



CITY OF
GRAND
RAPIDS



Green Infrastructure Guidance

December 2016

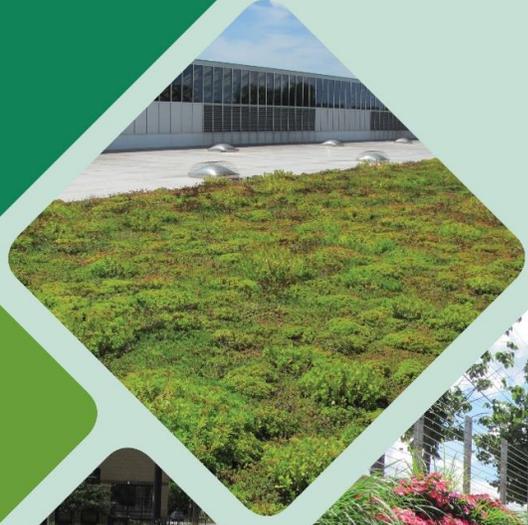


TABLE OF CONTENTS

1.0 INTRODUCTION	1
1.1 Purpose	1
1.2 How to Use this Guide	1
2.0 GREEN INFRASTRUCTURE PRACTICE SITING POSSIBILITIES	2
2.1 Design Principles	2
2.2 Constituent Components	4
2.3 Selection and Application	5
2.4 Residential Conceptual Design	7
2.5 Urban Conceptual Design	9
2.6 Correlating Green Infrastructure with Street and Property Characteristics	12
3.0 GREEN INFRASTRUCTURE PRACTICE FACT SHEETS	15
Capture and Reuse Systems	16
Curb Extensions (Bulb-Out)	20
Detention and Retention Basins	24
Leaching Basin	28
Linear Bioretention	32
Permeable Pavement	36
Stormwater Planter	40
Suspended Pavements	44
Trees	48
Underground Infiltration Basins	52
Water Quality Structures	56

TABLE OF FIGURES

Figure 1 Carrier St. NE Curb Bulb-Out	3
Figure 2 Example Green Infrastructure Practices in a Residential Neighborhood	7
Figure 3 Permeable Parking Lane and Linear Bioretention in Residential Neighborhood	8
Figure 4 Permeable Parking Lane and Bioretention Curb Extension in Residential Neighborhood	9
Figure 5 Example Green Infrastructure Practices in an Urban Setting	10
Figure 6 Urban Green Infrastructure Example	11
Figure 7 Urban Green Infrastructure Example	12
Figure 8 Green Infrastructure Possibilities in the Street Right-of-Way	13
Figure 9 Green Infrastructure Possibilities in Site Development Properties	14

1.0 INTRODUCTION

Stormwater runoff is a major cause of water pollution in urban areas. Stormwater carries trash, bacteria, heavy metals, and other pollutants from the urban landscape to local receiving waters. Higher flows also can cause erosion and flooding in urban streams, damaging habitat, property, and infrastructure. When rain falls in undeveloped areas, soil and plants absorb and filter the water. When rain falls on our roofs, streets, and parking lots, however, the water cannot soak into the ground.

Traditionally, the intent of stormwater management was to drain stormwater quickly away from urban areas into nearby water bodies for separate storm sewer areas or to the wastewater treatment plant for combined sewer areas. Stormwater management has now evolved into incorporating green infrastructure as an alternative to or in combination with the traditional “gray” infrastructure practices.

In Grand Rapids, green infrastructure refers to the patchwork of natural areas including parks, public spaces, environmental assets and the network of streetscapes, trails, and greenways that connect them. Green infrastructure is the vision for the future of Grand Rapids as described in the *Green Grand Rapids Master Plan* providing habitat, flood protection, cleaner air, cleaner water, and an enhanced public realm.

At a smaller scale, green infrastructure also refers to the engineered stormwater practices used to mimic nature using vegetation, soils, and natural processes. These practices soak up and store stormwater before it starts channeling into curb inlets and pipes. Green infrastructure practices foster multiple environmental, economic, and community benefits simultaneously improving water quality and helping to revitalize urban communities. Green infrastructure practices are the focus of this manual.

