Maintenance Requirement
	The contributing drainage area shall be fully stabilized before installation of the bioretention area. If it is not, prevent inflows to the area by blocking or using diversion measures until the contributing drainage area is fully and permanently stabilized. Cover stockpiles of construction and landscape materials to prevent their exposure to rainfall.
Bioretention Area	When asphalt is placed in the contributing drainage area to a bioretention area, keep erosion prevention and sediment control (EPSC) devices at inlets for at least three storm events after asphalt installation. This prevents the discharge of fine particles and grit from the newly installed asphalt to the bioretention area. Ensure bioretention area plants are watered and growing as expected. Remove and replace diseased, dying, or dead plants as soon as they are noticed. Ensure the planting bed remains free of sediment and wastes. Ensure vehicles, equipment, and people are not allowed in the bioretention area. Evidence of unwanted entry may look like tire tracks or footprints; mulch or stone displacement, or damage to components or vegetation; immediately determine and eliminate the cause and repair the area. Consider installing temporary fencing. Visually observe bioretention area function after rain events; there should be no standing water within 48 to 72 hours after a storm event, depending on the frequency of rainfall. If long-standing water is observed: • Inspect underdrain via the observation well looking for standing water indicative of a blockage or damage; make repairs if needed. • If underdrain/outlet blockages and damage can be ruled out, then the engineered soil mix may be clogged. This repair requires removal and replacement of the engineered soil mix, underdrain cleaning, and plant removal and reinstallation. Inspect the bioretention area for erosion or significant sediment buildup; immediately determine and eliminate the cause and repair the area.
Education	Alert onsite subcontractors to the SCM and the following requirements. • No muddy vehicles or equipment in the drainage area to the basin. • No stockpiling of material in the bioretention area. • No uncovered stockpiles in the contributing drainage area. • Block inlets prior to asphalt placement in the contributing drainage area. • Remove sediment, trash, debris, and empty trash cans frequently. Advise landscaping subcontractors on proper protection and maintenance of the bioretention area, especially the following: • No heavy equipment (hand tools only) • No dumping of lawn clippings or landscape debris • Plant maintenance needs/requirements (see above) • Mulch specifications (i.e., clean, undyed, natural hardwood mulch)

7.1.12 References

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition.* Atlanta Regional Commission, 2016.

Metro Water Services. *Volume 5 Low Impact Development Stormwater Management Manual.* Metropolitan Government Nashville and Davison County (TN), 2021.

7.2 DRY DETENTION BASIN design specifications

Water Quality Volume (WQv) Rainfall
Tier 3 Design (ED Basin only) P = 2.5 inches or the first 75% of the volume of the 1-yr, 24-hr storm, *whichever is less*

OTHER SCM ATTRIBUTES *(cost scale is $-low, $$-medium, $$$-high)*	
Channel Protection Volume (CPv)	Yes
Detention / Retention Control	Yes
Small Storm Local Flood Control	Yes
Typical SCM Footprint Size *(percent of contributing drainage area)*	2 to 3%
Construction Cost	$
Operation & Maintenance Cost *(when properly maintained)*	$

PROJECT SUITABILITY				
Industrial	**Commercial**	**Residential** *(common areas only)*	**Pollutant Hotspots**	**Private Roadways** *(requires HOA)*
✓	✓	✓	✗	✓

Legend: ✓ **High** ✓ **Limited** ✗ **None**

OVERVIEW

A traditional dry detention basin is an above-ground storage facility that provides water *quantity* (i.e., flood) control through temporary detention of stormwater. A dry extended detention (ED) basin is a variant of the traditional design that also provides stormwater *quality* control by extending the storage time of the WQv. Pollutants in the WQv settle to the basin bottom and cleaner water is released downstream. Because traditional dry detention basins require an upstream SCM for water quality treatment, they are not included in SCM Tiers. In contrast, dry ED basins are a Tier 3 SCM and do not require an upstream SCM for water quality treatment when properly sized. *(Photo credit: Hamilton County, TN)*

ADVANTAGES/BENEFITS

- High community acceptance and understanding
- Pleasing aesthetic if attention given to location & landscaping
- Easy to maintain if sited as maintained open space without steep, rip-rap slopes
- Can serve multiple functions during dry periods (e.g., ball field)

DISADVANTAGES/LIMITATIONS

- Large size relative to other SCMs
- Poor siting and design can contribute to owner neglect
- Dam height restrictions may apply in high relief areas

LOCATION, SIZING, & COMPONENTS

- Depth should not exceed 10 feet
- Sediment forebays required at inlets
- Typical outlet configuration is a multi-stage riser
- Emergency spillway/overflow required

LONG-TERM PROTECTION

- Primary concerns are slope erosion and damaged/clogged outlets
- Secure outlet(s) to prevent entry by children
- Suitable for a wide variety of protective designs

LONG-TERM MAINTENANCE

- Primary routine maintenance activities will be cleaning, mowing, and removal of woody vegetation
- Smallest outlets require frequent cleaning to prevent clogging
- Consider permanent signs to dissuade use of SCM as a pet relief area
- Provide trash cans and pet waste stations in the drainage area, if located near a pedestrian area
- Maintenance often neglected when located in isolated areas

7.2.1 General Description

Generally, dry detention basins are stormwater control measures (SCMs) that provide for the temporary, above-ground storage of stormwater (see Figure 7.2.1). Stored water is released at controlled rates of discharges via an outlet structure at the downstream end of the basin. The structure has one or more openings (usually orifices or weir notches) along its vertical length and is often open at the top (see Figure 7.2.2). Each opening is designed to control the rate of stormwater discharges from the outlet structure. The outlet structure typically discharges to a stormwater conveyance system (onsite or public) or a local stream.

Figure 7.2.1 Examples of Dry Detention Basin Applications

Top left: City of White House, TN; Top right: Clermont OH Soil & Water Conservation District; Bottom left and right: Detention basin used as recreational fields in Great Falls, MT during a dry period (left) and after a large storm (right), TDH Engineering.

7.2.2 Design Applications

Dry detention basins are one of the most commonly employed stormwater management techniques. While they may not always be suitable for highly urbanized developments because of their relatively large areal footprint, they possess relatively few other limitations. Some minor design modifications may be necessary on developments with obvious karst topography.

There are two different types of dry detention basins: traditional dry detention and extended dry (ED) detention. The design standards that can be addressed by each are described below.

Water Quality Volume (WQv) – Traditional detention basins are not designed to detain the WQv and therefore are not included in an SCM Tier. One or more upstream SCMs from SCM Tiers 1, 2, 3, or 4 are required to provide stormwater quality treatment.

As a Tier 3 SCM, dry ED basins are designed to detain the WQv. Suspended sediments and other pollutants are removed from the WQv by gravitational settling during the water detention period before it is discharged through the outlet structure. The basin must be properly maintained to prevent resuspension of deposited sediments.

Figure 7.2.2 Example of a Multi-Stage Outlet Structure

Channel Protection Volume (CPv) – Both traditional detention basins and dry ED basins can be designed to provide extended detention of the CPv (i.e., the runoff volume from the 1-year, 24-hour storm). For a traditional detention basin, a CPv outlet will need to be included in the design of the outlet structure. However, dry ED basins that are designed to provide extended detention of the entire WQv for its contributing drainage area meet the City of Alcoa's (City) channel protection requirements without further design effort. See Chapter 6 (SCM Standards, Methods, and SCM Selection) for more information.

Flood Protection (Qp) – Both traditional detention basins and dry ED basins can be designed to provide flood protection, by detaining stormwater and releasing it at the required post-development rate of flow.

7.2.3 SCM Suitability

Use Table 7.2.1 to determine if a detention basin is suitable for the application being considered. Note: the criteria pertain to both traditional detention and dry ED basins (generally, "detention basins"), unless one or the other is explicitly named.

Table 7.2.1 Suitability Factors

<table>
<tr><th>Factor</th><th>Suitability</th></tr>
<tr><td>Stormwater Quality Treatment</td><td>Traditional detention basins, as defined herein, do not satisfy the city's stormwater water quality treatment standards.
Dry ED basins designed in keeping with the specifications established herein will satisfy the city's water quality treatment standards.</td></tr>
<tr><td>Channel Protection</td><td>Detention basins can be designed to satisfy ity channel protection standards.</td></tr>
<tr><td>Detention</td><td>Detention basins can be designed to satisfy City peak discharge (flood) control requirements.</td></tr>
<tr><td>Pollutant Treatment Capability</td><td>Dry ED basins designed in keeping with the specifications established herein can address following common stormwater pollutants:
<table>
<tr><th>Total Suspended Solids (TSS)</th><th>Total Phosphorus (TP)[2]</th><th>Total Nitrogen (TN)[2]</th><th>Fecal Bacteria[2]</th><th>Metals[2,3]</th></tr>
<tr><td>80%[1]</td><td>10%</td><td>30%</td><td>N/A</td><td>50%</td></tr>
</table>
1 – If designed for the WQv specified in Tennessee Department of Environment and Conservation Rule 0400-40-10-.04.
2 – ARC, 2016
3 – Cadmium, Copper, Lead, and Zinc</td></tr>
</table>

Factor	Suitability
Treatment of Waste and Other Pollutants	Detention basins shall not be used to treat wastes and other pollutants, many types of which are listed below, should they be present in the contributing drainage area to the basin: • Construction sediment/waste • Landscape storage or waste • Sewage, pet, and livestock waste • Medical waste • Household & commercial wastes • Hazardous wastes • Gasoline, motor oils, greases, and other petroleum-based products • Fats, oils & grease (from food preparation) • Pesticides, fertilizers, herbicides • Other byproducts and waste materials expected, based on the property's land use
Suitability by Land Use	Privately owned detention basins are not allowed in the public right-of-way. General suitability criteria by land-use type is as follows. See Chapter 6 (SCM Standards, Methods, and SCM Selection) for more information.

Commercial	Industrial	Private Roadways	Single Family Residential	Multi-Family Residential
Yes	Yes	Yes	Common Areas Only	

7.2.4 SCM Location Requirements

Location constraints for detention basins are provided in Table 7.2.2. Note: the criteria pertain to both traditional detention and dry ED basins (generally, "detention basins"), unless one or the other is explicitly named.

Table 7.2.2 Detention Basin Location Requirements

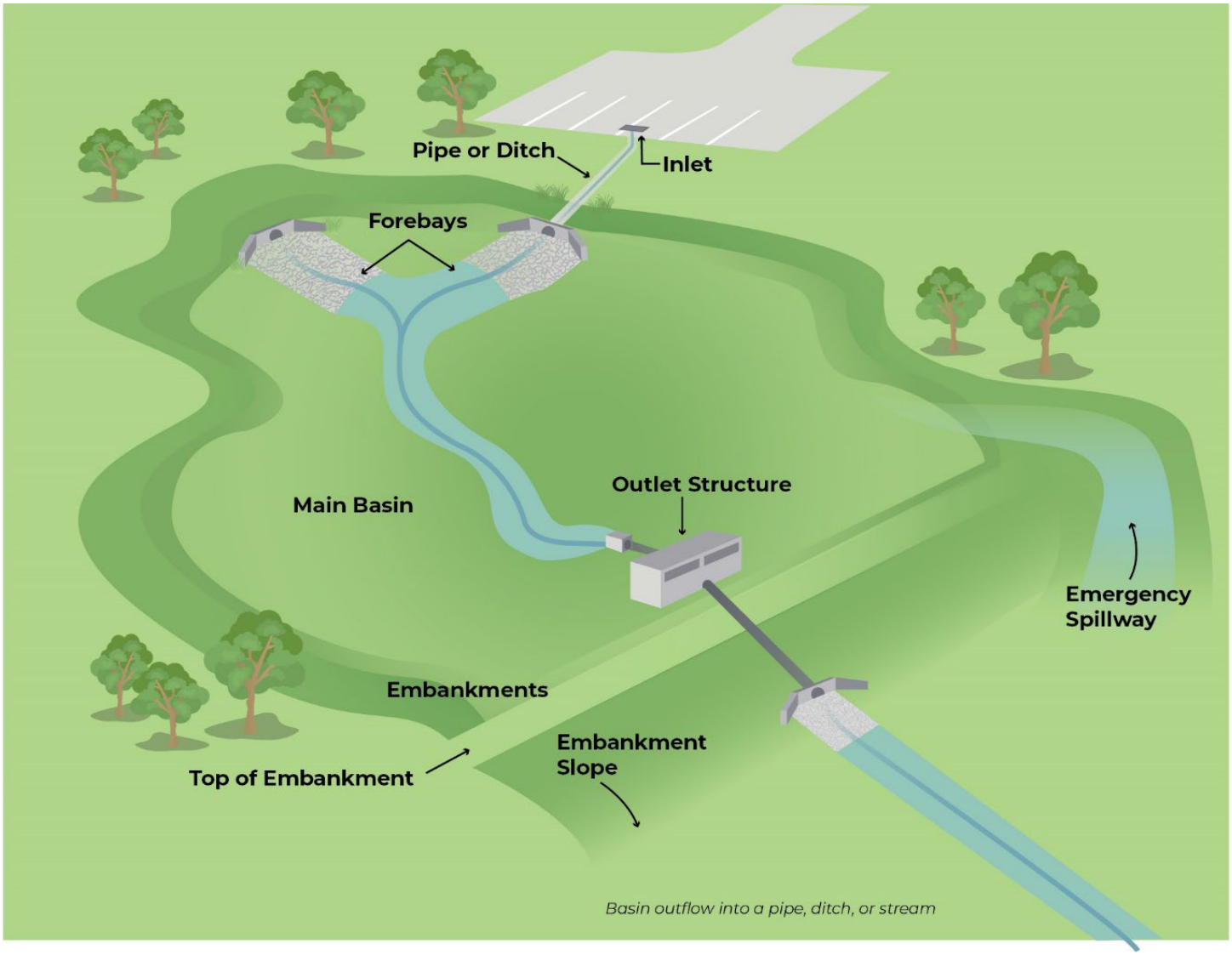
Physical Element	Requirement
SCM Setbacks	Minimum setbacks for outer boundary of the detention basement's easement are as follows: The first floor elevation (FFE) for any structure adjacent to the pond shall have an elevation no lower than 1 foot above the top of the berm. Further, the easement boundary for the detention basin shall be no closer than as follows: • From habitable structures – 15 feet • Public rights-of-way – 15 feet • Public water system well – TDEC specified distance per designated category • Private well – 50 feet; if the well is downgradient from a land use that must obtain a Special Pollution Abatement Permit, then the minimum is 250 feet • Septic system tank/leach field – 50 feet The toe of the embankment shall be at least 10 feet from property lines.
Flow Avoidance	Detention basins shall not be located where they will receive inflows from sump pumps, wash stations, or other non-stormwater discharges. Avoid locating detention basins where they will receive continuous or dry weather inflows from springs and seeps.
Utility Avoidance	Detention basins shall not be located above underground dry utility lines (electric, cable, and telephone) and water/wastewater infrastructure.

	Design professionals must consult the local utility to determine the horizontal and vertical clearance required between SCMs and dry and wet utility lines.

7.2.5 Design Schematics and Requirements

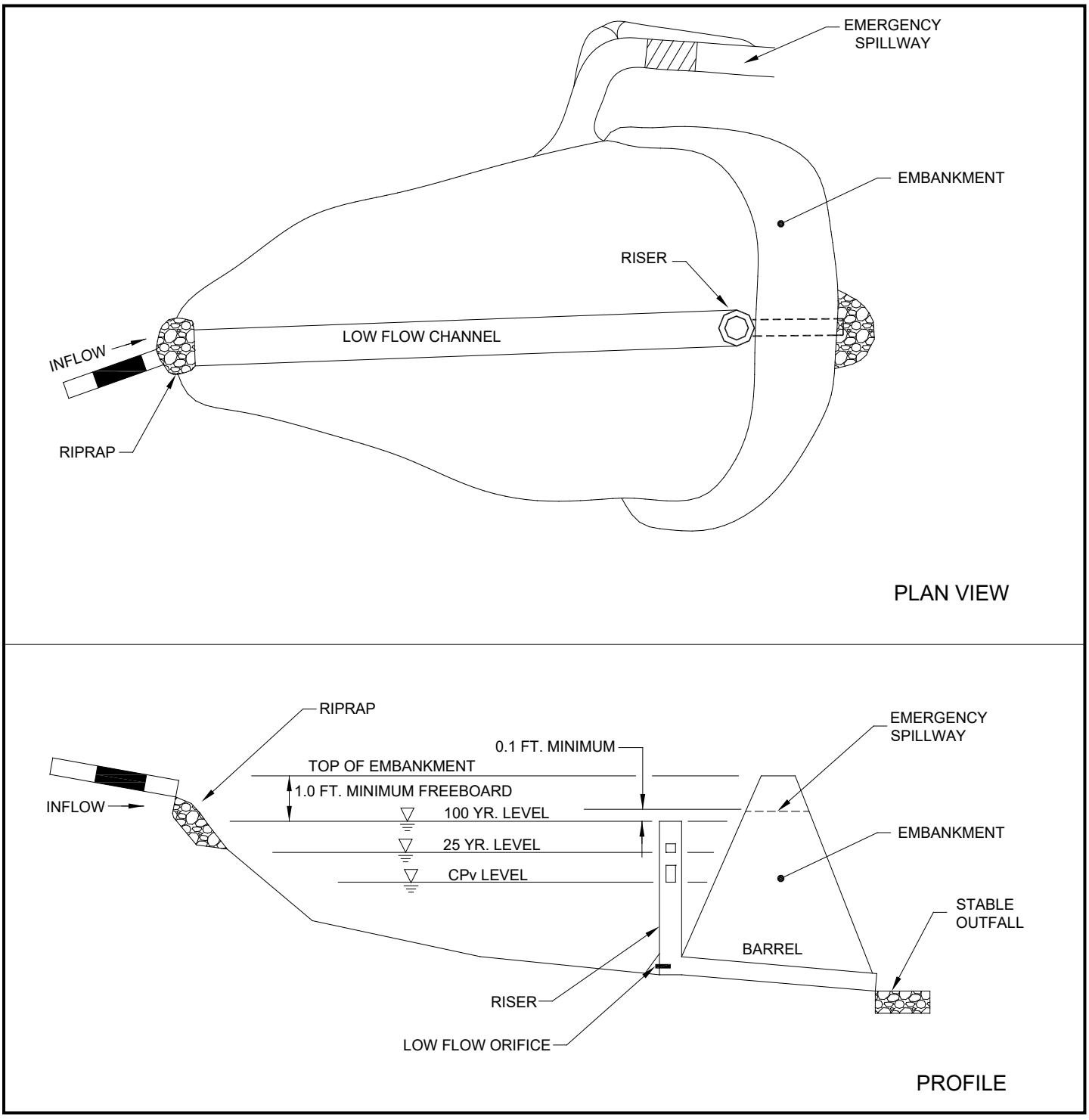
Figure 7.2.3 presents a general layout of a dry detention basin. Figure 7.2.4 presents plan and profile schematics.

Figure 7.2.3 General Layout of a Dry Detention Basin



The remainder of this page intentionally left blank.

Figure 7.2.4 Schematic of a Dry Detention Basin



The criteria provided in Tables 7.2.3 and 7.2.4 shall be considered minimum standards and specifications for the design of detention basins and their contributing drainage areas. The criteria pertain to both traditional detention and dry ED basins (generally, "detention basins"), unless one or the other is explicitly named.

Table 7.2.3 Design Specifications for the Contributing Drainage Area

Design Element	Specification(s)
Size	Generally, no restrictions; however, the City may impose a size restriction for very large contributing drainage areas to control the size of the detention basin. In this situation, multiple detention basins may be used.
Slope	Contributing drainage area slope cannot exceed 15%.
Controls for Waste & Other Pollutants	Appropriate controls shall be included in the design of the contributing drainage area to the SCM to address any wastes and other pollutants that are expected on the property after construction (see Treatment of Waste and Other Pollutants in Table 7.2.1 above). Use the proposed land use as a guide to determine appropriate controls. Examples of such controls include, but are not limited to, dumpsters, trash cans, covered materials/waste storage areas, covered materials transfer areas, oil and grease waste controls, and pet waste stations.

Table 7.2.4 Design Specifications

Design Element	Specification(s)
Water Quality Volume (WQv) *(Dry ED basins only)*	The water quality rainfall depth (P) for determination of WQv is P = 2.5 inches, or the WQv is the first 75% of the volume of the 1-yr, 24-hr storm, *whichever is less*. The design professional can select which volume to use. Acceptable methods to determine WQv are presented in Chapter 6 (SCM Standards, Methods, and SCM Selection). Dry ED basins that cannot treat the entire WQv for its contributing drainage area must be used in a treatment train or replaced with an alternate SCM that can treat the entire WQv.
Use in a Water Quality Treatment Train *(Dry ED basins only)*	If the wet detention basin cannot manage the entire WQv for its contributing drainage area, it must be placed in a treatment train with another SCM. For treatment train policies and calculations, see Chapter 6, Section 6.2.4.
Channel Protection Volume (CPv)	The runoff volume from the 1-year frequency, 24-hour duration storm event shall be detained for no less than 24 hours but no longer than 72 hours. Acceptable methods to determine CPv are presented in Chapter 6 (SCM Standards, Methods, and SCM Selection).
Peak Discharge Control (Flood Control)	The City may not require stormwater detention for properties that discharge directly to a stream or other waterbody. However, in the event that detention is required: • The post-development peak discharge shall be less than or equal to the pre-development peak discharge for the 2, 5, 10, 25, and 100-year, 24-hour storm events. NRCS methods shall be used for detention and retention SCM and outlet structure designs.
Drawdown Time	Dry ED basins shall be designed to discharge the WQv and CPv fully no sooner than 24 hours but no longer than 72 hours. Designing for a 48-hour drawdown is ideal. The minimum orifice diameters for WQv and CPv = 1 inch. Orifice diameters of 8-inches or less shall be protected against clogging using a stone cage. Use the orifice sizing guidance presented in Chapter 6 (SCM Standards, Methods, and SCM Selection) for extended detention outlet sizing guidance.

Design Element	Specification(s)
	There are no restrictions on drawdown time for flood control storm events.
Inlets & Sediment Forebays	Inflow channels shall be stabilized with flared riprap aprons or the equivalent to slow water to nonerosive velocities (maximum of 5 ft/sec). A sediment forebay shall be provided immediately downstream of each inlet in both traditional detention and dry ED basins. Forebays shall be sized to hold a minimum of 10% of the WQv of the basin. Forebay volume can be considered as part of the WQv, not additional volume of the basin. When determining forebay geometry, greater depth (ideally 4 to 6 feet) is preferred over greater width. This allows the forebay to dissipate turbulent inflows without resuspending previously deposited sediment; however, safety concerns and ease of maintenance must be considered when designing sediment forebays. Other pretreatment devices (e.g., MTDs, filter strips, etc.) cannot be substituted for sediment forebays; however, basins that are expected to readily encounter litter, leaves, and other floatables should include screens, grates, or other measures at the forebay discharge points to reduce floatable entry into the main basin.
Geometry	Designing dry ED basins with a high length to width ratio (i.e., at least 1.5:1) and incorporating other design features to maximize the flow path effectively increases the detention time in the system by eliminating the potential of flow to short circuit the basin. Designing basins with relatively flat side slopes can also help to lengthen the effective flow path.
Ponding Depth	Design dry detention basins for a maximum ponding depth of 6 feet. However, a depth of up to 10 feet is allowed if necessary.
Minimum Depth to Water Table	The bottom of the basin shall not intersect the groundwater table. A separation distance of 2 feet from the bottom of the basin to the seasonally high-water table may be required for detention basins located in a stormwater hotspot area or an area with known soil contamination. An impermeable liner below the basin may also be required. Hotspot designation is determined by the Cities. Soil borings shall be used to determine the seasonally high-water table. See Appendix E (Policies for Soil Infiltration Tests & Soil Borings) for soil boring requirements.
Basin Bottom	Bottom slopes must be between 2% and 4% and graded toward the outlet structure. A low-flow channel may be designed across the facility bottom from the inlet to the outlet to convey low flows and prevent standing water after smaller storm events. Traditional detention basin: Channel lining can be grass, riprap, or concrete. Dry ED basin: Channel lining must be dense grass, with optional riprap placed on the sides of the channel. Other stabilization materials may be approved by the city. Careful finish grading is required to avoid creation of surface depressions upland of the outlet structure that may cause standing water.
Embankments (including the dam)	Preferred maximum height = 10 to 12 feet All embankments shall adhere to the Tennessee Safe Dam Act guidelines. Preferred maximum embankment/dam slope is 3:1 (h:v); 2:1 slopes or higher may be allowed where a lower slope cannot be reasonably achieved, provided the berm height is 10 feet or less. Benching is required if the slope is greater 2:1 and the embankment is higher than 10 feet. In this case, a geotechnical slope stability analysis and stability engineering (if necessary) is mandatory Areas external to the embankments (surrounding the detention basin) that are above the normal high-water elevation of the basin shall be sloped toward the basin to prevent standing water.

Design Element	Specification(s)
	Careful finish grading is necessary to avoid the creation of upland surface depressions that may retain runoff. The top of the berm shall be a minimum of (1) foot above the water surface elevation for the 100-year, 24-hour storm event. If inclusion of an emergency spillway is not possible (this is rare), a minimum of 2 feet of freeboard above the top of the berm shall be provided. The berm shall be designed to allow safe passage of floodwaters without damage, should it be overtopped.
Storage Capacity	Designs for basins that impound more than 30 acre-feet of water shall adhere the Tennessee Safe Dams Act. Routing calculations must demonstrate that the storage volume of the detention basin is adequate (not including freeboard) for all design storms. See Chapter 6 (SCM Standards, Methods, and SCM Selection) for more information on storage design requirements.
Outlet Structure	Outlet risers shall be located within the basin embankment for maintenance access and safety. The City may not require stormwater detention for properties that discharge directly to a stream or other waterbody. However, in the event that detention is required: For detention basins that discharge directly to a stream with a FEMA-mapped floodplain, the downstream invert elevation of the outlet barrel shall be at least 1 foot above the base flood elevation. For detention basins that discharge directly to a stream without a FEMA-mapped floodplain or to a lake, the downstream invert elevation of the outlet barrel shall be at least 1 foot above the elevation of the edge of bank (for a stream) or normal pool elevation (for a lake). For additional requirements to those listed in this row, see Chapter 6, Section 6.5 (Storage Facility Outlet Structures). Water shall not be discharged from a dry ED basin in an erosive manner. Riprap, plunge pads or pools, or other energy dissipators shall be placed at the outlet of the barrel to prevent scouring and erosion. If a basin outlet discharges immediately to a channel that carries dry weather flow, care should be taken to minimize disturbance along the downstream channel and streambanks, and to reestablish a forested riparian zone in the shortest possible distance (if the downstream area is located in a water quality buffer). All outlet structures shall be designed so as not to permit access by children.
Emergency Spillway	An emergency spillway shall be designed to safely pass the peak discharge of the 100-year, 24-hour storm event without negative impacts to downstream structures. The emergency spillway elevation shall be a minimum 0.1 foot above the 100-year water surface elevation.
Safety Features	A safety bench shall be provided for embankments greater than 10 feet in height and having greater than a 3:1 side slope. For large basins, the safety bench shall extend no less than 15 feet outward from the normal water edge to the toe of the basin side slope. The slope of the safety bench shall not exceed 6%. The property owner may consider fencing the basin for the purpose of safety management. The posting of warning signs near the basin to prohibit swimming and fishing in the facility is highly encouraged.
Ground Cover	See Section 7.2.7 below for detention basin vegetation standards.

Design Element	Specification(s)
Maintenance Access and Easement	A maintenance easement shall be provided to the basin from a driveway, public or private road. It shall be designed as follows: • a minimum width of 15 feet • a maximum slope of no more than 15% • the access route in the easement shall be free of permanently affixed obstructions (e.g., trees, pools, fences without gates, permanent signs, etc.) and appropriately stabilized to withstand maintenance equipment and vehicles • to the extent feasible, allow vehicles to turn around The entire detention basin, (including inlets, pretreatment devices, the storage area embankments, outlet structure, and emergency spillway) shall be included in the easement and shall be accessible from the easement's drive path.

7.2.6 Design Procedure

Table 7.2.5 provides the design procedure for a detention basin.

Table 7.2.5 Design Procedure

Step	Design Activity
Step 1	**Evaluate basin feasibility for control of WQv and CPv.** Traditional detention basins are often required by the City for flood control purposes. However, design professionals should use the feasibility criteria provided in Tables 7.2.1 and 7.2.2 to determine if upgrading a traditional detention basin design to a dry ED basin design is appropriate for stormwater quality control (WQv) and channel protection (CPv). Consider maintenance requirements (e.g., self-maintenance, property/facilities management maintenance, landscape contractor). If possible, include the property owner(s) in SCM selection since they will be responsible for maintenance. If a dry ED basin is determined to be feasible and appropriate for the proposed development, create a rough layout of its dimensions, taking into consideration existing trees, utility lines, and other obstructions to ascertain if it will fit into the desired space, given its general design requirements.
Step 2	**Determine the goals and primary function of the basin.** Consider whether the intention is to: Comply with the City stormwater quality requirements (i.e., treat the WQv, provide channel protection, flood control, etc.). Include additional storage capacity for a higher level of stormwater quality treatment or to address small onsite drainage issues. Enhance landscape and provide aesthetic qualities.
Step 3	**Determine basin location and preliminary geometry.** This step involves initially designing the grading of the basin (rough contours, including the safety bench if needed), and determining the probable locations of inlets, the outlet structure, its discharge, and the emergency spillway. Evaluate the side slopes, depth, and available storage volumes.
Step 4	**Design the basin for WQv and (if required) CPv control.** Set up a stage-storage-discharge relationship for the control structure. Use the hydrologic methods established in Chapter 6 (SCM Standards, Methods, and SCM Selection) to determine the WQv and CPv (if required) for the basin's contributing drainage area.

Step	Design Activity
	Calculate the orifice release rates for WQv and CPv control (i.e., extended detention of 24 to 72 hours), and orifice sizes and elevations.
Step 5	**Design the basin for flood control.** Continue to use the stage-storage-discharge relationship to design the flood control portion of the basin and outlet. Calculate the peak discharges (Qp) for flood control and corresponding water surface elevations, completing the design of orifices on the detention outlet riser/box. Size the emergency spillway based on City requirements for design storm, freeboard, and embankment slopes and elevations.
Step 6	**Determine the pretreatment volume and design the sediment forebay(s).** Sediment forebays are required at each inlet and must manage a minimum of 10% of the WQv. For ponds that have multiple inlets, determine the volume/sizing of each forebay based on expected inflow volumes at each inlet, ensuring that, together, the forebays will comply with the 10% requirement. See Section 7.14 (Inlets, Energy Dissipation, and Pretreatment Measures) for more information. If needed, design screens, grates, or other treatment devices to keep floatables from discharging from the forebay to the main basin.
Step 7	**Design inlets, outlet structures, maintenance access, and safety features.** See Table 7.2.4 for more details.
Step 8	**Design the vegetation and protection measures.** The vegetation design shall be in accordance with the vegetation design requirements provided in Table 7.2.6. Use guidance found in Section 7.2.8 (below) to design protection measures.

7.2.7 Vegetation Design Requirements

Turf grass or other non-woody ground cover are critical to detention basins, primarily to prevent erosion on the embankments and basin bottom. For a dry ED basin, vegetation also serves as a means of filtering low flows. Table 7.2.6 provides the vegetation specifications for detention basins.

Table 7.2.6 Vegetation Design Specifications

Vegetation Design Element	Specification(s)
Minimum Coverage	All pervious areas of the basin, including bottom, embankment, and interior and exterior of berms, shall be stabilized with a thick stand of turf grass or similar non-woody, dense, vegetated ground cover to prevent soil erosion and provide filtration of low flows. Native vegetation is preferred. Other stabilization materials may be approved at the discretion of the City engineer. Shrubs and trees are prohibited due to potential issues with basin damage and maintenance. Riprap, if used, may be used for energy dissipation downstream of inlets and in forebays, and to stabilize steep slopes. When used, ensure riprap will not impede basin maintenance. Mulch, wood chips, and other loose (unanchored) soil stabilization materials are prohibited.
Plant Survival	Grass replacement with sod is required when the minimum coverage goal of 100% is not achieved. Tree/shrub replacement is not required.
Plant Selection	Grass must be resistant to cycles of drought and inundation, as both conditions will occur. For guidance on appropriate grass species, consult a plant and landscape expert, such as a landscape

Vegetation Design Element	Specification(s)
	architect, local nursery, or Master Gardener from the Tennessee Extension Master Gardener program. (https://mastergardener.tennessee.edu/) Native grasses better suited to local hydrologic conditions are recommended, provided a thick stand can be maintained. Grass suitable for United States Department of Agriculture Plant Hardiness Zoned 7b are recommended.

Compliance with the vegetation standards set forth in Table 7.2.6 shall be shown in a vegetation plan that is included with the stormwater management plan (SWMP). Plan preparation requirements are below.

- The plan shall include one or more labeled plans/details (to scale) showing the plants to be installed, their numbers, and locations. Plan notes showing a plant schedule and installation instructions are encouraged. This additional information allows both the plant installer at the time of construction, as well as the person(s) responsible for maintenance of the SCM after construction, to understand the original vegetation design and its compliance with the minimum standards.
- Landscaped SCMs may not be recognized under City codes as property landscaping. Therefore, additional requirements for property landscaping may apply.

7.2.8 Protection Design Guidance

For dry ED basins, protection is especially important for the outlet structure, which presents a safety hazard. Use grates, screens, locks, and other protective equipment to prevent tampering and entry. Consult the City for fencing and other protective requirements, if any. Figure 7.2.5 shows examples of protected basins.

Figure 7.2.5 Examples of Detention Basin Protection Methods

Top Left: Fencing can be installed around a basin's permitter (City of White House, TN); Top Right: Some basins are designed for dual purposes. This basin is used as recreational areas. (Sacramento State University); Bottom Right: Safety signage installed at a detention basin in Edmonton, Canada (Jolyn Hall, Schmidt Realty Group, inc.); Bottom Left: Landscaping can deter people and vehicles from entering a detention basin in Houston, TX (photo: Bryan Malloch).

7.2.9 SCM Maintenance on an Active Construction Site

Once an SCM is installed, its maintenance is regulated by Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code. Further, SCMs must pass a final inspection prior to construction termination. This inspection will be performed to ensure they are constructed in accordance with the approved SWMP, undamaged, and free of construction sediment and debris. Thus, SCM maintenance is good practice to ensure construction termination goes smoothly. Relevant policies are as follows:

- The property owner is responsible for SCM maintenance. If the property is still an active construction site, these responsibilities may fall to the land disturbance permittee until the project receives final approval from the City and/or a Certificate of Occupancy.
- Property owners may have others, such as a site contractor or landscaping company, maintain the basin on their behalf. However, the City will hold the property owner responsible for ensuring it is maintained in proper operating condition (i.e., as designed and constructed) regardless of who performs maintenance activities.
- Maintenance activities, which include ensuring proper operation of the SCM as designed and required SCM inspections, must begin immediately following installation of the dry ED basin.
- Maintenance activities shall be performed in keeping with the *SCM Inspection and Maintenance Manual*. Additional guidance on maintenance of a newly installed dry ED basin once it is constructed in its permanent (post-construction) state (i.e., no longer used as a sediment basin/trap) located on active construction sites is provided in Table 7.2.7.

Table 7.2.7 Maintenance Activities for Newly Installed Dry Extended Detention Basins

Area or Component	Post-Installation Maintenance Requirement
Contributing Drainage Area	Keep the contributing drainage area clean. Sweep trash, debris, and sediment frequently so that it does not wash in the basin during a rain event. The area should be fully stabilized before installation of the SCM. If it is not, prevent inflows to the SCM by blocking or using diversion measures until the contributing drainage area is fully stabilized. Stabilize the area as soon as possible to prevent the discharge of sediment to the SCM. Cover stockpiles of construction and landscape materials to prevent their exposure to rainfall.
Basin	Ensure the grass is watered and growing as expected. Remove and replace diseased, dying, or dead grass as soon as they are noticed. Remove uwanted plants, especially fast-growing vines such as English Ivy and Kudzu (Japanese/Chinese Arrowroot) so they do not damage basin components. Clean the sediment forebay as often as needed to prevent inflows of sediment and debris into the main basin. Inspect the area for erosion or significant sediment buildup; immediately determine and eliminate the cause and repair the area.
Education	Alert onsite subcontractors to the SCM and the following requirements: No muddy vehicles or equipment in the drainage area to the basin. No stockpiling or dumping of material, including landscape debris and grass clippings, in the basin and no exposed stockpiles in the basin's drainage area. Remove sediment, trash, debris, and empty trash cans frequently.

7.2.10 References

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition.* Atlanta Regional Commission, 2016.

7.3 DRY ENHANCED SWALE design specifications

Water Quality Volume (WQv) Rainfall
Tier 2 Design P = 1.25 inches

OTHER SCM ATTRIBUTES *(cost scale is $-low, $$-medium, $$$-high)*	
Channel Protection Volume (CPv)	No
Detention / Retention Control	No
Small Onsite Drainage Control	Yes
Typical SCM Footprint Size *(percent of contributing drainage area)*	5%
Construction Cost	$$
Operation & Maintenance Cost *(when properly maintained)*	$

PROJECT SUITABILITY

Industrial	Commercial	Residential *(common areas only)*	Pollutant Hotspots	Private Roadways *(requires HOA)*
Limited	High	High	None	High

Legend: High; Limited; None

OVERVIEW

Dry enhanced swales are structural stormwater control measures (SCMs) that capture and treat the water quality volume (WQV) within dry cells formed by check dams or other means. The primary stormwater treatment mechanism of a dry enhanced swale is biofiltration. Infiltration and evapotranspiration are secondary mechanisms. These SCMs can also be designed as part of the onsite stormwater conveyance system for large storms (up to the 25-year event). *(Photo on left from MD Dept. of Environment)*

ADVANTAGES/BENEFITS

- Provides stormwater treatment and runoff conveyance
- Less expensive to install than curb-and-gutter
- Reduces runoff velocity
- Easy to maintain

DISADVANTAGES/LIMITATIONS

- Does not provide stormwater detention
- Cannot be used on slopes greater than 4%
- SCM operation only after drainage area is permanently stabilized

LOCATION, SIZING, & COMPONENTS

- An underdrain is required for all applications
- Maximum contributing drainage area is 5 acres
- Channel slope cannot exceed 4%
- Permissible bottom width ranges from 2 to 8 feet
- Minimum 2-foot separation from seasonally high-water table
- Runoff pretreatment is required at all inlets
- Energy dissipation is required at all inlets
- Minimum required distance from the edge of buildings to the edge of a dry enhanced swale ranges from 10 to 100 feet

LONG-TERM PROTECTION

- Primary concerns are plant damage and soil compaction
- Suitable for a wide variety of SCM protection designs (curb blocks, plant borders, rocks/cobbles, signage, etc.)

LONG-TERM MAINTENANCE

- Primary routine maintenance activities will be inlet, pretreatment device, and channel cleaning, and grass/plant care
- Dense, healthy grass is a must for SCM function
- Locate near a water source for grass watering during dry periods
- Consider permanent signs to dissuade entry and use of SCM for pet relief or extra parking
- Provide trash cans and pet waste stations in the drainage area

7.3.1 General Description

Dry enhanced swales are SCMs designed for pollutant removal and stormwater conveyance. They differ from a normal drainage channel or swale because they have components that provide stormwater treatment of the water quality volume (WQv). In fact, enhanced swales are shallow, linear bioretention areas covered with grass. They are designed with limited longitudinal slopes to force the WQv to flow slow and shallow, thus allowing particulate filtration and erosion protection. Berms and/or check dams installed perpendicular to the flow path further slow the water and allow the WQv to infiltrate into a bed of engineered soil mix. The engineered soil mix will overlay an underdrain system. The WQv will biofilter through the engineered soil mix before entering the underdrain collection system as cleaner water.

In karst terrain (areas underlain by soluble carbonate bedrock), concentrated areas of infiltration into the in-situ soil can easily cause sinkhole formation. The location of sinkhole formation cannot be easily predicted. This phenomenon is a significant concern in the City of Alcoa (City), where karst terrain is highly prevalent and sinkhole formation is not infrequent. Thus, underdrains are required for all dry enhanced swales to reduce the possibility of sinkhole formation.

Enhanced swales must not be confused with a filter strip or grass channel, because they afford a much higher level of water quality treatment. Filter strips and grass channels do not overlay an engineered soil mix and underdrain. However, both a grass channel and filter strip may be used for pretreatment of stormwater before its entry into the enhanced swale.

7.3.2 Design Applications

Dry enhanced swales are typically used in place of stormwater pipes and grass channels to provide treatment of the WQv from one or more upstream impervious areas along with conveyance of stormwater from larger storms (see Figure 7.3.1). Uses along parking lot edges, private roadways, and paved trails are common.

Figure 7.3.1 Examples of Dry Enhanced Swale Applications

Left: A dry enhanced swale in Parma, Ohio. Note the underdrain that empties into the outlet structure. (NC State Extension Publications); Middle: Dry enhanced swale in a roadway median (Soils.org); Right: A dry enhanced swale in Montgomery County, MD (North Carolina Dept of Environmental Quality).

7.3.3 SCM Suitability

Use Table 7.3.1 to determine if a dry enhanced swale is suitable for the application being considered.

Table 7.3.1 Dry Enhanced Swale Suitability Factors

Factor	Suitability
Stormwater Quality Treatment	Dry enhanced swales designed in keeping with the specifications established herein will satisfy the City's stormwater quality treatment standards.

<table>
<tr><th>Factor</th><th>Suitability</th></tr>
<tr><td>Channel Protection</td><td>Typically, dry enhanced swales are not used to provide extended detention of the channel protection volume (CPv). However, for small sites, it may be possible to size a swale to manage the CPv.</td></tr>
<tr><td>Detention</td><td>Dry enhanced swales do not provide stormwater detention.</td></tr>
<tr><td>Pollutant Treatment Capability</td><td>Dry enhanced swales can be used to address following common stormwater pollutants:
<table>
<tr><th>Total Suspended Solids (TSS)</th><th>Total Phosphorus (TP)</th><th>Total Nitrogen (TN)</th><th>Fecal Bacteria[1]</th><th>Metals*</th></tr>
<tr><td>80%</td><td>50%</td><td>50%</td><td>Insufficient data</td><td>40%</td></tr>
</table>
*Cadmium, copper, lead, and zinc
Source: ARC, 2016</td></tr>
<tr><td>Treatment of Waste and Other Pollutants</td><td>Dry enhanced swales shall not be used to treat the following pollutants:

Construction sediment/waste
Landscape storage or waste
Sewage, pet, and livestock waste
Medical waste
Household & commercial wastes
Hazardous wastes
Gasoline, motor oils, greases, and other petroleum-based products
Fats, oils & grease (from food preparation)
Pesticides, fertilizers, herbicides
Other byproducts and waste materials expected, based on the property’s land use
</td></tr>
<tr><td>Suitability by Land Use</td><td>Privately owned dry enhanced swales are not allowed in the public right-of-way.
General suitability criteria by land-use type are as follows. See Chapter 6 (SCM Standards, Methods, and Selection) for more information.
<table>
<tr><th>Commercial</th><th>Industrial</th><th>Private Roadways</th><th>Single Family Residential</th><th>Multi-Family Residential</th></tr>
<tr><td>Yes</td><td>Limited</td><td>Yes</td><td colspan="2">Common Areas Only</td></tr>
</table></td></tr>
</table>

7.3.4 SCM Location Requirements

Location constraints for dry enhanced swales are provided in Table 7.3.2.

Table 7.3.2 Dry Enhanced Swale Location Requirements

Physical Element	Requirement

SCM Setbacks	Minimum setbacks, measured from the edge of the dry enhanced swale, are as follows:
	• At least 5 feet down gradient from underground utility lines
	• Building foundations:
	  ○ Offline configuration: 20 feet from a building’s foundation, if positioned downslope of the building and no closer than 30 feet from buildings that are downslope
	  ○ Online configuration: safe passage of the 100-year storm event is required; therefore, the distance of the edge of the swale from a building’s foundation shall be 15 feet from the expected extent of flooding around the SCM for the 100-year event, or the building’s first floor elevation (FFE) must be a minimum of 1 foot above the 100-year storm elevation.
	Since the swale design specified in this document includes underdrains and impermeable liners, the potential for negative impacts on subsurface water supplies and septic systems is minimal.

Physical Element	Requirement
	Adhere to minimum setbacks and separation distances specified in the city's zoning or subdivision regulations for drainage channels.
Flow Avoidance	Dry enhanced swales shall not be located where it will receive continuous or dry weather inflows from springs, seeps, sump pumps, wash stations, or other sources.
Utility Avoidance	Dry enhanced swales shall not be located above underground dry utility lines (electric, cable, and telephone), water/wastewater infrastructure, and existing storm drainage infrastructure. Design professionals must consult the local utility to determine the horizontal and vertical clearance required between SCMs and dry and wet utility lines.

7.3.5 Design Requirements

A schematic of a basic dry enhanced swale is shown in Figure 7.3.2. The design specifications provided in Tables 7.3.3 and 7.3.4 shall be considered minimum standards and specifications for the design of dry enhanced swales and their contributing drainage areas.

Figure 7.3.2 Schematic of a Dry Enhanced Swale

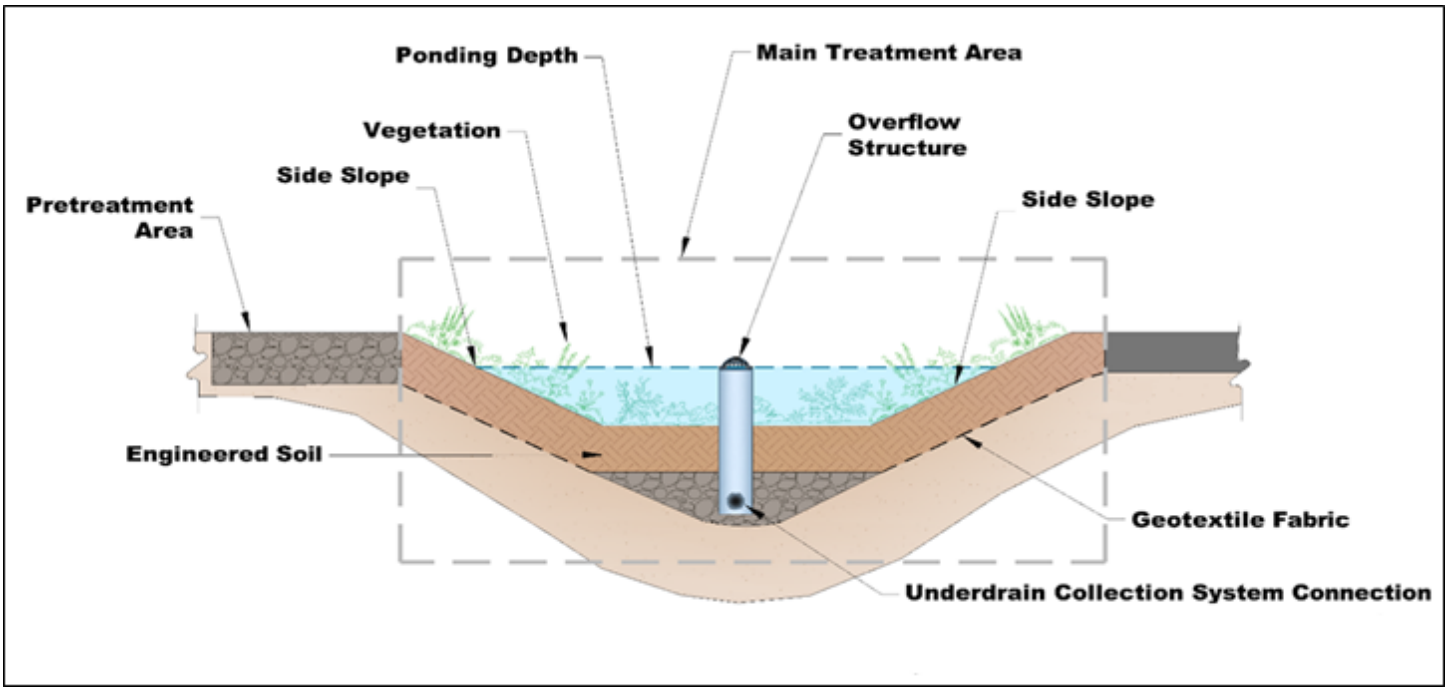


Table 7.3.3 Design Specifications for the Contributing Drainage Area

Design Element	Specification(s)
Drainage Area	Maximum contributing drainage area (CDA) = 5 acres; 0.5 to 2.0 acres is preferred.
Slope	Maximum slope of the contributing drainage area to a swale = 5%
Controls for Waste & Other Pollutants	Appropriate controls shall be included in the design of the contributing drainage area to the SCM to address any Wastes and Other Pollutants (see Table 7.3.1 above) that are expected on the

Design Element	Specification(s)
	property after construction. Use the proposed land use as a guide to determine appropriate controls. Examples of such controls include, but are not limited to, dumpsters, trash cans, covered materials/waste storage areas, covered materials transfer areas, oil and grease waste controls, and pet waste stations.

Table 7.3.4 Design Specifications for Dry Enhanced Swales

Design Element	Specification(s)
Water Quality Volume (WQv)	The water quality rainfall depth (P) for determination of WQv = 1.25 inches Acceptable methods to determine WQv are presented in Chapter 6 (SCM Standards, Methods, and Selection). Dry enhanced swales that cannot treat the entire WQv for its contributing drainage area must be used employed in parallel with another SCM that can treat the remaining portion of the WQv, or exchanged with an alternate SCM that can treat the entire WQv.
Use in a Water Quality Treatment Train	If the dry enhanced swale cannot manage the entire WQv for its contributing drainage area, it must be placed in a treatment train with another SCM. See treatment train policies and calculations in Chapter 6, Section 6.2.4 for treatment train policies and calculations.
Offline and Online Design Configuration	An online configuration is a common configuration for dry enhanced swales. Online swales are designed and constructed so the main flow path for the drainage area passes through the swale. The swale shall be designed to safely convey the peak discharge for the 25-year, 24-hour storm event (Q_{p25}) with a minimum of 12 inches of freeboard without damage to adjacent property, and shall not overtop in the 100-year, 24-hour storm event. An offline configuration is designed and constructed away from the main flow path for the drainage area, thus avoiding large flood flows. A flow splitter, diversion structure, or other means is used upstream of the swale's inlets to redirect the swale's design volume (typically this will be the WQv) from the main flow path to the SCM while still allowing larger flows to remain in the main flow path. The structure shall include a low-flow orifice, weir, or other hydraulic structure, sized to pass the peak discharge of the design volume (typically this will be the water quality peak discharge, Q_{wq}) to the swale. See Section 7.16 (Overflow Structures) for the diversion sizing design procedure. Regardless of design configuration (offline or online), dry enhanced swales shall always be located upstream of flood control SCMs (detention, retention, and engineered wetland basins) when employed in in a water quality treatment train.
Maintenance Access and Easement	A maintenance easement shall be provided to the swale from a driveway, public or private road. It shall be designed as follows: • a minimum width of 15 feet • a maximum slope of no more than 15% • the access route in the easement shall be free of permanently affixed obstructions (e.g., trees, pools, fences without gates, permanent signs, etc.) and appropriately stabilized to withstand maintenance equipment and vehicles • to the extent feasible, allow vehicles to turn around. The entire dry enhanced swale, including inlets, pretreatment devices, the storage area. embankments, outlet structure, and emergency spillway) shall be included in the easement and shall be accessible from the easement's drive path.

Design Element	Specification(s)
Inlets and Energy Dissipation	Maximum stormwater entry velocity = 5 ft/sec • Stormwater shall enter the dry enhanced swale as sheet or shallow concentrated flow. Energy dissipation measures, such as vegetated buffer strips or rock aprons shall be provided. These measures may also provide stormwater pretreatment.
Pretreatment	Pretreatment is required immediately below each inlet to remove gross solids, trash, and sediment from stormwater prior to flowing into the main treatment area. • Vegetated filter strips and gentle side slopes of dense grass are suitable pretreatment measures for lateral non-concentrated inflows. Rock aprons or other methods may be preferred for more concentrated inflows. Pretreatment options and design specifications are provided in Section 7.14 (Inlets, Pretreatment, and Energy Dissipation Devices). • Swales that will receive direct concentrated stormwater may require a 6-inch drop to a pea gravel diaphragm flow spreader at the upstream end of the control to slow and spread runoff entering the swale. • Consider screens, grates, baffles, or other pretreatment measures for debris capture in areas where high amounts of floatables (litter, trash, etc.) is expected.
Geometry	For an online configuration, the swale shall be designed to safely convey the peak discharge for the 25-year, 24-hour storm event (Q_{p25}) with a minimum of 12 inches of freeboard without damage to adjacent property, and shall not overtop in the 100-year, 24-hour storm event. Longitudinal swale slope = 1% to 2% preferred; 4% maximum • For slopes greater than 2%, limit the energy slope to the required range of 1% to 2% using drop structures with a vertical height of 6 to 12 inches. Energy dissipation shall be provided below drops (see Section 7.14 (Inlets, Pretreatment, and Energy Dissipation Devices)). Spacing between vertical drops shall be a minimum of 50 feet. Bottom width = 2 ft minimum; 8 ft maximum Bottom lateral slope = 0% (flat) • The WQv must flow evenly across the width of the swale. Bottom elevation = minimum of 1 foot below the lowest invert elevation of adjacent roadbeds and parking areas. Side slopes = 2:1 or flatter; 4:1 preferred Ensure the WQv will not bypass or short-circuit the bottom (e.g., inlets or curb cuts that are very close to outlet structures, or incoming flow diverted immediately to the underdrain).
Flow Velocity	Maximum peak flow velocity for the 2-year, 24-hour storm event = 5 ft/sec
Ponding Depth	Maximum surface ponding depth at the downstream end = 18 inches Average surface ponding depth = 12 inches
Minimum Depth to Water Table	Minimum separation distance (bottom of excavation to seasonally high-water table) = 2 feet Soil borings shall be used to determine the seasonally high-water table. See Appendix E (Policies for Soil Borings and Infiltration Tests) for soil boring requirements.
Minimum Hydraulic Head	Minimum hydraulic head = 3 to 5 feet The hydraulic head is the difference in the inflow elevation, including the design ponding depth, to the outflow elevation at the underdrain invert elevation or bottom of SCM at its downstream end.

<table>
<tr><th>Design Element</th><th>Specification(s)</th></tr>
<tr><td>Drawdown Time</td><td>The maximum water ponding time = 48 hours; 24 hours is preferred.
All water shall discharge from the swale within 48 hours.</td></tr>
<tr><td>Overflow Structure</td><td>Dry enhanced swales are typically designed in an online configuration, so they will carry flows up to the 25-year, 24-hour storm event, with 1 foot of freeboard. Thus, an overflow structure is typically required at a downstream berm, headwall, or check dam for storms up to the 25-year, 24-hour event.
Offline configurations require an overflow design to safely passes runoff that exceeds the swale's design volume.</td></tr>
<tr><td colspan="2">The remaining rows specify the subsurface layers of the SCM, starting at the bottom.</td></tr>
<tr><td>In-situ Soil</td><td>Limit the excavation to the width and depth specified in the design.
The bottom and sidewalls shall be uniform with no voids, and all large roots shall be trimmed before placement of swale liner and layers.</td></tr>
<tr><td>Liner Layer</td><td>An impermeable liner shall be installed on the sides and bottom of the swale to separate the SCM layers from the in-situ soil.</td></tr>
<tr><td>Bottom Stone Layer</td><td>Bottom stone layer = 6-inch layer of AASHTO #57 stone (double washed)</td></tr>
<tr><td>Underdrain & Internal Water Storage</td><td>Minimum depth of internal water storage = 12 inches (not shown in Figure 7.3.2).
The underdrain, observation wells, and internal water storage area shall be designed in accordance with Section 7.15 (Underdrain and Internal Water Storage Design).</td></tr>
<tr><td>Stone Choker Layer</td><td>Stone choker layer = 3-inch layer of double washed AASHTO #8 stone or double washed AASHTO #89 pea gravel, placed above the underdrain</td></tr>
<tr><td>Engineered Soil Mix Layer</td><td>Minimum depth of the engineered soil mix layer = 30 inches; beyond this minimum, the design depth is determined by the design volume (typically this will be the WQv), the geometry of the swale, and plant needs for establishment and long-term root growth.
The engineered soil mix shall be a homogenous mix and meet the standards in the following two tables to provide adequate infiltration, nutrient uptake, and plant support.
<table>
<tr><th>Material</th><th>Specification</th><th>Recommended Test Method</th></tr>
<tr><td>Medium to coarse washed sand:</td><td>70-85%
Particle size: 0.050 to 2.0 mm</td><td rowspan="2">AASHTO T88 Standard Method of Test for Particle Size Analysis of Soils</td></tr>
<tr><td>Clean, fine soil:</td><td>Silt + clay 10 to 20%, with clay content less than 10%
Clay particle size: < 0.002 mm
Silt particle size: 0.002 to 0.050 mm</td></tr>
<tr><td>Organic Matter</td><td>5 to 8%
*Animal or poultry manure, at any stage of composition, shall not be used for organic matter content</td><td>AASHTO T194 Standard Method of Test for Determination of Organic Matter in Soils</td></tr>
</table></td></tr>
</table>

Design Element	Specification(s)	
	Parameter	**Specification**
	pH	5.5 to 7.5
	Magnesium	Minimum 32 parts per million (ppm)
	Phosphorus* (as phosphate $P_2 0_5$)	Maximum 60 ppm as plant available phosphorus
	Potassium ($K_2 0$)	Minimum 78 ppm
	Soluble Salts	Maximum 500 ppm
	The volume of engineered soil mix specified and placed shall be based on 110% of the required volume for the SCM to account for settling just after mix placement in the SCM. Assume an infiltration rate of **2 inches per hour** for the engineered soil mix when determining the ponding depth and media depth.	
Planting Bed	See Section 7.3.7 of this design specification, titled Vegetation Design Requirements, for planting bed standards.	

7.3.6 Design Procedure

Table 7.3.5 provides the design procedure for a dry enhanced swale.

Table 7.3.5 Design Procedure

Step	Design Activity
Step 1	**Evaluate dry enhanced swale feasibility.** Use the feasibility criteria provided in Tables 7.3.1 and 7.3.2 to determine if a dry enhanced swale is feasible for the selected location on the land development site. Consider especially whether it is appropriate for the proposed development based on the intended land use of the property, the maintenance burden, and assumptions or knowledge of how the property owner(s) will care for the swale after construction (e.g., self-maintenance, property/facilities management maintenance, landscape contractor). If possible, include the property owner(s) in SCM selection since they will be responsible for maintenance. If a dry enhanced swale is determined to be feasible and appropriate for the proposed development, create a rough layout of its dimensions, taking into consideration existing trees, utility lines, and other obstructions to ascertain if it will fit into the desired space, given its general design requirements.
Step 2	**Determine the goals and primary function of the dry enhanced swale.** Consider whether the intention is to: • Comply with the City's stormwater quality requirements (i.e., treat the WQv, provide channel protection, etc.). • Convey stormwater for design storms up to the 25-year, 24-hour storm. • Enhance landscape and provide aesthetic qualities.
Step 3	**Calculate the design storage volume (DSv) for the contributing drainage area**. Typically, the DSv = WQv, unless the dry enhanced swale cannot manage the entire WQv or will be used to control a volume larger than the WQv. Use one of the calculation methods explained in Chapter 6 (SCM Standards, Methods, and Selection) to calculate WQv.
Step 4	**Determine the storage volume of the preliminary layout of the dry enhanced swale.**

Step	Design Activity
	Use the following equation: $$VP = PV + (VES \; x \; n)$$ *where:* VP = volume provided in temporary storage (ft^3) PV = ponding volume (ft^3), for a maximum ponding depth of 12 to 18 inches at the downstream end of the swale VES = volume of engineered soil mix (ft^3) n = porosity of the engineered soil mix *(most engineered soil has a porosity of 0.25; gravel has a porosity of 0.40)*
Step 5	**Determine if the proposed dry enhanced swale meets the WQv requirement.** • If VP ≥ WQv, proceed with Step 6. • If VP ≤ WQv, redesign the swale to provide sufficient volume for the WQv and recalculate VP, or employ a treatment train or alternate SCM to treat the WQv.
Step 6	**Create the swale design.** • Size the swale bottom width, depth, length, slope, and side slopes ○ Maximum ponding depth is 18 inches. ○ Longitudinal slope must not exceed 4% (1 to 2% is recommended). ○ Bottom width should be from 2 to 8 feet. ○ Side slopes must be no greater than 2:1; 4:1 is preferred. ○ Full discharge of the swale within 48 hours. • Compute the number of check dams required and their heights to detain the WQv so it infiltrates into the engineered soil mix. All larger storms should flow over the check dams without eroding the swale.
Step 7	**Check for adequate capacity to manage the entire WQv storm.** Route the hydrograph of the water quality storm event through the dry enhanced swale to ensure it captures the entire WQv, even when the WQv includes the peak flow of the water quality storm event.
Step 8	**Design the underdrain.** See Section 7.15 (Underdrain and Internal Water Storage Design) for
Step 9	**Calculate the drawdown time.** The entire WQv must discharge from the swale within 48 hours.
Step 10	**Check the velocity, erosion potential, and freeboard for the 2-year and 25-year, 24-hour storm events.** • Modify the design until erosive velocities are eliminated. • Provide 6 inches of freeboard for the 25-year event.
Step 11	**Size the overflow structure and any flow regulators. (for OFFLINE swales only).** Use Section 7.16 (Overflow Structures) for requirements.
Step 12	**Design the pretreatment measures.** See Section 7.14 (Inlets, Pretreatment, and Energy Dissipation Devices)
Step 13	**Design the vegetation and protection measures.** The vegetation design shall be in accordance with the vegetation design requirements provided in Table 7.3.6. Use guidance found in Section 7.3.8 (below) to design protection measures.

7.3.7 Vegetation Design Requirements

Dense, healthy grass is critical to the performance and function of a dry enhanced swale as a water quality treatment SCM. Plants filter and transpire stormwater, providing both pollutant removal and runoff volume reduction. They maintain soil health by preventing erosion and providing organic matter for nutrient replenishment. Further, they function as habitat for surface and subsurface fauna that help keep the engineered soil mix loose and permeable for stormwater infiltration.

The importance of plants to dry enhanced swale function means they, like any SCM component, have design, installation, and maintenance specifications. Much of the design and maintenance of dry enhanced swales center on plant coverage and replacement. Table 7.3.6 provides the vegetation specifications for dry enhanced swales.

Table 7.3.6 Vegetation Design Specifications

Vegetation Design Element	Specification(s)
Minimum Coverage	The entire (100%) surface area of the dry enhanced swale must be covered by dense, healthy grass. Stone/cobbles may be used where grass cannot be reliably established, provided they are sized sufficiently to remain in place during storm events. Shrubs and trees are prohibited in the swale to preserve its capacity and avoid damage to the underdrain and other components. To prevent erosion of the bottom and side slopes, grass should be established after construction of the swale using sod. Seeding is discouraged for swale installation but can be used for overseeding once grass is established. Grass coverage of 100% of the channel and side slopes is desired for swale operation. A dense and vigorous vegetative cover must be established over any pervious areas located within the contributing drainage area to the swale before runoff is accepted into it. Otherwise, the swale can become clogged with sediment carried by the stormwater runoff discharging to it. Areas of bare soil are not allowed.
Plant Survival	Grass replacement is required when the minimum coverage goal of 100% is not achieved. The use of sod is preferred over seeding to significantly reduce the potential for soil erosion within the swale's main treatment area.
Plant Selection	Select grass for the swale that will: • tolerate cycles of drought and inundation, as these conditions are expected • root deeply to resist scouring • tolerate salt (for swales that will receive drainage from areas treated for ice in winter). For guidance on appropriate grass species, consult a plant and landscape expert, such as a landscape architect, local nursery, or Master Gardener from the Tennessee Extension Master Gardener Program (https://mastergardener.tennessee.edu/). • Native plant species better suited to local hydrologic conditions are recommended. • Plants suitable for United States Department of Agriculture Plant Hardiness Zoned 7b are recommended. Consider future maintenance needs of vegetation when designing the dry enhanced swale. The level of plant care needed to maintain the landscape should influence plant selection.
Plant Location	Woody vegetation shall not be located at points of stormwater inflows, on the swale bottom and side slopes.

Compliance with the vegetation standards set forth in Table 7.3.6 shall be shown in a vegetation plan that is included with the stormwater management plan (SWMP). Plan preparation requirements are below.

- The plan must be prepared by a professional qualified in landscape design by their education or experience.
- The plan shall include one or more labeled plans/details (to scale) showing the plants to be installed, their numbers, and locations. Plan notes showing a plant schedule and installation instructions are encouraged. This additional information allows both the plant installer at the time of construction, as well as the person(s) responsible for maintenance of the SCM after construction, to understand the original vegetation design and its compliance with the minimum standards.
- Landscaped SCMs may not be recognized under the City's codes as property landscaping. Therefore, additional requirements for property landscaping may apply.

7.3.8 Protection Design Guidance

SCMs designed for stormwater quality purposes must be maintained in keeping with the approved SCM design for the life of the land development. **Design professionals can assist property owners with this requirement by including protective features in and around SCMs to limit the potential for damage by external factors**. Often, the landscape and impervious features around an SCM can be tailored to its specific needs, and therefore used to protect its critical components.

For dry enhanced swales, protection is most important for the swale bottom. Entry by vehicles, heavy equipment, and pedestrians can kill the grass, compact the engineered soil, and potentially damage the underdrain system. The good news is that dry enhanced swales are especially well-suited to a variety of protection methods that can both protect the area and enhance the property's landscape aesthetic or impervious surface function. Types of protection methods that work well with dry enhanced swales are listed in Table 7.3.7. Examples of protection measures are shown in Figure 7.3.3.

Table 7.3.7 Dry Enhanced Swale Protection Measures*

Passive Protection Measures	Active Protection Measures
• Natural fencing around the perimeter (e.g., dense, woody, or prickly shrubs or tall grass) • Driveways, sidewalks, or walkways around the SCM • Pedestrian benches on the perimeter • Geometry/sizing to allow maintenance without vehicles/equipment entering the swale	• Decorative fencing • Curbs or curb blocks • Hardscaping (cobble, boulder, or block edging; block walls; etc.) • Educational or directive (e.g., no pets) signs • Pet waste stations and trash cans near the SCM

** The list presented in the table is not exhaustive. There may be other possible protection measures.*

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Figure 7.3.3 Examples of Dry Enhanced Swale Protection Measures

Left: Passive protection is provided by pedestrian paths along both sides of the swale. (urbanbluegreengrids.com); Middle: a sidewalk allows pedestrians to cross over this thick grass swale (NACTO.org). Right: The decorative landscaping around this grassed dry swale is an example of passive protection. (Duke Farms, Hillsborough, NJ)

7.3.9 Site Preparation and Land Disturbance Requirements

The following information is provided to support proper and effective construction and protection of dry enhanced swales during land disturbance activities and site construction. Mandatory requirements are identified using "shall" or "must." All other statements can be regarded as non-mandatory guidance. **Site preparation and land disturbance practices described in this section shall be shown on Erosion Prevention and Sediment Control (EPSC) plan for the proposed land development.** Table 7.3.8 provides requirements for site preparation and land disturbance practices for land developments with dry enhanced swales.

Table 7.3.8 Site Preparation and Land Disturbance Requirements for Dry Enhanced Swales

SCM Type	Policy
Dry Enhanced Swale	Construction phasing and sequencing are critical to the success of dry enhanced swales. Thus, the following requirements apply: • Site construction shall be sequenced such that the swale is installed after the area draining to it has been fully and permanently stabilized. • Construction vehicle and equipment parking, thoroughfares, roadways, parking, and wash-off areas shall not be located where swales will be located. • The dry enhanced swale shall be protected using EPSC measures before, during, and, if necessary, after installation.

7.3.10 Installation Requirements

The information in Table 7.3.9 provides a typical construction sequence to properly install dry enhanced swales. These steps may be modified to reflect different applications or site conditions. **Installation practices shall be shown in the approved erosion prevention and sediment control plan and stormwater management plan, as appropriate for the proposed land development.** Table 7.3.8 provides requirements for site preparation and land disturbance practices for land developments with dry enhanced swales.

Table 7.3.9 Installation Steps

Step	Requirement
Step 1	The installation site shall be checked for existing utilities prior to swale construction to avoid potential conflicts and/or damage to utilities. Construction of the dry enhanced swale shall be performed only after the area draining to it has been fully stabilized to prevent sediment discharges to a newly installed swale and its sensitive plants. Where this requirement cannot be met, a temporary bypass shall be designed to prevent stormwater discharge to the swale until its drainage area is fully stable. It may be necessary to block certain curb or other inlets while the swale is being constructed. Supervision during construction is required to ensure the dry enhanced swale is constructed/installed in accordance with the approved EPSC and SWMP plans. The design professional or a designee under their supervision must inspect the dry enhanced swale at critical stages of construction. Examples of critical stages of construction include protection zone and EPSC measure installation, excavation, underdrain collection system installation, and final inspection. This ensures that the contractor's interpretation of the plan is consistent with the design professional's intentions and allows the design professional to certify (in the as-built plan) that the dry enhanced swale is built in keeping with the permitted plan.
Step 2	Construction sites can have many different contractors responsible for different portions of the site or aspects of construction. Therefore, subtle differences in site grading, drainage, and paving elevations from those identified in the design, or relative to different areas/aspects of construction, can affect the hydraulics of the proposed swale. The following practices should be done prior to construction to ensure the approved design is still valid: • During the preconstruction meeting, review and confirm that the actual boundaries of the swale's contributing drainage area and inlet elevations conform with the approved design. • Any changes that result from the preconstruction meeting must be shown as a revision to the SWMP and resubmitted to the City for approval. This includes changes to material certifications for aggregate, engineered soil mix, and liners if not approved prior to the preconstruction meeting.
Step 3	Install protection and EPSC measures as indicated in Table 7.3.7 above. Special protection measures, such as erosion control fabrics, may be necessary to protect vulnerable side slopes from erosion during the construction.
Step 4	Pretreatment measures shall be excavated first and then sealed to trap sediments prior to installation of the main treatment area.
Step 5	Excavate the swale to its appropriate design depth and dimensions. Excavators or backhoes, if used, must be located on the sides of the swale and have adequate reach inside the footprint for full excavation.
Step 6	Install the impermeable liner on the sides and bottom of the swale (with a 6-inch overlap at seams). Place the required depth of stone on the bottom, install the perforated underdrain pipe and its required stone jacket, and add the stone choker layer.
Step 7	Apply the engineered soil mix in 12-inch lifts until the desired top elevation of the dry enhanced swale is achieved. It is best to wait a few days to check for settlement and add additional engineered soil mix as needed to achieve the design elevation. Note: The batch receipt confirming the source of the engineered soil mix must be included with the As-Built Plan.
Step 8	Install temporary irrigation measures, if needed, to ensure plants will be watered during the remainder of site construction.

Step	Requirement
Step 9	Install sod and other plants as shown in the vegetation plan (see Section 7.3.7 and Table 7.3.6).
Step 10	EPSC devices can be removed from the inlets once the swale's side slopes have good vegetative stability, and the drainage area is fully and permanently stabilized. If the area draining to the swale includes newly installed asphalt, the EPSC devices at inlets should remain in place for at least three storm events after asphalt installation. A substantial amount of fine particles and grit are discharged from newly installed asphalt during the first several storms that produce runoff after installation. Maintenance will be required to remove the particles and grit if EPSC devices are removed too early.
Step 11	Maintain the swale in keeping with Section 7.3.11 below. Prepare the As-Built Plan and submit to the City for review and approval with the engineer's as-built certification before a final Certificate of Occupancy can be obtained. Advise the landowner (i.e., the person(s) taking ownership of the property immediately after its development) of the presence of the swale and provide them with a copy of the property's As-Built Plan and SCM location map. The plan must clearly show the location of the swale on the property and list the activities (and their frequencies) necessary for its proper maintenance.

7.3.11 SCM Maintenance on an Active Construction Site

Once an SCM is installed, its maintenance is regulated by Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code. Further, SCMs must pass a final inspection prior to construction termination. This inspection will be performed to ensure they are constructed in accordance with the approved SWMP, undamaged, and free of sediment and debris. Thus, SCM maintenance is good practice to ensure construction termination goes smoothly. Relevant policies are as follows:

- The property owner is responsible for SCM maintenance. If the property is still an active construction site, these responsibilities may fall to the land disturbance permittee until the project receives final approval from the City and/or a Certificate of Occupancy.
- Property owners may have others, such as a site contractor or landscaping company, maintain the swale on their behalf. However, the City will hold the property owner responsible for ensuring it is maintained in proper operating condition (i.e., as designed and constructed) regardless of who performs maintenance activities.
- Maintenance activities, which include ensuring proper operation of the SCM as designed and required SCM inspections, must begin immediately following installation of the swale.
- Maintenance activities shall be performed in keeping with the *SCM Inspection and Maintenance Manual*. Additional guidance on maintenance of newly installed dry enhanced swales located on active construction sites is provided in Table 7.3.10.

Table 7.3.10 Maintenance Activities for Newly Installed Dry Enhanced Swales

Area or Component	Post-Installation Maintenance Requirement
Contributing Drainage Area	Keep the contributing drainage area to the swale clean. Sweep trash, debris, and sediment frequently so that it does not wash in the basin during a rain event. The contributing drainage area should be fully stabilized before installation of the swale. If it is not, prevent inflows to the area by blocking or using diversion measures until the contributing drainage area is fully and permanently stabilized. Cover stockpiles of construction and landscape materials to prevent their exposure to rainfall.
Dry Enhanced Swale	Ensure the grass is watered and growing as expected. Remove and replace diseased, dying, or dead patches of grass as soon as they are noticed. Ensure the swale remains free of sediment and wastes. Ensure vehicles, equipment, and people are not allowed in the swale. Evidence of unwanted entries may look like tire tracks or footprints; stone displacement, or damage to components or vegetation; immediately determine and eliminate the cause and repair the area. Consider installing temporary fencing. Visually observe dry enhanced swale function after rain events; there should be no standing water within 48 to 72 hours after a storm event, depending on the frequency of rainfall. If long-standing water is observed: • Inspect underdrain via the observation well looking for standing water indicative of a blockage or damage; make repairs if needed. • If underdrain/outlet blockages and damage can be ruled out, then the engineered soil mix may be clogged. This repair requires soil removal, underdrain cleaning, and reinstallation of the main treatment area; consult the design engineer. Inspect the swale for erosion or significant sediment buildup; immediately determine and eliminate the cause and repair the area.
Education	Alert onsite subcontractors to the SCM and the following requirements. • No muddy vehicles or equipment in the drainage area to the swale. • No stockpiling of material in the swale. • No uncovered stockpiles in the contributing drainage area. • Block inlets prior to asphalt placement in the contributing drainage area. • Remove sediment, trash, debris, and empty trash cans frequently. Advise landscaping subcontractors on proper protection and maintenance of the swale, especially the following: • No heavy equipment (hand tools only) • No dumping of lawn clippings or landscape debris • Plant maintenance needs/requirements (see above)

7.3.12 References

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition.* Atlanta Regional Commission, 2016.

