project
downtown

GREEN INFRASTRUCTURE TOOLKIT

Prepared for the City of Littleton
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Littleton

consor Matrix LIVABLE CITIESTUDIO

Table of Contents

Front Cover: Flow through stormwater facility during a rain event

Inside Cover: Recent Birdseye of Downtown Littleton (circa 2020's)

Definitions & Abbreviations

Green Infrastructure (GI): Natural or nature-based systems and practices to manage water, provide ecological benefits, and enhance overall sustainability in urban and rural areas. This approach to infrastructure design aims to mimic natural processes to manage stormwater, reduce urban heat islands, improve air quality, and provide habitat for wildlife.

Impervious: Surfaces that prevent rainwater from infiltrating into the ground

Runoff: Runoff refers to the movement of water over the land surface when excess water, such as from rain, snowmelt, or irrigation, cannot infiltrate into the soil. Instead of being absorbed into the ground, this water flows over the land surface, eventually collecting in lower-lying areas, streams, rivers, lakes, and oceans.When precipitation falls onto surfaces such as roads, parking lots, rooftops, and compacted soil, it often cannot penetrate these surfaces easily and results in excess water running off these surfaces and collecting pollutants like sediment, oil, chemicals, and nutrients.

Water Quality Capture Volume (WQCV): The Water Quality Capture Volume is the volume of stormwater that needs to be captured, treated, and managed to reduce the amount of pollutants reaching natural water systems. For expanded definition reference CDPHE and MS4 for further clarification.

2-hour Peak Flow: 2-hour peak flow refers to the maximum rate of flow of water during a 2-hour period, typically used in hydrology and stormwater management calculations. It is an important parameter for designing infrastructure to manage stormwater and a 2-hour storm is a Colorado's typical target as it mimics our typical monsoon storm events.

Flow based treatment: Flow based treatment facilities treat specific flow rates and generally include bypass facilities where stormwater flows pass through the system. They do not typically account for any storage or infiltration.

Contextually Based Water Quality Treatment: Contextually based water quality treatment utilizes either flow based or volume-based treatment GI landscapes to detain, treat, filter, infiltrate, and release runoff captured from adjacent impervious surfaces. Using combinations of flow-based or volume-based devices in series may also be applicable for moderate stormwater capture.

Volume based treatment: Volume based treatment utilizes storage or infiltration to reduce stormwater runoff volumes. This is generally determined by local criteria but may differ based on site-specific constraints.

Introduction

Overview and Purpose

Downtown Littleton today has traditional gray infrastructure and a public realm with few street trees, many of which are in poor health, contributing to a lack of shade and comfort for pedestrians. This toolkit aims to outline the strategies and approaches necessary for implementing infrastructure that may enhance the resilience of Downtown Littleton and provide multi-layer benefits along key corridors such as Main Street, Alamo Street, Prince Street, and Nevada Street and Little's Creek. By doing so, the toolkit seeks to create a more comfortable, walkable environment that encourages pedestrian activity, economic activity and enhances Downtown Littleton as a destination. It will also help reduce heat, improve air quality, manage stormwater, and enhance the overall vibrancy of the downtown area, transforming it into a resilient, green, and connected urban space.

Climate Change and Why a Strategic Response is Needed

The City of Littleton understands the vital need to address the consequences of the warming planet today and in the future. The City also recognizes the value of preventing further acceleration of warming while mitigating what cannot be prevented. Green infrastructure is one of many ways Littleton can prevent and mitigate the impacts of climate change.

Green Infrastructure (GI) and Its Benefits

For the purposes of this toolkit, Green Infrastructure can be defined as "the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters." (Water Infrastructure Improvement Act, 2019). This definition is crucial when considering the multitude of pollutants in stormwater runoff as well as the hydromodification that can cause immense harm to our environment.

With the changing and warming climate, weather systems are also evolving. Warmer temperatures are likely to decrease water availability in Colorado, while storm events are likely to become more sporadic and intense. These types of storms can strain gray infrastructure systems. Historically, communities have relied on gray infrastructure—such as gutters and pipes—to collect, transport, and discharge stormwater to recieving waterbodies. However, when volumes exceed the designed limitations and capacity of gray infrastructure, it can lead to flooding.

Incorporating green infrastructure into downtown Littleton can greatly enhance the area's resilience to the changing climate while providing a range of environmental, social, and economic benefits. As Littleton continues to experience growth, green infrastructure can play a critical role in managing stormwater, improving water quality, and mitigating the urban heat island effect. These systems, which mimic natural processes, can help the city become more adaptable to peak storm events and seasonal variability, safeguarding the community against flooding while aiding in more sustainable water management.

One of the primary advantages of green infrastructure is its ability to improve water quality and manage peak storm events. Features like permeable pavements, bioswales, and green roofs allow water to infiltrate naturally, reducing the volume of runoff and filtering pollutants before they enter waterways. This reduces strain on the city's stormwater systems and helps prevent localized flooding, especially during intense rainfall events, which are becoming more frequent with climate change. In Littleton, these systems can also enhance the South Platte River and nearby water bodies by keeping pollutants like oil, sediment, debris, and heavy metals out of the waterways.

Green infrastructure also helps to reduce the urban heat island effect, a major concern in downtown areas with dense development. Trees, green roofs, and vegetation can cool the environment by providing shade and through evapotranspiration, which can reduce surface temperatures. This, in turn, improves air quality and enhances overall livability in the downtown area by creating cooler, more comfortable public spaces. Additionally, integrating green spaces with bike lanes, pedestrian paths, and public transit stops can enhance the multimodal environment, promoting sustainable modes of transportation.

The economic benefits of green infrastructure can also be substantial. While there are initial costs associated with implementing these systems, studies have shown that green infrastructure offers a significant return on investment (ROI) over time. Lowered infrastructure maintenance costs, enhanced property values, and improved public health are some of the tangible outcomes that contribute to a positive ROI. Moreover, by attracting visitors and businesses looking for sustainable, aesthetically pleasing environments, Littleton's downtown could see an increase in local economic activity. Green infrastructure can also extend the lifespan of gray infrastructure by reducing the burden on stormwater systems, thus delaying costly repairs or replacements.

Ultimately, green infrastructure represents a smart investment in downtown Littleton's future, not only for its environmental benefits but also for the long-term economic and social vitality of the city.

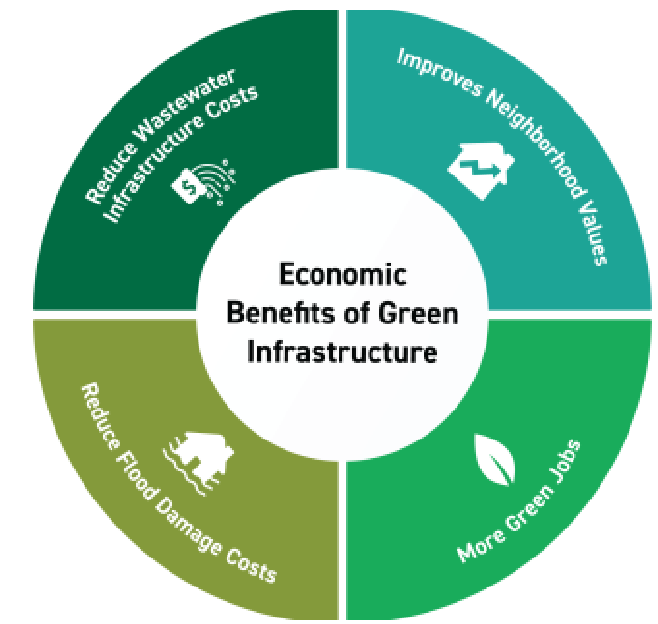


Image 1: EPA's Economic Benefits of Green Infrastructure

SOURCE: United States Environmental Protection Agency

Climate Variable/Event	Recent Trend	Projected Future Change	Confidence in Change
Heat Waves	More frequent/ intense	More frequent/ intense	Very High
Cold Waves	Fewer	Fewer	Medium
Droughts	More frequent/ intense	More frequent/ intense	High
Wildfires	More and larger	More and larger	High
Extreme precipitation	More intense	More frequent/ intense	Medium
Flooding	Mixed	Higher	Medium
Windstorms	Uncertain	Uncertain	Low
Severe thunderstorms	Uncertain	More frequent	Low
Hail	Uncertain	More large hail	Low
Tornadoes	Uncertain	Uncertain	Low
Winter storms	Uncertain	Larger storms	Low
Dust on snow events	Greater dust levels	Greater dust levels	Medium