1.1 PURPOSE

This guidance document is intended as a starting point for incorporating green infrastructure into a site or within the street right-of-way and targets developers, engineers, and city officials. The material in the manual provides planning level concepts only. For technical information, refer to the *Grand Rapids Green Infrastructure Technical Reference Manual*.

1.2 HOW TO USE THIS GUIDE

This document is divided into two sections. Section 2 focuses on the possibilities for siting and incorporating green infrastructure practices within the street right-of-way and within a site development using illustrations and matrices. Section 3 provides a set of fact sheets each assigned to design, maintenance, and costing considerations for one practice. The fact sheets present stand-alone information on a conceptual level.

2.0 GREEN INFRASTRUCTURE PRACTICE SITING POSSIBILITIES

Possibilities for incorporating green infrastructure into properties and within the street right-of-way are presented in this section. Possibilities are shown pictorially as well as in accompanying matrices and are not meant to encompass all opportunities for green infrastructure but rather provide ideas. Additionally, the concepts are not necessarily meant to be implemented together; for example, a curb extension downstream of a permeable parking lane may not be effective because runoff may be completely captured by the permeable pavement. At the planning level, these principles can be applied to a given property or street to assist in laying out green infrastructure concepts. The information is presented for residential neighborhoods and an urban commercial district.

2.1 DESIGN PRINCIPLES

Green infrastructure practices use a variety of methods to slow down and filter stormwater runoff thereby giving the runoff a chance to infiltrate and be taken up by plants. When determining the appropriate requirements, consideration should be given to site characteristics such as topography; soils; land use requirements such as dwellings and transportation; and policy issues such as treatment requirements and tree canopy targets. These characteristics and their impacts on design are important because green infrastructure practices are permanent features that can affect other project elements.

The following are some fundamental planning concepts to consider (adapted from Prince George's County LID Design Strategies 1999 and San Antonio River Basin LID Technical Guidance Manual 2013):

1. *Use hydrology as the integrating framework.* Integrating hydrology during project planning begins with identifying sensitive areas, including streams, floodplains, wetlands, steep slopes, highly permeable soils, and woodland conservation zones. Through that process, the total site area that affects the hydrology is defined. Reducing, minimizing and disconnecting impervious areas is an important step. Efforts should also focus on increasing flow paths to match timing issues and promoting storage to manage runoff volumes and peaks. The goal is an integrated hydrologically functional design that seeks to maintain predevelopment hydrology. The result is often improved recreational resources through the addition of additional landscape features.
2. *Use distributed practices.* Distributed control of stormwater throughout the project area can be accomplished by applying small scale practices across the site (e.g. bioretention in landscaped areas, permeable pavement in sidewalks and parking stalls). Such small-scale practices foster opportunities to maintain the natural hydrology, provide a greater range of control, allow practices to be integrated into landscape features, and provide redundancy if one technique fails.
3. *Control stormwater at the source.* Undeveloped sites possess natural stormwater mitigation functions such as interception, depression storage, water uptake by plants, and infiltration over large areas. Those hydrologic functions should be restored or mimicked through design to minimize and mitigate the hydrologic effects from the development project. Trying to control or restore these functions using an end-of-pipe stormwater management approach is difficult, if not impossible. Therefore, compensation or restoration of these hydrologic functions should be implemented as close as possible to the source.
4. *Use simple methods.* Traditional stormwater management techniques focus on flow conveyance and centralized detention systems. Small simple methods are often overlooked. Methods employing existing soils, native vegetation, and natural drainage features can be integrated into the design. These smaller facilities tend to feature shallow depths and gentle side slopes which

can reduce safety concerns. An example is a shallow depressed areas between the curb and the sidewalk that accepts runoff from a road and allows the water to soak into the ground. These types of facilities may be vegetated with a wide range of plants thereby increasing the public's acceptance and willingness to adopt and maintain such a system.

