Module 3 - Green Stormwater Infrastructure and Linear Biofiltration Systems

Estimated Reading Time: 75-90 minutes / Estimated Completion Time: ~ 1 hour 30 minutes

Recommended Audience: Civil Engineers, Land Development Professionals, Stormwater Engineers, Municipal Officials, Contractors and Superintendents, Developers and Property Owners, Landscape Architects, Estimators and Project Managers, Sales Professionals, Students of Civil Infrastructure, Anyone seeking a practical understanding of Green Stormwater Infrastructure, urban biofiltration systems, and sustainable stormwater design.

Rethinking Stormwater Management in the Modern City

Introduction

For much of the twentieth century, urban stormwater management was built around a simple objective: move water away as quickly as possible. Streets, parking lots, sidewalks, and rooftops were designed to collect rainfall and convey it through curb and gutter systems into underground pipe networks. Once captured, stormwater was transported downstream with little consideration given to water quality, groundwater recharge, urban heat, or ecological impacts.

While this approach successfully reduced localized flooding in many communities, it also created unintended consequences. As cities expanded and impervious surfaces replaced natural landscapes, stormwater runoff volumes increased dramatically. Pollutants accumulated on paved surfaces and were transported directly into streams, rivers, lakes, and wetlands. Urban waterways experienced increased erosion, degraded water quality, diminished aquatic habitat, and more frequent flooding events.

Over the last several decades, stormwater management philosophy has undergone a significant transformation. Engineers, planners, regulators, and developers increasingly recognize that rainfall should not be viewed as a waste product that must be rapidly removed from a site. Instead, stormwater is now managed as a resource that can be captured, treated, infiltrated, reused, and integrated into the built environment.

This shift has given rise to Green Stormwater Infrastructure (GSI), a collection of practices designed to mimic natural hydrologic processes while enhancing urban environments. Rather than relying exclusively on underground pipes and large detention facilities, GSI incorporates vegetation, engineered soils, filtration systems, permeable surfaces, and landscape features to improve water quality and reduce runoff impacts.

Among the most effective of these technologies are linear biofiltration systems. These systems transform traditional landscape areas into functional stormwater treatment assets capable of removing pollutants, supporting urban vegetation, and creating attractive public spaces. Their ability to fit within narrow corridors and heavily developed environments makes them particularly valuable in modern urban redevelopment projects.

As cities across the United States pursue higher density development, walkable districts, expanded greenways, and enhanced public spaces, linear biofiltration systems are becoming increasingly common components of urban infrastructure. Major redevelopment efforts such as Nashville's East Bank demonstrate the type of environment where these systems can provide substantial value. Streetscapes, plazas, transit corridors, mixed-use developments, and urban parks all present opportunities to integrate stormwater treatment directly into the public realm.

This module explores the principles, technologies, and applications behind modern linear biofiltration systems. While specific manufactured systems such as Modular Wetlands Linear will be discussed throughout the course, the primary focus is understanding the broader infrastructure category, the engineering principles that drive performance, and the role these systems play in creating more resilient and sustainable cities.

CHAPTER 1 - The Urban Stormwater Challenge

Understanding How Development Changes the Natural Movement of Water

Understanding the Problem We Are Trying to Solve

Stormwater management begins with a simple question: What happens when rain falls on a developed site? Before development occurs, rainfall is intercepted by vegetation, absorbed into the soil, evaporated back into the atmosphere, or slowly infiltrated into groundwater systems. Natural landscapes are remarkably effective at managing rainfall because they contain large amounts of permeable soil, organic matter, and vegetation.

Development fundamentally changes this process. Roadways, sidewalks, rooftops, parking lots, and other impervious surfaces prevent rainfall from infiltrating naturally. Water that once soaked into the ground now becomes surface runoff. The greater the percentage of impervious cover, the greater the volume and velocity of stormwater generated during rainfall events. In heavily urbanized environments, stormwater runoff can increase several times over pre-development conditions.

The Growth of Impervious Surfaces

Modern urban development depends on infrastructure. Streets provide transportation access. Sidewalks improve pedestrian mobility. Parking facilities support commercial activity. Buildings provide residential, office, retail, and institutional space.

Each of these improvements contributes to an increase in impervious cover, fundamentally changing how rainfall behaves across a developed site. As pavement, rooftops, and other hard surfaces replace natural ground cover, less water is able to infiltrate into the soil. Instead, larger volumes of stormwater become surface runoff, reaching drainage systems more quickly and producing higher peak discharge rates during rainfall events.

At the same time, the shortened travel time of runoff reduces the time of concentration, while groundwater recharge declines as fewer opportunities exist for water to soak into the underlying soils. These changes place greater stress on downstream channels, accelerating streambank erosion and increasing the transport of sediment, nutrients, metals, hydrocarbons, and other pollutants into receiving waters. Collectively, these impacts alter the natural hydrologic cycle and create many of the stormwater management challenges facing rapidly developing communities today.

The cumulative effect is a stormwater system that experiences greater hydraulic stress while simultaneously delivering larger pollutant loads to receiving waters. For rapidly growing cities such as Nashville, these challenges become increasingly significant as redevelopment and infill projects transform formerly underutilized properties into dense mixed-use environments.

Pollutants in Urban Runoff

Stormwater runoff is often mistakenly perceived as clean water because it originates as rainfall. In reality, runoff becomes contaminated as it travels across developed surfaces. Common urban stormwater pollutants include:

Sediment
Construction activities, exposed soils, and landscape disturbances contribute sediment to runoff. Sediment is one of the most common pollutants found in urban waterways and serves as a transport mechanism for numerous other contaminants.

Nutrients
Nitrogen and phosphorus originate from fertilizers, landscape maintenance activities, organic debris, and atmospheric deposition. Excessive nutrient loading contributes to algae growth and reduced water quality.

Heavy Metals
Vehicles, building materials, and industrial activities generate metals such as zinc, copper, lead, and cadmium. These pollutants accumulate on pavement surfaces and are mobilized during storm events.

Hydrocarbons
Oil, grease, fuel residues, and tire wear particles accumulate on roadways and parking areas. Stormwater runoff transports these materials into receiving waters.

Trash and Debris
Litter, plastics, organic debris, and floatable materials frequently enter storm drainage systems and contribute to aesthetic and environmental concerns.

Managing these pollutants is a primary objective of modern stormwater regulations and one of the key reasons green infrastructure systems have become increasingly important.

Urban Heat and Environmental Stress

Urban areas experience environmental conditions that differ significantly from surrounding undeveloped landscapes. Large concentrations of pavement, concrete, and buildings absorb solar energy and create what is commonly known as the urban heat island effect. Surface temperatures on pavement can exceed 140°F during summer months, increasing thermal stress on surrounding environments and contributing to elevated runoff temperatures.

Vegetation loss compounds this problem. Without trees and green space, cities lose natural cooling mechanisms provided by shading and evapotranspiration. Stormwater infrastructure that incorporates vegetation can provide meaningful benefits beyond water quality treatment. Properly designed systems can reduce localized temperatures, improve aesthetics, enhance pedestrian comfort, and contribute to urban canopy goals.

Space Constraints in Modern Development

Traditional stormwater facilities such as detention ponds, retention basins, and constructed wetlands can provide excellent hydraulic and water quality performance. However, these practices often require substantial land area, making them difficult to incorporate into dense urban environments where every square foot carries significant economic value.

Modern redevelopment projects must balance a wide range of competing priorities. Space is needed for buildings, parking, roadways, sidewalks, utility corridors, public gathering areas, landscaping, and other infrastructure that supports a vibrant community. As cities continue to grow and available land becomes increasingly limited, dedicating large portions of a site solely to stormwater management is often neither practical nor economically desirable. These challenges have driven engineers and planners to develop innovative solutions that allow stormwater treatment to be integrated into the built environment rather than occupying valuable developable land.

Stormwater infrastructure must compete for space alongside these critical project components.
As a result, engineers increasingly seek solutions that perform multiple functions simultaneously. The most successful modern stormwater systems often serve as landscape features, pedestrian amenities, urban forestry assets, and water quality treatment facilities at the same time. This need for multifunctional infrastructure has helped drive the adoption of linear biofiltration systems throughout urban environments.

A Changing Approach to Stormwater

The challenges facing modern stormwater management are largely the result of development replacing natural landscapes with impervious surfaces. As roads, parking lots, rooftops, and sidewalks expand, rainfall that once infiltrated into the ground is converted into surface runoff. That runoff carries sediment, nutrients, metals, hydrocarbons, and other pollutants while increasing downstream flooding potential, accelerating stream erosion, and placing greater demands on public infrastructure.

As communities continue to grow, the objective is no longer simply to move stormwater away as quickly as possible. Instead, engineers, planners, and developers are increasingly challenged to manage runoff in ways that protect water quality, preserve natural hydrologic processes, and create infrastructure that complements the built environment. Meeting those objectives requires a different way of thinking about stormwater management—one that views rainfall as a resource to be managed rather than a problem to be removed.

LOCAL APPLICATION - Nashville East Bank Redevelopment

The East Bank redevelopment area represents one of the largest urban redevelopment efforts in Tennessee history. Thousands of residential units, commercial spaces, public parks, streets, sidewalks, and civic gathering areas are planned within a relatively compact footprint, around 550 acres.

Traditional stormwater solutions alone would consume significant amounts of valuable developable land and provide limited public benefit. As a result, designers are increasingly exploring ways to integrate stormwater treatment directly into streetscapes, greenways, plazas, and landscape features.

This type of development demonstrates why modern stormwater infrastructure must often perform multiple functions simultaneously. Infrastructure is no longer expected to simply move water. It must also improve water quality, support urban forestry, enhance aesthetics, and contribute to the overall user experience.

CHAPTER 2 - Green Stormwater Infrastructure Principles

Restoring Natural Hydrology Through Modern Stormwater Design

Mimicking Natural Hydrology

Green Stormwater Infrastructure represents a fundamental shift in how stormwater is managed. Rather than moving water away as quickly as possible, GSI seeks to replicate the natural hydrologic processes that existed before development occurred. These systems are designed to slow, store, filter, infiltrate, and treat runoff while providing environmental and community benefits.

The goal is not simply flood control. The goal is to restore portions of the natural water cycle that are lost during urban development. Several key principles form the foundation of all Green Stormwater Infrastructure systems.

Bioretention

Bioretention is one of the most widely used stormwater treatment practices in modern urban design. Bioretention systems temporarily store stormwater and allow it to pass through engineered soil media where pollutants are removed through physical, chemical, and biological processes.

Unlike traditional landscape areas that are designed primarily for appearance, bioretention systems are engineered specifically to improve stormwater quality. Although they often resemble landscaped planting beds, every component is intentionally designed to perform a specific function within the treatment process. Surface storage temporarily captures runoff, vegetation slows flow and promotes biological uptake, engineered soil media filters pollutants, underdrain systems convey treated water when infiltration is limited, and overflow structures safely manage larger storm events.

Working together, these components create an integrated treatment system that removes pollutants while supporting healthy vegetation and improving the overall function of the site. For this reason, bioretention serves as the foundation for many of the linear biofiltration systems now being incorporated into urban streetscapes, redevelopment projects, and other forms of Green Stormwater Infrastructure.

Biofiltration

Biofiltration expands upon bioretention by utilizing engineered media and vegetation to remove pollutants from stormwater runoff. As runoff passes through a biofiltration system, several treatment mechanisms occur simultaneously. Sediment is physically filtered from the water column. Nutrients are absorbed by vegetation and soil organisms. Metals are adsorbed onto soil particles. Microbial activity helps break down organic contaminants.

The result is significant improvement in stormwater quality before discharge occurs. Many modern manufactured systems, including linear biofiltration systems, rely heavily on biofiltration principles.

Infiltration

Infiltration is the process by which stormwater moves from the surface into the underlying soil, where it becomes part of the natural hydrologic cycle. Before development, much of the rainfall that reached the ground infiltrated naturally, replenishing groundwater supplies, supporting vegetation, and reducing the amount of runoff entering nearby streams. This process also helped moderate peak storm flows by slowing the movement of water through the watershed.

As stormwater filters through the soil profile, naturally occurring physical, chemical, and biological processes further improve water quality by removing sediment and other pollutants. Preserving or restoring infiltration wherever practical is therefore one of the primary objectives of modern Green Stormwater Infrastructure. Urban development often eliminates infiltration opportunities by covering native soils with impervious surfaces. Green infrastructure seeks to restore infiltration wherever site conditions permit.

Not every site is suitable for full infiltration. Soil conditions, groundwater elevation, utility conflicts, and contamination concerns may limit infiltration potential. Even when full infiltration is not feasible, systems can still provide substantial treatment through biofiltration and temporary storage.

Evapotranspiration

Plants play a critical role in stormwater management. Water absorbed by plant roots is eventually released back into the atmosphere through evapotranspiration. This process reduces runoff volumes while supporting vegetation health and improving urban environmental conditions.

Trees, shrubs, grasses, and other vegetation are not merely aesthetic features within green infrastructure systems. They serve as active components of the treatment process.