Southwestern and South-central Colorado have experienced **the largest magnitude of warming**

Image 2: Summary of the Observed and Projected Changes in Climate Extremes and Hazards for Colorado

SOURCE: Colorado from the Colorado Climate Assessment Report 2024

Downtown Today

Littleton currently lacks formalized, constructed green infrastructure both city-wide and within its downtown core, leaving significant opportunities for improvement. The downtown study area, in particular, suffers from limited and inconsistent green spaces. The majority of the tree canopy is concentrated within the city's parks, leaving critical streetscapes, like Main Street, Alamo Street, and adjacent areas, largely without sufficient greenery. Historically, Main Street boasted a robust tree canopy that contributed to the vibrancy and charm of the area. However, sixty four (64) Honey Locust trees that once lined the street were recently removed after being identified with Thryonectria Canker, resulting in a considerable loss of shade, visual appeal, and environmental benefits.

Using This Toolkit

This toolkit is intended to guide green infrastructure-related improvements in the City of Littleton downtown area. A series of green infrastructure tools, commonly applicable in the public realm, are detailed with technical and spatial guidance for successful implementation. These tools are categorized by programmatic type and level of impact to assist in assessing applicability to a given project. This toolkit does not encompass all green infrastructure tactics, nor does it dismiss or discourage innovation and strategies outside of its scope.