5. *Create a multifunctional landscape and infrastructure.* Urban landscape features such as roofs, streets, sidewalks, parking, and green spaces, can be designed to be multifunctional by incorporating detention, retention, and filtration functions. Practices such as a curb bulb-out with bioretention can manage stormwater, increase safety for pedestrians by reducing street crossing lengths and provide traffic calming, while improving the urban aesthetics through increased vegetated areas.



Figure 1 Carrier St. NE Curb Bulb-Out

Site planning and right-of-way improvements have well-established processes consisting of numerous steps. Often incorporation of green infrastructure into this process introduces new considerations to better mimic the predevelopment hydrology and create a hydrologically functional landscape. These concepts include considering hydrology as a design focus, minimizing impervious cover, disconnecting impervious surfaces, increasing flow paths, and defining and siting small frequent distributed stormwater management practices. Siting and designing the appropriate practices is often an iterative process that requires a holistic planning and design approach.

A thorough site assessment is initially needed. The primary objective of the site assessment process is to identify limitations and development opportunities specific to green infrastructure. Constraints or limitations that need to be factored into the design process include:

- Slow-infiltrating soils
- Soil contamination
- Steep slopes
- Karst geological features
- Proximity to foundations or structures
- Proximity to sewers and the condition of the sewers
- Wells and groundwater recharge zones
- High seasonal water table

2.2 CONSTITUENT COMPONENTS

Green infrastructure can be applied at a range of scales. One way to look at green infrastructure opportunities is to think about the constituent components of the urban environment, i.e. buildings, property surface features, streets and open spaces.

- *Buildings.* Green infrastructure opportunities of buildings focus on the surface treatment of the roof and walls, and harvesting the stormwater runoff for other uses. Vegetated roofs can be used to promote temporary stormwater storage and improved evapotranspiration. Facilities on the walls of the building include disconnecting downspouts, vegetated screens and walls. Other benefits of vegetated roofs and walls include improved air quality, heat island mitigation, and urban biodiversity. Rainwater harvesting ranges from simple systems such as rain barrels for irrigation to complex systems whereby the water is reused for non-potable and possibly potable sources.
- *Property Surface Features.* Property surface features include a wide range of possibilities but may be grouped into pervious and impervious categories. Pervious surface features include, for example, lawns, planting beds, and natural areas. Common impervious surface features include: driveways, patios, and parking lots. Reducing the amount of impervious surfaces directly reduces the quantity of stormwater runoff needing stormwater management. Surface features may be altered to promote the green infrastructure principles. For example using permeable pavements in place of traditional pavement and replacing lawns with bioretention. Alternatively, bioretention or bioswales can be incorporated into a traditional pavement parking lot to divert runoff into the bioretention area.
- *Streets.* Like the surface features of parcels, streets can be designed to provide ecologically-based stormwater management while providing multiple transit modes. Common approaches include: creating narrower streets to reduce the amount of runoff generated; substituting permeable pavement in place of impervious surfaces to encourage infiltration; and maximizing landscaped areas to provide filtration, infiltration and evapotranspiration. The addition of shade trees reduces the heat island effect, improves air quality, and provides many social benefits while also helping to manage stormwater runoff.
- *Open Spaces.* Open spaces chiefly consist of publicly owned land areas and waterbodies which offer recreational, aesthetic and ecological functions. Open spaces can be used to manage stormwater at the block or neighborhood scale by directing runoff into them. The types of green infrastructure typically installed in open spaces include bioretention, constructed wetlands, retention ponds, and detention basins. Additionally, subsurface stormwater management practices may be incorporated leaving the surface available for a wide variety of uses.

2.3 SELECTION AND APPLICATION

This section provides guidance on selecting the best green infrastructure practice for a project site. Selection and application of a green infrastructure practice depends on the desired hydrologic outcomes. While site planning techniques such as preservation of natural features and minimizing the creation of impervious surfaces can greatly reduce the hydrologic impacts of development, additional green infrastructure practices are likely needed to meet post development requirements. Examples of green infrastructure practices and applications are provided in Table 1. Practices are selected, arranged and sized according to site constraints, aesthetics and costs. Green infrastructure practices are supplemented by conventional practices as needed to meet the overall design objectives.