Source Control

One of the fundamental principles of modern stormwater management is source control—the practice of managing stormwater as close to where it falls as possible. Rather than allowing runoff to travel through extensive drainage networks before treatment occurs, source control strategies intercept and manage stormwater near its point of origin. This approach not only reduces the volume of untreated runoff entering downstream systems but also prevents pollutants from being transported throughout the watershed.

Source control can be incorporated into many types of Green Stormwater Infrastructure, including streetscape bioretention areas, tree pits, green medians, linear biofiltration systems, and permeable pavement installations. By distributing treatment throughout a site instead of relying on a single downstream facility, these practices reduce pollutant loading, improve system resilience, and more closely replicate the natural hydrologic processes that existed before development. Source control has become one of the defining principles of sustainable site design because it addresses stormwater problems where they begin rather than where they ultimately end.

The Treatment Train Concept

One of the foundational principles of modern stormwater management is the concept of the treatment train. Rather than relying on a single structure or practice to manage stormwater, a treatment train combines multiple treatment processes that work together to improve overall system performance. Each component performs a specific function, building upon the effectiveness of the one before it. The result is a more reliable, resilient, and efficient stormwater management system than any individual practice could provide on its own
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A typical urban treatment train begins by collecting runoff through curb inlets, trench drains, or other surface collection systems. Before the water reaches the primary treatment area, pretreatment features remove larger sediment particles, trash, and debris that could reduce the performance of downstream components. The runoff then passes through engineered biofiltration media where physical filtration, chemical adsorption, and biological activity work together to remove pollutants. Depending on the design objectives, the treated water may be temporarily stored to reduce peak discharge rates before being released through a controlled outlet into the downstream drainage system.

By dividing stormwater treatment into multiple stages, the treatment train approach improves pollutant removal, reduces maintenance requirements, enhances system reliability, and provides greater resilience during larger storm events. For this reason, treatment trains have become one of the defining characteristics of modern Green Stormwater Infrastructure and are incorporated into many of today's most successful stormwater management systems.

Linear biofiltration systems are particularly effective because they integrate several treatment train components into a single infrastructure feature. Rather than requiring multiple standalone facilities, they combine conveyance, filtration, storage, vegetation, and treatment within one compact footprint.
This ability to perform multiple functions simultaneously is one of the primary reasons linear biofiltration systems are becoming increasingly common in modern urban redevelopment projects and public spaces.

LOOKING AHEAD

Green Stormwater Infrastructure represents a fundamental shift in how communities approach stormwater management. Instead of relying solely on pipes, detention ponds, and other conventional infrastructure, modern stormwater systems seek to restore many of the natural hydrologic processes that are disrupted by development. Practices such as bioretention, biofiltration, infiltration, evapotranspiration, and source control work together to slow runoff, improve water quality, reduce downstream impacts, and integrate stormwater treatment directly into the built environment.

Perhaps the most important lesson is that no single practice provides every solution. The most effective systems combine multiple treatment processes into a coordinated treatment train, allowing each component to perform a specific function while contributing to the performance of the overall system. This integrated approach has become the foundation of modern Green Stormwater Infrastructure and serves as the basis for the linear biofiltration systems explored throughout the remainder of this module.

LOCAL APPLICATION – Franklin, TN Streetscape Biofiltration Corridor

Consider a downtown Franklin street lined with sidewalks, street trees, decorative landscaping, and parallel parking. During a rainfall event, runoff from pavement surfaces enters a series of linear biofiltration planters located between the roadway and sidewalk.

Water is first slowed and filtered through vegetation before entering engineered soil media. Pollutants are removed through filtration, adsorption, and biological activity. Excess runoff is captured by an underdrain system and conveyed downstream.

To a pedestrian, the system appears to be an attractive landscape feature. To the engineer, it functions as a water quality treatment facility. This dual-purpose approach represents the essence of
Green Stormwater Infrastructure.

CHAPTER 3 - Linear Biofiltration Systems

Integrating Water Quality Treatment Into Streetscapes and Urban Development

Bringing Stormwater Treatment Into the Urban Environment

As cities continue to grow upward and outward, engineers are increasingly challenged to incorporate effective stormwater treatment within limited available space. Traditional stormwater facilities such as detention ponds, retention basins, and constructed wetlands often require large footprints that may not be practical within dense urban developments. At the same time, regulatory requirements continue to demand higher levels of water quality treatment and runoff management.

Linear biofiltration systems emerged as a solution to this challenge. These systems integrate stormwater treatment directly into streetscapes, pedestrian corridors, urban parks, public plazas, transit corridors, and mixed-use developments. By combining landscape architecture with stormwater engineering, linear biofiltration systems transform underutilized spaces into active infrastructure assets.

Unlike conventional facilities that are often hidden from public view, linear biofiltration systems become visible components of the urban landscape. When properly designed, they improve water quality, support urban vegetation, enhance aesthetics, reduce heat island effects, and create more attractive public spaces.

What Is a Linear Biofiltration System?

A linear biofiltration system is a type of Green Stormwater Infrastructure specifically designed to capture, treat, temporarily store, and convey stormwater runoff within long, narrow spaces commonly found in urban environments. Rather than requiring large detention ponds or expansive treatment facilities, these systems take advantage of existing landscape corridors adjacent to roadways, sidewalks, parking areas, pedestrian walkways, and public gathering spaces. Their elongated configuration allows stormwater treatment to be integrated directly into the built environment without sacrificing valuable developable land.

Although individual systems vary in appearance and proprietary design, they all rely on the same fundamental engineering principles. Stormwater is first collected and directed into the system, where pretreatment features remove larger sediment particles and debris before the runoff enters engineered filtration media. As water moves through the soil profile, physical filtration, chemical adsorption, and biological activity work together to remove pollutants while vegetation slows runoff, promotes evapotranspiration, and enhances the surrounding landscape. Depending on site conditions, treated water may infiltrate into the underlying soil, be collected by an underdrain system for downstream conveyance, or temporarily stored until it can be safely discharged through an overflow or outlet structure during larger storm events.

Although manufacturers may package these components differently, nearly every linear biofiltration system is built around the same essential elements: a method of collecting runoff, pretreatment to protect the system, engineered filtration media, carefully selected vegetation, an underdrain or infiltration zone, and a controlled overflow structure. Working together, these components transform what might otherwise be a simple landscaped area into a highly engineered treatment system capable of improving water quality while enhancing the appearance, functionality, and environmental performance of the surrounding development.

How Linear Biofiltration Systems Work

During a rainfall event, runoff enters the system through curb openings, trench drains, slot drains, surface inlets, or sheet flow from adjacent pavement surfaces. As water enters the facility, larger sediment particles and debris begin settling out within the pretreatment area. This initial step reduces loading on downstream filtration components and extends the lifespan of the treatment media.

Water then infiltrates through engineered soil media specifically designed to promote filtration and pollutant removal. As stormwater moves through the media, numerous treatment mechanisms occur simultaneously. Sediment is physically filtered from the water column. Metals become attached to soil particles through adsorption. Nutrients are consumed by vegetation and microbial communities.
Hydrocarbons are broken down through biological processes. Organic pollutants are trapped and degraded within the media profile. After treatment, water may infiltrate into native soils, be temporarily stored within the system, or be collected by an underdrain and discharged downstream.

Why Linear Systems Are Well Suited for Urban Development

I think this section is trying to do too much at once. It's introducing the concept, listing benefits, and concluding—all in one block. I would instead **tell the story** of why these systems have become so important, then naturally introduce the benefits as the result of that story.
Here's how I would rewrite it:

Why Linear Biofiltration Systems Are Changing Urban Design

One of the greatest advantages of linear biofiltration systems is their ability to transform spaces that already exist within the urban landscape into functional stormwater infrastructure. Throughout cities and redevelopment projects, narrow landscape areas are commonly found between roadways and sidewalks, within parking lot islands, along pedestrian corridors, and throughout public gathering spaces. Historically, these areas served primarily aesthetic purposes, providing little more than decorative landscaping or visual separation between transportation corridors and adjacent development.

Modern Green Stormwater Infrastructure has fundamentally changed how these spaces are viewed. Rather than treating them as leftover landscape areas, engineers and landscape architects now recognize them as opportunities to manage stormwater at its source. By incorporating engineered soils, carefully selected vegetation, and integrated drainage systems, these linear spaces become active treatment facilities capable of improving water quality while continuing to serve their landscape function.

This dual-purpose approach provides numerous benefits for both project owners and the surrounding community. Stormwater treatment is incorporated into land that would otherwise serve only an aesthetic purpose, reducing the need for dedicated treatment areas elsewhere on the site. Vegetation softens the appearance of dense urban environments, supports healthier streetscapes, and creates more comfortable pedestrian spaces. Trees and plantings become active components of the treatment process, contributing to pollutant removal, evapotranspiration, urban cooling, and long-term canopy development. At the same time, runoff is treated close to where it is generated, reducing pollutant loading on downstream drainage systems and improving overall watershed health.

Perhaps most importantly, linear biofiltration systems allow infrastructure to become part of the public realm rather than hidden beneath it. Instead of concealing stormwater management underground or behind fences, these systems demonstrate environmental stewardship through visible, attractive landscapes that contribute to the identity and character of a community.

For rapidly growing cities and redevelopment districts where available land is limited and every square foot must serve multiple purposes, this ability to combine engineering performance, environmental protection, and placemaking has made linear biofiltration systems one of the defining features of modern Green Stormwater Infrastructure.

Modular Wetlands Linear as an Example

One example of this infrastructure category is the Modular Wetlands Linear system developed by Contech Engineered Solutions. The system utilizes a series of engineered treatment cells designed to fit within streetscapes, urban corridors, and landscaped public spaces. Water enters the system through distributed collection points and passes through engineered media and vegetation before discharge.

While Modular Wetlands Linear is a proprietary system, its underlying principles are representative of the broader linear biofiltration category. The concepts of filtration, storage, biological treatment, and landscape integration are shared across numerous modern green infrastructure solutions.

For this reason, understanding the infrastructure category is often more valuable than understanding any single manufacturer's product.

The Future of Urban Stormwater Infrastructure

Cities like Murfreesboro, Clarksville and many other Middle Tennessee cities are increasingly seeking infrastructure that provides multiple benefits within a single footprint. Linear biofiltration systems represent a shift away from the idea that stormwater facilities should be hidden or isolated. Instead, these systems become integrated components of public space design, helping create environments that are both functional and attractive.

As redevelopment efforts continue throughout Nashville and other rapidly growing metropolitan areas, linear biofiltration systems will likely become increasingly common components of streetscapes, greenways, parks, and mixed-use developments.

Looking Ahead

Linear biofiltration systems represent far more than landscaped drainage features. They are carefully engineered infrastructure systems that combine stormwater treatment, landscape architecture, urban forestry, and environmental stewardship into a single, integrated solution. Their ability to capture runoff near its source while fitting seamlessly into streetscapes, parks, and redevelopment projects has made them one of the most versatile tools in modern Green Stormwater Infrastructure.

Although these systems may appear simple from the surface, their performance depends upon a series of carefully designed components working together as a coordinated treatment train. Understanding the purpose of each element—from surface collection and pretreatment to engineered soils, vegetation, underdrains, and overflow structures—is essential to designing systems that perform reliably for decades. The next chapter explores these individual components and examines how each contributes to the overall success of the system.

Local Application – Wedgewood-Houston Redevelopment

Nashville's Wedgewood-Houston neighborhood illustrates the type of urban redevelopment where linear biofiltration systems can provide significant value. Once dominated by industrial and warehouse uses, the district has evolved into one of the city's most vibrant mixed-use neighborhoods, featuring residential developments, restaurants, retail spaces, offices, art galleries, public gathering areas, and an increasingly walkable streetscape.

As redevelopment has intensified, available land has become too valuable to dedicate large portions of individual sites to traditional stormwater facilities. At the same time, projects must continue to meet increasingly stringent stormwater management and water quality requirements while creating attractive public spaces that support the character of the neighborhood.

Linear biofiltration systems offer an effective solution to this challenge. By integrating engineered planting areas, streetscape vegetation, and stormwater treatment into sidewalks, pedestrian corridors, parking areas, and public plazas, developers can manage runoff close to its source without sacrificing valuable building area. These systems not only improve water quality but also support urban trees, reduce heat island effects, enhance pedestrian comfort, and reinforce the walkable, landscape-oriented character that has become a defining feature of neighborhoods like Wedgewood-Houston.

CHAPTER 4 - Components of a Linear Biofiltration System

Understanding How Individual Components Work Together as a Complete Treatment Train

Understanding the Building Blocks of Performance

The effectiveness of any linear biofiltration system depends upon the proper integration of several individual components. While system layouts and manufacturer designs may vary, nearly all successful biofiltration systems rely upon the same fundamental elements working together as a treatment train.

Each component performs a specific function within the overall process. Failure of any individual component can reduce treatment performance, increase maintenance requirements, or shorten system lifespan. Understanding these components is essential for engineers, contractors, owners, and maintenance personnel responsible for designing and operating these systems.