Chesapeake Stormwater Network (CSN). 2008. Technical Bulletin 1: Stormwater Design Guidelines for Karst Terrain in the Chesapeake Bay Watershed. Version 1.0. Baltimore, MD. Available online at: http://chesapeakestormwater.net/2012/03/technical-bulletin-no-1-stormwater-design-guidelines-for-karst-terrain /.

CWP. 2007. National Pollutant Removal Performance Database, Version 3.0. Center for Watershed Protection, Ellicott City, MD.

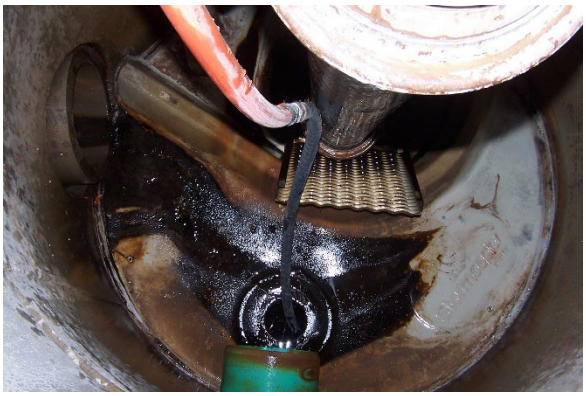
CDM, 2000. Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.

Federal Highway Administration (FHWA), United States Department of Transportation. Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. Accessed January 2006. http://www.fhwa.dot.gov/environment/ultraurb/index.htm .

MWS, 2021. Metropolitan Nashville-Davidson County Stormwater Management Manual Volume 5 Low Impact Development. Metro Water Services. Nashville, TN.

VADCR. 2011. Stormwater Design Specification No. 8: Infiltration, Version 1.9, March 1, 2011. Virginia Department of Conservation and Recreation. Available at: http://vwrrc.vt.edu/swc/NonProprietaryBMPs.html .

7.4 GRAVITY (OIL/GRIT) SEPARATOR design specifications



Water Quality Volume (WQv) Rainfall
Not applicable

OTHER SCM ATTRIBUTES *(cost scale is $-low, $$-medium, $$$-high)*	
Channel Protection Volume (CPv)	No
Detention / Retention Control	No
Small Onsite Drainage Control	No
Typical SCM Footprint Size *(percent of contributing drainage area)*	Minor
Construction Cost	$$$
Operation & Maintenance Cost *(when properly maintained)*	$$$

PROJECT SUITABILITY				
Industrial	**Commercial**	**Residential** *(common areas only)*	**Pollutant Hotspots**	**Private Roadways** *(requires HOA)*
✓	✓	✓	✓	✓

Legend: ✓ **High** ✓ **Limited** ✗ **None**

OVERVIEW

A gravity separator is a device designed to remove suspended solids, oil, grease, debris, and floatables from stormwater runoff through gravitational settling, hydrodynamic separation, and trapping of pollutants. Gravity separators are also called oil-grit separators or oil-water separators. *(Photo Source: SWC Canada Storm Water Compliance)*

ADVANTAGES/BENEFITS

- Useful as a pretreatment measure for downstream SCMs and for removal of oils and greases
- Can replace a conventional junction or inlet structure
- Multiple inlets can connect to a single unit

DISADVANTAGES/LIMITATIONS

- **Cannot be used to meet the 80% TSS removal standard**
- Failure to provide adequate inspection and maintenance can result in the resuspension of accumulated solids
- Some designs may require confined space entry for inspection, maintenance, and repairs

LOCATION, SIZING, & COMPONENTS

- Maximum drainage area is 5 acres; 1 acre or less of impervious cover to any single separator
- The total wet storage is at least 400 cubic feet per contributing impervious acre
- Minimum depth of permanent pools is 4 feet
- Velocities through the chamber are limited
- Include a trash rack in the design

LONG-TERM PROTECTION

- Protect from tampering, vehicles, and heavy equipment
- Care must be taken in landscape design to avoid significant debris discharging to the separator

LONG-TERM MAINTENANCE

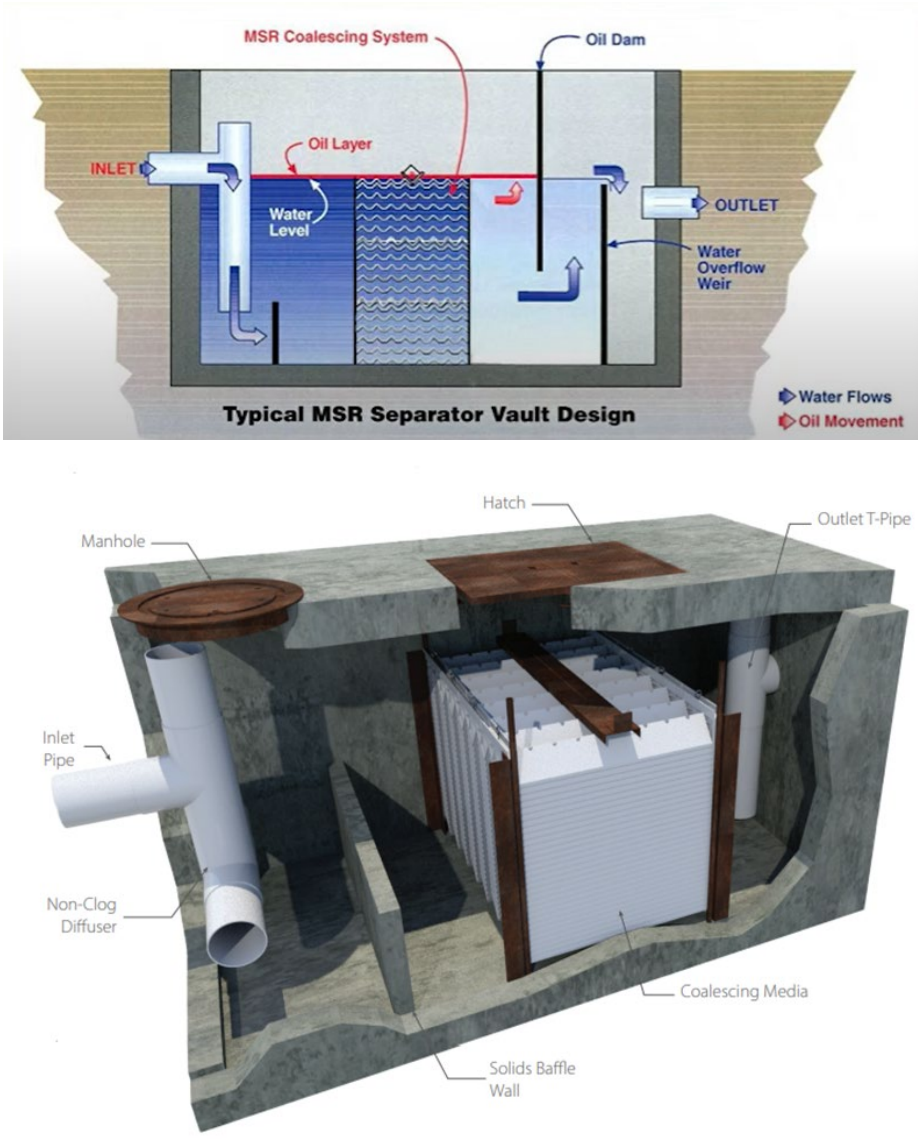
- Maintenance requirements for a proprietary system should be obtained from the manufacturer
- Frequency of inspection and maintenance is dependent on land use, climate, and design of the separator
- Proper disposal of oil, solids, and floatables removed from the gravity separator must be ensured
- Provide trash cans and pet waste stations in the drainage area

7.4.1 General Description

Gravity separators (also called oil/water separators or oil/grit separators) are hydrodynamic separation devices that are designed to remove grit, heavy sediments, oil, grease, debris, and floatable matter from stormwater through gravitational settling and trapping. Gravity separator units contain a permanent pool of water and typically consist of an inlet chamber, separation and storage chamber, a bypass chamber, and an access port for maintenance purposes (see Figure 7.4.1). Stormwater enters the inlet chamber where heavy sediments and solids drop to the bottom. The flow moves into the main gravity separation chamber, where further settling of suspended solids takes place. Oil and grease are skimmed and stored in a waste oil storage compartment for future removal. After moving into the outlet chamber, the clarified stormwater is then discharged.

The performance of these systems is based primarily on the relatively low solubility of petroleum products in water and the difference between their specific gravities. Gravity separators are not designed to separate other products, such as solvents, detergents, or dissolved pollutants. The typical gravity separator unit may be enhanced with a pretreatment swirl concentrator chamber, oil draw-off devices that continuously remove the accumulated light liquids, and flow control valves regulating the flow rate through the facility.

Figure 7.4.1 Examples of Gravity Separators



The two illustrations above demonstrate the typical design of a gravity separator SCM. The top picture shows oil and water movement through the SCM (Source: Mohr Separations Research, Inc.). The bottom picture shows the basic components of the SCM. SCM structure and componets will vary by manufacturer. (Source: Contech Engineered Solutions).

7.4.2 Design Applications

Gravity separators are often used in commercial, industrial, and transportation land uses and are intended primarily as a pretreatment measure for high-density or ultra-urban sites, or for use in hydrocarbon hotspots, such as gas stations and areas with high vehicular traffic. However, gravity separators cannot be used for the removal of dissolved or emulsified oils and pollutants such as coolants, soluble lubricants, glycols, and alcohols.

Since resuspension of accumulated sediments is possible during heavy storm events, gravity separator units are typically installed off-line. Gravity separators are available as prefabricated proprietary systems from several different commercial vendors.

7.4.3 SCM Suitability

Use Table 7.4.1 to determine if a gravity separator is suitable for the application being considered.

Table 7.4.1 Suitability Factors

Factor	Suitability
Stormwater Quality Treatment	Gravity separators will not satisfy the 80% TSS Removal standard. They are best applied as pretreatment devices for an SCM designed to address the TSS removal standard and/or for the removal/separation of the following pollutants from stormwater: • Gasoline, motor oils, greases, and other petroleum-based products • Fats, oils & grease (from food preparation)
Channel Protection	Gravity separators do not provide channel protection. Another SCM should be used in a treatment train with gravity separators to meet CPv standards.
Detention	Gravity separators do not provide peak discharge (detention) control.
Pollutant Treatment Capability	Testing of gravity separators has shown that they can remove between 40-50% of the TSS loading when used in an off-line configuration (Curran, 1996 and Henry, 1999). Gravity separators also provide removal of debris, hydrocarbons, trash, and other floatables. They provide only minimal removal of nutrients and organic matter. Actual field testing data and pollutant removal rates from an independent source should be obtained before using a proprietary gravity separator system.
Treatment of Waste and Other Pollutants	Gravity separators shall not be used to treat the following pollutants: • Construction sediment/waste • Landscape storage or waste • Sewage, pet, and livestock waste • Medical waste • Household & commercial wastes • Hazardous wastes • Pesticides, fertilizers, herbicides • Other byproducts and waste materials expected, based on the property's land use
Suitability by Land Use	Privately owned gravity separator SCMs are not allowed in the public right-of-way. General suitability criteria by land-use type are as follows. See Chapter 6 (SCM Standards, Methods, and Selection) for more information.

Commercial	Industrial	Private Roadways	Single Family Residential	Multi-Family Residential
Yes	Yes	Limited	Common Areas Only	

7.4.4 Design Requirements

The use of gravity separators should be limited to the following applications: pretreatment for other SCMs, high-density, ultra-urban, or other space- limited development sites, and hotspot areas where the control of grit, floatables, oil, and/or grease are required.

Before designing the gravity separator, the following data is necessary:

- Existing and proposed site, topographic, and location maps, as well as field reviews
- Impervious and pervious areas. Other means may be used to determine the land use data
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site
- Design data from nearby storm sewer structures
- Water surface elevation of nearby water systems and depth to seasonally high groundwater

The criteria provided in Table 7.4.2 are minimum standards and specifications for the design of gravity separators. For manufactured gravity separators (i.e., purchased from a manufacturer or vendor), the manufacturer's design specifications shall be used, with the exception of separator sizing, design configuration, and maintenance access and easements.

Table 7.4.2 Design Specifications

Design Element	Specification(s)
Prohibited Locations	To avoid rapid clogging and failure of the SCM, the use of gravity separators shall be avoided for drainage areas that: • have less than 75% impervious cover; or • are expected to yield high amounts of sediment comprised of clay/silt soils after construction is finished.
Controls for Waste & Other Pollutants	Appropriate controls shall be included in the design of the contributing drainage area to the SCM to address any wastes and other pollutants (see Table 7.4.1 above) that are expected on the property after construction. Use the proposed land use as a guide to determine appropriate controls. Examples of such controls include, but are not limited to, dumpsters, trash cans, covered materials/waste storage areas, covered materials transfer areas, oil and grease waste controls, and pet waste stations.
Offline Design Configuration	Gravity separators shall always be placed in an offline configuration as they are designed and constructed away from the main flow path for the drainage area, thus avoiding large flood flows. A flow splitter, diversion structure, or other means is used upstream of the SCM's inlets to redirect the gravity separator's design volume (typically this will be the WQv) from the main flow path to the SCM while still allowing larger flows to remain in the main flow path. The structure shall include a low-flow orifice, weir, or other hydraulic structure, sized to pass the maximum runoff generated from the 1-year, 24-hour design storm to the gravity separator. Gravity separators shall always be located upstream of other SCMs (e.g., detention basins designed for flood control, SCMs in a water quality treatment train, etc.).
Maintenance Access and Easement	A maintenance easement shall be provided to the gravity separator from a driveway, public or private road. It shall be designed as follows: • a minimum width of 15 feet • a maximum slope of no more than 15% • the access route in the easement shall be free of permanently affixed obstructions (e.g., trees, pools, fences without gates, permanent signs, etc.) and appropriately stabilized to withstand maintenance equipment and vehicles • to the extent feasible, allow vehicles to turn around. The entire gravity separator, (including all components) shall be included in the easement and shall be accessible from the easement's drive path.
Material	Gravity separators can be constructed from concrete, metal, or other durable materials.
Drainage Area	Maximum contributing drainage area = 5 acres or less. It is recommended that the contributing area to any individual gravity separator be limited to 1 acre or less of impervious cover
Slope	Gravity separators may be installed on sites with slopes up to 6%.

Design Element	Specification(s)
Minimum Depth to Water Table	Minimum separation distance (bottom of excavation to seasonally high-water table) = 2 feet Soil borings shall be used to determine the seasonally high-water table. See Appendix E (Soil Borings and Infiltration Tests) for soil boring requirements. Gravity separator units should be watertight to prevent possible groundwater contamination
Sizing	Gravity separators shall be sized for the maximum runoff generated from the 1-year, 24-hour design storm. This sizing method is described in the design specification for Manufactured Treatment Devices (MTDs) for Tier 3 and 4 SCMs (see Chapter 7, Section 7.6.6).
Minimum Hydraulic Head	Minimum hydraulic head = 4 feet (The minimum depth of the permanent pools should be 4 feet.)
Total Wet Storage	Minimum total wet storage of the gravity separator = 400 ft^3 per contributing impervious acre
Permanent Pool	Minimum depth of the permanent pool(s) = 4 feet
Surface Area and Geometry	The separation chamber shall provide for three separate storage volumes: 1. A volume for separated oil storage at the top of the chamber 2. A volume for settled solids accumulation at the bottom of the chamber 3. A volume required to give adequate flow- through detention time for separation of oil and sediment from the stormwater flow Ideally, a gravity separator design will provide an oil draw-off mechanism that empties to a separate chamber or storage area.
Velocity	Horizontal velocity through the separation chamber = 1-3 ft/min or less. The entrance velocity shall not be exceeded.
Pretreatment	Include a trash rack upstream of the inlet chamber to capture floating debris and prevent it from becoming saturated with oil.
Outlet Structures	The outlet must convey stormwater leaving the gravity separator as well as bypassed discharges without eroding the surrounding area. Typically, the high flow outlet will discharge at a higher elevation than the low flow outlet.
Safety Features	Inlets, access grates and outlets shall be designed and maintained so as not to permit access/entry by unauthorized personnel. Structural loading calculations, such as H-20 loading for traffic areas, should be performed when sizing and installing gravity separators. Some separators are considered confined spaces. Additional training may be required to perform work inside the units.

7.4.5 Gravity Separator Maintenance on an Active Construction Site

Once an SCM is installed, its maintenance is regulated by Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code. Further, it must pass a final inspection prior to construction termination. This inspection will be performed to ensure they are constructed in accordance with the approved SWMP, undamaged, and free of sediment and debris. Relevant policies are as follows:

- The property owner is responsible for gravity separator maintenance in the same way they are responsible for maintenance of any SCM. If the property is still an active construction site, these responsibilities may fall to the land disturbance permittee until the project receives final approval from the City and/or a Certificate of Occupancy.

- Property owners may have others, such as a site contractor or landscaping company, maintain the gravity separator on their behalf. However, the City will hold the property owner responsible for ensuring it is maintained in proper operating condition (i.e., as designed and constructed) regardless of who performs maintenance activities.
- Maintenance activities, which include ensuring proper operation of the gravity separator as designed, must begin immediately following its installation.

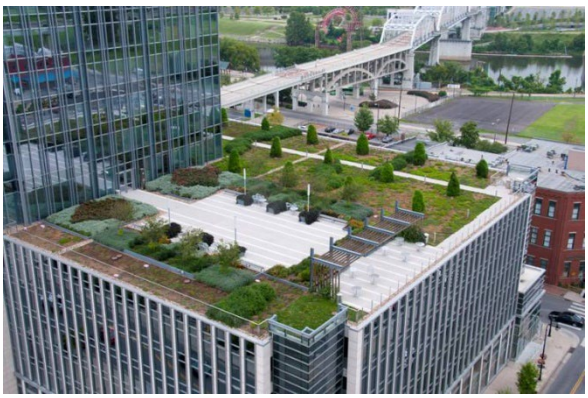
Table 7.4.3 Maintenance Activities for Newly Installed Gravity Separators

Area or Component	Post-Installation Maintenance Requirement
Contributing Drainage Area	Keep the contributing drainage area clean. Sweep trash, debris, and sediment frequently so that it does not wash into the gravity separator during a rain event. The contributing drainage area should be fully stabilized before installation of the gravity separator. If it is not, prevent inflows to the area by blocking or using diversion measures until the contributing drainage area is fully and permanently stabilized. Cover stockpiles of construction and landscape materials to prevent their exposure to rainfall.
Gravity Separator	When asphalt is placed in the contributing drainage area to a gravity separator, keep erosion prevention and sediment control devices at inlets for at least three storm events after asphalt installation. This prevents the discharge of fine particles and grit from the newly installed asphalt to the separator.
Education	Alert onsite subcontractors to the gravity separator and the following requirements. • No muddy vehicles, equipment, or uncovered stockpiles in the drainage area. • Block inlets prior to asphalt placement in the drainage area. • Remove sediment, trash, debris, and empty trash cans frequently. Advise landscaping subcontractors on proper protection of the gravity separator, especially no dumping of lawn clippings or landscape debris in the drainage area and to cover material stockpiles.

7.4.6 References

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition.* Atlanta Regional Commission, 2016.

7.5 GREEN ROOF design specifications



Water Quality Volume (WQv) Rainfall
Tier 1 Design P = 1.0 inch

OTHER SCM ATTRIBUTES *(cost scale is $-low, $$-medium, $$$-high)*	
Channel Protection Volume (CPv)	No
Detention / Retention Control	No
Small Storm Local Flood Control	No
Typical SCM Footprint Size *(percent of contributing drainage area)*	100%
Construction Cost	$ to $$$
Operation & Maintenance Cost *(when properly maintained)*	$ to $$

PROJECT SUITABILITY				
Industrial	**Commercial**	**Residential** *(common areas only)*	**Pollutant Hotspots**	**Private Roadways** *(requires HOA)*
✓	✓	✓	✗	✗

Legend: ✓ **High** ✓ **Limited** ✗ **None**

Overview

A green roof is a layer of vegetation installed on top of a conventional flat or slightly sloped roof that consists of waterproofing material, root barrier, permeable filter fabric, growing media, and specially selected plants. *(Photo courtesy of Metro Water Services of Nashville and Davidson County, Tennessee)*

ADVANTAGES/BENEFITS

- Reduce post-construction stormwater volumes and pollutant loads without consuming valuable land
- Particularly well-suited for urban developments

DISADVANTAGES/LIMITATIONS

- Cost may be greater than a conventional roof
- Requires more maintenance than a conventional roof
- Only captures and treats stormwater that falls on the roof

LOCATION, SIZING, & COMPONENTS

- Comply with the ASTM International Green Roof Standards
- Structural load-bearing capacity of the roof
- Roof pitch, access, and type
- Existing roof equipment and access, available space
- Green roofs may be installed on rooftops with slopes of up to 25% but are not generally recommended for use on rooftops with slopes greater than 10%.
- The use of extensive green roof systems (2”-6” deep growing media) should be considered prior to the use of more complex and expensive intensive green roof systems (See Section 7.5.2 for information on extensive/intensive green roof systems)
- A landscaping plan must be prepared for all green roofs and approved by the City prior to construction

LONG-TERM PROTECTION

- Protect from entry by humans and equipment to prevent soil compaction and plant/component damage
- Suitable for a wide variety of protection designs (decorative fencing, signage, seating, etc.) if providing access to pedestrians

LONG-TERM MAINTENANCE

- Primary routine maintenance activities will be plant care (e.g., weeding, pruning, mulching, leaf and landscape debris removal, plant replacement) and component maintenance
- May need to locate the SCM near a water source for plant watering

7.5.1 General Description

Green roofs (also known as vegetated roofs, living roofs, or eco-roofs) are alternative roof surfaces that typically consist of a layered system of waterproofing, drainage materials, an engineered growing media, and plants. Green roofs capture and temporarily store stormwater in the media before it is conveyed into the storm drain system. A portion of the captured stormwater evaporates or is absorbed by plants, which helps reduce stormwater volumes and pollutant loads.

7.5.2 Design Applications

While green roof designs vary based on climate, building type, and usage, they generally can be categorized into two main types: intensive and extensive. **Intensive green roofs** are the deepest (and usually heaviest), with a wide variety of plant species that typically require maintenance and an irrigation system. These roofs are often created for more than just stormwater management, such as gardens or crops for restaurants or amenity spaces with aesthetic appeal.

In contrast, **extensive green roofs** tend to be used only to meet minimum stormwater management requirements. Thus, they are relatively light, have little to no variety in vegetation, and are easier to install. Extensive green roofs are designed to have minimal maintenance requirements. Plant species are selected so that the roof does not need supplemental irrigation or fertilization after vegetation is initially established. These advantages make extensive green roofs ideal to meet local stormwater quality objectives.

Some roofs, called **semi-intensive green roofs**, are designed with a mix of extensive and intensive areas. This allows a lower life-cycle cost than an intensive green roof, while still achieving the desired aesthetics and performance (UrbanStrong Green Building Specialists, 2024). Table 7.5.1 presents a comparison of green roof types. Figure 7.5.1 shows a graphical comparison of intensive and extensive green roof system layers in profile. Figure 7.5.2 shows examples of all three types of green roofs.

Table 7.5.1 Green Roof System Comparison *(Source: Adapted from Archtoolbox.com)*

	Extensive	Semi-Intensive	Intensive
Plant Options	Sedum, moss, grass	Sedum, moss, grass, herbs, flowers, shrubs	Sedum, moss, grass, herbs, flowers, large shrubs, trees
Soil Depth	2 to 5 inches	5 to 8 inches	8 to 30+ inches
Dry Weight	10 to 25 lbs per ft^2	25 to 40 lbs per ft^2	40 to 100+ lbs per ft^2
System Types	Layered, Modular	Layered, Modular	Layered, Modular
Maintenance	Minimal	Occasional/Routine	Routine
Initial Cost	Low	Medium	High

Figure 7.5.1 Profile Comparison Intensive and Extensive Green Roofs *(Source: City of Portland OR, 2004)*

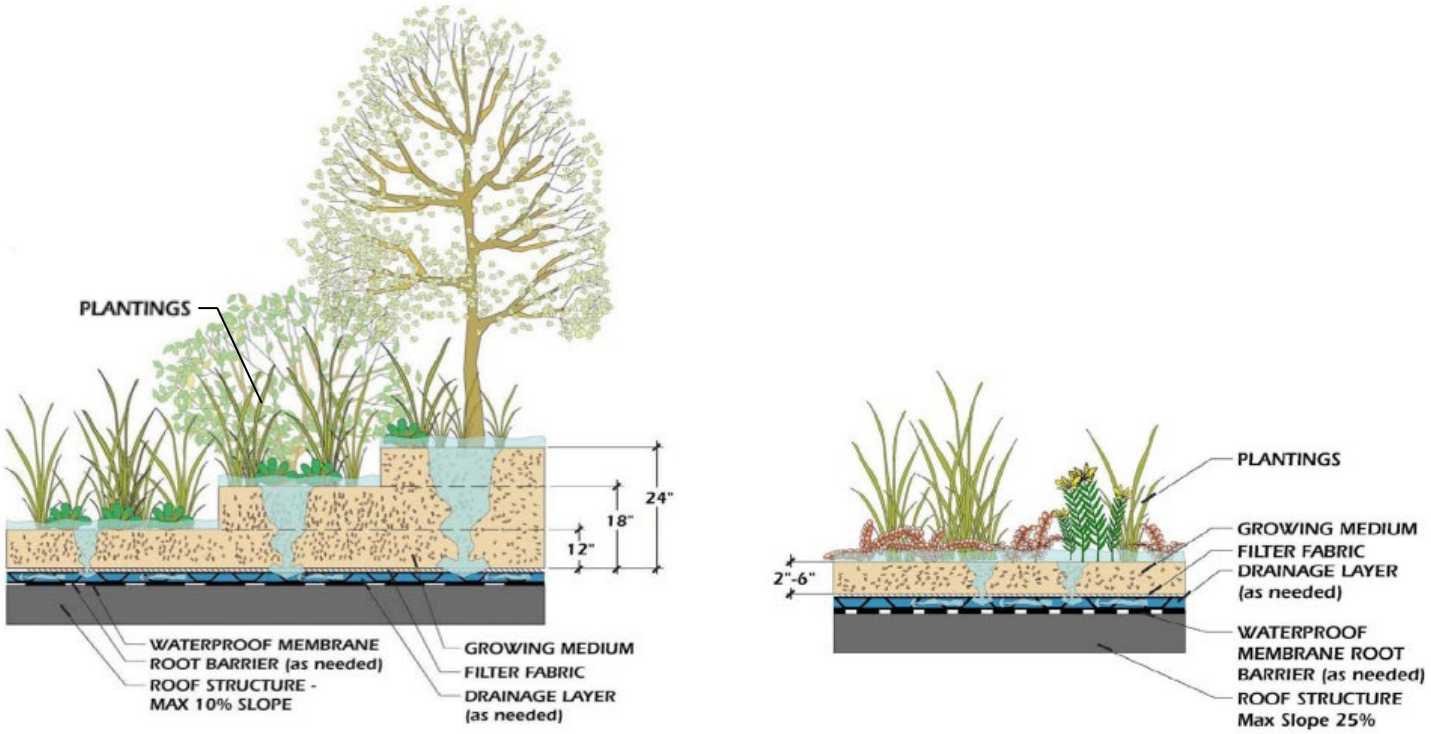


Figure 7.5.2 Examples of Intensive and Extensive Green Roofs

(Top left: intensive green roof at the Louisa apartments in Portland OR (Source:GBD Architects); Right: Semi-intensive green roof at Carnegie-Mellon University (Source:Green Roof Technology); Lower left: Extensive green roof on Howlett Hall at The Ohio State University (Source: Chadwick Arboretum & Learning Gardens)

Green roof designs include waterproofing, support for the increased structural loads of fully saturated soil, plant media, and plants. They are designed so that water drains vertically through the media and then horizontally along a waterproofing layer towards the outlet, without water ponding on the roof. They are constructed either "from scratch" by building up the roof layers, or using pre-made tray systems that create a seamless appearance but with less difficulty in construction. Figure 7.5.3 shows an example of a tray system and Figure 7.5.4 shows a layered system in use.

Figure 7.5.3 Examples of Layered and Modular (Tray) Green Roof Systems *(Source: Greenrise Technologies, Murfreesboro TN)*

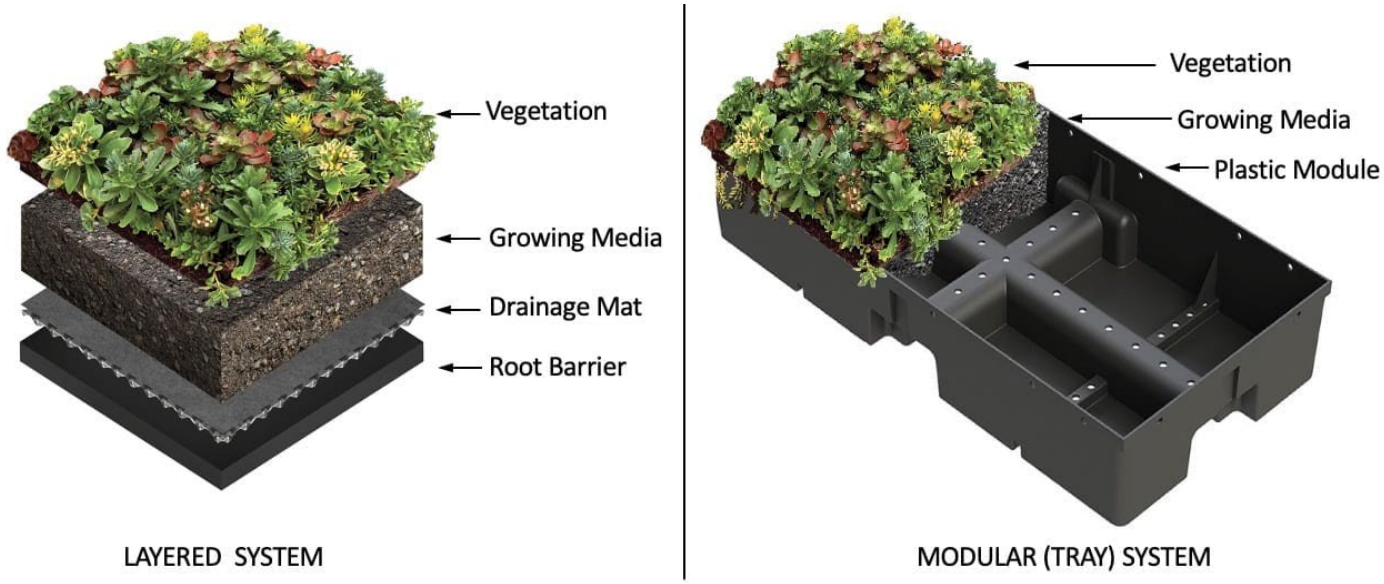


Figure 7.5.4 Layered Green Roof System *(Source: B. Hunt, North Carolina State University)*

7.5.3 SCM Suitability

Use Table 7.5.2 to determine if a green roof is suitable for the application being considered.

Table 7.5.2 Green Roof Basin Suitability Factors

Factor	Suitability
Stormwater Quality Treatment	Green roofs designed in keeping with the specifications established herein will satisfy City of Alcoa (City) stormwater quality treatment standards.
Channel Protection	Channel protection volume (CPv) storage is not provided by a green roof.
Detention	Stormwater detention is not provided by a green roof.
Pollutant Treatment Capability	Green roofs can be used to address the following common stormwater pollutants: Total Suspended Solids (TSS): 80% Total Phosphorus (TP): 50% Total Nitrogen (TN): 50% Fecal Bacteria[1]: -- Metals*: -- **Cadmium, copper, lead, and zinc*
Treatment of Waste and Other Pollutants	Green roofs shall not be used to treat the following pollutants: • Construction sediment/waste • Landscape storage or waste • Sewage, pet, and livestock waste • Medical waste • Household & commercial wastes • Hazardous wastes • Gasoline, motor oils, greases, and other petroleum-based products • Fats, oils & grease (from food preparation) • Pesticides, fertilizers, herbicides • Other byproducts and waste materials expected, based on the property's land use
Suitability by Land Use	General suitability criteria by land-use type is as follows. Commercial: Yes Industrial: Yes Private Roadways: N/A Single Family Residential: Common Areas Only Multi-Family Residential: Common Areas Only

7.5.4 Limitations of This Design Specification

The criteria provided in the remainder of this design specification are not comprehensive to fully design an operational green roof. Rather, they are intended as "guardrails" for green roofs that are proposed as SCMs to meet City stormwater quality control requirements (the WQv standard) and adhere to local building codes and/or ASTM International Green Roof Standards. Additional design objectives, such as energy efficiency, green building or Leadership in Energy and Environmental Design (LEED) points, architectural considerations, visual amenities, and landscaping features, are beyond the scope of this specification. Regardless, beyond the standards provided by these criteria, **design professionals must work with a commercial green roof manufacturer/installer to ensure proper design of functional green roofs**. Additionally, consult references from Weiler and Scholz-Barth (2009), Snodgrass and Snodgrass (2006) and Dunnett and Kingsbury (2004) for more information on green roof design.

7.5.5 Design Requirements

Table 7.5.3 provides a limited set of standards and guidance for green roof design to meet City stormwater quality requirements.

Table 7.5.3 Design Specifications for a Green Roof

Design Element	Specification(s)
Water Quality Volume (WQv)	The water quality rainfall depth (P) for determination of WQv: P = 1.0 inch. Since green roofs manage only the rainfall that falls on them, the contributing drainage area (A) for determination of WQv is the area of the green roof. *Note: roof access paths, mechanical equipment, photovoltaic panels, and skylights are counted as part of the green roof for calculation purposes. These areas shall not exceed 20% of the roof area counted as green roof.* Acceptable methods to determine WQv are presented in Chapter 6 (SCM Standards, Methods, and Selection).
Location	There are no location constraints for green roofs. However, green roofs proposed for residential land uses will be approved for compliance with the WQv standard only when placed on buildings owned in common (single and multi-family residential) or owned by the commercial property owner (multi-family residential only).
Pretreatment	Pretreatment is not required on a green roof.
Drawdown Time	Provide full treatment of the WQv within 72 hours of the rainfall event.
Building Codes	The green roof shall comply with all relevant City building codes.

Consult a commercial designer/installer proficient in green roof design and construction for design specifications for the following green roof components. Must comply with local building codes. In the event building codes do not address green roofs, must comply with the ASTM International Green Roof Standards.

- Roof deck
- Structural components and capacity
- Waterproofing layer
- Insulation layer
- Root barrier
- Drainage layer, system, and outlet structures
- Filter fabric
- Growing media
- Vegetation
- Safety features

7.5.6 Vegetation Design Requirements

The importance of plants to a green roof's function means they, like any SCM component, have design, installation, and maintenance specifications. Much of the design and maintenance of a green roof centers on plant coverage, health, and replacement. Table 7.5.4 provides the vegetation specifications for green roofs.

Table 7.5.4 Vegetation Design Specifications

Vegetation Design Element	Specification(s)
Minimum Coverage	Green roofs shall have a vegetation coverage requirement of 100% of the green roof area, not including roof access paths, mechanical equipment, photovoltaic panels, and skylights. The minimum coverage requirement must be achieved upon roof installation and then maintained thereafter.
Plant Survival	Plant replacement is required when the minimum coverage goal of 100% is not achieved. It is advisable for construction contracts to contain a replacement warranty that covers at least three growing seasons to help ensure adequate growth and survival of the vegetation planted on a green roof.

Vegetation Design Element	Specification(s)
Plant Selection	The general goal for vegetated roof systems designed for stormwater management is to establish a full and vigorous cover of low-maintenance vegetation that is self-sustaining and requires minimal mowing, trimming, or weeding. Green roof manufacturers/installers will have plant templates and resources to guide design professionals in achieving the desired vegetation design and aesthetic. See also ASTM E2400-06, Guide for Selection, Installation, and Maintenance of Plants for Green (Vegetated) Roof Systems. • The species and layout of the vegetation should reflect the location of the building, in terms of its height, exposure to wind, snow loading, heat stress, orientation to the sun, and shading by surrounding buildings. In addition, plants shall be selected that are fire resistant and able to withstand heat, cold, and high winds.

Compliance with the vegetation standards set forth in Table 7.5.4 shall be shown in a vegetation plan that is included with the stormwater management plan (SWMP). Plan preparation requirements are below.

- The plan must be prepared by a professional qualified in green roof design by their education or experience.
- The plan shall include one or more labeled plans/details (to scale) showing the plants to be installed, their numbers, and locations. Plan notes showing a plant schedule and installation instructions are encouraged. This additional information allows both the plant installer at the time of construction, as well as the person(s) responsible for maintenance of the SCM after construction, to understand the original vegetation design and its compliance with the minimum standards.

7.5.7 Protection Design Guidance

SCMs designed for stormwater quality purposes must be maintained in keeping with the approved SCM design for the life of the land development[1]. **Design professionals can assist property owners with this requirement by including protective features in and around SCMs to limit the potential for damage by external factors**. Often, the landscape and impervious features around an SCM can be tailored to its specific needs, and therefore used to protect its critical components.

For green roofs, protection is especially important for the planting area, the underlying layered components, and the roof drains and outlet(s). In general, walkways allow access for plant/roof maintenance. For semi-intensive and intensive green roofs, additional protective measures may be warranted depending on the intended use and design of the roof. Figure 7.5.5 shows an example of protective measures (i.e., sidewalk, bench, curbing) on an intensive green roof used as an amenity. Protection methods that work well are listed in Table 7.5.5.

Table 7.5.5 Green Roof Protection Measures*

Passive Protection Measures	Active Protection Measures
• Natural fencing such as vegetation borders/screens • Walkways and pedestrian benches • Geometry to allow maintenance without entering the planting area	• Decorative fencing • Hardscaping • Educational or directive (e.g., no pets) signs • Trash cans

** The list presented in the table is not exhaustive. There may be other possible protection measures.*

[1] Tennessee Rule *0400-40-10-.04*

Figure 7.5.5 Examples of Protective Landscaping

Left: Stepping stones on a green roof in Chicago (Source: US National Park Service); Right: Pedestrian walkways, benches, and curbing on a green roof in Toronto, Canada (Source: City of Toronto ON, Canada)

7.5.8 SCM Maintenance on an Active Construction Site

Once an SCM is installed, its maintenance is regulated by Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code. Further, SCMs must pass a final inspection prior to construction termination. This inspection will be performed to ensure they are constructed in accordance with the approved SWMP, and undamaged. Thus, SCM maintenance is good practice to ensure construction termination goes smoothly. Relevant policies are as follows:

- The property owner is responsible for SCM maintenance. If the property is still an active construction site, these responsibilities may fall to the land disturbance permittee until the project receives final approval from the City and/or a Certificate of Occupancy.
- Property owners may have others, such as a site contractor or landscaping company, maintain the green roof on their behalf. However, the City will hold the property owner responsible for ensuring it is maintained in proper operating condition (i.e., as designed and constructed) regardless of who performs maintenance.
- Maintenance activities, which include ensuring proper operation of the SCM as designed and required SCM inspections, must begin immediately following installation of the green roof.
- Maintenance activities shall be performed in keeping with the *SCM Inspection and Maintenance Manual*. Additional guidance on maintenance of newly installed green roofs located on active construction sites is provided in Table 7.5.6.

Table 7.5.6 Maintenance Activities for Newly Installed Green Roofs

Area or Component	Post-Installation Maintenance Requirement
Contributing Drainage Area	Keep the contributing drainage area clean. Sweep trash, debris, and sediment frequently so that it does not wash into the planting area during a rain event.
Green Roof	Ensure SCM plants are watered and growing as expected. Remove and replace diseased, dying, or dead plants as soon as they are noticed. Ensure the planting area remains free of sediment and wastes. Ensure equipment and people are not allowed in the planting area. Evidence of unwanted entry may look like tire tracks or footprints; mulch or stone displacement, or damage to components or vegetation; immediately determine and eliminate the cause and repair the area. Consider installing protection measures.

Area or Component	Post-Installation Maintenance Requirement
	Visually observe the SCM's function after rain events; there should be no standing water within 48 to 72 hours after a storm event, depending on the frequency of rainfall. If long-standing water is observed: • Inspect green roof components looking for standing water indicative of a blockage or damage; make repairs if needed. • If outlet blockages and damage can be ruled out, then the engineered soil mix may be clogged. This repair requires soil removal and reinstallation of the main treatment area; consult the design engineer.
Education	Alert onsite subcontractors to the SCM and the following requirements: • No stockpiling of material on the planting surface and no exposed stockpiles in the planting bed's drainage area. • Remove sediment, trash, debris, and empty trash cans frequently. • Green roof component protection Advise landscaping subcontractors on proper protection and maintenance of the green roof, especially the following: • No heavy equipment (hand tools only) • No dumping of lawn clippings or landscape debris • Plant maintenance needs/requirements (see above)

7.5.9 References

American Horticultural Society (AHS). 2003. United States Department of Agriculture Plant Hardiness Zone Map. Alexandria, VA.

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition.* Atlanta Regional Commission, 2016.

ASTM International. 2019. Standard Test Method for Maximum Media Density for Dead Load Analysis of Green (Vegetated) Roof Systems. Standard E2399-05. ASTM, International. West Conshohocken, PA. available online: https://www.astm.org/e2399_e2399m-19.html

ASTM International. 2019. Standard Test Method for Saturated Water Permeability of Granular Drainage Media [Falling-Head Method] for Green (Vegetated) Roof Systems. Standard E2396- 05. ASTM, International. West Conshohocken, PA. available online: https://www.astm.org/e2396_e2396m-19.html

ASTM International. 2019. Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Green (Vegetated) Roof Systems. Standard E2398-05. ASTM, International. West Conshohocken, PA. available online: https://www.astm.org/e2398_e2398m-19.html

ASTM International. 2019. Standard Practice for Determination of Dead Loads and Live Loads Associated with Green (Vegetated) Roof Systems. Standard E2397-05. ASTM, International. West Conshohocken, PA. available online: https://www.astm.org/e2397_e2397m-19.html

ASTM International. 2019. Standard Guide for Selection, Installation, and Maintenance of Plants for Green (Vegetated) Roof Systems. Standard E2400-06. ASTM, International. West Conshohocken, PA. available online: https://www.astm.org/e2400_e2400m-19.html

Berhage, R., A. Jarrett, D. Beattie and others. 2007. Quantifying evaporation and transpiration water losses from green roofs and green roof media capacity for neutralizing acid rain. Final Report. National Decentralized Water Resource Capacity Development Project Research Project. Pennsylvania State University.

City of Portland OR. 2004. *Stormwater Management Manual*.

Clark, S., B. Long, C. Siu, J. Spicher and K. Steele. 2008. "Early-life runoff quality: green versus traditional roofs." Low Impact Development 2008. Seattle, WA. American Society of Civil Engineers.

Dunnett, N. and N. Kingsbury. 2004. Planting Green Roofs and Living Walls. Timber Press. Portland, Oregon.

Maryland Department of Environment. (MDE). 2008. Chapter 5. Environmental Site Design. "Green Roofs." Baltimore, MD.

Miller, C. 2008. Green roofs as stormwater best management practices: Preliminary computation of runoff coefficients: sample analysis in the Mid-Atlantic states. Roofscapes, Inc. Philadelphia, PA.

MWS. 2012. Metropolitan Nashville-Davidson County Stormwater Management Manual Volume 5 Low Impact Development. Metro Water Services. Nashville, TN.

North Carolina State University (NCSU). 2008. Green Roof Research Web Page. Department of Biological and Agricultural Engineering. https://content.ces.ncsu.edu/plant-selection-for-extensive-green-roofs-in-the-research-triangle-area-of-north-carolina

Northern Virginia Regional Commission (NVRC). 2007. Low Impact Development Manual. "Vegetated Roofs." Fairfax, VA.

Philadelphia Water Department. July 2023. *Stormwater Management Guidance Manual. Version 3.3*

Schueler et al 2007. Urban Stormwater Retrofit Practices. Manual 3 in the Urban Subwatershed Restoration Manual Series. Center for Watershed Protection. Ellicott City, MD.

Snodgrass, E. and L. Snodgrass. 2006. Green Roof Plants: a resource and planting guide. Timber Press. Portland, OR.

UrbanStrong Green Building Specialists. 2023. www.urbanstrong.com

Van Woert, N., D. Rowe, A. Andersen, C. Rugh, T. Fernandez and L. Xiao. 2005. "Green roof stormwater retention: effects of roof surface, slope, and media depth." Journal of Environmental Quality. 34: 1036-1044.

VADCR. 2011. Stormwater Design Specification No. 5: Vegetated Roof, Version 2.3, March 1, 2011. Virginia Department of Conservation and Recreation. https://swbmpvwrrc.wp.prod.es.cloud.vt.edu/wp-content/uploads/2017/11/BMP-Spec-No-5_VEGETATED-ROOF_v2-3_03012011.pdf

Weiler, S. and K. Scholz-Barth 2009. Green Roof Systems: A Guide to the Planning, Design, and Construction of Landscapes over Structure. Wiley Press. New York, NY.

7.6 Manufactured Treatment Device design specifications

Water Quality Volume (WQv) Rainfall
Depends on SCM Tier (see Section 7.6.4 below)

OTHER SCM ATTRIBUTES *(cost scale is $-low, $$-medium, $$$-high)*	
Channel Protection Volume (CPv)	No
Detention / Retention Control	No
Small Storm Local Flood Control	No
Typical SCM Footprint Size *(percent of contributing drainage area)*	Minor
Construction Cost	$$
Operation & Maintenance Cost *(when properly maintained)*	Varies by type

PROJECT SUITABILITY				
Industrial	**Commercial**	**Residential** *(common areas only)*	**Pollutant Hotspots**	**Private Roadways** *(requires HOA)*

See Table 7.6.2 MTD Feasibility Guidelines by Land Use and MTD Tier

OVERVIEW

Manufactured treatment devices (MTDs) are pre-manufactured structural stormwater control measures (SCMs) that are purchased from a manufacturer or vendor and installed onsite (sometimes requiring onsite assembly). The purpose of the MTD is to remove pollutants from the stormwater that passes through them. Low impact development (LID)-MTDs are a subset of MTDs that remove pollutants using soil infiltration, biofiltration, and plant evapotranspiration. *(Photo source: Hydro International)*

ADVANTAGES/BENEFITS

- Application flexibility: A wide variety of MTDs are available in many different types, configurations, and sizes
- Often includes all necessary components (inlets, pretreatment, main treatment, outlet, and overflow)
- Very small to no surface footprint
- Good for high impervious and high density developments with no room for SCMs with larger footprints
- Some types are useful for hotspots and pollutants other than TSS
- Manufacturers/vendors often provide support for MTD design, construction, and maintenance

DISADVANTAGES/LIMITATIONS

- MTDs that serve developments where litter/floatables are common (e.g., fast-food restaurants) will require frequent cleaning
- Some MTDs require regular replacement of components
- Repairs can be costly; damage may require replacement of the entire MTD
- Should not be made operational until site construction is complete

LOCATION, SIZING, & COMPONENTS

- Requires NJDEP certification of MTD pollutant removal capability when designed as a stand-alone SCM
- Both City and manufacturer specifications apply

LONG-TERM PROTECTION

- Most components are located underground; additional protective features are typically minimal
- Signs, stamps, or placards can be helpful in MTD awareness

LONG-TERM MAINTENANCE

- Primary routine maintenance activities will be drainage area cleaning (e.g., street sweeping), and device cleaning
- Provide trash cans and pet waste stations in the drainage area as these may allow a reduction in the frequency of MTD cleaning

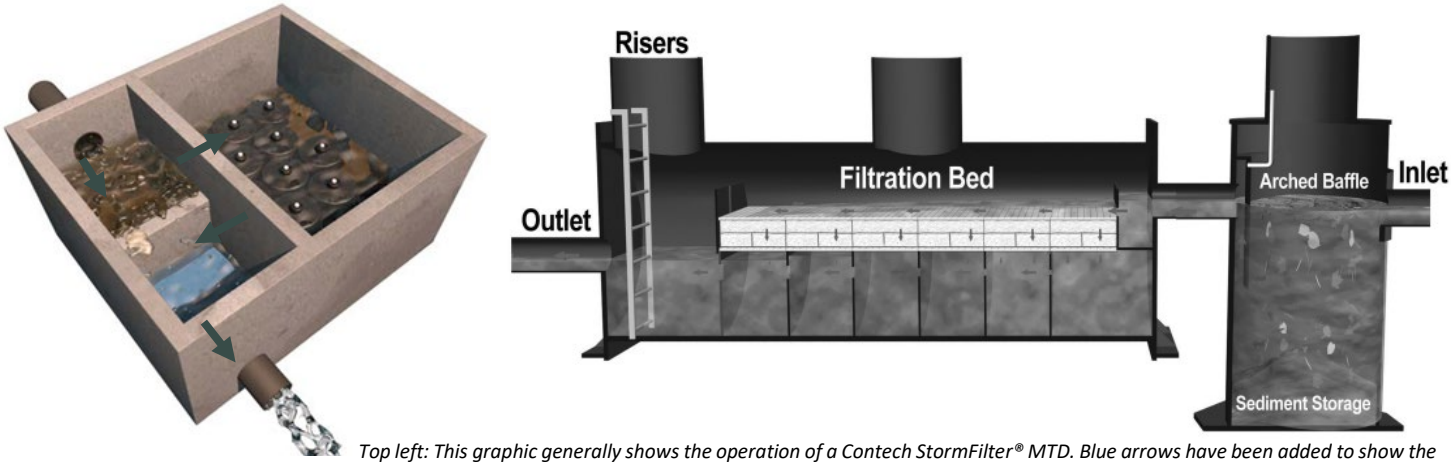
7.6.1 General Description

MTDs are structural SCMs constructed by commercial manufacturers at an offsite location before they are installed and connected to the onsite stormwater system. Their purpose is to capture pollutants in stormwater runoff before they are conveyed to the downstream stormwater drainage system, another SCM, or a local waterbody. Most MTDs are installed underground and thus have a very small or even zero surface footprint. This makes them an attractive option for property owners, especially on small, space-limited sites where most other SCMs can take up a significant amount of land.

When MTDs were first introduced as "flow-through" devices, they operated very differently from more traditional SCMs, such as an extended detention pond or sand filter. They removed pollutants much more quickly In general, older MTD designs can be grouped into two categories depending on their treatment type.

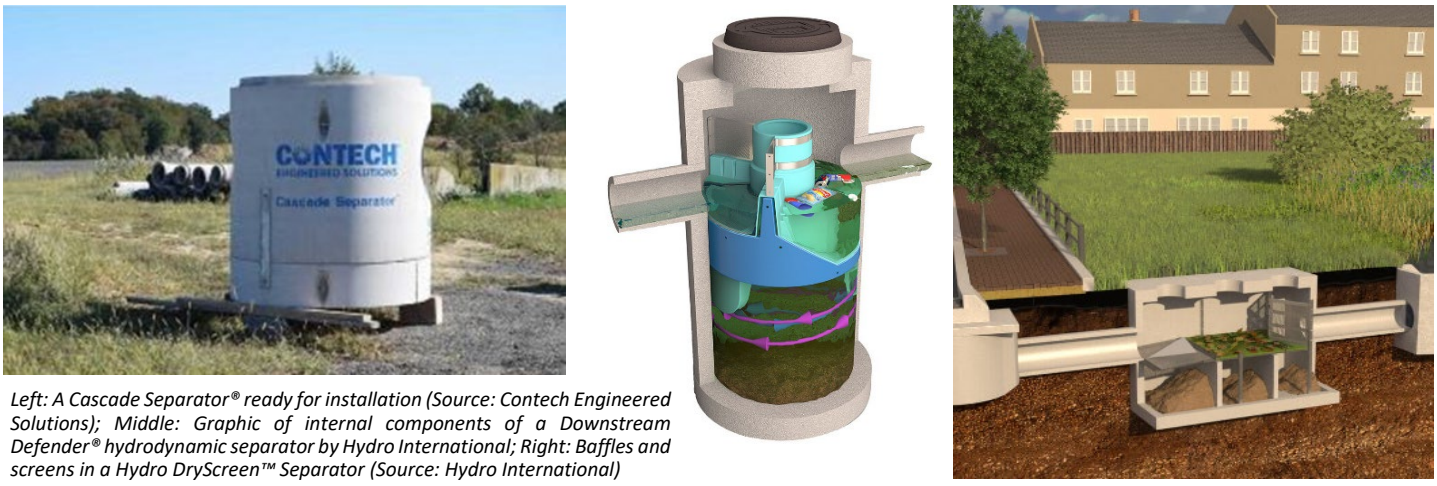
- Filtration MTDs operate via chemical or physical filtration using screen, cartridge, and granular media filter systems. These MTDs are included in this design specification in the Tier 3 MTD category. Examples are shown in Figure 7.6.1, although there are many more manufacturers and MTDs than what is shown.
- Hydrodynamic MTDs operate using mechanical or gravity separation, such as a hydrodynamic separator or baffle box settling system. These MTDs are included in this design specification in the Tier 4 MTD category. Examples are shown in Figure 7.6.2. There are many more manufacturers and MTDs than shown in the figure.

Figure 7.6.1 Examples of Tier 3 (Filtration) MTDs



Top left: This graphic generally shows the operation of a Contech StormFilter® MTD. Blue arrows have been added to show the direction of flow for pollutant removal. (Adapted from a graphic by Contech Engineered Solutions); Top right: Schematic of an AquaFilter™ Stormwater Filtration System by AquaShield (Source: Aquashield).

Figure 7.6.2 Examples of Tier 4 (Hydrodynamic) MTDs

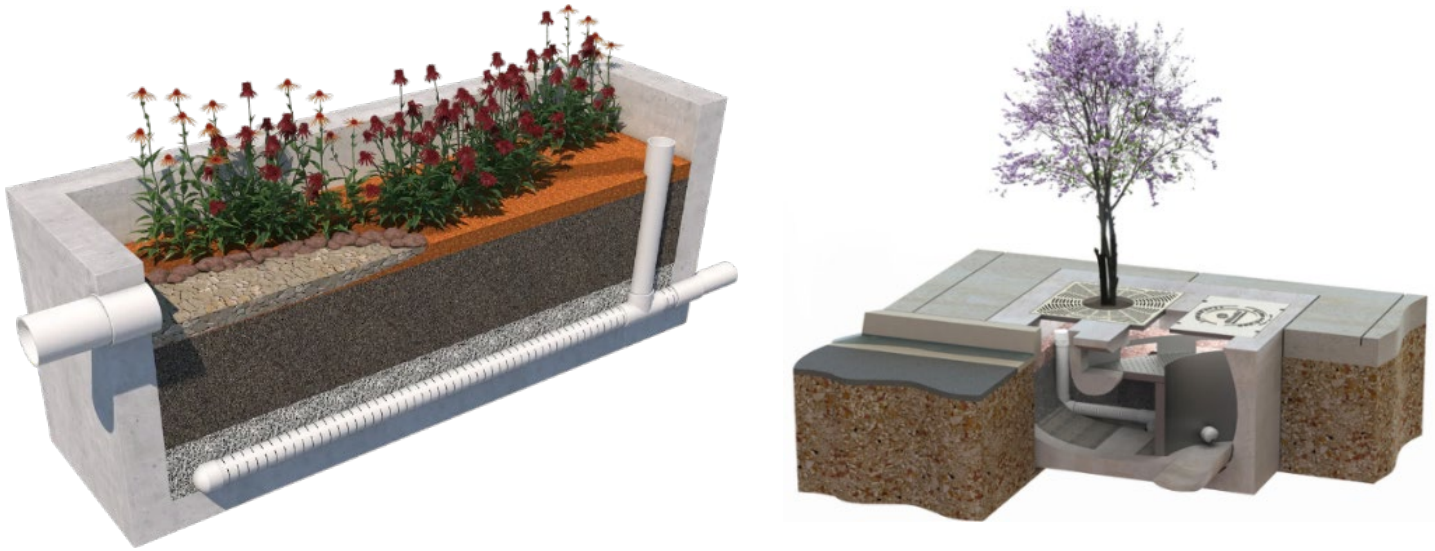


Left: A Cascade Separator® ready for installation (Source: Contech Engineered Solutions); Middle: Graphic of internal components of a Downstream Defender® hydrodynamic separator by Hydro International; Right: Baffles and screens in a Hydro DryScreen™ Separator (Source: Hydro International)

Filtration and hydrodynamic MTDs are still available today and are included in this design specification as Tier 3 and Tier 4 SCMs, respectively. They have very little detention time and are usually good at removing trash, debris, and gross solids. These characteristics make them particularly useful as pretreatment devices for other, larger SCMs, such as extended detention ponds. These MTD designs can sometimes be adapted to address pollutants other than total suspended solids (TSS), such as petroleum, metals, etc., thus allowing their use for special pollutant abatement purposes.

In the mid-2010s, the United States Environmental Protection Agency (USEPA) and state regulatory authorities began to emphasize "green infrastructure" (i.e., the use of infiltration, biofiltration, and evapotranspiration) as the most desirable approaches for pollutant removal. Many MTD manufacturers responded, adding new MTDs to their product lines. Today, there are a wide variety of these low impact development (LID) MTDs available in the commercial marketplace, with nearly all characterized by a compact surface footprint. They are included in this design specification as Tier 2 MTDs. Examples of Tier 2 MTDs are shown in Figure 7.6.3. There are many more manufacturers and MTDs than shown in the figure.

Figure 7.6.3 Examples of Tier 2 (Biofiltration) MTDs



Left: StormVault Biofiltration Planter (Source: Jensen Precast); Right: Filterra® bioretention MTD (Source: Contech Engineered Solutions)

7.6.2 Limitations of this Design Specification

The criteria provided in the remainder of this design specification are limited. Beyond the policies provided herein, **design professionals must work with a commercial MTD manufacturer/installer for proper MTD selection and installation**.

7.6.3 MTD Tiers

As SCMs, MTDs are categorized into the same SCM tiers based on their treatment method. Table 7.6.1 defines and describes the tiers for MTDs. These tiers match the SCM tiers, with the exception of the fifth tier, called "Other'.

Table 7.6.1 MTD Tiers by WQv Treatment Method

Tier	WQv Treatment Method	Description
1	Tier 1 MTDs which operate via infiltration of stormwater into the surrounding soil are prohibited due to concerns about sinkhole formation caused by infiltration in karst terrain.	
2	Biologically active filtration with an underdrain	MTDs that remove pollutants by filtering water through a planted soil/media bed, before discharge through an underdrain to the onsite stormwater system. *Note: 12-inches of internal water storage is required for a Tier 2 MTD. Thus, most MTDs in this Tier will have to add a stone layer to meet this requirement.*

Tier	WQv Treatment Method	Description
3	Sand or gravel filtration, settling	MTDs that remove pollutants using removable/replaceable filters, inserts, or screens and/or media-filled cartridges, before discharge to the onsite stormwater system. Tier 3 MTDs do not include drain filters, such as downspout filters, catch basin inserts, drop inlet baskets/filters, curb inlet inserts, and similar devices.
4	Pollutant/stormwater separation	MTDs that use hydrodynamic forces (e.g., centrifugal) or gravity to remove pollutants, before discharge to the onsite stormwater system. Tier 4 MTDs can also be used as pretreatment devices for other SCMs, etc.
Other	Depends on pollutant(s) of concern	MTDs designed to treat pollutants other than, or in addition to, TSS.

7.6.4 Design and Construction Policies

The following policies shall apply to MTDs proposed in a stormwater management plan (SWMP).

1. **MTD design.** All MTDs are considered SCMs and therefore are subject to all City of Alcoa (City) requirements pertaining to SCMs. They shall be designed in keeping with this design specification (i.e., the entirety of Section 7.6), the manufacturer's specifications for the exact MTD make(s), model(s), and size(s) proposed for a land development, and any design caveats established by the independent third-party agency certifying, verifying, or confirming that TSS removal percentage, such as a maximum flow rate and MTD scaling, to ensure the pollutant removal effectiveness of the proposed MTDs as defined in the third-party certification.

2. **Certification of MTD pollutant removal efficiency (in %) by the New Jersey Department of Environmental Protection (NJDEP) is required for MTDs proposed for developments within the City.** An NJDEP certification assures the City that MTDs used within its jurisdiction are capable of protecting water quality. For the developer and design professional, it ensures their money is well-spent. In the future, the City may allow pollutant removal certifications from other reputable industry-wide certification agencies as they become viable for use in east Tennessee.

   NJDEP certifications are found at https://www.nj.gov/dep/stormwater/treatment.html and must be provided with the SWMP and the SCM Record Drawing. The MTD inspection and maintenance guides developed by the MTD manufacturer must also be included.

   Note: MTDs that are not certified by NJDEP at 80% TSS removal must be placed in a treatment train to achieve the required 80% standard, or exchanged with an alternate SCM that can achieve the 80% standard.

3. **Situations where MTDs are required.** MTDs from Tier 3 (filtration) or Tier 4 (hydrodynamic) are required as pretreatment measures or for full compliance with the City stormwater management requirements for the land uses listed below.

   - Parking lots with more than 100 parking spaces
   - Gas stations, automobile repair centers, and storage facilities for petroleum products
   - Any other land use that may have a higher-than-normal potential for pollutant discharges, as deemed appropriate by the City.

   MTDs selected for these situations must be designed with a minimum of 60 gallons of internal volume dedicated to the storage of spilled petroleum. This extra storage provides time for spill recovery crews to remove the petroleum before it discharges from the MTD.

4. **MTD usage guidelines.** Prior to selection for a site, MTDs shall be evaluated for their appropriateness for the onsite conditions, the pollutants expected at the site, and the potential for effective long-term maintenance by the owner(s) in keeping with the MTD maintenance plan. Table 7.6.2 presents MTD feasibility guidelines by MTD tier and land use. Additional MTD usage policies follow the table. Table 7.6.3 lists the locations where MTDs cannot be used.

Table 7.6.2 MTD Feasibility Guidelines by Land Use and MTD Tier

Situation or Land Use	Tier			
	2	3	4	Other
Space limited, small, or ultra-urban sites	Yes	Limited	Yes	Yes
Commercial land uses	Yes	Limited	Yes	Yes
Industrial land uses	Yes	Yes	Limited	Yes
Single-family, duplex, and triplex residential land uses	No	No	No	No
Multi-family residential land uses *(common area only)*	Yes	Yes	Yes	Yes
Drainage areas with soil contamination or special (i.e., non-TSS) pollutants	Limited	Yes	Limited	Yes
Pretreatment *(in lieu of a sediment forebay)*	No	Yes	Yes	Limited

"Yes" *indicates MTDs in the tier are generally suitable for the land use.*

"No" *indicates the MTDs in the tier are generally prohibited for the specified situation or land use.*

"Limited" *indicates the MTDs in the tier have limited suitability, based on site conditions, expected pollutants, or concerns about required maintenance and future owner capabilities to effectively inspect and maintain the MTD. The City will consider these concerns when evaluating the MTD for a proposed development.*

Table 7.6.3 Prohibited Locations and Uses

Location or Use	Tier(s)
Federal Emergency Management Agency (FEMA)-designated Special Flood Hazard Areas (SFHAs) or floodplains in general.	Tier 2
Like all SCMs, MTDs shall not be used to treat the pollutants listed below unless specifically designed to do so. Information and design specifications from the MTD manufacturer indicating MTD suitability for such pollutants are required City approval. • Construction sediment/waste • Landscape storage or waste • Sewage, pet, and livestock waste • Medical waste • Household & commercial wastes • Hazardous wastes • Gasoline, motor oils, greases, and other petroleum-based products • Fats, oils & grease (from food preparation) • Pesticides, fertilizers, herbicides • Other byproducts and waste materials expected, based on the property's land use	All tiers

5. **MTDs in Treatment Trains.** MTDs that cannot treat the required water quality control volume/peak rate for its contributing drainage area must be used in a treatment train or replaced with an alternate SCM that can treat the entire WQv. When MTDs are used in a treatment train, the policies and calculations in Section 7.6.7 shall apply.

6. **Flow diverter design.** When MTDs are selected for installation in an off-line configuration, the design of the flow diverter that manages discharges greater than the MTD's design flow must be included in the SWMP.
7. **Permanent MTD identification.** Once installed, MTDs shall be identified using a sign, placard, or stamp that can be permanently affixed to a grate, manhole, or other above-ground element of the MTD
8. **Construction sequencing/MTD protection.** MTDs must be protected from inflows of construction sediment and waste. Ideally, they should be installed only after its contributing drainage area is fully and permanently stabilized. If this is not feasible, block the inflows to MTDs until full, permanent stabilization occurs.
9. **MTD substitutions during construction.** Deviation from the make, model, size, number, and design of an MTD shown in an approved SWMP is prohibited without prior approval for MTD substitution from the City. The City may require resubmittal of the SWMP with the substituted MTD to provide approval. In any case, the Record Drawing shall provide accurate information for the MTD(s) installed onsite.

   Failure to obtain prior approval for MTD substitutions may result in delays in construction inspections, approvals, or obtaining Temporary or Permanent Certificates of Occupancy.

7.6.5 MTD Sizing

See Chapter 6, Section 6.2.5 (Calculating the Water Quality Peak Discharge) for the sizing method for MTDs in Tier 2. This section presents the sizing method for MTDs in Tiers 3 and 4.

When sizing MTDs, design professionals shall adhere to sizing qualifiers related to the verified pollutant removal efficiencies that are certified by NJDEP. Such qualifiers can include, but are not limited to, a maximum flow rate, hydraulic loading rate, and MTD scaling.

MTDs in Tiers 3 and 4 must be sized for the maximum runoff generated from the 1-year, 24-hour design storm. This requires use of a different calculation procedure than that used for MTDs in other tiers to determine the water quality peak discharge (Q_{wq}). Equation 1 shall be used to design Tier 3 and 4 MTDs.

Equation 1

$$Q_{wq} = CiA$$

where: Q_{wq} = maximum water quality peak discharge (cfs)

C = Rational Method runoff coefficient for the drainage area (C = 0.95 for 100% impervious areas, otherwise see Chapter 6, Section 6.2.5).

i = rainfall intensity for 1-year, 24-hour storm at the location of the MTD (inches/hour); see steps 1 and 2 below

A = area draining to the MTD (acres)

The following steps explain how the rainfall intensity (i) is determined.

Step 1. Determine the maximum time of concentration (Tc) for the MTD's drainage area using NRCS[1] methods.

Step 2. The rainfall intensity is found using published precipitation frequency estimates published by the National Weather Service (NWS) Office of Water Prediction (OWP) in the **NOAA[2] Precipitation-Frequency Atlas of the United States, latest edition**. This data is available on the NOAA Precipitation Frequency Data Server (PFDS). In the NOAA Atlas:

a. select the data description of precipitation intensity,

b. select the location by station or using the PFDS map function at the location of land development.

[1] *NRCS is the acronym for National Resource Conservation Service, which was formerly named the Soil Conservation Service (SCS)*

[2] *NOAA is the acronym for the National Oceanic and Atmospheric Administration*

c. Find the data column for the 1-year, 24-hour storm. The rainfall intensity (i) is the value (in inches/hour) closest to the time of concentration (Tc) for the drainage area to the MTD.

The example below illustrates how to determine Q_{wq}.

Example: Determine the Maximum Water Quality Peak Discharge, Q_{wq}

A site designer has selected a hydrodynamic separator (an MTD from Tier 4) for a proposed small commercial redevelopment in Alcoa, TN. The development has a total area of 1.2 acres, all of which is impervious and located within a single drainage area. Determine the maximum water quality peak discharge, Q_{wq}, to size the MTD.

Step 1: Using NRCS methods, the site designer determines the time of concentration, Tc, is 9.3 minutes.

Step 2: Using NOAA's online Precipitation Frequency Data Server (PFDS), the site designer selects the "precipitation intensity" data description and navigates to the location of the redevelopment on the PFDS map. The resulting Point Precipitation Frequency Estimates table is partially shown in the screen capture below.

Step 3: The duration value in the table closest to the time of concentration, Tc, is 10 minutes. Thus, the rainfall intensity (i) is found for a rainfall having an average recurrence interval of 1-year and duration of 10 minutes. Thus, the rainfall intensity (i) = 2.96 inches/hour. See the red box in the screen capture.

Step 4: For Equation 1, C = 0.95 and A = 1.2 acres. Using Equation 1:

Q_{wq} = 0.95(2.96 in/hr)1.2 acres

Q_{wq} = 3.37 cfs

POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION
NOAA Atlas 14, Volume 2, Version 3

PF tabular | PF graphical | Supplementary information

PDS-based precipitation frequency estimates with 90% confidence intervals

Duration	Average recurrence interval (years)						
	1	2	5	10	25	50	100
5-min	3.71 (3.37-4.10)	4.36 (3.97-4.82)	5.11 (4.63-5.66)	5.72 (5.18-6.32)	6.54 (5.87-7.21)	7.15 (6.37-7.90)	7.79 (6.88-8.59)
10-min	2.96 (2.69-3.28)	3.49 (3.17-3.86)	4.10 (3.71-4.53)	4.58 (4.14-5.06)	5.21 (4.67-5.75)	5.70 (5.07-6.28)	6.19 (5.47-6.82)
15-min	2.47 (2.24-2.73)	2.92 (2.66-3.23)	3.46 (3.12-3.82)	3.86 (3.49-4.26)	4.40 (3.95-4.86)	4.81 (4.28-5.30)	5.21 (4.60-5.75)
30-min	1.69 (1.54-1.87)	2.02 (1.84-2.23)	2.45 (2.22-2.71)	2.80 (2.53-3.09)	3.26 (2.93-3.60)	3.62 (3.22-3.99)	3.99 (3.53-4.40)
60-min	1.05 (0.958-1.17)	1.26 (1.15-1.40)	1.57 (1.42-1.74)	1.82 (1.65-2.01)	2.17 (1.95-2.40)	2.45 (2.18-2.71)	2.75 (2.43-3.03)
2-hr	0.589 (0.537-0.648)	0.706 (0.643-0.778)	0.880 (0.800-0.968)	1.03 (0.931-1.13)	1.23 (1.11-1.35)	1.41 (1.26-1.54)	1.59 (1.41-1.75)

7.6.6 Using MTDs in a Treatment Train

A design option for SCMs that cannot manage the entire WQv, is to place it in a treatment train with an SCM. When an MTD is used in a treatment train, the following policies shall apply.

1. **MTD placement:** MTDs must always be the upstream SCM when placed in a treatment train.
2. **Multiple MTDs prohibited:** MTDs cannot be placed in a treatment train with another MTD.
3. **TSS Removal Calculation:** Treatment trains must provide an overall treatment efficiency of at least 80% total suspended solids (TSS) removal. Use Equation 2 and Table 7.6.4. to determine the total % TSS removal of the treatment train.

Equation 2

$$R = A + B - \frac{(A\ X\ B)}{100}$$

where: R = % TSS Removal for the treatment train
A = the % TSS removal applicable to the upstream SCM (this will be the MTD); use the certified % TSS removal (see Section 7.6.4 above)
B = the % TSS removal of the downstream SCM (from Table 7.6.4)

Note: the % TSS Removal values for the Tier 3 SCMs listed in the table are typical values for SCMs that DO NOT control the entire WQv. See the footnote below the table.

Table 7.6.4 % TSS Removal Values for SCMs when Used in a Treatment Train[1]

Tier	SCM Name	% TSS Removal	SCM Name	% TSS Removal
2	Bioretention Area	85%	Submerged Gravel Wetland	80%
	Dry Enhanced Swale	85%	Urban Bioretention Area	80%
3	Conventional Dry Detention Basin	10%	Stormwater Wetland (all types)	80%
	Dry Extended Detention Basin	60%	Underground Conventional Detention	10%
	Permeable Pavement System (all types)	80%	Underground Extended Detention	60%
	Sand Filter (all types)	80%	Wet Detention Basin	80%

1 – The % TSS Removal values listed in the table are used when the SCM cannot manage the entire WQv for its drainage area and is placed in a treatment train with an MTD. If the SCM can manage the entire WQv as specified in Chapter 6, Table 6.1, then the SCM is presumed to achieve 80% TSS removal, per Tennessee Rule 0400-40-10-.04, and a treatment train is not necessary.

7.6.7 Vegetation Design for Tier 2 MTDs

Tier 2 MTDs typically include vegetation, which provide pollutant removal, runoff volume reduction, and visual appeal. Their importance to MTD function means that plants, like any SCM component, have design, installation, maintenance, and replacement specifications. Plants contained within the MTD must be in keeping with plant specifications provided by the manufacturer. In the event the manufacturer does not provide plant specifications, or the City finds the manufacturer's information inadequate to fully display the intended vegetation for the MTD in the SWMP, the design professional may be required to provide a vegetation plan.

7.6.8 Protection Design

SCMs designed for stormwater quality purposes, including MTDs, must be maintained in keeping with the approved SCM design for the life of the land development[3]. **Design professionals can assist property owners with this requirement by including protective features in and around MTDs to limit the potential for damage by external factors**.

Many MTDs are designed by their manufacturer with protection in mind. With most of the MTD's components located underground, manhole covers, grates, or other protective devices are typically included to provide adequate protection from entries into the main treatment area in highly urbanized settings. Additional protection methods can include natural or decorative fencing, curbing/curb blocks, signs, stamps, or placards. The placement of trash cans around the development can also help limit the discharge of floatables to the MTD.

7.6.9 MTD Maintenance on an Active Construction Site

Once an MTD is installed, its maintenance is regulated by Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code. Further, MTDs must pass a final inspection prior to construction termination. This inspection will be performed to ensure they are constructed in accordance with the approved SWMP, undamaged, and free of sediment and debris. Thus, MTD maintenance is good practice to ensure construction termination goes smoothly. Policies are as follows:

- The property owner is responsible for MTD maintenance. If the property is still an active construction site, these responsibilities may fall to the land disturbance permittee until the project receives final approval from the City and/or a Certificate of Occupancy.
- Property owners may have others, such as a site contractor or landscaping company, maintain the MTD on their behalf. However, the City will hold the property owner responsible for ensuring it is maintained in proper operating condition (i.e., as designed and constructed) regardless of who performs maintenance activities.

[3] Tennessee Department of Environment and Conservation Rule *0400-40-10-.04*

- Maintenance activities, which include ensuring proper operation of the MTD as designed and required MTD inspections, must begin immediately following installation of the MTD.
- Maintenance activities shall be performed in keeping with the *SCM Inspection and Maintenance Manual*. Additional guidance on maintenance of newly installed MTDs located on active construction sites is provided in Table 7.6.5.

Table 7.6.5 Maintenance Activities for Newly Installed MTDs

Area or Component	Post-Installation Maintenance Requirement
Contributing Drainage Area	Keep the contributing drainage area clean and fully stabilized to prevent erosion. Sweep trash, debris, and sediment frequently so that it does not wash in the MTD during a rain event. Cover stockpiles of construction and landscape materials to prevent their exposure to rainfall.
Entire MTD	Block stormwater inflows to the MTD until the development is permanently and fully stabilized. Inspect the MTD frequently and follow the manufacturer's recommended activities for maintenance. Remove accumulated sediment, landscape debris, and trash from the MTD as often as possible. Inspect inlets and visible components of the MTD for clogging and damage; remove clogs and repair or replace damaged components as soon as they are noticed. For Tier 2 MTDs, maintain the plants (watering, weeding, etc.) in keeping with the manufacturer's guidelines.
Education	Alert onsite subcontractors to the SCM and the following requirements: • No muddy vehicles or equipment in the drainage area to the MTD. • No stockpiling or dumping of material, including landscape debris, into the MTD. • Do not blow leaves or lawn clippings into the MTD. • Remove sediment, trash, debris, and empty trash cans in the drainage area frequently.