Within each practice type there are a myriad of materials, layouts and construction methods. For example, permeable pavement materials can include concrete, asphalt, clay bricks, and plastic geocells. To continue the example of options, concrete can be used as poured-in-place porous concrete, precast porous concrete panels, open-celled paving grids, and open-jointed paving blocks. Similarly vegetated systems have countless options on the configuration, size, cross-section, and vegetation selection.

Table 1 Green Infrastructure Practices and Applications

			Quantity					Quality		Cost	
			Volume Reduction for WQv (90%)	Volume Reduction for Channel Protection (2-yr)	Peak Flow Reduction for Channel Protection (2-yr)	Peak Flow Reduction for Conveyance Capacity (10-yr)	Peak Reduction for Flood Control (25 to 100-yr)	Sediment	Temperature	Installation	Maintenance
Building	Buildings	Green Roofs	M/H	Med	Med	Low	Low	Med	High	High	Med
		Green Walls	Low	Low	Low	Low	Low	Low	Med	High	Med
	Water Harvesting	Rain Barrel	Low	Low	Low	N/A	N/A	Low	Low	Low	Low
		Cistern	Low	Low	Low	N/A	N/A	Low	Low	Med	Med
Property Surface Features	Bioretention	Open Area	High	Med	Med	Low	Low	High	High	Low	Med
		Next to Buildings	High	Med	Med	Low	Low	High	High	Med	Med
		Parking Lot Islands	High	Med	Med	Low	Low	High	High	Med	Med
		Parking Parameter	High	Med	Med	Low	Low	High	High	Med	Med
		Parking Between Stalls	High	Med	Med	Low	Low	High	High	Med	Med
		Tree Box Planting	High	Med	Med	Low	Low	High	High	High	Low
	Permeable Pavement	Park Lot	High	Med	Med	Low	Low	High	Med	Med	Med
		Sidewalks	High	Med	Med	Low	Low	Low	Low	Med	Med
Hydrodynamic	Devices	N/A	N/A	N/A	N/A	N/A	High	Low	High	Low	
Streets	Bioretention	Linear Systems	High	Med	Med	Low	Low	High	High	Med	Med
		Center Median	High	Med	Med	Low	Low	High	High	Med	Med
		Curb Extensions	High	Med	Med	Low	Low	High	High	Med	Med
		Planter Box	High	Med	Med	Low	Low	High	High	High	Med
		Tree Box	High	Med	Med	Low	Low	High	High	High	Low
	Permeable Pavement	Parking Lane	High	Med	Med	Low	Low	High	Med	Med	Med
		Travel Lane	High	Med	Med	Low	Low	High	Med	Med	Med
		Alleys	High	Med	Med	Low	Low	High	Med	Med	Med
Open Space	Vegetated	Detention / Retention Basins	Low	Low	Low	Med	High	L/H	Low	High	Low
		Constructed Wetlands	High	Med	Med	Low	Low	High	High	High	Med
		Filter / Buffer Strips	Med	Low	Low	Low	Low	Med	Low	Low	Low
	Leaching	Subsurface Infiltration Chamber	High	High	High	M/H	M/H	High	High	M/H	Med
Mulch	Leaching	Leaching Catch Basins	High	Med	Low	Low	Low	High	High	Low	Low
		Subsurface Linear Infiltration	High	Med	Low	Low	Low	High	High	Med	Med
		Surface Infiltration Trenches	High	Med	Low	Low	Low	High	High	Med	Med

2.4 RESIDENTIAL CONCEPTUAL DESIGN

This section provides conceptual design examples of how green infrastructure practices may be incorporated into a project. Figure 2 illustrates an example residential neighborhood with distributed green infrastructure practices to slow down, spread out and soak in the stormwater runoff. On the individual lots, the two largest impervious surfaces, and hence the largest sources of rainfall runoff, are the building roofs and the driveways. This illustration shows a rain garden next to a dwelling to manage the roof runoff and rainfall on the driveways is managed with permeable pavements. Within the right-of-way, the major sources of runoff is from the sidewalk and road surfaces. In this example, runoff is managed through the use of permeable sidewalks and parking lanes, and bioretention in a linear form next to the road and in curb bulb-outs at the end of the block. The overall theme emphasized in this example is to manage the runoff close to where the raindrop fell. This approach results in placing many small green infrastructure practices in many locations. One major benefit of this approach is that the potential to infiltrate the stormwater is maximized as the surface area increases.