Surface Collection Systems

Every linear biofiltration system begins with one essential task: collecting stormwater runoff and directing it into the treatment process. Regardless of how sophisticated the filtration media or vegetation may be, the system cannot perform effectively unless runoff is captured efficiently and conveyed to the appropriate treatment area. For this reason, the design of the surface collection system is one of the first and most important considerations in any biofiltration project.

The method of collection varies depending on the characteristics of the site, the contributing drainage area, anticipated runoff volumes, and the overall objectives of the project. In some applications, runoff simply flows across adjacent pavement as sheet flow before entering the biofiltration area. This approach allows water to spread evenly across the treatment surface and is commonly used where grades and site geometry permit.

In more highly developed environments, runoff is often concentrated and directed into the system through engineered collection features. Curb openings allow stormwater flowing along the gutter line to enter the biofiltration area directly, making them a common choice along urban streets. Trench drains provide continuous linear collection where larger volumes of runoff must be intercepted, such as public plazas, parking areas, and transportation corridors. Slot drains perform the same basic function but utilize a narrow surface opening that maintains a cleaner architectural appearance, making them particularly well suited for pedestrian-oriented developments and high-profile public spaces.

Selecting the appropriate collection method is more than a hydraulic decision. It influences maintenance requirements, pedestrian accessibility, aesthetics, constructability, and the overall integration of the stormwater system into the surrounding development. The most successful projects treat the collection system as an integral part of the overall design, ensuring that stormwater enters the biofiltration system efficiently while complementing the character and function of the built environment.

Pretreatment Areas

If the engineered filtration media is considered the heart of a linear biofiltration system, pretreatment serves as its first line of defense. Although it often receives far less attention than vegetation or filtration media, pretreatment is one of the most important factors influencing the long-term performance and maintenance requirements of the entire system.

As stormwater flows across developed surfaces, it collects much more than dissolved pollutants. Leaves, trash, sediment, organic debris, mulch, cigarette butts, and other floatable materials are transported with the runoff. If these materials are allowed to enter the filtration media unchecked, they can clog surface openings, reduce infiltration rates, smother vegetation, and significantly shorten the useful life of the treatment system.

Pretreatment is designed to intercept these larger materials before stormwater reaches the primary filtration media. Depending on the application, pretreatment may consist of sediment forebays, sump structures, proprietary treatment devices, rock diaphragms, grass filter strips, or specially designed inlet zones that slow incoming flows and encourage heavier particles to settle out before entering the treatment area.

By reducing the amount of sediment and debris entering the system, pretreatment preserves the hydraulic capacity of the filtration media, extends maintenance intervals, protects vegetation, and improves the overall efficiency of pollutant removal. In many respects, pretreatment functions much like the air filter on an engine or the prefilter in a household water filtration system. While it may not receive much attention, it protects the more critical treatment components from unnecessary wear and premature failure.

For this reason, experienced stormwater professionals understand that the long-term success of a biofiltration system often depends as much on effective pretreatment as it does on the quality of the filtration media itself. A well-designed pretreatment system can add years to the operational life of a biofiltration installation while significantly reducing maintenance costs over time.

Engineered Filtration Media

At the center of every successful linear biofiltration system lies its most important component: the engineered filtration media. While vegetation provides many of the visible benefits associated with Green Stormwater

Infrastructure, it is the carefully designed media profile beneath the surface that performs much of the actual water quality treatment. In many respects, the filtration media serves as the engine that drives the entire system.

Unlike native soils, which vary considerably in composition and performance from one site to another, engineered filtration media is manufactured to meet specific hydraulic and water quality objectives. The media is typically composed of carefully proportioned blends of sand, topsoil, compost, organic matter, and, in some cases, specialty amendments selected to improve the removal of nutrients, metals, hydrocarbons, or other target pollutants. Every component is included for a reason, and the proportions are selected to create a growing medium that supports healthy vegetation while providing consistent stormwater treatment.

Designing filtration media requires balancing several competing objectives. Water must move through the system quickly enough to prevent excessive ponding and allow the facility to recover between storm events, yet slowly enough to provide meaningful contact with the media and the biological processes occurring within it. If water moves too quickly, treatment efficiency is reduced. If it moves too slowly, the system may remain saturated, limiting plant health and reducing its ability to accept runoff from subsequent storms.
Achieving this balance is one of the most important aspects of biofiltration system design and is a primary reason engineered media specifications are developed using extensive laboratory testing and field performance data rather than relying on locally available soils. The composition, properties, and performance of engineered filtration media will be explored in much greater detail in Chapter 5, where we examine the physical, chemical, and biological processes responsible for pollutant removal.

Vegetation

Perhaps no component of a linear biofiltration system is more misunderstood than its vegetation. To the casual observer, the plants, grasses, shrubs, and trees appear to serve primarily an aesthetic purpose, softening the appearance of the surrounding infrastructure and creating a more attractive landscape. While they certainly enhance the visual character of a site, properly selected vegetation performs a far more important role. It is an active component of the stormwater treatment system.

As stormwater moves through a biofiltration facility, vegetation contributes to treatment in several ways. Plant roots help stabilize the filtration media, reducing erosion and maintaining soil structure over time. Vegetation absorbs nutrients that would otherwise be transported downstream, while evapotranspiration returns a portion of the captured water back into the atmosphere. Root systems also support healthy microbial communities within the soil, enhancing the biological processes responsible for breaking down organic pollutants and improving overall water quality. Together, these processes allow vegetation to contribute directly to the hydraulic and environmental performance of the system.

Selecting appropriate plant species is therefore an engineering decision as much as a landscape decision. Designers must consider factors such as drought tolerance, flood tolerance, rooting depth, maintenance requirements, seasonal appearance, native adaptability, and long-term resilience. The objective is to establish vegetation capable of thriving under highly variable moisture conditions while continuing to provide reliable treatment performance throughout the life of the system.

Beyond their functional benefits, vegetation also shapes how communities perceive stormwater infrastructure. Traditional drainage systems are often hidden beneath the ground or isolated behind fences, making them largely invisible to the public. Linear biofiltration systems, however, place stormwater management within the landscape itself. Attractive planting palettes, healthy trees, and well-maintained vegetation transform engineered infrastructure into inviting public spaces that improve neighborhood character, support urban biodiversity, and demonstrate a community's commitment to environmental stewardship.

In many respects, vegetation represents the point where engineering and landscape architecture intersect. It is the element that allows a stormwater treatment facility to perform as sophisticated infrastructure while appearing to function as an attractive and natural part of the surrounding environment.

Underdrain Systems

One of the defining characteristics of many linear biofiltration systems is the presence of an underdrain beneath the engineered filtration media. While the primary objective of Green Stormwater Infrastructure is often to promote infiltration and mimic natural hydrology, not every site possesses the soil conditions necessary to support complete infiltration. Clay soils, shallow bedrock, high groundwater tables, contaminated soils, and utility conflicts can all limit the ability of stormwater to infiltrate into the native subgrade.
Underdrains address these challenges by providing a controlled pathway for treated stormwater to leave the system after it has passed through the engineered filtration media. Typically constructed from perforated high-density polyethylene (HDPE) pipe, PVC pipe, or other specialty drainage products, underdrains collect filtered water beneath the treatment zone and convey it to the downstream storm drainage network or another approved discharge point.

Beyond simply conveying water, underdrains play several important roles in maintaining the long-term performance of the system. By preventing prolonged saturation of the filtration media, they help maintain healthy growing conditions for vegetation, preserve the hydraulic capacity of the treatment media, and allow the system to recover more quickly between storm events. This recovery is particularly important during consecutive rainfall events, when the facility must be capable of accepting additional runoff without sacrificing treatment efficiency.

Underdrains also expand the range of sites where biofiltration systems can be successfully implemented. Rather than limiting Green Stormwater Infrastructure to locations with highly permeable native soils, designers can incorporate biofiltration into dense urban environments where infiltration may be limited or even undesirable. This flexibility has made underdrain systems an essential component of many streetscape, campus, commercial, and urban redevelopment projects.

It is important to recognize that the presence of an underdrain does not diminish the treatment value of a biofiltration system. The primary objective is not simply infiltration—it is allowing stormwater to pass through the engineered media, where physical filtration, chemical adsorption, and biological activity remove pollutants before the treated water is discharged. In many applications, the quality of the water leaving the system is just as important as the quantity that infiltrates into the ground.

Overflow Structures

No stormwater treatment system can be designed to capture and treat every rainfall event. While linear biofiltration systems are highly effective at managing frequent storms and improving water quality, there will inevitably be larger rainfall events that exceed their storage and treatment capacity. Rather than allowing these events to damage the facility, engineers incorporate overflow structures that safely manage excess runoff while protecting the integrity of the system.

Overflow structures function as a controlled release mechanism. Once the treatment area reaches its design storage capacity, excess stormwater is diverted through an overflow inlet, standpipe, curb opening, or similar structure before it can overtop the system or erode the surrounding landscape. This controlled bypass protects the engineered filtration media, preserves vegetation, minimizes erosion, and prevents damage to adjacent infrastructure during high-intensity storm events.

Depending on the project design, overflow structures may discharge to a municipal storm sewer, drainage channel, downstream detention facility, another Green Stormwater Infrastructure practice, or an approved receiving water. The discharge point is selected to ensure excess runoff can be conveyed safely without creating downstream flooding or erosion concerns.

An effective overflow system is not an indication that the biofiltration facility has failed. Instead, it reflects good engineering practice. Stormwater infrastructure should be designed to perform efficiently during routine rainfall events while remaining resilient during the larger storms that inevitably occur throughout its service life. Overflow structures provide that resilience, ensuring the system continues to function as intended without compromising public safety or long-term performance.

In many respects, overflow structures represent one of the most important principles of resilient infrastructure design: successful stormwater systems are designed not only for normal operating conditions but also for the extreme events that test their limits.

Inspection and Maintenance Features

The long-term success of any biofiltration system depends not only on how well it is designed and constructed, but also on how easily it can be inspected, maintained, and repaired throughout its service life. Even the most sophisticated stormwater treatment system will gradually lose performance if maintenance personnel cannot readily access critical components or identify developing issues before they become significant problems.

For this reason, modern linear biofiltration systems are increasingly designed with maintenance in mind. Features such as cleanout risers, observation wells, inspection ports, sediment access points, and designated maintenance access areas are incorporated into the system during the design phase rather than added as an afterthought. These components allow maintenance personnel to evaluate system performance, monitor water levels, inspect underdrains, remove accumulated sediment, and verify that the facility continues to function as intended.

Designing for maintenance provides significant long-term benefits. Routine inspections become faster and more efficient, maintenance activities can be performed with less disruption to surrounding public spaces, and potential problems can often be identified before they result in costly repairs or diminished treatment performance. Over the life of the facility, these seemingly small design considerations can substantially reduce operating costs while extending the useful life of the entire system.

Perhaps most importantly, inspection and maintenance features reinforce a fundamental principle of infrastructure management: stormwater systems should be designed not only to perform well on the day they are constructed, but to remain functional, accessible, and maintainable for decades to come. Infrastructure that is easy to inspect is far more likely to receive the regular maintenance necessary to protect both the owner's investment and the long-term performance of the system.

Building a Complete Treatment Train

No individual component performs all treatment functions. Successful systems rely on multiple components working together as an integrated treatment train. Stormwater enters through collection systems, passes through pretreatment zones, infiltrates through engineered media, interacts with vegetation, and exits through underdrain or overflow systems.

Each component contributes to the overall treatment objective. The result is a highly efficient infrastructure system capable of improving water quality while supporting broader urban development goals.

Looking Ahead

A linear biofiltration system is much more than a collection of individual components assembled within a landscaped corridor. It is an integrated treatment system in which every element—from surface collection and pretreatment to engineered filtration media, vegetation, underdrains, and overflow structures—performs a specific function while contributing to the overall performance of the facility. The reliability, efficiency, and longevity of the system depend upon how well these components are designed to work together as a coordinated treatment train.

While each component plays an important role, no element has a greater influence on long-term treatment performance than the engineered filtration media beneath the surface. It is within this carefully designed soil profile that much of the physical filtration, chemical adsorption, and biological activity responsible for pollutant removal takes place. Understanding how these engineered media are developed, how they function, and why they differ from ordinary soils provides the foundation for designing biofiltration systems that perform consistently for decades. The next chapter explores the science behind engineered filtration media and the technologies that make modern biofiltration systems possible.

Local Application – NDOT's Choose How You Move Initiative

Nashville's **Choose How You Move** initiative demonstrates how transportation infrastructure and stormwater management can be planned as complementary systems rather than independent disciplines. While the program is widely recognized for its investments in sidewalks, smart traffic signals, transit improvements, Complete Streets, and safer multimodal transportation, many of these projects also create opportunities to incorporate Green Stormwater Infrastructure into the public right-of-way. The program includes major investments in new sidewalks, Complete Streets corridors, upgraded intersections, and enhanced pedestrian environments throughout Davidson County.