7.6.10 References

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition.* Atlanta Regional Commission, 2016.

7.7 PERMEABLE PAVEMENT SYSTEM design specifications

Water Quality Volume (WQv) Rainfall
Tier 3 Design P = 2.5 inches or the first 75% of the volume from the 1-yr, 24-hr storm, *whichever is less*

OTHER SCM ATTRIBUTES *(cost scale is $-low, $$-medium, $$$-high)*	
Channel Protection Volume (CPv)	Yes
Detention / Retention Control	Yes
Small Storm Local Flood Control	Yes
Typical SCM Footprint Size *(percent of contributing drainage area)*	100%
Construction Cost	$$$
Operation & Maintenance Cost (when properly maintained)	$$$

PROJECT SUITABILITY				
Industrial	**Commercial**	**Residential** *(common areas only)*	**Pollutant Hotspots**	**Private Roadways** *(requires HOA)*
✓	✓	✓	✗	✓

Legend: ✓ **High** ✓ **Limited** ✗ **None**

Overview

Permeable pavement systems are stormwater control measures (SCMs) that function as both a stormwater control facility and useable pavement (e.g., parking spaces, parking lanes, walkways, etc.). The rainfall that falls on the pavement soaks into an underlying stone reservoir through voids in the pavement surface and is collected by an underdrain that discharges to the onsite stormwater conveyance system (Tier 3 configuration). These SCMs can also accept and treat stormwater from other areas of the land development.

ADVANTAGES/BENEFITS

- Multi-functional SCM reduces post-construction stormwater rates, volumes, and pollutant loads without consuming valuable land for a single-function stormwater SCM
- Particularly well suited for use on urban development sites and in low-traffic areas, such as overflow parking lots
- Can be used for detention as well as water quality control

DISADVANTAGES/LIMITATIONS

- Relatively high construction costs, which are typically offset by savings on stormwater infrastructure (e.g., storm drain system)
- Systems should be installed only by experienced personnel

LOCATION, SIZING, & COMPONENTS

- Must be designed to completely drain within 48 hours
- Must be sized to capture the 10-year storm, with adjacent conventional drainage infrastructure used for overflows
- The maximum ratio of adjacent impervious drainage area discharging to a permeable system surface area is 3:1

LONG-TERM PROTECTION

- Protect from materials that could cause clogging and failure of system (e.g., mulch, soil, sand, sediment/debris, leaf litter, etc.)
- Educational signage, curbs, and decorative walls work well for protective designs

LONG-TERM MAINTENANCE

- Operational factors include structural surface integrity, clogging/damage, cleanliness, and surrounding area maintenance
- Regular landscape maintenance (e.g., debris removal, weeding, pruning, plant removal and replacement, mulching)
- Periodic cleaning of landscape debris, trash, and sediment from the permeable pavement and its drainage area
- Vacuum sweeping is needed every six months
- Subsurface clogging may require replacement of subsurface layers or pavement surface(s)

7.7.1 General Description

There are a variety of permeable pavement surfaces available in the commercial marketplace and accepted in the City of Alcoa (City), each of which is briefly described below.

Permeable Paver Systems: A pavement surface composed of structural units with void areas that are filled with pervious materials such as gravel, sand, or grass turf. Permeable paver systems are installed over a gravel base course that provides structural support and stores stormwater that infiltrates through the system into the underlying permeable soils or into an underdrain connected to the stormwater conveyance system. Permeable pavement systems are generally designed and installed by the manufacturer. Many vendors offer maintenance packages. Three basic types of permeable paver systems are discussed below.

Permeable Pavers. Permeable pavers are solid structural units (e.g., blocks, bricks) that are installed in a way that provides regularly spaced openings through which rainfall and stormwater can rapidly pass through the pavement surface and into the underlying stone reservoir (Figure 7.7.1a). The regularly spaced openings, which generally make up between 8% and 20% of the total pavement surface, are typically filled with pea gravel. Typical permeable paver systems consist of the pavers (typically 1.5 to 3 inches thick), a fine gravel bedding layer, and an underlying stone reservoir.

Concrete Grid Pavers. Concrete grid pavers are precast concrete units that allow water to pass through large openings that are filled with gravel, sand, or topsoil and turf (Figure 7.7.1b). Concrete grid pavers are typically 3.5 inches thick and have a void ratio between 20% and 50%. This means the material used to fill the spaces between the grids has a large influence on the overall permeability (i.e., void space) of the system. A typical installation consists of the pavers, 1 to 1.5- inch sand or pea gravel bedding layer, and an underlying stone reservoir. "Void structured concrete" is a design variation that uses molded cast-in-place concrete rather than pavers.

Plastic Grid Pavers. Plastic grid pavers are similar to concrete grid pavers, but use flexible, interlocking plastic units to provide strength and structure. The units allow rainfall and stormwater to pass through large openings that are filled with gravel, sand, or topsoil and turf (Figure 7.7.1c). Since the empty plastic grids have a void ratio of between 90% and 98%, the material used to fill the spaces between the grids has a large influence on the overall permeability (i.e., void space) of the system.

Figure 7.7.1 Permeable Surfaces

Figure 7.7.1a Permeable Pavers

Figure 7.7.1b Concrete Grid Pavers

Figure 7.7.1c Plastic Grid Pavers

Figure 7.7.1d Pervious Concrete

Pervious Concrete. Pervious concrete (also known as porous concrete) is similar to conventional concrete in structure and form but consists of a special open-graded surface course, typically 4 to 8 inches thick, that is bound together with Portland cement. This open-graded surface has a void ratio of 15% to 25% (conventional concrete pavement has a void ratio of between 3% and 5%), which gives it a high permeability that allows rainfall and stormwater to rapidly pass through it into the underlying stone reservoir (Figure 7.7.1d). Although this system may not need an underlying base layer to support traffic loads, a base layer can increase the water storage capacity. Pervious concrete applications are generally designed by the site's design engineer and installed by a local concrete company.

7.7.2 Design Applications

Permeable pavement systems are highly versatile SCMs appropriate for use in many applications, including parking lots, on-street parking lanes, driveways, sidewalks, bike paths, playgrounds, and tennis courts. They are commonly used in areas that have traditionally been surfaced with impermeable concrete or asphalt (see Figure 7.7.2). There are few limits on their geometry which means they can be sized to fit into tight site layouts. Additionally, permeable pavements can be especially helpful in developed areas with little open space that cannot accommodate SCMs that require dedicated surface area for stormwater management alone. With proper design and maintenance, this SCM can have a very long service life.

Figure 7.7.2 Examples of Permeable Pavement Systems Applications

(Top left: St. Mary's College, MD parking lot with concrete grid pavers filled with gravel; Top right: Plastic grid pavers filled with grass used at the Texas AgriLife Center in Dallas, TX (Source: Texas A&M University); Bottom right: Permeable pavers used in walkway (City of Boulder CO); Bottom left: Parking lot with pervious concrete parking spaces adjacent to a standard asphalt driveway (Hallsdale Powell Utility District, Knox County TN).

Permeable pavement systems can manage both the rainfall that falls on their surface and stormwater discharged to the pavement from other impervious areas (called "run-on"). For example, roof downspouts can discharge to a properly sized permeable pavement system, thus allowing the SCM to manage stormwater for large impervious surfaces (see Figure 7.7.3). This flexibility can decrease the necessity for extra spending and land utilization linked to traditional collection, conveyance, and management infrastructure.

Figure 7.7.3 Permeable Pavement Systems and Run-on

In an example of run-on to a permeable pavement system, the permeable paver parking lot is sized to manage the rainfall on the pavers, and run-on from the impervious driveways, sidewalks, and roof. Roof downspouts discharge to the permeable paver surface (The National Apartments located in Indianapolis IN)

7.7.3 Stormwater Management Plan (SWMP) Applicability

Permeable pavement systems reduce the effective impervious cover of a development site by mimicking an undeveloped (i.e., pervious) surface area, but only to the degree their storage capacity allows. Thus, if the system is designed to manage the WQv alone, the system is permeable/pervious for the water quality rainfall (i.e., 2.5 inches for a Tier 3 design) alone. As the depth of rainfall from a storm exceeds a pavement system's storage capacity, or the rainfall intensity exceeds the system's permeability, the pavement no longer reduces stormwater volumes until storage becomes available again. In this situation, the pavement system responds to rainfall like an impervious surface in that it generates stormwater that runs off its surface and discharges to the onsite stormwater infrastructure. So, the larger the storage capacity of the pavement system, the longer the pavement will remain hydrologically "pervious" during a storm event.

For this reason, **all areas of a site must be accounted for as impervious surface area for assessing whether a site qualifies for an exemption from Stormwater Management Plan (SWMP) requirements. Proposed permeable pavements cannot be used to exempt a proposed development from stormwater requirements and avoid the design and approval of a site's stormwater infrastructure**. A proper design is necessary to ensure the site is designed to manage stormwater from ALL design storm events, even for small sites that are on the edge of stormwater management requirement applicability.

7.7.4 General Material Specifications

Permeable pavement material specifications vary according to the specific pavement product selected. Table 7.7.1 compares material specifications for different permeable pavement types. The table is general guidance only. Similar information from individual pavement system manufacturers may differ.

Table 7.7.1 Comparison of General Material Specifications by Permeable Pavement Type

Material	Specification	Notes
Permeable Pavers	• Surface open area (void content): 8% to 20% • Thickness: minimum three (3)-inch width for standard passenger vehicles and low traffic uses. May be higher for heavier loads and high-traffic applications. • Compressive strength: 55 MPa • Open void fill media: aggregate	Conformance with ASTM C936 specifications.
Concrete Grid Pavers	• Open void content: 20% to 50% • Thickness: minimum 3.5 inches • Compressive strength: 35 MPa • Open void fill media: aggregate, topsoil/grass, coarse sand	Conformance with ASTM C1319 specifications.
Plastic Reinforced Grid Pavers	• Void content: depends on fill material • Compressive strength: varies, depending on fill material • Open void fill media: aggregate, topsoil/grass, coarse sand	-
Pervious Concrete	• Void content: 15% to 25% • Thickness: typically, 4 to 8 inches • Compressive strength: 2.8 to 28 MPa • Open void fill media: None	-

7.7.5 SCM Suitability

Since permeable pavement has a very high stormwater reduction capability, it should always be considered as an alternative to conventional pavement. Use Table 7.7.2 to determine if a permeable pavement system is suitable for the application being considered.

Table 7.7.2 Suitability Factors

Factor	Suitability
Stormwater Quality Treatment	Permeable pavement systems designed in keeping with the specifications established herein can satisfy City stormwater quality treatment standards.
Channel Protection	Permeable pavement systems that will serve small contributing drainage areas (either the pavement itself or with run-on from adjacent impervious surfaces) may be suitable to address City channel protection standards.
Detention	Permeable pavement systems that will serve small contributing drainage areas (either the pavement itself or with run-on from adjacent impervious surfaces) may be suitable to address City detention (flood control) requirements.
Pollutant Treatment Capability	Permeable pavement systems can be used to address following common stormwater pollutants: Total Suspended Solids (TSS)[1] / Total Phosphorus (TP)[2] / Total Nitrogen (TN)[2] / Fecal Bacteria[1] / Metals[2,3] 80% / 50% / 50% / Not applicable / 60% *1 – If designed for the WQv specified in Tennessee Department of Environment and Conservation Rule 0400-40-10-.04.* *2 – ARC, 2016* *3 – Cadmium, Copper, Lead, and Zinc*
Treatment of Waste and Other Pollutants	Permeable pavement systems shall not be used to treat the following pollutants: • Construction sediment/waste • Landscape storage or waste • Sewage, pet, and livestock waste • Medical waste • Household & commercial wastes • Hazardous wastes • Gasoline, motor oils, greases, and other petroleum-based products • Fats, oils & grease (from food preparation) • Pesticides, fertilizers, herbicides • Other byproducts and waste materials expected, based on the property's land use
Suitability by Land Use	Privately owned permeable pavement system SCMs are not allowed in the public right-of-way. General suitability criteria by land-use type for purposes of meeting City stormwater management requirements is as follows. See Chapter 6, Section 6.6 for more information. Commercial / Industrial / Private Roadways / Single Family Residential / Multi-Family Residential Yes / Limited / Yes / Common Areas Only* / Common Areas Only* **These policies do not preclude the use of permeable pavement systems on individually owned single family or multi-family residential lots. However, systems placed on residential lots will not be considered by the city as suitable for compliance with stormwater management requirements due to the inherent difficulties in oversight and enforcement of long-term protection and maintenance requirements on residential lots.*

7.7.6 SCM Location Requirements

Location constraints for permeable pavement systems are provided in Table 7.7.3.

Table 7.7.3 Location Requirements

Physical Element	Requirement
SCM Setbacks	Setbacks to structures and roads vary, based on the scale of the permeable pavement installation. At a minimum, small- and large-scale pavement applications shall be located:

	• 15 feet down gradient from buildings (where this setback is infeasible, an impermeable liner may be used along the sides of the permeable pavement nearest the building foundation, extending from the surface to the bottom of the practice). • 100 feet from private water supply wells • 200 feet from public water supply reservoirs (measured from edge of water) • 1200 feet from public water supply wells • 50 feet from septic systems • at least 5 feet down-gradient from dry or wet utility lines.
Flow Avoidance	Permeable pavement systems shall not be located where it will receive continuous or dry weather inflows from springs, seeps, sump pumps, wash stations, or other sources.
Utility Avoidance	Permeable pavement systems shall not be located above underground dry utility lines (electric, cable, and telephone), water/wastewater infrastructure, and stormwater drainage infrastructure. Consult the local utility to determine the horizontal and vertical clearance required between SCMs and dry and wet utility lines.

7.7.7 Design Requirements

The specifications in this document do not describe the complete design of a functional permeable pavement system. **Beyond the design standards for WQv, CPv, and flood control to meet the city's stormwater management requirements, design professionals must work with commercial permeable pavement system manufacturers/vendors and to follow manufacturer's specifications for design and construction.**

A generalized depiction of a Tier 3 permeable pavement system cross section is provided in Figure 7.7.4. The minimum standards for permeable pavement system design are provided in Table 7.7.4.

Figure 7.7.4 Generalized Permeable Pavement System Main Components (Tier 3 Type)

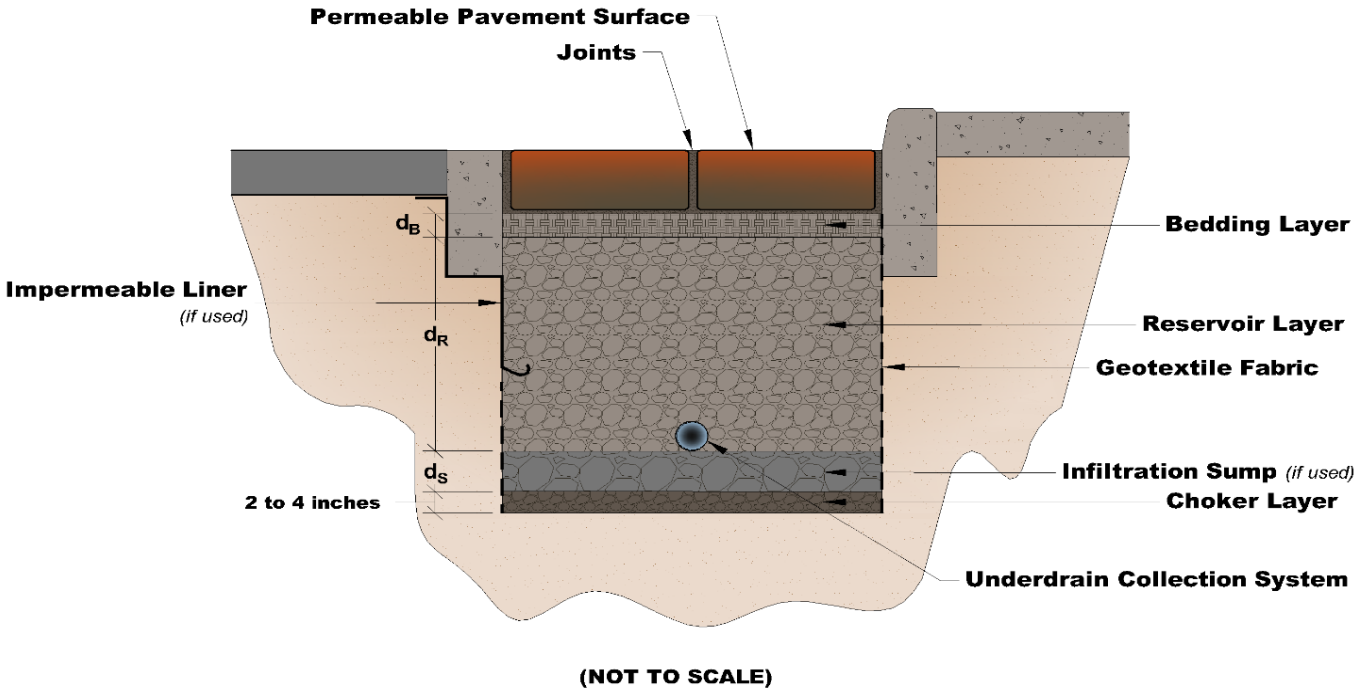


Table 7.7.4 Design Specifications for Permeable Pavement Systems

Design Element	Specification(s)
Water Quality Volume (WQv) *(Dry ED basins only)*	The water quality rainfall depth (P) for determination of WQv are as follows: • Permeable pavement with an underdrain (Tier 3 SCM): P = 2.5 inches or 75% of the total runoff volume from the 1-yr, 24-hr design storm, *whichever is less*. The design professional can select which volume to use. • In the WQv equation (Chapter 6, Equation 6.1), the SCM drainage area (A) is as follows: ○ If the pavement system is managing the rainfall that falls on the system only, (A) equals the surface area of the permeable pavement system itself. ○ If the pavement system will also manage stormwater from an adjacent impervious surface, (A) equals the surface areas of both the system itself and the adjacent impervious surface. Acceptable methods to determine WQv are presented in Chapter 6, Section 6.2 (Water Quality Management). If the pavement system can treat the entire WQv for its contributing drainage area, additional SCMs for stormwater quality treatment are not required in the contributing drainage area.
Use in a Water Quality Treatment Train *(Dry ED basins only)*	Treatment Trains with Tier 1 or 2 SCMs: The volume treated by the upstream (Tier 1 or 2) SCM may be subtracted from the WQv for a permeable pavement system, using the equation below. This WQv reduction is optional; however, if the design professional opts to include the reduction, a flow splitter, diverter, or other device must be used to prevent flow from the upstream SCM from discharging to the pavement system. $$Tv_{ds} = WQv_{ds} - Tv_{bio}$$ where: Tv_{ds} = the design volume of the Tier 3 (downstream) SCM (ac-ft); WQv_{ds} = the WQv of the Tier 3 (downstream) SCM (ac-ft); Tv_{bio} = the treatment volume of the permeable pavement system (ac-ft). Treatment Trains with Tier 4 SCMs: When a permeable pavement system is placed in a treatment train with a Tier 4 SCM (i.e., manufactured treatment device), the TSS removal percentage must be determined using the method established in Chapter 6 (SCM Standards, Methods, and SCM Selection).
Controls for Waste & Other Pollutants	Appropriate controls shall be included in the design of the permeable pavement system and any adjacent areas draining to it to address any wastes and other pollutants (see Table 7.7.2 above) that are expected after construction. Use the proposed land use as a guide to determine appropriate controls. Examples of such controls include, but are not limited to, dumpsters, trash cans, covered materials/waste storage areas, covered materials transfer areas, oil and grease waste controls, and pet waste stations.
Minimum Design Requirements in Addition to WQv	For smaller sites, a permeable pavement system may be able to address City requirements for the channel protection volume (CPv) and/or detention. A maximum drainage area is not specified; rather, the available space, stormwater volume, and subsurface capacity will drive the design. Regardless of design application (WQv, CPv, and/or detention), all permeable pavement system designs must adhere to the following rules • Permeable pavement systems shall be sized to capture the 10-year, 24-hour storm event, with adjacent conventional drainage infrastructure used for overflows up to the 25-year, 24-hour storm event. The City may require larger events if necessary for adequate flood and drainage control.

Design Element	Specification(s)
	• Permeable paver systems that will receive stormwater from adjacent impervious areas shall have a ratio of adjacent drainage area discharging to a permeable pavement system surface area no greater than 3:1. • The reservoir layer must be designed with consideration of the volume needed to detain the design storms (including chamber structures that can increase the available storage volume in the layer), expected exfiltration of water from the reservoir layer into the surrounding soil (if any), and any outlet structures used as part of the design. • Use routing calculations to provide a more accurate solution of the peak discharge and required storage volume. • Calculate outflow pathways to handle subsurface flows, which can be regulated using underdrains, volume of storage in the reservoir layer, the bed slope of the reservoir layer, and/or a control structure at the outlet.
Pavement Selection	Permeable pavement system manufacturers typically provide substantial information to assist design professionals in the selection and design of the appropriate pavement system for the intended application and site characteristics.
Minimum Depth to Water Table	Minimum separation distance (bottom of excavation to seasonally high-water table) = 2 feet Soil borings shall be used to determine the seasonally high-water table. See Appendix E (Policies for Soil Infiltration Tests & Soil Borings) for soil boring requirements.
Drawdown Time	The WQv shall fully discharge from the underdrain within 48 hours Generally, Tier 3 systems must be designed so the volume stored in the reservoir layer is detained for as long as possible (up to 48 hours) before completely discharging through the underdrain collection system.
Underdrain	All permeable pavement systems shall be designed with an underdrain collection system. Use the pavement manufacturer's specification for the underdrain pipe and design based on the expected use/loads/speeds the pavement will encounter (e.g., pedestrian traffic only, passenger vehicles only, etc.).
Internal Water Storage (IWS)	Additional storage beyond the pavement's required design volume is possible in permeable pavement systems, but not mandatory. Use the pavement manufacturer's specification to design additional internal water storage areas.
Maintenance Access and Easement	A maintenance easement to (and including) the permeable pavement system must be provided from a public roadway. It shall be designed as follows: • a minimum width of 15 feet • a maximum slope of no more than 15% • the access route in the easement shall be free of permanently affixed obstructions (e.g., trees, pools, fences without gates, permanent signs, etc.) and appropriately stabilized to withstand maintenance equipment and vehicles • to the extent feasible, allow vehicles to turn around The entire permeable pavement system, (including inlets, pretreatment devices, and the storage area.) shall be included in the easement and shall be accessible from the easement's drive path.

7.7.8 Protection Design Guidance

SCMs designed for stormwater quality purposes must be maintained in keeping with the approved SCM design for the life of the land development (Tennessee Rule *0400-40-10-.04*). **Design professionals can assist property owners with this**

requirement by including protective features in and around SCMs to limit the potential for damage by external factors. Often, the landscape and impervious features around an SCM can be tailored to its specific needs.

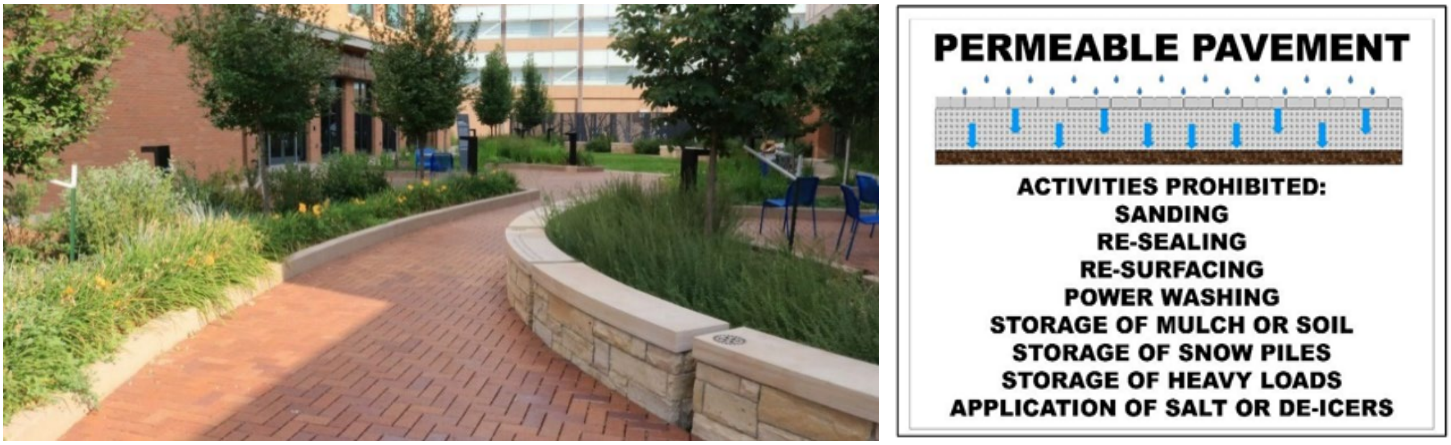
For permeable pavement systems, protection is especially important to keep the pavement surface from clogging. These SCMs should be carefully located to minimize the amount of sediment, mulch, grass clippings, leaves, nuts, and fruits that will drop or be washed onto the pavement. Routine cleaning (blowing/sweeping) can mitigate this issue; however, where these materials will be significant year-round, use conventional pavement and select a different SCM to address stormwater treatment requirements. Protection methods for permeable pavement systems are listed in Table 7.7.5. Examples are shown in Figure 7.7.5.

Table 7.7.5 Permeable Pavement Protection Measures*

Protection Measures	
• Grade adjacent pervious areas to drain away from the permeable pavement system • Locate trees and plants prone to dropping leaves, nuts, fruits, buds, or sap well away from the edges of the permeable pavement system • Hardscaping to direct or contain debris within adjacent pervious areas	• Educational or directive (e.g., no pets or maximum load) signs (see Figure 7.7.5) • Provide ample trash and cigarette disposal containers within the drainage area • Provide pet waste stations for systems located within or near pedestrian walking areas (e.g., sidewalks, trails, parking lots in recreational areas)

** The list presented in the table is not exhaustive. There may be other possible protection measures.*

Figure 7.7.5 Examples of Permeable Pavement Protection Measures



Left: Permeable pavement can be landscaped so that barriers, like curbing and walls, keep mulch, sediment, and plant debris within pervious areas. (Source: City of Boulder CO); Right: Example layout for a sign to be located at a permeable pavement (Source: NCDEQ Stormwater Design Manual)

7.7.9 Site Preparation and Land Disturbance Requirements

The following information is provided to support proper and effective construction and protection of permeable pavement systems during land disturbance activities and site construction. Mandatory requirements are identified using "shall" or "must." All other statements can be regarded as non-mandatory guidance. **Site preparation and land disturbance practices described in this section shall be shown on Erosion Prevention and Sediment Control (EPSC) plan for the proposed land development.** Table 7.7.6 provides requirements for site preparation and land disturbance practices for land developments with permeable pavement systems.

Table 7.7.6 Site Preparation and Land Disturbance Requirements for Permeable Pavement Systems

SCM Type	Policy
Permeable Pavement Systems with an Underdrain *(Tier 3 SCMs)*	Construction phasing and sequencing are critical to the success of Tier 3 permeable pavement systems. Thus, the following requirements apply: • Permeable pavement systems can infiltrate stormwater even though they have an underdrain. This capability should be preserved during construction, if possible, by identifying and protecting the permeable pavement system location using highly visible orange fencing (or similar visible protective measures) and signage to advise construction personnel not to enter the area. • Construction vehicle and equipment parking, thoroughfares, roadways, parking, and wash-off areas shall not be located where permeable pavement will be located. • The permeable pavement system shall be protected using erosion prevention and sediment control measures before, during, and, if necessary, after installation. • Site construction shall be sequenced such that the permeable pavement system is installed only after the area draining to it has been fully and permanently stabilized.

7.7.10 SCM Maintenance on an Active Construction Site

Once an SCM is installed, its maintenance is regulated by Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code. Further, SCMs must pass a final inspection prior to construction termination. This inspection will be performed to ensure they are constructed in accordance with the approved SWMP, undamaged, and free of sediment and debris. Thus, SCM maintenance is good practice to ensure construction termination goes smoothly. Relevant policies are as follows:

- The property owner is responsible for SCM maintenance. If the property is still an active construction site, these responsibilities may fall to the land disturbance permittee until the project receives final approval from the City and/or a Certificate of Occupancy.
- Property owners may have others, such as a site contractor or landscaping company, maintain the permeable pavement system on their behalf. However, the City will hold the property owner responsible for ensuring it is maintained in proper operating condition (i.e., as designed and constructed) regardless of who performs maintenance activities.
- Maintenance activities, which include ensuring proper operation of the SCM as designed and required SCM inspections, must begin immediately following installation of the permeable pavement system.
- Maintenance activities shall be performed in keeping with the *SCM Inspection and Maintenance Manual*. Additional guidance on maintenance of newly installed permeable pavement systems located on active construction sites is provided in Table 7.7.7.

Table 7.7.7 General Maintenance Activities for Newly Installed Permeable Pavement Systems (all types)

Activities
Construction sediment, materials stockpiles, and equipment and vehicles that exceed the pavement design loads are the most significant concerns for permeable pavement systems that are installed before active construction is complete. Employ the following activities to ensure the integrity of the pavement system is preserved throughout construction.

Activities
• Keep the permeable pavement system clean according to manufacturer's instructions and information in Tables 7.7.8, 7.7.9, or 7.7.10. • Remove trash, debris, and sediment from adjacent areas frequently so they do not wash onto the permeable pavement system during a rain event. • Do not allow construction and landscaping materials to be stockpiled, loaded, unloaded, or transferred on the permeable pavement and impervious areas draining to it. If this cannot be avoided, place highly durable tarps on the pavement where these materials will be stockpiled, loaded, or transferred. Cover stockpiles entirely covered to prevent exposure to rainfall. • Stabilize pervious areas as soon as possible to prevent the discharge of construction sediment to the pavement. If unstable areas are still present, ensure that erosion prevention and sediment control (EPSC) measures in these areas are maintained and effective. It may be necessary to use diversion measures to direct water away from the SCM until the area draining to it is stabilized. • Identify and cordon-off the permeable pavement from construction traffic to prevent heavy construction loads or tracking of construction-related sediments onto the permeable pavement area. Provide alternate routes for construction vehicles that avoid the pavement system and provide ample visual cues (signs, arrows, traffic barriers or cones, etc.) to ensure they can be seen and understood. • If use of the pavement is necessary while construction is on-going, provide a fully paved, clean entry and exit location for access by non-construction vehicles only. DO NOT USE GRAVEL OR SIMILAR MATERIALS for this entry/exit, as they produce fine particles and dust when under vehicle/equipment loads, and tires will carry the particles onto the pavement. Over time, this will lead to pavement clogs in areas near the gravel and the need for repairs. • If necessary, cover the permeable pavement system to protect it from sediment tracking from light construction vehicles or construction foot traffic. • The rate of sediment deposition should be monitored and cleaned per manufacturer recommendations conducted frequently. • Alert onsite construction and landscaping subcontractors to the presence of the permeable pavement system and advise them on the above rules, relevant to their onsite activities.

Table 7.7.8 Additional Maintenance Activities for Permeable Paver Systems

Activities
The general maintenance guidelines, above, apply to permeable pavers. Following the manufacturer's recommendation is best practice. Below are some guidelines specifically for permeable pavers. • Use a coarse bristle "stable" broom to clean the surface of the pavers when sediment and debris are on the surface. • Weeds can grow quickly, even on active construction sites. Weeds can shift pavers apart over time. Apply a granular weed preventative between the joints during growing season. • Do not use a high pressure water system or compressed air units on permeable pavers, because they will push the particles deeper into the pavement. • Use a commercial vacuum sweeper every six months to remove sediment accumulation and ensure continued porosity. • In the event of an oil spill, remove it promptly with granular oil absorbent. Spills should be soaked up, not rubbed. Rubbing will drive the stain deeper into the permeable pavers. • Keep the joints topped off with sand to prevent the sand-bedding layer below from deteriorating, causing the pavers to shift.

Table 7.7.9 Additional Maintenance Activities for Concrete Grid & Plastic Grid Pavement Systems

Activities

The general maintenance guidelines, above, apply to concrete and plastic grid pavement systems. Following the manufacturer's recommendation is best practice. Below are some guidelines specific to concrete/plastic grid pavement systems, either filled with gravel, sand, or turf.
• Grids filled with gravel or sand:
  ○ Sweep gravel/sand back into cells with a rake or broom.
  ○ If necessary, use a shop vacuum (6 horsepower or better) to remove a clog. The sand or gravel can be loosened to facilitate better cleaning before vacuuming. Rocks removed from the grid can be washed and put back into place.
• Grids filled with turf:
  ○ Grids filled with turf should be mowed as appropriate for the grass species used.
  ○ Do not aerate. Aeration can damage the pavement system's base.
  ○ Protect from traffic until turf root system is well established.
  ○ Large oil/antifreeze spills will effectively sterilize affected soil for years and prevent growth of most vegetation. If this occurs, the soil, base course, rings, and grass should be replaced, and soil disposed of according to City codes relating to hazardous materials.

Table 7.7.10 Additional Maintenance Activities for Pervious Concrete

Activities
The general maintenance guidelines, above, apply to pervious concrete. Following the manufacturer's recommendation is best practice. Below are some additional guidelines specific to pervious concrete. • Sediment can easily clog the pore space of pervious concrete. Using a leaf blower to remove light sediment and debris may be necessary. Additionally, a vacuum truck or walk behind unit may be needed to remove more significant sediment deposits. • Deep cleaning/unclogging is best accomplished by simultaneous pressure washing and vacuuming. Several equipment manufacturers have developed pressure washing/vacuum systems that have proven to rehabilitate the pore structure of pervious concrete. • If moss is visible on the pavement, it can be controlled by sprinkling baking soda on the surface, followed by a dry vacuuming within a few weeks to remove the debris. • Use of chemicals to clean pervious concrete should be done with extreme caution to prevent damage to the aquifer, the biological organisms within the pervious system, or the pervious concrete pavement itself.

7.7.11 References

AG-588-14. North Carolina State University. Raleigh, NC. Available online at: http://www.bae.ncsu.edu/stormwater/PublicationFiles/ Perm Pave2008.pdf.

American Society for Testing and Materials (ASTM). 2003. "Standard Classification for Sizes of Aggregate for Road and Bridge Construction." *ASTM D448-03a*. West Conshohocken, PA.

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition.* Atlanta Regional Commission, 2016

Belgard ®. *Maintenance. Now that we have completed our project, keep your pavers looking as good as new by following the maintenance tips.* Online. Accessed January 2024. https://www.belgard.com/plan-design/installation-beyond/maintenance/

Chesapeake Stormwater Network (CSN). 2009. Technical Bulletin No. 1. *Stormwater Design Guidelines for Karst Terrain in the Chesapeake Bay watershed. Version 2.0*. Baltimore, MD. Available online at: http://chesapeakestormwater.net/2012/03/technical-bulletin-no-1-stormwater-design-guidelines-for-karst-terrain/

Chesky, Sheldon. For Construction Pros.com. *Is It Possible to Maintain Porous Pavement.* Online. March, , 2015. Accessed January 2024. https://www.forconstructionpros.com/asphalt/article/12045017/maintaining-porous-pavement

CWP. 2007. *National Pollutant Removal Performance Database, Version 3.0.* Center for Watershed Protection, Ellicott City, MD.

Hathaway, J. and W. Hunt. 2007. *Stormwater BMP Costs*. Report to NC DEHNR. Department of Biological and Agricultural Engineering. North Carolina State University. Raleigh, NC.

Hirschman, D., L. Woodworth and S. Drescher. 2009. *Technical Report: Stormwater BMPs in Virginia's James River Basin: An Assessment of Field Conditions & Programs*. Center for Watershed Protection. Ellicott City, MD.

Hunt, W. and K. Collins. 2008. "Permeable Pavement: Research Update and Design Implications." *North Carolina Cooperative Extension Service Bulletin*. Urban Waterways Series.

Interlocking Concrete Pavement Institute (ICPI). 2008. *Permeable Interlocking Concrete Pavement: A Comparison Guide to Porous Asphalt and Pervious Concrete*.

Invisible Structures. *Grasspave² Maintenance Guide for Owners and Maintenance Staff.* Online. Accessed January 2024. https://www.invisiblestructures.com/wp-content/uploads/GP2MaintenanceGuide.pdf

Mrucagz, J. Wolf Paving. *Asphalt Paving Blog.* Online. November 20, 2018. Accessed January 2024. https://www.wolfpaving.com/blog/bid/85363/keep-your-porous-asphalt-pavement-looking-brand-new

MWS. 2012. *Metropolitan Nashville-Davidson County Stormwater Management Manual Volume 5 Low Impact Development*. Metro Water Services. Nashville, TN.

National Ready Mix Concrete Association. *Pervious Concrete Pavement and Operation Guide.* Online. Accessed January 2024. https://www.perviouspavement.org/downloads/pervious_maintenance_operations_guide.pdf

Northern Virginia Regional Commission (NVRC). 2007. *Low Impact Development Supplement to the Northern Virginia BMP Handbook*. Fairfax, Virginia

Philadelphia Water Department (PWD). 2007. Philadelphia Stormwater Management Guidance Manual. Philadelphia

Sustainable Infrastructure Alternative Paving Materials Subcommittee Report. Portland, Oregon. Available online at: https://www.portlandoregon.gov/bes/article/53556

Schueler, T., C. Swann, T. Wright and S. Sprinkle. 2004. *Pollution source control practices*. Manual No. 8 in the Urban Subwatershed Restoration Manual Series. Center for Watershed Protection. Ellicott City, MD.

Schueler et al 2007. *Urban Stormwater Retrofit Practices*. Manual 3 in the Urban Subwatershed Restoration Manual Series. Center for Watershed Protection. Ellicott City, MD.

Schueler, T. 2008. Technical Support for the Baywide Runoff Reduction Method. Chesapeake Stormwater Network. Baltimore, MD. http://chesapeakestormwater.net/2012/03/technical-bulletin-no-4-baywide-runoff-reduction-method/

Smith, D. 2006. *Permeable Interlocking Concrete Pavement-selection design, construction and maintenance*. Third Edition. Interlocking Concrete Pavement Institute. Herndon, VA.

TDOT. 2010. *Roadway Design Guidelines*. Tennessee Department of Transportation, Nashville, TN. https://www.tn.gov/tdot/topic/chief-engineer-design-design-guidelines

TRUEGRID® Paver. *Maintenance Tips for Permeable Paver Performance.* Online. Accessed January 2024. https://www.truegridpaver.com/permeable-paver-maintenance/

U.S EPA. 2008. June 13 2008 Memo. L. Boornaizian and S. Heare. "Clarification on which stormwater infiltration practices/technologies have the potential to be regulated as "Class V" wells by the Underground Injection Control Program." Water Permits Division and Drinking Water Protection Division. Washington, D.C.

VADCR. 2011. Stormwater Design Specification No. 7: Permeable Pavement, version 1.8, March 1, 2011. Virginia Department of Conservation and Recreation. http://vwrrc.vt.edu/swc/NonProprietaryBMPs.html.

Water Environment Research Federation (WERF). 2005. *Performance and Whole-life Costs of Best Management Practices and Sustainable Urban Drainage Systems*. Alexandria, VA.

7.8 SAND FILTER design specifications

Water Quality Volume (WQv) Rainfall
Tier 3 Design P = 2.5 inches or the first 75% of the volume from the 1-yr, 24-hr storm, *whichever is less*

OTHER SCM ATTRIBUTES *(cost scale is $-low, $$-medium, $$$-high)*	
Channel Protection Volume (CPv)	Yes
Detention / Retention Control	No
Small Storm Local Flood Control	Minor
Typical SCM Footprint Size *(percent of contributing drainage area)*	Varies by type
Construction Cost	$$$
Operation & Maintenance Cost *(when properly maintained)*	$$$

PROJECT SUITABILITY

Industrial	Commercial	Residential *(common areas only)*	Pollutant Hotspots	Private Roadways *(requires HOA)*
✓	✓	✓	✓	✓

Legend: ✓ **High** ✓ **Limited** ✗ **None**

OVERVIEW

Sand filters are structural stormwater control measures (SCMs) with multiple chambers designed to treat stormwater through filtration, using a sediment forebay, a sand bed as the primary filter media, and an underdrain system. This design specification addresses the three types of sand filters: surface; perimeter; and underground. *(Photo on the left courtesy of the City of Concord, North Carolina)*

ADVANTAGES/BENEFITS

- High pollutant removal
- Applicable to small drainage areas
- Good for highly impervious areas
- Good retrofit capability

DISADVANTAGES/LIMITATIONS

- High maintenance burden
- Not recommended for areas with high sediment content in stormwater, especially those where clay/silt is expected
- Relatively costly when compared to other SCMs
- Odor problems are possible
- Should not be installed until site construction is complete

LOCATION, SIZING, & COMPONENTS

- Must include sedimentation chamber for pretreatment
- Requires 2 to 6 feet of head depending on sand filter type
- Maximum drainage area of 10 acres (*surface sand filters*); maximum drainage area of 2 acres (*perimeter and underground sand filters*)
- Drainage areas should be comprised primarily of impervious surfaces (minimum 75% impervious coverage, although a much higher percentage is preferred)
- Underdrain system required (all types)

LONG-TERM PROTECTION

- Protect access area mechanism from tampering
- Protect from vehicles and heavy equipment
- Landscaping must not cause clogging of the filtering area

LONG-TERM MAINTENANCE

- Primary routine maintenance activities will be drainage area cleaning (e.g., street sweeping), sedimentation chamber cleaning, and sand replacement
- Provide trash cans and pet waste stations in the drainage area

7.8.1 General Description

Sand filters (also referred to as filtration basins) are SCMs that capture and temporarily store stormwater and pass it through a filter bed of sand. The filtered stormwater is collected by the underdrain and returned to the onsite stormwater conveyance system. Most sand filter systems are multi-chamber structures (see Section 7.8.2, Design Applications for additional information).

Sand filters have few site constraints beside head requirements, so they can be used on development sites where other SCMs may not be feasible. Most often, sand filters are designed as off-line systems for treatment of the water quality treatment volume (WQv). However, they are not useful for flood protection (peak discharge control) and will typically need to be used in conjunction with a conventional detention basin. Sand filter facilities utilized on-line must be designed to include flow diverters or overflow structures that will provide protection for the filter bed.

Sand filter systems can be relatively expensive to construct and install and require a relatively high level of maintenance and inspection. Because of this, sand filters are not recommended for residential land use.

Water Quality: In sand filter systems, stormwater pollutants are removed through a combination of gravitational settling, filtration, and adsorption. The filtration process effectively removes suspended solids and particulates, biochemical oxygen demand (BOD), fecal coliform bacteria, and other pollutants. Surface sand filters with a grass cover have additional opportunities for bacterial decomposition as well as vegetation uptake of pollutants, particularly phosphorus.

Channel Protection (CPv): In keeping with design allowances specified for the channel protection (CPv) standard, sand filters designed to manage the entire WQv for its drainage area also meet the CPv standard (see Chapter 6, Section 6.3).

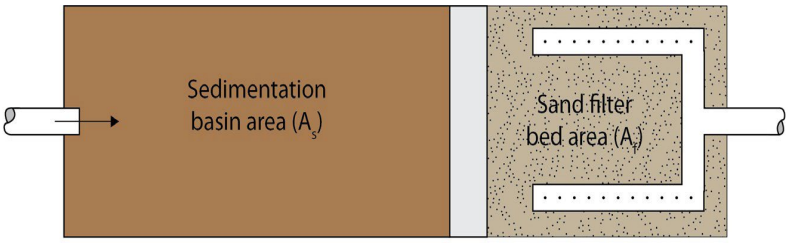
Peak Discharge Control (Flood Control/Detention): Another SCM must be used in conjunction with a sand filter system to reduce the post- development peak flows.

7.8.2 Design Applications

Sand filters are well suited for highly impervious areas where land available for SCMs is limited. Sand filters should primarily be considered for new construction or retrofit opportunities for commercial, industrial, and institutional areas where the sediment load is relatively low, such as: parking lots, driveways, loading docks, gas stations, garages, airport runways/taxiways, and storage yards. Sand filters may also be feasible and appropriate in some multi-family or higher density residential developments. The three primary sand filter designs are described in the paragraphs that follow.

Surface Sand Filter – The surface sand filter is a ground-level open air structure that consists of a pretreatment sediment forebay and a filter bed chamber (see Figure 7.8.1). This system can treat drainage areas up to 10 acres in size and must be used in an off-line configuration only, unless otherwise permitted by the City of Alcoa (City). Surface sand filters can be designed as an excavation with earthen embankments, as shown in Figure 7.8.1, or as a concrete or block structure.

Figure 7.8.1 Examples of Surface Sand Filters



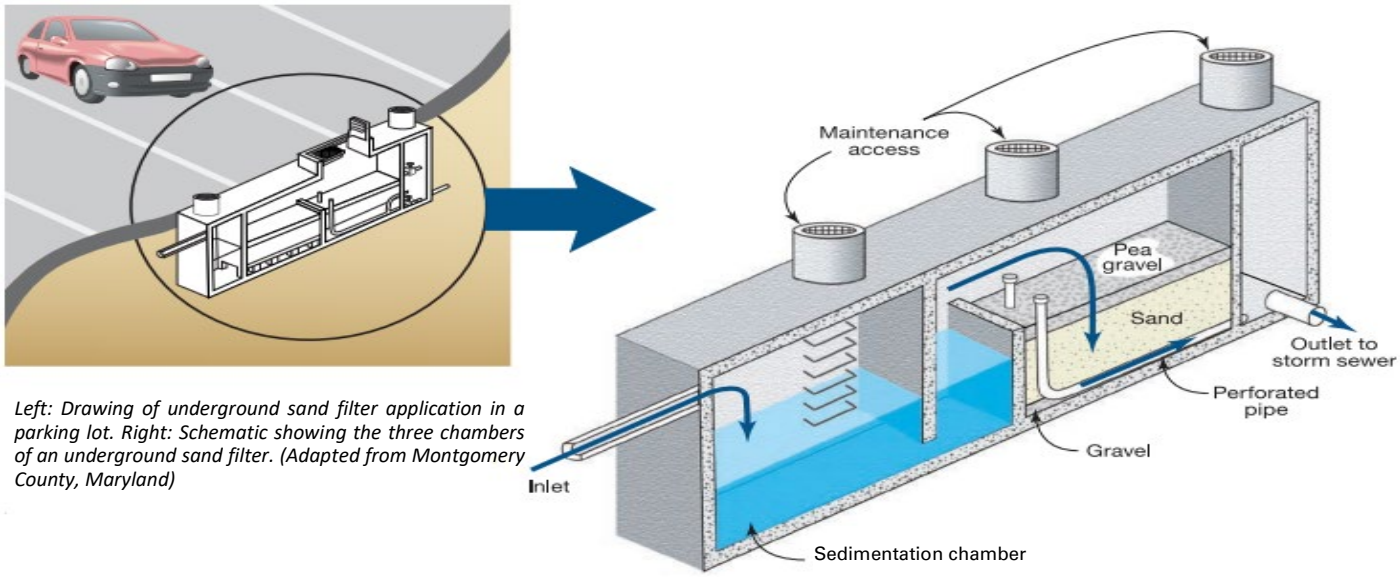
Left: Schematic of a surface sand's filter basic components (Source: GDOT Drainage Manual, 2023); Right: Sand filter bed of a surface sand filter (Source: NCDEQ Stormwater BMP Manual).

Underground Sand Filter – The underground sand filter (also known as the DC filter) is primarily intended for extremely space limited and highly dense areas. Due to their location below the surface, underground sand filters have a high maintenance burden and should only be used where properly trained inspection and maintenance staff can be ensured.

In an underground sand filter, stormwater is conveyed to the sand filter via the stormwater conveyance system. The filter device typically has three chambers (see Figure 7.8.2). The initial chamber is a sedimentation (pretreatment) chamber that services as a temporary wet pool to capture heavy sediment and trash. It is connected to the filter bed chamber by a submerged wall that prevents the passage of oil and trash. The filter bed is 18 to 24 inches deep and may have a protective screen of gravel or permeable geotextile to limit clogging. By gravity, filtered water enters the underdrain, which discharges to the third chamber and the outlet. Flows beyond the filter capacity are diverted through an overflow weir.

Underground sand filters can be purchased, fully manufactured with all components, from manufacturers of drainage infrastructure and manufactured treatment devices. Design professionals must adhere to manufacturer specifications for this design configuration and must submit said specifications with the stormwater management plan.

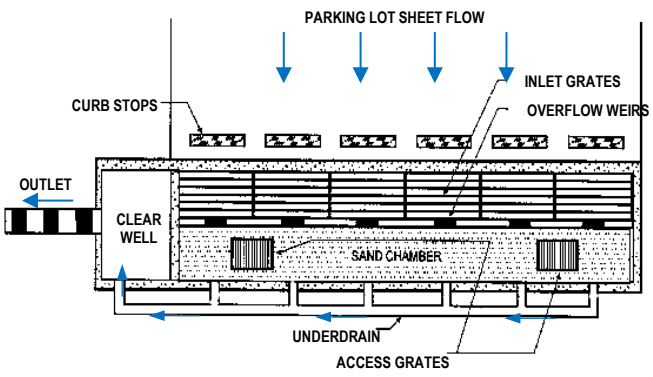
Figure 7.8.2 Examples of Underground Sand Filters



Left: Drawing of underground sand filter application in a parking lot. Right: Schematic showing the three chambers of an underground sand filter. (Adapted from Montgomery County, Maryland)

Perimeter Sand Filter – The perimeter sand filter (often called a Delaware sand filter) is an enclosed filter system typically constructed just below grade in a vault along the edge(s) of an impervious area such as a parking lot or street. It works in much the same manner as an underground sand filter. The system consists of a sedimentation chamber and a sand bed filter. Stormwater flows directly from impervious surfaces into the sedimentation chamber through a series of inlets (typically grated) located along the top of the control. Water from the sedimentation chamber then flows into the main filter area. Figure 7.8.3 presents an example of a perimeter sand filter and filter schematic.

Figure 7.8.3 Examples of Perimeter Sand Filters



Far left: Perimeter sand filter in the right-of-way (Source: Delaware DOT); Near left: Schematic of basic design elements of a perimeter sand filter (Adapted from stormwatercenter.net)

7.8.3 SCM Suitability

Use Table 7.8.1 to determine if a sand filter is suitable for the application being considered.

Table 7.8.1 Sand Filter Suitability Factors (all types)

Factor	Suitability
Stormwater Quality Treatment	Sand filters designed in keeping with the specifications established herein will satisfy City stormwater quality treatment standards.
Channel Protection	Sand filters sized to manage the entire WQv, as described in Chapter 6 (SCM Standards, Methods, and Selection), will meet the CPv standard without the need for additional design. If the basin cannot retain the entire WQv, then the CPv standard is not met.
Detention	Sand filters are generally not suitable for peak discharge (detention) control.
Pollutant Treatment Capability	Sand filters can be used to address following common stormwater pollutants: Total Suspended Solids (TSS): 80% Total Phosphorus (TP): 50% Total Nitrogen (TN)[2]: 25% Fecal Bacteria: 40% Metals*: 50% * – Cadmium, Copper, Lead, and Zinc Source: ARC, 2016;
Treatment of Waste and Other Pollutants	Sand filters shall not be used to treat the following pollutants: • Construction sediment/waste • Landscape storage or waste • Sewage, pet, and livestock waste • Medical waste • Household & commercial wastes • Hazardous wastes • Gasoline, motor oils, greases, and other petroleum-based products • Fats, oils & grease (from food preparation) • Pesticides, fertilizers, herbicides • Other byproducts and waste materials expected, based on the property's land use
Suitability by Land Use	Privately owned sand filter SCMs are not allowed in the public right-of-way. General suitability criteria by land-use type are as follows: Commercial: Yes Industrial: Yes Private Roadways: Yes Single Family Residential: No Multi-Family Residential: Common Areas Only

7.8.4 Design Requirements

Design specifications for sand filters are presented in this section, as follows.

- Table 7.8.2 presents specifications applicable to all three types of sand filters (surface, perimeter, and underground).
- The specifications in Table 7.8.2 are not sufficient for a comprehensive design of an underground sand filter. Thus, beyond the standards in the table, **design professionals must work with a drainage supply/infrastructure manufacturer of underground sand filters to ensure proper design**.
- Table 7.8.3 presents specifications applicable to surface and perimeter filters only.

The criteria provided in the tables shall be considered minimum standards and specifications for the design of sand filters and their contributing drainage areas.

Table 7.8.2 Design Specifications for Surface, Perimeter, and Underground Sand Filters

Design Element	Specification(s)
SAND FILTER LOCATION	
Flow Avoidance	Sand filters shall not be located where they will receive continuous or dry weather inflows from springs, seeps, sump pumps, wash stations, or other sources.
Utility Avoidance	Sand filters shall not be located above underground dry utility lines (electric, cable, and telephone), water/wastewater infrastructure, and stormwater drainage infrastructure. Design professionals must consult the local utility to determine the horizontal and vertical clearance required between SCMs and dry and wet utility lines.
Proximity to Trees	Avoid locating a surface sand filter within 15 feet of shade trees to avoid continued wet conditions, algal blooms, and odors during dry periods. Avoid locating any type of sand filter where leaf litter and other landscape debris will collect and clog the inlets or filter bed.
Soils	Sand filters shall not be used in drainage areas with clay and/or silt soils as clogging and failure of the filter bed can occur if the drainage area is not fully stabilized.
Controls for Waste & Other Pollutants	Appropriate controls shall be included in the design of the contributing drainage area to the SCM to address any wastes and other pollutants (see Table 7.8.1 above) that are expected on the property after construction. Use the proposed land use as a guide to determine appropriate controls. Examples of such controls include, but are not limited to, dumpsters, trash cans, covered materials/waste storage areas, covered materials transfer areas, oil and grease waste controls, and pet waste stations.
Other constraints	To avoid rapid clogging and failure of the filter media, the use of sand filters shall be avoided for drainage areas that: • have less than 75% impervious cover; or • are expected to yield high amounts of sediment comprised of clay/silt soils after construction is finished.
SAND FILTER DESIGN	
Water Quality Volume (WQv)	The water quality rainfall depth (P) for determination of WQv is: • P = 2.5 inches, or • The WQv is the first 75% of the volume of the 1-yr, 24-hr storm. The design professional can select the volume to use for design from the above two options. Acceptable methods to determine WQv are presented in Chapter 6 (SCM Standards, Methods, and Selection). Sand filters that cannot treat the entire WQv for its contributing drainage area must be used in a treatment train or replaced with an alternate SCM that can treat the entire WQv.
Use in a Water Quality Treatment Train	If the sand filter cannot manage the entire WQv for its contributing drainage area, it must be placed in a treatment train with another SCM. See treatment train policies and calculations in Chapter 6, Section 6.2.4 for treatment train policies and calculations.
Drawdown Time	The treatment volume (typically this will be the WQv) shall fully discharge from the underdrain collection system within 48 hours.
Outlet Structures	Sand filter discharge velocities shall not exceed 5 ft/sec.
Emergency Overflow/Spillway	An emergency or bypass spillway shall be included to safely pass flows that exceed the treatment volume (typically this is the WQv).

Design Element	Specification(s)
Offline and Online Design Configuration	An offline configuration is constructed away from the main flow path for the drainage area, avoiding large flood flows. A flow splitter, diversion structure, or other means is used upstream of the sand filter's inlets to redirect the sand filter's design volume (typically this will be the WQv) from the main flow path to the SCM while still allowing larger flows to remain in the main flow path. • ***Surface and perimeter sand filters*:** An offline configuration is required • ***Underground sand filters*:** An offline configuration is preferred; however, consult the sand filter manufacturer Flow regulators (flow splitters, diversion structures, and overflow structures) shall be designed in keeping with Sections 7.14 (Inlets, Pretreatment, and Energy Dissipation) and 7.16 (Overflow Structures).
Safety Features	Inlets, access grates and outlets shall be designed and maintained so as not to permit access/entry by unauthorized personnel.
Maintenance Access and Easement	A maintenance easement shall be provided to the sand filter from a driveway, public or private road. It shall be designed as follows: • a minimum width of 15 feet • a maximum slope of no more than 15% • the access route in the easement shall be free of permanently affixed obstructions (e.g., trees, pools, fences without gates, permanent signs, etc.) and appropriately stabilized to withstand maintenance equipment and vehicles • to the extent feasible, allow vehicles to turn around The entire sand filter, (including inlets, pretreatment devices, the storage area embankments, outlet structure, and emergency spillway) shall be included in the easement and shall be accessible from the easement's drive path.

Table 7.8.3 Design Specifications for Surface and Perimeter Sand Filters

Design Element	Specification(s)
SCM Setbacks	Minimum setbacks, measured from the edge of the sand filter, are as follows: • 10 feet from a property line • 100 feet from private water supply wells. If the well is downgradient from a land use with a high pollutant load (hotspot area), then the minimum is 250 feet • TDEC specified distance per designated category from public water supply wells • 50 feet from underground septic systems
Contributing Drainage Area	Maximum contributing drainage area: • ***Surface sand filter***: 10 acres • ***Perimeter sand filter***: 2 acres Maximum slope of CDA (both sand filter types): 6%
Energy Dissipation	• Energy dissipation shall be provided for inflow velocities greater than 5 ft/sec • Exit velocities from sedimentation chambers must be less than 5 ft/sec
Side Slopes	***Surface sand filters***: no restrictions; however, ensure side slopes are stable and the filter bed is safely accessible to maintainers that enter the filter bed ***Perimeter sand filters***: use precast or cast-in-place structures to create a stable, vertical side wall.

Design Element	Specification(s)
Minimum Depth to Water Table	Minimum separation distance (bottom of excavation to seasonally high-water table) = 2 feet Soil borings shall be used to determine the seasonally high-water table. See Appendix E (Policies for Soil Infiltration Tests & Soil Borings) for soil boring requirements.
Minimum Hydraulic Head	Minimum hydraulic head: • ***Surface sand filter:*** 5 feet • ***Perimeter sand filter:*** 2 to 3 feet The hydraulic head is the difference in the inflow elevation, including the design ponding depth, to the outflow elevation at the underdrain invert elevation or bottom of SCM at its downstream end.
Materials, Sizing, Geometry, and Underdrain	***Surface sand filter:*** see Section 7.8.5 below ***Perimeter sand filter:*** see Section 7.8.6 below

7.8.5 Additional Specifications for Surface Sand Filters

The following specifications pertain only to surface sand filters. A general schematic of a surface sand filter is presented in Figure 7.8.4.

- **Structure:** The sand filter may be constructed of impermeable materials such as concrete, or through the use of excavations and earthen embankments. Inlet and outlet structures shall be located at opposite ends of the chamber.
- **System sizing:** The entire sand filter system, including the sedimentation chamber, must be designed to temporarily hold at least 75% of the treatment volume (typically this will be the WQv) prior to filtration. Figure 7.8.5 illustrates the distribution of the treatment volume among the various components of the surface sand filter.
- **Sedimentation chamber sizing:** The sedimentation chamber must:
  - hold at least 25% of the treatment volume (typically this will be the WQv), and
  - have a length-to-width ratio of at least 2:1.
- **Filter (sand) bed sizing and composition:**
  - Size the filter bed based on the principles of Darcy's Law (i.e., the flow rate is proportional to the hydraulic gradient and the hydraulic conductivity). Use 3.5 ft/day for the coefficient of permeability (k) for sand.

$$A_f = \frac{DSv \times d_f}{k \times (h_f + d_f) \times t_f}$$

where:

A_f = surface area of the ponding area (ft^2)

DSv = design storage volume (typically this will be the WQv) (ft^3)

d_f = planting media depth (ft)

k = coefficient of permeability of planting media (ft/day) *(use 3.5 ft/day for sand)*

h_f = average height of water ponding above filter bed (ft)

t_f = design drain time (days*) (two days is the recommended maximum)*

- The filter bed is comprised of an 18-inch layer of clean washed medium aggregate concrete sand (ASTM C-33) on top of the underdrain (see Figure 7.8.6).
- Place a permeable filter fabric/geotextile between the sand bed layer and underdrain layer to prevent clogging of the underdrain.
- Optional. If the sand bed will be vegetated, place a layer of permeable filter fabric/geotextile above the sand bed. A 3 to 4-inch layer of topsoil layered on top of the fabric. See also vegetative cover requirements below.

- **Excavation liner:** Sand filters constructed of earthen walls/embankments, line the bottom and side slopes of the excavation with an impermeable liner before installation of the underdrain and filter media to prevent migration of the in-situ soil into the sand filter layers and avoid sinkhole formation.
- **Underdrain Design:**
  - **Gravel jacket:** The perforated pipe is embedded in an 8-inch gravel jacket of clean-washed No. 1 stone aggregate (1.5 inches to 3.5 inches in diameter, with a void space of about 40%). Aggregate contaminated with soil shall not be used.
  - **Pipe:** Use 6-inch perforated pipe underdrain (PVC AASHTO M 252, HDPE, or other suitable pipe material) Holes shall be 3/8-inch diameter and spaced approximately 6 inches on center. Pipe spacing shall be a maximum of 10 feet on center. At a minimum, provide 1 underdrain for every 1,000 square feet of surface area (see Figure 7.8.5).
  - **Slope:** The underdrain shall have a minimum grade of 1/8-inch per foot (1% slope).
  - **Cleanouts:** Cleanouts shall be designed as follows:
    - Constructed of a 4- to 6-inch diameter solid wall (not perforated) PVC (AASHTO M 252) pipe that couples with the underdrain.
    - One cleanout per line of underdrain pipe, extend to the surface of the SCM, rising high enough to be readily visible to SCM maintainers and landscape crews. Each cleanout must have a watertight, removable cap and lock to prevent tampering and vandalism.
  - **Observation Wells:** An observation well shall be placed at the upstream and downstream ends of the filter bed, with each placed on the centerline of the SCM. Observation wells shall be designed in keeping with the following requirements.
    - Use 4-inch diameter perforated PVC (AASHTO M 252) pipe that extends from the bottom of the SCM to the surface, rising high enough to be readily visible to SCM maintainers and landscape crews.
    - A visible (e.g., brightly colored) floating marker shall be placed in each observation well to allow the viewer to see the water level.
    - The top of each well shall have a watertight, removal cap and lock to prevent tampering and vandalism.
- **Vegetative cover:** The filter bed of earthen surface sand filters may be covered with a 3- to 4-inch layer of topsoil and vegetative cover, overlaying a filter fabric/permeable geotextile above the sand bed. Typically, the cover is turf grass, but can also be any non-woody ground cover that will not damage the filter bed. Plants should be selected carefully to ensure no tap roots will penetrate the filter fabric located between the topsoil layer and filter bed (sand).

Figure 7.8.4 Schematic of Surface Sand Filter ***(Source: ARC, 2016)***

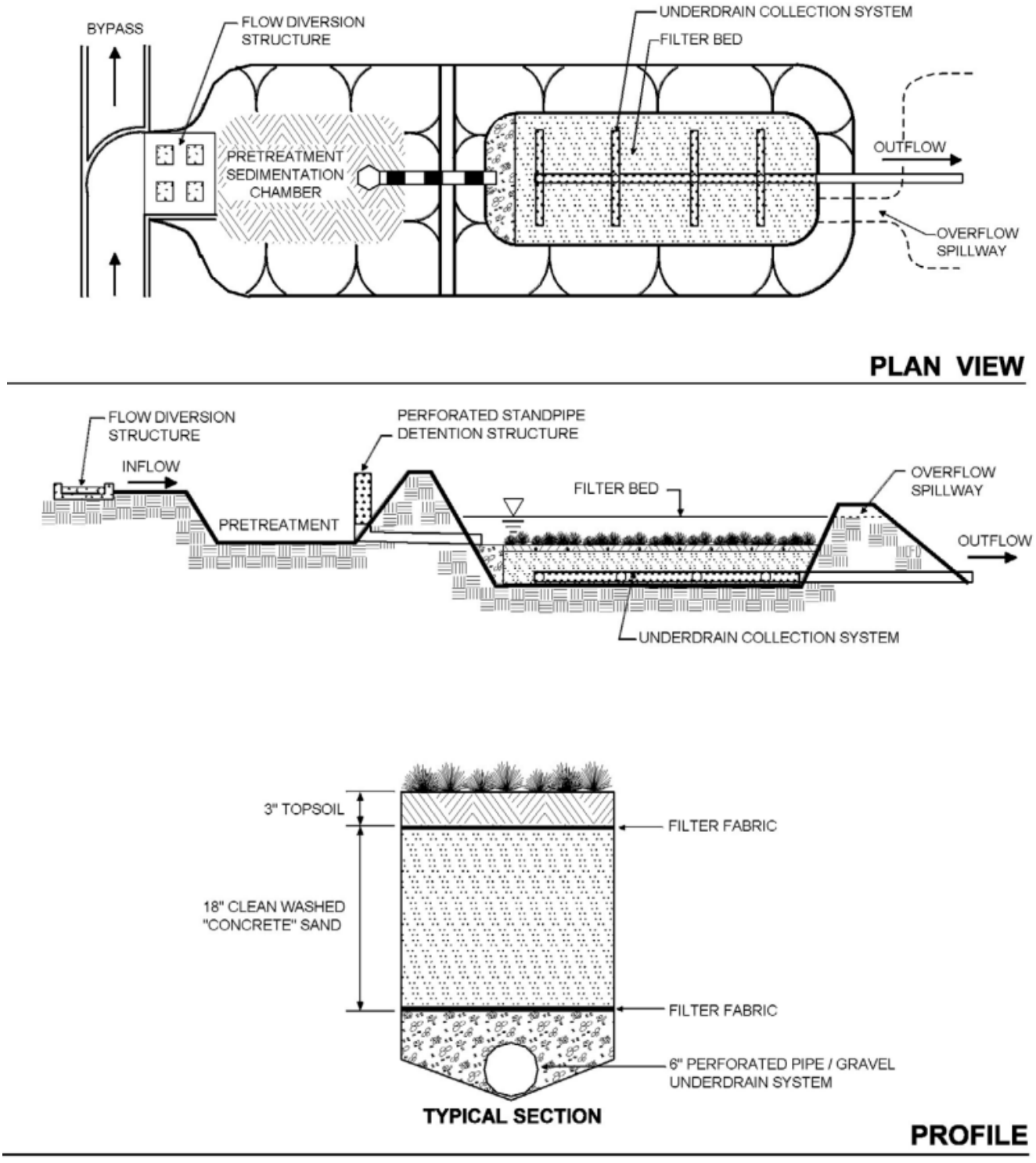
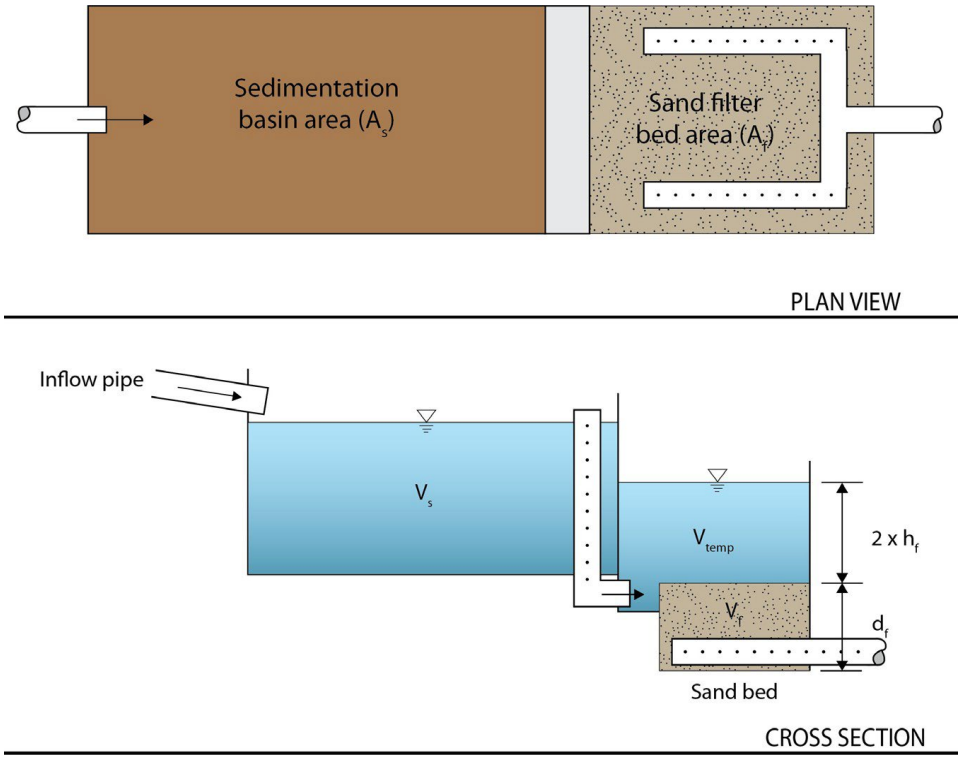
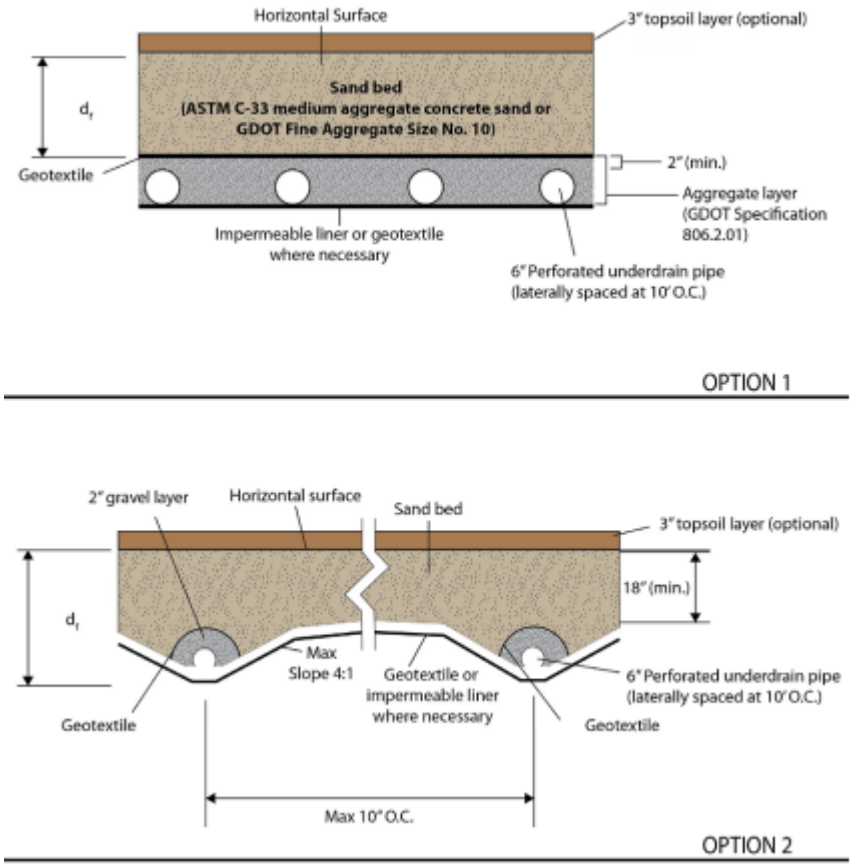


Figure 7.8.5 Surface Sand Filter Volumes



Source for both figures: GDOT Drainage Manual, 2014

Figure 7.8.6 Surface Sand Filter Cross-Sections



Variables depicted in Figures 7.8.5 and 7.8.6 are as follows:

A_s = the surface area of the sedimentation basin
A_f = surface area of the filter media
V_s = volume within the sedimentation basin
V_{temp} = temporary volume stored above the filter bed
V_f = volume within the voids in the filter bed
h_f = average height of water above the filter media
d_f = depth of filter media (minimum 18 inches)

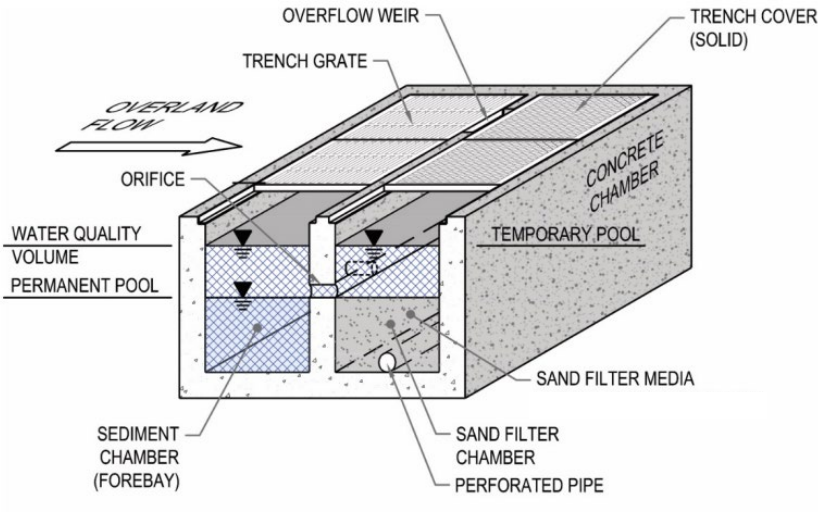
7.8.6 Additional Specifications for Perimeter Sand Filters

The following specifications pertain only to perimeter sand filters.

- **Structure:** See Figure 7.8.7. Perimeter sand filters are typically constructed of impermeable materials such as concrete. Inflow enters perpendicular to the length of the sand filter through trench grates over the sedimentation chamber. The trench grates also provide access to the sedimentation chamber for maintenance purposes. Once filtered, the water enters an underdrain pipe located throughout the length of the filter bed chamber until the outflow point located at the downstream end of the filter.