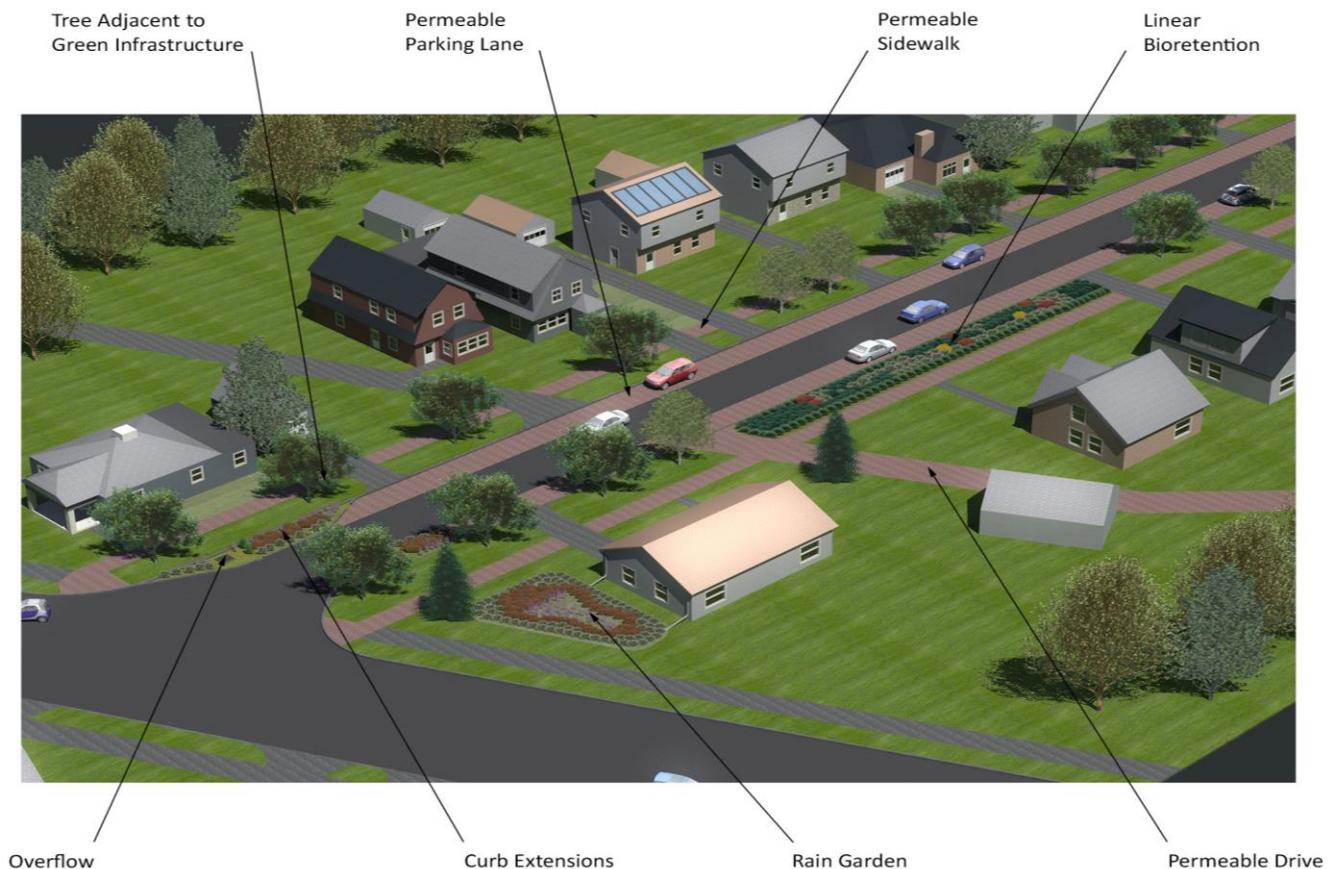


Figure 2 Example Green Infrastructure Practices in a Residential Neighborhood

Streets represent a significant portion of the impervious surfaces within a residential neighborhood and consequently contribute a large percentage of the stormwater runoff. A typical road right-of-way includes the road, sidewalks on either side of the road and a vegetated area between the sidewalk and the road. The vegetated area is most commonly planted as turf grass and is higher than the gutter pan of the road. In a traditional design approach, runoff drains from the individual lot, across the sidewalk, across the turf grass strip and into the gutter. And the road is crowned in the middle so each side of the road drains to gutter pan. The road drainage is then routed to a series of catch basins and piped to a nearby receiving stream.

In the close up view in Figure 3 a different approach is shown using the vegetated space between the sidewalk and the road. In this case a linear bioretention is located in the vegetated space at an elevation lower than the road so it becomes the low point collecting the runoff from the right-of-way. As can be seen in the illustration, the vegetation in the linear bioretention is shown as native shrubs and perennials. However many different options are available for the plant selection within a bioretention system. For example, this area could be planted as turf grass with street trees. Also illustrated in Figure 3 is the use of a permeable parking lane, displayed as interlocking paver. The permeable parking lane accepts runoff from the road surface and promotes infiltration into the ground.



Figure 3 Permeable Parking Lane and Linear Bioretention in Residential Neighborhood

Figure 4 illustrates the use of bioretention placed in curb bulb-outs and permeable parking lanes. The benefits of using a curb bulb-out is an overall reduction in impervious surfaces and social benefits from traffic calming and shorter pedestrian crossing distances. The downside to bulb-outs is potentially a loss of parking spaces which may be mitigated by placing the bulb-outs in areas where no parking is allowed. Additionally, adequate turning radius and emergency vehicle access needs to be considered when designing bulb-outs.