As streets are reconstructed to accommodate pedestrians, cyclists, transit users, and motorists, engineers have the opportunity to rethink how stormwater is managed within those same corridors. Landscape strips between sidewalks and roadways, curb extensions, medians, transit stops, and public gathering spaces can all be designed to serve a dual purpose. Rather than functioning solely as decorative landscaping, these areas can become linear biofiltration systems that capture runoff, improve water quality, support urban trees, reduce heat island effects, and contribute to a safer, more attractive streetscape.

This integrated approach reflects a broader shift in urban infrastructure design. Sidewalks improve walkability. Street trees provide shade and comfort. Green Stormwater Infrastructure improves water quality and reduces runoff. Together, these elements create corridors that are more resilient, environmentally responsible, and enjoyable for the people who use them every day.

As Nashville continues implementing the Choose How You Move program over the coming years, projects throughout the city will provide opportunities to demonstrate how transportation improvements and sustainable stormwater management can work together. By viewing streets not simply as corridors for moving vehicles but as complete public spaces, engineers, planners, and landscape architects can deliver infrastructure that supports mobility, environmental stewardship, and long-term community investment simultaneously.

CHAPTER 5 - Engineered Soil Media and Filtration Technologies

Exploring the Science Beneath the Surface That Makes Biofiltration Systems Work

The Engine Behind Biofiltration

When most people look at a biofiltration system, they see plants, mulch, and landscaping. What they often fail to recognize is that the true treatment mechanism lies beneath the surface. The engineered soil media is the heart of every biofiltration system.

While vegetation provides important environmental and aesthetic benefits, it is the media profile that performs much of the pollutant removal, flow attenuation, and water quality treatment. Without properly designed filtration media, even the most attractive biofiltration system will fail to achieve its intended performance.

For this reason, engineers spend considerable effort developing media specifications that balance hydraulic performance, pollutant removal efficiency, plant health, constructability, and long-term maintenance requirements.

Engineered Media Is Not Simply Dirt

One of the most common misconceptions about biofiltration systems is that they are filled with ordinary topsoil. In reality, the filtration media is a carefully engineered blend of sand, topsoil, compost, organic matter, fine aggregates, and, when required, specialized amendments selected to meet specific hydraulic and water quality objectives.

The proportions of these materials vary based on project requirements, regulatory standards, and desired treatment performance. The goal is to create a growing medium that supports healthy vegetation while providing consistent filtration, pollutant removal, and long-term hydraulic performance.

Hydraulic Conductivity

One of the most important characteristics of engineered filtration media is its hydraulic conductivity, or the rate at which water moves through the soil profile. Achieving the proper balance is essential to the long-term performance of a biofiltration system.

If water moves too slowly, excessive ponding may occur, vegetation can become stressed, system recovery between storm events is reduced, and standing water may create maintenance concerns. Conversely, if water moves too quickly, runoff passes through the media before sufficient filtration and biological treatment can occur, reducing overall pollutant removal efficiency.

For this reason, engineered filtration media is designed to achieve a specific range of hydraulic conductivity that balances drainage with treatment. Most biofiltration specifications establish acceptable performance ranges to ensure the system functions reliably while providing consistent water quality treatment throughout its service life.

Physical Filtration

Physical filtration is the first stage of treatment within most biofiltration systems. As stormwater passes through the engineered media, suspended particles become trapped within the pore spaces between soil grains, removing sediment, trash, organic debris, and other fine particulates from the runoff.

This process provides benefits beyond simply removing visible materials. Many pollutants, including nutrients, heavy metals, and hydrocarbons, attach themselves to sediment particles. As sediment is captured, these attached pollutants are removed as well, significantly improving overall water quality.

Over time, however, accumulated sediment can reduce the permeability of the filtration media and diminish system performance. This is why effective pretreatment and routine maintenance are essential—they protect the filtration media, preserve hydraulic capacity, and extend the operational life of the system.

Chemical Treatment Mechanisms

In addition to physical filtration, engineered biofiltration media improves water quality through chemical treatment processes. One of the most important of these is **adsorption**, a process in which dissolved pollutants attach themselves to the surface of soil particles rather than passing through the system with the water.

This process is particularly effective at removing contaminants such as zinc, copper, lead, hydrocarbons, and certain nutrients commonly found in urban stormwater runoff. Although these pollutants may not be visible, they can have significant impacts on downstream water quality if left untreated.

To enhance treatment performance, many engineered media blends incorporate specialty amendments selected for their ability to increase adsorption capacity. Materials such as activated carbon, iron-based amendments, biochar, and specialty mineral blends are often included when projects require higher levels of pollutant removal or must meet specific regulatory performance standards.

As stormwater regulations continue to evolve, so too does the science behind engineered filtration media. Ongoing research and product development continue to improve the ability of biofiltration systems to target emerging pollutants while maintaining reliable hydraulic performance and supporting healthy vegetation.

Biological Treatment

Perhaps the most fascinating aspect of a biofiltration system is that much of its treatment occurs through natural biological processes. Healthy filtration media supports diverse communities of bacteria, fungi, and other microorganisms that actively participate in improving water quality.

As stormwater passes through the media, these microorganisms decompose organic matter, break down hydrocarbons, transform nutrients into less harmful forms, and contribute to the overall health and stability of the soil. Working in partnership with plant roots, they create a living ecosystem that continuously treats stormwater long after construction is complete.

Unlike purely mechanical treatment devices, a biofiltration system becomes more than a collection of engineered components. It functions as a living treatment facility, where physical filtration, chemical adsorption, and biological activity work together to improve water quality every time it rains.

Specialty Media for Enhanced Performance

While conventional engineered filtration media provides excellent treatment for most stormwater applications, some projects require enhanced removal of specific pollutants to meet regulatory requirements or site-specific water quality objectives. In these situations, engineers may incorporate specialty media amendments designed to target particular contaminants.

Depending on project needs, these enhancements may include phosphorus-removal media to reduce nutrient loading, activated carbon for improved removal of dissolved organic compounds and hydrocarbons, biochar to increase adsorption capacity while improving soil structure, or specialized mineral amendments that enhance the removal of dissolved metals commonly found in urban runoff.

The selection of these materials is based on the pollutants of concern, regulatory performance requirements, and the long-term treatment objectives established during project design. As research continues and water quality standards evolve, specialty media technologies will play an increasingly important role in helping biofiltration systems address emerging environmental challenges.

Long-Term Media Performance

Like any infrastructure asset, engineered filtration media gradually changes over time. Sediment loading, pollutant concentrations, hydraulic loading rates, vegetation health, and maintenance practices all influence how well the media continues to perform throughout its service life.

The good news is that properly designed and maintained biofiltration systems can remain highly effective for many years. Routine inspections, effective pretreatment, healthy vegetation, and periodic maintenance help preserve the hydraulic capacity of the media, maintain treatment performance, and delay the need for rehabilitation or replacement.

Ultimately, the long-term success of a biofiltration system depends not only on how well it is designed, but also on how well it is maintained. Understanding this relationship is essential to protecting both the owner's investment and the system's ability to provide reliable water quality treatment for decades.

Looking Ahead

Although engineered filtration media is hidden beneath the surface, it serves as the primary treatment engine within a biofiltration system. Through the combined processes of physical filtration, chemical adsorption, and biological activity, the media removes pollutants while supporting healthy vegetation and regulating the movement of stormwater through the system. Achieving the proper balance between hydraulic performance, pollutant removal, and long-term durability is one of the most important aspects of successful biofiltration design.

While the media provides the foundation for treatment, it does not function alone. Healthy vegetation and well-developed root systems play an equally important role by stabilizing the media, supporting biological activity, reducing runoff through evapotranspiration, and improving the overall performance of the system. The next chapter explores how urban forestry and stormwater infrastructure work together to create greener, healthier, and more resilient communities.

Local Application – Capitol View, Nashville

The Capitol View development along Charlotte Avenue illustrates the type of mixed-use urban environment where linear biofiltration systems can provide significant value. Developments of this scale must balance office space, residential buildings, retail, restaurants, structured parking, sidewalks, and public gathering areas while still meeting stringent stormwater management requirements.

Rather than relying exclusively on conventional underground drainage infrastructure, landscaped streetscapes and pedestrian corridors can be designed to function as active stormwater treatment systems. During rainfall events, runoff from adjacent streets and sidewalks enters engineered planting areas where it is filtered through specially designed media. Sediment, nutrients, heavy metals, and hydrocarbons are removed before the treated water is conveyed through an underdrain system or discharged downstream.

To visitors, these areas appear to be thoughtfully designed landscaping that enhances the pedestrian experience. In reality, they are highly engineered treatment systems working continuously to improve water quality while contributing to the character and sustainability of the development.

CHAPTER 6 - Urban Forestry and Stormwater Integration

Designing Trees, Soil, and Stormwater Infrastructure to Function as One System

Trees as Infrastructure

Historically, trees and stormwater infrastructure were viewed as separate elements of urban design. Engineers focused on drainage systems. Landscape architects focused on vegetation. Urban planners focused on public space. Today, these disciplines are increasingly converging.

Modern stormwater management recognizes that trees can serve as functional infrastructure assets that contribute directly to runoff reduction, water quality improvement, urban cooling, and public health.
When properly integrated into biofiltration systems, urban trees become active participants in the treatment process. This integration represents one of the most significant advancements in modern Green Stormwater Infrastructure.

The Value of Urban Trees

Trees provide benefits that extend far beyond aesthetics. While they are often appreciated for their beauty and seasonal character, they also function as essential components of modern Green Stormwater Infrastructure. Mature urban trees provide shade, sequester carbon, improve air quality, reduce ambient temperatures, create wildlife habitat, and contribute to healthier, more livable communities.

From a stormwater perspective, trees intercept rainfall before it reaches the ground, reducing runoff volumes and slowing the movement of water across developed sites. Their root systems stabilize soils, promote infiltration, support healthy microbial activity, and remove nutrients through natural biological processes. Through evapotranspiration, trees also return significant amounts of captured stormwater to the atmosphere, further reducing runoff volumes entering downstream drainage systems.

In Middle Tennessee, species such as **Bald Cypress**, **Swamp White Oak**, **Willow Oak**, **Overcup Oak**, **American Sycamore**, **River Birch**, **Black Gum (Tupelo)**, and **Kentucky Coffeetree** are frequently considered for urban streetscapes and Green Stormwater Infrastructure because they tolerate periodic inundation while adapting well to urban conditions. Selecting the appropriate species is an important design decision that balances stormwater performance, mature canopy size, rooting characteristics, maintenance requirements, and long-term resilience.

Studies have shown that a mature urban tree can intercept thousands of gallons of rainfall annually before it ever reaches the ground. When multiplied across an entire streetscape or redevelopment district, this interception represents a significant form of source control, reducing runoff while improving both water quality and the pedestrian experience.

The Urban Tree Challenge

Despite their many benefits, establishing healthy trees in urban environments is often far more challenging than planting them. Unlike natural forests, city trees must compete with buildings, utilities, sidewalks, roadways, and other infrastructure for limited space and resources. Compacted soils, restricted rooting volume, poor drainage, construction impacts, and the urban heat island effect all contribute to reduced tree health and shorter life expectancy.

These challenges are particularly common throughout rapidly growing communities such as Nashville, where redevelopment often occurs on heavily disturbed sites with extensive underground utilities and limited available soil volume. Traditional tree pits frequently provide insufficient space for healthy root development, preventing trees from reaching their mature size and limiting the environmental and stormwater benefits they can provide.

Modern Green Stormwater Infrastructure seeks to overcome these limitations by designing systems that allow trees and infrastructure to function together rather than compete with one another. Through the use of engineered soils, structural soil systems, suspended pavement technologies, and thoughtfully designed biofiltration facilities, today's urban trees can become long-term infrastructure assets rather than short-lived landscape features.

Tree Pits as Stormwater Infrastructure

One of the most innovative developments in Green Stormwater Infrastructure has been the evolution of the traditional tree pit into a functional stormwater treatment system. Rather than serving solely as a planting area, modern tree pits are increasingly engineered as bioretention facilities that capture, treat, and manage runoff close to its source.

During rainfall events, stormwater is directed into the tree pit where it is temporarily stored before filtering through engineered media. As the water moves through the soil profile, sediment and pollutants are removed while vegetation and soil microorganisms contribute to the treatment process. Depending on site conditions, the treated runoff may infiltrate into the native soil or be collected by an underdrain system for controlled discharge.

This approach transforms a conventional landscape feature into an active component of the stormwater treatment train. Tree pits improve water quality, reduce runoff volumes, support healthy urban trees, and enhance the pedestrian environment without requiring additional land dedicated solely to stormwater management. Engineered tree pits have become an increasingly common feature along Complete Streets, downtown revitalization projects, and mixed-use developments where available space is limited, and every square foot must serve multiple purposes. Communities such as Nashville are incorporating these practices into streetscape improvements because they provide lasting environmental, aesthetic, and infrastructure benefits within the public right-of-way.