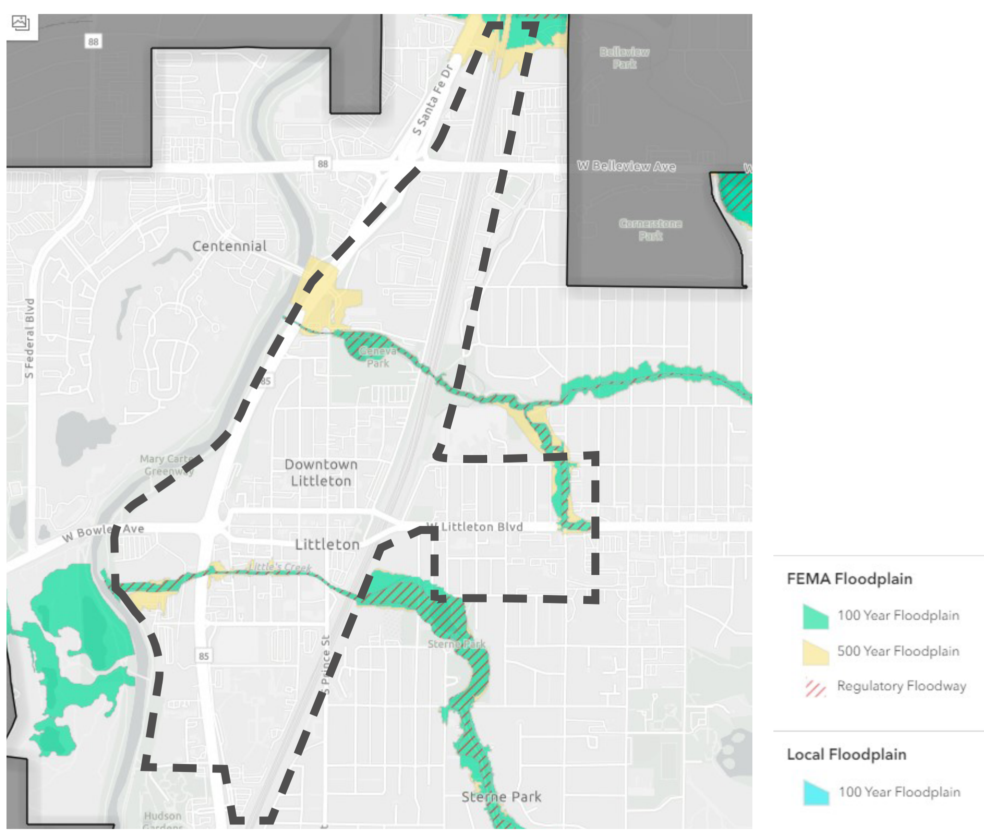


Image 3A: Regulatory floodplain in downtown Littleton

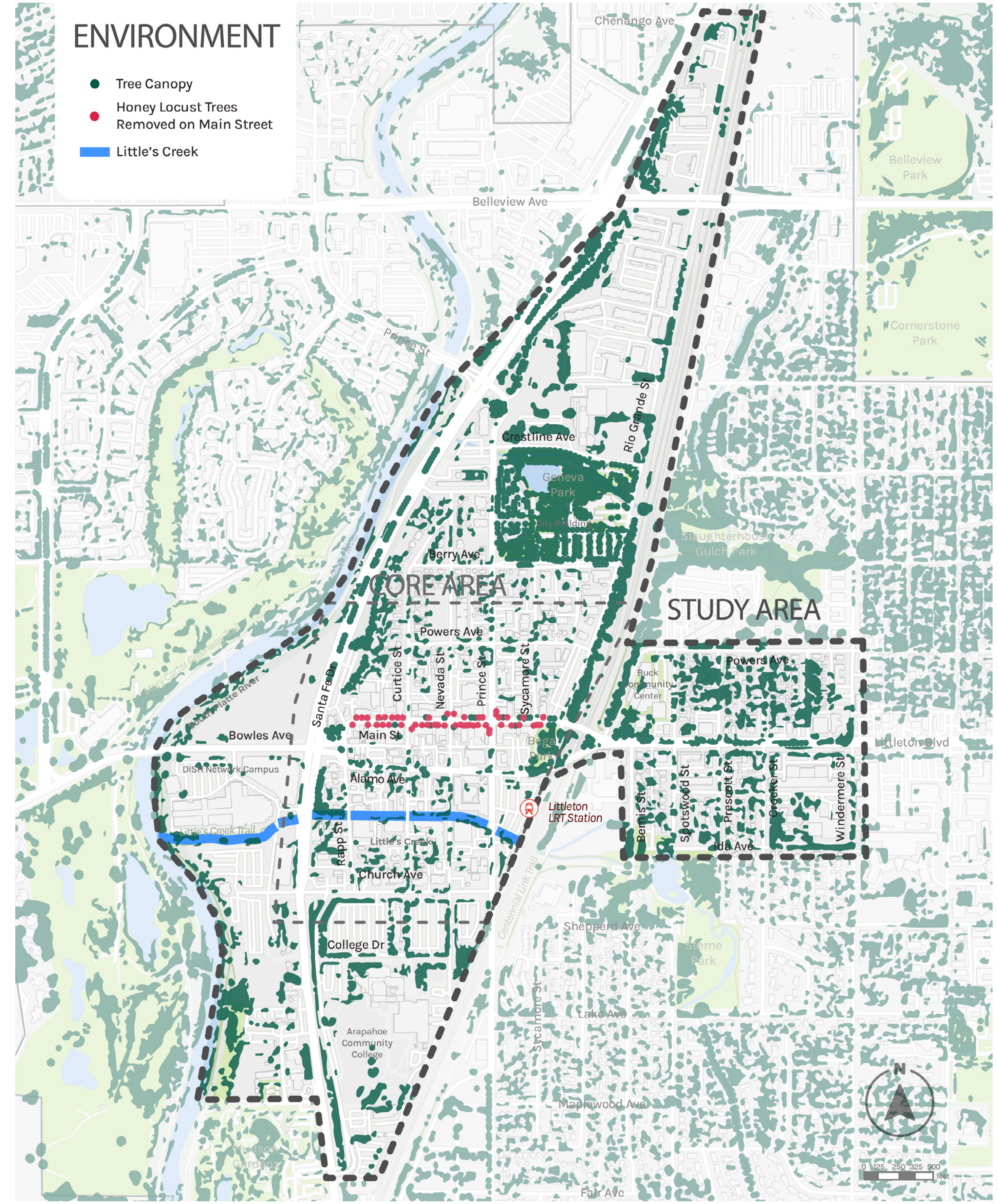


Image 3B: Tree Canopy in Downtown Littleton as of 2023

Design Principles

The following design principles represent core ideas and values in the effective implementation of green infrastructure. Taking a holistic approach, the design principles are grouped into three major categories of consideration:

- Stormwater
- Canopy, Diversity and Resilience
- Placemaking

Stormwater

Principles

- Reduce Stormwater Runoff Volume
- Reduce Stormwater Peak Flows During Events
- Improve Water Quality

Canopy, Diversity and Resilience

Principles

- Increase Urban Canopy Coverage
- Provide Adequate Soil Volume
- Increase Species Diversity
- Provide Ecosystem Services

Placemaking

Principles

- Use Materials that Reinforce Downtown’s Heritage and Unique Character
- Improve Pedestrian Environment and Public Realm Aesthetics
- Increase Public Awareness and Education
- Strategy Implementation
- Economic Development

Stormwater

Successful green infrastructure prioritizes a meaningful and quantifiable response to stormwater as a primary objective. The following principles should be when considering stormwater treatment:

Reduce Stormwater Runoff Volume

- Reduce impervious surfaces
- Promote infiltration and allow for ground water recharge
- Increase vegetation water and nutrient uptake
- Minimize directly connected impervious area

Reduce Stormwater Peak Flows During Frequent Events

- Slow runoff
- Increase flow path lengths
- Leverage downstream infrastructure capacity

Improve Water Quality

- Increase filtration
- Reduce sediment in runoff
- Remove and uptake pollutants such as metals and bacteria

Image 4: Stormwater Planters with Rails and Pedestrian Connection from Curb to Sidewalk

Canopy, Diversity and Resilience

Principles

- Increase Urban Canopy Coverage
- Provide Adequate Soil Volume
- Increase Species Diversity
- Provide Ecosystem Services

Green infrastructure projects should also consider the potential for additional environmental benefits, through canopy cover, species diversity, habitat and landscape ecosystem services, contributing to greater environmental resilience. The following principles should be when considering tree canopy, diversity, and treatment:

Increase Urban Canopy Coverage

- Reduce heat island effect by shading over impervious surfaces
- Create shaded comfortable spaces for people.

Provide Adequate Soil Volume

- For large shade trees, provide 1000 cubic feet of soil volume per tree
- For ornamental trees, provide a minimum of 500 cubic feet of soil volume per tree

Increase Species Diversity

- Apply the 5:10:20 diversity metric (City of Littleton Urban Forestry Management Plan) meaning 5 families, 10 genuses, & 20 species to increase resilence to disease and canopy loss

Provide Ecosystem Services

- Utilize species which also have additional ecosystem services, such as pollinator benefits and habitat

Image 5: Sidewalk Chase to Flow Through Landscape

Image 6: At Grade Planting Area with Ornamental Grasses and Perennials

Placemaking

Principles

- Use Materials that Reinforce Downtown's Heritage and Unique Character
- Improve Pedestrian Environment and Public Realm Aesthetics
- Increase Public Awareness and Education
- Economic Development

Inclusion of placemaking when designing and implementing green infrastructure projects leverages the social benefits of green infrastructure, allowing interventions to surpass a solely functional stormwater purpose to support social concepts like sense of place and community stewardship. The following principles should be when considering placemaking:

Use Materials that Reinforce Downtown's Heritage and Unique Character

- Select materials that are durable and aligned to the City's operational and maintenance capacity
- Materials should be contextual, appropriate for their intended use and urban context
- Character of materials should be thoughtfully considered and integrated into a designed scheme or the established character of the surrounding environment
- Consider local architectural vernacular and incorporating materials, patterns and/or architectural styles that respond to historical context

Improve Pedestrian Envrionment

- Enhance pedestrian safety and comfort through the implementation of GI facilities

Increase Public Awareness and Education

- Explore opportunities for environmental education and interpretation

Economic Development

- Drive local business activity through enhancements to Downtown's streetscapes and pedestrian comfort

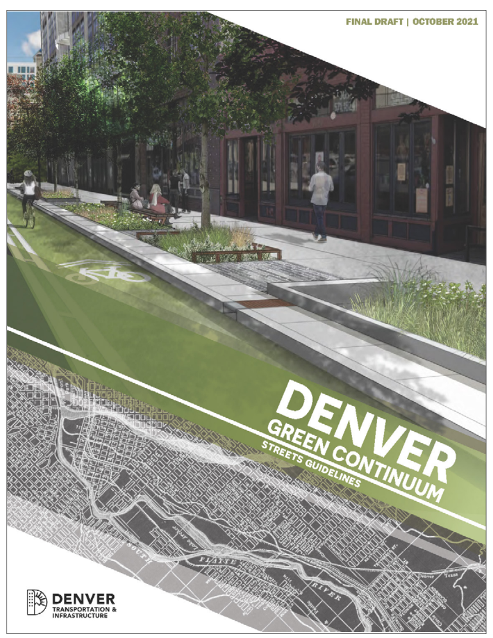
Image 7: Stormwater Planters with Concrete Curb Walls and Integrated Seating

Image 8: Stormater Planter Adjacent to Bike Facility

Green Infrastructure (GI) References

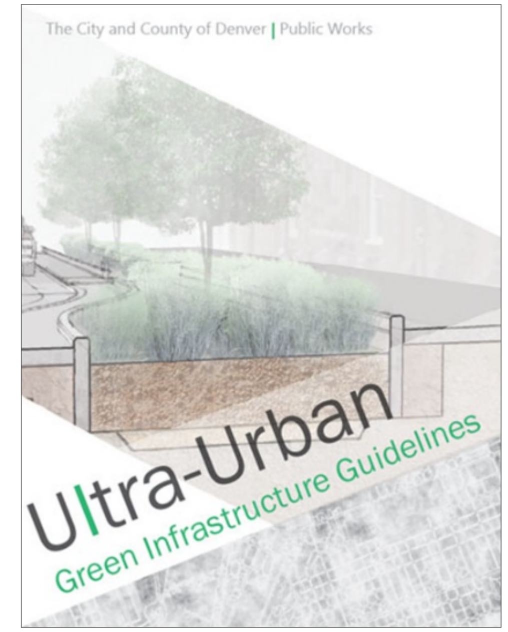
As the effects of climate change become increasingly present, other Colorado communities have turned to green infrastructure planning and policy to combat the effects of climate change, improve water quality, create habitat and promote a positive environment for their citizens to live. As part of the green infrastructure toolkit initiative by the City of Littleton, the following documents were reviewed for applicability to this document. It is encouraged that users of this document reference both of these document for more detailed information related to the design of GI facilities.