Figure 7.8.7 Concrete Perimeter Sand Filter

Source: NCDEQ Stormwater Design Manual

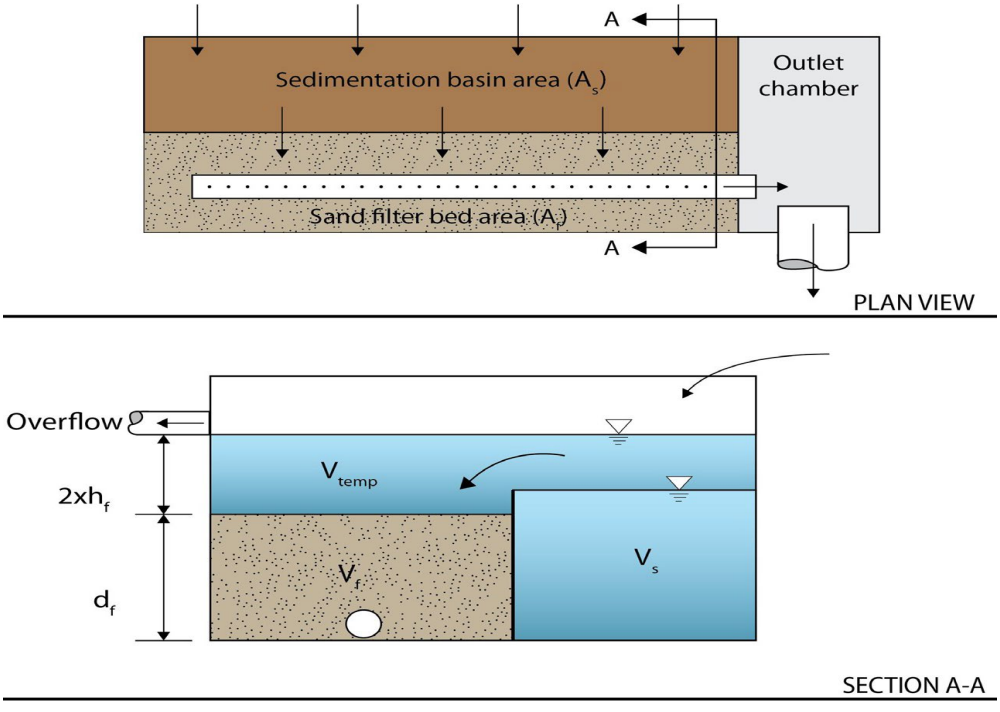


Source: MA (DEP, 2008)

- **System sizing:** The entire sand filter system, including the sedimentation chamber, must be designed to temporarily hold at least 75% of the treatment volume (typically this will be the WQv) prior to filtration. Figure 7.8.8 illustrates the distribution of the treatment volume among the various components of the surface sand filter.
- **Sedimentation chamber sizing:** The sedimentation chamber shall be sized to at least 50% of the computed WQv.
- **Filter (sand) bed sizing and composition:**
  - Size the filter bed based on the principles of Darcy's Law (i.e., the flow rate is proportional to the hydraulic gradient and the hydraulic conductivity). Use 3.5 ft/day for the coefficient of permeability (k) for sand. See Step 4 of the design procedure in Section 7.8.7.
  - The filter bed is comprised of a 12- to 18-inch layer of clean washed medium aggregate concrete sand (ASTM C-33) on top of the underdrain (see Figure 7.8.8).
  - Place a permeable filter fabric/geotextile between the sand bed layer and underdrain layer to prevent clogging of the underdrain.
  - Access to the filter bed shall be provided through solid trench covers placed along the length of the filter bed chamber. Covers shall be sufficient in number and size to allow unimpeded access to the entire length, width, and depth of the filter bed for maintenance and repair. Covers may need to be secured to prevent tampering and vandalism.

- **Underdrain Design:**
  - **Gravel jacket:** The perforated pipe is embedded in an 8-inch gravel jacket of clean-washed No. 1 stone aggregate (1.5 inches to 3.5 inches in diameter, with a void space of about 40%). Aggregate contaminated with soil shall not be used.
  - **Pipe:** Use 4-inch perforated pipe underdrain (PVC AASHTO M 252). The holes shall be 3/8-inch diameter and spaced approximately 6 inches on center.
  - **Slope:** The underdrain shall have a minimum grade of 1/8-inch per foot (1% slope).
  - **Cleanouts and Observation Wells:** A cleanout/observation well shall be installed at the upstream and downstream ends of the underdrain, at its centerline. For very long perimeter sand filters, additional cleanouts may be added along the length of the filter bed. The maximum spacing is 50 linear feet between cleanouts.
    - Construct the upstream and downstream cleanouts/observation wells using 4- to 6-inch diameter perforated PVC (AASHTO M 252) pipe that couples with the underdrain. They should extend from the bottom of the SCM to just above the filter bed surface, rising high enough to be readily visible to SCM maintainers. Each must have a watertight, removable cap and lock to prevent tampering and vandalism.
    - A visible (e.g., brightly colored) floating marker shall be placed in each observation well to allow the viewer to see the water level.
    - Additional cleanouts along the length of the filter bed (if any), can be constructed of 6-inch diameter solid (not perforated) PVC (AASHTO M252) pipe.

Figure 7.8.8 Perimeter Sand Filter Dimensions and Volumes ***(Source: GDOT Drainage Manual, 2023)***

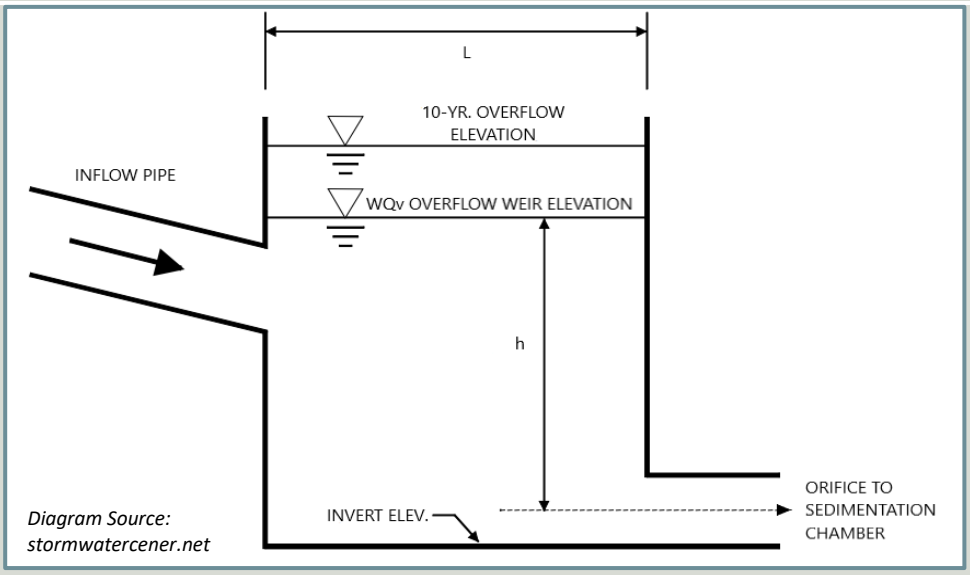


A_s = the surface area of the sedimentation basin
A_f = surface area of the filter media
h_f = average height of water above the filter media
d_f = depth of filter media
V_{temp} = temporary volume stored above the filter bed
V_f = volume within the voids in the filter bed
V_s = wet pool volume within the sedimentation basin

7.8.7 Design Procedure

Table 7.8.4 provides the design procedure for sand filters.

Table 7.8.4 Design Procedure

Step	Design Activity
Step 1	**Evaluate sand filter feasibility.** • Use the specifications in Table 7.8.2 to determine if a sand filter is feasible for the selected location on the land development site. Consider especially whether it is appropriate for the proposed development based on the intended land use of the property, the maintenance burden, and assumptions or knowledge of how the property owner(s) will care for the sand filter after construction (e.g., self-maintenance, property/facilities management maintenance, landscape contractor). If possible, include the property owner(s) in SCM selection since they will be responsible for maintenance. • If a sand filter is determined to be feasible and appropriate for the proposed development, determine which type will be used and create a rough layout of its dimensions, taking into consideration existing trees, utility lines, and other obstructions to ascertain if it will fit into the desired space, given its general design requirements.
Step 2	**Calculate the design storage volume (DSv) for the contributing drainage area**. • Typically, the DSv = WQv, unless the sand filter cannot manage the entire WQv and will be designed in a treatment train or will be used to control a volume larger than the WQv. • Use one of the calculation methods explained in Chapter 6 Section 6.2 (Water Quality Management) to calculate WQv.
Step 3	**Determine the water quality peak discharge (Q_{wq}) and head, then size the diversion structure for flows larger than the WQv.** • See Chapter 6, Section 6.2.5 (Calculating the Water Quality Peak Discharge) for determination of Q_{wq}. • Use the 10-year, 24-hour storm for the overflow elevation. • The graphic (below) and associated text provides an example of flow diversion structure design. • Size the orifice to the sedimentation chamber (the low flow orifice) using the orifice equation: $$Q = CA(2gh)$$ where: $$A = \pi \frac{d^2}{4}$$  *Diagram Source: stormwatercener.net*

Step	Design Activity
Step 4	**Size the filter (sand) bed chamber.** $$A_f = \frac{DSv \times d_f}{k \times (h_f + d_f) \times t_f}$$ *where:* A_f = surface area of the ponding area (ft^2) DSv = design storage volume (typically this will be the WQv) (ft^3) d_f = planting media depth (ft) k = coefficient of permeability of planting media (ft/day) *(use 3.5 ft/day for sand)* h_f = average height of water ponding above filter bed (ft) t_f = design drain time (days*) (two days is the recommended maximum)*
Step 5	**Size the sedimentation chamber** Surface sand filter: Size to at least 25% of the computed WQv and have a length-to-width ratio of 2:1. Perimeter sand filter: Size to at least 50% of the computer WQv. The same approach (the Camp-Hazen equation) is used to compute the required surface area for both types of sand filters. $$A_s = \frac{Q_O}{w} E'$$ *where:* A_s = surface area of the sedimentation chamber (ft^2) Q_O = rate of outflow from sedimentation chamber = WQv over a 24-hour period w = Particle settling velocity (ft/sec) *(use 0.0033 ft/sec)*[1] E' = sediment trapping efficiency *(use 2.30)* The equation reduces to: $$A_s = 0.0081(WQv)$$
Step 6	**Compute the minimum volume of the entire sand filter (V_{min}), including both the sedimentation chamber and filter bed chamber.** $$V_{min} = 0.75(WQv)$$
Step 7	**Compute storage volumes for entire system and the sedimentation orifice size** $$V_{min} = 0.75(WQv) = V_s + V_f + V_{f-temp}$$
Step 7a	**For a SURFACE SAND FILTER** (see Figures 7.8.5 and 7.8.6 for variable definitions) (1) Compute V_f = water volume within filter bed/gravel/pipe = A_f * d_f * n; where n = porosity = 0.4 (2) Compute $V_{f\text{-}temp}$ = temporary storage volume above the filter bed = 2 * h_f * A_f (3) Compute Vs = volume within sediment chamber = V_{min} - V_f - $V_{f\text{-}temp}$ (4) Compute h_s = height in sediment chamber = V_s/A_s (5) Ensure h_s and h_f fit available head and other dimensions still fit. Change as necessary in design iterations until all site dimensions fit.

[1] Shaver and Baldwin, 1991

Step	Design Activity
7b	(6) Size orifice from sediment chamber to filter chamber to release V_s within 24-hours at average release rate with 0.5 h_s as average head. (7) Design outlet structure with perforations allowing for a safety factor of 10 times the orifice capacity. (8) Size distribution chamber to spread flow over filtration media – level spreader weir or orifices. **For a PERIMETER SAND FILTER** (see Figure 7.8.8 for variable definitions) (1) Compute V_f = water volume within filter bed/gravel/pipe = A_f * d_f * n where: A_f = surface area of filter bed (ft^2) d_f = filter bed depth (1.5 ft) n = porosity = 0.4 (2) Compute V_w = wet pool storage volume A_s * 2 feet minimum (3) Compute $V_{f\text{-}temp}$ = temporary storage volume = V_{min} – (V_f + V_w) (4) Compute h_{temp} = temporary storage height = $V_{f\text{-}temp}$ / (A_f + A_s) (5) Ensure $h_{temp} \geq 2 * h_f$, otherwise decrease h_f and re-compute. Ensure dimensions fit the available head and area. Change as necessary in design iterations until all site dimensions fit. (6) Size distribution slots from sediment chamber to filter bed chamber.
Step 8	**Design inlets, pretreatment facilities, underdrain, and outlet structures** See Table 7.8.3 and Sections 7.8.5 and 7.8.6 for more specifications.
Step 9	**Computer the overflow weir sizes** **For a SURFACE SAND FILTER:** (1) Size overflow weir at elevation h_s in sedimentation chamber (above perforated standpipe) to handle a surcharge of flow through the sand filter system from the 25-year storm. (2) Plan inlet protection for overflow from sedimentation chamber and size overflow weir at elevation h_f in filtration chamber (above the perforated standpipe) to handle a surcharge of flow through filter system from the 25-year storm. **For a PERIMETER SAND FILTER:** Size the overflow weir at the end of the sedimentation chamber to handle excess inflow, set at the WQv elevation.
Step 10	**Design the vegetation (if desired for surface sand filters only) and protection measures.** Vegetative cover requirements are addressed in Section 7.8.5. Use guidance found in Section 7.8.8 (below) to design protection measures.

7.8.8 Protection Design Guidance

SCMs designed for stormwater quality purposes must be maintained in keeping with the approved SCM design for the life of the land development[2]. **Design professionals can assist property owners with this requirement by including protective features in and around SCMs to limit the potential for damage by external factors**. Often, the landscape and impervious features around an SCM can be tailored to its specific needs, and therefore used to protect its critical components.

For surface sand filters, protection is important for the filter bed and other exposed components, to prevent damage by persons or vehicles that may inadvertently enter the filter bed. Protection methods that work well are listed in Table 7.8.5.

[2] Tennessee Rule *0400-40-10-.04*

Table 7.8.5 Sand Filter Protection Measures*

Passive Protection Measures	Active Protection Measures
• Natural fencing such as vegetation borders/screens (woody/prickly shrubs or tall grass) • Driveways, sidewalks, or walkways around the SCM	• Fencing, curbs, curb blocks • Hardscaping, such as block walls, boulders, cobbles • Educational or directive (e.g., no pets, no entry) signs • Pet waste stations and trash cans near the SCM

** The list presented in the table is not exhaustive. There may be other possible protection measures.*

7.8.9 Site Preparation, Land Disturbance, and Installation Requirements

The information in Table 7.8.6 provides a typical construction sequence to properly install sand filters. These steps may be modified to reflect different applications or site conditions. **Installation practices shall be shown in the EPSC and SWMP plans, as appropriate for the proposed land development.**

Table 7.8.6 Installation Steps

Step	Requirement
Step 1	The installation site shall be checked for existing utilities prior to construction. Sand filters can quickly become clogged if they receive sediment as a result of construction. Thus, sequence site construction so the sand filter is installed only after the area draining to it has been fully and permanently stabilized. • If this is infeasible, block the inlet(s) to the sand filter to entirely prevent inflows of stormwater and cover the filter bed (if exposed) to avoid damage during construction. Install additional erosion prevention and sediment control (EPSC) measures as necessary. For surface sand filters, consider installing temporary signage and high visibility fencing to alert onsite construction staff to the SCM's presence. Supervision during construction is required to ensure the sand filter is constructed/installed in accordance with the approved EPSC and SWMP plans. The design professional or a designee under their supervision must inspect the sand filter at critical stages of construction, such as underdrain installation and final inspection. This ensures that the contractor's interpretation of the plan is consistent with the design professional's intentions and allows the design professional to certify (in the as-built plan) that the sand filter is built in keeping with the permitted plan.
Step 2	Construction sites can have many different contractors responsible for different portions of the site or aspects of construction. Therefore, subtle differences in site grading, drainage, and paving elevations from those identified in the design, or relative to different areas/aspects of construction, can affect the hydraulics of the proposed sand filter. The following practices should be done prior to construction to ensure the approved design is still valid: • During the preconstruction meeting, review and confirm that the actual boundaries of the sand filter's contributing drainage area and inlet elevations conform with the approved design. • Any changes that result from the preconstruction meeting must be shown as a revision to the SWMP and resubmitted to the City for approval. This includes changes to material certifications for aggregate, media, and liners if not approved prior to the preconstruction meeting.
Step 3	Install protection and EPSC measures so that construction site stormwater is directed away from the sand filter area. Special protection measures, such as erosion control fabrics, may be necessary to protect vulnerable side slopes from erosion during the construction.

Step	Requirement
Step 4	Excavate the sand filter to its appropriate design depth and dimensions, providing appropriate shoring and sheeting for deep excavations. • If the drainage area to the filter is not fully stabilized, it may be appropriate to excavate the sedimentation chamber first, then seal it to trap sediments prior to installation of the main treatment area. • During and after excavation of the sand filter, all excavated materials shall be placed downstream, away from the sand filter, to prevent redeposit of the material during runoff events. • **Confirm and document invert elevations and dimensions for all structures such as vaults and pipes prior to Step 5.**
Step 5	Install structures such as inlet boxes, reinforced concrete boxes, inlet controls, and outlet controls according to approved SWMP.
Step 6	For earthen surface sand filters, place liner layer on bottom and sides ensuring continuous contact with subgrade. Ensure adequate overlap of 16 inches. For sand filters constructed of concrete or other hard materials (surface and perimeter), place pre-cast vault or perform form work, reinforcement, and concrete work in conformance with project specifications.
Step 7	Place underdrain gravel jacket and set the underdrain according to plans. Place geotextile above underdrain. Secure the geotextile at least 4 feet outside filter bed
Step 8	Place sand layer in 6 to 8 inch lifts within structure or excavated area, over the underdrain and storage stone and cover with debris screen, stone filter layer, or non-woven fabric.
Step 9	Backfill to finished sand grade. Ensure backfill is properly compacted in accordance with specifications. Ensure backfill process does not disrupt pipe placement and configuration.
Step 10	Install any remaining structures that could not be placed in Step 5, such as inlet boxes, reinforced concrete boxes, inlet controls, and outlet controls according to approved SWMP.
Step 11	For surface sand filters that will have other cover (e.g., river cobbles, pea gravel), place the surface cover. For surface sand filters with vegetative cover: • Install filter fabric/geotextile on sand layer, with at least 16 inches of overlap at seams and at least 4 feet of extension beyond filter bed. • Install temporary irrigation measures, if needed, to ensure plants will be watered during the remainder of site construction. • Install plants as shown in the approved SWMP.
Step 12	EPSC measures can be removed from the inlets once the sand filter's side slopes and contributing drainage area are fully and permanently stabilized. However, if the area draining to the sand filter includes newly installed asphalt, the EPSC devices in place to block the inlets should remain in place for at least three storm events after asphalt installation. A substantial amount of fine particles and grit are discharged from newly installed asphalt during the first several storms that produce runoff after installation. Maintenance will be required to remove the particles and grit if EPSC devices are removed too early.
Step 13	Maintain the sand filter in keeping with Section 7.8.10 below. Prepare the As-Built Plan and submit to the City for review and approval with the engineer's as-built certification before a final Certificate of Occupancy can be obtained. Advise the landowner (i.e., the person(s) taking ownership of the property immediately after its development) of the presence of the sand filter and provide them with a copy of the property's Record Drawing and SCM maintenance plan. The plan must clearly show the location of the sand filter on the property and list the activities (and their frequencies) necessary for its proper maintenance.

7.8.10 SCM Maintenance on an Active Construction Site

Once an SCM is installed, its maintenance is regulated by Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code. Further, SCMs must pass a final inspection prior to construction termination. This inspection will be performed to ensure they are constructed in accordance with the approved SWMP, undamaged, and free of sediment and debris. Thus, SCM maintenance is good practice to ensure construction termination goes smoothly. Relevant policies are as follows:

- The property owner is responsible for SCM maintenance. If the property is still an active construction site, these responsibilities may fall to the land disturbance permittee until the project receives final approval from the City and/or a Certificate of Occupancy.
- Property owners may have others, such as a site contractor or landscaping company, maintain the sand filter on their behalf. However, the City will hold the property owner responsible for ensuring it is maintained in proper operating condition (i.e., as designed and constructed) regardless of who performs maintenance activities.
- Maintenance activities, which include ensuring proper operation of the SCM as designed and required SCM inspections, must begin immediately following installation of the sand filter.
- Maintenance activities shall be performed in keeping with the *SCM Inspection and Maintenance Manual*. Additional guidance on maintenance of newly installed sand filters located on active construction sites is provided in Table 7.8.7.

Table 7.8.7 Maintenance Activities for Newly Installed Sand Filters

Area or Component	Post-Installation Maintenance Requirement
Contributing Drainage Area	Keep the contributing drainage area clean. Sweep trash, debris, and sediment frequently so that it does not wash in the basin during a rain event. The area should be fully stabilized before installation of the SCM. If it is not, prevent inflows to the sand filter as described previously. Stabilize the area as soon as possible to prevent the discharge of sediment to the SCM. Cover stockpiles of construction and landscape materials to prevent their exposure to rainfall.
Sand Filter	For surface sand filters that have vegetative cover, ensure SCM plants are watered and growing as expected. Ensure the filter bed remains free of accumulated sediment, landscape debris, and trash. Ensure vehicles, equipment, and people are not allowed in the sand filter. Evidence of unwanted entry may look like tire tracks or footprints; sand or stone displacement, or damage to components; immediately determine and eliminate the cause and repair the area. Consider installing temporary fencing. Visually observe sand filter function after rain events; there should be no standing water in 48 after a storm event, depending on the frequency of rainfall. If long-standing water is observed: • Inspect the underdrain via the observation wells, looking for standing water indicative of a blockage or damage; make repairs if needed. • If underdrain/outlet blockages and damage can be ruled out, then the filter bed may be clogged. This repair may require filter media removal, underdrain cleaning, and reinstallation of the filter bed chamber; consult the design engineer.

Area or Component	Post-Installation Maintenance Requirement
Education	Alert onsite subcontractors to the SCM and the following requirements: • No muddy vehicles or equipment in the drainage area to the sand filter. • No stockpiling of material in the filter bed and no exposed stockpiles in the filter's drainage area. • Block inlets prior to asphalt placement in the drainage area. • Remove sediment, trash, debris, and empty trash cans frequently. Advise landscaping subcontractors on proper protection and maintenance of the sand filter, especially no dumping of lawn clippings or landscape debris in the filter area and to cover materials stockpiles.

7.8.11 References

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition.* Atlanta Regional Commission, 2016.

Georgia Department of Transportation. *Drainage Design for Highways. Revision 3.3.* March 31, 2023.

Knox County, TN. *Stormwater Management Manual. Volume 2.* January 2018.

Montgomery County, Maryland, Department of Environmental Protection. *Structural Maintenance: Underground Sand Filters.* Stormwater Facility Maintenance Program. 2013.

North Carolina Department of Environmental Quality. *Stormwater Design Manual. C-6. Sand Filter.* Revised November 7, 2018.

Shaver, E. and R. Baldwin. 1991. *Sand Filter Design for Water Quality Treatment.* Delaware Department of Natural Resources and Environmental Control. Dover, DE.

Stormwatercenter.net. *Performance Criteria: Stormwater Filtering Systems.* Online. Accessed February 2024. https://www.stormwatercenter.net/Manual_Builder/Performance%20Criteria/Filtering%20Systems.htm

7.9 STORMWATER WETLAND design specifications

Water Quality Volume (WQv) Rainfall

Tier 3 Design
P = 2.5 inches or the first 75% of the volume from the 1-yr, 24-hr storm, *whichever is less*

OTHER SCM ATTRIBUTES *(cost scale is $-low, $$-medium, $$$-high)*	
Channel Protection Volume (CPv)	Yes
Detention / Retention Control	Yes
Small Storm Local Flood Control	Yes
Typical SCM Footprint Size *(percent of contributing drainage area)*	3 to 5%
Construction Cost	$$
Operation & Maintenance Cost *(when properly maintained)*	$

PROJECT SUITABILITY

Industrial	Commercial	Residential *(common areas only)*	Pollutant Hotspots	Private Roadways *(requires HOA)*
✓	✓	✓	✗	✓

Legend: ✓ **High** ✓ **Limited** ✗ **None**

OVERVIEW

Stormwater wetlands are stormwater storage facilities that provide water *quantity* (i.e., flood) control through temporary detention of stormwater and stormwater *quality* control by extending the storage time of the WQv. Stormwater is treated through natural filtration, plant uptake, and settling during extended detention in the wetland before discharging offsite, or to the onsite stormwater conveyance system.

ADVANTAGES/BENEFITS

- Provides both stormwater quality and quantity control
- Some design variations can serve very large drainage areas
- Can provide a park-like amenity and natural wildlife habitat
- Relatively low maintenance costs
- Ideal for use in flat terrain and in areas with high groundwater

DISADVANTAGES/LIMITATIONS

- The wetland itself requires a large land area
- A permanent wetland pool must be maintained
- Requires strict control of incoming sediment to sustain wetlands
- Mosquitos can be problematic

LOCATION, SIZING, & COMPONENTS

- Best located in areas with a continuous high-water table or baseflow
- Minimum dry weather inflow to outflow path of 2:1 (length:width)
- Requires design of a variable pool areas and depths

LONG-TERM PROTECTION

- Primary concerns are dumping (trash, landscape debris, etc.) and poor plant management (mowing, clearing, etc.) due to landscaper ignorance about the SCM
- Consider permanent “no mow zone” or similar signs to alert landscapers to the presence and preservation of the wetland
- Maintained vegetated areas and quiet walkways along the wetland border can support its protection as intentional landscape or even a property amenity

LONG-TERM MAINTENANCE

- Primary routine maintenance activities will be plant care (e.g., plant replacement, invasive species management) and inlet/outlet cleaning (trash, debris, plant matter, etc.)
- Consider permanent signs to dissuade entry, dumping, and use of SCM as a pet relief area if located is near a pedestrian area
- Provide trash cans and pet waste stations in the drainage area

7.9.1 General Description

Stormwater wetlands (sometimes also called constructed wetlands) are stormwater control measures (SCMs) designed and constructed as shallow marsh systems. They are typically designed to remove pollutants from stormwater and provide flood control by reducing peak discharges for large storms. They are among the most effective stormwater practices in terms of pollutant removal. Stormwater entering the wetland displaces a portion of the retained pool volume as it flows slowly through the wetland. During this time multiple pollutant removal processes occur including filtration of water through plant leaves, gravitational settling in pool areas, and uptake of nutrients and other pollutants by plants, soil, and microorganisms. A multi-stage outlet structure at the downstream end of the wetland provides peak flow control.

Stormwater wetlands differ from natural wetland systems in that they are designed specifically for the purpose of treating stormwater. They also often have less biodiversity than natural wetlands both in terms of plant and animal life. However, they are similar to natural wetlands in that they require a continuous baseflow or a high-water table to support wetland vegetation and function.

7.9.2 Design Configurations

Stormwater wetlands can be designed in either a Level 1 or Level 2 configuration, as follows.

Level 1 designs are "full control" designs. They provide for WQv, channel protection volume (CPv) control, and flood control (post-development to pre-development peak discharge matching) for large storm events regulated via a multi-stage outlet riser and emergency spillway.

Level 2 designs are "WQv only" designs. They address the WQv, but cannot provide extended detention, thus requiring another SCM, such as a wet detention basin, for CPv and flood control. Stormwater wetlands with Level 2 designs are suitable for a parallel installation to a wet detention basin. In this design configuration, the wetland provides stormwater quality treatment of the WQv and CPv, while the basin is designed to provide stormwater detention. The base also helps maintain the permanent pool within the wetland.

There are several types of stormwater wetlands, each differing in the relative number and volume of dry storage areas and shallow water and deep-water pools. The wetland types are described in the following paragraphs and shown in Figure 7.9.1. Schematics of each wetland type are shown at the end of this design specification (Section 7.9.14).

Extended Detention (ED) Shallow Wetland (Level 1 – full control) – The extended detention (ED) shallow wetland design is the same as the shallow wetland; however, part of the WQv is provided as extended detention above the surface of the marsh and released over a period of 24 hours. This design can treat a greater volume of stormwater in a smaller space than the shallow wetland design. Plants that can tolerate both wet and dry periods need to be specified in the ED zone.

Basin/Shallow Wetland System (Level 1 – full control) – The basin/wetland system has two separate cells: a wet basin and a shallow marsh. The wet basin traps sediments and reduces velocities prior to stormwater entry into the wetland. Additional treatment is then provided in the remainder for the wetland. A basin/wetland system requires less land than the shallow wetland and ED shallow wetland systems.

Shallow Wetland (Level 2 – WQv only) – In a shallow wetland, most of the water quality volume (WQv) is in the relatively shallow high marsh or low marsh depths. The only deep portions are the forebay at the wetland inlet and the micropool at the outlet. A disadvantage of this design is that a relatively large amount of land is typically needed to store the WQv since the pool is very shallow.

Pocket Wetland (Level 2 – WQv only) – The stormwater wetland design variations described above serve a minimum drainage area of 10 to 25-acres, depending on source water availability. In contrast, a pocket wetland is intended for smaller drainage areas of 5 to 10 acres. However, it often requires excavation down to the water table for a reliable water source to support the wetland system. Pocket wetlands are smaller, more compact wetland systems intended for use where drainage area sizes will not support a larger wetland system.

Figure 7.9.1 Examples of Stormwater Wetland Variations

Top left: Shallow wetland (Maryland Department of Transportation); Top right: Extended detention shallow wetland (Maryland Department of Environment); Bottom right: Basin/wetland system (Connecticut Stormwater Quality Manual); Bottom left: Pocket wetland (Athens-Clarke County, GA)

7.9.3 SCM Suitability

Use Table 7.9.1 to determine if a stormwater wetland is suitable for the application being considered.

Table 7.9.1 Stormwater Wetland Suitability Factors

Factor	Suitability
Hydrologic Feasibility	**IMPORTANT!** A continuous baseflow or high-water table is required to support wetland vegetation. See Section 7.9.5 (Hydrologic Requirements & Design Options) below for more information.
Stormwater Quality Treatment	Level 1 and Level 2 stormwater wetlands designed in keeping with the specifications established herein will satisfy City water quality treatment standards.
Channel Protection	Level 1 stormwater wetlands can be designed to satisfy City channel protection standards. Level 2 stormwater wetlands do not provide extended detention and therefore cannot met the CPv standard.
Peak Discharge Control (Flood Control)	Level 1 stormwater wetlands can be designed to satisfy City peak discharge (flood) control requirements. Level 2 stormwater wetlands do not provide peak discharge control.

<table>
<tr><th>Factor</th><th>Suitability</th></tr>
<tr><td>Pollutant Treatment Capability (Level 1 Designs)</td><td>Level 1 wetland systems designed in keeping with the specifications established herein can address following common stormwater pollutants:
<table>
<tr><th>Total Suspended Solids (TSS)[1]</th><th>Total Phosphorus (TP)[2]</th><th>Total Nitrogen (TN)[2]</th><th>Fecal Bacteria[2]</th><th>Metals[2,3]</th></tr>
<tr><td>80%</td><td>40%</td><td>30%</td><td>70%</td><td>50%</td></tr>
</table>
1 – If designed for the WQv specified in Tennessee Department of Environment and Conservation Rule 0400-40-10-.04.
2 – ARC, 2016
3 – Cadmium, Copper, Lead, and Zinc</td></tr>
<tr><td>Pollutant Treatment Capability (Level 2 Designs)</td><td>Level 2 wetland systems designed in keeping with the specifications established herein can address following common stormwater pollutants:
<table>
<tr><th>Total Suspended Solids (TSS)[1, 2]</th><th>Total Phosphorus (TP)[2]</th><th>Total Nitrogen (TN)[2]</th><th>Fecal Bacteria[2]</th><th>Metals[2,3]</th></tr>
<tr><td>85%</td><td>75%</td><td>55%</td><td>85%</td><td>60%</td></tr>
</table>
1 – If designed for the WQv specified in Tennessee Department of Environment and Conservation Rule 0400-40-10-.04.
2 – ARC, 2016
3 – Cadmium, Copper, Lead, and Zinc</td></tr>
<tr><td>Treatment of Waste and Other Pollutants</td><td>Stormwater wetlands shall not be used to treat the following pollutants:
Construction sediment/waste
Landscape storage or waste
Sewage, pet, and livestock waste
Medical waste
Household & commercial wastes
Hazardous wastes
Gasoline, motor oils, greases, and other petroleum-based products
Fats, oils & grease (from food preparation)
Pesticides, fertilizers, herbicides
Other byproducts and waste materials expected, based on the property’s land use</td></tr>
<tr><td>Suitability by Land Use</td><td>Privately owned stormwater wetlands are not allowed in the public right-of-way.
General suitability criteria by land-use type is as follows. See Chapter 6 (SCM Standards, Methods, and Selection) for more information.
<table>
<tr><th>Commercial</th><th>Industrial</th><th>Private Roadways</th><th>Single Family Residential</th><th>Multi-Family Residential</th></tr>
<tr><td>Yes</td><td>Yes</td><td>Yes</td><td colspan="2">Common Areas Only</td></tr>
</table></td></tr>
</table>

7.9.4 SCM Location Requirements

Location constraints for stormwater wetlands are provided in Table 7.9.2.

Table 7.9.2 Stormwater Wetland Location Requirements

Physical Element	Requirement
SCM Setbacks	Minimum setbacks for all wetland designs, measured from the edge of the stormwater wetland, are as follows: • 20 feet from property lines • 100 feet from private water supply wells; if well is downgradient from a hotspot land use, then the minimum setback is 250 feet • TDEC specified distance per designated category from public water supply reservoirs

Physical Element	Requirement
	• 50 feet from underground septic systems • 5 miles from airports (due to propensity for waterfowl habitation)
Prohibited Locations	Stormwater wetlands cannot be located within navigable waters of the U.S., including wetlands, without obtaining a Section 404 permit under the Clean Water Act, and any other applicable State permit. In some isolated cases, a wetlands permit may be granted to convert an existing degraded wetland in the context of local watershed restoration efforts. Where an appeal or variance of this policy is desired, the property owner must obtain coverage under a Section 404 permit under the Clean Water Act and/or an Aquatic Resource Alteration Permit (ARAP) and provide proof of such coverage with the stormwater management plan. Stormwater wetlands often intersect the groundwater table. Thus, these SCMs are not suitable for locations: • with an underlying water supply aquifer • where they will receive stormwater discharges from land uses where high level(s) of pollutant(s) are expected (see Treatment of Wastes and Other Pollutants in Table 7.9.1 above) • locations where soil contamination is known or suspected.
Trout Streams	Stormwater wetlands can have a thermal influence on downstream trout waters. Avoid placement in locations that discharge directly to trout streams.
Utility Avoidance	All utilities shall be located outside of the stormwater wetland.

7.9.5 Hydrologic Requirements & Design Options

A primary cause of stormwater wetland failure is the inability to maintain the permanent pool elevation (PPE) at its design elevation. Poorly draining soil and a frequent high groundwater elevation are critical to PPE support, and therefore stormwater wetland operation and their ultimate success or failure. Thus, knowledge of the seasonal high-water table (SHWT) and in-situ soil permeability are critical to determine the feasibility of a stormwater wetland as a viable SCM.

Soil permeability tests and SWHT determination and infiltration tests shall be performed by either a professional geologist or civil (geotechnical) engineer with an active license in the State of Tennessee.

SOIL PERMEABILITY: Permeable soils are not well-suited for a constructed stormwater wetland without a high-water table. Underlying soils of hydrologic group "C" or "D" should be adequate to maintain wetland conditions. Most group "A" soils and some group "B" soils will require a liner.

Soil permeability must be tested in the proposed stormwater wetland location to ensure that excessive infiltration will not cause the SCM to dry out. If necessary, stormwater wetlands should have a highly compacted subsoil or an impermeable liner to minimize infiltration.

SOIL BORINGS AND CORE INTERPRETATION: Soil borings provide information on the SHWT. Table 7.9.3 provides soil boring location and depth requirements.

Table 7.9.3 Soil Boring Requirements

Factor	Requirement
Location	A minimum of: • one (1) boring within the footprint of the proposed stormwater wetland embankment; and, • one (1) boring in the vicinity of the proposed outlet structure; and,

Factor	Requirement
	• one (1) boring for every 20,000 square feet within the proposed wetland area.
Depth	Soil borings shall be conducted to a depth of at least 10 feet below the estimated lowest bottom elevation of the stormwater wetland.

Each soil core shall be observed to determine the anticipated SHWT based on:

- the date of soil boring with respect to any visual observations of water in the core (or boring)
- recent and seasonal rainfall patterns
- the presence of hydric soils
- redoximorphic features or other indicator of water table variation
- and depth to bedrock if encountered.

If mottling showing redoximorphic features is observed, at any season of the year, the SHWT shall be taken as the highest level at which the mottling is observed, except when the water table is observed at a level higher than the level of the redoximorphic depletions or concentrations. Otherwise, use best practices for SWHT determination as appropriate for water table/soil conditions at the location of the wetland. Use the most recent version of the USDA-NRCS reference document titled *Field Indicators of Hydric Soils in the United States – A Guide for Identifying and Delineating Hydric Soils* for more information on determining whether saturated soils are present.

HYDROLOGIC SUPPORT DESIGN OPTIONS. Three options exist for the design of wetlands depending on the depth to groundwater and native soils, as follows:

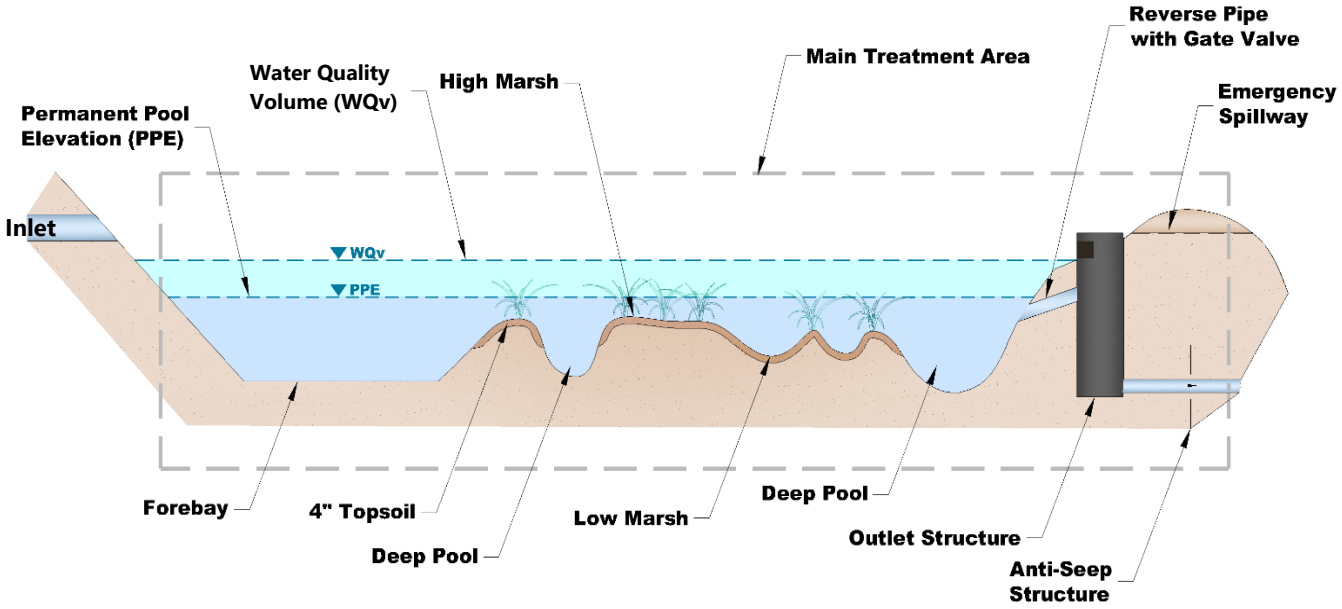
1. **Wetland intersecting groundwater (required configuration for pocket wetlands):** If the wetland will intersect a shallow groundwater table, groundwater may be utilized to maintain the permanent pool elevation (PPE) at the design elevation. The PPE established for the wetland shall be within 6 inches above or below the SHWT. Based on the results of the water balance calculations [see Chapter 6 (SCM Standards, Methods, and Selection)], an impermeable liner may be required under the deep pools to reduce the likelihood of the pools drying up completely during a time of unusually low groundwater elevation.
2. **Wetland above groundwater with low-permeability native soils:** If the SHWT is below the proposed wetland elevation and soil testing shows that the native soil beneath the wetland is clay or similar with an infiltration rate of less than 0.01 in/hr, the wetland will hold water and can be designed without an impermeable liner. If, during construction, any areas with more permeable soil types are discovered, an impermeable liner shall be designed and installed for these areas.
3. **Wetland above groundwater with highly permeable native soils (allowed only if other SCMs are not feasible for the proposed development):** If the native soils above the SHWT are highly permeable soils like loam and sand, installation of an impermeable liner with an infiltration rate of less than 0.01 in/hr is required. The liner can be constructed of clay, other soils that meet the infiltration rate requirement, or an impermeable geomembrane. Location constraints for stormwater wetlands are provided in Table 7.9.2.

WATER BALANCE. Once the hydrologic support design option is determined, design professionals are strongly encouraged to perform a water balance calculation **BEFORE** further design activities are undertaken. The water balance must demonstrate that the stormwater wetland can withstand a 30-day drought at summer evaporation rates without creating a drawdown that will dry the wetland and damage or destroy the wetland vegetation. See Chapter 6, Section 6.2.8 for more information on water balance calculations.

7.9.6 Components

Figure 7.9.2 presents a general schematic cross-section of a stormwater wetland.

Figure 7.9.2 General Cross-Section of A Stormwater Wetland



In general, stormwater wetlands consist of eight primary components, described below.

1. **Inlet(s):** Stormwater enters the wetland via one or more inlets. A specific type of inlet is not required. Inlets can be swales, pipes, diverter boxes, areas of sheet flow, or other methods of transporting water to the wetland.
2. **Forebay:** The forebay is a deep pool that directly follows the inlet and provides two important functions: (1) dissipates stormwater velocity and energy; and (2) collects gross solids and sediment to ease maintenance. The forebay essentially acts as a pretreatment device for the stormwater wetland. The water flows out of the forebay and into the wetland. The entrance to the forebay is deeper than the exit of the forebay. This design will dissipate the energy of the water entering the system and ensure that large solids settle out.
3. **Deep pools:** Deep water cells include the outlet pool and deepwater channels running through the wetland. Very little rooted vegetation exists in these areas because they are always under water, but they may support submerged and floating plants. However, the deep pool at the outlet should not have any vegetation to avoid outlet clogging. Deep pools provide additional pollutant removal and storage volume as well as habitat for aquatic wildlife such as mosquito-eating fish.
4. **Low marsh:** Low marsh areas are shallow water areas inundated by the permanent pool to a depth of 3 to 6 inches with occasional drying during periods of drought. Low marsh areas provide a constant hydraulic connection between the inlet and outlet structure of the stormwater wetland. The top of low marsh areas represents the top of the permanent pool elevation (PPE). Wetland tolerant, herbaceous plants (i.e., plants with flexible, green stems and few to no woody parts) are recommended for this area because they are more efficient in the pollutant removal process and less likely to encourage mosquito growth.
5. **High marsh:** High marsh areas support a greater density and diversity of wetland plants (described in the paragraph above), thus providing much of the vegetative pollutant uptake.
6. **Lowland:** Lowland areas (not shown in the figure) are located above the permanent pool and are wet only during larger storm events. Rooted plants including woody vegetation can live in this zone to provide shade and non-aquatic wildlife habitat. Vegetation must be able to withstand irregular inundation and occasional drought.

7. **Upland:** Upland areas (not shown in the figure above) are never wet. They are not a required element of wetland design and can be eliminated if space is a concern. They may serve as an amenity and provide access for maintenance. Some wetlands have upland areas as an island in the center of the wetland.

8. **Outlet:** For a Level 2 stormwater wetland (WQv only), the outlet consists of a drawdown orifice placed at the top of the shallow water elevation so that stormwater in the shallow land area will be able to slowly discharge from the wetland. For a Level 1 wetland, an outlet riser is designed to discharge the WQv/CPv and flood control events (i.e., providing peak discharge control). An emergency spillway may be included at the top of the outlet riser or can be located on the wetland embankment.

   Adjustable gate valves or other mechanism can be used to adjust detention time for the WQv and CPv.

In addition to the above eight components, basin/shallow wetland configurations must include a wet basin located in parallel. Design specifications for the latter SCM are provided in Section 7.12 (Wet Detention).

Additional components (not shown) for all stormwater wetland types include a safety bench, and upland areas for maintenance access and a wetland buffer. Upland areas may also serve as amenity areas or even islands in the center of the wetland for waterfowl and upland vegetation.

7.9.7 Design Specifications

Design specifications are provided in Tables 7.9.4 and 7.9.5 and shall be considered minimum standards and specifications for the design of stormwater wetlands and their contributing drainage areas. The schematics of stormwater wetlands provided at the end of this design specification (Section 7.9.14) may also be helpful with wetland design.

Table 7.9.4 Design Specifications for the Contributing Drainage Area

Design Element	Specification(s)
Size	For pocket wetlands: minimum contributing drainage area = 5 acres For all other stormwater wetlands: the minimum contributing drainage area is: • 25 acres if stormwater is the only source of water for the wetland • 10 acres if groundwater will supply the wetland (i.e., the wetland bottom will intercept the water table) See also Section 7.9.5 (above) regarding hydrologic support for the wetland.
Slope	Maximum slope of contributing drainage area = 8%
Controls for Waste & Other Pollutants	Appropriate controls shall be included in the design of the contributing drainage area to the SCM to address any wastes and other pollutants (see Table 7.9.1 above) that are expected on the property after construction. Use the proposed land use as a guide to determine appropriate controls. Examples of such controls include, but are not limited to, dumpsters, trash cans, covered materials/waste storage areas, covered materials transfer areas, oil and grease waste controls, and pet waste stations.

Table 7.9.5 Design Specifications for the Stormwater Wetland

Design Element	Specification(s)
Water Quality Volume (WQv)	The water quality rainfall depth (P) for determination of WQv is P = 2.5 inches, or the WQv is the first 75% of the volume of the 1-yr, 24-hr storm, *whichever is less*. The design professional can select which volume to use. Acceptable methods to determine WQv are presented in Chapter 6 (SCM Standards, Methods, and Selection).

Design Element	Specification(s)
Use in a Water Quality Treatment Train	If the stormwater wetland cannot manage the entire WQv for its contributing drainage area, it must be placed in a treatment train with another SCM. See treatment train policies and calculations in Chapter 6, Section 6.2.4 for treatment train policies and calculations.
Channel Protection Volume (CPv)	The runoff volume from the 1-year frequency, 24-hour duration storm event shall be detained for no less than a 24-hour period, up to a maximum of 48 hours. Acceptable methods to determine WQv are presented in Chapter 6 (SCM Standards, Methods, and SCM Selection).
Peak Discharge Control (Flood Control)	The City may not require stormwater detention for properties that discharge directly to a stream or other waterbody. However, in the event that detention is required: • The post-development peak discharge shall be less than or equal to the pre-development peak discharge for the 2, 5, 10, 25, and 100-year, 24-hour storm events. NRCS methods shall be used for detention and retention SCM and outlet structure designs.
Offline and Online Configurations	An offline configuration is the required design configuration for Level 2 (WQv only) stormwater wetland applications as they are designed and constructed away from the main flow path for the drainage area, thus avoiding large flood flows. A flow splitter, diversion structure, or other means is used upstream of the stormwater wetland's inlets to redirect the WQv from the main flow path to the SCM while still allowing larger flows to remain in the flow path. • The structure shall include a low-flow orifice, weir, or other hydraulic device, sized to pass the peak discharge (Q_{wq}) of the design volume to the offline wetland. • Water diverted away from the wetland shall discharge to an appropriately sized onsite storm drainage system or detention basin. • Flow regulators (flow splitters, diversion structures, and overflow structures) shall be designed in keeping with Sections 7.14 (Inlets, Pretreatment, and Energy Dissipation Devices) and 7.16 (Overflow Structures). An online configuration (allowed for Level 1 wetlands only) is designed and constructed so the main flow path for the drainage area passes through the stormwater wetland, similar to online configurations for detention basins and wet basins.
Maintenance Access and Easement	A maintenance easement shall be provided to the basin from a driveway, public or private road. It shall be designed as follows: • a minimum width of 15 feet • a maximum slope of no more than 15% • the easement shall be free of permanently affixed obstructions (e.g., trees, pools, fences without gates, permanent signs, etc.) and appropriately stabilized to withstand maintenance equipment and vehicles • to the extent feasible, allow vehicles to turn around. The entire stormwater wetland, including inlets, pretreatment devices, the storage area. embankments, outlet structure, and emergency spillway) shall be included in the easement and shall be accessible from the easement's drive path.
Forebay	Forebays are critical to wetland longevity as they trap sediment and protect the capacity of the internal wetland cells located downstream. The following criteria apply to forebay design. • A forebay shall be provided for every individual storm drain inlet pipe or open channel conveying stormwater into the wetland from at least 10% of the contributing drainage area. • The forebay is a separate cell and formed by a dike formed by an earthen berm, concrete weir, gabion baskets, or similar. • Required volume = 10% of the WQv of the basin

Design Element	Specification(s)
	○ The forebay volume can be considered as part of the WQv, not additional volume of the wetland. • Depth = 4 to 6 feet ○ When determining forebay geometry, greater depth is preferred over greater width. This allows the forebay to dissipate turbulent inflows without resuspending previously deposited sediment; however, safety concerns and ease of maintenance must be considered when designing sediment forebays. • A safety bench is required around the perimeter of forebay per specifications described for deep pools in the previous row of this table. A fixed vertical sediment depth marker (metered rod) shall be located in the center of the forebay pool (as measured lengthwise along low-flow water travel path) to measure sediment deposition over time.
Hydrologic Support	A continuous baseflow or high-water table is required to support wetland vegetation. See Section 7.9.5 above.
Minimum Hydraulic Head	Minimum elevation difference from wetland inflow to outflow: • Pocket wetland = 2 to 3 feet • All other wetland types = 3 to 5 feet
Water Balance	A water balance calculation must demonstrate that the stormwater wetland can withstand a 30-day drought at summer evaporation rates without creating a drawdown that will dry the wetland and damage or destroy the wetland vegetation. See Chapter 6, Section 6.2.8 for more information on water balance calculations.
Geometry, Depths, and Storage Volumes	Stormwater wetlands shall be irregularly shaped with long, sinuous flow paths. Stormwater wetlands are constructed by excavating the overall wetland basin, building up earthen embankments (dikes), or a combination of the two methods, sufficiently to create the desired number of internal cells. In general, Level 1 stormwater wetlands should be divided into at least four internal cells of different elevations: the forebay, a deep pool at the outlet, and two additional cells. This rule of thumb does not extend to Level 2 wetlands. If multiple cells are used, divider dikes can be used to separate cells and to produce the desired length-to-width ratios. On steep sites, they can be used to terrace cells. Dikes forming internal cells shall be constructed of soils with adequate fine-grained material to ensure compaction into relatively stable and impervious embankments. Placement of erosion control matting on dike side slopes is acceptable. Dikes should be high enough to contain the expected volume within each internal cell plus freeboard (at least 1 ft above the largest storm event controlled in the wetland) to accommodate occasional high flows and sediment/litter buildup over time. Table 7.9.6 provides general rules for pool depths and volumes for stormwater wetland sub-cells.

Table 7.9.6 Sub-Cell Depths & Volumes for Various Level 1 and 2 Wetland Zones

Wetland Zone (see Figure 7.9.2)	Criteria	Level 1 Design	Level 2 Design
Deep pools	Depth % of total volume	-18 to -72 inches 20%	-18 to -48 inches 25%
Low marsh	Depth[1] % of total volume	-6 to -18 inches 20%	*Not applicable* *Not applicable*
High marsh	Depth[1]	-6 to 0 inches	-6 to 6+ inches

Design Element	Specification(s)

	% of total volume	10%	75%
Lowland	Depth % of total volume	0 inches + 50%	*Not applicable* *Not applicable*

[1] *Designers must account for 4 to 6-inches of topsoil to be placed on in-situ soils.*

Finger dikes within the internal cells are used to create the sinuous flow path, further refine the desired length-to-width ratio and minimize short circuiting of water through the wetland. Finger dikes can be constructed of soil, sand berms/bags (anchored by rock at each end), back-filled coir fiber logs, or leaving-in place existing upland areas as forested peninsulas (extending as wedges across 95% of the wetland width).

Geometry, Depths, and Storage Volumes *(continued)*

Table 7.9.7 provides additional geometry criteria for Level 1 and Level 2 stormwater wetlands.

Table 7.9.7 Sub-Cell Depths & Volumes for Various Level 1 and 2 Wetland Areas

Criteria	Level 1 Design	Level 2 Design
Number of deep pools	2 *(forebay and outlet)*	3 *(forebay, middle, outlet)*
Maximum side slopes (H:V) *(wetland boundary and dikes)*	2:1 *(3:1 preferred)*	2:1 *(5:1 preferred)*
Slope profile	8% across entire site	Generally flat *(use several cells if needed with a maximum drop of 1 ft between each)*
Normal flow path (length : width) *(distance from nearest inlet to the outlet)*	1:1	1.5:1
Dry weather flow path	Not required	5:1
Average depth *(including topsoil)*	Can be > 1 ft	Should be less than 1 ft
Topsoil depth and composition *(marsh zones & safety benches)*	4 to 6-inches High organic content loam or sandy loam	
Safety bench *(required for deep pools)*	Width = 4 to 6 feet Depth = 1 to 2 feet below the water surface, transitioning to zero width at grade	
Minimum Freeboard	1 foot	Not required
Extended detention	Limit to 1 ft vertically	Not allowed

Designs for wetlands that impound more than 30 acre-feet of water may require adherence to the Tennessee Safe Dams Act. Consult the Tennessee Department of Environment and Conservation (TDEC) for more information.

Level 1 (full control) stormwater wetlands:

- Routing calculations must demonstrate that the storage volume of the wetland is adequate (not including freeboard) for all design storms. See Chapter 6 (SCM Standards, Methods, and Selection) for more information on storage design requirements.

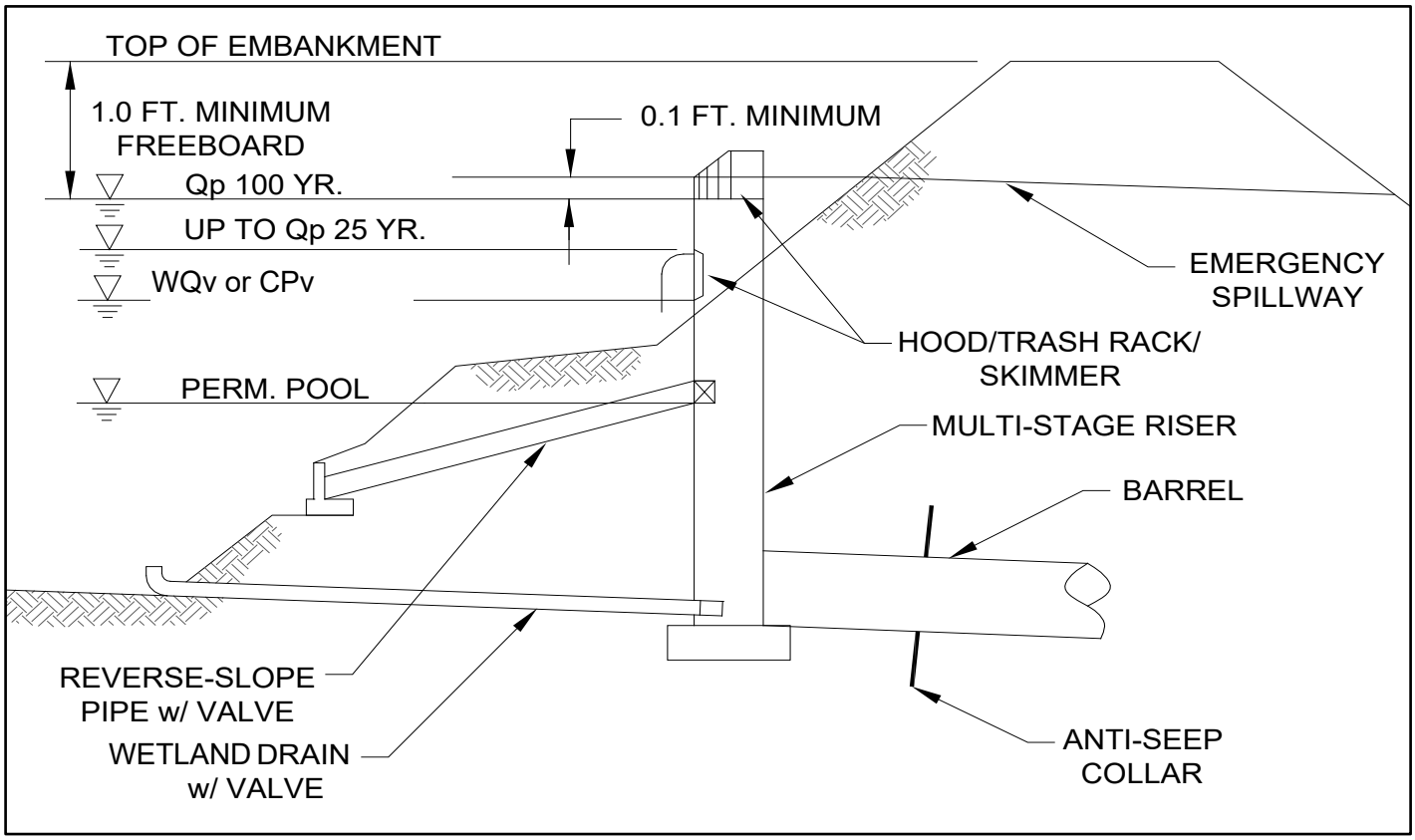
Design Element	Specification(s)
	Level 2 (WQv only) stormwater wetlands: • Micro-topology is important to Level 2 wetland designs. Planting peninsulas are the preferred method, but the following list can be used to enhance micro-topology: ○ Snags ○ Tree peninsulas ○ Internal pools ○ Inverted root wads ○ Coir fiber islands ○ Cobble sand weirs **ADDITIONAL DESIGN TIPS FOR ALL STORMWATER WETLANDS** Stormwater wetland designs should be kept simple, as complex technological approaches often invite failure. Tips for stormwater wetland designs are as follows. • Design the system to use natural energies, such as gravity flow. • Design the wetland with the landscape, not against it. Integrate the design with the natural topography of the site. • Avoid over-engineering the design with rectangular basins, rigid structures and channels, and regular morphology. Rather, mimic natural systems. • Design the system for function, not form. For instance, if initial plantings fail, but the overall function of the wetland, based on initial objectives, is intact, then the system has not failed. • Design for the extremes of weather and climate, not the average. Storms, floods, and droughts are to be expected, so the design must reflect this fact.
Outlet Structures	Requirements for all stormwater wetlands: • Drawdown of the stormwater wetland's temporary pool shall be accomplished no sooner than 24 hours but no longer than 72 hours after completion of a rain event. • Outlets shall be located within the outlet pool and basin embankment, and shall be designed for easy access, maintenance, and safety. • Outlets, including emergency spillways, shall be designed so that discharges will not cause negative impacts to downstream structures. • The minimum orifice diameters for WQv and CPv = 1 inch. Orifice diameters of 8-inches or less shall be protected against clogging using a stone cage. • Use the orifice sizing guidance presented in Chapter 6 (SCM Standards, Methods, and SCM Selection) for extended detention outlet sizing guidance. • Clogs, even of the low-flow orifice, can result in long-standing, high water elevations that can potentially kill wetland vegetation. Outlets shall be carefully designed to be resistant to fouling by floating or submerged plant material or debris. Orifices, spillways, and outlet pipes must be protected by trash racks, other anti-clogging measures, or reverse-sloped pipes extending to mid-depth of the micro-pool. • If the stormwater wetland discharges directly to a mapped floodplain, the downstream invert elevation of the outlet barrel shall be at least 1 foot above the base flood elevation. Ideally, this allows the wetland to drain during extreme flood events. • If the stormwater wetland discharges directly to an unmapped stream or waterbody (e.g., stream or lake), the downstream invert elevation of the outlet barrel shall be at least 1 foot above the elevation of the edge of bank (for a stream) or normal pool elevation (for a lake).
Outlet Structures *(continued)*	Additional requirements for Level 1 (full control) stormwater wetlands: • Flow control from a stormwater wetland is typically accomplished with the use of a concrete riser attached to the base of the micropool and its embankment with a watertight connection. The outlet barrel is a horizontal pipe attached to the riser that conveys flow under the embankment. Multiple openings (orifices, slots, weirs, etc.) in the riser discharge the WQv and flood (i.e., peak discharge) events according to the flow designs. An emergency spillway may be

Design Element	Specification(s)
	included at the top of the outlet riser or can be located on the wetland embankment. See Chapter 6, Section 6.5 (Storage Facility Outlet Structures) for more information on outlet riser design. Examples of stormwater wetland outlet structures are shown in Figures 7.9.3 and 7.9.4 (below this table). • A minimum of 1 foot of freeboard shall be provided based on the 100-year, 24-hour storm event, measured from the top of the water surface elevation for the flood to the lowest point of the dam embankment, not counting the emergency spillway. Additional requirements for Level 2 (WQv only) stormwater wetlands: • The outlet shall be a drawdown orifice, weir, or other device placed at the top of the shallow water elevation so that stormwater in the shallow land area will be able to discharge from the wetland. • An emergency spillway shall be a minimum of 0.1 ft above the WQv elevation.
Safety Features	The following safety features are more likely for Level 1 stormwater wetlands than Level 2. • See safety bench requirements for deep pools in the Geometry, Depths, and Storage Volumes row above. • Consider fencing the wetland for the purpose of safety management. • Signs located in close proximity to the wetland prohibiting swimming and fishing are highly encouraged.
Vegetation	See Section 7.9.9 (below) for stormwater wetland vegetation design.
Wetland Buffer	A wetland buffer shall extend 25 feet outward from the maximum water surface elevation with an additional setback of 15 feet to structures. The buffer should be contiguous with stream buffers (if present) or other buffers required by City regulations.

Figure 7.9.3 Examples of Stormwater Wetland Outlet Structures

Photo sources: left – Clemson University; right – Dragonfly Pond Works

Figure 7.9.4 Typical Outlet Structure Design for a Stormwater Wetland ***(Adapted from ARC, 2016)***



7.9.8 Design Procedure

Table 7.9.8 provides the design procedure for a stormwater wetland.

Table 7.9.8 Design Procedure

Step	Design Activity
Step 1	**Evaluate stormwater wetland feasibility, goals, and primary function.** Use the feasibility criteria provided in Tables 7.9.1 and 7.9.2 to determine if a stormwater wetland is feasible for the selected location on the land development site. Consider especially whether it is appropriate for the proposed development based on the intended land use of the property, the maintenance burden, and assumptions or knowledge of how the property owner(s) will care for the wetland after construction (e.g., self-maintenance, property/facilities management maintenance, landscape contractor). If possible, include the property owner(s) in SCM selection since they will be responsible for maintenance. Consider whether the intention is to: • Comply with the City stormwater quality requirements (i.e., treat the WQv). • Include additional storage capacity for flood control. • Enhance landscape and provide aesthetic qualities.
Step 2	**If a stormwater wetland is feasible based on the factors identified in the above row, evaluate its feasibility from a hydrologic perspective.** Perform the water balance described in Section 7.9.5 (Hydrologic Requirements & Design Options) above. If the water balance indicates a stormwater wetland is feasible, collect soil permeability and SHWT information per the requirements in Section 7.9.5 (Hydrologic Requirements & Design Options) above.

Step	Design Activity
	If the onsite tests indicate a stormwater wetland is feasible, determine the most appropriate design configuration (i.e., hydrologic support design, Level 1 or Level 2, and wetland type) based on the information provided in this design specification. Create a rough layout of its dimensions, taking into consideration existing trees, utility lines, and other obstructions to ascertain if it will fit into the desired space, given its general design requirements.
Step 3	**Calculate the design storage volume for the contributing drainage area**. Use the required methods established in Chapter 6 (SCM Standards, Methods, and Selection) to calculate WQv for the wetlands contributing drainage area. Level 1 stormwater wetlands (full control): • Determine the stage-storage relationship for the wetland. Level 2 stormwater wetlands (WQv only): • Typically, the design storage volume (DSv) is equal to WQv, unless the wetland cannot manage the entire WQv or will be used to treat a volume larger than the WQv. • In areas to be planted, 4 to 6 inches of appropriate topsoil should be installed above liners/geotextiles to support wetland plantings. **This must be accounted for when designing storage volumes.**
Step 4	**Determine the approximate minimum surface area of the stormwater wetland.** A stormwater wetland is designed to always be inundated with water. Thus, the volume required for the permanent pool is not the WQv (for Level 1 wetlands) or WQv and higher, flood control volumes (for Level 2 wetlands). Rather, the WQv and larger temporary volumes must be contained above the permanent pool elevation (PPE). The required surface area of the wetland is then directly dependent on the required highest volume and the allowable depth of ponding in the temporary pool. The temporary pool ponding depth is set based on the depth that the wetland plants can sustain for several days after a rainfall. • The minimum surface area of the wetland is determined using the equation below. $$A = \frac{DSv}{d_T}$$ where: A = surface area of total wetland ponding area (ft^2) DSv = highest design volume (ft^3); *for a Level 2 wetland, DSv = WQv* d_T = temporary ponding depth (ft); *ponding depth is up to one 1 ft* • This minimum surface area calculation will slightly overestimate the surface area of the permanent pool required due to the sloped sides of the wetland and safety benching not yet designed. Do not adjust the calculation.
Step 5	**Design pool soils and liners for dike stability and hydrologic support establishment.** Design the geotextiles and erosion matting for slope stability, where needed. Include specifications for impermeable liners if required to maintain wetland hydrology.
Step 6	**Determine the approximate surface areas and depths of the stormwater wetland pools/zones, including the forebay. Refine the volumes and design the wetland topography.** Use design specifications provided in Table 7.9.5 (above) for this purpose. Prepare a grading plan showing the wetland areas and depths, accounting for necessary liners, topsoil (4 to 6-inches), and safety benches in all deep pools, including the forebay. Determine the final volume of water below the permanent pool elevation and within the temporary storage volume above the permanent pool elevation. Confirm that: $V_T \geq DSv$; where V_T = the temporary storage volume (ft^3) Refine the topographic design (and grading plan) until DSv is accurate and the above equation is true.

Step	Design Activity
Step 7	**Size the outlet structure and any flow regulators.** Use Sections 7.14 (Inlets, Pretreatment, and Energy Dissipation Devices) and 7.15 (Overflow Structures) for requirements.
Step 8	**Design the vegetation and protection measures.** The vegetation design shall be in accordance with the vegetation design requirements provided in Table 7.9.9.
Step 9	**Design safety measures and wetland protection measures external to the pools, if needed.** Safety measures may include fencing, signs, and other protective features as appropriate for the proposed development. Use guidance found in Section 7.9.10 (below) to design protection measures.

7.9.9 Vegetation Design Requirements

Plants are critical to stormwater wetland performance and function. They filter and take up water and pollutants through their roots, providing pollutant removal. Plants also maintain the wetland health by preventing erosion and providing organic matter for aquatic and soil organisms habitat. With careful consideration, wetland plants can integrate with, and even enhance, the overall landscaping of the land developments in which a stormwater wetland is located.

The importance of plants to stormwater wetland function means they, like any SCM component, have design, installation, and maintenance specifications. Tables 7.9.9 and 7.9.10 provide plant specifications and guidance for wetlands.

Table 7.9.9 Vegetation Design Specifications

Wetland Zone (see Figure 7.9.2)	Minimum Coverage[1]	Vegetation Specifications
Safety bench *(including benches in deep pools)*	60% within one year of construction	• Install emergent[2] wetland species that have high colonization and growth rates; the ability to establish large, dense populations even in winter (for pollutant removal); and are robust in continuously or periodically flooded environments. • Greater plant diversity, density, and numbers are expected in the high marsh and on safety benches, due to greater sunlight and nutrient-support via wildlife and stormwater inflows. • Live plants shall be used for wetland construction. Wetland seed mixes are prohibited due to the probability of displacement by stormwater inflows before plants are fully and securely rooted.
High marsh		
Low marsh	20% within one year of construction	
Deep pools	No target	• Install emergent[2] wetland species, only on safety benches. *Deep pools generally do not support emergent wetland vegetation. They may support submerged or floating vegetation, and these plants are recommended if available.*
Lowland *(and wetland buffers, if included in design, not shown in Figure 7.9.2)*	100% of areas stabilized upon construction termination and fully (100%) vegetated within one year of construction	• Install non-wetland species. Both woody and non-woody vegetation is permissible. Trees are prohibited in Level 1 wetlands. • Select plants that can tolerate repeated cycles of inundation and drought. Avoid plants that experience seasonal leaf drop and have seed pods that float as these can too easily clog outlets. • Areas of bare soil and impervious surfaces are not allowed. • Loose, light ground cover, such as mulch and pea gravel, is not allowed as they can clog outlets. Use only vegetative soil stabilization methods.

[1] Minimum target coverage the required surface area that must be covered by vegetation within the specified timeframe. [2] Emergent plants are rooted in shallow water or near the water's edge, and therefore encounter full-time or frequent inundation. If rooted underwater, their leaves and steams typically extend out of the water.

Table 7.9.10 Vegetation Selection Requirements and Guidance

Vegetation Design Element	Specification(s)

Plant Selection	• Select plants suitable for use in local conditions, based on specific site, soils, and hydric conditions expected at the plant's intended location within or adjacent to the wetland, and the desired aesthetic. Plants tolerant of salt are recommended for areas that will encounter high salt loads in the winter. In all cases, native plant species suited to local hydrologic conditions are recommended.
	• Non-native, invasive species are prohibited as these can result in dense monocultures that do not foster insect, animal, or plant diversity, thus degrading wetland plant growth and overall wetland health.
	• For guidance on appropriate plant species, consult a plant and landscape expert, such as a landscape architect, local nursery, or Master Gardener from the Tennessee Extension Master Gardener program (https://mastergardener.tennessee.edu/). More information on wetland plants can be found at the following websites:
	  ○ The Tennessee Wetland Plant list from the University of Tennessee Extension Horticulture Team at https://www.uthort.com/
	  ○ http://wetlands.fws.gov/
	  ○ https://plants.usda.gov/home/wetlandSearch
	• Plants suitable for United States Department of Agriculture Plant Hardiness Zoned 7b are recommended.
	• More information on nuisance emergent plant species in Tennessee can be found at:
	  ○ Tennessee Wildlife Resource Agency. *Tennessee Aquatic Nuisance Species Management Plan*. February 2008.
	• Consider future maintenance needs of vegetation when designing the wetland. The level of plant care needed to maintain the landscape should influence plant selection to minimize care needs as much as possible.

Plant Diversity Guidance	The list below is an example of the level of both species and maturity diversity desired in stormwater wetland vegetation designs. Use of this example is not mandatory.
	• Stormwater wetlands should have a minimum of 10 different species total, of which at least 5 are emergent species, with no more than 30% of a single species.
	• Minimum plant quantities and sizes per 200 ft^2 of **high marsh and safety bench** area:
	  ○ 50 herbaceous plants of at least 4 cubic-inch container (equivalent to 2 ft on center minimum; 1.5 ft on center recommended)
	• Lower density of the same diversity/plants as used in the high marsh shall be planted in low marshes.
	• Minimum plant quantities and plant sizes per 200 ft^2 of **lowland** area:
	  ○ 50 herbaceous plants which come from a container having a minimum volume of 4 cubic inches, OR
	  ○ 8 shrubs which come from a container having a minimum volume of 1 gallon (equivalent to shrubs planted 5 ft on center minimum; 3 ft on center recommended), OR
	  ○ 1 tree which comes from a container having a minimum volume of 3 gallons and 40 grass-like herbaceous plants from containers having a minimum volume of at least 4 cubic-inches

Compliance with the vegetation standards set forth above shall be shown in a vegetation plan that is included with the stormwater management plan (SWMP). An example of a vegetation plan for a stormwater wetland is provided in Figure 7.9.5. Plan preparation requirements are below.

- The plan must be prepared by a professional qualified in landscape design by their education or experience.
- The plan shall include one or more labeled plans/details (to scale) showing the plants to be installed, their numbers, and locations. Plan notes showing a plant schedule and installation instructions are encouraged. This additional information allows both the plant installer at the time of construction, as well as the person(s) responsible for maintenance of the SCM after construction, to understand the original vegetation design and its compliance with the minimum standards.
- Landscaped SCMs may not be recognized under the City's codes as property landscaping. Therefore, additional requirements for property landscaping may apply.

Figure 7.9.5 Example of a Stormwater Wetland Vegetation Plan ***(Source: Alabama LID Manual)***

7.9.10 Protection Design Guidance

SCMs designed for stormwater quality purposes must be maintained in keeping with the approved SCM design for the life of the land development[1]. **Design professionals can assist property owners with this requirement by including protective features in and around SCMs to limit the potential for damage by external factors**. Often, the landscape and impervious features around an SCM can be tailored to its specific needs, and therefore used to protect its critical components.

Stormwater wetlands are especially well-suited to a variety of protection methods that can enhance the landscape aesthetic, listed in Table 7.9.11 and shown in Figure 7.9.6.

Table 7.9.11 Stormwater Wetland Protection Measures*

Passive Protection Measures	Active Protection Measures
• Natural fencing such as vegetation borders/screens (woody/prickly shrubs, dense or tall grass) • Driveways, sidewalks, or walkways around the SCM • Observation decks, benches, and safe viewing areas	• Hardscaping, such as Block or cobble/boulder edging or walls • Educational or directive (e.g., no pets) signs • Pet waste stations and trash cans near the SCM

** The list presented in the table is not exhaustive. There may be other possible protection measures.*

[1] Tennessee Rule *0400-40-10-.04*

Figure 7.9.6 Examples of Protective Landscaping for a Stormwater Wetland

Left: A stormwater wetland with a safety bench and educational signage (Source: Horsely Witten Group); Right: A wetland with walking paths and fencing that suggests pedestrians should stay out of the wetland (Source: Watershed Company)

7.9.11 Site Preparation and Land Disturbance Requirements

The following information is provided to support proper and effective construction and protection of stormwater wetlands during land disturbance activities and site construction. Mandatory requirements are identified using "shall" or "must." All other statements can be regarded as non-mandatory guidance. **Site preparation and land disturbance practices described in this section shall be shown on Erosion Prevention and Sediment Control (EPSC) plan for the proposed land development.** Table 7.9.12 provides requirements for site preparation and land disturbance practices for land developments with stormwater wetlands.

Table 7.9.12 Site Preparation and Land Disturbance Requirements for Stormwater Wetland

Action	Policy
Site Preparation	• For safety purposes, a protection zone should be placed around the perimeter of the stormwater wetland once excavation begins. Mark the zone with highly visible orange fencing (or similar visible protective measures) and signage to advise construction personnel of wet conditions and potentially deep excavations.
Land Disturbance	• Once constructed, protect the wetland using EPSC measures to prevent sediment discharges that could smother installed plants and healthy wetland soils, and clog outlets. • It is best to construct the stormwater wetland after the area draining to it has been fully and permanently stabilized.