Structural Soil Systems

Healthy urban trees require far more than a planting hole—they require adequate soil volume to support long-term root growth. In traditional urban construction, however, pavement, underground utilities, and heavily compacted subgrades often restrict root development, preventing trees from reaching their mature size and limiting the many environmental and stormwater benefits they provide.

Structural soil systems address this challenge by allowing pavement and pedestrian areas to remain structurally stable while preserving uncompacted soil beneath the surface. These systems create shared underground space that supports sidewalks, plazas, streets, and other hardscape features while providing room for root expansion, stormwater storage, and healthy soil development.

By separating structural support from rooting volume, engineers and landscape architects can establish healthier, longer-lived urban trees without compromising the integrity of the surrounding infrastructure. This approach has become increasingly common in streetscape improvements, Complete Streets projects, urban redevelopment, and municipal infrastructure throughout Nashville and other rapidly growing communities where every square foot of surface area must serve multiple purposes.

One of the best-known examples of this technology is the **Silva Cell®** system, developed by **DeepRoot**, which uses suspended pavement to create large volumes of uncompacted soil beneath sidewalks, streets, and public plazas. Similar structural soil systems are now used throughout North America to support healthy urban tree canopies while integrating Green Stormwater Infrastructure into dense urban environments.

Regardless of the manufacturer, the engineering objective remains the same: provide sufficient rooting volume to support mature trees, maintain the structural capacity of the pavement above, and create opportunities for stormwater storage, infiltration, and treatment beneath the surface. The result is healthier urban forests, more resilient infrastructure, and streetscapes that continue to improve both environmental performance and community character for decades after construction is complete.

Root Barriers

Healthy trees and healthy infrastructure do not always develop in harmony. As trees mature, their roots naturally seek moisture, oxygen, and available space, often following paths of least resistance beneath sidewalks, curbs, pavement, utilities, and drainage systems. Without proper planning, root growth can lead to cracked pavement, displaced sidewalks, damaged utilities, and increased maintenance costs over the life of a project.

Root barriers are designed to manage this interaction by directing root growth away from critical infrastructure while allowing trees access to adequate soil volume for healthy development. Installed vertically within the soil profile, these barriers encourage roots to grow deeper rather than outward, reducing the likelihood of conflicts with nearby hardscape and underground utilities.

One of the most widely recognized examples of this technology is the **DeepRoot Root Barrier®** system, which has been used extensively in urban streetscapes, commercial developments, and municipal infrastructure projects throughout North America. Similar root management systems are available from several manufacturers, all designed to balance healthy tree growth with long-term infrastructure protection.

Regardless of the manufacturer, the engineering objective remains the same: allow trees to reach their full potential without compromising the performance, safety, or longevity of the surrounding infrastructure. When combined with structural soil systems, suspended pavement technologies, and properly designed biofiltration facilities, root barriers help create urban landscapes where trees and infrastructure can successfully coexist for decades.

Suspended Pavement Systems

Suspended pavement systems represent one of the most significant advancements in urban forestry and Green Stormwater Infrastructure. By supporting pavement on an underground structural framework, these systems create large volumes of uncompacted soil beneath sidewalks, streets, and public spaces without sacrificing structural capacity.

One of the best-known examples is the **Silva Cell®** system, developed by **DeepRoot**, which has become a widely specified solution for urban streetscapes, Complete Streets projects, and mixed-use developments. Similar suspended pavement technologies allow healthy root development, stormwater storage, utility coordination, and long-term canopy growth within densely developed environments.

Regardless of the manufacturer, the engineering objective remains the same: maximize rooting volume beneath paved surfaces while integrating stormwater management and preserving the long-term performance of both trees and infrastructure.

Urban Forestry and the East Bank Vision

Large-scale redevelopment projects increasingly recognize that urban trees are more than landscape features—they are critical components of resilient infrastructure. Nashville's East Bank redevelopment, along with projects such as Nashville Yards and Wedgewood-Houston, reflects a growing emphasis on walkable streets, expanded public spaces, and healthier urban environments supported by a robust tree canopy.

Achieving that vision requires far more than planting trees after construction is complete. It demands thoughtful planning that provides adequate soil volume, stormwater access, root management, and long-term coordination between civil engineers, landscape architects, utility designers, and municipal agencies. When these elements are integrated from the beginning, urban forestry becomes an active part of the stormwater management system rather than an afterthought.

The result is infrastructure that improves water quality, supports healthy tree growth, enhances the pedestrian experience, and creates more resilient communities. As Nashville and other Middle Tennessee communities continue to grow, this integrated approach to urban forestry and Green Stormwater Infrastructure will play an increasingly important role in shaping the public spaces of the future.

Creating Infrastructure That Appreciates in Value

Most infrastructure assets gradually deteriorate over time, requiring ongoing maintenance while providing fewer benefits as they age. Healthy urban trees are different. When properly planned and supported, they become more valuable with each passing year as their canopies expand and their environmental benefits continue to grow.

Mature trees provide increasing shade, intercept greater volumes of rainfall, improve air quality, reduce urban heat, and create more attractive, walkable public spaces. They also contribute to higher property values, improved community character, and healthier urban ecosystems.

When integrated with well-designed Green Stormwater Infrastructure, urban trees become one of the few infrastructure investments that continues to deliver increasing returns for decades. Designing for long-term tree health is therefore not simply a landscape decision—it is an investment in more resilient, sustainable, and valuable communities.

Looking Ahead

Urban forestry and stormwater management are no longer separate disciplines. Through engineered tree pits, structural soil systems, root barriers, suspended pavement technologies, and thoughtfully selected vegetation, modern Green Stormwater Infrastructure demonstrates that healthy urban trees can serve as both environmental assets and functional infrastructure. When designed together, these systems improve water quality, strengthen urban tree canopies, enhance the pedestrian experience, and create more resilient communities.

While these practices form the foundation of successful urban biofiltration, they rely on a much broader family of supporting products and technologies to function effectively. Trench drains, permeable pavements, geocells, geotextiles, underdrain systems, and other engineered components all play important roles in collecting, conveying, supporting, and treating stormwater. The next chapter explores how these complementary technologies work together to create complete Green Stormwater Infrastructure systems.

Local Application – Nashville Yards Urban Forestry

The Nashville Yards development illustrates how modern urban forestry has become an essential part of infrastructure planning rather than simply a landscape improvement. Built within one of Nashville's most densely developed districts, the project required designers to accommodate streets, sidewalks, utilities, parking structures, public plazas, and thousands of daily pedestrians while creating an attractive and comfortable urban environment.

Achieving those objectives required more than planting trees along the sidewalks. Healthy urban tree canopies depend on adequate soil volume, thoughtful root management, coordinated utility planning, and systems that allow stormwater to reach the rooting zone. Technologies such as structural soil systems, suspended pavement systems like **Silva Cell®**, engineered tree pits, and root barriers provide solutions that allow trees and infrastructure to coexist within highly constrained urban environments.

As redevelopment continues throughout Nashville, projects such as Nashville Yards demonstrate that urban forestry is no longer simply an architectural feature—it is a critical component of resilient infrastructure that improves stormwater management, pedestrian comfort, environmental performance, and the long-term value of the built environment.

CHAPTER 7 - Supporting Products and Technologies

Connecting Drainage Products, Geosynthetics, and Landscape Systems Into Complete Green Infrastructure Solutions

Building a Complete Green Infrastructure System

Linear biofiltration systems rarely operate as standalone installations. While engineered soil media and vegetation provide the primary treatment mechanisms, numerous supporting products and technologies contribute to the overall effectiveness, durability, and functionality of the system.

The most successful projects integrate multiple infrastructure components into a coordinated treatment train. Each element performs a specific role in collecting, conveying, storing, filtering, or protecting stormwater as it moves through the site. Understanding these supporting technologies helps engineers, contractors, and owners recognize how individual products contribute to overall system performance.

Trench Drains and Slot Drains

Every stormwater treatment system begins with effective runoff collection. In urban environments, trench drains and slot drains provide efficient, low-profile solutions for intercepting stormwater while maintaining pedestrian accessibility, architectural aesthetics, and reliable hydraulic performance. These systems are commonly integrated into streetscapes, plazas, parking areas, and other public spaces where stormwater must be collected without disrupting the surrounding environment.

Trench Drains

Trench drains are linear surface drainage systems designed to intercept and convey stormwater before it can pond on paved surfaces or enter adjacent buildings and pedestrian areas. Unlike conventional point drains, trench drains collect runoff continuously along their length, making them particularly effective in areas with large, paved surfaces or concentrated sheet flow.

Today, trench drains are commonly incorporated into streetscapes, public plazas, parking facilities, commercial developments, industrial sites, loading docks, airports, sports facilities, and transit stations where reliable surface drainage and pedestrian safety are essential.

Modern trench drain systems are available in a variety of materials and load ratings to meet specific project requirements. Lightweight HDPE systems are often selected for commercial landscapes and light-duty applications, while polymer concrete, fiberglass, and reinforced concrete systems provide greater structural capacity for heavy vehicular traffic and industrial environments. Grating options range from decorative architectural patterns for public spaces to heavy-duty ductile iron grates designed for highways, loading docks, and airport pavements.

Several manufacturers offer trench drain systems that serve different segments of the market. **NDS** provides a broad range of residential, commercial, and light-duty drainage solutions, while **ACO** is widely recognized for architectural and heavy-duty trench drain systems used in transportation, commercial, and municipal projects. **Eric'sons Dura Trench** manufactures fiberglass trench drain systems that offer excellent corrosion resistance and are commonly specified for industrial facilities, food processing plants, and water or wastewater applications.

Here in Middle Tennessee, **JBS** manufactures precast concrete trench drain systems that are frequently used on municipal, industrial, and transportation projects requiring high structural capacity and long-term durability. Regardless of the manufacturer or material, the engineering objective remains the same: rapidly collect surface runoff, safely convey stormwater to the appropriate treatment or drainage system, and integrate seamlessly into the surrounding infrastructure while meeting the hydraulic, structural, and aesthetic requirements of the project.

Slot Drains

Slot drains perform the same basic function as trench drains but offer a cleaner, more discreet appearance by replacing a traditional grate with a narrow continuous slot at the pavement surface. This architectural profile makes them particularly well suited for urban streetscapes, public plazas, pedestrian corridors, parks, and other high-visibility environments where aesthetics are as important as hydraulic performance.

In addition to their appearance, slot drains provide a continuous collection point that efficiently intercepts sheet flow while reducing trip hazards and simplifying maintenance in heavily traveled public spaces. They are frequently incorporated into mixed-use developments, civic spaces, transportation projects, and Complete Streets initiatives where stormwater infrastructure must blend seamlessly into the surrounding landscape.

Several manufacturers offer slot drain systems designed for a variety of applications. **ACO** is widely recognized for architectural slot drain systems used in commercial and municipal projects, while **NDS** offers drainage solutions that complement landscape and light commercial applications. Other manufacturers provide systems tailored to specific hydraulic, structural, or aesthetic requirements depending on the project.

Whether a designer selects a trench drain or a slot drain ultimately depends on the project's hydraulic demands, anticipated traffic loading, maintenance requirements, architectural character, and overall design objectives. In either case, these systems often serve as the first component of the treatment train, efficiently collecting runoff and directing it to downstream biofiltration systems, water quality treatment devices, or conventional storm drainage infrastructure.

Permeable Pavement Systems

Permeable pavement systems are designed to reduce stormwater runoff by allowing rainfall to pass through the pavement surface and into an underlying stone reservoir where it can temporarily be stored, infiltrated, or conveyed to downstream treatment systems. Unlike conventional pavement, which rapidly sheds runoff, permeable pavements help restore natural hydrologic processes while supporting both pedestrian and vehicular traffic.

Common permeable pavement systems include **permeable interlocking concrete pavers (PICP)**, **pervious concrete**, and **porous asphalt**. Each utilizes a different surface material, but all are designed to reduce runoff, promote infiltration, and improve water quality when properly designed and maintained.

Permeable pavements are increasingly specified for parking lots, sidewalks, plazas, trails, low-volume roadways, and other developments seeking to reduce impervious cover while meeting stormwater management requirements established by agencies such as **TDEC**, local **MS4** programs, and municipal stormwater regulations.

When incorporated into a larger treatment train, permeable pavements reduce the volume of runoff reaching downstream biofiltration systems, water quality units, and detention facilities, improving overall system performance.

Grass and Gravel Paving Systems
Not every surface requires traditional pavement. Areas with occasional vehicular traffic, emergency access requirements, or low-speed vehicle movements often benefit from permeable stabilization systems that maintain infiltration while supporting structural loads.

Grass pavers utilize structural grids filled with soil and vegetation to create reinforced turf surfaces suitable for emergency access lanes, overflow parking, parks, and greenways. Gravel paving systems use interconnected cells to stabilize aggregate while preventing rutting and migration, making them well suited for service roads, utility access corridors, trails, and low-volume parking areas.

Manufacturers such as **NDS**, **Invisible Structures**, and other specialty suppliers offer systems that balance structural performance with environmental benefits. When properly designed, these technologies reduce impervious cover, improve infiltration, and preserve the natural appearance of the landscape.