Denver Green Continuum



The Denver Green Continuum: Streets Guidelines aim to increase the use of green infrastructure (GI) in Denver to address climate change impacts. Framed similarly to the goals and actions of this toolkit, The Denver Green Continuum offers guidance on a wide range of practical GI solutions and focuses on managing stormwater runoff, mitigating urban heat, and providing additional benefits like improved air quality and aesthetics. The Denver Green Continuum defines a series of "Level of Green" categories, indicating the intensity of the approach. Where it starts to differ from the goals of this toolkit are the complexity and thoroughness of the strategies described. The Denver Green Continuum covers a higher level of technical information within. The Green Continuum offers strategies for incorporating GI into small capital projects, even those that don't meet regulatory water quality requirements, addressing a gap where many projects previously failed to include GI.

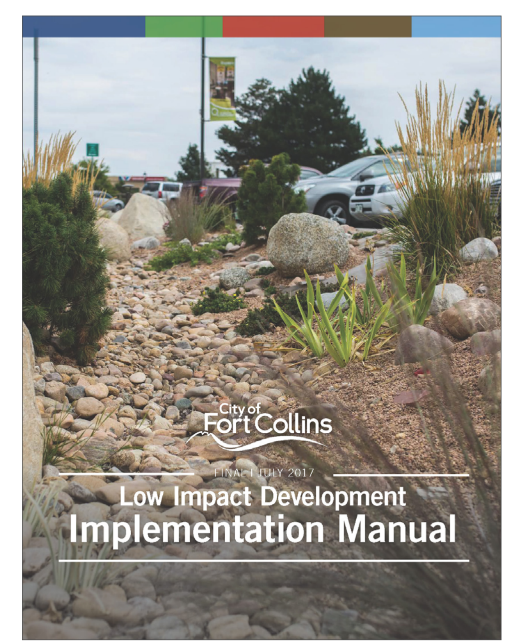
Denver Ultra Urban Green Infrastructure Guidelines



Denver's Ultra-Urban Green Infrastructure Guidelines provide design support for site-scale green infrastructure, particularly in space-constrained public rights-of-way with high pollutant loads. The document offers project considerations, example designs, and guidance on installation and maintenance. Each green infrastructure practice is selected for suitability to Denver's climate and urban density, with fact sheets for five types: streetside stormwater planters, bumpout planters, green gutters, green alleys, and tree pits/trenches.

The 2nd edition of the UUGIG is anticipated for public release in 2025.

Fort Collins Low Impact Development (LID Implementation Manual



The City of Fort Collins' LID Implementation Manual outlines strategies for stormwater management using Low Impact Development (LID) practices. These practices mimic natural water systems and aim to minimize development's impact on water resources. There is often substantial overlap between LID practices and GI strategies. The manual emphasizes distributed management of stormwater at the site level, treating rainwater near where it falls. While the City of Fort Collins' LID Implementation Manual is designed for both professionals and citizens, it shares similar goals to this toolkit in promoting a healthy environment, vibrant community, and a unified approach to stormwater treatment across the city. The manual offers detailed information and requirements for implementing various LID systems of similar level of detail that this toolkit aims to do. However, while the Fort Collins' LID Implementation Manual carries regulatory power for developments involving greater than 1,000 square feet of additional impervious area, this toolkit is designed to offer guidance to any and all city projects across the City of Fort Collins.

Green Infrastructure (GI) Landscapes

The following descriptions of drainage treatment and flow control facilities provide the defining quality and characteristics, sample applications, and design guidelines for each type of facility to assist designers in selecting the best approaches for their projects. Facilities from various categories can be combined, as site conditions can differ significantly from one block to another or even within the same block. These facilities can be implemented individually, at an intersection, or across a block or multiple blocks. The designer should verify all regulatory requirements and that the design meets current local, state and federal requirements, standards, and guidelines.

Flow Based Treatment

Limited stormwater function when no regulatory requirements apply

Qualities / Characteristics

Flow based treatment GI landscapes have limited stormwater function by way of volume, but excel in their application versatility, environmental services, and placemaking potential. These facilities look to reduce runoff, improve water quality, and minimize impervious surfaces all through the introduction of landscaped areas.

Tributary: Flow based treatment green infrastructure measures accept direct rainfall, runoff from sidewalks or walkways, and can accept runoff from roadway gutters as well.

Environmental: Flow based treatment green infrastructure measures look to increase vegetated area and tree canopy, increasing opportunities for stormwater infiltration and reducing the urban heat island effect. Depending on species selection and diversity, they have the potential to provide pollinator habitat and a sustained food source to birds and pollinators throughout the seasons, while also increasing an area's resilience to changing climate conditions. Flow based treatment green infrastructure measures are also effective tools for placemaking and emphasizing a sense of character within the urban environment.

Volume/Depression: Flow based treatment green infrastructure measures may include a slight depression or none at all. Slight depressions are used only to encourage infiltration and do not provide volumetric storage capacity.

Drainage Infrastructure: Flow based treatment green infrastructure measures do not require underdrains or connections to storm drain systems.

Utilities: Due to their shallow to neutral cross-section, flow based treatment green infrastructure measures are generally well suited for sites that have underground utilities. Care should be taken to use best practices for tree placement in proximity to underground utilities. In areas where there are numerous surface utility features such as cabinets, vaults, meters, etc. a measure that has a neutral cross-section is recommended.

Soil Media and Planting: Flow based treatment green infrastructure measures use trees, shrubs, perennials, and groundcovers, or a combination thereof to create various types of landscaped areas. Landscape areas should utilize amended site soils or engineered media to promote sustainable vegetation establishment and growth. 750-1000 cubic feet of uncompacted soil volume should be provided per tree for healthy root establishment and growth. This provides adequate soil space for a tree to reach maturity.

Mulch is not recommended in these facilities due to potential for migration.

Planting strategies should be compatible with their spatial context to avoid unnecessary conflicts and hazards. When making species selections, consider mature size, branching habit, flowering, seed pods, thorns, and burs. Also consider tolerance to salt, pollutants, and temporary inundation, as well as potential ecological services.

Maintenance: A proper maintenance regime for flow based treatment landscapes includes regular removal of weeds and debris to ensure effective water filtration and prevent clogging. Routine inspections are also necessary to monitor plant health, soil conditions, and drainage performance, while occasional pruning, replanting, and sediment removal may be required to sustain optimal functionality and aesthetic appeal.