7.9.12 Installation Requirements

The information in Table 7.9.13 provides a typical construction sequence to properly install stormwater wetlands. These steps may be modified to reflect different applications or site conditions. **Installation practices shall be shown in the EPSC and SWMP plans, as appropriate for the proposed land development.**

Table 7.9.13 Installation Steps

Step	Requirement
Step 1	The installation site shall be checked for existing utilities prior to construction. Supervision during construction is required to ensure the stormwater wetland is constructed/installed in accordance with the approved EPSC and SWMP plans. **The design professional or a designee under their supervision must inspect the stormwater wetland at critical stages of construction.** Examples of critical stages of construction include excavation of the various wetland pools, grading of dikes, outlet construction, plant installation, and final inspection. This ensures that the contractor's interpretation of the plan is consistent with the design professional's intentions and allows the design professional to certify (in the as-built plan) that the wetland is built in keeping with the permitted plan.
Step 2	During the preconstruction meeting, review and confirm that the actual boundaries of the wetland's contributing drainage area and inlet elevations conform with the approved design. Any changes that result from the preconstruction meeting must be shown as a revision to the SWMP and resubmitted to the City for approval.
Step 3	Install any stormwater diverters/flow blocks that may be necessary to divert stormwater flows from the wetland areas during its construction.
Step 4	Since most wetlands will intercept the water table, construct the outlet structure first (or if not feasible, with the construction of the embankment) to control the water level in the wetland during excavation.
Step 5	Construct the embankment in 8 to 12 inch lifts or as directed by geotechnical recommendations and compact as required with appropriate equipment. Ensure that the top invert of the emergency spillway (if located on the embankment) is constructed to be level and at the proper design elevation. • Compaction reports must be kept, reviewed, and approved by the design professional before submission to the City with the as-built plan and engineer's as-built certification.
Step 6	Excavate and grade the wetland to its appropriate configuration and dimensions, working from the outlet and moving toward the inlet, until the appropriate elevations and desired contours are achieved for the bottom and side slopes of the wetland. • For excavation of large wetlands, use a cell construction approach where the wetland is split into 500 to 1,000 square foot temporary cells with a 10 to 15 foot earth bridge in between. This allows cell excavation from the sides. • Tracked excavators are recommended, especially on wet sites. Toothed buckets are recommended to avoid smearing and unintended soil compaction. A hydraulic thumb attachment for the bucket is especially useful for removing debris, placing structures, and scarifying soil surfaces. • Special protection measures, such as erosion control fabrics, may be necessary to protect vulnerable side slopes from erosion during the construction.
Step 7	Add topsoil and soil amendments. Equipment should not be allowed to traverse over the planting soil, once placed. Planting soil should be tamped as directed in the design specifications, but it should not be overly compacted. After topsoil is placed, it should be saturated and allowed to settle for at least 1 week prior to installation of plants. Install temporary irrigation measures, if needed, to ensure plants will be watered during the remainder of site construction.
Step 8	Install plants and surface covers as shown in the approved vegetation plan.
Step 9	EPSC devices can be removed from the inlets once the wetland's side slopes have good vegetative stability, and the drainage area is fully and permanently stabilized.

Step	Requirement
	• If the area draining to the wetland includes newly installed asphalt, inlet blocks or EPSC devices should remain for at least three storm events after asphalt installation. A substantial number of fine particles and grit are discharged from newly installed asphalt during the first several storms that produce stormwater after installation. Maintenance will be required to remove the particles and grit if EPSC devices are removed too early.
Step 10	Maintain the stormwater wetland in keeping with Section 7.9.13 (below). Prepare the As-Built Plan and submit to the City for review and approval with the engineer's as-built certification before a final Certificate of Occupancy can be obtained. Advise the landowner (i.e., the person(s) taking ownership of the property immediately after its development) of the presence of the stormwater wetland and provide them with a copy of the property's Record Drawing and SCM maintenance plan. The plan must clearly show the location of the stormwater wetland on the property and list the activities (and their frequencies) necessary for its proper maintenance.

7.9.13 SCM Maintenance on an Active Construction Site

Once an SCM is installed, its maintenance is regulated by Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code. Further, SCMs must pass a final inspection prior to construction termination. This inspection will be performed to ensure they are constructed in accordance with the approved SWMP, undamaged, and free of sediment and debris. Thus, SCM maintenance is good practice to ensure construction termination goes smoothly. Relevant policies are as follows:

- The property owner is responsible for SCM maintenance. If the property is still an active construction site, these responsibilities may fall to the land disturbance permittee until the project receives final approval from the City and/or a Certificate of Occupancy.
- Property owners may have others, such as a site contractor or landscaping company, maintain the stormwater wetland on their behalf. However, the City will hold the property owner responsible for ensuring it is maintained in proper operating condition (i.e., as designed and constructed) regardless of who performs maintenance activities.
- Maintenance activities, which include ensuring proper operation of the SCM as designed and required SCM inspections, must begin immediately following installation of the stormwater wetland.
- Maintenance activities shall be performed in keeping with the *SCM Inspection and Maintenance Manual*. Additional guidance on maintenance of newly installed stormwater wetlands located on active construction sites is provided in Table 7.9.14.

Table 7.9.14 Maintenance Activities for Newly Installed Stormwater Wetlands

Area or Component	Post-Installation Maintenance Requirement
Contributing Drainage Area	Keep the contributing drainage area clean. Sweep trash, debris, and sediment frequently so that it does not wash in the wetland during a rain event. The area should be fully stabilized before installation of the SCM. If it is not, prevent inflows to the SCM by blocking or using diversion measures until the contributing drainage area is fully stabilized. Stabilize the area as soon as possible to prevent the discharge of sediment to the SCM. Cover stockpiles of construction and landscape materials to prevent their exposure to rainfall.
Stormwater Wetland Area	Ensure SCM plants are watered and growing as expected. Remove and replace diseased, dying, or dead plants as soon as they are noticed.

Area or Component	Post-Installation Maintenance Requirement
	Check the forebay regularly to monitor sediment accumulation and remove sediment, trash, and debris as needed. Beyond the forebay, ensure the wetland remains free of sediment and wastes. Inspect the wetland for erosion or significant sediment buildup downstream of the forebay; immediately determine and eliminate the cause and repair the area. Keep an eye on the wetland water levels after storm events to determine if the outlet structure is operating as expected. The wetland should return to its permanent pool elevation with two days, under normal climatic conditions. • If the wetland dries out too quickly or beyond expectations, or experiences long-standing high water when not expected, inspect the outlet structure and main flow path for clogging and damage; remove clogs and repair or replace damaged components as soon as they are noticed.
Education	Alert onsite subcontractors to the SCM and the following requirements: ○ No muddy vehicles or equipment in the drainage area to the wetland. ○ No stockpiling of material in the wetland and no exposed stockpiles in the drainage area. ○ Block inlets prior to asphalt placement in the drainage area. ○ Remove sediment, trash, debris, and empty trash cans frequently. Advise landscaping subcontractors on proper protection and maintenance of the stormwater wetland especially the following: ○ No dumping of lawn clippings or landscape debris ○ Plant maintenance needs/requirements (see above)

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7.9.14 Schematics

Figure 7.9.7 Schematic of an ED Shallow Wetland *(Source: Adapted from Atlanta Regional Council, 2016)*

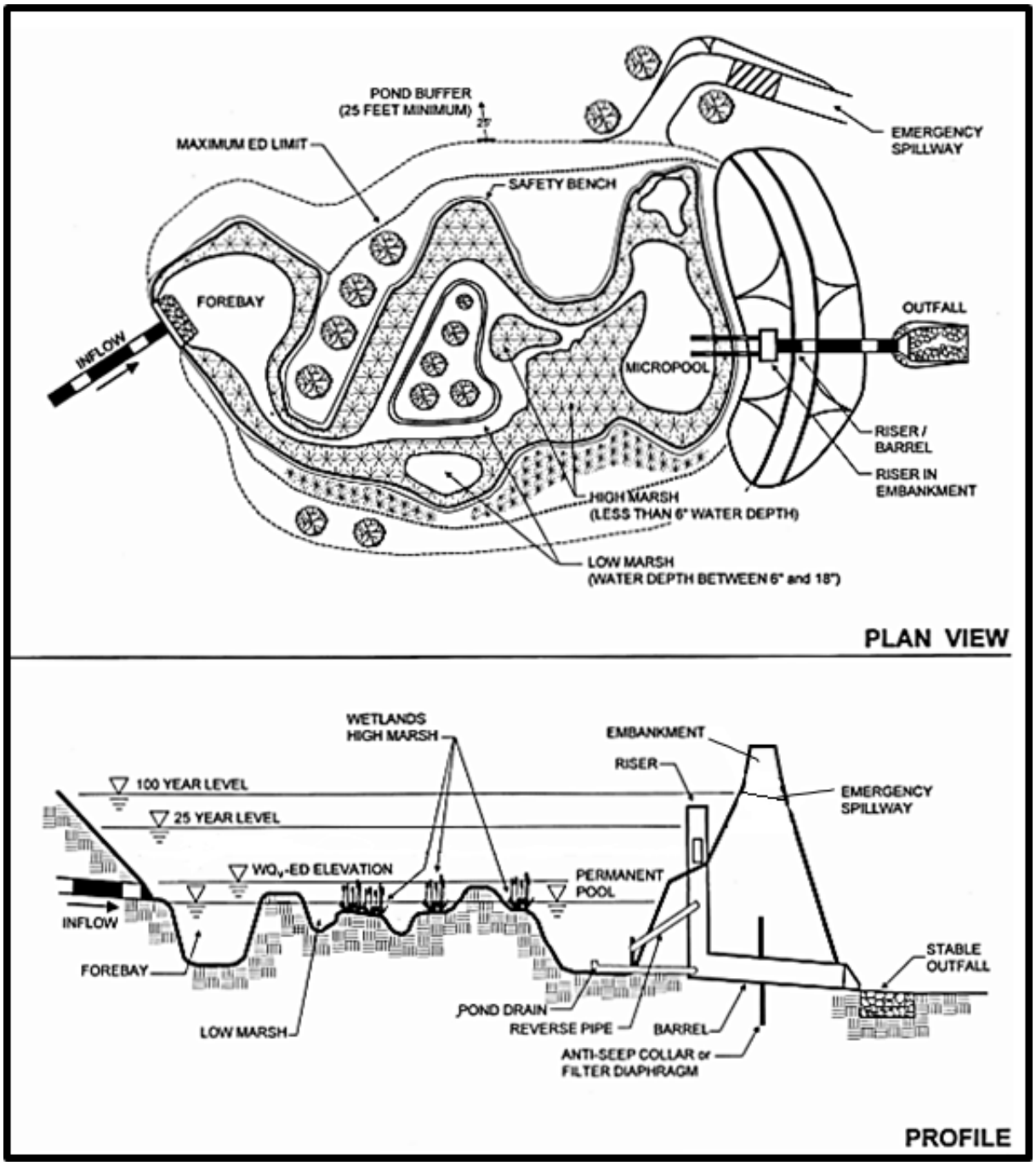

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Figure 7.9.8 Schematic of a Basin/Shallow Wetland System *(Source: Adapted from Atlanta Regional Council, 2016)*

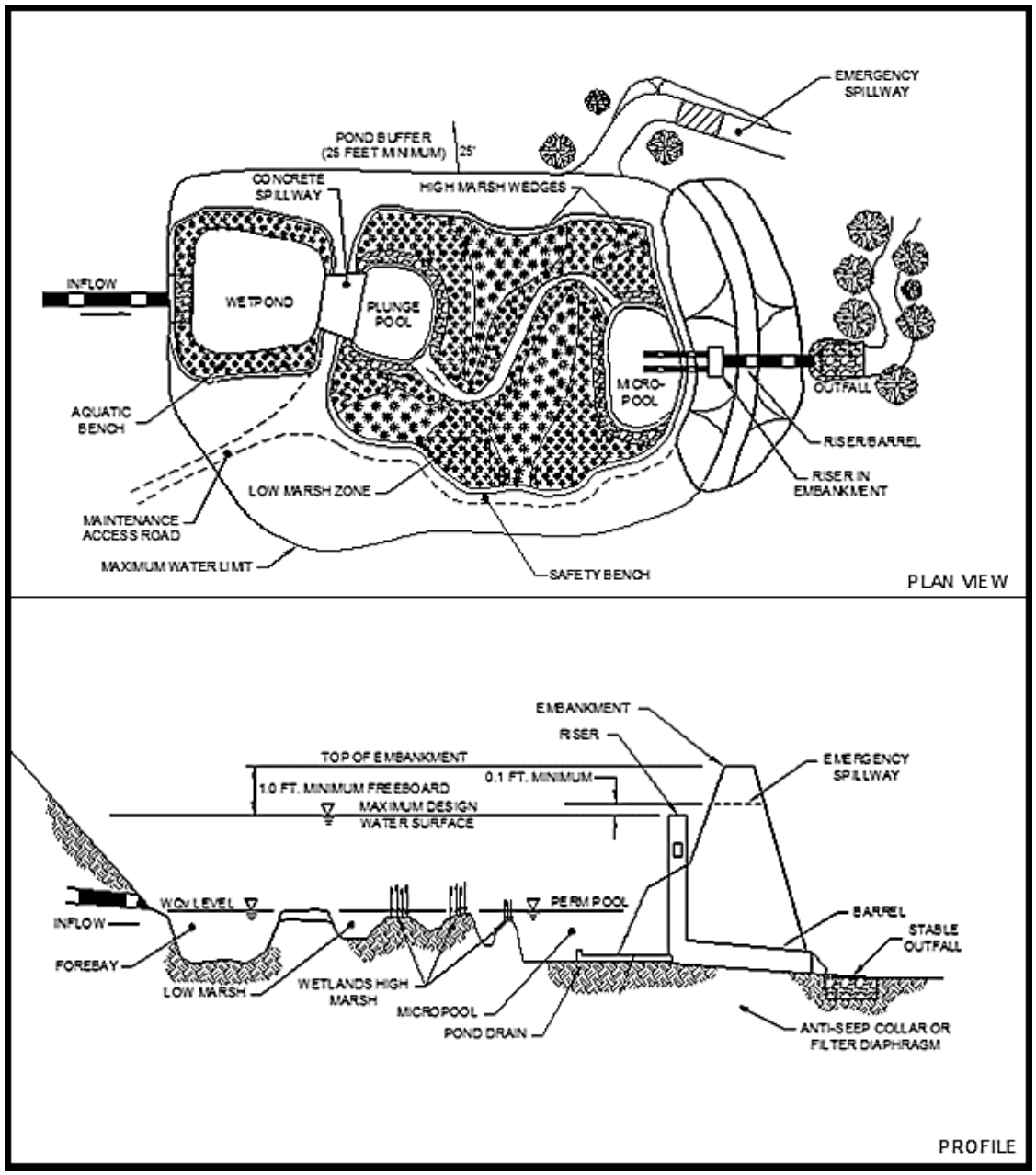

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Figure 7.9.9 Schematic of a Shallow Wetland *(Source: Adapted from Atlanta Regional Council, 2000)*

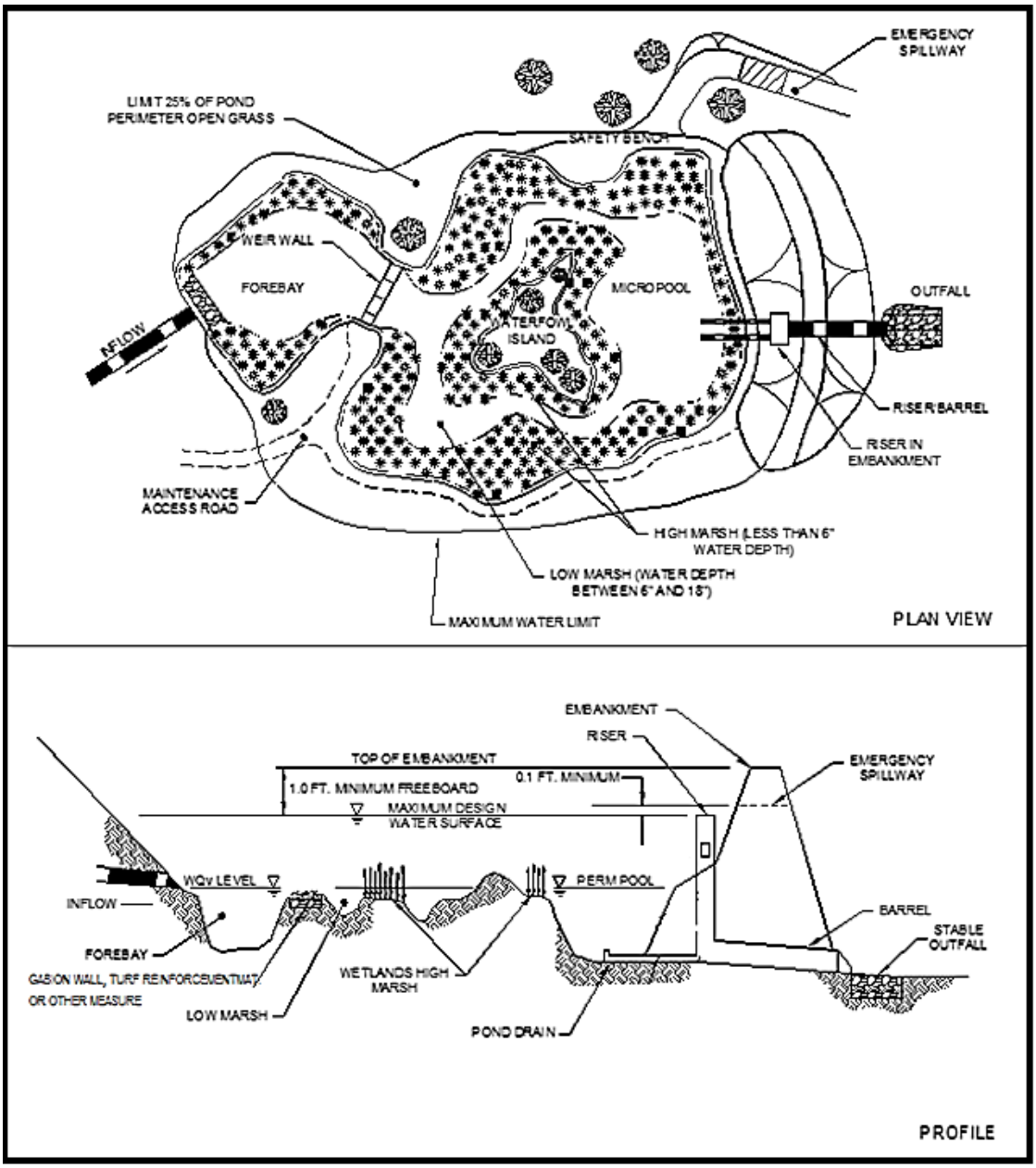

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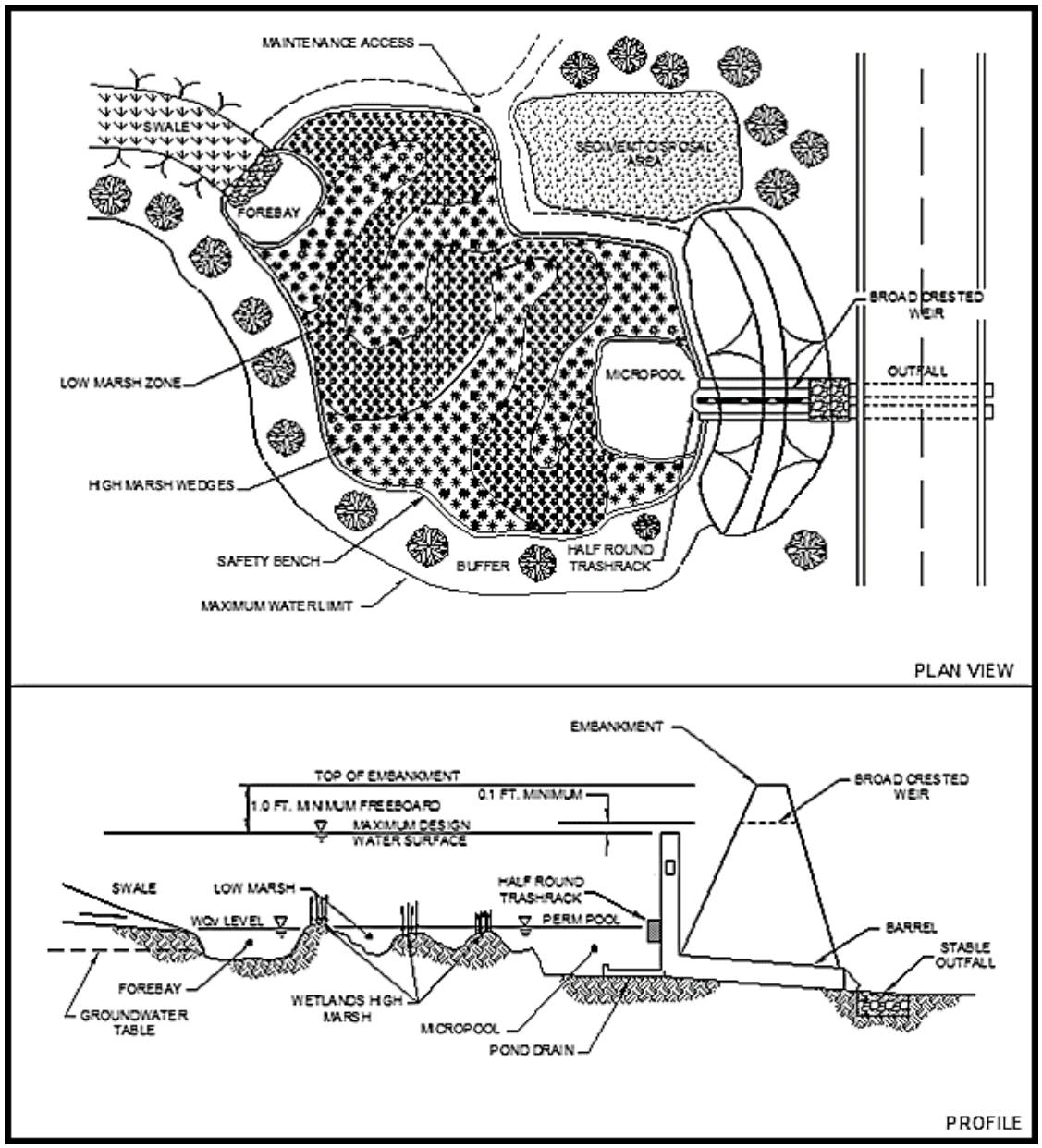
Figure 7.9.10 Schematic of a Pocket Wetland *(Source: Adapted from Atlanta Regional Council, 2016)*



7.9.15 References

ARC, *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition.* Atlanta Regional Commission, 2016.

USDA-NRCS et al., *A Handbook of Constructed Wetlands. A Guide to Creating Wetlands for Agricultural Wastewater, Domestic Wastewater, Coal Mine Drainage, Stormwater in the Mid-Atlantic Region. Volume 1. General Considerations.* United States Department of Agriculture – Natural Resourced Conservation Service.

USDA-NRCS et al., *Field Indicators of Hydric Soils in the United States. A Guide for Identifying and Delineating Hydric Soils, Version 8.2, 2018.* United States Department of Agriculture – Natural Resources Conservation Service.

7.10 UNDERGROUND DETENTION SYSTEM design specifications

(Source: Philadelphia PA Water Department)

Water Quality Volume (WQv) Rainfall

Tier 3 Design (open bottom basins only)
P = 2.5 inches or the first 75% of the volume of the 1-yr, 24-hr storm, *whichever is less*

OTHER SCM ATTRIBUTES *(cost scale is $-low, $$-medium, $$$-high)*	
Channel Protection Volume (CPv)	Yes
Detention / Retention Control	Yes
Small Storm Local Flood Control	Yes
Typical SCM Footprint Size *(percent of contributing drainage area)*	Below grade
Construction Cost	$$$
Operation & Maintenance Cost *(when properly maintained)*	$$

PROJECT SUITABILITY

Industrial	Commercial	Residential *(common areas only)*	Pollutant Hotspots	Private Roadways *(requires HOA)*
✓	✓	✓	✓	✗

Legend: ✓ High ✓ Limited ✗ None

OVERVIEW

Underground detention systems are flood control facilities located in underground pipe systems or vaults. Closed bottom systems provide channel protection using extended detention and flood (i.e., peak discharge) control using detention. Open bottom vaults placed above a lined, gravel bed can provide stormwater quality treatment. This SCM is becoming more popular in commercial and industrial areas because of its versatility in location, configuration, and size.

ADVANTAGES/BENEFITS

- Ideal for highly urbanized areas where land is limited
- Longevity is high with proper maintenance
- SCM manufacturers/vendors can assist with proper location and design

DISADVANTAGES/LIMITATIONS

- Performance dependent on frequency of maintenance
- Requires consideration of structural loads

LOCATION, SIZING, & COMPONENTS

- Maximum contributing drainage area is 10 acres
- Not appropriate for slopes greater than 15%
- Tier 3 designs (i.e., open bottom with underdrain) must include pretreatment, a gravel bed, underdrain, and impermeable liner
- Minimum 2-foot separation from seasonally high-water table
- Minimum pipe diameter is 36 inches
- Requires consideration of structural loads for overburden and traffic/parking
- Maintenance access location(s) must be thoughtfully considered

LONG-TERM PROTECTION

- Underground design creates good protection from inadvertent damage
- Protection measures primarily focus on preventing access to the SCM

LONG-TERM MAINTENANCE

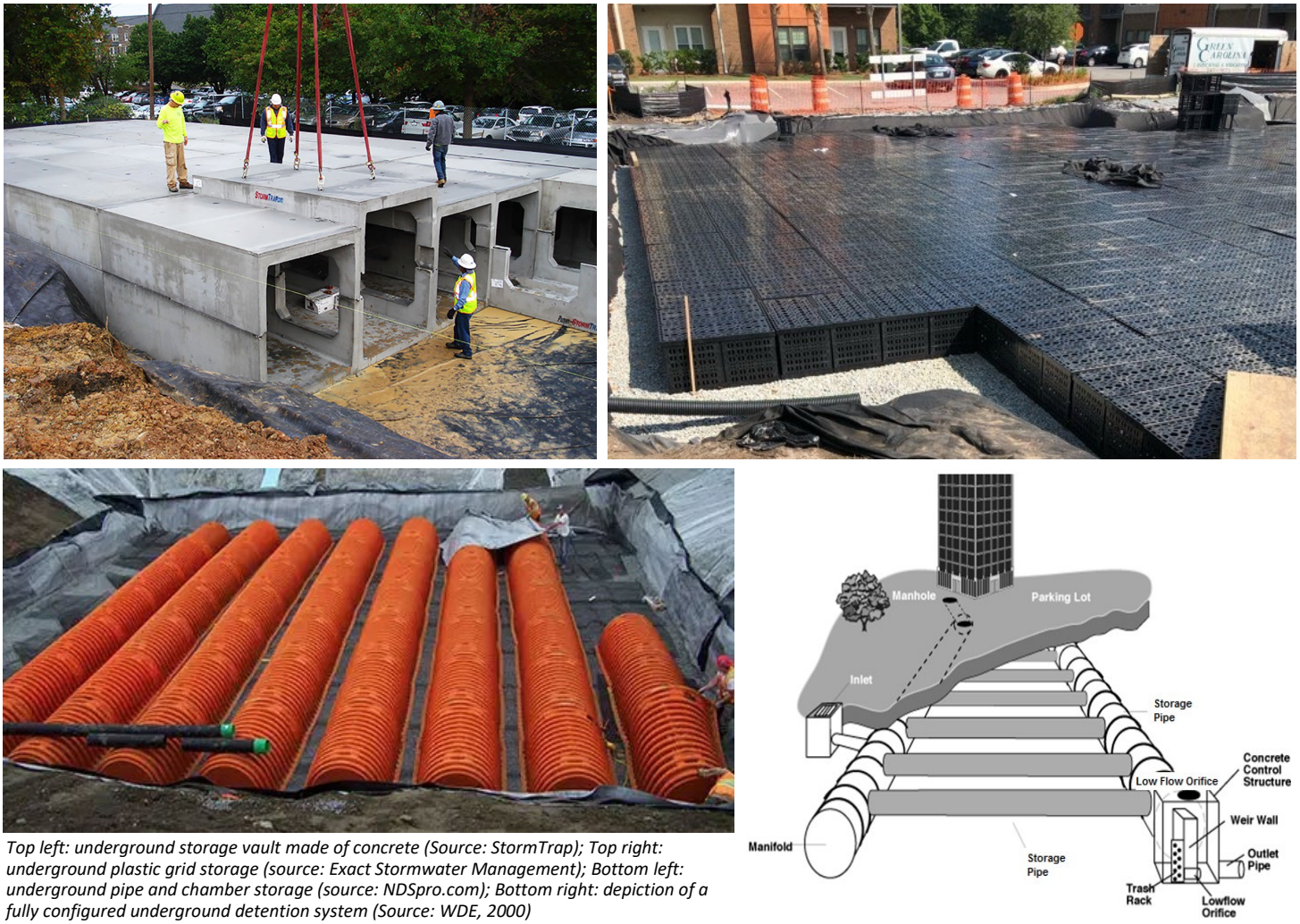
- Primary routine maintenance activities will be trash and debris removal from inlets, removing sediment accumulation
- Special equipment (vacuum trucks) and confined space entry certification may be required

  Some SCM vendors/manufacturers can provide maintenance services

7.10.1 General Description

Underground detention systems are typically utilized on sites where developable surface area is at a premium. Many design and material configurations are available, including box-shaped systems and round or semi-round "barrel" systems (see Figure 7.10.1). Materials used include reinforced concrete vaults, gasketed reinforced concrete pipe, and high density polyethylene (HDPE) pipe. These SCMs serve as alternatives to surface dry detention for stormwater quantity control and channel protection volume (CPv) management where there is not adequate land for a dry or wet detention basin. Basic storage and extended detention design and routing methods are the same as for surface detention basins, except that a bypass (as opposed to an emergency spillway) is included for extreme flows. Pre-manufactured, modular underground detention systems are available from commercial stormwater equipment vendors.

Figure 7.10.1 Examples of Underground Detention Systems



Top left: underground storage vault made of concrete (Source: StormTrap); Top right: underground plastic grid storage (source: Exact Stormwater Management); Bottom left: underground pipe and chamber storage (source: NDSpro.com); Bottom right: depiction of a fully configured underground detention system (Source: WDE, 2000)

Fully enclosed systems such as four-sided concrete vaults and closed bottom arched pipe chambers are not capable of significant pollutant removal due to concerns with sediment resuspension during high flow events. For this design configuration, an SCM that provides treatment of the water quality volume (WQv) must be additionally provided upstream or through diversion of the WQv after detention and before discharge from the property. SCMs with very small footprints such as urban bioretention areas, Tier 2 manufactured treatment devices, and sand filters may be the best options for stormwater quality treatment where closed bottomed underground detention systems are employed.

Some underground detention systems can provide stormwater quality control through open bottom structures placed on a gravel bed. Open bottom structures must include an impermeable liner and underdrain to drain the WQv without increasing the potential for sinkhole formation in the region's karst topography. This design configuration is a Tier 3 SCM.

7.10.2 Design Applications

Underground detention systems can be designed in a variety of ways, but commonly fit into the following three categories. All serve as an alternative to surface detention for stormwater quantity control by providing temporary storage of stormwater and release at controlled rate(s).

- **Underground storage vaults** are buried concrete, fiberglass, or polyethylene chambers.
- **Underground pipe and chamber storage** consists of perforated plastic or metal pipes, or pipe-like linear chambers, that are placed in a stone bed to provide more storage per unit volume. Various pipe dimensions and shapes can be used to optimize the storage volume to meet the specific site requirements.
- **Underground plastic grid storage** consists of buried plastic structures that can be stacked and inter-connected to form various shapes and sizes. Grid systems can provide substantial void space for storage of stormwater.

Because of their versatility, underground detention systems can be placed in a variety of locations. Typical locations for underground detention basins include the following.

- **Parking lots.** Underground systems can be placed under parking lots in locations where space is limited. The underground unit(s) perform the same as surface detention basins.
- **Multi-use pervious areas on a site.** Underground ED basins can be placed under open space area on a site to provide stormwater management in locations without a lot of land for above ground detention.
- **Retrofitting.** Numerous options are available to retrofit detention areas in the urban landscape to increase buildable area.

7.10.3 SCM Suitability

Use Table 7.10.1 to determine if an underground detention system is suitable for the application being considered.

Table 7.10.1 Underground ED Basin Suitability Factors

<table>
<tr><th>Factor</th><th>Suitability</th></tr>
<tr><td>Stormwater Quality Treatment</td><td>Open bottom structures placed on a gravel bed with an underdrain and impermeable liner are suitable for stormwater quality control.
Fully enclosed underground detention systems are not suitable to provide stormwater quality control.</td></tr>
<tr><td>Channel Protection</td><td>Underground detention basins can be designed to satisfy channel protection standards.</td></tr>
<tr><td>Detention</td><td>Underground detention basins can be designed to satisfy peak discharge (flood) control requirements.</td></tr>
<tr><td>Suitability by Land Use</td><td>Privately owned underground detention systems are not allowed in the public right-of-way.
General suitability criteria by land-use type is as follows. See Chapter 6, Section 6.6 for more information.
<table>
<tr><th>Commercial</th><th>Industrial</th><th>Private Roadways</th><th>Single Family Residential</th><th>Multi-Family Residential</th></tr>
<tr><td>Yes</td><td>Yes</td><td>No</td><td colspan="2">Common Areas Only</td></tr>
</table></td></tr>
</table>

7.10.4 SCM Location Requirements

Location constraints for underground detention systems are provided in Table 7.10.2.

Table 7.10.2 Underground Detention System Location Requirements

Physical Element	Requirement
SCM Setbacks	Minimum setbacks, measured from the edge of the underground detention, are as follows: • 50 feet from private water supply well; if the well is down gradient from a land use with a high pollutant load (hotspot), then the minimum setback is 250 feet • Public water supply wells – see TDEC specifications • 50 feet from underground septic systems/leach field
Stormwater quality SCMs	Underground detention systems shall be located downstream of SCMs that provide stormwater quality control.
Flow Avoidance	An underground detention system shall not be located where it will receive continuous or dry weather inflows from springs, seeps, sump pumps, wash stations, or other sources.
Utility Avoidance	Underground ED basins shall not be located above underground dry utility lines (electric, cable, and telephone), water/wastewater infrastructure, and stormwater drainage infrastructure. Design professionals must consult the local utility to determine the horizontal and vertical clearance required between SCMs and dry and wet utility lines.

7.10.5 Design Requirements

The criteria provided in Table 7.10.3 shall be considered minimum standards and specifications for the design of underground ED basins and their contributing drainage areas. Beyond the policies provided herein, design professionals are encouraged to work with a commercial underground detention system manufacturer/vendor to understand any additional design constraints and ensure proper selection and installation.

Table 7.10.3 Design Specifications for Underground Detention Systems

Design Element	Specification(s)
Water Quality Volume (WQv)	Open bottom structures placed on a gravel bed with an underdrain and impermeable liner are suitable for stormwater quality control. The water quality rainfall depth (P) for determination of WQv is P = 2.5 inches, or the WQv is the first 75% of the volume of the 1-yr, 24-hr storm, whichever is less. The design professional can select which volume to use. Acceptable methods to determine WQv are presented in Chapter 6 (SCM Standards, Methods, and SCM Selection).
Controls for Waste & Other Pollutants	Underground detention basins can clog. Appropriate controls shall be included in the design of the contributing drainage area to the SCM to address any wastes and other pollutants (see Table 7.10.1 above) that are expected on the property after construction, especially floatables. Use the proposed land use as a guide to determine appropriate controls. Examples of such controls include, but are not limited to, dumpsters, trash cans, covered materials/waste storage areas, covered materials transfer areas, oil and grease waste controls, and pet waste stations.
Channel Protection Volume (CPv)	The runoff volume from the 1-year frequency, 24-hour duration storm event shall be detained for no less than a 24-hour period, up to a maximum of 48 hours.

Design Element	Specification(s)
	Acceptable methods to determine WQv are presented in Chapter 6 (SCM Standards, Methods, and SCM Selection).
Peak Discharge Control (Flood Control)	The post-development peak discharge shall be less than or equal to the pre-development peak discharge for the 2, 5, 10, 25, and 100-year, 24-hour storm events. NRCS methods shall be used for detention and retention SCM and outlet structure designs.
Maintenance Access and Easements	Adequate maintenance access must be provided to each component of the underground detention system, including access to each chamber/vault/pipe separately. Access openings can consist of a stand frame, grate, solid cover, removable panel, or other access mechanism. Vaults with widths of 10 feet or less should have removable lids. A maintenance easement shall be provided to the underground ED detetnion from a driveway, public or private road. It shall be designed as follows: • a minimum width of 15 feet • a maximum slope of no more than 15% • the access route in the easement shall be free of permanently affixed obstructions (e.g., trees, pools, fences without gates, permanent signs, etc.) and appropriately stabilized to withstand maintenance equipment and vehicles • to the extent feasible, allow vehicles to turn around The entire underground ED detention system, (including inlets, pretreatment devices, the storage, outlet structure, and emergency spillway) shall be included in the easement and shall be accessible from the easement's drive path.
Drainage Area	Maximum contributing drainage area = 10 acres; larger drainage areas require multiple underground drainage systems Maximum slope of the contributing drainage area = 15%
System Volume & Drawdown	Underground detention systems designed to manage the WQv and/or CPv shall discharge the WQv and/or CPv fully no less than 24 hours but no longer than 72 hours. Use the orifice sizing guidance presented in Chapter 6 (SCM Standards, Methods, and Selection). There are no restrictions on drawdown time for flood control storm events. Routing calculations must demonstrate that the system's storage volume is adequate for the design storms it is intended to control.
Minimum Depth to Water Table	A minimum separation distance between the bottom of the basin and the elevation of the seasonally high-water table = 2 feet Soil borings shall be used to determine the seasonally high-water table. See Appendix E (Policies for Soil Borings and Infiltration Tests) for soil boring requirements.
Minimum Hydraulic Head	Minimum hydraulic head = 4 to 8 feet.
Structural Load Bearing	Structural load bearing capacity of subsurface soils must be adequate to support the detention system and stormwater volume at full capacity. Underground detention vaults and tanks must meet structural requirements for overburden support and any additional loads expected (i.e., traffic, parked vehicles, etc.).
Physical Specifications	General: • Maximum depth from finished grade to system invert = 12 feet • All construction joints must be provided with water stops Concrete vaults: • Material: minimum 3,000 psi structural reinforced concrete

Design Element	Specification(s)
	• Cast-in-place wall sections must be designed as retaining walls Pipes/Chambers: • Minimum diameter = 36 inches (3 feet) Consult with manufacturer recommendations for additional physical specifications.
Pretreatment & Inlets	Stormwater pretreatment shall be provided at inlets for underground detention systems that do not receive water from water quality treatment SCMs. Sediment and floatables (i.e., trash, debris, etc.) are the primary pollutants to be targeted for pretreatment, although consideration of other pollutants (e.g., oil and grease) may be needed depending on land use. • For underground detention systems that will provide WQv control, sediment forebays (e.g., a sump or vault) are required. Forebays shall be sized to hold a minimum of 10% of the WQv. Forebay volume can be considered as part of the WQv, not additional volume of the basin. • For non-WQv applications, A basket, screen, grate, or hydrodynamic separator (Tier 4 MTD) are suitable for this purpose. Some pre-manufactured underground systems are designed to capture floatables without additional pretreatment device(s). When a hydrodynamic separator is used for pretreatment, it is not subject to NJDEP certification for 80% TSS removal. Forebays and other pretreatment devices must be easily accessible for frequent cleaning but also protected against unwanted entry.
Gravel Bed & Underdrain	Consult the underground detention system manufacturer regarding design of the gravel bed for temporary storage of the WQv, and underdrain for WQv release.
Outlet Structure & High Flow Bypass	The outlet structure shall consist of a weir, orifice, outlet pipe, combination outlet, or their control structure. See Chapter 6 (SCM Standards, Methods, and Selection) for more information on outlet structure design. Water shall not be discharged from an underground detention system in an erosive manner. Riprap, plunge pools or pads, or other energy dissipaters must be located at the end of the outlet to prevent scouring and erosion. If the system outlet discharges immediately to a channel that carries dry weather flow, care should be taken to minimize disturbance along the downstream channel and streambanks, and to reestablish a forested riparian zone in the shortest possible distance (if the downstream area is located in vegetated buffer). A high flow bypass is required to safely pass flows greater than the maximum design storm required for detention by the City. The bypass provides system protection and release in the event of outlet structure blockage or mechanical failure. The bypass shall be located so that the downstream structures will not be impacted by emergency discharges.
Safety Features	A safety ladder (preferably permanently affixed) shall be provided for vaults deeper than 4 feet.

7.10.6 Design Procedure

Table 7.10.4 provides the design procedure for underground detention systems.

Table 7.10.4 Design Procedure

Step	Design Activity
Step 1	**Evaluate underground detention system feasibility.** Use the feasibility criteria provided in Tables 7.10.1 and 7.10.2 to determine if an underground detention system basin is feasible for the selected location. Consider especially whether it is appropriate for the proposed development based on the intended land use of the property, the maintenance burden, and assumptions or knowledge of how the property owner(s) will care for the underground detention basin after construction (e.g., self-maintenance, property/facilities management maintenance, landscape contractor). If possible, include the property owner(s) in SCM selection since they will be responsible for maintenance.
Step 2	**Determine underground basin location and preliminary geometry.** Ensure that there is adequate site area for installation of the underground detention facility, including maintenance access to vault. Do this by creating a rough layout of its dimensions, taking into consideration existing trees, utility lines, and other obstructions.
Step 3	**Design the system and outlet for WQv and/or CPv control.** If the system will provide stormwater quality treatment and/or channel protection, set up a stage-storage-discharge relationship for the control structure. • Use the hydrologic methods established in Chapter 6 (SCM Standards, Methods, and SCM Selection) to determine the WQv and CPv (if required) for the basin's contributing drainage area. • Calculate the orifice release rates for WQv and CPv control (i.e., extended detention of 24 to 72 hours), and orifice sizes and elevations.
Step 4	**Design the system and outlet for flood control.** Use the stage-storage-discharge relationship to design the outlet for the required detention design storms. Also refine the sizing of the system itself based on the stage-storage-discharge curve.
Step 5	**Design the emergency bypass** Size emergency bypass and analyze safe passage downstream. Set the emergency bypass inlet elevation a minimum of 0.1 feet above the water surface elevation for the 100-year, 24-hour storm event.
Step 6	**Design inlets and maintenance access.** See Table 7.10.3 above for more details. Ensure maintenance access is protected from unwanted entry.

7.10.7 SCM Maintenance on an Active Construction Site

Once an SCM is installed, its maintenance is regulated by Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code. Further, SCMs must pass a final inspection prior to construction termination. This inspection will be performed to ensure they are constructed in accordance with the approved stormwater management plan (SWMP), undamaged, and free of sediment and debris. Thus, SCM maintenance is good practice to ensure construction termination goes smoothly. Relevant policies are as follows:

- The property owner is responsible for SCM maintenance. If the property is still an active construction site, these responsibilities may fall to the land disturbance permittee until the project receives final approval from the City and/or a Certificate of Occupancy.

- Property owners may have others, such as a site contractor maintain the underground detention basin on their behalf. However, the City will hold the property owner responsible for ensuring it is maintained in proper operating condition (i.e., as designed and constructed) regardless of who performs maintenance activities.
- Maintenance activities, which include ensuring proper operation of the SCM as designed and required SCM inspections, must begin immediately following installation of the underground detention basin.
- Maintenance activities shall be performed in keeping with the *SCM Inspection and Maintenance Manual*. Additional guidance on maintenance of newly installed underground detention basin located on active construction sites is provided in Table 7.10.5.

Table 7.10.5 Maintenance Activities for Newly Installed Underground Detention Systems

Area or Component	Post-Installation Maintenance Requirement
Contributing Drainage Area	Keep the contributing drainage area clean. Sweep trash, debris, and sediment frequently so that it does not wash in the underground detention basin during a rain event. The area should be fully stabilized before installation of the SCM. If it is not, prevent inflows to the SCM by blocking or using diversion measures, or establish and maintain EPSC measures to prevent sediment-laden water from discharging into the SCM. Cover stockpiles of construction and landscape materials to prevent their exposure to rainfall.
Underground Detention Area	Remove sediment and debris from pretreatment and detention area. Visually observe the SCM's function after rain events; there should be no standing water within about 72 hours after a storm event, depending on the frequency of rainfall. If long-standing water is observed in the outlet structure(s) inspect for blockages; make repairs if needed.
Education	Alert onsite subcontractors and landscapers to the SCM and the following requirements: • No muddy vehicles or equipment in the drainage area to the underground detention. • No stockpiling of material and no exposed stockpiles in the basin's drainage area. • No dumping of materials, lawn clippings, or landscape debris in the drainage area. • Repair areas of bare soil and erosion in the drainage area. • Block inlets prior to asphalt placement in the drainage area. • Remove sediment, trash, debris, and empty trash cans frequently.

7.10.8 References

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition*. Atlanta Regional Commission, 2016.

Connecticut Department of Energy & Environmental Protection (CT DEEP). *CT Stormwater Manual. Chapter 11 Design Guidance. Underground Detention Facilities*. CT DEEP, Hartford, Connecticut ,March 26, 2024.

7.11 URBAN BIORETENTION AREA design specifications

STORMWATER QUALITY CONTROL
Tier 2 Design P = 1.25 inches

OTHER SCM ATTRIBUTES	
Channel Protection Volume (CPv)	**No**
Detention / Retention Control	**No**
Small Storm Local Flood Control	**No**
Typical SCM Footprint Size *(percent of contributing drainage area)*	**5%** *(approx.)*
Construction Cost	**$$**
Operation & Maintenance Cost *(when properly maintained)*	**$$**

PRIVATE PROJECT SUITABILITY				
Industrial	**Commercial**	**Residential** *(common areas only)*	**Pollutant Hotspots**	**Private Roadways** *(requires HOA)*
✓	✓	✓	✗	✓

Legend: ✓ High; ✓ Limited; ✗ None

OVERVIEW

Urban bioretention areas are low impact development (LID) stormwater control measures (SCMs) designed to treat stormwater quality in highly impervious areas. Sometimes referred to as "stormwater planters", these SCMs treat very small drainage areas. This makes them compact and thus useful for managing stormwater quality on zero-lot-line and highly developed properties. They are filled with an engineered soil mix for biofiltration. Plants provide evapotranspiration and visual appeal. Urban bioretention areas are designed to address stormwater quality only, filtering water through the engineered soil mix and discharging it to the onsite stormwater drainage system via an underdrain.

ADVANTAGES/BENEFITS

- Can be formed and sized to optimize the use of space
- Useful for any development context, including ultra-urban
- Improves property value through attractive landscaping

DISADVANTAGES/LIMITATIONS

- Maximum drainage area is 2,500 ft^2

LOCATION, SIZING, & COMPONENTS

- Must completely drain within 24-hours after a rain event
- Maximum ponding depth of 6 inches prevents nuisance ponding
- Minimum depth of 24 inches; minimum width of 18 inches
- Minimum 2 feet separation from seasonally high water table
- Underdrain required

LONG-TERM PROTECTION

- Primary concerns are plant damage and soil compaction
- Protect from entry by vehicles and heavy equipment
- Suitable for a wide variety of protective designs (prickly shrub borders, curbing, decorative fencing, bench seating, etc.)

LONG-TERM MAINTENANCE

- Primary routine maintenance activities will be inlet, pretreatment device, and plant bed cleaning and plant care (e.g., watering, weeding, pruning, mulching, leaf and landscape debris removal, plant replacement)
- Consider installing pet waste stations to dissuade entry and use of SCM as a pet relief area
- Provide trash cans in the drainage area
- Select plants (no trees) that can withstand occasional short-term inundation

7.11.1 General Description

Urban bioretention areas are small stormwater treatment areas designed to fit within tight landscape spaces (see Figure 7.11.1). What sets these SCMs apart from conventional bioretention areas is their small drainage areas, compact size, and vertical side walls. They must always include impermeable liners and underdrains. However, they treat stormwater in the same way a conventional Tier 2 bioretention area does. Stormwater enters a landscaped bed planted then soaks into the engineered soil mix below. Evaporation, plant transpiration, and biofiltration removes pollutants from the captured stormwater, which is then discharged to the onsite stormwater drainage conveyance system through the underdrain.

This design specification pertains to urban bioretention SCMs that are uniquely designed, sized, and constructed to fit the needs and aesthetic of the proposed land development. It does not address Tier 2 LID manufactured treatment devices (MTDs), which are similar in function but manufactured as standardized product lines in a range of sizes/capacities. See Section 7.6 (Manufactured Treatment Devices) for the design specifications pertaining to LID-MTDs.

Figure 7.11.3 Examples of Urban Bioretention Areas

Left: An urban bioretention area receives roof runoff through a downspout and serves as a decorative planter box; Upper Right: Urban bioretention areas manages runoff from the sidewalk and street in the City of Ukiah, CA (Source: Russian River Watershed Association); Lower middle: Urban bioretention boxes at the Tennessee Association of Realtors in Nashville TN (Metro Water Services); Lower Right: An urban bioretention area receives stormwater from the downspout of the adjacent building

7.11.2 Design Applications

Urban bioretention SCMs are similar in function to conventional bioretention SCMs [see Section 7.1 (Bioretention Area)] except they are adapted to fit into "containers" within urban landscapes. They are becoming popular SCMs for urban streetscape or City street Right of Way (ROW). On privately owned properties, these highly versatile SCMs are appropriate

for exterior planters adjacent to buildings, between buildings and sidewalks, or within outdoor congregational areas such as court yards and plazas (see Figure 7.11.2).

Urban bioretention areas feature hard edges, often with vertical sides typically made of pre-cast or cast-in-place concrete. Impermeable liners prevent water seepage, which is key to their flexibility in location. These SCMs always have an underdrain. These design requirements ensure building foundations are not negatively impacted by water and adjacent areas do not experience nuisance water ponding during large events.

Urban bioretention areas are not intended for large commercial areas, nor should they be used to treat small sub-areas of a large drainage area such as a parking lot. Rather, these SCMs are intended to be incorporated into small, fragmented drainage areas such as shopping or pedestrian plazas within a larger urban development. Curbs, benches, and other decorative features are often placed along the perimeter of the SCM, providing both protection for the plants and soil and adding visual appeal.

A primary concern associated with the design of an urban bioretention area is its storage capacity. Each urban bioretention area must be able to manage the entire water quality volume (WQv). If this cannot be accomplished, due to site characteristics or constraints, consider using them in combination with other LID-SCMs, such as permeable pavement systems [Section 7.7 (Permeable Pavement System)]. These SCMs in particular partner well with urban bioretention areas and can easily supplement the stormwater management benefits provided by them.

Figure 7.11.2 Urban Bioretention in Plazas

Top: Urban bioretention areas outside Epler Hall at Portland State University (Source: Oregon Bureau of Environmental Services); Bottom: Urban bioretention areas in a plaza [Source: Clean Water Services (Water Resources Management Utility), Washington County, OR]

7.11.3 SCM Suitability

Use Table 7.11.1 to determine if an urban bioretention SCM is suitable for the application being considered.

Factor	Suitability
Stormwater Quality Treatment	Urban bioretention areas designed in keeping with the specifications established herein will satisfy City of Alcoa (City) stormwater quality treatment standards.
Channel Protection	Urban bioretention areas are not suitable for managing the channel protection volume (CPv). The SCM must be designed to bypass the CPv.
Detention	Urban bioretention areas are not suitable for peak discharge (detention) control, even for small design storms (the 2-year event). The urban bioretention area must be designed to bypass these flows.

<table>
<tr><th>Factor</th><th>Suitability</th></tr>
<tr><td>Pollutant Treatment Capability</td><td>Urban bioretention areas can be used to address following common stormwater pollutants)[1]:
<table>
<tr><th>Total Suspended Solids (TSS)</th><th>Total Phosphorus (TP)</th><th>Total Nitrogen (TN)</th><th>Fecal Bacteria</th><th>Metals*</th></tr>
<tr><td>80%</td><td>60%</td><td>60%</td><td>80%</td><td>Not applicable</td></tr>
</table>
[1] Georgia Stormwater Management Manual, Volume 2 Technical Handbook, 2016 Edition.
*Cadmium, copper, lead, and zinc</td></tr>
<tr><td>Treatment of Waste and Other Pollutants</td><td>Urban bioretention areas shall not be used to treat the following pollutants:
• Construction sediment/waste
• Landscape storage or waste
• Sewage, pet, and livestock waste
• Medical waste
• Household & commercial wastes
• Hazardous wastes
• Gasoline, motor oils, greases, and other petroleum-based products
• Fats, oils & grease (from food preparation)
• Pesticides, fertilizers, herbicides
• Other byproducts and waste materials expected, based on the property's land use</td></tr>
<tr><td>Suitability by Land Use</td><td>Privately owned urban bioretention SCMs are not allowed in the public right-of-way.
General suitability criteria by land-use type are as follows. See Chapter 3 (Standards, Methods, and SCM Selection) for more information.
<table>
<tr><th>Commercial</th><th>Industrial</th><th>Private Roadways</th><th>Single Family Residential</th><th>Multi-Family Residential</th></tr>
<tr><td>Yes</td><td>Yes</td><td>Yes</td><td colspan="2">Common Areas Only</td></tr>
</table></td></tr>
</table>

7.11.4 SCM Location Requirements

Location constraints for urban bioretention areas are provided in Table 7.11.2.

Table 7.11.2 Urban Bioretention Area Location Requirements

Physical Element	Requirement
SCM Setbacks	Minimum setbacks are as follows: • 10 feet from property lines • 100 feet from private water supply wells • 400 feet from public water supply reservoirs (measured from edge of water) • 1200 feet from public water supply wells • 100 feet from underground septic systems • At least 5 feet down gradient from underground utility lines
Risk Avoidance	Do not use urban bioretention areas in locations where their operation may create a risk for basement flooding, interfere with subsurface sewage disposal systems, or negatively affect other underground structures.
Flow Avoidance	Urban bioretention areas shall not be located where it will receive continuous or dry weather inflows from springs, seeps, sump pumps, wash stations, or other sources.
Pollutant Hotspots	Urban bioretention areas are required to have impermeable liners, therefore they can be used in pollutant hotspots and at locations where contaminated soil is known or suspect.

Utility Avoidance	Urban bioretention areas shall not be located above underground dry utility lines (electric, cable, and telephone), water/wastewater infrastructure, and stormwater drainage infrastructure. Design professionals must consult the local utility to determine the horizontal and vertical clearance required between SCMs and dry and wet utility lines.

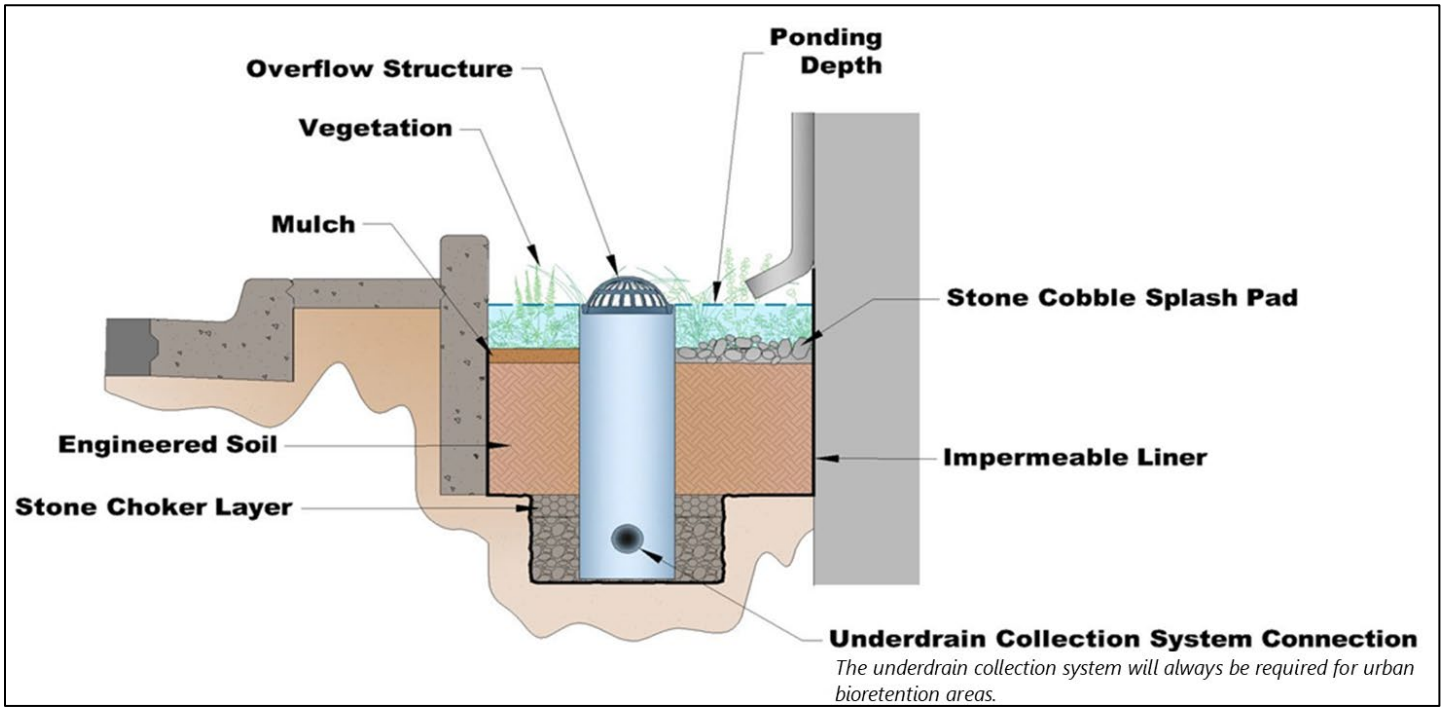
7.11.5 Design Requirements

The criteria provided in Tables 7.11.3 and 7.11.4 shall be considered minimum standards and specifications for the design of urban bioretention areas and their contributing drainage areas. These criteria shall be applied in the design of all Tier 2 urban bioretention areas unless stated otherwise. Figure 7.11.3 is provided to identify the components described in the table.

Table 7.11.3 Design Specifications for the Contributing Drainage Area

Design Element	Specification(s)
Size	Maximum contributing drainage area =2,500 ft^2
Slope	Maximum slope of contributing drainage area = 6%; however, slopes that are as close to flat as possible are preferred to help ensure that stormwater is evenly distributed over the planting bed. If slopes exceed 6%, multiple urban bioretention areas can be constructed at varying elevations.
Controls for Waste & Other Pollutants	Appropriate controls shall be included in the design of the contributing drainage area to the SCM to address any wastes and other pollutants (see Table 7.11.1 above) that are expected on the property after construction. Use the proposed land use as a guide to determine appropriate controls. Examples of such controls include, but are not limited to, dumpsters, trash cans, covered materials/waste storage areas, covered materials transfer areas, oil and grease waste controls, and pet waste stations.

Figure 7.11.4 Primary Components of an Urban Bioretention Area (Cross-Section View)



The underdrain collection system will always be required for urban bioretention areas.

Table 7.11.4 Design Specifications for the Urban Bioretention Area

Design Element	Specification(s)
Water Quality Volume (WQv)	Urban bioretention areas are a Tier 2 SCM, therefore the water quality rainfall depths (P) for determination of WQv is: P = 1.25 inches: Acceptable methods to determine WQv are presented in Chapter 6, Section 6.2 (Water Quality Management). If the urban bioretention area can treat the entire WQv for its contributing drainage area, additional SCMs for stormwater quality treatment are not required in the contributing drainage area.
Use in a Water Quality Treatment Train	If the urban bioretention cannot manage the entire WQv for its contributing drainage area, it must be placed in a treatment train with another SCM. See treatment train policies and calculations in Chapter 6, Section 6.2.4 for treatment train policies and calculations. Urban bioretention areas shall always be located upstream of other SCMs (e.g., detention basins designed for flood control, SCMs in a water quality treatment train, etc.).
Offline and Online Design Configuration	An offline configuration is designed and constructed away from the main flow path for the drainage area, thus avoiding large flood flows. This configuration is the preferred configuration for urban bioretention areas that receive inflows from ground level surfaces, such as a courtyard, as opposed to rooftops. • A flow splitter, diversion structure, or other means is used upstream of the SCM's inlets to redirect the WQv from the main flow path to the SCM while still allowing larger flows to remain in the main flow path. • The diversion structure shall include a low-flow orifice, weir, or other hydraulic structure, sized to pass the peak discharge of the water quality peak discharge (Q_{wq}) to the urban bioretention area. An online configuration is designed and constructed so the main flow path for the drainage area passes through the urban bioretention area. This is a common configuration for urban bioretention areas that receive rooftop drainage, as the rooftop is the extreme upstream end of a flow path. However, it is not recommended for urban bioretention areas located at ground level and in a flow path for a large drainage area as there is a high potential for significant sediment accumulation and remedial maintenance. Thus, an online urban bioretention area is permissible only for drainage areas that are 100% impervious and have low potential for sediment and debris loads, such as drainage from a small building rooftop. Flow regulators (flow splitters, diversion structures, and overflow structures) shall be designed in keeping with Sections 7.14 (Inlets, Pretreatment, and Energy Dissipation Devices) and (Overflow Structures).
Maintenance Access and Easement	A maintenance easement shall be provided to the urban bioretention area from a driveway, public or private road. It shall be designed as follows: • a minimum width of 15 feet • a maximum slope of no more than 15% • the access route in the easement shall be free of permanently affixed obstructions (e.g., trees, pools, fences without gates, permanent signs, etc.) and appropriately stabilized to withstand maintenance equipment and vehicles • to the extent feasible, allow vehicles to turn around

Design Element	Specification(s)
	The entire urban bioretention area, (including inlets, pretreatment devices, the storage area, and outlet structure) shall be included in the easement and shall be accessible from the easement's drive path.
Inlets and Energy Dissipation	Stormwater shall enter the urban bioretention area at non-erosive velocities (maximum of 5 ft/sec). Energy dissipation control measures, such as rock aprons or stilling basins shall be provided for inflows exceeding 5 ft/sec. Such measures are common within urban bioretention areas that receive rooftop runoff, as depicted in Figure 7.11.3. If used to receive non-rooftop drainage, consider employing a pea gravel diaphragm or equivalent level spreader device (e.g., concrete sills, curb stops, curbs with "sawteeth" cut into them) to intercept inflowing stormwater and distributing it evenly, as overland flow, across the urban bioretention area.
Pretreatment	Pretreatment is not required for urban bioretention areas due to their small, highly impervious drainage areas that typically have low potential for sediment and debris loads.
Overflow Structure	An overflow structure that safely passes stormwater that exceeds the design volume (typically this will be the WQv) must be included in the design to prevent overfilling the SCM and flooding in adjacent areas. Small, offline urban bioretention areas may be exempted from this requirement depending on the design situation. • The overflow structure is typically a yard drain inlet with a debris/trash rack [see Figures 7.11.3 (above) and 7.11.4 (below)], though any number of conventional systems could be used. For example, a spillway that discharges to a nearby inlet for the onsite stormwater conveyance system is suitable. • The overflow structure shall bypass the underdrain and either discharge to the outlet pipe/channel for the urban bioretention area or directly to the onsite stormwater conveyance system (or a stabilized watercourse). Discharges from the overflow structure must be non-erosive (maximum of 5 ft/sec). • The elevation at which the overflow structure becomes operational must be set at the maximum ponding elevation (i.e., no more than 12 inches above the mulch layer). • Metal debris/trash racks are recommended over plastic to avoid UV degradation and need for rack replacement (see Figure 7.11.5).
Flow Paths	Maximum flow path lengths: • Pervious contributing drainage areas: 150 ft • Impervious contributing drainage areas: 75 ft For longer flow paths: • use multiple urban bioretention areas to break up the flow path, or • use a conventional bioretention area [Section 7.1 (Bioretention Area)] instead.
Minimum Depth to Water Table	Minimum separation distance (bottom of excavation to seasonally high-water table) = 2 feet Soil borings shall be used to determine the seasonally high-water table. See Appendix E (Policies for Soil Borings & Infiltration Tests) for soil boring requirements.
Minimum Hydraulic Head	Minimum hydraulic head = 2 feet • The hydraulic head is the difference in the inflow elevation, including the design ponding depth, to the outflow elevation at the underdrain invert elevation at its downstream end.
Drawdown Time	The WQv shall fully discharge from the underdrain within 24 hours

<table>
<tr><th>Design Element</th><th>Specification(s)</th></tr>
<tr><td>Material</td><td>Urban bioretention areas can be constructed of stone, concrete, brick, or other durable material. Chemically treated wood is not allowed as it can leach toxic chemicals into the stormwater discharged through the underdrain.</td></tr>
<tr><td>Surface Area and Geometry</td><td>Urban bioretention areas should be designed so that overflow drains away from buildings to prevent damage to building foundations.
Minimum width (inside wall to inside wall) = 18 inches
Walls must be vertical or near vertical
The geometry of the urban bioretention area shall be designed such that:
stormwater flowing into the SCM is distributed evenly across its entire surface area,
soil and vegetation within the SCM are not bypassed or short-circuited (e.g., incoming flow is diverted immediately to the underdrain).</td></tr>
<tr><td>Ponding Depth</td><td>Maximum surface ponding depth = 12 inches (above the mulch layer); 6 inches is recommended to avoid nuisance ponding</td></tr>
<tr><td colspan="2">The remaining rows specify the subsurface layers of the SCM, starting at the bottom.</td></tr>
<tr><td>Liner Layer</td><td>30 mil (0.030 inch) polyvinylchloride (PVC) impermeable liner
Install the liner on the sides and bottom of the urban bioretention area to prevent damage to building foundations and other adjacent impervious surfaces.</td></tr>
<tr><td>Underdrain & Internal Water Storage (IWS)</td><td>Minimum internal water storage (IWS) depth = 12 inches
IWS (located in the engineered soil mix layer) shall be provided using an upturned elbow underdrain configuration. See Section 7.15 (Underdrain and Internal Water Storage Design) for underdrain design requirements.</td></tr>
<tr><td>Stone Choker Layer</td><td>Double washed AASHTO #8 stone or double washed AASHTO #89 pea gravel.
Layer depth = 3 inches; placed above the underdrain’s stone jacket</td></tr>
<tr><td>Engineered Soil Mix Layer</td><td>Minimum depth of engineered soil mix layer = 24 inches (includes the required minimum depth of 12 inches for IWS); beyond this minimum, the design depth is determined by the design volume (typically this will be the WQv), the design IWS (minimum is 12 inches), the SCM geometry, and plant needs for establishment and long-term root growth.
The engineered soil mix shall be a homogenous mix and meet the standards in the following two tables to provide adequate infiltration, nutrient uptake, and plant support.
<table>
<tr><th>Material</th><th>Specification</th><th>Recommended Test Method</th></tr>
<tr><td>Medium to coarse washed sand:</td><td>70-85%
Particle size: 0.050 to 2.0 mm</td><td rowspan="2">AASHTO T88 Standard Method of Test for Particle Size Analysis of Soils</td></tr>
<tr><td>Clean, fine soil:</td><td>Silt + clay 10 to 20%, with clay content less than 10%
Clay particle size: < 0.002 mm
Silt particle size: 0.002 to 0.050 mm</td></tr>
<tr><td>Organic Matter</td><td>5 to 8%
*Animal or poultry manure, at any stage of composition, shall not be used for organic matter content</td><td>AASHTO T194 Standard Method of Test for Determination of Organic Matter in Soils</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Design Element</th><th colspan="2">Specification(s)</th></tr>
<tr><td></td><td colspan="2">
<table>
<tr><th>Parameter</th><th>Specification</th></tr>
<tr><td>pH</td><td>5.5 to 7.5</td></tr>
<tr><td>Magnesium</td><td>Minimum 32 parts per million (ppm)</td></tr>
<tr><td>Phosphorus* (as phosphate P_20_5)</td><td>Maximum 60 ppm as plant available phosphorus</td></tr>
<tr><td>Potassium (K_20)</td><td>Minimum 78 ppm</td></tr>
<tr><td>Soluble Salts</td><td>Maximum 500 ppm</td></tr>
</table>
The volume of engineered soil mix specified and placed shall be based on 110% of the required volume for the SCM to account for settling just after mix placement in the SCM.
Assume an infiltration rate of 2 inches per hour for the engineered soil mix when determining the ponding depth and media depth.</td></tr>
<tr><td>Mulch Layer</td><td colspan="2">Topsoil is not necessary as the engineered soil mix described above will support plant life.
Minimum depth of mulch layer = 4 inches
The mulch shall be clean, undyed, triple-shredded, hardwood mulch, free of weeds and debris. Where mulch is not used, native ground cover or washed, decorative landscape stone having a size large enough to withstand the maximum inflow velocity of 5 ft/sec.
The following materials are PROHIBITED for use as a mulch layer.
Shredded pine bark (will float and clog outlets and downstream stormwater systems)
Un-composted bark mulch, lawn and landscape clippings, and immature composted materials (will alter oxygen and nitrogen content of underlying soil)
Rubber mulch or “crumb rubber” (can release pollutants and clog outlets and downstream stormwater systems)
Plastic sheeting of any kind, as it can disintegrate from sun exposure</td></tr>
<tr><td>Planting Bed</td><td colspan="2">See Section 7.11.7 of this design specification, titled Vegetation Design Specifications, for planting bed standards.</td></tr>
</table>

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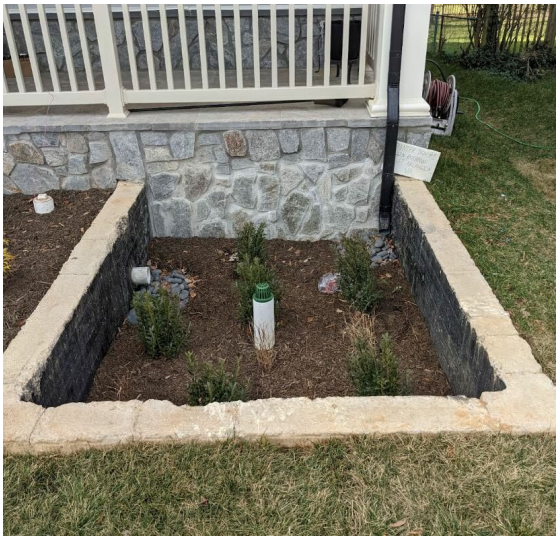
Figure 7.11.5 Examples of Inflow and Overflow Structures



Top left: The inlet pipe, splash pad, and overflow device are visible in this newly installed urban bioretention area (Source: Demarr Engineering). Top right: A large stormwater planter manages roof drainage at a school in Newport News, VA (Timmons Group); Lower left: The grayish color of this plastic inlet grate indicates UV degradation. Metal is preferred (City of Fort Wayne, IN); Lower right: A metal grate on an overflow in an Emeryville, CA urban bioretention SCM (wiki.sustainabletechnologies.ca)

7.11.6 Design Procedure

Table 7.11.5 provides the design procedure for an urban bioretention area.

Table 7.11.5 Design Procedure

Step	Design Activity
Step 1	**Evaluate urban bioretention area feasibility.** • Use the feasibility criteria provided in Tables 7.11.1 and 7.11.2 to determine if an urban bioretention area is feasible for the selected location on the land development site. Especially consider whether it is appropriate for the proposed development based on the intended land use of the property, the maintenance burden, and assumptions or knowledge of how the property owner(s) will care for the urban bioretention area after construction (e.g., self-maintenance, property/facilities management maintenance, landscape contractor). If possible, include the property owner(s) in SCM selection since they will be responsible for maintenance. • If an urban bioretention area is determined to be feasible and appropriate for the proposed development, create a rough layout of its dimensions, taking into consideration existing trees, utility lines, and other obstructions to ascertain if it will fit into the desired space, given its general design requirements.
Step 2	**Calculate the design storage volume (DSv) for the contributing drainage area**. • Typically, the DSv = WQv, unless the urban bioretention area cannot manage the entire WQv or will be used to control a volume larger than the WQv for a higher level of stormwater treatment. • Use one of the calculation methods explained in Chapter 6, Section 6.2 (Water Quality Management) to calculate WQv.

Step	Design Activity
Step 3	**Determine the minimum surface area of the urban bioretention area.** $$A_f = \frac{DSv \times d_f}{k \times (h_f + d_f) \times t_f}$$ *where:* A_f = surface area of the ponding area (ft^2) DSv = design storage volume (typically this will be the water quality treatment volume) (ft^3) d_f = planting media depth (ft) k = coefficient of permeability of planting media (ft/day) *(use one [1] ft/day for the engineered soil mix)* h_f = average height of water ponding above urban bioretention bed (ft) t_f = planting media design drain time (days) *(t_f = 1)*
Step 4	**Size the overflow structure and any flow diverters or regulators.** See Sections 7.14 (Inlets, Pretreatment, and Energy Dissipation Devices) and 7.16 (Overflow
Step 5	**Design the underdrain.** See Section 7.15 (Underdrain and Internal Water Storage Design).
Step 6	**Design the vegetation and protection measures.** The vegetation design shall be in accordance with the vegetation design requirements provided in Table 7.11.6. Use guidance found in Section 7.11.8 (below) to design protection measures.

7.11.7 Vegetation Design Requirements

Plants are critical to urban bioretention area performance and function. Plants filter and transpire stormwater, providing both pollutant removal and stormwater volume reduction. They also maintain the health and permeability of the engineered soil mix by preventing erosion, creating root space, and providing organic matter for nutrient replenishment. Finally, the plants are the primary visual attribute of the urban bioretention area and thus enhance the landscape.

The importance of plants to urban bioretention area function means they, like any SCM component, have design, installation, and maintenance specifications. Table 7.11.6 provides the vegetation specifications for urban bioretention areas.

Table 7.11.6 Vegetation Design Specifications

Vegetation Design Element	Specification(s)
Minimum Coverage	A minimum of 75% of the urban bioretention surface area must be covered by vegetation. Remaining areas must be covered by mulch (see mulch specifications in Table 7.11.4) or decorative landscape stone having a size large enough to withstand the maximum inflow velocity of 5 ft/sec. Areas of bare soil are not allowed. The minimum coverage requirement must be achieved within the first growing seasons (March through November) after installation, and then maintained thereafter.
Plant Survival	Plant replacement is required when the minimum coverage goal of 75% is not achieved.
Plant Selection	Plants selected for an urban bioretention area must be resistant to cycles of drought and inundation, as both conditions will occur.

Vegetation Design Element	Specification(s)
	• Non-native, flowering annuals are often not well suited to such conditions, and thus can require a lot of care. For guidance on appropriate plant species, consult a plant and landscape expert, such as a landscape architect, local nursery, or Master Gardener from the Tennessee Extension Master Gardener program. (https://mastergardener.tennessee.edu/) • Trees can damage the underdrain and thus, are prohibited. If trees are desired for the location, consider a Tier 2 manufactured treatment device (MTD) that includes trees as part of the standard unit provided. • Native plant species better suited to local hydrologic conditions are recommended. • Plants suitable for United States Department of Agriculture Plant Hardiness Zoned 7b are recommended. • Consider future maintenance needs of vegetation when designing the urban bioretention area. The level of plant care needed to maintain the landscape should influence plant selection to minimize care needs as much as possible.

Compliance with the vegetation standards set forth in Table 7.11.6 shall be shown in a vegetation plan that is included with the stormwater management plan (SWMP). Plan preparation requirements are below.

- The plan must be prepared by a professional qualified in landscape design by their education or experience.
- The plan shall include one or more labeled plans/details (to scale) showing the plants to be installed, their numbers, and locations. Plan notes showing a plant schedule and installation instructions are encouraged. This additional information allows both the plant installer at the time of construction, as well as the person(s) responsible for maintenance of the SCM after construction, to understand the original vegetation design and its compliance with the minimum standards.
- Landscaped SCMs may not be recognized under the City's codes as property landscaping. Therefore, additional requirements for property landscaping may apply.

7.11.8 Protection Design Guidance

SCMs designed for stormwater quality purposes must be maintained in keeping with the approved SCM design for the life of the land development[1]. **Design professionals can assist property owners with this requirement by including protective features in and around SCMs to limit the potential for damage by external factors**. Often, the landscape and impervious features around an SCM can be tailored to its specific needs, and therefore used to protect its critical components.

For urban bioretention areas, protection is especially important for the planting bed. Entry by vehicles, heavy equipment, and pedestrians can damage plants, compact the engineered soil mix, damage the overflow structure, and potentially deform or crush the underdrain collection system. Trash and pet waste are also a common problem. Urban bioretention areas are especially well-suited to a variety of protection methods, as indicated in Table 7.11.7 and Figure 7.11.5.