Geocellular Confinement Systems
Geocellular confinement systems, commonly known as **geocells**, provide three-dimensional soil confinement that improves load distribution, reduces erosion, and stabilizes weak soils. Although originally developed for ground stabilization, geocells have become valuable components of Green Stormwater Infrastructure because they help support vegetation while maintaining infiltration and reducing soil movement.

Applications include slope stabilization, channel protection, reinforced landscape areas, tree protection zones, permeable pavement support, and stormwater infiltration systems.

One of the best-known examples is **Presto Geoweb®**, which pioneered geocellular confinement technology. Similar systems are available from manufacturers such as **Strata Systems**, **Maccaferri**, and others. Regardless of the manufacturer, the engineering objective remains the same: improve soil stability while preserving permeability and supporting long-term vegetation establishment.

Geotextiles
Geotextiles are one of the most versatile and widely used materials in civil engineering, serving critical functions in stormwater management, transportation, earthwork, and environmental construction. Within Green Stormwater Infrastructure, they help improve system performance by separating soil layers, filtering stormwater, reinforcing weak subgrades, and protecting sensitive system components.

In biofiltration systems, nonwoven geotextiles are commonly used to separate engineered filtration media from underlying stone reservoirs while maintaining hydraulic connectivity. Woven geotextiles may be incorporated where additional soil stabilization or reinforcement is required. Selecting the appropriate geotextile is essential to maintaining infiltration rates, preserving media integrity, and ensuring long-term system performance.

One of the most recognized manufacturers in this field is **Carthage Mills**, whose geotextiles are widely specified for stormwater, transportation, and environmental projects throughout North America. Other manufacturers, including **Propex**, **Skaps, TenCate, Solmax**, and **Maccaferri**, offer geosynthetic products designed to address a wide range of engineering applications.

Regardless of the manufacturer, the engineering objective remains the same: select the appropriate geotextile for the specific application and allow it to perform its intended function without compromising drainage, filtration, or structural performance. Because geotextiles are used extensively throughout civil infrastructure, they are covered in much greater detail in **Terrain Civil University – Module 6: Geotextiles and Geosynthetics**.

Underdrain Systems

Once stormwater has passed through the engineered filtration media, it must be safely conveyed to the next stage of the drainage system. Underdrains provide that pathway, collecting treated water beneath the biofiltration media and transporting it to downstream storm sewer systems, detention facilities, water quality structures, or approved discharge points.

Most underdrain systems consist of perforated HDPE or PVC pipe surrounded by clean, uniformly graded aggregate and wrapped in an appropriate nonwoven geotextile to prevent soil migration while maintaining long-term hydraulic performance. Depending on the application, cleanouts, inspection ports, observation wells, and drainage structures may also be incorporated to simplify inspection and maintenance.

One of the most common materials used in these systems is **corrugated HDPE drainage pipe**, such as **ADS N-12®** or similar products, although PVC and other specialty drainage products may also be specified depending on hydraulic requirements, local standards, and owner preferences. Connections to downstream drainage networks frequently utilize structures such as **Nyloplast®** basins or watertight connection systems like **Inserta Tee®**, creating a complete and maintainable stormwater conveyance system.

Regardless of the products selected, the engineering objective remains the same: collect treated stormwater efficiently, preserve the hydraulic performance of the biofiltration system, and ensure the facility is ready to accept the next rainfall event while providing reliable, long-term service.

Inspection and Monitoring Features

Modern stormwater infrastructure is increasingly being designed with long-term asset management in mind. As municipalities, transportation agencies, developers, and property owners invest more heavily in Green Stormwater Infrastructure, there is growing recognition that long-term performance depends on the ability to inspect, monitor, and maintain these systems throughout their service life.

For this reason, many biofiltration systems incorporate observation wells, cleanout risers, inspection ports, maintenance access points, and other features that allow operators to evaluate system performance without disturbing the treatment media or surrounding landscape. These components simplify routine inspections, facilitate maintenance, and help identify potential issues before they affect hydraulic or water quality performance.

The industry is also moving toward **smart stormwater infrastructure**, where sensors, remote monitoring, and data collection technologies provide real-time information on water levels, flow rates, infiltration performance, and maintenance needs. As municipalities adopt more comprehensive asset management programs and MS4 permit requirements continue to evolve, these technologies are expected to play an increasingly important role in managing stormwater infrastructure.

Regardless of the technology used, the engineering objective remains the same: design systems that are not only effective on the day they are installed, but also accessible, maintainable, and measurable throughout their operational life. Infrastructure that can be monitored is more likely to be maintained, and infrastructure that is properly maintained is far more likely to deliver its intended performance for decades.

Creating a Complete Treatment Train

The true strength of Green Stormwater Infrastructure lies not in any single product or technology, but in the way multiple systems work together to manage stormwater from the moment it falls until it leaves the site. Permeable pavements reduce runoff at the surface. Trench drains and slot drains efficiently collect and convey stormwater.

Biofiltration systems improve water quality through engineered media and vegetation. Structural soils, suspended pavement systems, and urban forestry support healthy tree growth while contributing to stormwater treatment. Beneath the surface, underdrain networks, drainage structures, geotextiles, and monitoring features ensure the system continues to perform reliably for years to come.

No individual component is responsible for the success of the system. Instead, each element performs a specific function within the treatment train, contributing to a coordinated approach that improves water quality, reduces runoff, supports healthy landscapes, and creates more resilient communities.

This systems-based approach represents the future of stormwater management. As cities like Nashville continue to redevelop and grow, successful projects will increasingly rely on integrated infrastructure that balances engineering performance, environmental stewardship, long-term maintainability, and the needs of the people who live, work, and gather within these spaces.

Looking Ahead

Modern Green Stormwater Infrastructure is built on integration. Trench drains, slot drains, permeable pavements, geocells, geotextiles, structural soils, underdrain systems, and monitoring technologies each perform a specific function, but their greatest value is realized when they work together as a coordinated treatment train. Successful stormwater systems are not defined by any single product - they are defined by how well each component contributes to the performance of the whole.

While these technologies provide the tools to build effective stormwater systems, engineers must also determine which solutions are best suited for a particular project. The next chapter explores many of the manufacturers, technologies, and product families that shape today's Green Stormwater Infrastructure industry, demonstrating how different companies apply the same engineering principles to solve complex stormwater challenges.

Field Application – Nashville’s East Bank Civic Corridor

The planned redevelopment of Nashville's East Bank, including the new **Tennessee Performing Arts Center (TPAC)** and its connection to the new **Nissan Stadium**, illustrates how multiple Green Stormwater Infrastructure technologies can be integrated into a single public space. Designed to accommodate thousands of pedestrians while creating an attractive civic destination, the corridor will require careful coordination between transportation infrastructure, utilities, landscaping, stormwater management, and public gathering spaces.

Rather than relying solely on conventional underground drainage systems, projects of this scale create opportunities to integrate trench drains, slot drains, permeable pavements, engineered tree pits, structural soils, suspended pavement systems, biofiltration planters, and urban forestry into the streetscape. Together, these systems can collect runoff, improve water quality, support healthy tree growth, reduce urban heat, and enhance the pedestrian experience while meeting stormwater management requirements established by **Metro Water Services**, **NDOT**, and **TDEC**.

Projects like the East Bank Civic Corridor demonstrate that successful Green Stormwater Infrastructure is not defined by a single product or manufacturer. It is the result of thoughtfully integrating multiple technologies into one coordinated treatment train that supports environmental performance, public safety, long-term maintainability, and the creation of vibrant public spaces.

CHAPTER 8 - Manufacturers and System Providers

Understanding the Technologies, Product Categories, and Companies Shaping Modern Green Stormwater Infrastructure

Understanding the Market

As Green Stormwater Infrastructure has evolved, manufacturers have developed an increasingly diverse range of products designed to improve water quality, manage urban runoff, and support sustainable site development. Although these systems differ in appearance, materials, and proprietary features, they are all built upon the same fundamental engineering principles explored throughout this module: filtration, storage, infiltration, vegetation, pollutant removal, and treatment train integration.

Each manufacturer brings a unique approach to solving these challenges. Some technologies emphasize a smaller footprint for dense urban environments, while others focus on enhanced pollutant removal, simplified maintenance, modular construction, or long-term lifecycle performance. The result is a marketplace that offers engineers and owners multiple solutions capable of meeting similar project objectives.

For designers, contractors, and owners, understanding the infrastructure category is ultimately more important than understanding any single product. The objective is not to specify a particular manufacturer, but to select the technology that best satisfies the project's hydraulic requirements, water quality goals, regulatory standards, constructability considerations, maintenance capabilities, and long-term performance expectations.

Successful stormwater professionals begin by understanding the engineering problem. Product selection follows.

Proprietary Versus Non-Proprietary Systems

One of the first decisions engineers make when selecting a stormwater treatment system is whether the project will utilize a proprietary or non-proprietary approach. Neither is inherently better than the other. The appropriate choice depends on the project's objectives, regulatory requirements, owner preferences, budget, maintenance capabilities, and overall design philosophy.

Non-proprietary systems are designed using established engineering principles and project-specific specifications rather than a single manufacturer's product. Examples include bioretention areas, rain gardens, bioswales, tree trenches, infiltration systems, and other Green Stormwater Infrastructure practices that can be constructed using commonly available materials. These systems offer flexibility in design, encourage competitive bidding, and can often be tailored to the unique characteristics of a site.

Proprietary systems, on the other hand, utilize manufacturer-developed technologies that have been engineered, tested, and standardized to deliver specific levels of hydraulic or water quality performance. Many agencies and municipalities recognize these systems because they are supported by documented testing, established maintenance procedures, and predictable performance data. In many cases, proprietary technologies also provide a smaller footprint, simplified design, and easier integration into highly constrained urban environments.

Examples of proprietary systems include **Contech's Modular Wetlands Linear®**, **CDS® Hydrodynamic Separators**, **Jellyfish® Filters**, **ADS Barracuda®**, **StormFilter®**, and numerous other manufactured treatment devices that have become widely accepted throughout the stormwater industry.
In practice, many of today's most successful projects combine both approaches. A development may utilize non-proprietary bioretention areas and bioswales alongside proprietary water quality units, hydrodynamic separators, or underground detention systems to create a treatment train that meets regulatory requirements while addressing site-specific constraints.

The engineering objective is not to choose between proprietary and non-proprietary systems—it is to understand the strengths of each approach and apply the right technology in the right location to achieve the best overall project outcome.

ADS and StormTech

Advanced Drainage Systems (ADS) is one of North America's leading manufacturers of stormwater management and drainage infrastructure. While many engineers associate ADS with StormTech® underground detention and retention systems, the company's product portfolio extends well beyond stormwater storage and includes HDPE pipe, water quality treatment technologies, drainage structures, chambers, fittings, and complete stormwater management solutions.

StormTech chamber systems are widely used to provide underground detention, retention, infiltration, and stormwater harvesting beneath parking lots, roadways, parks, and commercial developments where preserving developable land is a priority. By relocating stormwater storage below grade, these systems allow valuable surface space to remain available for buildings, parking, landscaping, and public amenities.

Beyond storage, ADS offers products that support nearly every stage of the stormwater treatment train. Dual-wall N-12® pipe and HP Storm® pipe provide durable conveyance for storm sewer systems, while Nyloplast® drainage structures improve accessibility and maintenance. Water quality technologies such as the Barracuda®

Hydrodynamic Separator provide pretreatment by removing sediment, debris, trash, and floatables before runoff reaches downstream biofiltration systems, detention facilities, or receiving waters.

Because of this broad product offering, ADS systems are frequently integrated with upstream Green Stormwater Infrastructure practices such as permeable pavements, bioswales, engineered tree pits, and linear biofiltration systems. Together, these technologies create a complete treatment train that manages runoff from collection through conveyance, treatment, storage, and controlled release.

Regardless of the specific products selected, the engineering objective remains the same: safely collect, convey, treat, store, and release stormwater while meeting hydraulic, water quality, constructability, and long-term maintenance requirements established by project owners and regulatory agencies.

NDS

NDS Drainage Solutions has been a leading innovator in residential, commercial, and municipal drainage products for more than 50 years. Their extensive product portfolio supports nearly every stage of stormwater collection and conveyance, making NDS one of the most widely recognized manufacturers of surface drainage and landscape water management systems in North America.

The company's offerings include trench drains, slot drains, catch basins, channel drains, permeable pavement systems, drainage fittings, flow management products, and a variety of stormwater collection and distribution components. These products are commonly specified for streetscapes, parks, commercial developments, athletic facilities, residential communities, and municipal infrastructure where effective surface drainage and water management are essential.

Within Green Stormwater Infrastructure, NDS products frequently serve as the first link in the treatment train. Surface drainage systems efficiently collect runoff and direct it toward engineered tree pits, biofiltration planters, permeable pavement systems, water quality treatment devices, or conventional storm drainage networks. Their broad product offering allows engineers to create integrated drainage systems that balance hydraulic performance, constructability, maintenance, and aesthetics.