Image 9: Flow Based Treatment Planter Accepting Runoff from Sidewalk Only

Image 10: Flow Based Treatment Planter Accepting Runoff from Sidewalk and Street

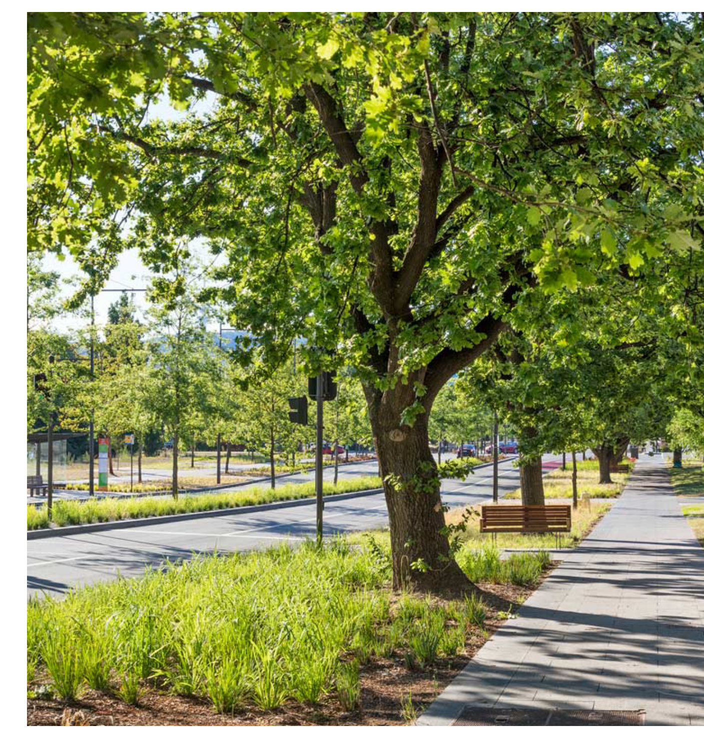


Image 11: At Grade Planting Area with Low Water Planting Palette

Facility Design Criteria

Design metrics to follow for implemention:

- Utilize small depression to ensure grade drop from impervious areas to receiving pervious areas
- Infiltration zones: slopes between 0% and 2%. Design for system overflow into street
- Drainage to flow based treatment green infrastructure sites: less than 0.5 acres, split to minimize continuous impervious areas
- Stormwater Inlet/Outlet: Curb cuts, slotted curbs, chase drains, or curb headers are all appropriate options for inlet conditions. Underdrains not recommended
- Soil / Media: Ensure soil infiltration rates fulfill at least 1” per hour or consider different tool. Ensure drainage is met before implementing depressed areas. Amend soil organic amendments per best practices

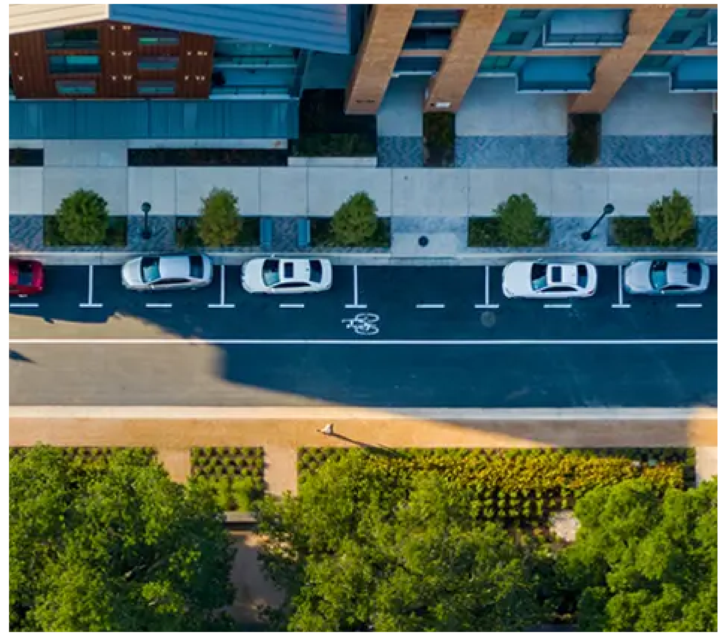


Image 12: Amenity Zone Trees in Planters from Above

Image 13: Stormwater Planter with No Curbing or Walls

Image 14: Flow Through Median in Parking Lot

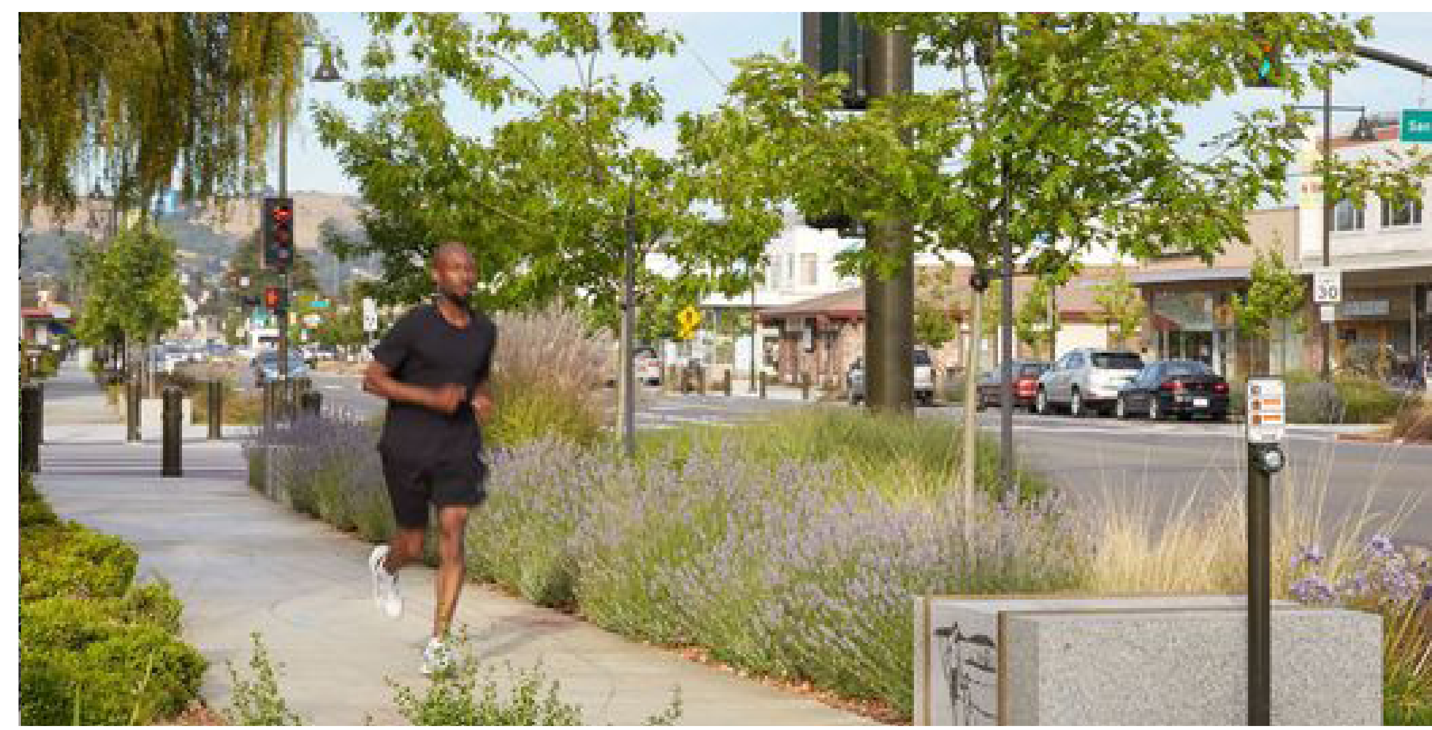


Image 15: At Grade Planting Area with Low Water Planting

Contextually Based Water Quality Treatment

Moderate stormwater capture volume

Qualities / Characteristics

Contextually based water quality treatment utilizes either flow based or volume-based treatment GI landscapes to detain, treat, filter, infiltrate, and release runoff captured from adjacent impervious surfaces. Using combinations of flow-based or volume-based devices in series may also be applicable for moderate stormwater capture. These measures capture a moderate volume of stormwater with full volumes being dependent on contextual site constraints including space available, permeability of soils, and vegetation type. The impact of these systems is highly dependent on each site and allows for flexibility when the goal is to maximize benefits without meeting a particular capture volume goal. These landscapes can have a greater impact on reducing localized flooding, flow volumes, and strain on gray infrastructure systems while remaining adaptable to a variety of urban, multi-use, and commercial contexts.