Table 7.11.7 Urban Bioretention Protection Measures

Passive Protection Measures	Active Protection Measures
• Natural fencing such as vegetation borders/screens • Dense vegetation throughout the practice • Pedestrian benches on the perimeter	• Decorative fencing or hardscaping (e.g., curbs, cobbles) • Educational or directive (e.g., no pets) signs • Pet waste stations and trash cans near the SCM

[1] Tennessee Rule *0400-40-10-.04*

Figure 7.11.6 Examples of Protective Landscaping

Left: Decorative fencing, a bench, and curbs protect this newly installed urban bioretention area from foot traffic (Russian River Watershed Association); Top Right: Small recessed urban bioretention cells discourage entrance by pedestrians and pets. However, the drop curb design may present a safety hazard for some local governments. Fencing or curbs are highly recommended. (City of Rockville, MD); Bottom right: curbs and dense vegetation protect this large urban bioretention area that receives roof runoff. (Source: Center for Watershed Protection)

7.11.9 Installation Requirements

The information in Table 7.11.8 provides a typical construction sequence to properly install urban bioretention areas. These steps may be modified to reflect different applications or site conditions. **Installation practices shall be shown in the EPSC and SWMP plans, as appropriate for the proposed land development.**

Table 7.11.8 Installation Steps

Step	Requirement
Step 1	Check the installation location for existing utilities prior to construction. **REQUIRED: Site construction shall be sequenced such that the urban bioretention area is installed only after the area draining to it has been fully and permanently stabilized. If this is not feasible, block the inlets to the area until the contributing drainage area is fully and permanently stabilized.** Supervision during construction is required to ensure the urban bioretention area is constructed/installed in accordance with the approved EPSC and SWMP plans. The design professional or a designee under their supervision must inspect the urban bioretention area at critical stages of construction. Examples of critical stages of underdrain installation and connection to the onsite stormwater conveyance system and final inspection. This ensures that the contractor's interpretation of the plan is consistent with the design professional's intentions and allows the design professional to certify (in the as-built plan) that the urban bioretention area is built in keeping with the permitted plan.
Step 2	Construction sites can have many different contractors responsible for different portions of the site or aspects of construction. Therefore, subtle differences in site grading, drainage, and paving elevations from those identified in the design, or relative to different areas/aspects of construction, can affect the hydraulics of the proposed urban bioretention area. The following practices should be done prior to construction to ensure the approved design is still valid: • During the preconstruction meeting, review and confirm that the actual boundaries of the urban bioretention area's contributing drainage area and inlet elevations conform with the approved design. • Any changes that result from the preconstruction meeting must be shown as a revision to the SWMP and resubmitted to the City for approval.

Step	Requirement
Step 3	Install inlet protection and/or erosion prevention and sediment control (EPSC) measures as indicated in Step 1.
Step 4	Excavate the urban bioretention area to its appropriate design depth and dimensions. Remove rocks and trim roots that enter the excavation area. Install the urban bioretention area walls (and bottom if full enclosure is desired).
Step 5	Install the impermeable liner on the sides and bottom with a minimum 12 inch substantial overlap at seams. Place the required depth of stone on the bottom (per underdrain design specifications), then install the underdrain, its connection to the onsite drainage system, and the outlet structure (if a standpipe attached to the underdrain). Install any observations wells needed. Typically, one observation well is sufficient given the small size of this SCM. Carefully place the top of the underdrain's stone jacket. Place the stone choker layer to its design depth.
Step 6	Apply the engineered soil mix in 12 inch lifts until the desired top elevation of the urban bioretention area is achieved. A rule-of-thumb is to apply 110% of the design volume of soil to account for settling that will occur. Wait a few days for settlement and add or remove additional engineered soil mix as needed to achieve the design elevation. • Note: The batch receipt confirming the source of the engineered soil mix must be included with the Record Drawing
Step 7	Install temporary or permanent irrigation measures, if included in the design. Irrigation may be needed during dry periods to sustain plant health. If coir or jute matting will be used, the matting will need to be installed prior to planting (Step 8), and holes or slits will have to be cut in the matting to install the plants.
Step 8	Install plants as shown in the vegetation plan (see Section 7.11.7). Install the surface cover (i.e., mulch, river stone, or turf).
Step 9	Install SCM protective measures.
Step 10	EPSC control devices and inlet blockages can be removed from the inlets if the drainage area to the urban bioretention area is fully and permanently stabilized. • If the area draining to the urban bioretention cell includes newly installed asphalt, the EPSC devices or inlet blocks should remain in place for at least three storm events after asphalt installation. A substantial amount of fine particles and grit are discharged from newly installed asphalt during the first several storms that produce stormwater after installation. Maintenance will be required to remove the particles and grit if EPSC devices are removed too early.
Step 11	Maintain the urban bioretention area in keeping with Section 7.11.10 below. Prepare the As-Built Plan and submit to the City for review and approval with the engineer's as-built certification before a final Certificate of Occupancy can be obtained. Advise the landowner (i.e., the person(s) taking ownership of the property immediately after its development) of the presence of the urban bioretention area and provide them with a copy of the property's Record Drawing and SCM maintenance plan. The plan must clearly show the location of the urban bioretention area on the property and list the activities (and their frequencies) necessary for its proper maintenance.

7.11.10 SCM Maintenance on an Active Construction Site

Once an SCM is installed, its maintenance is regulated by Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code. Further, SCMs must pass a final inspection prior to construction termination. This inspection will be performed to ensure they are constructed in accordance with the approved SWMP, undamaged, and free of sediment and debris. Thus, SCM maintenance is good practice to ensure construction termination goes smoothly. Relevant policies are as follows:

- The property owner is responsible for SCM maintenance. If the property is still an active construction site, these responsibilities may fall to the land disturbance permittee until the project receives final approval from the City and/or a Certificate of Occupancy.
- Property owners may have others, such as a site contractor or landscaping company, maintain the urban bioretention area on their behalf. However, the City will hold the property owner responsible for ensuring it is maintained in proper operating condition (i.e., as designed and constructed) regardless of who performs maintenance activities.
- Maintenance activities, which include ensuring proper operation of the SCM as designed and required SCM inspections, must begin immediately following installation of the urban bioretention area.
- Maintenance activities shall be performed in keeping with the *SCM Inspection and Maintenance Manual*. Additional guidance on maintenance of newly installed urban bioretention areas located on active construction sites is provided in Table 7.11.9.

Table 7.11.9 Maintenance Activities for Newly Installed Urban Bioretention Areas

Area or Component	Post-Installation Maintenance Requirement
Contributing Drainage Area	Keep the contributing drainage area clean. Sweep trash, debris, and sediment frequently so that it does not wash in the basin during a rain event. The area should be fully stabilized before installation of the SCM. If it is not, prevent inflows to the SCM by blocking or using diversion measures until the contributing drainage area is fully stabilized. Stabilize the area as soon as possible to prevent the discharge of sediment to the SCM. Cover stockpiles of construction and landscape materials to prevent their exposure to rainfall.
Urban Bioretention Area	Ensure SCM plants are watered and growing as expected. Remove and replace diseased, dying, or dead plants as soon as they are noticed. Clean the inlet(s) and planting bed frequently, removing trash, debris, and accumulated sediment. Ensure vehicles, equipment, and people are not allowed in the urban bioretention area. Evidence of unwanted entry may look like tire tracks or footprints; mulch or stone displacement, or damage to components or vegetation; immediately determine and eliminate the cause and repair the area. Consider installing temporary fencing if the area isn't fenced already. Visually observe the SCM's function after rain events; there should be no standing water within 24 hours after a storm event, depending on the frequency of rainfall. If long-standing water is observed: • Inspect underdrain's outlet and overflow device looking for standing water indicative of a blockage or damage; make repairs if needed. • If underdrain/outlet blockages and damage can be ruled out, then the engineered soil mix may be clogged. This repair requires soil removal, cleaning of the stone, underdrain, and outlet structure, and reinstallation of all the urban bioretention area layers; consult the design engineer. Inspect the urban bioretention area for erosion or significant sediment buildup; immediately determine and eliminate the cause and repair the area.

Area or Component	Post-Installation Maintenance Requirement
Education	Alert onsite subcontractors to the SCM and the following requirements: • No muddy vehicles or equipment in the drainage area to the SCM. • No stockpiling of material in the SCM and no exposed stockpiles in the SCM's drainage area. • Block inlets prior to asphalt placement in the drainage area. • Remove sediment, trash, debris, and empty trash cans frequently. Advise landscaping subcontractors on proper protection and maintenance of the urban bioretention area, especially the following: • No heavy equipment (hand tools only) • No dumping of lawn clippings or landscape debris in the SCM • Plant maintenance needs/requirements (see above) • Mulch specifications (i.e., clean, undyed, natural hardwood mulch)

7.11.11 References

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition.* Atlanta Regional Commission, 2016.

7.12 WET DETENTION BASIN design specifications

Water Quality Volume (WQv) Rainfall
Tier 3 Design P = 2.5 inches or the first 75% of the volume of the 1-yr, 24-hr storm, *whichever is less*

OTHER SCM ATTRIBUTES *(cost scale is $-low, $$-medium, $$$-high)*	
Channel Protection Volume (CPv)	Yes
Detention / Retention Control	Yes
Small Storm Local Flood Control	Yes
Typical SCM Footprint Size *(percent of contributing drainage area)*	2 to 3%
Construction Cost	$$
Operation & Maintenance Cost *(when properly maintained)*	$

PROJECT SUITABILITY

Industrial	Commercial	Residential *(common areas only)*	Pollutant Hotspots	Regional Stormwater Control
✓	✓	✓	✓	✓

Legend: ✓ High ✓ Limited ✗ None

OVERVIEW

Wet detention basins are large SCMs that have a permanent pool of water. They provide water quality control in the pool primarily through pollutant settling to the bottom of the basin. Flood control is provided by detaining stormwater above the permanent pool.

ADVANTAGES/BENEFITS

- Can satisfy multiple stormwater design standards
- Can be part of an amenity area for development(s) served
- High community acceptance if maintained

DISADVANTAGES/LIMITATIONS

- Potential for thermal impacts/downstream warming
- Dam height restrictions for high relief areas

LOCATION, SIZING, & COMPONENTS

- Minimum contributing drainage area of 25 acres; 10 acres for micropool extended detention (ED) basin
- Minimum length to width ratio for the basin is 1.5:1
- Maximum depth of permanent pool is 8 feet
- Side slopes range from 2:1 to 3:1 (h:v)
- A liner may be required to sustain a permanent pool.
- Sediment forebay(s) are required for pretreatment at each inlet
- Multi-stage riser outlet structure is necessary
- Safety measures must be included

LONG-TERM PROTECTION

- Primary concerns are slope stability and outlet structure clogging and damage
- Suitable for a wide variety of protective and aesthetic designs (vegetated borders, hardscaping, fencing, signage, etc.)

LONG-TERM MAINTENANCE

- The potential for adequate long-term maintenance can increase when the SCM is designed and constructed as an attractive feature or amenity of the development
- Primary routine maintenance activities will be removing debris from inlets and the outlet structure, forebay cleaning, and plant care (e.g., removing invasive vegetation, repairing and revegetating eroded areas, etc.)
- Consider permanent signs to prohibit swimming
- If part of a pedestrian area or trail, consider permanent signs and provide pet waste stations with trash cans
- Consider geese deterrent design measures

7.12.1 General Description

Wet detention basins are stormwater retention basins that are designed to maintain a permanent pool of water throughout the year. They can be created by excavating an existing natural depression or through the construction of embankments. Depending on design, a single wet detention basin can meet multiple stormwater design standards, functioning as follows:

- **Water Quality Volume (WQv)** – In a wet detention basin, stormwater from each storm is detained at, or above, the permanent pool until it is displaced by inflows of stormwater from the next storm. While the stormwater is in the basin, suspended sediments are removed via gravitational settling. In turn, other pollutants can be removed via settling or biological uptake by basin flora and fauna. The permanent pool also serves to protect deposited sediments from resuspension.
  For stormwater quality control, wet detention basins must be designed for extended detention (minimum 24-hours) of the water quality WQv. If the basin cannot be designed to detain the entire WQv, the basin must be placed in a treatment train with an upstream SCM or exchanged with a SCM that can treat the entire WQv.
  As a Tier 3 SCM, the WQv is based on 2.5 inch rainfall or 75% of the stormwater volume from the 1-year, 24-hour storm event (whichever is less) at the location of the development.

- **Channel Protection Volume (CPv**) – The channel protection standard reduces or eliminates streambank incising and instream sedimentation resulting from high frequency storm events. The standard requires extended detention of the CPv (i.e., the stormwater volume from the 1-year, 24-hour storm) for no less than a 24-hour period. This requirement is nearly the same as the WQv standard. Thus, basins that treat the entire WQv will not require additional design for CPv control. See Chapter 6 (SCM Standards, Methods, and Selection) for more information.

- **Flood Protection –** Wet detention basins can provide stormwater control for water quantity by detaining stormwater from large storm events to prevent flooding of adjacent and downstream properties. Additional temporary storage (live storage) is created above the permanent pool for this purpose, and a multi-stage outlet riser allows discharge of stormwater at design flow rates.

7.12.2 Design Applications

There are several variants of wet detention basin design, the most common of which include the wet detention basin, the wet extended detention basin, and the micropool extended detention basin. In addition, multiple wet detention basins can be placed in series or parallel to increase performance or meet site design constraints. Below are descriptions of each design variant:

- **Wet Basin –** Wet basins are constructed with a permanent (dead storage) pool of water equal to the WQv. Stormwater displaces the WQv already present in the pool. Temporary storage (live storage) can be provided above the permanent pool elevation for flood control.

- **Wet Extended Detention (ED) Basin –** A wet extended detention basin is a wet basin where the WQv is split evenly between the permanent pool and extended detention (ED) storage provided above the permanent pool. During storm events, water is detained above the permanent pool and released over 24 hours. This design has similar pollutant removal to a traditional wet basin but consumes less space. Temporary storage (live storage) can be provided above the permanent pool elevation for flood control.

- **Micropool Extended Detention (ED) Basin** –The micropool extended detention basin is a variation of the wet ED basin where only a small "micropool" is maintained at the outlet to the basin. The outlet structure is sized to detain the WQv for 24 hours. The micropool prevents resuspension of previously settled sediments and prevents

clogging of the low flow orifice. Temporary storage (live storage) can be provided above the permanent pool elevation for flood control.

- **Multiple Basin Systems** – Multiple basin systems consist of constructed facilities that provide WQv and flood control storage in two or more cells. The additional cells can create longer pollutant removal pathways and improved downstream protection.

Figure 7.12.1 shows several examples of wet detention basin variants.

Figure 7.12.1 Examples of Wet Detention Basins

Top left: A wet basin located at the Risteau at Rockland in Baltimore County, MD; Top right: A wet ED basin (location and source unknown); Bottom right: A multiple basin system in Brunswick County, NC (Source: NC State Extension); Bottom left: A micropool ED basin at Grant Ranch in Denver, CO (Source: Mile High Flood District)

7.12.3 SCM Suitability

Use Table 7.12.1 to determine if a wet detention basin is suitable for the application being considered.

Table 7.12.1 Water Quality Suitability Factors

Factor	Suitability
Stormwater Quality Treatment	Wet detention basins designed in keeping with the specifications established herein will satisfy City of Alcoa (City) stormwater quality treatment standards.
Channel Protection	Wet detention basins sized to manage the entire WQv, as described in Chapter 6 (SCM Standards, Methods, and Selection), will meet the CPv standard without the need for additional design. If the basin cannot retain the entire WQv, then the CPv standard is not met.
Detention	Wet detention basins can be designed to satisfy City peak discharge (flood) control requirements.
Pollutant Treatment Capability	Wet detention basins can be used to address the following common stormwater pollutants:

<table>
<tr><th>Factor</th><th>Suitability</th></tr>
<tr><td></td><td>
<table>
<tr><th>Total Suspended Solids (TSS)[1]</th><th>Total Phosphorus (TP)[2]</th><th>Total Nitrogen (TN)[2]</th><th>Fecal Bacteria [2,4]</th><th>Metals[2,3]</th></tr>
<tr><td>80%</td><td>50%</td><td>30%</td><td>70%</td><td>50%</td></tr>
</table>
1 – If designed for the WQv specified in Tennessee Department of Environment and Conservation Rule 0400-40-10-.04.
2 – ARC, 2016
3 – Cadmium, Copper, Lead, and Zinc
4 – If waterfowl populations are not in residence
</td></tr>
<tr><td>Treatment of Waste and Other Pollutants</td><td>Wet detention basins shall not be used to treat the following pollutants:
Construction sediment/waste
Landscape storage or waste
Sewage, pet, and livestock waste
Medical waste
Household & commercial wastes
Hazardous wastes
Gasoline, motor oils, greases, and other petroleum-based products
Fats, oils & grease (from food preparation)
Pesticides, fertilizers, herbicides
Other byproducts and waste materials expected, based on the property's land use</td></tr>
<tr><td>Suitability by Land Use</td><td>Privately owned wet detention basin SCMs are not allowed in the public right-of-way.
General suitability criteria by land-use type is as follows. See Chapter 6, Section 6.6 for more information.
<table>
<tr><th>Commercial</th><th>Industrial</th><th>Private Roadways</th><th>Single Family Residential</th><th>Multi-Family Residential</th></tr>
<tr><td>Yes</td><td>Yes</td><td>Yes</td><td colspan="2">Common Areas Only</td></tr>
</table>
</td></tr>
</table>

7.12.4 SCM Location Requirements

Location constraints for wet detention basins are provided in Table 7.12.2.

Table 7.12.2 Wet Detention Basin Location Requirements

Physical Element	Requirement
SCM Setbacks	Minimum setbacks for wet detention basins are as follows: • 10 feet from property lines • 100 feet from private water supply wells • TDEC specified distance per designated category from public water supply reservoirs • 5 miles from airports (due to propensity for waterfowl habitation) The toe of the embankment shall be at least 10 feet from property lines.
Flow Avoidance	Wet detention basins shall not be located where they will receive inflows from sump pumps, wash stations, or other non-stormwater discharges. Wet detention basins shall not be located in a stream or any other navigable waters of the United States, including natural (i.e., not constructed) wetlands. Where an appeal or variance of this policy is desired, the property owner must obtain coverage under a Section 404 permit under the Clean Water Act and/or an Aquatic Resource Alteration Permit (ARAP) and provide proof of such coverage with the Stormwater Management Plan.
Utility Avoidance	All utilities shall be located outside of the water quality easement.

7.12.5 General Design Information

Figures 7.12.2 through 7.12.4 show schematics of the four different types of wet detention basins

Figure 7.12.2 Schematic of a Wet Basin*

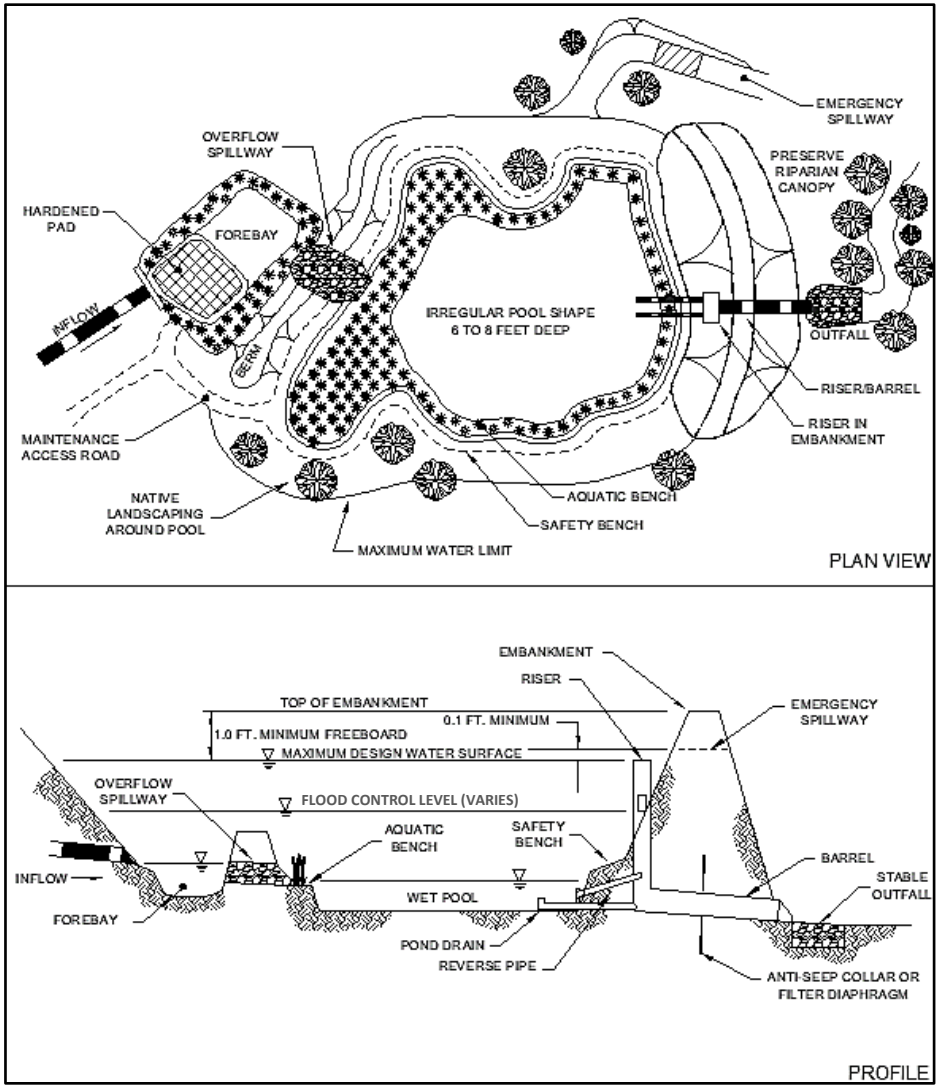
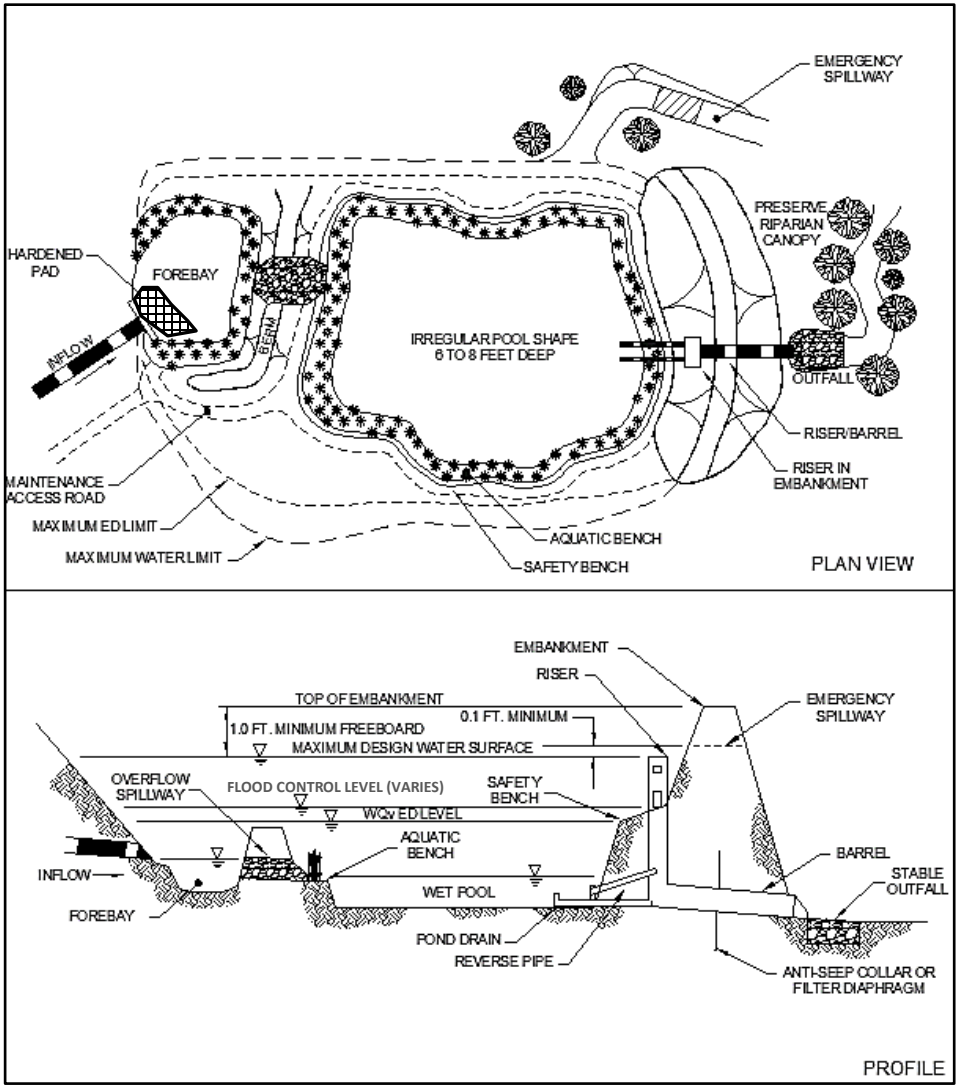


Figure 7.12.3 Schematic of a Wet ED Basin*



**Both figures are adapted for use in this manual from original schematics developed by the Center for Watershed Protection*

Figure 7.12.4 Schematic of a Micropool ED Basin*

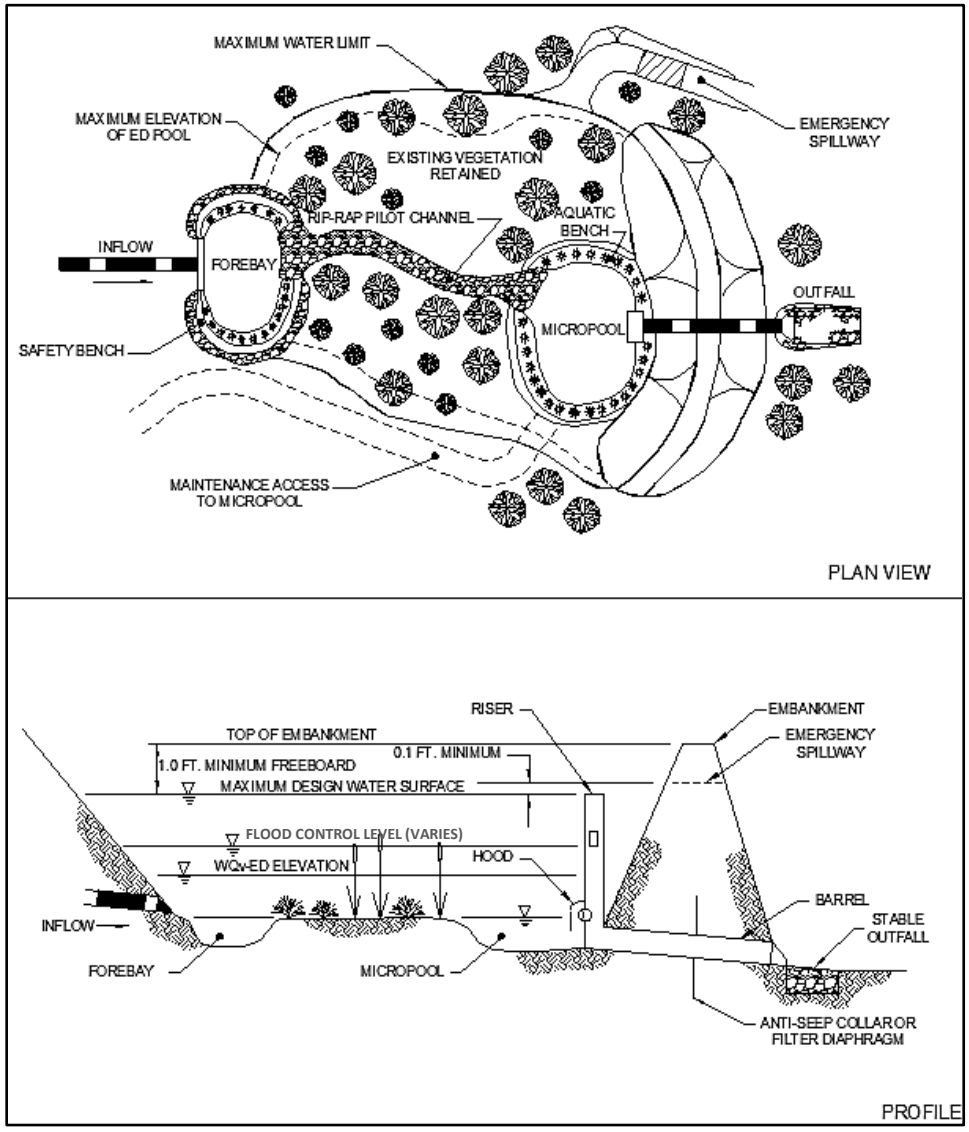
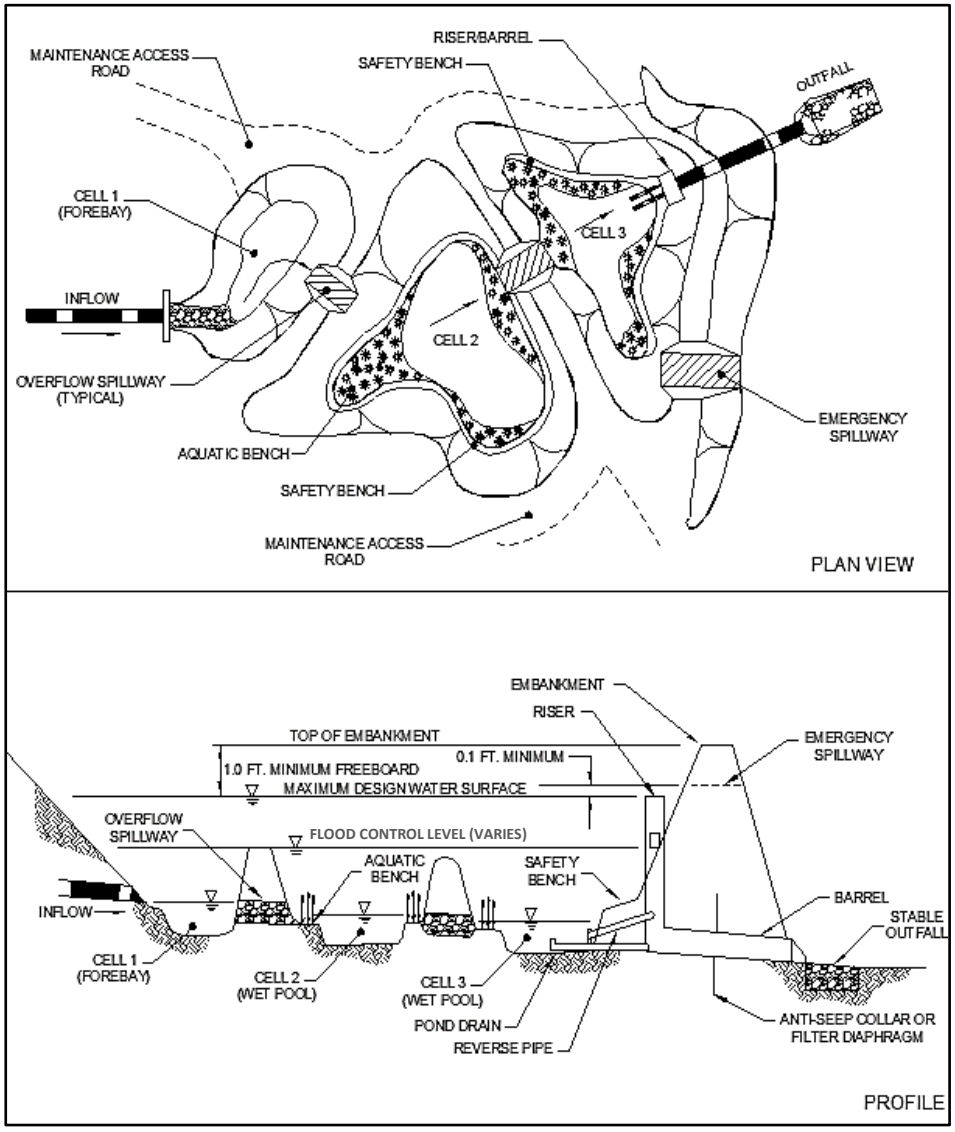


Figure 7.12.5 Schematic of a Multi-Basin System



** Both figures are adapted for use in this manual from original schematics developed by the Center for Watershed Protection.*

Wet detention basins typically include the following components.

- One or more permanent pools of water
- Live storage where stormwater volumes are temporarily stored before release in a controlled manner
- An aquatic bench in the permanent pool, called a littoral zone, that serves as a biological filter for stormwater inflows from surrounding areas
- A sediment forebay for pretreatment of stormwater inflows from the contributing drainage area
- An outlet (usually a multi-stage riser for ponds that provide flood control) and emergency spillway
- A safety bench
- A maintenance easement and maintenance access location(s)
- A pond buffer and surrounding landscape, preferably composed of native vegetation

Design specifications for wet detention basin components are provided in the following sections.

7.12.6 Design Requirements

The criteria provided in Table 7.12.3 shall be considered minimum standards and specifications for the design of wet detention basins and their contributing drainage areas. Each criterion applies to all wet detention basin types unless otherwise specified.

Table 7.12.3 Design Specifications

Design Element	Specification(s)
Water Quality Volume (WQv)	The water quality rainfall depth (P) for determination of WQv is P = 2.5 inches, or the WQv is the first 75% of the volume of the 1-yr, 24-hr storm, *whichever is less*. The design professional can select which volume to use. Acceptable methods to determine WQv are presented in Chapter 6 (SCM Standards, Methods, and Selection).
Use in a Water Quality Treatment Train	If the wet detention basin cannot manage the entire WQv for its contributing drainage area, it must be placed in a treatment train with another SCM. For treatment train policies and calculations, see Chapter 6, Section 6.2.4.
Channel Protection Volume (CPv)	The runoff volume from the 1-year frequency, 24-hour duration storm event shall be detained for no less than a 24-hour period, up to a maximum of 48 hours. Acceptable methods to determine WQv are presented in Chapter 6 (SCM Standards, Methods, and SCM Selection).
Peak Discharge Control (Flood Control)	The post-development peak discharge shall be less than or equal to the pre-development peak discharge for the 2, 5, 10, 25, and 100-year, 24-hour storm events. NRCS methods shall be used for detention and retention SCM and outlet structure designs.
Online and Offline Basin Configurations	Wet detention basins should be located where site topography allows maximum stormwater storage with minimum excavation and construction. An online configuration is designed and constructed so the main flow path for the drainage area passes through the wet detention basin. • If the online basin is designed to treat the WQv only, a bypass or overflow structure shall be provided to convey stormwater flows larger than the WQv safely around, or through, the basin without flooding or damaging it or adjacent areas. The bypass shall discharge to the onsite detention basin or stormwater conveyance system (properly sized in keeping with city requirements). • If the online basin is designed to provide flood control as well as WQv treatment, an overflow structure (typically an emergency spillway) shall be provided to safely pass the peak discharge

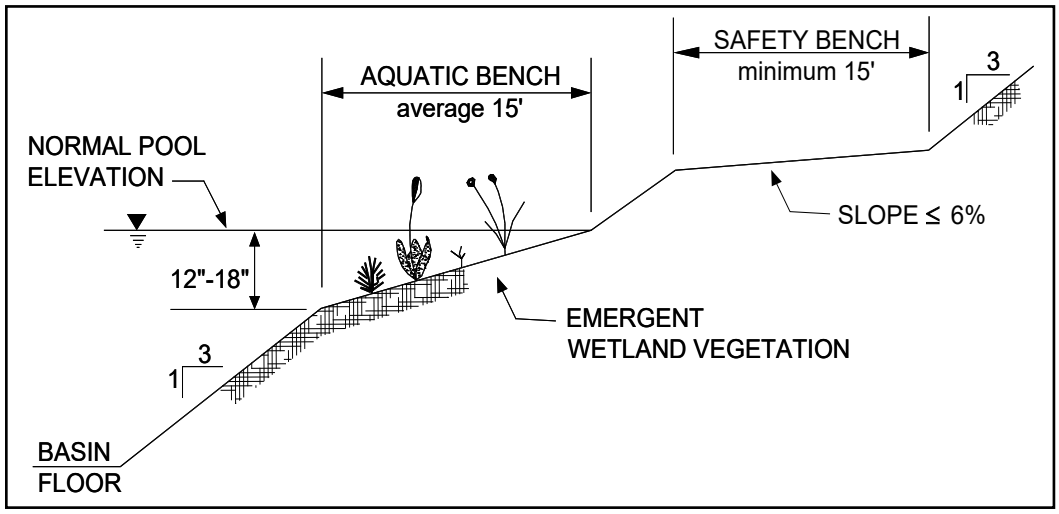
Design Element	Specification(s)
	of the 100-year, 24-hour event with a minimum of 1-foot of freeboard, without negative impacts to downstream structures. The spillway shall be located a minimum of 0.1 foot above the water surface elevation (WSEL) in the basin for the 100-year, 24-hour storm. An offline configuration is designed and constructed away from the main flow path for the drainage area. Offline basins are typically designed for WQv treatment only. • A diversion structure must be included to redirect the WQv from the main flow path to the basin while still allowing larger flows to remain in the main flow path. The structure shall include a low-flow orifice, weir, or other hydraulic structure, sized to pass the water quality peak discharge (Q_{wq}) and direct it to the offline wet detention basin. See Chapter 6 (SCM Standards, Methods, and Selection) for the calculation of Q_{wq}. Flow regulators (flow splitters, diversion structures, and overflow structures) shall be designed in keeping with Section 7.16 (Overflow Structures).
Maintenance Access and Easement	A maintenance easement shall be provided to the basin from a driveway, public or private road. It shall be designed as follows: • a maximum slope of no more than 15% • the access route shall have a minimum width of 15 feet • be free of permanently affixed obstructions (e.g., trees, pools, fences without gates, permanent signs, etc.) and appropriately stabilized to withstand maintenance equipment and vehicles • to the extent feasible, allow vehicles to turn around. The entire wet detention basin, (including inlets, pretreatment devices, the storage area, embankments, outlet structure, and emergency spillway) shall be included in the easement and shall be accessible from the easement's drive path. Access to the riser should be provided by lockable manhole covers, and manhole steps within easy reach of valves and other controls.
Minimum Drainage Area	The minimum contributing drainage area to maintain a permanent pool is as follows: • Wet basins and wet ED basins: 25 acres • Micropool ED basins: 10 acres The City may approve a smaller drainage area with an adequate water balance and anti-clogging device. See Chapter 6 (SCM Standards, Methods, and Selection) for water balance calculations.
Slope	Wet detention basins shall not be located on unstable slopes or slopes greater than 15%.
Drawdown Time	Wet detention basins shall be designed to discharge the WQv and CPv fully (to the permanent pool elevation) no sooner than 24 hours but no longer than 72 hours after completion of a rain event. Designing for a 48-hour drawdown is ideal. • The minimum orifice diameters for WQv and CPv = 1 inch. Orifice diameters of 8-inches or less shall be protected against clogging using a stone cage. • Use the orifice sizing guidance presented in Chapter 6 (SCM Standards, Methods, and SCM Selection) for extended detention outlet sizing guidance. There are no restrictions on drawdown time for flood control storm events.
Minimum Hydraulic Head	Minimum hydraulic head = 6 to 8 feet *(from inflow to outflow)*
Minimum Depth to Water Table	There are no restrictions on the minimum separation distance from the bottom of the basin to the seasonally high water table except for certain situations, as follows: • Basins located above an underlying water supply aquifer: 2 feet

Design Element	Specification(s)
	• Basins serving land uses that have the potential to discharge wastes or pollutants that cannot be managed by the wet detention basin (as determined by the city): 2 feet • Basins located in a wellhead protection zone: 4 feet Soil borings shall be used to determine the seasonally high-water table. See Appendix E (Policies for Soil Infiltration Tests & Soil Borings) for soil boring requirements.
In-situ Soil	The properties of the underlying soils are important to determine if the permanent pool can be maintained without a liner. The use of a soil survey can provide preliminary insight into the potential design, appropriate soil tests and subsurface analysis shall be performed to properly evaluate the suitability of in-situ soils. • Underlying soils of hydrologic soil groups (HSGs) C or D may be adequate to maintain a permanent pool. • Underlying soils of HSGs A or B will likely require a basin liner (see the row titled "Liners" in this table)
Liners	Clay or impermeable poly liners are required.
Inlets, Energy Dissipation, & Forebay	Inflow channels shall be stabilized with flared riprap aprons or the equivalent energy dissipation to slow water to nonerosive velocities (maximum of 5 ft/sec). A sediment forebay shall be provided immediately downstream of each inlet. Specifications are below. Additional requirements are provided in Section 7.14 (Inlets, Pretreatment Measures and Energy Dissipation Devices). • Forebays shall be sized to hold a minimum of 10% of the WQv of the basin. Forebay volumes can be considered as part of the WQv, but not additional volume of the basin. • Ideal depths for forebays are 4 to 6 feet. When determining forebay geometry, greater depth is preferred over greater width. This allows the forebay to dissipate turbulent inflows without resuspending previously deposited sediment; however, safety concerns and ease of maintenance must be considered when designing sediment forebays. • Forebays shall contain a fixed vertical sediment depth marker to measure sediment deposition over time. • Other pretreatment devices (e.g., MTDs, filter strips, etc.) cannot be substituted for sediment forebays; however, basins that are expected to readily encounter litter, leaves, and other floatables should include screens, grates, or other measures at the forebay discharge points to reduce the entry of floatable debris into the main basin.
Plan View Geometry	Proper geometric design is essential to prevent hydraulic short-circuiting (unequal distribution of inflow), which results in the failure of the basin to achieve adequate levels of pollutant removal. Geometry specifications and guidance are as follows. • Minimum length-to-width ratio = 1.5:1 • Ideal length-to-width ratio = 3:1 (to avoid short-circuiting) • Basins should be wedge-shaped when possible so that flow enters the basin and gradually spreads out, facilitating sediment deposition. • The contours and shape (plan view) of the permanent pool should be irregular to provide a more natural landscaping effect. Baffles, basin shaping, or islands can be added within the permanent pool to increase the flow path. Figures 7.12.2 through 7.12.5 (above) provide examples of this irregularity.
Permanent Pool Depth and Volume	Permanent pool depth specifications are as follows: • Minimum depth = 3 feet

Design Element	Specification(s)
	• Maximum depth = 8 feet; a greater depth may be approved if measures are included to prevent pool stratification and anoxic conditions, and adequate safety measures are provided. • Designing the basin with deep depths near the outlet will result in cooler bottom water discharges from the pond. To some degree, this can mitigate downstream thermal effects caused by discharges of warm stormwater, especially for ponds that discharge directly to a stream or other natural waterbody. However, ensure adequate access and safety measures are included on (or with) the outlet riser located in the deep area. Permanent pool volumes are determined based on basin type, as follows. • Wet basins: 100% of the WQv • Wet ED basins: 50% of the WQv • Micropool ED basins: 0.1 inch per impervious acre draining to the pond Note: the storage volume of the forebay (minimum of 10% of the WQv) can be considered part of the total design requirement and may be subtracted from the WQv for permanent pool sizing. See "Energy Dissipation & Pretreatment" in this table for more information.
Storage Capacity	Designs for basins that can impound more than 30 acre-feet of water or have embankment(s) with a height of 20 feet or greater shall adhere the Tennessee Safe Dams Act. Routing calculations must demonstrate that the storage volume of the basin is adequate (not including freeboard) for all design storms. See Chapter 6 (SCM Standards, Methods, and Selection) for more information on storage design requirements.
Profile View Geometry	See Figure 7.12.6 for illustrations of the specifications in this table row. **SLOPES** Maximum side slopes = 3:1 (horizontal to vertical) • Steeper slopes (2:1 or higher) may be allowed if one side of the basin, extending from the maintenance right of way to the forebay and outlet structure, has a maximum slope of 3:1 to facilitate access for maintenance and repair. • Slopes greater than 3:1 and having a height of 10 feet or more must be benched. • Riprap-protected embankments shall be no steeper than 2:1. **PERIMETER BENCHING** The perimeter of the basin is surrounded by two benches: safety and aquatic. Information and specifications are as follows. Safety bench: The safety bench is a gently sloped, graded area that extends outward from the permanent pool. The purpose of the bench is to reduce safety risks of pedestrians falling into deep water by providing a flat or gently sloped area adjacent to the permanent pool. The safety bench also provides valuable habitat area for pond flora and fauna. • Maximum bench slope = 6%; although gentler slopes are preferred • For large ponds, the safety bench shall extend no less than 15 feet outward from the normal water edge to the toe of the basin side slope. • The requirement for a safety bench may be waived if basin side slopes are 4:1 or gentler. • When selected and maintained appropriately, safety bench vegetation can dissuade use of the basin by waterfowl. See Section 7.12.8 (below) for more information.

Design Element	Specification(s)

Figure 7.12.6 Typical Water Quality Pond Geometry in Profile View



Profile View Geometry (continued)

EMBANKMENTS (OUTWARD FROM THE SAFETY BENCH)

- Maximum side slopes = 3:1 (horizontal to vertical)
- Maximum height = 20 feet
- The top of the berm shall be a minimum of (1) foot above the water surface elevation for the 100-year, 24-hour storm event. If inclusion of an emergency spillway is not possible (this is rare), a minimum of 2 feet of freeboard above the top of the berm shall be provided. The berm shall be designed to allow safe passage of floodwaters without damage, should it be overtopped.
- All embankments and spillways shall be designed to TDEC rules and regulations as applied to the Safe Dams Act of 1973, where applicable.

UPLAND AREAS

- Areas external to the embankments (surrounding the basin) that are above the high water elevation shall be sloped toward the basin to prevent standing water. Careful finish grading is necessary to avoid the creation of upland surface depressions that may retain stormwater.

Outlet Structures

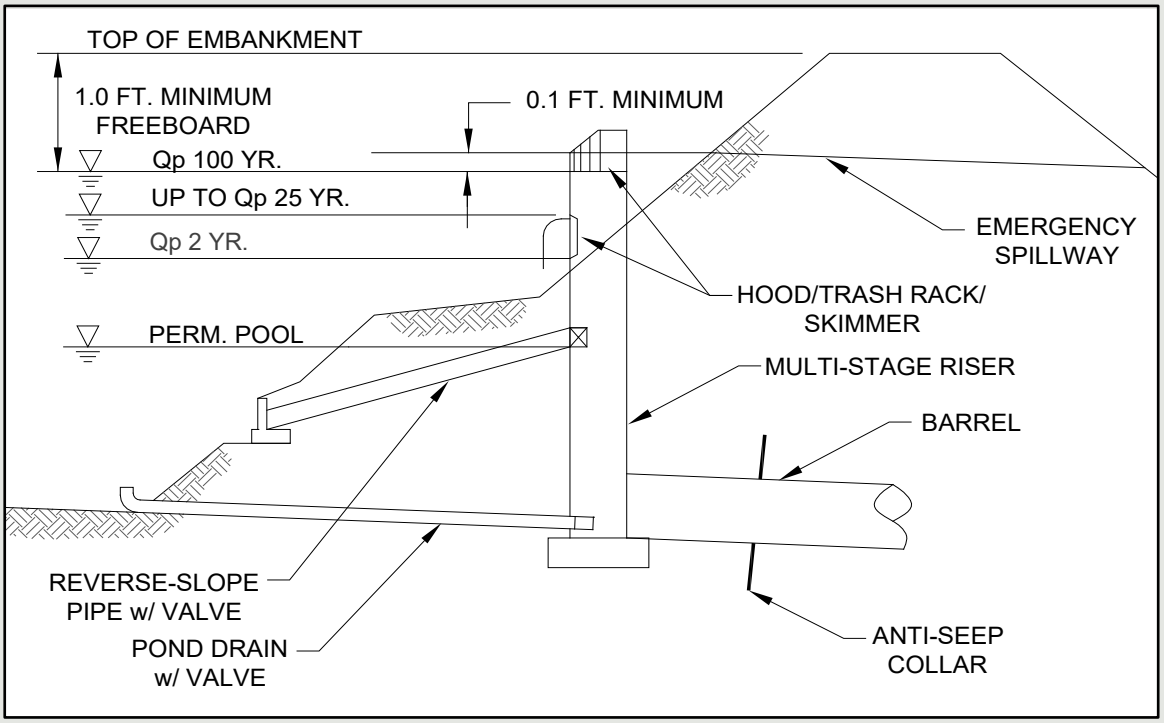
See Chapter 6, Section 6.4 (Storage Design) for more information on multi-stage riser design. Additional requirements and information are as follows.

Note: the preferred minimum orifice size is 3 inches. If a smaller orifice is required, provide internal orifice protection with an over-perforated vertical standpipe with ½ inch orifices or slots that are protected by wirecloth and a stone filtering jacket. Adjustable slide gates can also be used to achieve this equivalent diameter.

WET DETENTION BASINS DESIGNED FOR WQV CONTROL ONLY

When a wet detention basin is used for control of the *entire WQv only*, it provides control of both the WQv and CPv. In this case, the outlet structure can be simple, as follows.

- Wet basins: The WQv is fully contained in the permanent pool. Thus, an orifice is not necessary. As a new WQv enters the basin, it simply displaces the WQv from the previous storm. Thus, an off-line basin providing only water quality treatment (i.e., not flood control) can use a simple overflow weir as the outlet structure.
- Wet ED and micropool ED basins: The WQv is only partly contained in the permanent pool, thus there is a need for an outlet that is sized to pass the extended detention portion of the

Design Element	Specification(s)
Outlet Structures (continued)	WQv that is surcharged on top of the permanent pool in 24 hours. Again, for an off-line basin, a properly sized overflow weir can serve as an outlet structure. **WET DETENTION BASINS DESIGNED FOR WQV AND FLOOD CONTROL** When a wet detention basin is used for flood control, the basin provides WQv and CPv control, as well as detention and peak flow control of larger storm events. In this case, discharge from the basin is typically accomplished with the use of a concrete multi-stage riser and outlet barrel. Figure 7.12.7 illustrates such a structure. **Figure 7.12.7 Schematic of a Multi-Stage Riser for a Wet Detention Basin**  • Wet basins: The WQv is fully contained in the permanent pool. As a new WQv enters the basin, it must displace the WQv from the previous storm. The preferred design is a reverse slope pipe attached to the riser. Its inlet is submerged 1 foot below the elevation of the permanent pool to prevent floatables from clogging the pipe and to avoid discharging warmer water at the surface of the pond. Its outlet is located 0.1 ft above the permanent pool elevation. • Wet ED and micropool ED basins: The WQv is only partly contained in the permanent pool, thus the extended detention portion of the WQv must be discharged. The preferred design is a reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool to prevent floatables from clogging the pipe and to avoid discharging warmer water at the surface of the pond. Flow will first pass through this orifice, which is sized to release the ED volume in 24 hours. The next outlet is sized for the release of the first (i.e., most frequent) flood control design storm. The outlet (often an orifice) invert is located at the maximum elevation associated with the extended detention portion of the WQv and is sized to release the first flood control design storm in a 24-hour period.
Outlet Structures (continued)	If necessary, the water quality outlet shall be fitted with adjustable slide gates or another mechanism that can be used to adjust detention time.

Design Element	Specification(s)
	• All basin types: Higher flows (e.g., the 2-yr and higher storms) pass through openings or slots protected by trash racks further up on the riser. The largest design storm often discharges through a weir at the top of the riser or via weir flow through the open top of the riser. **REQUIREMENTS FOR OUTLET STRUCTURES (ALL BASIN TYPES)** • Alternative hydraulic control methods to an orifice include the use of a broad-crested, rectangular, V-notch, or proportional weir, or an outlet pipe protected by a hood that extends at least 12 inches below the normal pool. See Chapter 6, Section 6.4 (Storage Design) for more information. • After entering the riser, flow is conveyed through the barrel and is discharged downstream. Anti-seep collars shall be installed on the outlet barrel to reduce the potential for pipe or embankment failure. • All outlet structures and orifices shall be designed so as not to permit access to, or entry by, children. Orifices, weirs, and other openings shall be protected with permanently affixed or locked grates, trash racks, or other similar features. • Outlet risers shall be located within the basin embankment for maintenance access and safety. • Each basin shall have a bottom drainpipe with an adjustable gate valve that can completely or partially drain the basin within 24 hours. • Water shall not be discharged from the basin in an erosive manner. Riprap, plunge pads or pools, or other energy dissipators shall be placed at the outlet of the barrel to prevent scouring and erosion. If a basin outlet discharges immediately to a stream, additional care is needed to minimize disturbance in the stream and floodplain. • For detention basins that discharge directly to a stream with a FEMA-mapped floodplain, the downstream invert elevation of the outlet barrel shall be at least 1 foot above the base flood elevation. • For detention basins that discharge directly to a stream without a FEMA-mapped floodplain or to a lake, the downstream invert elevation of the outlet barrel shall be at least 1 foot above the elevation of the edge of bank (for a stream) or normal pool elevation (for a lake).
Emergency Spillway	An emergency spillway shall be designed to safely pass the peak discharge of the 100-year, 24-hour storm event without negative impacts to downstream structures. The emergency spillway elevation shall be a minimum 0.1 foot above the 100-year water surface elevation.
Pond Buffer	A pond buffer should be provided that extends 25 feet outward from the maximum water surface elevation of the pond. The pond buffer should be contiguous with other buffer areas that are required by existing regulations (e.g., stream buffers) or that are part of the overall stormwater management concept plan. No structures should be located within the buffer, and an additional setback to permanent structures may be provided. Existing trees can remain in the buffer area during construction. The installation of new trees is prohibited. To discourage resident waterfowl populations, the buffer can be planted with shrubs and native ground covers. The soils of a pond buffer are often severely compacted during construction to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration and, therefore, may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large, deep holes around the proposed planting sites and backfill these with uncompacted topsoil.
Additional Safety Features	See requirements for a safety benches and outlet/orifice access and entry prevention above. All embankments and spillways shall be designed to TDEC rules and regulations as applied to the Safe Dams Act of 1973, where applicable.

Design Element	Specification(s)
	The property owner may consider fencing the basin for the purpose of safety management. Posting of warning signs near the basin to prohibit swimming and fishing in the facility is encouraged.
Controls for Waste & Other Pollutants	Appropriate controls shall be included in the design of the contributing drainage area to the SCM to address any wastes and other Pollutants (see Table 7.12.1 above) that are expected on the property after construction. Use the proposed land use as a guide to determine appropriate controls. Examples of such controls include, but are not limited to, dumpsters, trash cans, covered materials/waste storage areas, covered materials transfer areas, oil and grease waste controls, and pet waste stations.

7.12.7 Design Procedure

Table 7.12.4 provides the design procedure for a wet detention basin.

Table 7.12.4 Design Procedure

Step	Design Activity
Step 1	**Evaluate wet detention basin feasibility.** Use the feasibility criteria provided in Tables 7.12.1 and 7.12.2 to determine if a wet detention basin is feasible for the selected location on the land development site. Consider especially whether it is appropriate for the proposed development based on the intended land use of the property, the maintenance burden, and assumptions or knowledge of how the property owner(s) will care for the wet detention basin after construction (e.g., self-maintenance, property/facilities management maintenance, landscape contractor). If possible, include the property owner(s) in SCM selection since they will be responsible for maintenance. If a wet detention basin is determined to be feasible and appropriate for the proposed development, create a rough layout of its dimensions, taking into consideration existing trees, utility lines, and other obstructions to ascertain if it will fit into the desired space, given its general design requirements.
Step 2	**Determine the goals and primary function of the wet detention basin.** Consider whether the intention is to: • Comply with the city's stormwater quality requirements (i.e., treat the WQv, provide flood control, address an onsite or regional drainage issue, etc.). • Enhance landscape and provide aesthetic qualities.
Step 3	**Determine basin location and preliminary geometry.** This step creates a rough grading design for the basin (contours, including the sediment forebay, safety bench, aquatic bench, and deep pool), and determine the probable locations of inlets, the outlet structure, its discharge, and the emergency spillway. Evaluate the side slopes, depth, and available storage volumes.
Step 4	**Create the basin design for WQv/CPv, flood control, and pretreatment.** Use the hydrologic methods established in Chapter 6 (SCM Standards, Methods, and Selection) to determine the WQv for the basin's contributing drainage area. If the entire WQv can be managed by the basin, no additional design is required for CPv control. Consult City requirements for detention/flood control standards (e.g., post-development peak discharge shall not exceed pre-development peak discharge), required design storms, data requirements, and hydrologic methods for peak discharge, stage, and storage determination. Note: the preferred minimum orifice size is 3 inches. If a smaller orifice is required, provide internal orifice protection with an over-perforated vertical standpipe with ½ inch orifices or slots that are protected by

Step	Design Activity

	wirecloth and a stone filtering jacket. Adjustable slide gates can also be used to achieve this equivalent diameter.
	Set up the stage-storage-discharge relationship for the basin and control structure, using it as follows.
	• Determine the WQv volume, the release rate, and the volume and WSEL of the permanent pool.
	  ○ Wet basin: Size permanent pool volume to 100% of the WQv.
	  ○ Wet ED basin: Size permanent pool volume to 50% of the WQv. Size extended detention volume to 50% of the WQv.
	  ○ Micropool ED basin: Size permanent pool volume at 0.1 foot per impervious acre. Size extended detention volume to remainder of WQv.
	• Determine the peak discharges (Qp), and associated volumes and WSEL for all flood control (detention) design storms.
	• Size the pretreatment sediment forebay for a minimum of 10% of the WQv of the basin, taking care not to reduce the size of the permanent pool.
	  ○ A sediment forebay is required at each inlet to the basin. For ponds that have multiple inlets, determine the volume/sizing of each forebay based on expected inflow volumes at each inlet, ensuring that, together, the forebays will comply with the 10% requirement.
	• Since the volume of the forebay can be considered a portion of the total design volume, refine the basin volumes, WSELs, and orifice elevations and sizes for WQv and flood control accordingly, completing the design of orifices on the outlet structure.
	• Size the emergency spillway based on City requirements for design storm, freeboard, and embankment slopes and elevations.

Step 5	**Investigate potential basin hazard classification.** The design and construction of stormwater management basins are required to follow the latest version of the TDEC Rules and Regulations Application to the Safe Dams Act of 1973.
Step 6	**Complete the outlet structure design.** Include trash racks, grates, covers, and other measures for basin safety and to prevent clogging of the outlet barrel.
Step 7	**Design the inlets (all basin types) and any flow regulators or overflow structures (for OFFLINE basins only).** Use Sections 7.14 (Inlets, Pretreatment Measures and Energy Dissipation Devices) and 7.16 (Overflow Structures) for requirements.
Step 8	**Design inlets, maintenance access and easement, and remaining safety features.** See Table 7.12.4 for more details.
Step 9	**Design vegetation and protection measures** The vegetation design shall be in accordance with the vegetation design requirements provided in Table 7.12.5. Use guidance found in Section 7.12.8 (below) to design protection measures.

7.12.8 Vegetation Design Requirements

Aquatic vegetation can play an important role in pollutant removal in a wet detention basin, including enhancing the appearance of the basin, stabilizing side slopes, serving as wildlife habitat, and temporarily concealing unsightly trash and debris. Plants are the primary visual attribute of the wet detention basin and should enhance the landscaping of the property.

Like any SCM component, basin vegetation has design, installation, and maintenance specifications. Much of the design and maintenance of a wet detention basin center on plant coverage and replacement. Table 7.12.5 provides the vegetation specifications for wet detention basins.

Table 7.12.5 Vegetation Design Specifications

Vegetation Design Element	Specification(s)
Minimum Coverage	**Permanent pool:** Wetland plants shall cover the 100% of the aquatic bench around the perimeter of the basin and in shallower areas of the permanent pool (generally areas less than 4 to 5 feet), without overcrowding. Native wetland plants are preferred. See also the 'Waterfowl Control' row of this table. A minimum of 90% of the area above the permanent pool area, including the safety bench, must be covered by vegetation. Areas of bare soil above the permanent pool are not allowed, therefore any areas not covered by vegetation must be permanently stabilized with other forms of ground cover (sidewalks, etc.). Mulch, pea gravel, and similar forms of ground cover are prohibited within the embankments to avoid clogging of outlet structures. The minimum coverage requirement must be achieved within the first two growing seasons (March through November) after installation, and then maintained thereafter. The planting of new trees in the pond buffer is prohibited. Existing trees can remain if desired.
Waterfowl Control	Wet detention basins can attract waterfowl. The presence of herons, egrets, and other desirable waterfowl can improve the basin as an interesting amenity. However, a lack of waterfowl management measures can cause problems. Geese and ducks can be particularly destructive because they tend to defoliate the area surrounding the permanent pool and can create fecal bacteria issues. A key factor in managing waterfowl is to discourage foraging and residence along the shoreline. Guidance is below. • Select and plant a tall grass (preferably native) for the safety bench and include signs to identify this area as a "no mow" zone (see Figure 7.12.8). This lush, watery landscape attracts waterfowl to the water, but does not encourage them to exit the water and take up residence. Signs discouraging waterfowl feeding may also be warranted in areas where sidewalks or trails are located in close proximity to a wet detention basin. • While impractical for some pond owners, physical barriers that may deter the birds include netting, wire or string grids around the pond, and fencing.
Plant Survival	Vegetation installation or replacement is required when the minimum coverage goals are not achieved.
Plant Selection	Aquatic bench and shallow areas of the permanent pool: Wetlands plants are encouraged and will have more survival ability. The best elevations for establishing wetland plants, either through transplantation or volunteer colonization, are within 6 inches (plus or minus) of the normal pool elevation. More information on wetland plants can be found at the following websites: • http://wetlands.fws.gov/ • https://plants.usda.gov/home/wetlandSearch Safety bench: No restrictions; however tall grass is recommended from the edge of the permanent pool for at least several feet toward the embankments. Upland areas within the embankments: No restrictions General recommendations: • Between the permanent pool and on the embankments, select plants resistant to cycles of drought and inundation, as both conditions will occur. For guidance, consult a plant and

Vegetation Design Element	Specification(s)
Plant Selection (cont.)	landscape expert, such as a landscape architect, local nursery, or Master Gardener from the Tennessee Extension Master Gardener program. (https://mastergardener.tennessee.edu/) • Native plant species better suited to local hydrologic conditions are recommended. • Plants suitable for United States Department of Agriculture Plant Hardiness Zoned 7b are recommended. • Existing deciduous trees and shrubs are strongly discouraged as leaf drop can contribute to basin clogging. • Consider future maintenance needs of vegetation when designing the basin. The level of plant care needed to maintain the landscape and their potential impacts on the maintenance of basin components should influence their selection to minimize care needs as much as possible. For example, potential long-term maintenance issues associated with shrubs and (existing) trees include poor grass growth, outlet clogging due to leave/debris drop, and root damage to embankments and components. Future property owners will need to deal with all of these issues.
Plant Location	Requirements pertaining to the location of plants are as follows: • Woody vegetation shall not be planted within 15 feet of the toe of an embankment and 25 feet from the outlet and spillway structures. They are not allowed on the dam, embankments, or basin floor. • Mulch, wood chips, pea gravel, and other loose (unanchored) soil stabilization materials are prohibited around inlets and within the embankments.

Compliance with the vegetation standards set forth in Table 7.12.5 shall be shown in a vegetation plan that is included with the stormwater management plan (SWMP). Plan preparation requirements are below.

- The plan must be prepared by a professional qualified in landscape design by their education or experience.
- The plan shall include one or more labeled plans/details (to scale) showing the plants to be installed, their numbers, and locations. Plan notes showing a plant schedule and installation instructions are encouraged. This additional information allows both the plant installer at the time of construction, as well as the person(s) responsible for maintenance of the SCM after construction, to understand the original vegetation design and its compliance with the minimum standards.
- Landscaped SCMs may not be recognized under the city's codes as property landscaping. Therefore, additional requirements for property landscaping may apply.

7.12.9 Protection Design Guidance

SCMs designed for stormwater quality purposes must be maintained in keeping with the approved SCM design for the life of the land development[1]. **Design professionals can assist property owners with this requirement by including protective features in and around SCMs to limit the potential for damage by external factors**. Often, the landscape and impervious features around an SCM can be tailored to its specific needs, and therefore used to protect its critical components.

For wet detention basins, protection is about more than preventing damage to the SCM. These basins pose a drowning risk. Thus, protective measures are especially important on all slopes, the safety bench, and around the outlet structure. Wet detention basins are especially well-suited to a variety of protection methods, some of which can enhance the

[1] Tennessee Rule *0400-40-10-.04*

property's landscape aesthetic. Protection methods that work well are listed in Table 7.12.6. Examples of wet detention basin protection measures are shown in Figure 7.12.8.

Table 7.12.6 Wet Detention Basin Protection Measures*

Passive Protection Measures	Active Protection Measures
• Natural fencing such as vegetation borders/screens (woody/prickly shrubs or tall grass) • Dense vegetation or clumping at the perimeter	• Physical fences • Educational or directive signs (see Figure 7.12.8) • Pet waste stations and trash cans near the SCM

** The list presented in the table is not exhaustive. There may be other possible protection measures.*

Figure 7.12.8 Examples of Protective Measures

Top left: Dense vegetation for a few feet within the safety bench can deter people and waterfowl (Source: Solitude Lake Management). Top right: Educational signage and fencing are protection measures for a wet detention basin in Milton, Ontario, Canada. (Source: Town of Milton); Bottom left: Dense vegetation, a pedestrian bridge, and attractive landscaping make this wet basin an amenity (Source: George Mason University); Bottom middle: No Mow sign used in Carrboro NC (Source: City of Carrboro NC).

Basin safety signs can be purchased commercially.

7.12.10 SCM Maintenance on an Active Construction Site

Once an SCM is installed, its maintenance is regulated by Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code. Further, SCMs must pass a final inspection prior to construction termination. This inspection will be performed to ensure they are constructed in accordance with the approved SWMP, undamaged, and free of sediment and debris. This section applies to wet detention basins once it is constructed in its permanent (post-construction) state. Thus, SCM maintenance is good practice to ensure construction termination goes smoothly. Relevant policies are as follows:

- The property owner is responsible for SCM maintenance. If the property is still an active construction site, these responsibilities may fall to the land disturbance permittee until the project receives final approval from th e City and/or a Certificate of Occupancy.
- Property owners may have others, such as a site contractor or landscaping company, maintain the wet detention basin on their behalf. However, the City will hold the property owner responsible for ensuring it is maintained in proper operating condition (i.e., as designed and constructed) regardless of who performs maintenance activities.
- Maintenance activities, which include ensuring proper operation of the SCM as designed and required SCM inspections, must begin immediately following installation of the wet detention basin.
- Maintenance activities shall be performed in keeping with the *SCM Inspection and Maintenance Manual*. Additional guidance on maintenance of newly installed wet detention basins located on active construction sites is provided in Table 7.12.7.

Table 7.12.7 Maintenance Activities for Newly Installed Wet Detention Basins

Area or Component	Post-Installation Maintenance Requirement
Contributing Drainage Area	Keep the contributing drainage area clean. Trash, debris, and sediment from construction activities discharged to a fully constructed basin can clog pretreatment measures, kill basin plants, reduce the basin's design capacity, block the inlets, and clog outlet structures. Stabilize the area as soon as possible to prevent the discharge of sediment to the SCM. Cover stockpiles of construction and landscape materials to prevent their exposure to rainfall.
Wet Detention Basin Area	Vegetation management should focus on ensuring the vegetation planted in and around the basin is well-established and healthy, to meet the vegetation design standard for the SCM. The following activities may apply: • Watering: Depending on rainfall, regular watering may be necessary to keep vegetation healthy and thriving. Evaluate watering needs based on vegetation type, season, and near-term precipitation conditions. • Fertilization: Fertilization should be performed only when needed, based on the needs identified by a soil test and of the vegetation planted in the SCM. In general, fertilization of SCMs is discouraged because it introduces pollutants (nutrients) into the SCM. • Weed and invasive species control: Remove undesirable plants manually instead of using herbicides. Herbicides can enter the water during a rainfall, kill aquatic plants, and be discharged into local streams. • Spot Reseeding: Bare or eroding areas on the basin's embankments shall be stabilized with permanent vegetation as soon as they are noticed. • Plant Replacement: Dead plants must be removed and replaced. Unhealthy plants should be removed and replaced if they cannot be rehabilitated. Inspect the installed SCM at least weekly and after every storm event until construction is terminated. Look for signs of erosion, significant sediment accumulation, stormwater short-circuiting, outlet clogging, vegetation distress or removal, the presence of burrowing animals, and long-standing high water. Check weirs, check dams, and inlet and outlet structures to ensure proper functioning. • Clean the inlets, sediment forebay, and outlet structure when needed. • Check for signs of unhealthy or overpopulation of plants and/or fish (if utilized). • Note signs of algal growth or pollution, such as oil sheens, discolored water, or unpleasant odors. Determine the cause and correct the issue • Check for proper operation of control gates, valves, or other mechanical devices.

Area or Component	Post-Installation Maintenance Requirement
	• Note changes to the basin or contributing drainage area as such changes may affect the basin's performance.
Education	Alert onsite subcontractors to the SCM and the following requirements: • No stockpiling of material in the basin and no exposed stockpiles in the basin's drainage area. • Remove sediment, trash, debris, and empty trash cans frequently. • Advise landscaping subcontractors on proper protection and maintenance of basin plants. • No dumping of lawn clippings or landscape debris

7.12.11 References

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition.* Atlanta Regional Commission, 2016.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005.

SOLitude Lake Management. www.solitudelakemanagement.com 2024.

7.12.12 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

United States Environmental Protection Agency. *Methodology for Analysis of Detention Basins for Control of Urban Runoff Quality,* 1986.

Urban Drainage and Flood Control District. *Urban Storm Drainage Criteria Manual – Volume 3 – Best Management Practices – Stormwater Quality.* Denver, Colorado, September 1992.

Walker, W. *Phosphorus Removal by Urban Runoff Detention Basins.* Lake and Reservoir Management, North American Society for Lake Management, 314, 1987.

Wanielista. M. *Final Report on Efficiency Optimization of Wet Detention Ponds for Urban Stormwater Management.* University of Central Florida, 1989.

7.13 WET ENHANCED SWALE design specifications

Water Quality Volume (WQv) Rainfall
Tier 3 Design P = 2.5 inches or the first 75% of the volume from the 1-yr, 24-hr storm, *whichever is less*

OTHER SCM ATTRIBUTES *(cost scale is $-low, $$-medium, $$$-high)*	
Channel Protection Volume (CPv)	No
Detention / Retention Control	No
Small Storm Flood Control	Yes
Typical SCM Footprint Size *(percent of tributary impervious area)*	10 to 20%
Construction Cost	$$
Operation & Maintenance Cost *(when properly maintained)*	$

PROJECT SUITABILITY				
Industrial	**Commercial**	**Residential** *(common areas only)*	**Pollutant Hotspots**	**Private Roadways** *(requires HOA)*
✓	✓	✓	✗	✓

Legend: ✓ **High** ✓ **Limited** ✗ **None**

OVERVIEW

Wet enhanced swales are structural stormwater control measures (SCMs) with vegetated open channels that are designed to capture and treat the water quality volume (WQv) within wet cells formed by check dams or other means. The primary stormwater treatment mechanisms of a wet enhanced swale biofiltration, evapotranspiration, and settling. (Photo on left from Baltic Smart Water HUB)

ADVANTAGES/BENEFITS

- Provides stormwater treatment and conveyance
- Less expensive to install than curb-and-gutter
- Reduces stormwater velocity
- Easy to maintain

DISADVANTAGES/LIMITATIONS

- Does not provide stormwater detention
- Possible odor/mosquitoes if poorly maintained

LOCATION, SIZING, & COMPONENTS

- Maximum contributing drainage area is 5 acres
- Channel slope cannot exceed 4%, 1 to 2% recommended
- Permissible bottom width ranges from 2 to 8 feet
- Pretreatment and energy dissipation are required at all inlets
- High groundwater table and/or poorly drained soils are required
- Dense, healthy vegetation is a must for SCM function

LONG-TERM PROTECTION

- Primary concerns are dumping (trash, landscape debris, etc.) and poor plant management (mowing, clearing, etc.) due to landscaper ignorance about the SCM
- Consider permanent “no mow zone” or similar signs to alert landscapers to the presence and preservation of the swale
- Maintained vegetated areas and quiet walkways along the swale can support its protection as intentional landscape or even a property amenity

LONG-TERM MAINTENANCE

- Primary routine maintenance activities will be plant care (e.g., plant replacement, invasive species management) and inlet/outlet cleaning (trash, debris, plant matter, etc.)
- Consider permanent signs to dissuade entry, dumping, and use of SCM as a pet relief area if location is near a pedestrian area
- Provide trash cans and pet waste stations in the drainage area

7.13.1 General Description

Wet enhanced swales are SCMs with small storm conveyance channels engineered to capture and treat the water quality volume (WQv) for a drainage area. They differ from a normal drainage channel or swale through the incorporation of specific features that enhance stormwater pollutant removal effectiveness. They are designed with limited longitudinal slopes to force a slow and shallow flow, thus allowing for particulates to settle, and limiting the effects of erosion. Berms and/or check dams installed perpendicular to the flow path reduce flow velocities to promote biofiltration, evapotranspiration, and pollutant settling.

Wet enhanced swales are designed to retain water or create marshy conditions that support wetland vegetation. The swale essentially acts as a linear shallow wetland treatment system, where the WQv is retained. A high water table and/or poorly drained soils are necessary to retain water.

A wet enhanced swale must not be confused with a vegetated filter strip or grass swale, neither of which are acceptable for meeting the stormwater quality standard of 80% total suspended solids (TSS) removal of the WQv. Filter strips and grass swales provide sediment filtration, but do not provide substantial pollutant removal to meet the standard.

7.13.2 Design Applications

Wet enhanced swales are typically used in place of stormwater pipes and grass channels to provide treatment of the WQv from one or more upstream impervious areas along with conveyance of stormwater from larger storms. Uses along parking lot edges, private roadways, and paved trails are common. Impermeable liners can be used to allow the location of wet swales in close proximity to structures. See Figure 7.13.1.

Figure 7.13.1 Examples of Wet Enhanced Swale Applications

Left: A wet enhanced swale receives drainage from a roadway in East Hampton, NY. (Source: tomtwomeyseries.org); Right: A wet swale in Montreal, Canada (Source: NC State Extension Publication AG-588-26, Feb. 10, 2020)

7.13.3 SCM Suitability

Use Table 7.13.1 to determine if a wet enhanced swale is suitable for the application being considered.

Table 7.13.1 Wet Enhanced Swale Suitability Factors

Factor	Suitability
Hydrologic Feasibility	**IMPORTANT!** A continuous baseflow or high-water table is required to support wetland vegetation. See Section 7.13.5 (Hydrologic Requirements & Design Options) below for more information.