Beyond drainage, NDS has continued expanding its product portfolio to include technologies that support infiltration, groundwater recharge, and sustainable site development. Systems such as **Flo-Well®** dry wells, permeable pavement products, and water harvesting components reflect the industry's growing emphasis on managing stormwater as close to its source as possible.

Regardless of the specific products selected, the engineering objective remains the same: efficiently collect, convey, distribute, and manage stormwater while supporting long-term infrastructure performance and creating safer, more resilient communities.

Contech Engineered Solutions

Contech Engineered Solutions is one of North America's leading providers of stormwater management, water quality treatment, and site infrastructure products. The company's portfolio includes a broad range of engineered solutions designed to address runoff collection, pollutant removal, detention, retention, infiltration, erosion control, and environmental compliance across commercial, municipal, transportation, and land development projects.

Contech's water quality technologies include **Modular Wetlands Linear®**, **Modular Wetlands Biofiltration Systems**, **CDS® Hydrodynamic Separators**, **Jellyfish® Filters**, **StormFilter®** systems, underground detention and retention facilities, and numerous proprietary treatment devices designed to meet increasingly stringent water quality regulations. Together, these technologies allow engineers to develop treatment trains tailored to the hydraulic, regulatory, and space constraints of individual projects.

Among these products, **Modular Wetlands Linear®** is particularly noteworthy because it extends the principles of bioretention into dense urban environments where traditional stormwater facilities are often impractical. By integrating engineered filtration media, vegetation, and stormwater treatment into streetscapes, pedestrian corridors, parks, and public gathering spaces, the system transforms landscape areas into functional water quality infrastructure. This approach aligns closely with redevelopment trends occurring throughout Nashville and other major metropolitan areas where public space, walkability, and environmental stewardship are increasingly important design objectives.

Beyond stormwater treatment, Contech also provides bridge solutions, retaining wall systems, pipe products, precast structures, and geotechnical technologies, making the company a comprehensive supplier of civil infrastructure solutions. Regardless of the specific product selected, the engineering objective remains the same: improve water quality, manage runoff effectively, and deliver durable infrastructure that meets both regulatory requirements and long-term owner expectations.

Oldcastle Infrastructure

Oldcastle Infrastructure is one of North America's largest manufacturers of precast concrete and civil infrastructure products, serving transportation, utility, stormwater, communications, and site development markets. Their stormwater portfolio includes biofiltration systems, underground detention systems, water quality treatment structures, precast drainage structures, utility vaults, manholes, box culverts, and a wide variety of engineered precast infrastructure.

Oldcastle products are frequently specified on municipal, transportation, commercial, and institutional projects where durable precast construction and standardized infrastructure components are desired. Their broad product offering allows engineers to integrate water quality treatment, stormwater storage, conveyance, and utility infrastructure into a coordinated site design.

Like many manufacturers in the Green Stormwater Infrastructure industry, Oldcastle offers solutions that support a variety of project objectives. The engineering challenge remains selecting the technologies that best satisfy the site's hydraulic requirements, regulatory obligations, constructability, maintenance expectations, and long-term performance goals.

DeepRoot and Silva Cell

DeepRoot Green Infrastructure is widely recognized for advancing urban forestry through its **Silva Cell®** suspended pavement system. The technology creates large volumes of uncompacted soil beneath sidewalks, plazas, and streets, allowing healthy root development while supporting pavement, managing stormwater, and coordinating underground utilities.

Silva Cell systems have been specified on numerous streetscape, campus, municipal, and urban redevelopment projects where maximizing tree health and canopy growth are important design objectives. Their ability to integrate urban forestry with Green Stormwater Infrastructure has made suspended pavement systems an increasingly common feature of modern Complete Streets and public realm projects.

Like many innovative technologies discussed throughout this module, suspended pavement systems represent one approach to solving a broader engineering challenge. Regardless of the manufacturer, the objective remains providing adequate rooting volume, supporting healthy urban tree canopies, and integrating stormwater management into the built environment.

The Importance of Product Selection

Selecting the appropriate stormwater technology is rarely as simple as choosing the newest product or the most recognized manufacturer. Every project presents its own combination of hydraulic conditions, site constraints, regulatory requirements, construction considerations, maintenance expectations, budget limitations, and long-term owner objectives. Successful designs balance all of these factors to arrive at the most appropriate solution.

Experienced engineers begin by understanding the problem they are trying to solve. They evaluate available space, water quality goals, constructability, maintenance capabilities, lifecycle costs, local regulations, and the owner's expectations before selecting the products that best support those objectives. In many cases, the final design incorporates technologies from multiple manufacturers, each chosen because it performs a specific function within the overall treatment train.
The best stormwater systems are not built around a particular brand - they are built around sound engineering principles. Product selection should always support the project's objectives, regulatory requirements, and long-term performance rather than forcing the project to fit a preferred technology.

Looking Beyond Products and Manufacturers

One of the most important lessons in modern stormwater management is that successful infrastructure is never the result of a single product or manufacturer. It is the result of thoughtful planning, sound engineering, regulatory compliance, constructable designs, quality installation, and a long-term commitment to inspection and maintenance. Products provide the tools - engineering determines how those tools are applied.

The most successful projects rarely rely on a single manufacturer's solution. Instead, experienced engineers combine technologies from multiple product categories to create a treatment train that addresses the unique hydraulic, environmental, operational, and economic requirements of each site. That systems-based approach ultimately produces infrastructure that performs reliably throughout its service life while delivering lasting value to owners, communities, and the environment.

Throughout this module, we've explored the technologies, products, and manufacturers that shape today's Green Stormwater Infrastructure industry. The greatest lesson, however, is not which products exist - it is understanding how to evaluate them, integrate them, and apply them to solve real engineering challenges.

Looking Ahead

Throughout this chapter, we've examined many of the manufacturers and technologies shaping today's Green Stormwater Infrastructure industry. While each company brings unique products and innovations to the marketplace, they all seek to solve the same fundamental engineering challenges - managing runoff, improving water quality, maximizing developable land, and creating resilient infrastructure that serves communities for decades.

Understanding these technologies is important but understanding when and where to apply them is even more valuable. The next step is learning how engineers evaluate site conditions, development goals, regulatory requirements, and community needs to determine which solutions are most appropriate. The following chapter explores how Green Stormwater Infrastructure is being applied in streetscapes, mixed-use developments, parks, campuses, transportation corridors, and urban redevelopment projects throughout Nashville, Middle Tennessee, and communities across the country.

Local Application - Nashville Yards Mixed Use Development

Large mixed-use developments such as **Nashville Yards** demonstrate how today's stormwater infrastructure is assembled from a combination of proprietary and non-proprietary technologies working together as a complete treatment train. Rather than relying on a single manufacturer or product, engineers evaluate the site's hydraulic conditions, available space, regulatory requirements, maintenance expectations, and long-term development goals before selecting the most appropriate combination of systems.

A typical project might utilize **ACO** or **NDS** trench drains to collect runoff from streets, sidewalks, and public plazas before directing stormwater into engineered tree pits or linear biofiltration systems such as **Contech's Modular Wetlands Linear®**. Structural soil systems, suspended pavement technologies like **Silva Cell®**, and carefully selected urban trees work together to improve water quality while creating healthy streetscapes and public gathering spaces. Beneath the surface, **Carthage Mills** geotextiles separate engineered media from stone reservoirs, while **ADS N-12®** pipe, **Nyloplast®** structures, and **Inserta Tee®** connections convey treated runoff to **StormTech®** underground detention systems or downstream storm sewer infrastructure. Where additional pretreatment is required, proprietary technologies such as **Contech CDS®** or **ADS Barracuda®** hydrodynamic separators may be incorporated upstream to remove sediment, trash, and floatables before stormwater enters the primary treatment system.

Although these products come from different manufacturers, they function as one coordinated system. Each technology performs a specific role within the treatment train, contributing to the overall objectives of water quality improvement, runoff management, regulatory compliance, constructability, long-term maintenance, and community enhancement. Successful projects are not defined by a single product - they are defined by how well multiple technologies are integrated to solve complex engineering challenges.

CHAPTER 9 - Design Applications for Linear Biofiltration Systems

Applying Green Stormwater Infrastructure to Streetscapes, Parks, Campuses, and Urban Redevelopment

Where Green Infrastructure Creates the Greatest Value

The true strength of linear biofiltration systems lies in their versatility. Unlike many traditional stormwater facilities that require dedicated land area, linear biofiltration systems can be integrated into a wide variety of development types and public infrastructure projects.

As communities continue to urbanize and available land becomes increasingly valuable, engineers are being challenged to create infrastructure that serves multiple purposes simultaneously. Linear biofiltration systems are uniquely suited to meet this challenge because they combine water quality treatment, landscape enhancement, urban forestry support, and public space improvements within a single footprint.

Understanding where these systems are most effectively deployed helps designers identify opportunities to maximize both environmental and economic value.

Urban Streetscapes

Urban streetscapes represent one of the most common applications for linear biofiltration systems. Traditional roadway design often dedicates significant space to pavement while providing limited opportunity for stormwater treatment. Linear biofiltration corridors can be incorporated between sidewalks and roadways, within medians, or adjacent to curb lines to intercept runoff before it enters the storm sewer system. Benefits include:

- Source control treatment
- Improved streetscape aesthetics
- Urban tree support
- Traffic calming effects
- Reduced heat island impacts

These systems are increasingly common in downtown redevelopment projects where stormwater infrastructure must coexist with pedestrians, cyclists, utilities, and transportation facilities.

Mixed-Use Developments

Mixed-use developments present unique stormwater challenges due to high levels of impervious cover and competing land-use demands. Residential units, retail spaces, restaurants, offices, structured parking, and public gathering areas often occupy a relatively compact footprint.

Linear biofiltration systems provide an effective means of incorporating stormwater treatment without sacrificing valuable development area. These systems can be integrated into:

- Building setbacks
- Public plazas
- Pedestrian corridors
- Streetscapes

- Courtyards
- Parking lot islands

As a result, stormwater management becomes part of the overall site design rather than a separate infrastructure requirement.

Public Parks and Civic Spaces

Parks and civic spaces provide excellent opportunities for visible green infrastructure.
Historically, stormwater facilities within parks were often hidden from public view. Modern design approaches increasingly celebrate water management as an educational and aesthetic feature.
Linear biofiltration systems can be incorporated into:

- Greenways
- Community parks
- Urban plazas
- Amphitheaters
- Civic campuses

These installations demonstrate environmental stewardship while providing practical stormwater treatment benefits.

Transit Corridors

Public transportation investments often create opportunities for integrated stormwater infrastructure.
Bus rapid transit systems, rail corridors, greenways, and pedestrian connectors frequently include linear landscape areas suitable for biofiltration applications. Benefits include:

- Water quality treatment
- Corridor beautification
- Reduced maintenance requirements
- Improved public perception
- Urban cooling

Because transportation corridors often extend across large portions of a watershed, they can collectively provide meaningful stormwater management benefits.

Educational and Institutional Campuses

Universities, schools, hospitals, and corporate campuses are increasingly utilizing Green Stormwater Infrastructure as part of broader sustainability initiatives. These facilities often contain:

- Large roof areas
- Extensive pedestrian networks
- Parking facilities
- Open space corridors

Linear biofiltration systems allow institutions to demonstrate environmental leadership while addressing regulatory requirements and improving campus aesthetics. In many cases, these installations also serve as educational resources for students, staff, and visitors.

Urban Redevelopment Districts

Perhaps no application better illustrates the value of linear biofiltration systems than large-scale urban redevelopment. Redevelopment districts frequently seek to achieve multiple objectives simultaneously:

- Increased density
- Walkability
- Public space creation
- Environmental sustainability
- Economic development

Stormwater infrastructure must support all of these goals while remaining largely invisible to the public. Projects such as Nashville's East Bank redevelopment illustrate the type of environment where linear biofiltration systems can provide significant value. Streetscapes, parks, public gathering spaces, and pedestrian corridors all create opportunities to integrate stormwater treatment directly into the urban fabric.

Importantly, these systems allow stormwater management to contribute to the overall character of a place rather than simply meeting a regulatory requirement.

Designing for Multiple Benefits

The most successful projects recognize that stormwater infrastructure can generate benefits beyond runoff management. Linear biofiltration systems may contribute to:

- Water quality improvement
- Flood reduction
- Urban forestry goals
- Heat mitigation
- Property value enhancement
- Public health objectives
- Community identity

The ability to achieve multiple outcomes from a single investment is one of the primary reasons Green Stormwater Infrastructure continues to gain acceptance among developers, municipalities, and design professionals.

Chapter Summary

Linear biofiltration systems are adaptable infrastructure solutions that can be integrated into streetscapes, mixed-use developments, public parks, transit corridors, educational campuses, and urban redevelopment projects. Their ability to provide stormwater treatment while supporting broader community goals makes them particularly valuable in densely developed environments.

Successful implementation requires viewing stormwater infrastructure as an opportunity to improve both environmental performance and the overall quality of public space.