Tributary: Contextually based water quality treatment GI devices accept direct rainfall, runoff from sidewalks, walkways, downspouts, as well as runoff from roads. When used in series, they may accept discharge from upstream devices. For these moderate stormwater GI landscapes, it is important to appropriately match the amount of tributary area to the overall size of the receiving landscapes. Designers should reference MHFD Vol. 3 run-on ratios.

Environmental: Contextually based water quality treatment GI devices share the same environmental benefits as flow or volume-based treatment but vary depending on their application. While they have more potential than small flow-based treatment devices, they may not meet regulatory requirements for volume-based devices. However, they can still reduce runoff volumes, increase infiltration, and treat flows through detention of smaller volumes of water quality events and remove sediment and pollutants.

Volume/Depression: Contextually based water quality treatment GI devices can be depressed below the roadway curb and gutter flowline. Their depth can vary between 3 and 6 inches below adjacent surfaces. The overall intent of moderate devices is that depressions or depths of flow through devices are relatively shallow and can thus blend more seamlessly with the adjacent urban context.

Drainage Infrastructure: Contextually based water quality treatment GI devices should be designed based on the site constraints and conditions. They may include either underdrains or be full infiltration or may utilize multiple devices in series. The intent of moderate GI landscapes is that they can be implemented in locations without storm drain infrastructure in close proximity. However, soil conditions and proximity to other infrastructure should be carefully considered when selecting facility types. Devices with underdrains should be placed in close proximity to existing or proposed storm drain systems.

Utilities: Contextually based water quality treatment GI devices require vertical clearance for storage and engineered components. These devices may have surface utilities around their perimeter but should have few subsurface conflicts. Subsurface utility impacts such as water, sanitary, etc. present challenges for the successful implementation of combination flow and volume based treatment green infrastructure devices.

Soil Media and Planting: Contextually based water quality treatment GI devices utilize engineered soil media that allows sustainable vegetation establishment and growth, while maximizing infiltration properties. Mulch is not recommended for contextually based water quality treatment GI devices. Planting selections should be compatible with the depressed condition and tolerate frequent inundation.

Image 16: Sunken Infiltration Planters Treat Stormwater

Image 17: Stormwater Median

Image 18: Storm Water Planter Adjacent to Trench Drain System

Image 19: Stormwater Planters Between Walk and Parking Step Out Zone

Planting strategies should be compatible with their spatial context to avoid unnecessary conflicts and hazards. When making species selections, consider mature size, branching habit, flowering, seed pods, thorns, and burs. Also consider tolerance to salt, pollutants, and temporary inundation, as well as potential ecosystem services.

Maintenance: A proper maintenance regime for Contextually based water quality treatment GI devices includes regular removal of weeds and debris to ensure effective water filtration and prevent clogging. Routine inspections are also necessary to monitor plant health, soil conditions, and drainage performance, while occasional pruning, replanting, and sediment removal may be required to sustain optimal functionality and aesthetic appeal.

Facility Design Criteria

Design metrics to follow for implemention:

- Inflow gutters at minimum slope of 0.5% should be installed directly upstream of infrastructure to help reduce sediment deposition within the infrastructure
- Ensure structures are a minimum of 10’ from buildings with slope away from surrounding structures
- Stormwater Inlet/Outlet: Underdrains should be avoided if possible but may be used to help link devices in series together
- Soil / Media: ensure infiltration rates fulfill at least 2” per hour for full infiltration facilities or design similar to volume based facilities. Ensure drainage is met before implementing depressed areas.

Image 20: Flow Through Landscapes In Parking Medians Treat Stormwater

Image 21: Flow Through Swale Adjacent to Parking Lot

Volume Based Treatment

High functioning landscapes with significant stormwater Capture Volume

Qualities / Characteristics

Volume based treatment green infrastructure landscapes use engineered stormwater control measures to manage 100% of the regulatory water quality capture volume (WQCV). These measures are typically supported by extensive underground infrastructure, including underdrains, overflows, and piped connections to the gray infrastructure system. Underdrains are frequently incorporated into volume based treatment GI landscapes to meter and control runoff rates and volumes; however, full infiltrating sections may also be possible with high-infiltrating subsurface soil conditions. Volume based treatment green infrastructure landscapes can be characterized as detention or bioretention facilities, and require rigorous engineering, calculations, and design to properly implement.

Designer should follow the City of Littleton Storm Drainage Design and Technical Criteria Manual (latest version) and Mile High Flood District Criteria Manual Volume 3 guidance.

Tributary: Volume based treatment green infrastructure devices accept direct rainfall, runoff from sidewalks, walkways, downspouts and runoff from roadways.

Environmental: Volume based treatment green infrastructure landscapes use a design engineered to treat flows by reducing runoff, increasing infiltration, and detaining stormwater flows to remove sediment and pollutants. They may also provide other environmental benefits though increased tree canopy and vegetation but are not the primary goals of volume based treatment green infrastructure devices.

Volume/Depression: Volume based treatment green infrastructure devices are depressed below the roadway curb and gutter flowline with greater volumetric capacity than flow based sized facilities.

Drainage Infrastructure: Volume based treatment green infrastructure designs should include underdrains connected to storm drain systems. These facilities should be placed in close proximity to existing or proposed storm drain systems. It should be noted that if subgrade infiltration rates exceed 3-inches per hour, modifications may be required to the design to lengthen the amount of time water is detained in the facility so that plant material may have sufficient time to uptake water.

Utilities: Volume based treatment green infrastructure devices require vertical clearance for storage and engineered components. These devices may have surface utilities around their perimeter but should be free of subsurface conflicts. Subsurface utility impacts such as water, sanitary, etc. may need to be moved to the outside of the device footprint or lowered below the bottom of the device and sleeved.

Soil Media and Planting: Volume based treatment green infrastructure landscapes utilize engineered soil media that allows sustainable vegetation establishment and growth, while maximizing infiltration properties. Mulch is not allowed in volume based treatment GI devices. Planting selections should be compatible with the depressed condition and tolerate frequent inundation.

Maintenance: A proper maintenance regime for volume based treatment landscapes includes regular removal of weeds and debris to ensure effective water filtration and prevent clogging. Routine inspections are also necessary to monitor plant health, soil conditions, and drainage performance, while occasional pruning, replanting, and sediment removal may be required to sustain optimal functionality and aesthetic appeal. Cleanout of inlets, overflows should be conducted on a seasonal basis to ensure the system remains unclogged and functions properly.