<table>
<tr><th>Factor</th><th>Suitability</th></tr>
<tr><td>Stormwater Quality Treatment</td><td>Wet enhanced swales designed in keeping with the specifications established herein will satisfy City of Alcoa (City) stormwater quality treatment standards.</td></tr>
<tr><td>Channel Protection</td><td>Wet enhanced swales do not provide channel protection.</td></tr>
<tr><td>Detention</td><td>Wet enhanced swales do not provide peak discharge control.</td></tr>
<tr><td>Pollutant Treatment Capability</td><td>Wet enhanced swales designed in keeping with the specifications established herein can address following common stormwater pollutants.
<table>
<tr><th>Total Suspended Solids (TSS)[1]</th><th>Total Phosphorus (TP)[2]</th><th>Total Nitrogen (TN)[2]</th><th>Fecal Bacteria[2]</th><th>Metals[2,3]</th></tr>
<tr><td>80%</td><td>25%</td><td>40%</td><td>Insufficient data</td><td>20%</td></tr>
</table>
1 – If designed for the WQv specified in Tennessee Department of Environment and Conservation Rule 0400-40-10-.04.
2 – ARC, 2016
3 – Cadmium, Copper, Lead, and Zinc</td></tr>
<tr><td>Treatment of Waste and Other Pollutants</td><td>Wet enhanced swales shall not be used to treat the following pollutants:
Construction sediment/waste
Landscape storage or waste
Sewage, pet, and livestock waste
Medical waste
Household & commercial wastes
Hazardous wastes
Gasoline, motor oils, greases, and other petroleum-based products
Fats, oils & grease (from food preparation)
Pesticides, fertilizers, herbicides
Other byproducts and waste materials expected, based on the property’s land use</td></tr>
<tr><td>Suitability by Land Use</td><td>Privately owned wet enhanced swales are not allowed in the public right-of-way.
General suitability criteria by land-use type is as follows. See Chapter 6 (SCM Standards, Methods, and Selection) for more information.
<table>
<tr><th>Commercial</th><th>Industrial</th><th>Private Roadways</th><th>Single Family Residential</th><th>Multi-Family Residential</th></tr>
<tr><td>Yes</td><td>Yes</td><td>Yes</td><td colspan="2">Common Areas Only</td></tr>
</table></td></tr>
</table>

7.13.4 SCM Location Requirement

Location constraints for wet enhanced swales are provided in Table 7.13.2.

Table 7.13.2 Wet Enhanced swales Location Requirements

Physical Element	Requirement

SCM Setbacks	Minimum setbacks for all wet enhanced swale designs, measured from the edge of the wet enhanced swale, are as follows:
	• Building foundations:
	  ○ Offline configuration: 10 feet from a building’s foundation, if positioned downslope of the building and no closer than 30 feet from buildings that are downslope
	  ○ Online configuration: safe passage of the 100-year storm event is required; therefore, the distance of the edge of the SCM from a building’s foundation shall be determined based on the expected extent of flooding around the SCM for the 100-year event
	• 100 feet from private water supply wells

Physical Element	Requirement
	• 200 feet from public water supply reservoirs (measured from edge of water) • 1200 feet from public water supply wells • 100 feet from underground septic systems • At least 5 feet down gradient from underground utility lines
Prohibited Locations	Wet enhanced swales cannot be located within navigable waters of the U.S., including wetlands, without obtaining a Section 404 permit under the Clean Water Act, and any other applicable State permit. In some isolated cases, a wetlands permit may be granted to convert an existing degraded wetland to a wet enhanced swale in the context of local watershed restoration efforts. Wet enhanced swales can have a thermal influence on downstream trout waters. Avoid placement in locations that discharge directly to trout streams. Wet enhanced swales often intersect the groundwater table. Thus, these SCMs are not suitable for locations: • with an underlying water supply aquifer • where they will receive stormwater discharges from land uses where high level(s) of pollutant(s) are expected (see Treatment of Wastes and Other Pollutants in Table 7.13.1 above) • locations where soil contamination is known or suspected.
Utility Avoidance	Wet enhanced swales shall not be located above underground dry utility lines (electric, cable, and telephone), water/wastewater infrastructure, and stormwater drainage infrastructure. Design professionals must consult the local utility to determine the horizontal and vertical clearance required between SCMs and dry and wet utility lines.

7.13.5 Hydrologic Requirements & Design Options

A wet enhanced swale consists of an open conveyance channel which has been excavated to the water table, or to poorly drained soils. Check dams are used to create multiple wetland "cells" which act as miniature shallow marshes. A primary cause of wet swale failure is the inability to maintain wet conditions. The swale must be located where the water table is at, or very near, the soil surface, or in poorly drained soils with a sufficient water balance to support wetland plants. Thus, knowledge of the water table and in-situ soil permeability are critical to determine the feasibility of a wet enhanced swale.

Soil permeability tests and water table determination shall be performed by a Soil Scientist with an active license in the State of Tennessee.

SOIL PERMEABILITY: Underlying soils of hydrologic group "C" or "D" with a normally high water table or sufficient water balance should be adequate to maintain wetland conditions, although soil testing is needed to confirm permeability. Permeable soils are not well-suited for a wet enhanced swale.

SOIL BORINGS AND CORE INTERPRETATION: Soil borings provide information on the water table. Table 7.13.3 provides soil boring location and depth requirements.

Each soil core shall be observed to determine the anticipated normal water table based on:

- the date of soil boring with respect to any visual observations of water in the core (or boring)
- recent and seasonal rainfall patterns
- the presence of hydric soils
- redoximorphic features or other indicator of water table variation

- and depth to bedrock if encountered.

Table 7.13.3 Soil Boring Requirements

Factor	Requirement
Location	A minimum of: • one (1) boring within the footprint of the proposed swale embankment; and, • one (1) boring in the vicinity of the proposed outlet structure; and, • one (1) boring for every 20,000 square feet within the proposed swale area.
Depth	Soil borings shall be conducted to a depth of at least 10 feet below the estimated lowest bottom elevation of the wet enhanced swale.

If mottling showing redoximorphic features is observed, in any season of the year, the seasonal high water table (SHWT) shall be taken as the highest level at which the mottling is observed, except when the water table is observed at a level higher than the level of the redoximorphic depletions or concentrations. Otherwise, use best practices for SHWT determination as appropriate for water table/soil conditions at the location of the swale. Use the most recent version of the USDA-NRCS reference document titled *Field Indicators of Hydric Soils in the United States – A Guide for Identifying and Delineating Hydric Soils* for more information on determining whether saturated soils are present.

HYDROLOGIC SUPPORT DESIGN OPTIONS. Two options exist for the design of a wet enhanced swales, as follows:

1. **Swale intersecting groundwater:** If the swale will intersect a shallow groundwater table, groundwater may be utilized to maintain an average surface ponding depth of 12 inches, with a maximum ponding depth at the swale's downstream end of 18 inches.
2. **Swale above groundwater with low-permeability native soils:** If the SHWT is below the proposed swale elevation and soil testing shows that the native soil beneath the swale is clay or similar with an infiltration rate of less than 0.01 in/hr, the swale should hold water if the water balance is sufficient to ensure the average ponding depth (12 inches) can be sustained during dry periods.

WATER BALANCE. Once the hydrologic support design option is determined, a water balance calculation must be performed **BEFORE** the design is created. The water balance must demonstrate that the swale can withstand a 30-day drought at summer evaporation rates without creating a drawdown that will dry the swale. See Chapter 6, Section 6.2.8 for water balance calculations.

7.13.6 Design Specifications

The criteria provided in Table 7.13.4 shall be considered minimum standards and specifications for the design of wet enhanced swales. Figures 7.13.2 and 7.13.3 provide schematic examples.

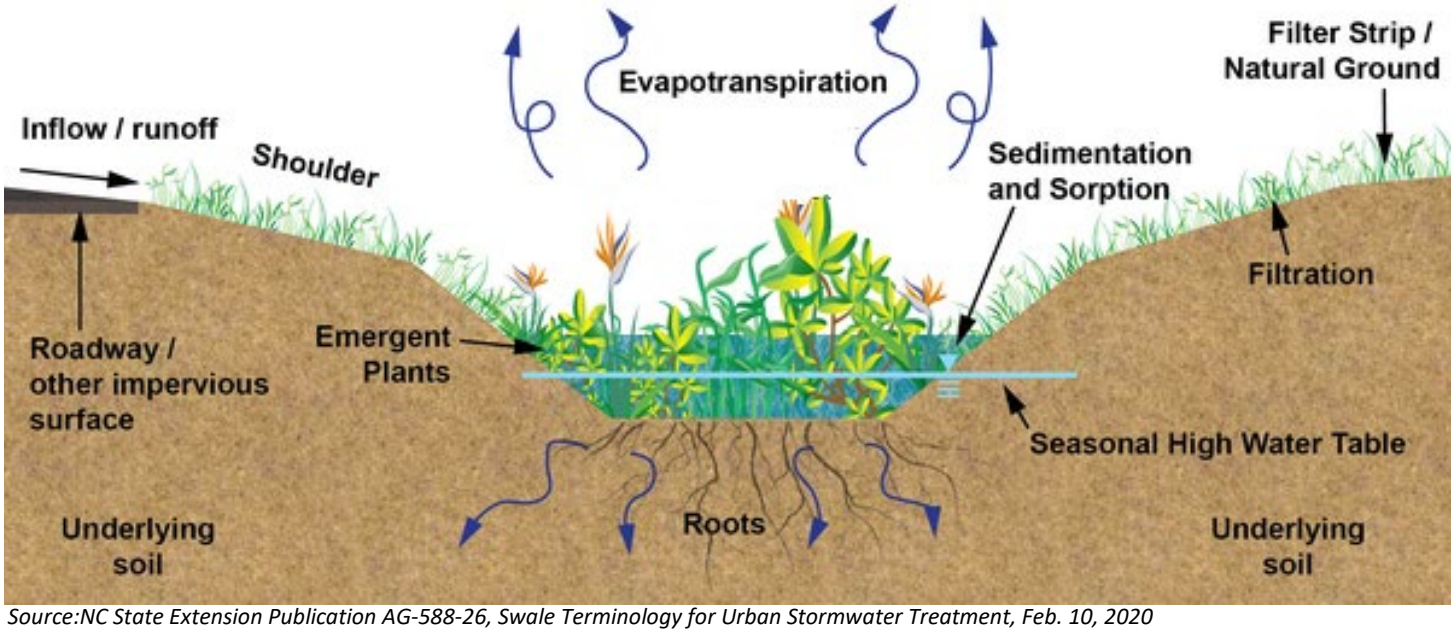
Table 7.13.4 Design Specifications for the Wet Enhanced Swale

Design Element	Specification(s)
Water Quality Volume (WQv)	The water quality rainfall depth (P) for determination of WQv is P = 2.5 inches, or the WQv is the first 75% of the volume of the 1-yr, 24-hr storm, *whichever is less*. The design professional can select which volume to use. Acceptable methods to determine WQv are presented in Chapter 6 (SCM Standards, Methods, and Selection).
Use in a Water Quality Treatment Train	If the wet enhanced swale cannot manage the entire WQv for its contributing drainage area, it must be placed in a treatment train with another SCM or exchanged with an alternate SCM that can treat the required WQv. See treatment train policies and calculations in Chapter 6, Section 6.2.4.

Design Element	Specification(s)
Offline and Online Design Configuration	An online configuration is a common configuration for wet enhanced swales. Online swales are designed and constructed so the main flow path for the drainage area passes through the swale. The swale must be designed to safely convey the peak discharge for the 25-year, 24-hour storm event (Q_{p25}) with a minimum of 12 inches of freeboard. An offline configuration is designed and constructed away from the main flow path for the drainage area, thus avoiding large flood flows. A flow splitter, diversion structure, or other means is used upstream of the swale's inlets to redirect the swale's design volume (typically this will be the WQv) from the main flow path to the SCM while still allowing larger flows to remain in the main flow path. The structure shall include a low-flow orifice, weir, or other hydraulic structure, sized to pass the peak discharge of the design volume (typically this will be the water quality peak discharge, Q_{wq}) to the swale. See Section 7.16 (Overflow Structures) for the diversion procedure.
Maintenance Access and Easement	A maintenance easement shall be provided to the swale from a driveway, public or private road. It shall be designed as follows: • a minimum width of 15 feet • a maximum slope of no more than 15% • the access route in the easement shall be free of permanently affixed obstructions (e.g., trees, pools, fences without gates, permanent signs, etc.) and appropriately stabilized to withstand maintenance equipment and vehicles • to the extent feasible, allow vehicles to turn around The entire wet enhanced swale, (including inlets, pretreatment devices, the storage area embankments, outlet structure, and emergency spillway) shall be included in the easement and shall be accessible from the easement's drive path.
Contributing Drainage Area	Maximum contributing drainage area (CDA) = 5 acres
Hydrologic Support	See Section 7.13.5 above for hydrologic support requirements. See also Appendix E (Policies for Soil Borings and Infiltration Tests). A water balance calculation must demonstrate that the wet enhanced swale can withstand a 30 day drought at summer evaporation rates without creating overly dry conditions that will damage or destroy wetland vegetation. The swale holds the WQv. There is no design drawdown time.
Minimum Hydraulic Head	Minimum hydraulic head = 1 foot The hydraulic head is the elevation difference from inflow to outflow.
Channel Slope & Ponding Depths	Channel slope shall not exceed 4%, but slopes between 1% and 2% are recommended If site topography necessitates a steeper slope, place drop structures in the channel to limit the energy slope to within 1% to 2%. Drop structures can be used as check dams (see Check Dams row below) • Drop height = 6 to 12 inches • Longitudinal drop structure spacing = 50 feet or greater • Energy dissipation will be required below to drops to prevent flow velocity increases and channel erosion. Maximum surface ponding depth at the downstream end = 18 inches Average surface ponding depth = 12 inches

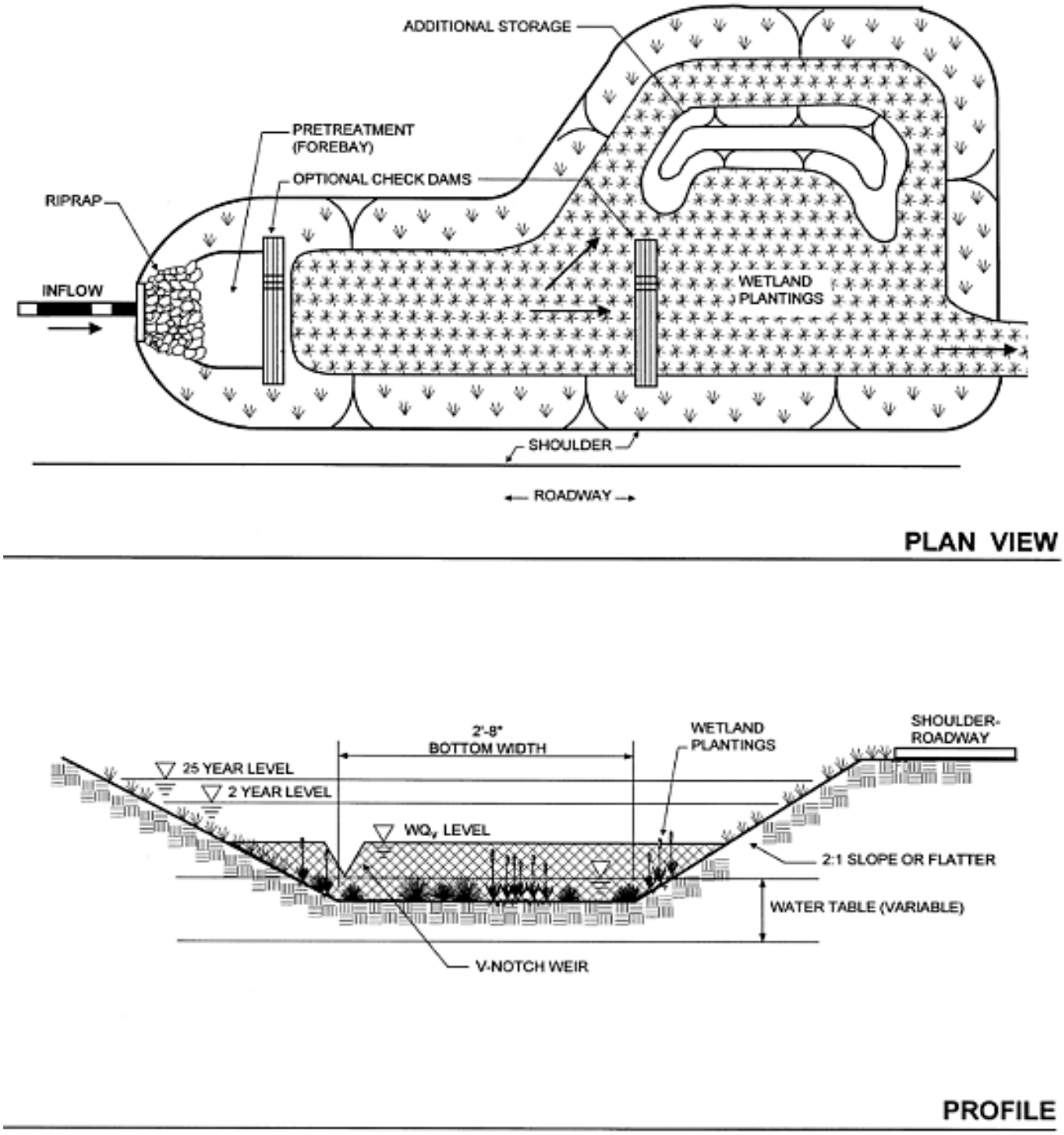
Design Element	Specification(s)
Bottom Width	Bottom width = 2 to 8 feet; wider channels can be designed, but should contain berms, walls, or multi-level cross section to prevent channel braiding or uncontrolled sub-channel formation. Bottom lateral slope (if trapezoidal in design cross section) = 0% (flat)
Cross Section & Side Slopes	Wet enhanced swales are parabolic or trapezoidal in cross section. Side slopes = 4:1 preferred; 2:1 maximum
Flow Velocity	Maximum peak flow velocity for the 2-year, 24-hour storm event = 5 ft/sec
Check Dams	Use check dams to achieve multiple wetland cells along the channel bottom. Use V-notch weirs in the check dams to direct low flow volumes.
Inlets	Energy dissipators must be provided for inlets to limit inflow velocities to no greater than 5 ft/sec. Direct concentrated inflows may require a 6 inch drop to a pea gravel diaphragm flow spreader at the upstream end of the swale or inflow. Ensure the WQv will not bypass or short-circuit the bottom (e.g., inlets or curb cuts that are very close to the channel outlet).
Pretreatment	Pretreatment is provided at the upstream end of the swale via a sediment forebay located at the inlet. Size the forebay volume for 0.1 inches per impervious acre served by the swale. This volume is typically obtained by providing check dams at pipe inlets and driveway crossings. For lateral sheet inflows to the swale, provide vegetated filter strips and gentle side slopes for pretreatment.
Outlets & Emergency Spillway	The swale must be designed to hold the WQv. Outlets must allow safe conveyance and passage of larger storms, up to the 25-year, 24-hour storm event, in keeping with an online or offline configuration as indicated previously in this table. Outlet protection must be used at all discharge points from the swale to prevent scour and downstream erosion.
Vegetation	See Section 7.13.8 of this design specification, titled Vegetation Design, for planting bed standards.

Figure 7.13.2 Plan and Profile Schematics of a Wet Enhanced Swale



Source:NC State Extension Publication AG-588-26, Swale Terminology for Urban Stormwater Treatment, Feb. 10, 2020

Figure 7.13.3 Wet Enhanced Swale Typical Cross Section



Source: Center for Watershed Protection via ARC, 2016.

7.13.7 Design Procedure

Table 7.13.5 provides the design procedure for a wet enhanced swale.

Table 7.13.5 Design Procedure

Step	Design Activity
Step 1	**Evaluate wet enhanced swale feasibility.** Use the feasibility and location criteria provided in Table 7.13.2 and the hydrologic requirements in Section 7.13.5 to determine if a wet enhanced swale is feasible for the selected location on the land development site. Also consider the intended land use of the property, the maintenance burden, and assumptions or knowledge of how the landowner(s) will care for the wet enhanced swale (e.g., maintain it themselves, through a property manager, or hiring a landscape contractor). Communicate the requirements for long-term maintenance to the landowner(s) before deciding. If a wet enhanced swale is determined to be feasible and appropriate for the proposed development, create a rough layout of its dimensions, taking into consideration existing trees, utility lines, and other obstructions to ascertain if it will fit into the desired space, given its general design requirements.
Step 2	**Calculate the design storage volume (DSv) for the contributing drainage area.** Typically, the DSv = WQv, unless the wet enhanced swale cannot manage the entire WQv. Use one of the calculation methods explained in Chapter 6, Section 6.2 (Water Quality Management) to calculate WQv.
Step 3	**Determine the ponding volume (PV) of the preliminary layout of the wet enhanced swale.** The ponding volume (PV) is determined for an average ponding depth of 12 inches and maximum ponding depth of 18 inches at the downstream end of the swale
Step 4	**Determine if the proposed wet enhanced swale meets the WQv requirement.** If PV ≥ WQv, proceed with Step 5. If PV ≤ WQv, redesign the swale to provide sufficient volume for the WQv and recalculate PV.
Step 5	**Create the swale design.** Size the swale bottom width, depth, length, slope, and side slopes. • Maximum ponding depth is 18 inches. • Longitudinal slope must be 1% to 2%. Use drop structures if needed. • Bottom width should be from 2 to 8 feet with zero lateral slope, or parabolic. • Side slopes should be 4:1; 2:1 maximum. • The swale must hold the WQv. Compute the number of check dams required and their heights to detain the WQv. All larger storms should flow over the check dams without eroding the swale.
Step 6	**Check for adequate capacity to manage the entire WQv storm.** Route the hydrograph of the water quality storm event through the swale to ensure it captures the entire WQv, even when the WQv includes the peak flow of the water quality storm event.
Step 7	**Check the velocity, erosion potential, and freeboard for the 2-year and 25-year, 24-hour storm events.** Modify the design until erosive velocities are eliminated. Provide 6 inches of freeboard for the 25-year event.

Step	Design Activity
Step 8	**Size the overflow structure (for all swales) and any flow regulators (for offline swales only).** See Section 7.16 (Overflow Structures) for requirements.
Step 9	**Design the pretreatment measures.** See Section 7.14 (Inlets, Pretreatment, and Energy Dissipation) for requirements.
Step 10	**Design the vegetation and protection measures.** The vegetation design shall be in accordance with the vegetation design requirements provided in Table 7.13.6. Use guidance found in Section 7.13.9 (below) to design protection measures.

7.13.8 Vegetation Design Requirements

Plants are critical to the performance and function of a wet enhanced swale as a water quality treatment SCM. Plants filter and transpire stormwater, providing both pollutant removal and stormwater volume reduction. They maintain soil health by preventing erosion and providing organic matter for nutrient replenishment. Further, they function as habitat for surface and subsurface fauna that help keep wetland plants healthy.

The importance of plants to wet enhanced swale function means they, like any SCM component, have design, installation, and maintenance specifications. Much of the design and maintenance of a wet enhanced swale centers on plant coverage and replacement. Table 7.13.6 provides the vegetation specifications for a wet enhanced swale.

Table 7.13.6 Vegetation Design Specifications

Vegetation Design Element	Specification(s)
Minimum Coverage	Wet enhanced swales must be entirely (100%) covered by vegetation as indicated in the next row of this table. Areas of bare soil are not allowed at any location within, or in close proximity to, the swale. For newly installed wet enhanced swales, this coverage requirement must be achieved within the first two growing seasons (March through November) after installation, and then maintained thereafter. A dense and vigorous vegetative cover should be established over the contributing pervious drainage areas before stormwater can be accepted into the wet enhanced swale. Sediment in stormwater can create an unhealthy environment for wetland plants.
Plant Location	Plant location requirements are as follows: • Emergent wetland plants shall be located on the channel bottom and on the lower portion of the side slopes up to the design's average ponding depth. The area above the average ponding depth can be vegetated with wetland and/or non-wetland plants depending on the expected hydric conditions. • Woody vegetation shall not be located at points of stormwater inflow and outflow. • Trees shall not be located in the channel or on side slopes. Trees can be located outside the perimeter of the swale.
Plant Selection	Plants selected for the wet areas of the swale shall be emergent wetland vegetation. To establish the wetland areas, they should be placed by plug. Seed stock can be used to supplement plugging if needed. Plant selection guidance is provided below: • Select plants suitable for use in local conditions, based on specific site, soils, and hydric conditions expected at the plant's intended location within or adjacent to the swale, and the

Vegetation Design Element	Specification(s)
	desired aesthetic. For non-wetland plants to be located along the side slopes and perimeter, select vegetation that can tolerate extended periods of inundation. • Select plants that are salt tolerant if the swale will receive drainage from areas treated for ice in winter) For guidance on appropriate plant species, consult a plant and landscape expert, such as a landscape architect, local nursery, or Master Gardener from the Tennessee Extension Master Gardener Program (https://mastergardener.tennessee.edu/). Native plant species may be better suited to local hydrologic conditions. Plants suitable for United States Department of Agriculture (USDA) Plant Hardiness Zone 7b are recommended.
Plant Survival	Replacement of vegetation is required where plant coverage has degraded.

Compliance with the vegetation standards set forth above shall be shown in a vegetation plan that is included with the stormwater management plan (SWMP). Plan preparation requirements are below.

- The plan must be prepared by a professional qualified in landscape design by their education or experience.
- The plan shall include one or more labeled plans/details (to scale) showing the plants to be installed, their numbers, and locations. Plan notes showing a plant schedule and installation instructions are encouraged. This additional information allows both the plant installer at the time of construction, as well as the person(s) responsible for maintenance of the SCM after construction, to understand the original vegetation design and its compliance with the minimum standards.
- Landscaped SCMs may not be recognized under the City's codes as property landscaping. Therefore, additional requirements for property landscaping may apply.

7.13.9 Protection Design Guidance

SCMs designed for stormwater quality purposes must be maintained in keeping with the approved SCM design for the life of the land development[1]. **Design professionals can assist property owners with this requirement by including protective features in and around SCMs to limit the potential for damage by external factors**. Often, the landscape and impervious features around an SCM can be tailored to its specific needs, and therefore used to protect its critical components.

Protection is especially important for the wetland plants and outlet structure which are key to pollutant removal and wet enhanced swale water levels and flow rates, respectively. A variety of protection methods are listed in Table 7.13.7 and shown in Figure 7.13.4. Protection measures listed or shown are not exhaustive. Other measures are possible.

Table 7.13.7 Wet Enhanced Swale Protection Measures*

Passive Protection Measures	Active Protection Measures
• Natural fencing around the perimeter (e.g., dense, woody, or prickly shrubs or tall grass) • Driveways, sidewalks, or walkways around the SCM • Pedestrian benches on the perimeter • Geometry to allow maintenance without equipment	• Decorative fencing • Curbs or curb blocks • Hardscaping (cobbles, boulders, block edging, etc.) • Educational or directive (e.g., no pets) signs • Pet waste stations and trash cans near the SCM

[1] Tennessee Rule *0400-40-10-.04*

Figure 7.13.4 Examples of Wet Enhanced Swale Protection Measures

Left: Passive protection is provided by pedestrian paths along both sides of the swale. (Seattle Public Utilities); Middle Hardscaping and a foot bridge protect this wet swale (City of Talent, OR). Right: A wet swale on Heriot Watt Campus in Edinburgh, Scotland has pedestrian walkways, protective landscaping, *and decorative fencing (Edinburg Council).*

7.13.10 Installation Requirements

The information in Table 7.13.8 provides a typical construction sequence to properly install wet enhanced swales. These steps may be modified to reflect different applications or site conditions. **Installation practices shall be shown in the EPSC and SWMP plans, as appropriate for the proposed land development.**

Table 7.13.8 Installation Steps

Step	Requirement
Step 1	The installation site shall be checked for existing utilities prior to swale construction to avoid potential conflicts and/or damages to utilities. Supervision during construction is required to ensure the wet enhanced swale is constructed/installed in accordance with the approved the EPSC and SWMP plans. The design professional or a designee under their supervision must inspect the wet enhanced swale at critical stages of construction. Examples of critical stages of construction include excavation, drop structure installation, vegetation installation, and final inspection. This ensures that the contractor's interpretation of the plan is consistent with the design professional's intentions and allows the design professional to certify (in the as-built plan) that the swale is built in keeping with the approved plan.
Step 2	During the preconstruction meeting, review and confirm that the actual boundaries of the swale's contributing drainage area and inlet elevations conform with the approved design. Any changes that result from the preconstruction meeting must be shown as a revision to the SWMP and resubmitted to the City for approval. This includes changes to material certifications for aggregate, engineered soil mix, and liners if not approved prior to the preconstruction meeting
Step 3	Install any stormwater diverters/flow blocks that may be necessary to divert stormwater flows from the swale during its construction.
Step 4	If the swale will intercept the water table, construct the outlet structure first (or if not feasible, with the construction of the embankment) to control the water level in the swale during excavation.
Step 5	Excavate and grade the swale from the outlet and moving toward the inlet, until the appropriate elevations and desired contours are achieved for the bottom and side slopes of the wetland. • Tracked excavators are recommended, especially on wet sites. Toothed buckets are recommended to avoid smearing and unintended soil compaction. A hydraulic thumb attachment for the bucket is especially useful for removing debris and scarifying soil surfaces.

Step	Requirement
	• Special protection measures, such as erosion control fabrics, may be necessary to protect vulnerable side slopes from erosion during the construction. Ensure that the outlet is constructed to be level and at the proper design elevation.
Step 6	Add topsoil and soil amendments. Equipment should not be allowed to traverse over the planting soil, once placed. Planting soil should be tamped as directed in the design specifications, but it should not be overly compacted. After topsoil is placed, it should be saturated and allowed to settle for at least 1 week prior to installation of plants. Install temporary irrigation measures, if needed, to ensure plants will be watered during the remainder of site construction.
Step 7	Install plants and surface covers as shown in the approved vegetation plan.
Step 8	Erosion prevention and sediment control (EPSC) devices can be removed from the inlets once the swale's side slopes have good vegetative stability, and the drainage area is fully and permanently stabilized. If the area draining to the swale includes newly installed asphalt, inlet blocks or EPSC devices should remain for at least three storm events after asphalt installation. A substantial number of fine particles and grit are discharged from newly installed asphalt during the first several storms that produce stormwater after installation. Maintenance will be required to remove the particles and grit if EPSC devices are removed too early.
Step 9	Maintain the wet enhanced swale in keeping with Section 7.14.11 below. Prepare the As-Built Plan and submit to the City for review and approval with the engineer's as-built certification before a final Certificate of Occupancy can be obtained. Advise the landowner (i.e., the person(s) taking ownership of the property immediately after its development) of the presence of the wet enhanced swale and provide them with a copy of the property's As-Built Plan and SCM location map. The plan must clearly show the location of the wet enhanced on the property and list the activities (and their frequencies) necessary for its proper maintenance.

7.13.11 SCM Maintenance on an Active Construction Site

Once an SCM is installed, its maintenance is regulated by Title 16, Chapter 5 (Stormwater Management) of the Alcoa (TN) Municipal Code. Further, SCMs must pass a final inspection prior to construction termination. This inspection will be performed to ensure they are constructed in accordance with the approved SWMP, undamaged, and free of sediment and debris. Thus, SCM maintenance is good practice to ensure construction termination goes smoothly. Relevant policies are as follows:

- The property owner is responsible for SCM maintenance. If the property is still an active construction site, these responsibilities may fall to the land disturbance permittee until the project receives final approval from the City and/or a Certificate of Occupancy.
- Property owners may have others, such as a site contractor or landscaping company, maintain the wet enhanced swale on their behalf. However, the City will hold the property owner responsible for ensuring it is maintained in proper operating condition (i.e., as designed and constructed) regardless of who performs maintenance activities.
- Maintenance activities, which include ensuring proper operation of the SCM as designed and required SCM inspections, must begin immediately following installation of the wet enhanced swale.
- Maintenance activities shall be performed in keeping with the *SCM Inspection and Maintenance Manual*. Additional guidance on maintenance of newly installed wet enhanced swales located on active construction sites is provided in Table 7.13.9.

Table 7.13.9 Maintenance Activities for Newly Installed Wet Enhanced Swales

Area or Component	Post-Installation Maintenance Requirement
Contributing Drainage Area	Keep the area draining to the SCM clean. Sweep trash, debris, and sediment frequently so that it does not wash in the swale during a rain event. The area should be fully stabilized before installation of the SCM. If it is not, prevent inflows to the SCM by blocking or using diversion measures until the contributing drainage area is fully stabilized. Stabilize the area as soon as possible to prevent the discharge of sediment to the SCM. Cover stockpiles of construction and landscape materials to prevent their exposure to rainfall.
Wet Enhanced Swale Area	Ensure the plants within the swale are growing as expected and plants on the side of the swale watered during dry periods. Remove and replace diseased, dying, or dead plants as soon as they are noticed. Remove accumulated sediment and wastes from the forebays and channel. Visually observe swale function after rain events to ensure it is holding water as expected and discharging large events without erosion. Inspect the swale for erosion or significant sediment buildup; immediately determine and eliminate the cause and repair the area.
Education	Alert onsite subcontractors to the SCM and the following requirements: • No muddy vehicles or equipment in the drainage area to the swale. • No stockpiling of material in the swale and no exposed stockpiles in the swale's drainage area. • Remove sediment, trash, debris, and empty trash cans frequently. Advise landscaping subcontractors on proper protection and maintenance of the wet enhanced swale, especially the following: • No mowing in the swale, or dumping of lawn clippings or landscape debris • Plant maintenance needs/requirements (see above)No dumping of lawn clippings or landscape debris • Plant maintenance needs/requirements (see above)

7.13.12 References

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition.* Atlanta Regional Commission, 2016.

7.14.1 Introduction to Inlets and Energy Dissipation

Inlets are the structures or landscape features that manage the flow of stormwater into a stormwater control measure (SCM). Sometimes, their design is combined with an energy dissipator which slows the inflow rate to prevent erosion within the SCM itself. Inlets and energy dissipators can also be combined with a pretreatment measure, which is intended to capture heavy sediment, debris, and trash. Together, these SCM components manage the volume, rate, and cleanliness of flow entering the main treatment area of the SCM.

Sections 7.14.2, 7.14.3, and 7.14.4 address two non-standard inlets: curb openings and flow splitters, as well as energy dissipators. Design information for standard inlet controls can typically be found in the City of Alcoa's (city) street design (i.e., public works) standards.

7.14.2 Inlets - Curb Openings

For SCMs located in or adjacent to parking lots and roadways, curb blocks and continuous curbing are popular ways to establish an SCM border and protect it from entry (see Figure 7.14.1). When an SCM is bounded by a curb, openings allow stormwater to flow into the SCM. Curb openings are also called "curb cuts" in continuous curbing applications. Curb cuts can be implemented in an SCM design when standard inlet control and conveyance system structures are not feasible (due to space or other constraints) or desired. These designs have advantages and limitations, as shown in Table 7.14.1.

Figure 7.14.1 Curb Opening Design

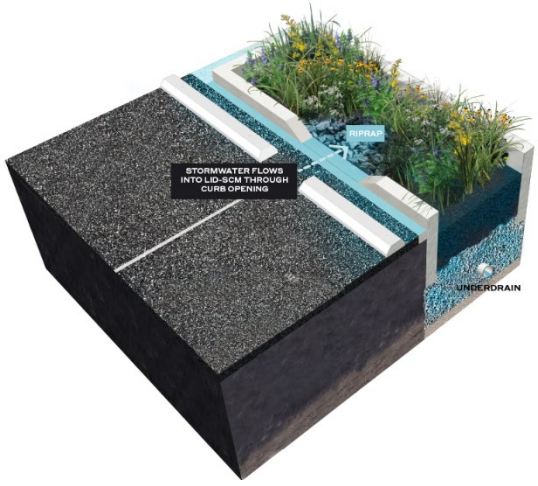


Table 7.14.1 Curb Opening Advantages and Limitations

Advantages	Limitations
Can reduce SCM depths and associated excavation and materials costs when chosen in lieu of inlets	Provides only limited control of bypass flows
Can be implemented as a strategy to reduce the concentration of stormwater flows into the SCM, thus reducing erosion potential	May not be appropriate for large contributing drainage areas, or those with long flow paths over impervious areas, along driveways, or near roadways where a sump condition is not feasible

Design specifications for curb openings are provided in Table 7.14.2. Beyond these specifications, check with the City to determine any further design requirements. Examples of curb opening designs are provided in Figure 7.14.2.

Table 7.14.2 Curb Opening Design Specifications

Design Element	Specification
Elevation	The pavement edge at the curb opening must be higher than the elevation of the vegetated areas within the SCM, including any mulch layers that will be present, to avoid backflow from the SCM into the curb opening.
Flow Design	Curb openings must convey flow into an SCM without causing erosive conditions (flow velocity less than 5 ft/sec). Energy dissipators will likely be needed for curb openings since they concentrate flow and increase its velocity. See Section 7.14.4 for information on energy dissipators.

Design Element	Specification
	Curb openings must be designed to prevent bypass of gutter flow past the curb opening. This is a common problem with many curb openings that are oriented perpendicular to flow.
Sizing	Curb openings must be sized to convey the design discharge into the SCM. Typically, openings range from 12 to 48 inches wide, with the following caveats: • Minimum curb opening width = 8 inches; this minimum width reduces clogging and provides for easier maintenance than smaller widths • Size curb openings appropriately for on-grade or sump conditions, whichever is appropriate.
Location & Spacing	Curb openings are to be designed as gaps in otherwise continuous sections of curb conforming to the city's street design standards. Trench drains can be used to convey flow from curb openings through sidewalks. See Figure 7.14.2 for an example.
Roadway Material	Roadway materials and thicknesses must be able to withstand the appropriate loads at the edge and prevent undercutting.
Subsurface Material	All subsurface portions of curb (i.e., below finished pavement grade) must be continuously installed within the extents of the curb opening.
Flood Protection	If curb openings are used to capture stormwater, especially from driveways or roadways where the curb openings are not in a sump condition, verification that stormwater from the 1-year, 24-hour storm event will be captured by the curb opening must be provided.
Safety Considerations	Pedestrian fall safety must be considered where a curb opening location is adjacent to or beneath sidewalks. The need for edge visibility and edge protection, such as railings or wheel stops, must be evaluated and accommodated.

Figure 7.14.2 Examples of Different Curb Cut Designs

Top Left: A parking lot with curb cuts that allow stormwater into the bioretention areas (Mississippi Department of Marine Resources); Bottom Left: A trench drain directs stormwater into the curbed bioretention area (Chachula Design); Right: Curb cuts allow stormwater to enter a parking lot bioretention area (City of Sacramento, CA)

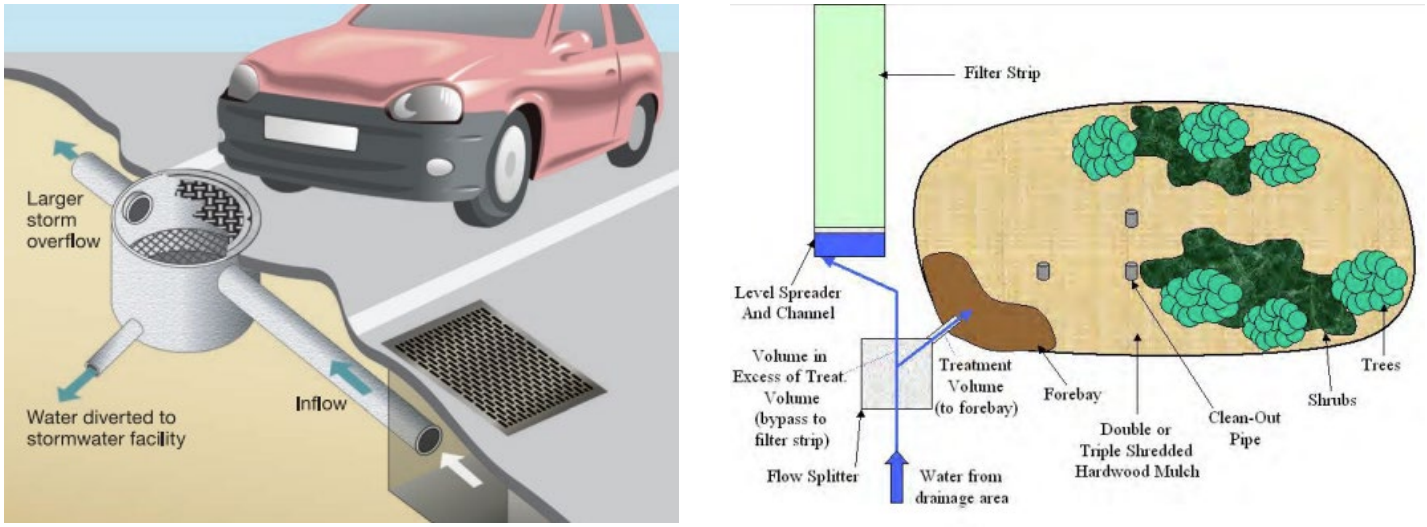
7.14.3 Inlets - Flow Splitters

Flow splitters are inlet controls used to divert a fraction of stormwater (typically the water quality treatment volume [WQv]) to an SCM while bypassing larger flows to a downstream SCM (such as a conventional detention basin), onsite stormwater conveyance system, or receiving waterbody. They may also have other applications where flow diversion/splitting is needed. The advantages and limitations of flow splitters are shown in Table 7.14.3. Example flow splitter layouts are shown in Figure 7.14.3.

Table 7.14.3 Advantages and Limitations of Flow Splitters

Advantages	Limitation
Divide and divert the stormwater volume to alleviate downstream flooding during a storm or to prevent an SCM from exceeding its designed capacity	Have the potential to cause flow reversal under certain circumstances (e.g., due to lack of backflow preventer or one-way valve) in which water will flow from an SCM back through the flow splitter
Reduce the cost of building an SCM by reducing the storage capacity needed to provide positive overflow	
Enhance SCM longevity by reducing the volume of stormwater treatment and the amount of erosion, slope, and vegetation damage	
Separate the WQv, which contains most of the stormwater pollutants, allowing it to be treated for a longer period of time without being diluted by additional stormwater, which can be diverted downstream or to another SCM	

Figure 7.14.3 Example Flow Splitter Layouts



Left: Flow splitter shown in a drawing of a parking lot (Montgomery County, MD, Department of Environmental Protection). Right: Flow splitter directing WQv to a bioretention area (Mississippi Dept of Environmental Quality, Erosion and Sediment Control Manual, Vol. 2)

When applied as inlet controls, flow splitters are typically constructed by installing bypass weirs in inlets and manholes (see Figure 7.14.4.a and 7.14.4.b). On a larger scale, they can be constructed using concrete baffles in manholes. Other designs that can route the design flow to the SCM and divert higher flows may also be acceptable.

Design specifications for flow splitters are described in Table 7.14.4. Materials specifications are provided in Table 7.14.5.

Figure 7.14.4 Example Flow Splitter Designs *(adapted from 2021 Kitsap County Stormwater Design Manual)*

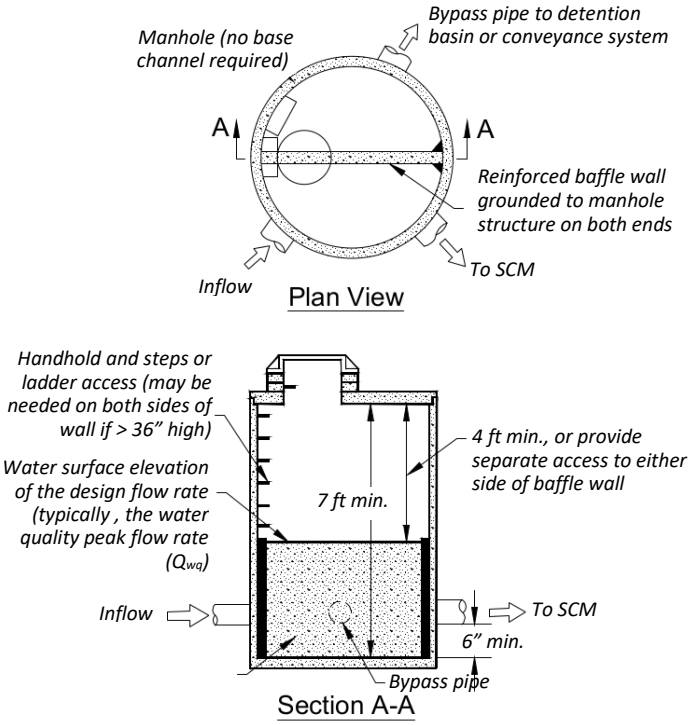


Figure 7.14.4.a

Note: The outlet pipe to the SCM may require an orifice plate to control the water surface elevation (weir height) for the design flow rate [typically the water quality peak flow rate (Q_{wq})]. The water surface elevation of the design flow rate should be set to provide a minimum headwater/diameter ratio of 2.0 on the outlet pipe

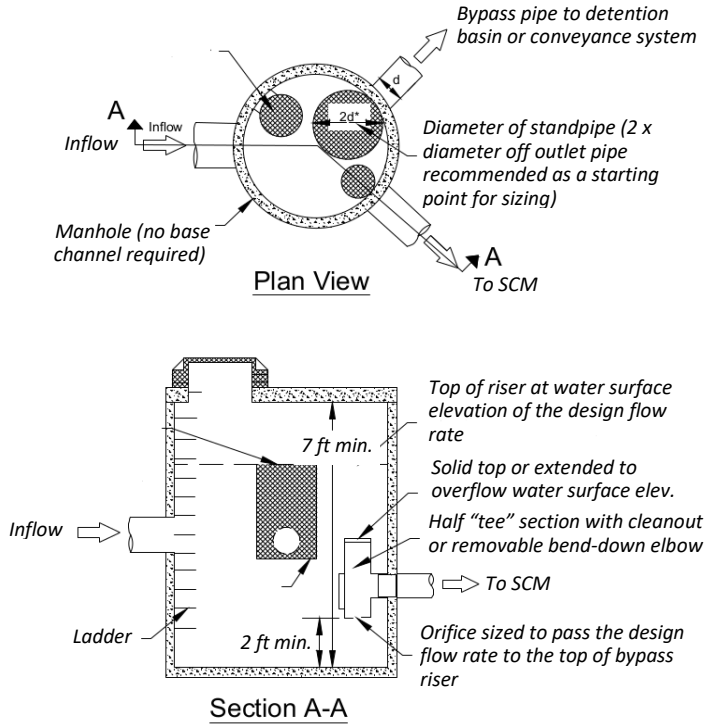


Figure 7.14.4.b

Note: Diameter of standpipe (2d) should be large enough to minimize the head above the water surface elevation of the design flow rate [typically the water quality peak flow rate (Q_{wq})] and to keep water quality flows from increasing more than 10% during 100-year flows.

Table 7.14.4 Flow Splitter Design Specifications

Specification
In Figure 7.14.4.a, the top of the baffle wall shall be located at the water surface elevation for the design flow rate (e.g., the water quality peak flow (Q_{wq}), the maximum flow rate to stormwater wetlands, etc.)
The maximum head shall be minimized for flow in excess of the design flow rate. Specifically, flows to the SCM when at the 100-year water surface elevation shall not exceed the design flow rate by more than 10%.
In Figure 7.14.4.b, an alternative to a solid top plate is a full tee section with the top of the tee at the 100-year water surface elevation. This alternative would route emergency overflows (if the overflow pipe were plugged) through the SCM rather than back up from the manhole.
Special applications, such as SCMs adjacent to roads, may require the use of a modified flow splitter where the baffle wall in Figure 7.14.4.a is to be fitted with a notch and adjustable weir plate to proportion stormwater volumes rather than high flows.
Backwater effects shall be considered in designing the height of the standpipe in the manhole or vault flow splitter structure.
Ladder or step and handhold access shall be provided. If the baffle wall in Figure 7.14.4.a is higher than 36 inches, two ladders shall be provided, one on each side of the wall.

Table 7.14.5 Flow Splitter Materials

Design Element	Specification
Manhole or Vault	Type 2 (also known as a storm manhole or Type 2 catch basin)
Baffle wall	Reinforced concrete or another suitable material resistant to corrosion Minimum thickness = 4 inches Minimum clearance between the wall and bottom of the manhole cover = 4 feet; this distance can be smaller if dual access points are provided.
Metal parts	All metal parts (e.g., weir or orifice plate) shall be corrosion resistant. Preferred materials include aluminum, stainless steel, or use a sturdy plastic. Zinc and galvanized materials and painted metal or plastic are prohibited due to aquatic toxicity.

7.14.4 Energy Dissipators

Energy dissipators are devices or practices designed to reduce the velocity, energy, and (sometimes) turbulence of flow. These structures can be employed when highly erosive velocities are encountered at the end of flow inlets, outlets, culverts, and at the bottom of steep slopes. They are required at the inlets of most SCMs. Energy dissipators include, but are not limited to, rock aprons (also called "splash pads"), riprap basins, and baffled dissipators.

Rock aprons are commonly used for energy dissipation due to their relatively low cost and ease of installation. A flat rock apron can be used to slow and spread the flow, thus reducing the inflow energy. Rock aprons are a popular choice to prevent erosion at the transition from an inlet into a forebay or SCM. They will provide adequate protection against erosive flows, provided there is sufficient length and flare to dissipate energy by expanding the flow. Rock apron examples are shown in Figure 7.14.5.

Riprap basins are pre-shaped scour holes lined with riprap that function as energy dissipators. Like a riprap apron, a riprap basin can be used to prevent erosion at flow transitions. Riprap basins are more commonly used in SCMs that serve large drainage areas and provide both water quality and quantity control, such as extended detention basins, water quality basins, and stormwater wetlands.

Baffled dissipators, such as a Hook Type Energy Dissipator Basin, are concrete or fiberglass boxes containing an alternating series of baffles and/or chambers. In addition to reducing flow velocity and energy, this energy dissipator can effectively remove sediment, suspended particles, and associated pollutants from stormwater. Baffled outlets are typically used for much larger stormwater applications but have been successfully applied in SCMs.

Advantages and limitations of energy dissipators are presented in Table 7.14.6. Design specifications for energy dissipators are detailed in Table 7.14.7.

Table 7.14.6 Advantages and Limitations of Energy Dissipators

Advantages	Limitations
Reduce velocities of concentrated stormwater flow	May increase erosion if not properly designed and installed
Reduce erosion potential and allow for more efficient sediment removal efforts, reducing overall maintenance costs and improving SCM performance	
Prevent scour that may undermine the structure discharging concentrated stormwater runoff	
Prevent downslope erosion that may create gullies and scour holes	

Figure 7.14.5 Example Riprap Aprons

Top left: Perimeter rock apron in a bioretention SCM (NJ Stormwater Management BMP Manual); Lower left: A riprap basin in a newly planted bioretention SCM; Top right: Riprap aprons at curb cut inlets to an infiltration basin (both pictures from NCDEQ Stormwater Design Manual); Lower right: Stone lined inlet aprons in a movie theater parking lot bioretention area (wiki.sustainabletechnologies.com)

Table 7.14.7 Energy Dissipator Design Specifications

Design Element	Specification
Selection	Select an appropriate energy dissipator type based on site characteristics such as slope, available area, and aesthetics.
Flow	Energy dissipators must be used if flow is concentrated at inlet to an SCM and/or has a flow rate greater than 5 ft/sec. The design professional is referred to the United States Army Corps of Engineers, Hydraulic Engineering Center Circular 14 (HEC-14) for the design of alternate types of energy dissipators, such as drop structures and stilling basins.
Vegetation Interface	A key design issue is the interface between the end of the energy dissipator and the adjacent downstream area, which is typically vegetated. Vegetation should be well established at this interface. Turf reinforcement matting may be used at this interface to provide additional structure for vegetation.
Rock Apron Design	Rock apron design shall be in accordance with the riprap apron design for culverts provided in the latest edition of the Tennessee Department of Transportation (TDOT) Drainage Manual.
Riprap Basins & Other Energy Dissipators	The design of riprap basins and other energy dissipators shall be in accordance with the energy dissipation chapter provided in the latest edition of the TDOT Drainage Manual.

Design Element	Specification
Aesthetics	Decorative landscape rock may be used in place of riprap for rock aprons (not riprap basins or other energy dissipators), provided the rock is of sufficient size to not dislodge in the highest flows expected from the SCM inlet. Vegetation may be used to obscure views of energy dissipation structures if aesthetics is a concern. However, avoid the use of woody vegetation and wandering vines near inlets, energy dissipators, and pretreatment devices as they can obstruct flow, cause component damage, and create maintenance difficulties.
Baffled or Other Energy Dissipators	For stream outfalls, the energy dissipation design tools from the Federal Highway Administration (FHWA), HEC-14, HEC-15, and HEC-23 (which supersedes former HEC-11) must be used for riprap, energy dissipators, and flexible linings, respectively.

7.14.5 Pretreatment Measures

Pretreatment measures are critical to SCM maintenance and must be included in every structural SCM. This is especially true for infiltration based SCMs, such as a bioretention areas, urban bioretention areas, and infiltration basins. These SCMs operate through soil or gravel infiltration and filtration, they are more sensitive to clogging by sediment accumulation than traditional SCMs, such as an extended detention pond. Properly designed pretreatment measures will sustain the water quality management function, extend the service life, and reduce the maintenance costs of SCMs.

There are a variety of pretreatment measures available to design professionals. All of them function by decreasing peak stormwater velocities and allowing solids and sediment to be removed via filtering (through vegetation) or settling before the stormwater enters the main treatment area of the SCM (see Figure 7.14.6). Some design professionals prefer to use hydrodynamic manufactured treatment devices (MTDs) or proprietary pretreatment devices (PPDs) for pretreatment purposes. Regardless of the pretreatment measure used, all capture debris in focused or hidden areas, ideally providing for easy cleaning. This tends to also improve SCM aesthetics if the main treatment area, which can be the focal point of the SCM, is kept relatively clean and free of litter, trash, etc.

Figure 7.14.6 Example of a Concrete Forebay

A small concrete forebay, as shown in the foreground, slows stormwater inflows substantially to allow most of the sediment to settle out of the water before it flows into the main treatment area of the SCM. (Source: Urban Water Center)

This design specification describes a variety of options for pretreatment measures. However, design professionals should not feel limited to only the options provided. The necessity for stormwater pretreatment varies according to the specific circumstances of the proposed development, including the pollutants and pollutant volume(s) expected, nature of flow (diffuse or concentrated), space limitations, design, and aesthetics. If the design professional can demonstrate compliance with requirements of this section, alternate pretreatment designs may be accepted.

The pretreatment measures designed should fit the situation at hand. For example, vegetated filter strips are typically better suited for diffused stormwater flow, while forebays and MTDs are better suited for concentrated stormwater flow. However, other factors must be considered. For instance, SCMs located on a fast-food development will likely see a high volume of floating debris (cups, lids, straws, cartons, wrappers, etc.) but will also be constrained due to limited space. In this case, vegetated filter strips or grass channels are probably not suitable; they are better for filtration of smaller pollutants (e.g., sediment, cigarette butts, etc.) and will probably take up too much space for a typical fast-food

development lot size. A hydrodynamic MTD may be more appropriate for this situation. Even so, the MTD will likely require frequent cleaning to prevent clogging. For a fast-food restaurant, a pretreatment device combined with appropriate good housekeeping measures (e.g., outdoor trash cans and frequent trash pickup by employees) is the best approach.

7.14.6 Applicability Guidance

Table 7.14.8 provides general guidance on the applicability of pretreatment devices to the SCMs included in this manual.

Table 7.14.8 Pretreatment Measure Applicability

SCM Type	Applicability by Pretreatment Device				
	Forebay (Sec. 7.14.8)	**Vegetated Filter Strip** (Sec. 7.14.9)	**Proprietary Pretreatment Device**[1] (Sec. 7.14.10)	**MTD**[1] (Sec. 7.7)	**Other** *(rock apron, baffles, sumps, etc.)* (Sec. 7.14.4)
7.1 Bioretention Area	Yes	Yes	Yes	Yes	Yes
7.2 Dry Detention Basins	Required	No	No	No	Used for energy dissipation only
7.3 Dry Enhanced Swales	Yes	Yes	Yes	Yes	Yes
7.4 Gravity (Oil-Grit) Separators	Gravity separators are used as pretreatment devices for other SCMs.				
7.5 Green Roof	Green roofs do not typically require pretreatment devices.				
7.6 MTDs	A pretreatment measure is usually included within the MTD unit				
7.7 Permeable Pavement Systems	Permeable pavement systems do not typically require pretreatment devices.				
7.8 Sand Filters	Yes	Yes	Yes	Yes	Yes
7.9 Stormwater Wetlands	Required	No	No	No	Used for energy dissipation only
7.10 Underground Detention Basins	Yes	No	Yes	Yes	Yes
7.11 Urban Bioretention Areas	Yes	Yes	Yes	Yes	Yes
7.12 Wet Detention Basins	Required	No	No	No	Used for energy dissipation only
7.13 Wet Enhanced Swales	Yes	Yes	No	No	Used for energy dissipation only

[1] *PPDs are different from manufactured treatment devices (MTDs). MTDs are structural SCMs that can be used, alone, to meet the city's requirements for stormwater treatment or can be used as pretreatment. PPDs cannot be used to meet stormwater quality treatment standards by themselves.*

7.14.7 General Policies

The following general policies apply to the use of pretreatment measures with structural SCMs:

1. **Pretreatment required.** Pretreatment of stormwater inflows is specified for most SCMs. When pretreatment is specified in a SCM design specification, it must be provided at every inlet to the structural SCM, unless otherwise established in the SCMs' design specification.

2. **Pretreatment measure documentation.** Pretreatment measures are NOT considered stand-alone SCMs. Rather, they are considered a component of the structural SCM and thus shall be fully included, shown, described, and otherwise addressed in the stormwater management plan (SWMP), record drawing, and any other required documents for design, post-construction, or structural SCM operation and maintenance purposes. Pretreatment measures are required to be maintained in the same manner as the structural SCM itself.

   When hydrodynamic MTDs or other proprietary devices are used for pretreatment purposes, the manufacturer's name and contact information, and the device's make, model, size, design, and inspection, operation, and maintenance information provided by the manufacturer shall be provided in all required documents.

3. **Pretreatment selection.** Some SCMs specify a required type of pretreatment measure (i.e., a sediment forebay is the only pretreatment device allowed for detention basins, wet detention basins, and stormwater wetlands). Otherwise, pretreatment measure selection and design shall take into consideration ease of maintenance and maintenance access.

4. **Access requirements.** Inlets, energy dissipators, and pretreatment measures are considered components of the SCM. As thus, they shall be designed so all parts of it are readily accessible for inspection, cleaning, and maintenance, and must be included the easement associated with the SCM.

7.14.8 Sediment Forebays (Pretreatment Measure)

A sediment forebay is a small impoundment designed at inflow points of an SCM to dissipate the energy of incoming stormwater and allow for initial settling of coarse sediments and capture of larger debris and trash. Sediment forebays are required for Tier 3 SCMs that also provide water quantity storage (i.e., dry extended detention basins, wet detention basins, and stormwater wetlands), but can be used for other SCMs as well.

Sediment forebays are located at areas of concentrated inflows; and are separated from the SCM's main treatment area by an earthen, stone, or concrete berm located at the downstream end of the forebay. Pretreated stormwater flows over the berm, or through a notch in the berm, and enters the main treatment area. This separation of the forebay and main treatment area aids in ease of maintenance and gross pollutant removal. Depending on the design, forebays can provide both pretreatment and energy dissipation (see Figure 7.14.7). Forebays are usually designed as surface features (addressed in this section) but can also serve in underground configurations.

Figure 7.14.7 Example of a Rock Basin/Forebay

A bioretention area's forebay (also rock basin or rip rap basin) is shown in the foreground. (Source: Water Conservation Technologies)

There are many variations of forebays, including: small shallow detention areas, deeper stilling-well types of areas; shallow areas with baffles, boulders, or cobbles that stormwater flows through; and drop gravel trenches/level spreaders. Forebay design is not limited to the examples shown or described herein. Rather, design

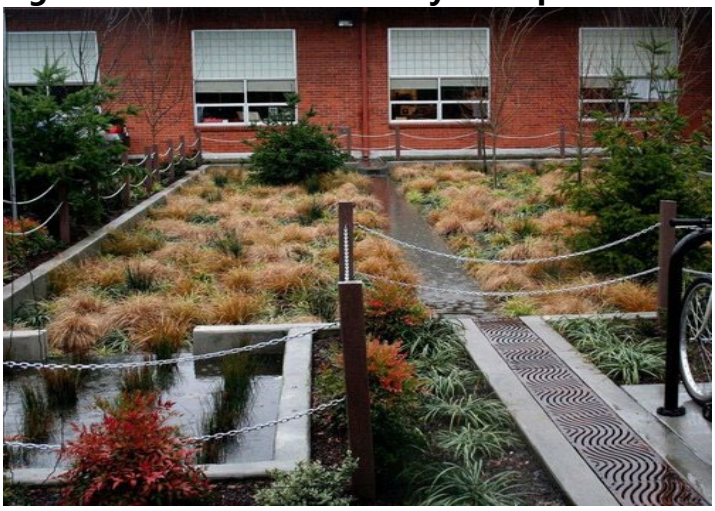
professionals have the flexibility to design forebays in ways that fit their site, provided the design considerations identified in this Section are addressed. Successful SWMPs will combine appropriate materials and designs specific to each site.

Table 7.14.9 lists the advantages and limitations of forebays. Figure 7.14.8 shows examples of different forebay designs.

Table 7.14.9 Advantages and Limitations of Forebays

Advantages	Limitations
• Effective at removing coarse sediment and debris from small frequent storm events • Helps define the space and awareness of the SCM • Easy to vary the design and aesthetic yet still retain the desired function(s)	• Generally ineffective at fine particulate removal • Requires more land than most other pretreatment measures • Usually visible to passersby, and therefore can create aesthetic concerns if not cleaned regularly

Figure 7.14.8 Other Forebay Examples



Left: A creative approach to forebay and inlet design is shown with the stilling-well type of forebay shown in the foreground on the left (source: Chachula Design); Right: A large forebay created by rip-rap gabion baskets, shown in the foreground of the picture, pretreats stormwater before it discharges to the main treatment area of the stormwater wetland (Source: Center for Watershed Protection).

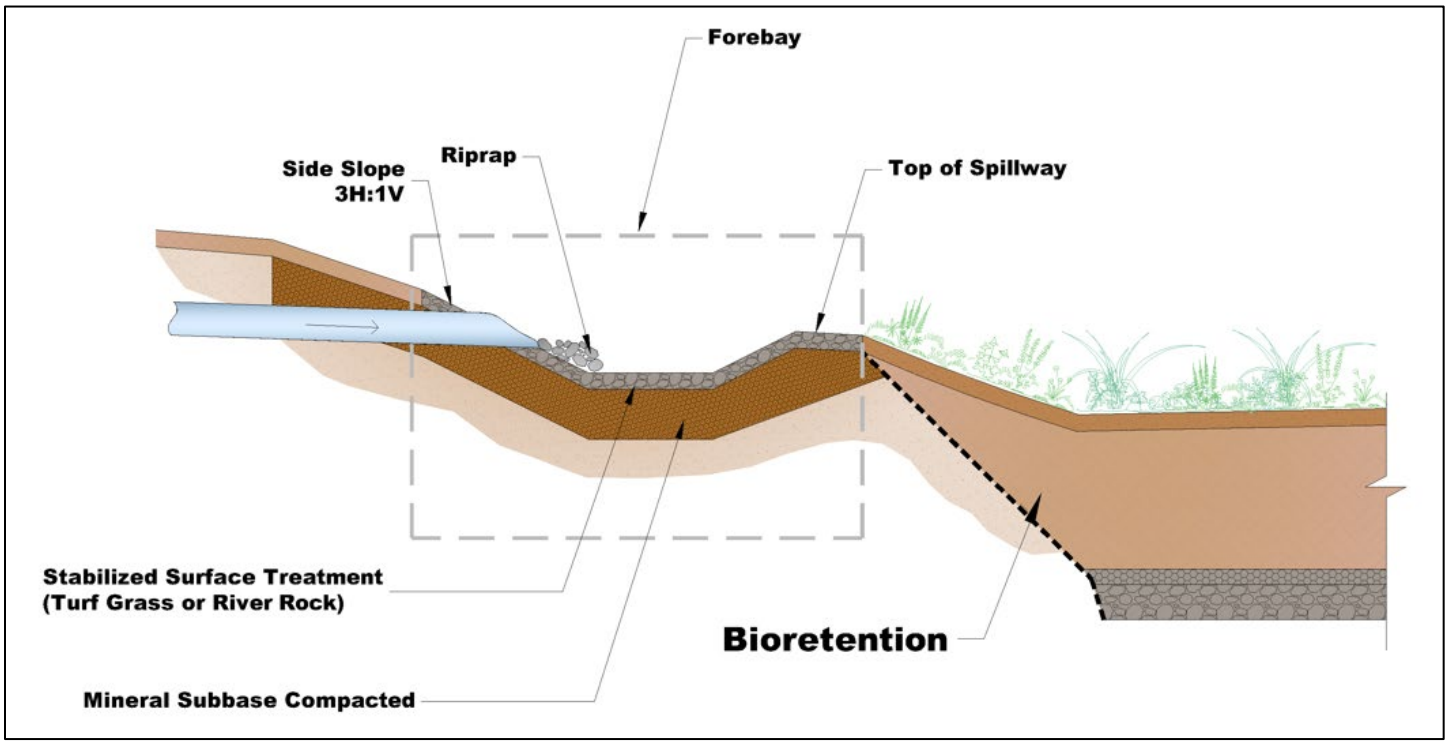
Table 7.14.10 provides design specifications for forebay pretreatment measures. Additional policies and considerations follow the table, as well as a schematic of a shallow forebay in Figure 7.14.9. The use of "shall" indicates a design requirement that will be enforced by the city. All other statements are to be considered as non-mandatory guidance.

Table 7.14.10 Forebay Design Specifications

Design Element	Specification
Excavation	Forebays for Tier 2 and non-storage Tier 3 SCMs (e.g., sand filters) can be created with limited excavation by placing a berm on the downslope side of a mild slope, provided stormwater does not overflow the sides of the forebay and flows only over the berm for the water quality storm rainfall. This design generally will not be effective in forebays for Tier 3 storage SCMs [i.e., dry extended detention basins, stormwater wetlands, and wet detention basins], as they are required to be much deeper than can be afforded by a mild slope. Excavation is required for forebays designed within Tier 3 storage SCMs.

Design Element	Specification
Inlet Control	Forebay inlets must include riprap aprons, stone placed in concrete, or some other type of energy dissipation device to rapidly reduce the inflow velocity for erosion/scour protection, provide separation of gross solids and floating debris, and encourage settlement of suspended solids.
Volume/Sizing	Forebays designed for use in Tier 3 storage SCMs [i.e., dry extended detention basins, stormwater wetlands, and stormwater (wet) basins] shall have a minimum storage volume of 10% of the water quality volume (WQv). For all other SCMs, forebays shall have a minimum storage volume of 0.1 inch per impervious acre. Forebay sizing shall consider an expected level of sediment loading. Where high volumes of sediment are anticipated, a deeper or larger forebay may be necessary. (Note: Some SCMs, and especially SCMs utilizing plants and engineered soil, are not suitable for use where high volumes of sediment are expected.) Drainage area size and characteristics have an impact on the nature and frequency of maintenance activities and corresponding long-term performance. For example, large parking lots deliver more sediment to an SCM than rooftops. Therefore, forebays that receive drainage from large parking lots may require a different design than those that receive stormwater from rooftops only.
Liner	Sediment forebays may be lined with concrete, rocks/cobbles or other hardscape material sized appropriately to withstand expected inflows, dense grass, or other dense vegetation ground cover. Bare soil and ground cover materials that are easily dislodged by flowing water (e.g., mulch or pebbles) are prohibited. Vegetation within forebays can help to improve aesthetics and assist with pollutant removal; however, high velocities and high rates of sedimentation within forebays can make vegetation survival difficult. As well, vegetated forebays require more frequent cleaning to ensure vegetation is not covered from sunlight by deposited sediment, trash, and debris for long periods. Seed mixes used in vegetation forebays must be appropriate for the underlying soils and be able to withstand occasional inundation by stormwater. Stormwater shall be prevented from entering vegetated forebays (and the main treatment areas of the SCM) until the entire forebay is fully and permanently stabilized from potential erosion.
Berms	A berm must physically separate the forebay from the main treatment area of the SCM. The berm should span the entire width of the SCM and shall be constructed of stone, concrete, or other solid material. Earthen berms are prohibited. An outlet control, such as a weir, may be needed to drain the forebay to the main treatment area of the SCM.
Sediment Depth	Forebays designed for use in Tier 3 storage SCMs [i.e., dry extended detention basins, stormwater wetlands, and wet detention basins] shall include permanent vertical markers constructed of durable materials must be installed within the forebay area to indicate the sediment depth.
Maintenance	Inspection and maintenance access is most commonly provided via stabilized and mildly sloping graded areas that can be accessed by heavy equipment.
Forebay discharge	The exit velocities from the forebay into the main treatment area must be non-erosive, maximum velocity of five (5) ft/sec.

Figure 7.14.9 Schematic of a Forebay in a Bioretention Area



7.14.9 Vegetated Filter Strips

Vegetated filter strips are densely vegetated areas that provide both energy dissipation for small storms and stormwater pretreatment. They treat stormwater from adjacent pervious and impervious areas by slowing stormwater velocity and filtering some pollutants before stormwater enters the main treatment area of an SCM (see Figure 7.14.10). They are a pretreatment measure typically applied within bioretention area and dry enhanced swale SCMs but can be used as grass channels for shallow flows. They may infiltrate a small amount of stormwater; however, this is usually negligible and should not be considered to reduce the design volume of the main treatment area of the structural SCM.

Figure 7.14.10 Vegetated Filter Strip

A densely grassed vegetated filter strip is located between the parking lot and main treatment area of the SCM. Sheet flow from the parking lot flows through the filter strip before it enters the SCM. (Source: Philadelphia Water Department)

Shallow, dispersed flow is required for pretreatment using a vegetated filter strip. In fact, filter strips treat stormwater only in sheet flow. A grass swale is a variation of this pretreatment measure, consisting of a gently sloped, densely grassed, very low-flow channel. Grass swales can pretreat water in shallow concentrated flow. However, neither filter strips nor swales will provide pretreatment for concentrated flow.

Vegetated filter strips and grass swales are generally a sensible and cost-effective stormwater pretreatment option applicable to a variety of development sites and structural SCMs. Their designs are not limited to the examples shown within this text. The advantages and limitations of filter strips are shown in Table 7.14.11.

Table 7.14.11 Advantages and Limitations of Vegetated Filter Strips

Advantages	Limitations
• Effective at removing coarse sediment, fine particulates, and small debris/trash (e.g., cigarette butts) from small frequent storm events • Flexible design allows application in many situations • Easy to design, construct, and maintain • Low-cost pretreatment measure	• Generally ineffective at removing large debris and floating debris • Requires erosion prevention and plant maintenance • Can require more land than other pretreatment measures (depends on situation) • Usually visible to passersby, and therefore can create aesthetic concerns if not cleaned regularly

Table 7.14.12 provides design specifications for vegetated filter strip pretreatment measures. The use of existing vegetated areas that have surface features that disperse stormwater is encouraged, as the use of these areas will also reduce overall site disturbance and soil compaction. An example schematic of a vegetated filter strip is provided in Figure 7.14.12.

Table 7.14.12 Vegetated Filter Strip Design Specifications

<table>
<tr><th>Design Element</th><th>Specification</th></tr>
<tr><td>Drainage Area</td><td>The maximum contributing drainage area that discharges through a filter strip or grass swale shall be less than 5 acres and must not exceed a drainage area to filter strip/grass swale area ratio of 6:1.</td></tr>
<tr><td>Length</td><td>The “contributing flow path” is defined as the maximum length of the flow path in the area draining to the vegetated filter strip or grass swale.
For contributing flow paths less than 30 feet in length, Figure 7.14.11 must be used to determine the filter strip length. The length requirements shown are scaled from dimensions of a grassy vegetative swale for the same slope and flow conditions identified below:
<table>
<tr><th colspan="2">Required Starting Design Values for Filter Strip Length</th></tr>
<tr><td>Strip length perpendicular to flow path</td><td>Longest length feasible</td></tr>
<tr><td>Strip length parallel to flow path</td><td>Four (4) feet* to 150 feet</td></tr>
</table>
*The minimum pretreatment filter strip length is based on the length of the receiving flow path. Figure 7.14.11 shows how the minimum length requirement changes as both the flow path and filter strip slope change.
For contributing flow paths greater than 30 feet in length, the required flow characteristics for maximum velocity and depth listed below must be used:
<table>
<tr><th colspan="2">Required Starting Design Values for Filter Strip Length</th></tr>
<tr><td>Maximum velocity</td><td>One (1) ft/sec max, < 0.5 ft/sec preferred</td></tr>
<tr><td>Maximum water depth</td><td>One (1) inch max, < 0.5 inch preferred</td></tr>
</table>
Source: United States Department of Transportation (USDOT) Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring and the Seattle BMP Manual.</td></tr>
<tr><td>Inflow</td><td>Flow must enter a vegetated filter strip as sheet flow.
Flow must enter a grass swale as sheet flow or shallow concentrated flow.
Concentrated flow can erode the soil and cause the pretreatment measure to be ineffective. If flow is concentrated, design a level spreader to provide sheet flow.</td></tr>
</table>

Design Element	Specification
Slope	The maximum contributing drainage area slope must be less than 5% unless energy dissipation and/or flow spreaders are provided up-gradient of the filter strip. The filter strip slope must not exceed 8%. Slopes less than 5% are generally preferred. Filter strips with slopes that exceed 5% should implement check dams to encourage ponding and prevent scour and erosion of the filter strip area. The slope (parallel to the flow path) of the top of the filter strip, after a flow spreading device, must be very flat (less than 1%) and gradually increase to the designed value to protect from erosion and undermining of the device.
Energy Dissipation	When energy dissipators or level spreaders are not included in the design, the maximum allowable flow path to a vegetated filter strip is 75 feet for impervious ground cover and 150 feet for pervious ground cover. When energy dissipators or level spreaders are included, the flow path can be increased beyond the above-stated maximums provided shallow, dispersed flow having a velocity less than 5 ft/sec is maintained.
Plant Selection and Installation	Vegetated filter strips and grass swales shall be entirely vegetated with dense native grass or other dense, non-woody, vegetated ground cover that does not require substantial maintenance or mowing. The planting regime should be as dense as the soil conditions can sustain. This is especially true at the top portions of the filter strip where the highest sheet flow velocities are found. Soils that can sustain higher quantities and qualities of vegetation may need to be added to ensure the thick vegetative densities needed for sustainable filter strip performance. Turf grass is generally not recommended because it is maintained by frequent mowing. Cut grass reduces the potential for contact between vegetation and pollutants, thus reducing pretreatment (i.e., filtration) effectiveness. Areas of bare soil are prohibited. Mulch, pebbles, and other non-vegetated ground cover materials are prohibited. Trees and shrubs may be allowed in the flow path if the strip exceeds the minimum length. It is critical that plants used in vegetated filter strips and grass swales are appropriate for soil, hydrologic, light, and other site conditions. Ponding depth, drain-down time, sunlight, salt tolerance, soil infiltration capacities, pollution tolerances, root structure, and other conditions must be taken into consideration when selecting plants. Plants must be established at the time of filter strip completion (at least 3 months after seeding). No stormwater shall be allowed to flow across the filter strip and into the main treatment area of the SCM until the vegetation is fully and permanently established.
Protection Measures	Filter strips shall not be used in highly used pedestrian areas unless precautions are taken to minimize disturbance of the filter strip, such as signage, fences, and placement of sidewalks or paths to minimize pedestrian or vehicular traffic.
Enhancements	Vegetated filter strips may be enhanced by installing berms and retentive grading perpendicular to the flow path. A pervious berm and/or retentive grading allows for a reduction in both stormwater velocity and volume, thus improving pollutant removal capabilities by providing a temporary (very shallow) ponded area.