Local Application – The Gulch

A redevelopment district includes new residential buildings, retail storefronts, public parks, bicycle facilities, and pedestrian-oriented streetscapes. Traditional detention facilities would consume valuable development area and contribute little to the public experience.

Instead, linear biofiltration systems are incorporated throughout the district. Stormwater treatment becomes part of the landscape architecture, supporting urban trees, improving aesthetics, and enhancing pedestrian comfort while meeting regulatory requirements.

The resulting infrastructure serves both environmental and community objectives without requiring dedicated stormwater parcels.

CHAPTER 10 - Inspection, Maintenance, and Long-Term Performance

Protecting Infrastructure Investments Through Inspection, Stewardship, and Lifecycle Management

Infrastructure Requires Stewardship

One of the most common misconceptions surrounding Green Stormwater Infrastructure is that it functions indefinitely without maintenance. In reality, biofiltration systems are living infrastructure assets that require ongoing inspection, maintenance, and stewardship to achieve long-term success.

Unlike underground pipe systems that often remain out of sight, linear biofiltration systems contain visible components such as vegetation, mulch, soil media, inlets, and surface treatment areas. These elements are exposed to weather, sediment loading, debris accumulation, and routine public use.

The long-term performance of any biofiltration system depends not only on good design and construction but also on a commitment to maintenance throughout its operational life.

Inspection Fundamentals

Routine inspections provide the foundation for effective maintenance programs. Regular inspections help identify:

- Sediment accumulation
- Vegetation health concerns
- Erosion
- Standing water
- Inlet blockages
- Structural damage
- Drainage issues

Early detection often allows minor issues to be corrected before they develop into costly repairs.
Inspection frequency should reflect site conditions, drainage area characteristics, and maintenance objectives.

Vegetation Management

Vegetation is one of the most visible and important components of a biofiltration system. Healthy vegetation contributes to:

- Pollutant removal
- Soil stabilization
- Evapotranspiration
- Aesthetic value

Maintenance activities may include:

- Weed control
- Plant replacement
- Pruning
- Mulch replenishment
- Irrigation during establishment

Plant selection plays a significant role in long-term maintenance requirements. Native and adaptive species often provide the greatest resilience and sustainability.

Sediment Management

Sediment accumulation is inevitable in nearly all stormwater treatment systems.
Over time, sediment can:

- Reduce storage volume
- Limit infiltration
- Restrict flow paths
- Impact vegetation health

Routine sediment removal helps preserve treatment capacity and extend system lifespan.
Pretreatment features often provide the first line of defense against excessive sediment loading and should be inspected regularly.

Inlet and Outlet Maintenance

Hydraulic performance depends upon properly functioning inlets and outlets. Maintenance personnel should routinely verify that:

- Curb openings remain unobstructed.
- Trench drains are clear.
- Slot drains are functioning properly.
- Overflow structures remain operational.
- Outlet controls are not blocked.

A small blockage can significantly reduce system performance during storm events.

Media Evaluation and Replacement

Engineered filtration media experiences gradual changes over time. Depending on site conditions, media may become:

- Compacted
- Clogged
- Nutrient saturated
- Contaminated

Periodic evaluation helps determine whether rehabilitation or replacement is necessary.
Fortunately, properly maintained systems often achieve many years of successful operation before major media replacement becomes necessary.

Adaptive Management

No two stormwater systems perform exactly the same over time. Factors such as land use changes, climate variability, traffic patterns, and maintenance practices can influence performance.
Successful owners adopt an adaptive management approach that includes:

- Monitoring
- Inspection
- Performance evaluation
- Continuous improvement

This approach allows systems to evolve and remain effective throughout their lifespan.

Measuring Success

The ultimate measure of success extends beyond regulatory compliance.
Well-maintained systems should:

- Improve water quality
- Support healthy vegetation
- Enhance public spaces
- Function reliably
- Provide community value

When properly maintained, linear biofiltration systems often become some of the most visible and appreciated infrastructure assets within a development.

Designing for Maintenance

Maintenance should be considered during design, not after construction. Features that improve maintainability include:

- Accessible inlets
- Observation wells
- Cleanouts
- Maintenance access routes
- Durable plant selections
- Pretreatment systems

Infrastructure that is easy to maintain is more likely to be maintained. This simple reality often determines long-term success.

Chapter Summary

Inspection and maintenance are essential components of every successful biofiltration system. Routine inspections, vegetation management, sediment removal, hydraulic maintenance, and periodic media evaluation help preserve treatment performance and extend infrastructure lifespan.

Long-term success depends upon recognizing that Green Stormwater Infrastructure is a living system that requires ongoing stewardship.

Field Application - Municipal Streetscape Program

A city installs a series of biofiltration corridors as part of a downtown streetscape improvement initiative.
To ensure long-term success, maintenance requirements are incorporated into the project from the beginning. Access points, pretreatment features, observation wells, and maintenance schedules are established during design.

Years after construction, the systems continue to provide water quality treatment, support healthy vegetation, and enhance the public realm because maintenance was treated as a core component of the project rather than an afterthought.

Conclusion - Building Cities That Work With Water

The evolution of stormwater management reflects a broader shift in how communities think about infrastructure. For generations, stormwater systems were designed primarily to move water away as quickly as possible. While effective at conveyance, these approaches often overlooked opportunities to improve water quality, support ecological functions, and enhance the urban environment.
Green Stormwater Infrastructure represents a fundamentally different philosophy.

Rather than treating rainfall as a problem to be removed, modern infrastructure seeks to manage water as a resource. Through biofiltration, infiltration, evapotranspiration, urban forestry, and integrated treatment trains, cities can restore portions of the natural hydrologic cycle while creating healthier and more resilient communities. Linear biofiltration systems exemplify this approach.

Their ability to integrate stormwater treatment into streetscapes, parks, redevelopment districts, transit corridors, and public spaces allows infrastructure to serve multiple purposes simultaneously. These systems improve water quality, support vegetation, enhance aesthetics, reduce urban heat, and contribute to the overall character of a place.

As redevelopment continues throughout Nashville and communities across the country, the demand for infrastructure that delivers environmental, social, and economic benefits will continue to grow.

The future of stormwater management will not be defined solely by pipes, ponds, and regulations.
It will be defined by how effectively we integrate water management into the places where people live, work, and gather.

The most successful projects will be those that recognize stormwater infrastructure not as a constraint, but as an opportunity to create more sustainable, attractive, and resilient communities for generations to come.

Frequently Asked Questions

What is Green Stormwater Infrastructure (GSI)?
Green Stormwater Infrastructure (GSI) is an approach to **stormwater management** that captures, treats, infiltrates, and manages rainfall as close to its source as possible. Instead of relying exclusively on storm sewer systems, detention ponds, and underground pipes, GSI incorporates practices such as **linear biofiltration systems, bioretention areas, engineered tree pits, permeable pavements, bioswales, and urban forestry** to mimic natural hydrologic processes. These systems improve water quality, reduce runoff, support groundwater recharge, and create healthier public spaces. Throughout Nashville and Middle Tennessee, Green Stormwater Infrastructure is becoming an increasingly important part of mixed-use developments, Complete Streets projects, and public infrastructure designed to satisfy **TDEC**, **EPA**, and local **MS4** stormwater requirements while improving community resilience.

What is a linear biofiltration system?
A linear biofiltration system is a long, narrow **Green Stormwater Infrastructure** practice designed to capture and treat runoff within streetscapes, sidewalks, parking lots, medians, pedestrian corridors, and other urban environments where land is limited. Stormwater enters the system through curb openings, trench drains, slot drains, or sheet flow before passing through engineered filtration media and vegetation that remove sediment, nutrients, metals, hydrocarbons, and other pollutants. Depending on the design, treated water may infiltrate into native soils or be collected by an underdrain system for downstream conveyance. These systems are particularly valuable in urban redevelopment because they provide stormwater treatment without consuming large areas of developable land.

What is the difference between bioretention and biofiltration?
Although the terms are often used interchangeably, they describe different aspects of the same process. **Bioretention** is the overall stormwater management practice that temporarily stores and manages runoff using engineered soils and vegetation. **Biofiltration** describes the treatment processes occurring within that system, including physical filtration, chemical adsorption, and biological activity that remove pollutants from stormwater. Most modern linear biofiltration systems combine both concepts, using bioretention as the overall design strategy while relying on biofiltration to achieve water quality treatment. Understanding this distinction helps engineers, contractors, and owners better understand how Green Stormwater Infrastructure functions as an integrated treatment system.

Why are engineered soils used instead of ordinary topsoil?
Engineered filtration media is specifically designed to provide predictable **hydraulic performance**, support healthy vegetation, and maximize pollutant removal. Unlike ordinary topsoil, engineered media is carefully blended using sand, compost, topsoil, organic matter, and other amendments to achieve specific infiltration rates and water quality objectives. These materials must balance rapid drainage with sufficient contact time for physical filtration, chemical adsorption, and biological treatment to occur. Properly designed engineered media improves the long-term performance of linear biofiltration systems while reducing maintenance needs and supporting healthy vegetation throughout the life of the project.

What role do trees play in Green Stormwater Infrastructure?
Urban trees are far more than landscape features - they are active components of modern **Green Stormwater Infrastructure**. Trees intercept rainfall before it reaches the ground, reduce runoff volumes, stabilize soils, promote evapotranspiration, improve air quality, and help remove nutrients from stormwater. In Middle Tennessee, species such as **Willow Oak, Bald Cypress, River Birch, Swamp White Oak, and Black Gum** are frequently incorporated into engineered tree pits and biofiltration systems because they perform well under urban conditions. When combined with structural soils, suspended pavement systems such as **Silva Cell®**, and proper root management, urban trees become valuable infrastructure assets that continue increasing in value as they mature.

What are Silva Cells and suspended pavement systems?
Silva Cell® is one of the best-known suspended pavement systems used in urban forestry and Green Stormwater Infrastructure. Developed by **DeepRoot**, the system creates large volumes of uncompacted soil beneath sidewalks, plazas, and streets while supporting the structural loads of the pavement above. This allows healthy root development, improves stormwater storage, supports infiltration, and coordinates underground utilities within highly developed environments. Although Silva Cell is the industry's best-known example, several manufacturers offer similar suspended pavement technologies. Regardless of the product selected, the engineering objective remains the same - supporting mature urban tree canopies while integrating stormwater management into the built environment.

Why are trench drains and slot drains important?
Trench drains and slot drains are often the first components of the **stormwater treatment train** because they efficiently collect runoff from streets, sidewalks, plazas, and parking areas before directing it to downstream treatment systems. Trench drains are commonly selected where durability and hydraulic capacity are priorities, while slot drains provide a cleaner architectural appearance for pedestrian-oriented developments and public spaces. Manufacturers such as **ACO**, **NDS**, **Eric'sons Dura Trench**, and **JBS** provide systems suited to different applications. Properly designed collection systems improve hydraulic performance while supporting biofiltration systems, water quality treatment devices, and underground stormwater infrastructure.

Why do Green Stormwater Infrastructure projects use products from multiple manufacturers?
Successful stormwater projects are rarely built around a single manufacturer. Instead, engineers select the technologies that best satisfy the site's hydraulic requirements, regulatory obligations, constructability, maintenance expectations, and long-term performance goals. A project may incorporate **NDS** trench drains, **Contech Modular Wetlands Linear®**, **ADS N-12®** pipe, **StormTech®** detention chambers, **Carthage Mills** geotextiles, and **Silva Cell®** suspended pavement systems within the same treatment train. Each product

performs a specific function while contributing to the performance of the overall system. The engineering objective is always selecting the right combination of technologies rather than forcing every project to fit a particular manufacturer.

Where is Green Stormwater Infrastructure being used in Middle Tennessee?
Green Stormwater Infrastructure is becoming increasingly common throughout Middle Tennessee as communities invest in sustainable development and resilient public infrastructure. Projects such as **Nashville's East Bank**, **Nashville Yards**, **The Gulch**, **Wedgewood-Houston**, **Capitol View**, **Southall**, and **NDOT's Choose How You Move** initiative demonstrate how stormwater management can be integrated into streetscapes, parks, transportation corridors, and mixed-use developments. Facilities such as **Geodis Park** also demonstrate how rainwater harvesting and reuse can complement Green Stormwater Infrastructure by reducing potable water demand while supporting landscape irrigation and long-term sustainability.

Why is Green Stormwater Infrastructure important for the future of civil engineering?
Green Stormwater Infrastructure represents one of the most significant changes in modern civil engineering because it expands the role of infrastructure beyond simple stormwater conveyance. Today's systems are expected to improve water quality, reduce flooding, support urban forestry, enhance public spaces, increase community resilience, and contribute to sustainable development simultaneously. As cities continue to grow and environmental regulations evolve, engineers will increasingly rely on integrated treatment trains that combine biofiltration, permeable pavements, engineered tree pits, water quality treatment devices, and underground detention systems. The future of stormwater management will be defined not by individual products, but by the thoughtful integration of technologies that create healthier watersheds and stronger communities.