Image 22: Sunken Stormwater Planters Treat Water

Image 23: Stormwater Planters with Weir Walls

Image 24: Sunken Stormwater Planters with Edge Protection

Image 25: Sunken Stormwater Planters with Concrete Curbs

Facility Design Criteria

Design metrics to follow for implemention:

- Inflow gutters at minimum slope of 0.5% should be installed directly upstream of infrastructure to help reduce sediment deposition and maintenance of structures
- Ensure structures are a minimum of 10' from buildings with slope away from surrounding structures
- Stormwater Inlet/Outlet: Refer to MHFD or City for inlet and outlet design criteria
- Ensure a max depth 12" within structures
- Soil / Media: Ensure MHFD approved filter material is installed within facility

Image 26: Sunken Stormwater Planters with Gabion Seat Walls and Kick Rails

Green Infrastructure (GI) Tools

Canopy

At Grade landscape / open air planters

GI Landscape Classification

- Flow based treatment

Materials

- Soil media and trees, additional understory planting optional
- Irrigation equipment and infrastructure or irrigation for establishment (at a minimum)

Edging / Walk-off Protection

- No walk-off protection required
- Decorative edging may be utilized as a stylistic choice, or as applicable for areas with high pedestrian traffic

Context

- In streetside conditions, locate tree planting areas directly behind the back of curb
- Where parallel parking is present, provide a step out zone between 6 and 18 inches in a trafficable material

Tree Grate

GI Landscape Classification

- Flow based treatment
- Contextually based water quality treatment

Materials

- Durable, trafficable cast iron, in compliance with ADA standards and ASTM specifications
- Soil media & trees
- Irrigation equipment and infrastructure

Edging / Walk-off Protection

- Edging and/or walk-off protection not applicable
- Tree grates shall be installed flush with surrounding finished grade

Context

- Best applied in high pedestrian traffic areas for additional trafficable space
- Ensure placement puts tree free of conflict with the route-of-travel

Image 27: At Grade Planters with Generous Soil Volume to Support Trees

Image 28: Trees in Tree Grates with Shared Soil Volume

Structural Soil Cells

GI Landscape Classification

- Flow based treatment
- Contextually based water quality treatment

Materials

- Proprietary structural soil cell units
- Soil media & trees, additional understory planting optional, as applicable
- Irrigation equipment and infrastructure

Edging / Walk-off Protection

- Edging and/or walk-off protection not applicable
- Soil cells installed below finished grade

Context

- Site soil cells under sidewalks, where feasible
- Avoid placement under roadways to limit tree disturbance due to access & maintenance of roadways
- Soil cells shall be situated below finished grade, per the manufacturers specifications
- Soil cells shall be utilized in areas where necessary pavements prevent adequate sizing of an at-grade planting area to achieve recommended tree soil volume

Hardscape

Permeable Pavements

GI Landscape Classification

- Flow based treatment

Materials

- Permeable precast concrete unit pavers
- Precast grasscrete products
- Permeable plastic cell paver systems

Context

- Permeable pavement systems should consider pavements use - vehicular or pedestrian, as well as the intensity of that use
- Permeable precast concrete unit pavers are most widely applicable, suitable for vehicular and pedestrian environments and high trafficked areas
- Permeable plastic cell paver systems may be infilled and topped with grass or permeable gravel. Grass applications may be in large open space areas that vehicles may traverse. Gravel applications may be utilized in vehicular or pedestrian environments with low to moderate traffic intensity. Examples include soft trail systems, maintenance routes, overflow or low use parking areas etc.

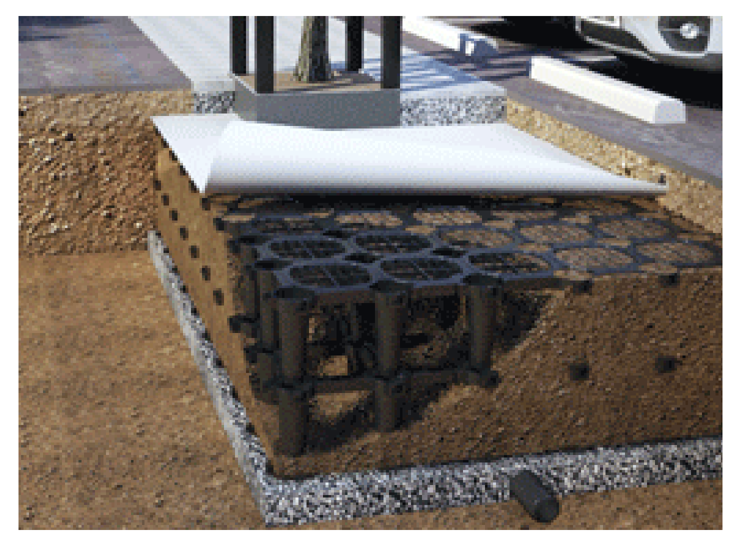


Image 29: Structural Soil Cell System

Image 30: Permeable Concrete Unit Pavers

Softscape

Landscape Areas

GI Landscape Classification

- Flow based treatment

Materials

- Soil media and plant material
- Irrigation equipment and infrastructure optional, as applicable for selected species

Edging / Walk-off Protection

- No walk-off protection required
- Decorative edging may be utilized as a stylistic choice, or as applicable for areas with high pedestrian traffic

Context

- In streetside conditions, locate planting areas within the amenity zone
- Ensure landscape areas are free of conflict with the route-of-travel
- For at-grade landscape areas where parallel parking is present, provide a step out zone between 6 and 18 inches in a trafficable material behind the back of curb
- For raised landscape areas where parallel parking is present, provide a minimum 18 inch step out zone between back of curb and the planter wall

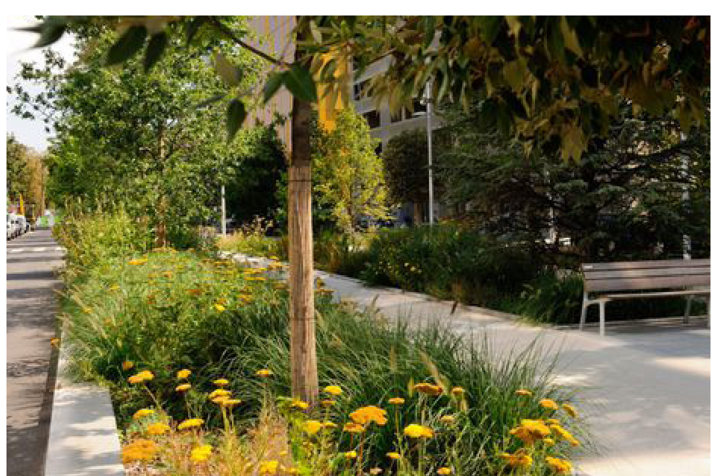


Image 31: At Grade Landscape Area

Flow Through Planter

GI Landscape Classification

- Flow based treatment
- Contextually based water quality treatment

Materials

- Soil media and plant material
- Modified roadway curb with either formed curb cuts or curb breaks and steel grate covers
- Intake energy-diffusing device such as cobble or a grasscrete pad

Edging / Walk-off Protection

- No walk-off protection required
- Decorative edging may be utilized as a stylistic choice, or as applicable for areas with high pedestrian traffic

Context

- Best located in streetside applications
- Where adjacent pedestrian walkways are present, locate between roadway and pedestrian walkway
- Where parallel parking is present, opt for a curb break and steel grate cover approach, providing a concrete step out zone of 18 inches
- In pedestrian contexts, horizontal stretches should be limited to 40 feet before offering a pedestrian cut through

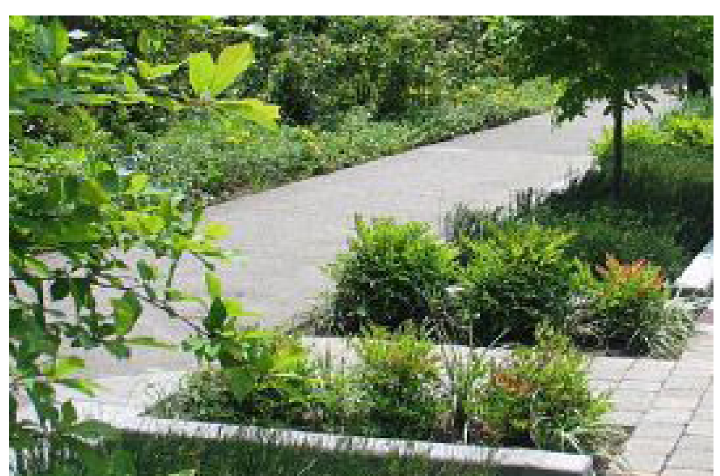


Image 32: Flow Through Planters

Infiltration Planter

GI Landscape Classification

- Contextually based water quality treatment
- Volume based treatment

Materials

- Soil media and plant material
- Modified roadway curb with either formed curb cuts or curb breaks and steel grate covers
- Overflow weir
- Intake energy-diffusing device such as cobble, grasscrete pad, or forebay