Figure 7.14.11 Filter Strip Length

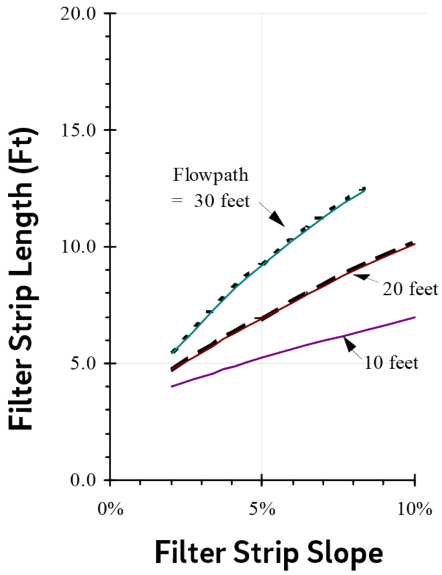
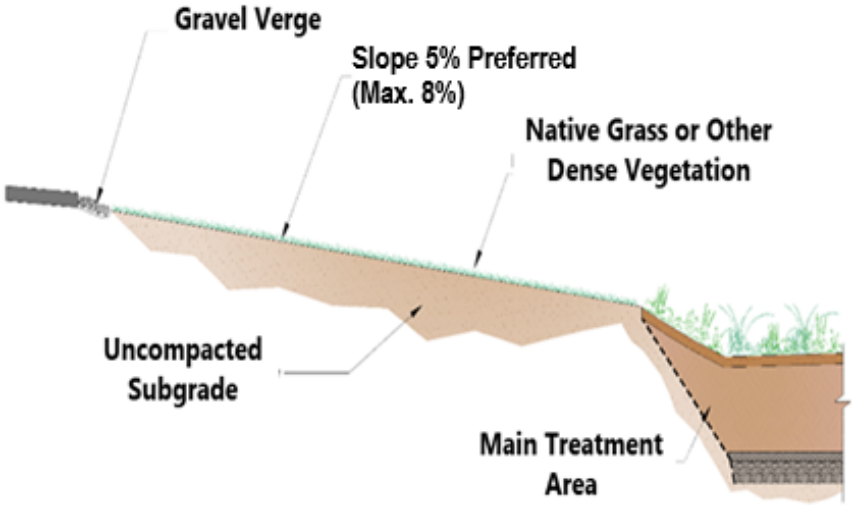


Figure 7.14.12 Schematic of a Vegetated Filter Strip

(Source: adapted from the Seattle Stormwater Manual Vol. 3, 2008)



7.14.10 Proprietary Pretreatment Device

A proprietary pretreatment device (PPD) is a manufactured device that can be included in structural SCM designs specifically for the purpose of stormwater pretreatment. There are several types of PPDs on the market that combine both the inlet structure and pretreatment measures. PPDs are generally easy to install and maintain (see Figures 7.14.13 and 7.14.14).

Figure 7.14.13 Example of a Proprietary Pretreatment Device

The PPD shown in the pictures facilitates easy inspection and maintenance. Sediment can be removed from the chamber with a shovel, and the drop-in filter can be cleaned with a broom or hose. (Source: Rain Guardian)

Figure 7.14.14 Installation of a Proprietary Treatment Device

Source: ACF Environmental/PRETX system

PPDs work well as pretreatment practices for most SCMs, especially where space constraints don't allow for larger pretreatment measures such as forebays or vegetated filter strips. The individual PPD specifications should be consulted on a site-by-site basis to ensure they are feasible for the proposed application. Manufacturer's specifications must be consulted to determine the device-specific requirements and applicable SCMs.

PPDs are different from manufactured treatment devices (MTDs). MTDs are structural SCMs that can be used, alone, to meet the city's requirements for stormwater treatment. Hydrodynamic MTDs are a popular choice for pretreatment in jurisdictions that have a specific pollutant removal threshold, as their small surface footprint is helpful for space-limited areas. In contrast, PPDs are specifically intended to provide pretreatment for the primary SCM selected for a drainage area. PPDs cannot, alone, meet the city's stormwater quality requirements.

See Chapter 7, Section 7.6 for more information and design specifications for MTDs, including the use of hydrodynamic MTDs used as pretreatment devices.

7.14.11 References

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition.* Atlanta Regional Commission, 2016.

7.15.1 Introduction

This section provides design specifications for underdrains and Internal Water Storage (IWS) components of stormwater control measures (SCMs). Table 7.15.1 lists the SCMs that include design configurations with underdrains and/or IWS.

Table 7.15.1 Underdrain and Internal Water Storage Applicability by SCM

SCM *(listed by design specification section # and SCM name)*	SCM Tier	Upturned Elbow Underdrain & IWS	Elevated Underdrain & IWS	Underdrain on Bottom
7.1 Bioretention Area	2	●	●	
7.3 Dry Enhanced Swale	2	●	●	
7.6 Manufactured Treatment Devices[1]	2	●	●	
7.7 Permeable Pavement System	3	●	●	●
7.8 Sand Filter	3	●	●	●
7.11 Urban Bioretention	2	●	●	

1 – Tier 2 Manufactured Treatment Devices (MTDs) may have other underdrain configurations than described in the table but MUST a minimum of 12 inches of IWS.

The following figures demonstrate the design configurations described in the header row of Table 7.15.1. Although a specific SCM is shown in each figure, the underdrain and IWS design configuration can be applied to other SCMs in the table, in keeping with the applicability information in the table. Figures 7.15.1 and 7.15.2 demonstrate the only underdrain configurations allowed for Tier 2 SCMs, again using a bioretention area SCM. Both pictures indicate the requirement for a minimum of 12 inches of IWS for Tier 2 SCMs. An impermeable liner is required to prevent sinkhole formation.

Figure 7.15.1 Upturned Elbow Underdrain Design Configuration

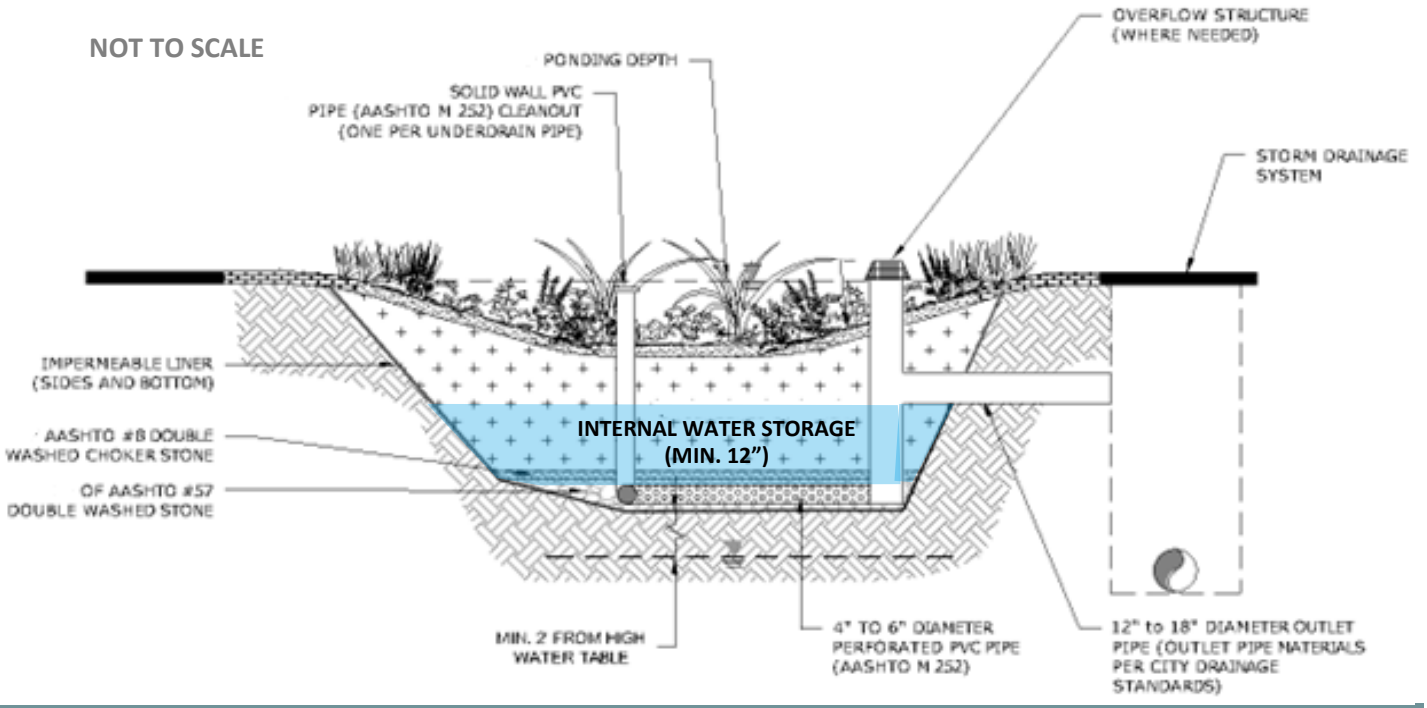
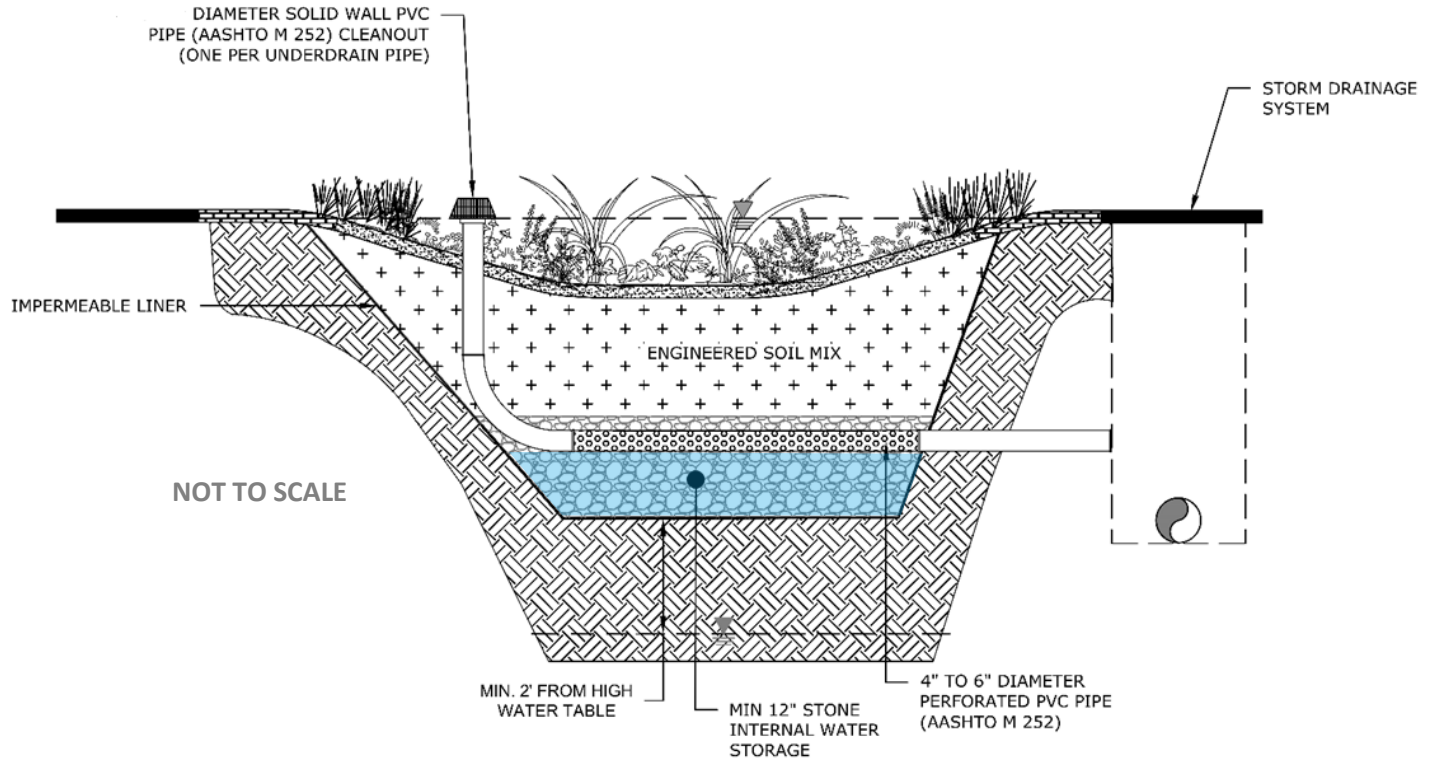


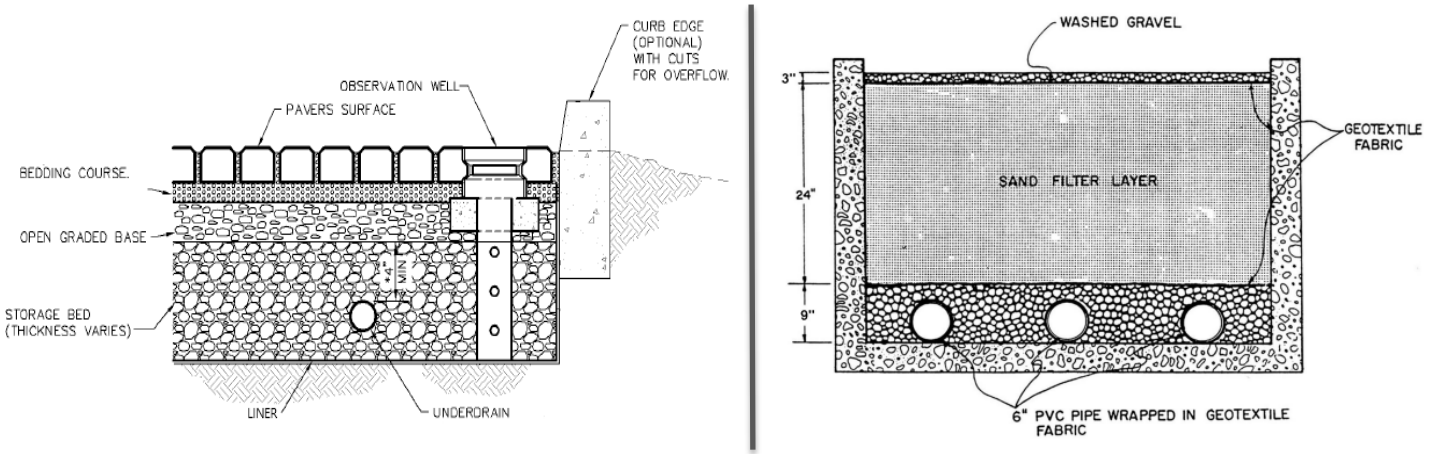
Figure 7.15.2 Elevated Underdrain above IWS



To create IWS, underdrains must either have an upturned elbow (Figure 7.15.1) or be elevated above an IWS layer (Figure 7.15.2). The underdrain configuration increases the hydraulic residence time of water in the SCM within the IWS and creates an anoxic zone. This facilitates improved denitrification of stormwater in the IWS.

Figure 7.15.3 demonstrates the typical underdrain configuration for Tier 3 SCMs, with examples of a permeable pavement system and sand filter. Both are the Tier 3 SCMs that include underdrains. It is important to note that Tier 3 SCMs can include underdrain design configurations with IWS as shown in the previous figures to provide denitrification or to address small, localized drainage issues. However, Tier 3 SCMs with IWS are not considered a Tier 2 SCM, and therefore cannot be designed with to the smaller WQv specified for Tier 2 SCMs, due to the lack of biofiltration (water filtration through plants and soil media).

Figure 7.15.3 Example of Tier 3 SCM Underdrains (Underdrain at Bottom Configuration)



Left: Example of underdrain and observation well for a permeable paver surface (Source: greatriversgreenway.org); Right: Cross-section of a sand filter showing the underdrain lines on the bottom of the SCM (Source: Department of Energy and Environment Stormwater Management Guidebook, Washington DC)

7.15.2 Underdrain Design Specifications

Table 7.15.2 provides design specifications and guidance for underdrains.

Table 7.15.2 Underdrain Design Specifications

Design Element	Specifications
Pipe Material	For lateral and longitudinal lines, and vertical inflows (to distribute or increase inflows to subsurface layers): • 4 to 6 inch polyvinyl chloride (PVC) pipe (Schedule 40) or corrugated high density polyethylene (HDPE) pipe (AASHTO M252) with ⅜ inch perforations, spaced at a minimum of 6 inch centers, and a minimum of 4 holes per row
Pipe Layout & Spacing	Underdrain line layouts can vary as some SCMs, especially bioretention areas, can have a free form design. More than one line may be needed. Use the specifications below to design a configuration that best serves the SCM. Figure 7.15.4 provides examples of pipe spacing. • Minimum surface area = 1 underdrain for every 1,000 ft^2 of SCM surface area • Maximum distance between lines = 10 feet on center
Slope	Minimum slope = 0.5% The underdrain slope shall not cause water flow to exceed 5 ft/sec The design slope of the underdrain should be maintained through the entire length of the pipe. Where this is not possible within a single length of pipe, a tiered underdrain design can be used. An example of a tiered design is shown in Figure 7.15.3.
Stone Jacket	Lateral and longitudinal underdrain lines shall be placed in stone jacket consisting of 8 inch clean, double-washed AASHTO #57 stone
Stone Choker Layer	A stone choker layer separates the underdrain from soil or sand layers located above the pipe jacket. Specifications are as follows. • Material = AASHTO #8 stone or AASHTO #89 pea gravel, double-washed and clean • Thickness = 3 to 4 inches
Geotextiles (Filter Fabric and Pipe Socks)	**Pipes embedded in stone:** Avoid the use of geotextiles in underdrain system designs (as a pipe sock in place of the stone jacket or between SCM subsurface layers) as they have propensity to become clogged, thus causing an expensive repair. **Pipes embedded in sand:** While a sand bedded underdrain is not included in the design specifications in this manual, should there be a need to bed a perforated pipe in sand, pipe socks should be used. This circular knit geotextile filter fabric is a water-permeable barrier that will keep sand deposits from building up in the pipe, extending its useful life (see Figure 7.15.4). **Note:** The above statements do not preclude the placement of a permeable geotextile on the sides (and sometimes, bottom) of an SCM excavation when specified for the SCM in its design specification. This is done to prevent migration of in-situ soils surrounding the excavation into the SCM layers.
Cleanouts	An underdrain cleanout is a vertical pipe connected to, and extending from, an underdrain line to the surface of the SCM. A cleanout allows access to the underdrain for maintenance. Often, unclogging an underdrain can be done via a cleanout rather than excavating the entire SCM. Cleanouts shall be designed as follows: • One (1) cleanout per underdrain pipe shall be provided. For example, if an underdrain collection system includes 3 parallel underdrain pipes, each pipe will have a cleanout.

Design Element	Specifications
	• Cleanouts shall be constructed of a 4 to 6 inch diameter solid wall (not perforated) PVC pipe (AASHTO M252) that couples with the perforated underdrain pipe. • Cleanouts shall extend to the surface of the SCM, rising high enough to be readily visible to SCM maintainers and landscape crews. If the SCM will have a grassed surface, ensure cleanouts are tall enough to avoid being run over by mowers. • Cleanouts shall have a watertight, removable cap and lock to prevent tampering and vandalism.

Observation Wells	An observation well is a pipe that is used to determine if there is standing water in an SCM's subsurface layers. Design specifications are as follows:
	• Two (2) observation wells shall be installed in every SCM listed in Table 7.15.1 (above). One shall be located at the upstream end and one at the downstream end, with each placed on the centerline of the SCM.
	• Observation wells shall be constructed as follows:
	  ○ 4 inch diameter perforated PVC pipe (AASHTO M252) is used within gravel layer(s) to allow inflow into the pipe and extends to the bottom of the SCM.
	  ○ 4 inch diameter solid wall PVC pipe (AASHTO M252) is attached with a watertight connection to the perforated pipe, and extends above gravel layers (i.e., in soil, sand, and mulch layers and above grade) to the surface of the SCM.
	• The observation well shall rise high enough above the SCM to be readily visible to SCM maintainers and landscape crews. If the SCM will have a grassed surface, ensure cleanouts are tall enough to avoid being run over by mowers.
	• A visible (e.g., brightly colored) floating marker shall be placed in each observation well to allow the viewer to see the water level.
	• The top of each well shall have a watertight, removal cap and lock to prevent tampering and vandalism.
	• An underdrain cleanout may be used as an observation well; however, the cleanout/observation well shall be designed and installed in keeping with the cleanout design specifications provided above.

Underdrain Outlet	When an underdrain is used, discharges shall not exit the underdrain outlets in an erosive manner (> 5 ft/sec). Due to the slow rate of discharge, outlet erosion protection is generally unnecessary. For SCMs with underdrains that are used for flood control, the outlet barrel material shall be reinforced concrete. For underdrains that daylight on grade, include a marking stake and animal guard.

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Figure 7.15.4 Examples of Underdrains with Lateral and Longitudinal Lines

Left: SCM installation with HDPE underdrain pipe and capped PVC observation wells (Source: Philadelphia Water Department); Right: A bioretention area under construction in Salem, NC. Note the upturned elbow underdrain and capped cleanouts (Source: Hazen and Sawyer)

7.15.3 Internal Water Storage (IWS) Design

There are two approaches to creating IWS within an SCM: an upturned elbow underdrain (shown in Figures 7.15.1 and 7.15.4) and IWS located below an elevated underdrain (Figure 7.15.2). Specifications for both approaches are provided in Table 7.15.3.

Table 7.15.3 Internal Water Storage Specifications

Design Element	Specifications
Upturned Elbow Underdrain	An upturned elbow underdrain design typically includes a 90-degree elbow located at the downstream end of the underdrain system. The elbow shall be located so that all upstream lines are subject to the IWS requirement. • Tier 2 SCMs: A minimum of 12 inches of IWS shall be provided[1]. Thus, the invert of the upturned elbow shall be a minimum of 12 inches from the invert of the underdrain line(s). • Tier 3 SCMs: The invert of the upturned elbow is determined by the design professional based in the volume of IWS desired. In vegetated SCMs of either tier, the elbow invert (and thus the IWS) must be located well below (12 to 18 inches) the bottom of the planted area to reduce saturated conditions in the root zone.
Elevated Underdrain	In an elevated underdrain design, the underdrain lines are design as specified in Table 7.15.2, except the stone jacket for the underdrain sits above the IWS area, which is filled with clean, double-washed AASHTO #57 stone. • Tier 2 SCMs: The IWS shall have a minimum depth of 12 inches[1], measured from the bottom of the SCM excavation to the invert of the underdrain line. • Tier 3 SCMs: The depth of the IWS layer is determined by the design professional based in the volume of IWS desired. In vegetated SCMs, the IWS layer shall be located at least 12 inches below the bottom of the planted area to reduce saturated conditions in the root zone. The IWS must be placed above an impermeable liner to avoid sinkhole formation.

7.15.4 References

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition.* Atlanta Regional Commission, 2016.

[1] Tennessee Department of Environment and Conservation Rule *0400-40-10-.04*

7.16.1 Introduction

Overflow controls are designed to allow excess stormwater flows to exit a stormwater control measure (SCM) when the capacity of the SCM is exceeded. The overflow control can be designed to control water levels both at the surface and in the subsurface of the SCM. Stormwater above the finished grade of the SCM is controlled with an overflow structure or a weir that is overtopped once the ponding elevation in the SCM is exceeded. The overflow control conveys flows away from the SCM to a downstream stormwater conveyance system. This section does not address storage facility outlet structures (refer to Chapter 6, Sections 6.5.1 to 6.5.9), underdrains and internal water storage (refer to Chapter 7, Section 7.15), or emergency spillways (refer to Chapter 6, Section 6.5.10).

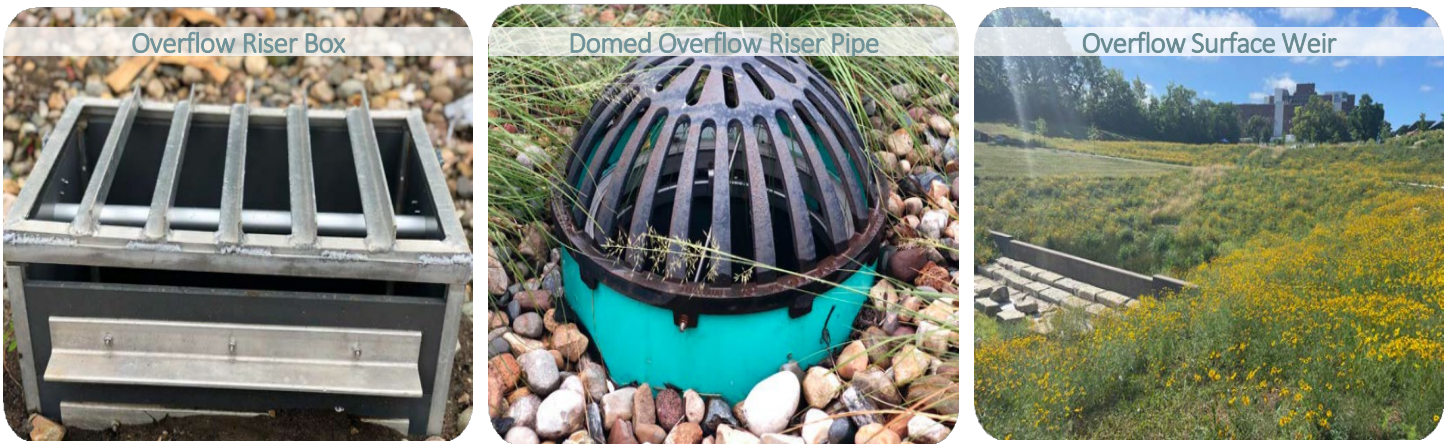
7.16.2 Description

Overflow controls are commonly employed in SCMs, enabling excess stormwater to bypass the subsurface media by overflowing the SCM. Overflow controls can consist of solid plastic pipe and fittings, a manufactured structure with a grated cover, or an overflow weir that extends above the finished grade of the SCM to collect stormwater from the SCM surface. When the design ponding elevation in the SCM is exceeded, the overflow conveys flows away from the SCM to a downstream conveyance system. Overflow controls typically consist of the following types (see Figure 7.16.1):

1. **Overflow Riser:** Consists of a solid plastic pipe, usually polyvinyl chloride (PVC) or high-density polyethylene (HDPE) with a domed or flat grated top.
2. **Manufactured Overflow Riser:** Consists of prefabricated overflow control structure, it should be noted that manufactured overflow controls are often referred to by the manufacturer as “inlets” due to their stormwater collection function.
3. **Overflow Surface Weir:** Can consist of soil, stacked stone, concrete, or manufactured weirs located along the embankment or berm of an SCM. Weirs are discussed as part of the storage facility outlet structures in Chapter 6, Section 6.5.

Overflow controls are necessary in SCMs that are not designed for flood control (i.e., will not manage storms larger than the 1-year, 24-hour storm event) as the stormwater inflows will, at times, surpass their design capacity. It is crucial to manage the ponded elevation to avoid flooding areas adjacent to these SCMs. Overflow controls are most commonly used to control the ponded water surface elevation within SCMs.

Figure 7.16.1 Typical Overflow Controls for Tier 1 and Tier 2 SCMs



(Source: Kansas City, MO Green Stormwater Infrastructure Manual, 2022)

The overflow controls described in this section are meant for use with non-regional, on-site SCMs and are not considered storage facility outlet structures (refer to Chapter 6, Section 6.5). In many cases, on-site SCMs do not warrant elaborate studies to determine overflow control capacity. While the risk of damage due to failure is a real one, it normally does not approach the catastrophic risk involved in the overtopping or breaching of a major reservoir. By contrast, regional facilities with homes immediately downstream could pose a significant hazard if failure were to occur, in which case emergency spillway considerations are a major design factor. Refer to Chapter 6, Section 6.5.10 for information on emergency spillway design.

7.16.3 Overflow Control Design Considerations

Table 7.16.1 provides guidance for site designers when designing overflow controls. Refer to City of Alcoa (City) regulations for construction and material requirements.

Table 7.16.1 Overflow Control Design Considerations

Design Element	Design Consideration
Elevation	Overflow elevations must be set at the design ponding height to avoid flooding of the SCM. Any ponding above the overflow elevation is not recognized as part of the water quality volume (WQv) or any additional design storage volume in the SCM, as it discharges through the overflow control and bypasses the treatment provided by the SCM.
Downstream Impact	The design professional must evaluate the potential impacts of outflow from the overflow control on the downstream drainage system by providing existing and proposed hydraulic grade line elevations.
Overflow System Capacity	All City design requirements for stormwater conveyance structures shall be met when designing overflow systems. **SCMs designed for WQv treatment only** Positive overflow must be provided for storm events larger than the water quality peak discharge, Q_{wq}, up to and including the 25-year, 24-hour storm. Overflow controls and associated components (e.g., pipes connecting to the onsite or public drainage system) must be designed to convey at least the peak discharge for the 25-year, 24-hour storm without surcharging the structure. **SCMs designed for WQv, CPv, and flood control (detention)** Positive overflow must be provided for storm events up to and including the peak discharge for the largest storm event used for design. Typically, this is the 100-year, 24-hour storm. Overflow controls and associated components (e.g., pipes connecting to the onsite or public drainage system) must be designed to convey at least the peak discharge for the 100-year, 24-hour storm without overtopping the SCM's embankments.
Overflow Risers	Overflow risers should consist of two 45˚ elbow fittings to connect to outlet piping, when feasible. The two 45˚elbow fittings may be replaced with a 90˚ elbow or tee fitting when constrained by depth. An example detail for an overflow riser is provided in Figure 7.16.2. The riser shall be topped by a domed or flat grate to prevent debris from entering the overflow riser. Consider ease of maintenance when selecting the grate. Any metal components of an overflow riser embedded in concrete must be stainless steel. An anchoring design for the overflow riser to mitigate flotation of the structure shall be considered, as needed. Consider specifying a catch basket or strainer product within in the overflow control to minimize debris exiting the facility. Measures should be taken to minimize standing water in structure sumps to mitigate mosquito habitat.

Design Element	Design Consideration
	Aesthetics of the portion of the riser that is exposed above grade should be considered. It is recommended that exposed pipe be black in color or consider specifying decorative rock around the exposed pipe. Design specifications and typical details for manufactured overflow risers shall be included with the stormwater management plan (SWMP) and record drawing. Details are typically provided by the manufacturer.
Overflow Surface Weirs	Surface weirs should be sized, configured, and placed to control discharge over the weir and direct it to the desired flow path. Consider weirs with sharp crests, broad crests, notches, or be of various shapes (e.g. rectangular or trapezoidal) to achieve such design objectives. Refer to Chapter 6, Section 6.5 for more information on weirs. Surface weirs may be constructed of concrete, stone, or vegetated earthen berms. Select weir materials based on velocity, shear stresses, and hydrostatic pressure to prevent failure across the full range of anticipated flow conditions, as well as aesthetics and compatibility with the surrounding context. Additional energy dissipation (See Chapter 7, Section 7.14) or stabilization is required on the downstream side of weirs to prevent scour. Earthen surface weirs should be well vegetated to prevent erosion and failure and may require additional stabilization.

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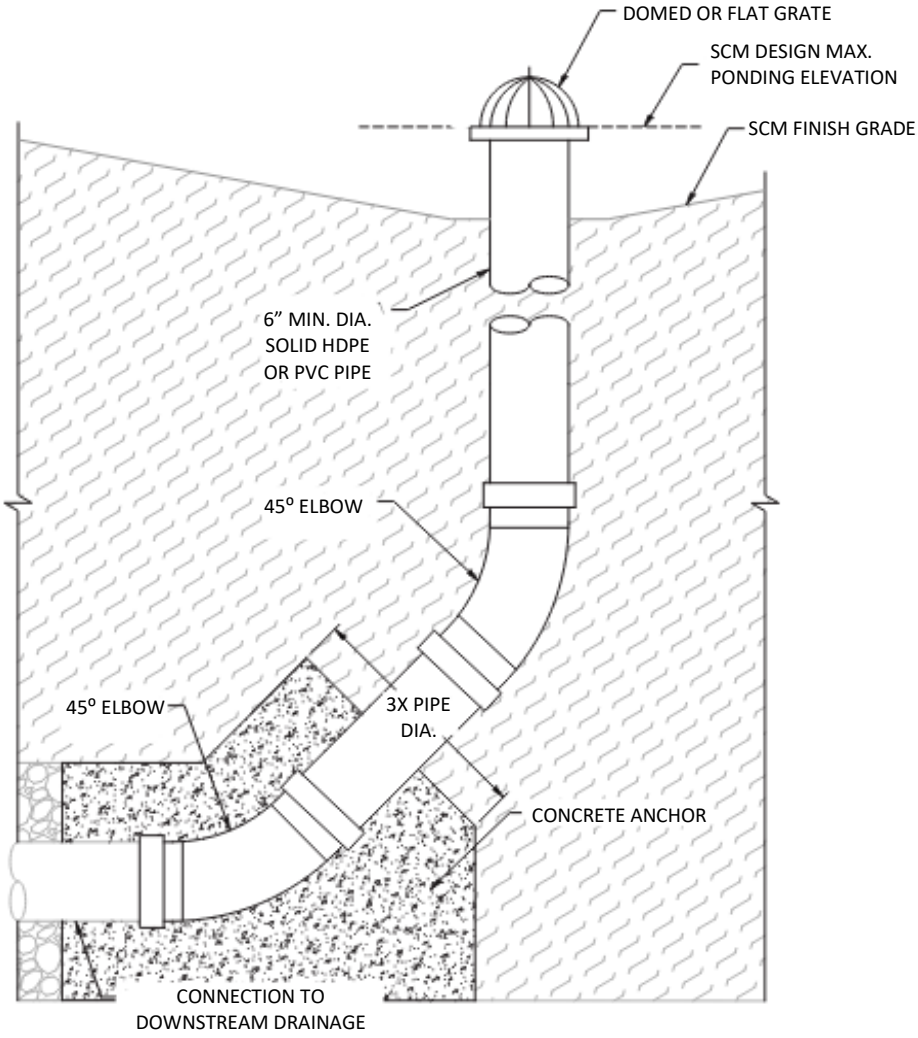
Figure 7.16.2 Example Detail of an Overflow Riser



7.16.4 References

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook, 2016 Edition*. Atlanta Regional Commission, 2016.

City of Kansas City, Missouri. *Green Stormwater Infrastructure Manual.* October 2022.

Acronyms and Key Variables

Acronym	Definition
A	Contributing drainage area (usually to an SCM)
CDA	Contributing drainage area (usually to an SCM)
cfs	Cubic feet per second
CN	Curve number
CPv	Channel protection volume (acre-feet or cubic feet)
CRS	Community rating system
ED	Extended detention
EPSC	Erosion prevention and sediment control
FEMA	Federal Emergency Management Agency
HEL	Highly erodible land
I	Percent impervious area
I_a	Initial abstraction for runoff curve numbers
I_A	Total impervious surface in an SCM's contributing drainage area (acres or square feet)
IWS	Internal water storage
LOD	Limit of disturbance
LID	Low impact development
MS4	Municipal separate storm sewer system
MTD	Manufactured treatment device
NFIP	National Flood Insurance Program
NPDES	National Pollutant Discharge Elimination system
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
Q_p	Peak discharge (cubic feet per second)
q_u	Unit peak discharge (cubic feet per second per mi^2 of drainage area per inch of runoff)
Q_{wq}	Water quality peak discharge (cfs)
Q_{wv}	Water quality volume (inches)
P	Water quality design rainfall depth (inches)
ROI	Return on investment
R_v	Volumetric runoff coefficient
SCM	Stormwater control measure
SWMP	Stormwater management plan
Tc	Time of concentration

Acronym	Definition
TDEC	Tennessee Department of Environment and Conservation
TNCGP	Tennessee construction general permit
Tp	Time (on a hydrograph) to reach the required rainfall depth for the WQv
TSS	Total suspended solids
Tv_{ds}	Design volume of the downstream SCM in a treatment train after subtraction of Tv_{us} (acre-feet)
Tv_{us}	Design volume of the upstream SCM in a treatment train (acre-feet)
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
WQv	Water quality volume (acre-feet or cubic feet)
WQv_{ds}	Water quality volume of the downstream SCM in a treatment train before subtraction of Tv_{us} (acre-feet) (acre-feet)

Definitions

As-Built Plan – (also, as-built certification). As-built, field-verified plans signed and sealed by a registered land surveyor licensed to practice in the State of Tennessee, showing contours, elevations, grades, locations, drainage and hydraulic structures, best management practices, permanent stormwater control measures, stormwater easements, detention basin volumes and other features as required per the City of Alcoa.

Contributing Drainage Area (CDA) – The land area from which stormwater drains to a specific location, such as a stormwater control measure (SCM).

Detention – Temporary storage of stormwater for the purpose of decreasing peak flow rates of stormwater discharges into the downstream conveyance or waterbody. Also referred to as "flood control".

Drawdown Time – The specified time or timespan to drain a stormwater control measure (SCM) to a dry condition (except any internal water storage areas) after a storm.

Emergency Spillway – A component of a detention pond (wet or dry) or stormwater wetland designed to safely allow the discharge of stormwater over the embankment during extreme storm condition to prevent SCM overtopping. Usually the term "emergency spillway" is used for SCMs that are designed in an online configuration and thus control large volumes of stormwater. For smaller SCMs, see "Overflow Structure".

Energy Dissipator – A device used to dispel the energy, and therefore reduce the velocity, of concentrated stormwater flows.

Engineered Soil Mix – A specified mix of soil, sand, and organic matter used for biofiltration in stormwater control measures (SCMs) that operate using biofiltration. In this manual, biofiltration is provided by Tier 2 SCMs and manufactured treatment devices (MTDs).

Flood Control – See "detention".

Forebay (also "sediment forebay") – A storage basin, structure, or impoundment that pretreats stormwater runoff before its discharge into the main treatment area of an SCM. Typically, a forebay is used to remove heavy sediments and floatables (trash and other debris).

Impervious Surface – Those areas that prevent or impede the infiltration of stormwater into the soil as it entered in natural conditions prior to development. Common impervious areas include, but are not limited to, rooftops, sidewalks,

walkways, patio areas, driveways, parking lots, storage areas, gravel surfaces, awnings and other fabric or plastic coverings.

In-situ Soil – Soil in its naturally deposited location.

Internal Water Storage (IWS) – A design approach that allows water to pond, at least temporarily, in a reservoir located with a stormwater control measure (SCM). For the SCMs in this manual, the purposes of IWS are to serve as: an anoxic zone for stormwater denitrification (Tier 2 SCMs only); and/or, temporary additional storage to address small, localized drainage issues.

Karst – A topography formed from the dissolution of soluble rocks, such as limestone or dolomite. Karst areas are characterized by distinctive landforms, like sinkholes, caves, underground streams, and springs.

Low Impact Development (LID) – From a stormwater management perspective, LID is a site design approach that uses landscape practices to manage stormwater runoff and improve water quality by mimicking natural processes to infiltrate, filter, store, and evaporate stormwater runoff. LID can take the form of non-structural site planning and construction practices, and specially designed structural practices. LID practices can be used for new development, redevelopment, or as retrofits to existing development. It can also have other benefits, such as cost savings and improved air quality. In this manual, the structural LID practices are bioretention and urban bioretention areas, cisterns, dry and wet enhanced swales, green roofs, and Tier 1 and 2 manufactured treatment devices.

Maintenance Easement – A legally dedicated right-of-way for the City of Alcoa to manage/maintain stormwater flow facilities or other utilities within specified boundaries.

Native Vegetation – Plants that are naturally found in an area and have adapted to its climate.

Offline Configuration – An arrangement where a stormwater control measure (SCM) is designed to receive only a specified flow through the use of a flow regulator (diversion structure, flow splitter, etc.). Flow regulators are typically used to divert the water quality volume (WQv) to an offline SCM sized and designed to treat and control the WQv . After the design runoff flow has been treated and/or controlled it is returned to the conveyance system.

Online Configuration – An arrangement where a stormwater control measure (SCM) is designed to receive, but not necessarily control or treat, runoff volumes up to the maximum design storm specified by the city. Online SCMs must be able to handle the entire range of storm flows.

Outlet Structure – A component of a stormwater control measure (SCM) that controls the rate of stormwater discharges from the SCM. An outlet structure may have multiple openings (e.g., orifice, slots, weirs, etc.) to control the discharge for multiple storms.

Overflow Structure – A component of a stormwater control measure (SCM) designed to safely allow the discharge of stormwater that exceeds the storage capacity of the SCM. For detention ponds and stormwater wetlands, see "Emergency Spillway".

Permeable Surface – (also "pervious surface"). Land cover surfaces that do not prevent or impede the infiltration of stormwater into the soil.

Ponding depth – The depth of standing water in a stormwater control measure (SCM). A maximum ponding depth is specified for most SCMs.

Pre-Development Hydrology Map – A layered map (or set of maps) that depicts the existing hydrologic condition of a property prior to the proposed development. The map is used primarily to find design opportunities to minimize stormwater volumes and maximize natural hydrologic function after development. It is prepared using available data and visual observations and submitted with the stormwater management plan (SWMP).

Pretreatment – (or "pretreatment device"). A component of a stormwater control measure (SCM) that removes trash, debris, and heavy sediments from stormwater inflows to the SCM before discharge to the main treatment area.

Riparian Buffer – see "Water quality buffer".

Setback – When stated in this manual, a setback is the distance from a specified feature, such as a building or the public right-of-way, to the edge (or other location as specified) of a stormwater control measure (SCM).

Stormwater Control Measure (SCM) – Non-structural land development design strategies and structural stormwater facilities intended to prevent or reduce the discharge of pollution in, and/or regulate the volume or peak discharge of, stormwater runoff from a property. SCMs may include structural devices, such as stormwater ponds, detention ponds, and bioretention areas, and non-structural practices such as water quality buffers and natural open spaces.

Stormwater Management Plan (SWMP) - An engineering plan for the location and/or design of best management practices, water quality buffers, stormwater management facilities, including stormwater control measures (SCMs), and water quality credit areas within a proposed development or redevelopment. A stormwater management plan includes a map showing the extent of the land development activity and location of SCMs, design calculations for SCMs, and may contain as-built drawings and covenants for permanent maintenance of SCMs.

Stormwater Quality Treatment Standard – The City of Alcoa's mandatory performance standard for the management of total suspended solids (TSS) in stormwater runoff from applicable developments, as established in the City of Maryville Municipal Code Title 16. The stormwater quality treatment standard is: Stormwater control measures (SCMs) shall be designed to achieve a minimum treatment of 80% TSS removal from the required water quality volume (WQv) for their contributing drainage area.

Tier 1 SCM – The group of stormwater control measures (SCMs) that remove stormwater volume, and therefore pollutants, by capturing and reusing stormwater runoff for onsite purposes. A green roof is the only Tier 1 SCM specified in this manual.

Tier 2 SCM – The group of stormwater control measures (SCMs) that remove stormwater pollutants via biologically active filtration (biofiltration). An underdrain and impermeable liner is always included in the design of a Tier 2 SCM. Manufactured treatment devices (MTDs) that operate via biofiltration, bioretention areas, urban bioretention areas, and dry enhanced swales and are Tier 2 SCMs specified in this manual.

Tier 3 SCM – The group of stormwater control measures (SCMs) that remove stormwater pollutants via sand or gravel filtration or settling. Manufactured treatment devices (MTDs) that operate via filtration, detention basins, stormwater and submerged gravel wetlands, sand filters, and permeable pavement systems are Tier 3 SCMs specified in this manual.

Tier 4 SCM – Manufactured treatment devices (MTDs) that remove stormwater pollutants via hydrodynamic filtration.

Total Suspended Solids (TSS) - Sediment that is entrained in the water column and transported downstream in suspension and forms deposits. In Tennessee, TSS is used by the Tennessee Department of Environment and Conservation (TDEC) as the indicator for the reduction of pollutants.

Treatment Train – Two or more stormwater control measures (SCMs) located in series. In a treatment train, treated stormwater from an upstream SCM flows into one or more downstream SCMs which provide additional pollutant removal.

Vegetation Plan – The portion of a water quality management plan (WQMP) or other design plan, such as a landscape plan, that describes the vegetation design for stormwater control measures (SCMs).

Water Quality Buffer - An overlaying zone that encompasses all land within the areas as described in City of Alcoa Municipal Code Title 16 containing trees and other vegetation that exist or are established to protect the physical and

ecological integrity of the buffered waterbody, reduce the potential for flooding, provide tree canopy, stabilize the banks/shoreline, and filter runoff from developed areas.

Water Quality Peak Discharge (Q_{wq}) – The peak rate of discharge for the water quality design storm. Q_{wq} is used to size stormwater control measures (SCM) components, such as inlets and flow diverters, especially for offline SCMs.

Water Quality Volume (WQv) – The WQv is the required volume of stormwater that must be treated to remove 80% of the total suspended solids (TSS).

APPENDIX B: WQv REDUCTIONS FORM

This appendix is reserved and will be completed at a later date.

APPENDIX C: STORMWATER MANAGEMENT PLAN CHECKLIST

Submittal/Resubmittal Date: **Review No. *(circle one)* 1 2 3 4 5 or more**

Project Owner: **Phone:**

Applicant: **Phone:**

Project Name:

Project Address:

Property Zoning: **Variance Requested *(circle)*: Yes No**

Variance Description:

This checklist lists items the must be included in the stormwater management plan (SWMP). An item listed must be checked under the "Yes" column, and thus provided with the SWMP unless it is not applicable to the project. Items that are not applicable to the project must be checked under the "N/A" column. Checks placed under the "No" column and thus not provided with the plan even though they may be applicable to the project must be justified in a written statement attached to this checklist. This checklist must be submitted to the City of Alcoa (City) along with the SWMP.

All maps shall be shown to scale (with scale provided), with accurate bearings and distances.

Yes	No	N/A		STORMWATER MANAGEMENT PLAN PREPARATION CHECKLIST
GENERAL PROJECT AND PLAN INFORMATION				
			1	Date(s) of original plan and any plan revisions
			2	Seal/signature of TN professional engineer in responsible charge of stormwater designs
			3	Vicinity map including:
			3a	- North arrow
			3b	- Scale
			3c	- Adjacent roadways
			3d	- Property boundaries
			3e	- Onsite and nearby watercourses
			3f	- Other necessary information to locate and describe the project
PRE-DEVELOPMENT HYDROLOGY MAP(S) *These maps define EXISTING condition hydrology and drainage patterns for the purposes of identifying potential constraints to the location and design of Stormwater Control Measures (SCMs) and the onsite stormwater conveyance system. They also support visualization and location of Low Impact Development (LID) practices, which can reduce the volume and peak discharges of the development. Collect and overlay the data that is readily available. Site survey, geotechnical tests, and similar intensive investigations are not required for these maps.*				
			4	Property boundaries
			5	Land cover identifying existing building footprints, pavement, gravel surfaces, woods, meadow, turf grass, maintained landscape, agriculture, and unvegetated (bare) soil
			6	Topography, with slopes greater than 15% labeled
			7	Hydrologic soil groups (label natural areas as A, B, C, or D, and label areas that are previously developed, compacted, or filled as “urban soil”

Yes	No	N/A	STORMWATER MANAGEMENT PLAN PREPARATION CHECKLIST	
			8	Natural water features (streams, rivers, lakes, ponds, wetlands, seeps, springs, bogs, etc.)
			9	Sinkholes (known or suspected) and known areas of soluble bedrock, shallow bedrock, high water table, hardpan, clay lenses, or similar hydrologically limiting conditions
			10	Known areas of frequent flooding or prolonged wet conditions
			11	Known or suspected areas with geotechnical or structural concerns (contractive/expansive soils, etc.)
			12	100-year floodplain boundary
			13	Locations of known or suspected soil pollution
			14	Water supply, wellhead protection, or groundwater recharge areas
			15	Vegetated buffers, conservation, or protected areas
			16	Utility, access, drainage, and other public easement boundaries, labeled
			17	Areas of cultural, historical, or archeological significance
			18	Areas of ecological significance, such as endangered species habitat
PROPOSED DEVELOPMENT HYDROLOGY REPORT & MAP(S) *These maps, reports, and narratives describe the PROPOSED condition hydrology and drainage patterns and the location and design of Low Impact Development (LID) practices, Stormwater Control Measures (SCMs), and the onsite stormwater conveyance system. They also are used to confirm that said designs are compliant with City of Alcoa stormwater standards. Supporting data, such as onsite survey, geotechnical tests, and engineering analyses and calculations, are required as described below. Additional information on City design standards and SCM design criteria is provided in the City of Alcoa Stormwater Management Manual, Volume 1.*				
			19	Property boundaries
			20	Established benchmark of known elevation to which every other elevation is referenced
			21	Horizontal control
			22	Topography, with slopes greater than 15% labeled
			23	Cut and fill quantities for site work
			24	Utility, access, drainage, and other public easement boundaries, labeled
			25	Natural water features (streams, rivers, lakes, ponds, wetlands, seeps, springs, bogs, etc.)
			25	Sinkholes (known or suspected) and known areas of soluble bedrock, shallow bedrock, high water table, hardpan, clay lenses, or similar hydrologically limiting conditions
			26	100-year floodplain boundary with its 100-yr elevation labeled every 300 linear feet
			27	100-year regulatory floodway boundaries
			28	Vegetated buffer map(s), as follows:
			28a	- Plan view with location, width, and lines showing the boundaries of inner and outer zones, and the top-of-bank location (for streams) or normal pool elevation (ponds and lakes) or edge of wetland (natural wetlands)
			28b	- Labels that state “Vegetated Buffer. Do Not Disturb”
			28c	- Proposed land cover including impervious surfaces (where allowed), pervious areas (see next row), buffer crossings including their purpose (e.g., roadway crossing, utility corridor, etc.) and dimensions, and any special use areas as allowed (e.g., trail, picnic area, etc.)
			28d	- Description and map of buffer vegetation. If existing vegetation to remain does not comply with City’s buffer vegetation standards for the inner and outer zone, locate and identify each tree/plant to be installed.

Yes	No	N/A	STORMWATER MANAGEMENT PLAN PREPARATION CHECKLIST	
			29	Recommendations included in the soils engineering or engineering geology report incorporated in the plans and/or specifications
			30	Dates and reference number of the soils report(s) together with the names, addresses and phone numbers of the firm(s) or individual(s) who prepared the report(s
			31	Dimensioned proposed structures (and existing structures to remain), on and within 15 feet of the property boundaries, with finished floor and grade at foundation elevations
			32	Impervious area information, as follows:
				- For site plans and subdivisions where the location and footprint of all buildings are known, provide location and footprint for all impervious surfaces including buildings, roadways, driveways, sidewalks, parking lots, decks, and outbuildings.
				- For subdivisions where the location(s) and footprint(s) for all buildings are unknown, provide the impervious footprint for known buildings and impervious surfaces, and the expected percent impervious value(s) for the subdivided lots. Percent impervious values are provided in Chapter 6 of the *City of Alcoa Stormwater Management Manual, Volume 1*.
			33	Other land covers including pavement, gravel surfaces, woods, meadow, turf grass, maintained landscape, agriculture, and unvegetated (bare) soil
			34	Utility, access, drainage, and other public easement boundaries, labeled
			35	Surface drainage directions, including drainage directions from roof downspouts
			36	The proposed stormwater conveyance system, identifying conveyance component types (e.g., open channel, pipe, culvert, etc.), materials, dimensions, and direction of flow
			37	Location(s) and easement boundaries for stormwater control measures (SCMs), identifying the type of SCM (by proper name), and the locations of all inflows and outflows
			38	Construction notes, specifications, and design details (to scale) of each SCM, including all required components, showing component types, materials, and relevant diameter, dimensions, and elevations. Include also descriptions, depictions, and designs of SCM protection measures (e.g., fencing, bollards, vegetative screening, etc.) to be employed **after construction** for the purpose of SCM protection.
			39	*Manufactured Treatment Devices (MTDs) only:* For each MTD to be located onsite, provide the make, model, and size/capacity, and any additional identifying names or numbers. Also describe its purpose [i.e., pretreatment or primary treatment]. Provide all construction notes, specifications, and design details (to scale) of each MTD. *MTDs proposed for primary stormwater quality treatment*: The NJDEP certification letter, in its entirety. The certification must be for the exact make and model of MTD proposed. MTD design shall be compliant with the design conditions established in the NJDEP certification letter.
			40	Depictions and descriptions (preferably as plan notes) of measures to be employed **during construction** to protect SCMs (including MTDs) from construction sediment and activities, once installed. *Note: unless the SCM is used as a sediment basin/trap during construction, SCM inlets must be blocked to prevent inflows of stormwater until its drainage area is fully and permanently stabilized.*
			41	Proof of compliance with the stormwater quality treatment standard, including detailed calculations for each SCM, to include the required WQv versus SCM capacity/sizing, water quality peak flow, WQv credits included (if applicable), %TSS removal achieved. *SCM Treatment Trains only*: Identify each treatment train, its SCMs (including MTDs), their location in the train (upstream and downstream), and the direction of flow. Include compliance calculations to confirm treatment of the required WQv (based on the downstream SCM). For treatment trains that include an MTD, include total % TSS removal calculations.

Yes	No	N/A	STORMWATER MANAGEMENT PLAN PREPARATION CHECKLIST	
			42	Proof of compliance with the channel protection standard, including detailed calculations for CPv and SCM sizing
			43	Proof of compliance with flood control (detention/retention) standards, including calculation and comparison of peak discharges for the required design storms in the pre- and post-development conditions
			44	*Flood control (detention) SCMs only*: Calculations confirming that the ditch, pipe, or other conveyance structure located immediately downstream of flood control SCMs (detention) is of adequate size to accept discharges from the SCM without localized flooding.
			45	Construction notes, specifications, and design details for other stormwater system components (i.e., ditches, pipes, culverts, inlets, outfalls, etc.)
SCM VEGETATION PLAN *This plan provides a detailed description of the plants to be installed in vegetated SCMs (e.g., bioretention areas, extended detention basins, stormwater wetlands, vegetated MTDs etc.). Consult the City to determine if this plan must be submitted with the SWMP, or the landscape plan for the entire development, or both. Landscaped SCMs may not be recognized under the City's codes as property landscaping. Therefore, additional requirements for property landscaping may apply. In any case, the following information must be provided for each vegetated SCM. Vegetation requirements for SCMs are specified in Chapter 7 of the City of Alcoa Stormwater Management Manual, Volume 1.*				
			46	SCM vegetation plan (may be provided with the landscape plan) (check Yes or No)
			47	Labeled plans/details (to scale) depicting the plants to be installed, their numbers, and locations. Plan notes shall show the plant schedule and installation instructions.
			48	Location of water source to be used for plant watering until fully established
			49	Documentation of plant warranties, if required
SCM MAINTENANCE REPORT *This report must describe the inspection and maintenance requirements for each proposed SCM. This report will be used by the property owner to guide SCM management after construction.*				
			50	A map that accurately identifies each SCM and its location on the property relative to property boundaries, buildings, driveways and parking areas, etc., such that persons responsible for SCM inspection and maintenance can visually locate it. For each SCM, include also the locations of each inlet and outlet, and its associated easements. SCMs shall be identified by proper name as established in Chapter 7 of the *City of Alcoa Stormwater Management Manual, Volume 1*.
			51	The SCM maintenance guidance and inspection checklist(s) for each proposed SCM. For SCMs constructed onsite, this information is provided in the *SCM Maintenance Manual,* which can be found on the City's stormwater webpage. For MTDs and manufacturer/vendor supplied SCMs (e.g., cisterns, green roofs), the maintenance and inspection information developed by the manufacturer must be provided. Design professionals may provide additional SCM maintenance and inspection information as appropriate for the expected conditions of the proposed development.
			52	An executed copy of the SCM Maintenance Covenants
OTHER INFORMATION, as requested by the City				
			53	A copy of correspondence with the US Fish and Wildlife office concerning any identified Endangered Species on the property, if required
			54	A Special Pollutant Abatement Plan, if required
			55	Other (describe):
			56	Other (describe):
			57	Other (describe):
			58	Other (describe):

Yes	No	N/A	STORMWATER MANAGEMENT PLAN PREPARATION CHECKLIST
Notes:			
END OF CHECKLIST			

Submittal/Resubmittal Date: **Review No. *(circle one)*** **1 2 3 4 5 or more**

Project Owner: **Phone:**

Applicant: **Phone:**

Project Name:

Project Address:

This checklist lists items that must be included in an SCM as-built plan. An item listed must be checked under the "Yes" column, and thus provided with the plan unless it is not applicable to the project. Items that are not applicable to the project must be checked under the "N/A" column. Checks placed under the "No" column and thus not provided with the Drawing even though they may be applicable to the project must be justified in a written statement attached to this checklist. This checklist must be submitted to the City of Alcoa (City) for review and approval.

All maps shall be shown to scale (with scale provided), with accurate bearings and distances.

Yes	No	N/A		AS-BUILT PLAN CHECKLIST
GENERAL INFORMATION				
			1	Date(s) of original as-built plan and revisions
			2	Seal/signature of TN professional engineer in responsible charge of stormwater designs
			3	Copy of executed SCM maintenance covenants, if required by the City
			4	Copy of the plat already (or to be) recorded including any City-required notes.
			5	Established benchmark of known elevation to which every other elevation is referenced
			6	Horizontal control
			7	Vicinity map including:
				- North arrow
				- Scale
				- Adjacent roadways
				- Property boundaries
				- Onsite and nearby watercourses
				- Other necessary information to locate and describe the project
			8	Natural water features (streams, rivers, lakes, ponds, wetlands, seeps, springs, bogs, etc.)
			9	Sinkholes and areas of soluble bedrock, shallow bedrock, high water table, hardpan, clay lenses, or similar hydrologically limiting conditions
			10	100-year floodplain boundary with its 100-yr elevation labeled every 300 linear feet
			11	100-year regulatory floodway boundaries
			12	Location(s) and easement boundaries (drainage and access easements) for Stormwater Control Measures (SCMs), identifying the type of SCM (by proper name), and the locations of all inflows and outflows
			13	General land cover including buildings, pavement, gravel surfaces, woods, meadow, turf grass, maintained landscape, agriculture, and unvegetated (bare) soil

Yes	No	N/A		AS-BUILT PLAN CHECKLIST
			14	Utility, access, drainage, and other public easement boundaries, labeled
			15	Surface drainage directions, including drainage directions from roof downspouts
			16	Plan view map of all vegetated buffers showing the boundaries and widths of inner and outer zones, the location, length and width of approved buffer crossings, encroachments, and impervious surfaces. Include labels that state "Vegetated Buffer. No land clearing or building construction allowed. Buffer vegetation must adhere to City requirements."
			17	Location(s) of permanent markers/signs for vegetated buffers, if required
DESIGN PROFESSIONAL'S CONFIRMATIONS *Check either Yes or No. Provide an explanation of all "No" answers in the Notes section at the end of this checklist or on an attached page. "No" answers may result in corrective actions or the withholding of Record Drawing and other City approvals.*				
			18	Does the title block have the same project name, address, and contact persons as shown on the approved stormwater management plan (SWMP)?
			19	Are seal and signature for the certifying Engineer & Surveyor shown on the as-built plan?
			20	Does the as-built plan contain survey benchmarks or other reference points?
			21	Does the as-built plan contain a north arrow, bar scale, and coordinates?
			22	Does the as-built plan contain the professional certifications required by the City?
			23	Does the as-built plan contain the property owner's acknowledgement, or the maintenance agreement/covenant required by the City?
			24	Is construction complete and have disturbed areas been adequately stabilized to prevent soil erosion?
			25	Is a Stormwater Control Measure (SCM) Report provided for each SCM located on the development?
			26	Are all SCMs depicted in this as-built plan fully installed/constructed, undamaged, and free of trash, debris, and construction sediment? If no, identify the non-conforming SCM(s), the corrective actions required, and the schedule for completion.
			27	Do the SCMs (including MTDs) depicted in this as-built plan conform with the SCM types, required water quality volume (WQv), and designs shown in the approved SWMP? If no, identify the non-conforming SCMs and provide a reason for each instance of non-conformance.
			28	Are the access easements to each SCM unobstructed? If no, identify the easements and their obstructions, the corrective actions required to remove the obstruction, and the schedule for completion.
STORMWATER CONTROL MEASURE REPORT *These maps, reports, and narratives describe the CONSTRUCTED condition of Low Impact Development (LID) practices, SCMs (including MTDs), and water quality volume (WQv) reduction areas.* ***NOTE: A SEPARATE SCM REPORT SHALL BE PROVIDED FOR EACH SCM LOCATED ON THE DEVELOPMENT.***				
			29	Plan view map, accurately showing the SCM at a readable scale, with 1-ft contours where 2-ft contours do not show sufficient detail
			30	Locations and invert elevations for all pipe(s) and ditch(s) that discharge to the SCM
			31	Locations and boundaries of SCM and access easements, labeled
			32	Accurate details of the entire SCM, including inlets, outlets, and other flow control structures, pretreatment measures, protective measures, underdrains, and connections to the downstream stormwater conveyance system. Include the name, type, material, dimensions, elevations, means of anchoring, etc.
			33	Calculations showing the SCM, SCM treatment train, or MTD as constructed achieves 80% TSS Removal of the required WQv

Yes	No	N/A		AS-BUILT PLAN CHECKLIST
			34	Calculations showing the SCM as constructed meets the Channel Protection Standard (i.e., extended detention of 1-yr, 24-hr storm), if applicable to the SCM.
			35	Calculations showing the SCM as constructed meets the flood control (detention) standards, if applicable to the SCM.
			36	*For SCMs that provide flood control (detention)*: confirmation that the minimum freeboard of 1 foot is provided between the 100-year storm event elevation and top of berm.
			37	*Manufactured Treatment Devices (MTDs) only:* The make, model, and size/capacity, and any additional identifying names or numbers. Describe the MTD's purpose [i.e., pretreatment or primary treatment]. Provide all construction notes, specifications, and design details (to scale) of each MTD. *MTDs proposed for primary stormwater quality treatment*: The NJDEP certification letter for the installed MTD, in its entirety. If the MTD differs certification must be for the exact make and model of MTD depicted in the approved SWMP.
			38	*Flood control (detention) SCMs only*: Calculations confirming that the ditch, pipe, or other conveyance structure located immediately downstream of flood control SCMs (detention) is of adequate size to accept discharges from the SCM without localized flooding.
SCM VEGETATION PLAN *This plan provides a detailed description of the plants installed the SCM.*				
			39	Labeled plans/details (to scale) depicting the plants installed and their locations.
			40	Location of water source to be used for plant watering until fully established
			41	Documentation of plant warranties, if required
SCM MAINTENANCE REPORT *This report is intended for use by the existing and future property owners to guide inspection and maintenance of the SCM by the owner(s) or their designee(s).*				
			42	A map that accurately identifies each SCM and its location on the property relative to property boundaries, buildings, driveways and parking areas, etc., such that persons responsible for SCM inspection and maintenance can visually locate it. For each SCM, include also the locations of each inlet and outlet, and its associated easements. SCMs shall be identified by proper name as established in Chapter 7 of the *City of Alcoa Stormwater Management Manual, Volume 1* .
			43	The SCM maintenance guidance and inspection checklist(s) from the *SCM Maintenance Manual* for each proposed SCM. For MTDs and manufacturer/vendor supplied SCMs (e.g., cisterns, green roofs), the maintenance and inspection information developed by the manufacturer must be provided. Design professionals may provide additional SCM maintenance and inspection information as appropriate for the expected conditions of the proposed development.
			44	An executed copy of the SCM Maintenance Covenants, if required by the City.
Notes:				
END OF CHECKLIST				

E.1 Applicability

This Appendix establishes the requirements for performing soil infiltration tests and soil borings.

INFILTRATION TESTS are used to determine the infiltration rate of in-situ or engineered soil at the location of a proposed SCM. **These tests are required when specified in an SCM design specification (see Table E.1) or requested by the City.**

SOIL BORINGS are used to determine the depth of the seasonal high-water table (SHWT) beneath the bottom of a proposed SCM. For stormwater wetlands and wet enhanced swales, soil borings also tell the designer the type of in situ soil at the SCM, which can help determine if wet conditions can be maintained. **Soil borings are required for *all* proposed SCMs for which a minimum depth to the SHWT is specified (see Table E.1).**

Table E.1 presents a list of SCMs included in this manual and whether soil infiltration tests and/or soil borings are required.

Table E.1 Infiltration Test and Soil Boring Applicability by SCM

SCM Tier	Stormwater Control Measure (SCM) *(design configuration)*	Soil Infiltration Test Required?	Soil Borings Required?
Tier 1	Green Roof	No	No
Tier 2	Bioretention Area *(with underdrain)*	No	Yes
	Dry Enhanced Swale *(with underdrain)*	No	Yes
	LID-MTDs[1] *(with underdrain)*	No	Yes
	Urban Bioretention *(with underdrain)*	No	Yes
Tier 3	Dry Extended Detention (ED) Basin	No	Yes
	Filtration MTDs[1]	No	Yes
	Permeable Pavement System *(with underdrain)*	No	Yes
	Sand Filter *(all types, with underdrain)*	No	Yes
	Stormwater Wetland	Yes	Yes
	Underground ED Basin	No	Yes
	Wet Detention Basin *(all types)*	No	Yes
	Wet Enhanced Swale	Yes	Yes
Tier 4	Hydrodynamic separation MTDs[1]	No	No
Other	Gravity (Oil-Grit) Separator	No	No

1 – MTD is an acronym for Manufactured Treatment Device. See MTD design specifications in Chapter 7 of this manual

E.2 Professional License Requirements

Soil borings and infiltration tests shall be performed and interpreted by a Soil Scientist with an active license in the State of Tennessee.

E.3 Stormwater Management Plan Requirements

The stormwater management plan (SWMP) shall include the following information pertaining to soil infiltration tests and soil borings.

1. A map showing the location(s) of infiltration tests and/or soil borings, with each test/boring location having a unique identifier (e.g., 1, 2, 3)
2. A narrative that identifies the tests, protocols, and reference documents used for soil infiltration tests and/or soil core interpretation from the soil borings.
3. A table providing the following information at a minimum as appropriate for the SCM: test/boring number per SCM map; depth to seasonal high water table (SHWT); infiltration rate; comments

E.4 Soil Borings

Policies pertaining to soil borings and interpretation of soil cores are as follows:

1. **Required number of soil borings.**
    a. Depth to SHWT Determination – One soil boring shall be conducted for every 20,000 square feet of SCM area.
    b. Soil Infiltration Information – When infiltration tests are required, one soil boring shall accompany each infiltration test performed. See Section E.5 below for more information.
2. **Minimum required depth.** Soil borings shall be performed, at a minimum, to a depth of 10 feet below the lowest bottom elevation of the SCM.
3. **Soil core interpretation.** Each soil core shall be observed to determine the anticipated SHWT based on the date of soil boring with respect to any visual observations of water in the core (or boring), recent and seasonal rainfall patterns, and the presence of hydric soils, redoximorphic features, or other indicator of water table variation, and depth to bedrock if encountered. If mottling showing redoximorphic features is observed, at any season of the year, the SHWT shall be taken as the highest level at which the mottling is observed, except when the water table is observed at a level higher than the level of the redoximorphic depletions or concentrations. Otherwise, use best practices for SHWT determination as appropriate for water table/soil conditions at the location of the SCM. Soil Scientists are referred to the most recent version of the reference document by USDA-NRCS, entitled *Field Indicators of Hydric Soils in the United States – A Guide for Identifying and Delineating Hydric Soils* (NRSC, 2018) for more information on determining whether saturated soils are present.

E.5 Soil Infiltration Tests

Policies pertaining to field tests performed to determine the soil infiltration rate, when required.

1. **Field infiltration tests required.** Field infiltration tests of the soil for which the infiltration rate is to be determined shall be performed as indicated herein. *This is the only allowed approach to determining the in-situ infiltration rate as field tests yield results that reflect actual site conditions.*

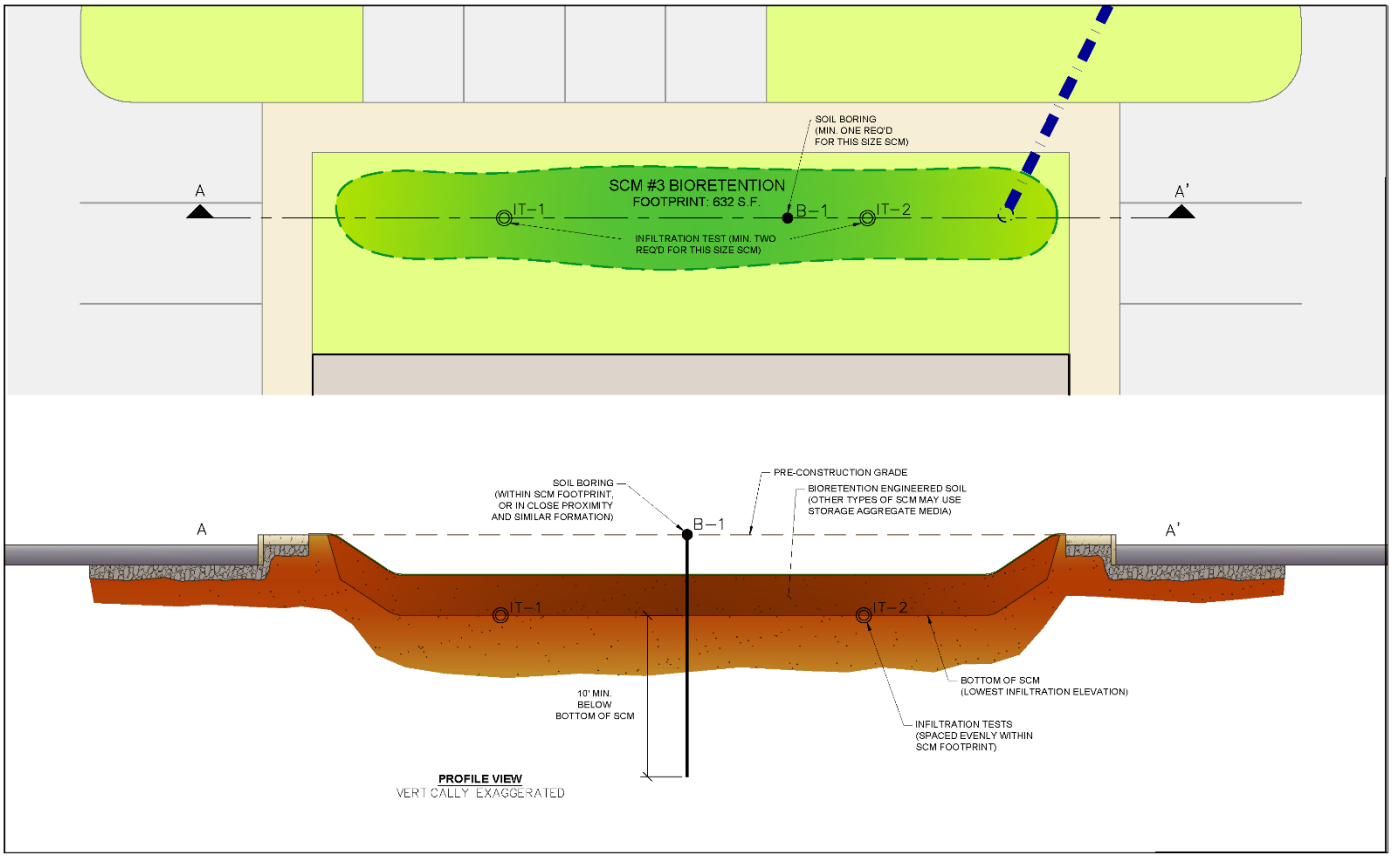
    The City may require field infiltration tests to confirm infiltration rates of the soil surrounding, below, or within (i.e., the engineered soil mix) an SCM after construction is complete if soil compaction or clogging is known or suspected during construction. When required, field infiltration test information shall be provided with the as-built plan.

2. **Multiple infiltration rates.** When multiple soil types are present at a SCM location, multiple infiltration tests are required. Once infiltration rates have been determined, refer to the SCM design specification for design requirements based on the rates.

3. **Suitable weather conditions.** Infiltration tests shall not be conducted in the rain, within 24 hours of significant rainfall events (> 0.5 inch), or when temperatures are below freezing.

4. **Required number of tests.** At least two (2) infiltration tests shall be conducted for every SCM for which tests are required, using the test spacing criteria established below. See Figure E.1 for example spacing and location of required tests.
   a. Two infiltration tests shall be conducted for every 3,000 to 10,000 square feet of SCM area. Tests shall be spaced appropriately to provide sufficient infiltration rate information across the length and width of the SCM.
   b. For small SCMs (<3,000 square feet), at least one (1) test shall be located within the SCM's footprint. The second test can be performed outside the footprint but must be located within 20 feet of the perimeter of the SCM and in soil formations that are representative of the conditions within the footprint of the SCM.
   c. For SCMs that have an area greater than 10,000 square feet, one infiltration test shall be conducted for every additional 10,000 square feet of surface area up to a maximum of five infiltration tests. The City may require additional tests for SCMs greater than 10,000 square feet, or when unique soil or geological conditions are known or suspected at the site.

Figure E.1 Example of Appropriate Spacing and Depth for Soil Infiltration Tests



5. **Required test elevation.** When testing in-situ soil, the elevation of all infiltration tests shall be at or below the bottom (lowest permitted infiltration elevation) of the SCM. When testing engineered soil mix, two tests shall be performed: one within 6 inches of the surface of the mix layer; one within 6 inches of the bottom of the mix layer.

6. **Soil borings required.** Soil borings aid in interpretation of infiltration test results by providing information on groundwater conditions and soil stratification. Therefore, each infiltration test shall be accompanied by a soil boring test performed in the manner described in the previous section.

7. **Allowed infiltration test methods.** Field infiltration tests shall utilize a double-ring infiltrometer or modified Philip Dunne infiltrometer following the specifications of ASTM D3385 or ASTM 8152, respectively. A double-ring infiltrometer test estimates the vertical movement of water through the bottom of the test area. The results from this test, generally reported in inches per hour (in/hour), are appropriate for use in sizing the SCM. This is the preferred methodology for soil infiltration testing, appropriate factor of safety shall be applied to field verified infiltration rates. Key points are summarized below:

    - Double-ring infiltrometer testing methodology is provided in ASTM D 3385.
    - Two concentric metal rings are driven into the ground and filled with water. The outer ring helps to reduce lateral movement of water in the soil, while the inner ring is used to calculate an infiltration rate.
    - Test holes must be presoaked immediately prior to testing. The presoaking procedure is intended to simulate saturated condition in the environment and to minimize the influence of unsaturated flow.
    - The tests must be performed for at least 6 hours or a length of time adequate for the infiltration rate to stabilize.

E.6 Reference

Natural Resources Conservation Service (NRCS). *Field Indicators of Hydric Soils in the United States – A Guide for Identifying and Delineating Hydric Soils, Version 8.2, 2018.* United States Department of Agriculture (USDA) NRCS. 2018.