Edging / Walk-off Protection

- Edging / Walk-off protection is recommended adjacent to pedestrian and/or bicycle traffic
- Devices should be permeable to allow planter intake

Context

- These devices are most effective when sited in between a roadway and sidewalk, allowing intake from both sides
- Where parallel parking is present, opt for a curb break and steel grate cover approach, providing a concrete step out zone of 18 inches
- In pedestrian contexts, horizontal stretches should be limited to 40 feet before offering a pedestrian cut through

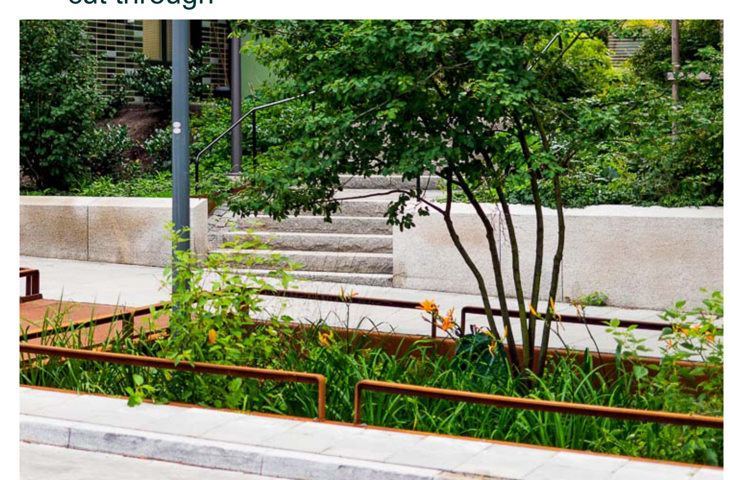


Image 33: Infiltration Planters with Kickrails

Stormwater Planter (with infrastructure)

GI Landscape Classification

- Volume based treatment

Materials

- Soil media and plant material
- Modified roadway curb with either formed curb cuts or curb breaks and steel grate covers
- Intake energy-diffusing device such as cobble, grasscrete pad, and forebay
- Overflow device and underdrain connected to the gray infrastructure network

Edging / Walk-off Protection

- Edging / Walk-off protection is recommended on all sides of these devices
- Protection devices should be permeable to allow planter intake

Context

- These devices are most effective when sited in between a roadway and sidewalk, allowing intake from both sides
- Implemented most efficiently when paired with other intensive roadway modifications
- Where parallel parking is present, use a curb break and steel grate cover approach, providing a concrete step out zone of 18 inches
- In pedestrian contexts, horizontal stretches should be limited to 40 feet before offering a pedestrian cut through

Image 34: Stormwater Planters with Curbs

IMAGE CREDITS

IMAGE #	SOURCE
FRONT COVER	https://www.chesapeakequarterly.net/images/uploads/siteimages/CQ/V15N1/p-3_urban-raingarden-small.png
INSIDE COVER	https://scontent-den2-1.xx.fbcdn.net/v/t31.18172-8/19417262_10155390100831462_3979876536872563621_o.jpg?_nc_cat=104&ccb=1-7&_nc_sid=b895b5&_nc_ohc=Dd4hudAN5vIQ7kNvgGkS8Dy&_nc_zt=23&_nc_ht=scontent-den2-1.xx&_nc_gid=Av4GoDBVyatPhNFQoGUDyMa&oh=00_AYAxqRCBu5_myaFpbgYw3vBxhqP4ODUvU4qY7IQpyL3Y5w&oe=67361BDF
1	epa.gov/green-infrastructure/economic-benefits-green-infrastructure
2	https://climatechange.colostate.edu/downloads/CCC%202024%20Climate%20Assessment%20Report%20pages%20view.pdf
3A	https://littleton.maps.arcgis.com/apps/instant/lookup/index.
3B	Project Downtown Existing Conditions Data Book
4	https://funkia.se/projekt/taby-park/
5	https://19january2017snapshot.epa.gov/sites/production/files/region8/greeninfrastructure/RainGardens/Colorado6WenkTaxi.jpg
6	http://asburyparkchoice.com/wp-content/uploads/native-plantings.jpg
7	https://landezine.com/constitution-avenue-canberra-by-jane-irwin-landscape-architecture/
8	https://www.anovafurnishings.com/media/anovafurnishings/project/CO-BrightonBlvd-gabion-14.jpg
9	https://landezine.com/wp-content/uploads/2012/10/AAUPC_Patrick_Chavannes-Boulogne_Cours_Seguin-3.jpg
10	https://dropinblog.net/34241096/files/featured/14490897207_d57d41aa3b_b.jpg
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13	https://www.deeproot.com/wp-content/uploads/stories/2018/03/10794561065_3c249f3bc6_z.jpg
14	https://www.epa.gov/sites/default/files/2015-05/documents/meeting-presentation-11-06-13.pdf
15	https://encrypted-tbn2.gstatic.com/images?q=tbn:ANd9GcT1YPDqfB57rTgpdG4V8D0WbOikCvyX5jNrcpplfTqMk4b60bvf
16	https://www.aj-landskap.se/wp-content/uploads/2021/05/KDn_djurg%C3%A5rdsstaden_D_19879.jpg
17	https://usercontent.one/wp/bluegreengrey.edges.se/wp-content/uploads/2021/06/c-540x1024.jpg
18	https://landezine-award.com/wp-content/uploads/2020/04/Sankt-Kjelds-Square-and-Bryggervangen_Mikkel-Eye_21.jpg
19	https://climate.asla.org/images/case-images/SW12thAveGreenStreet-2.jpg
20	https://www.southsidegreen.com/wp-content/uploads/2014/01/Urban-Parking-.jpg
21	https://leabraze.com/wp-content/uploads/2023/03/Bio-swale-2-1024x886.jpg
22	https://live.staticflickr.com/5483/10979885363_2336518a2d_w.jpg
23	https://encrypted-tbn3.gstatic.com/images?q=tbn:ANd9GcT808OIuLbrgz7rHGRezwhb1aA-syDpN4VFfi5MqNiaJk7x9a_l
24	https://www2.minneapolismn.gov/media/content-assets/images/MWMO_8th_st_2_Tile-Resized.jpg
25	https://www.reasite.com/
26	https://www.anovafurnishings.com/media/anovafurnishings/project/CO-BrightonBlvd-gabion-14.jpg
27	https://www.bergerpartnership.com/wp-content/uploads/2016/04/Smaller-rectangle-Stack-House-2.jpg
28	https://www.ironagegrates.com/wp-content/uploads/2017/04/Chestnut-St-Laser-Cut-6-E-1.jpg
29	https://www.sensoterra.com/wp-content/uploads/2024/04/Strata-animated-CityGreen.gif
30	https://www.belgardcommercial.com/wp-content/uploads/2023/09/ecodublin_sri.jpeg
31	https://landezine.com/wp-content/uploads/2012/10/AAUPC_Patrick_Chavannes-Boulogne_Cours_Seguin-3.jpg
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34	https://livablecitiesstudio.com/wp-content/uploads/2024/03/Livable-Cities-Studio-39th-Greenway-TheUnfoundDoor-4-1024x682.jpg