Figure 4 Permeable Parking Lane and Bioretention Curb Extension in Residential Neighborhood

2.5 URBAN CONCEPTUAL DESIGN

Figure 5 illustrates a conceptual design of green infrastructure placed in an urban commercial setting. Many different types of practices are placed throughout the illustration emphasizing the concept of using many distributed practices instead of a large centralized approach. The figure illustrates the following practices:

- **Trees Planted in Structural Cells.** Planting trees in a trench system under a sidewalk allows for sufficient soil to grow healthy mature trees and manage the stormwater runoff within the soil layer. In these systems runoff may be routed to the tree trench from the sidewalk, road and building roofs. The trees benefit from soil volume and natural irrigation. Pedestrians benefit from the shade and improved aesthetics and the building uses less energy due to the shading.
- **Curb Extensions (or bulb-outs).** Curb extensions along the roadway are constructed as a form of bioretention to manage the road runoff. Protruding the bioretention into the road removes impervious cover, provides a traffic calming effect and reduces the pedestrian street crossing distance.
- **Permeable Sidewalks.** Permeable sidewalks may be constructed out of many different types of materials and can be constructed to fully comply with ADA requirements. Since the sidewalk is permeable rainwater simply drains straight through it.
- **Median Bioretention.** Medians in our roadways are nothing new and are traditionally constructed raised above the road surface. By depressing a median below the road surface and providing vegetation, the median is transformed into a bioretention system. Vegetated medians remove impervious cover from the roadway. Medians constructed as bioretention not only remove impervious cover but can also manage runoff from the surrounding impervious surfaces.

- **Green Roof.** Green roofs offer a host of benefits right where the rain falls. They provide improved insulation to the building and typically manage the first inch of rainfall. In addition, they provide an aesthetic improvement for people looking out windows from taller, adjacent buildings and can provide many ecological benefits for pollinators.

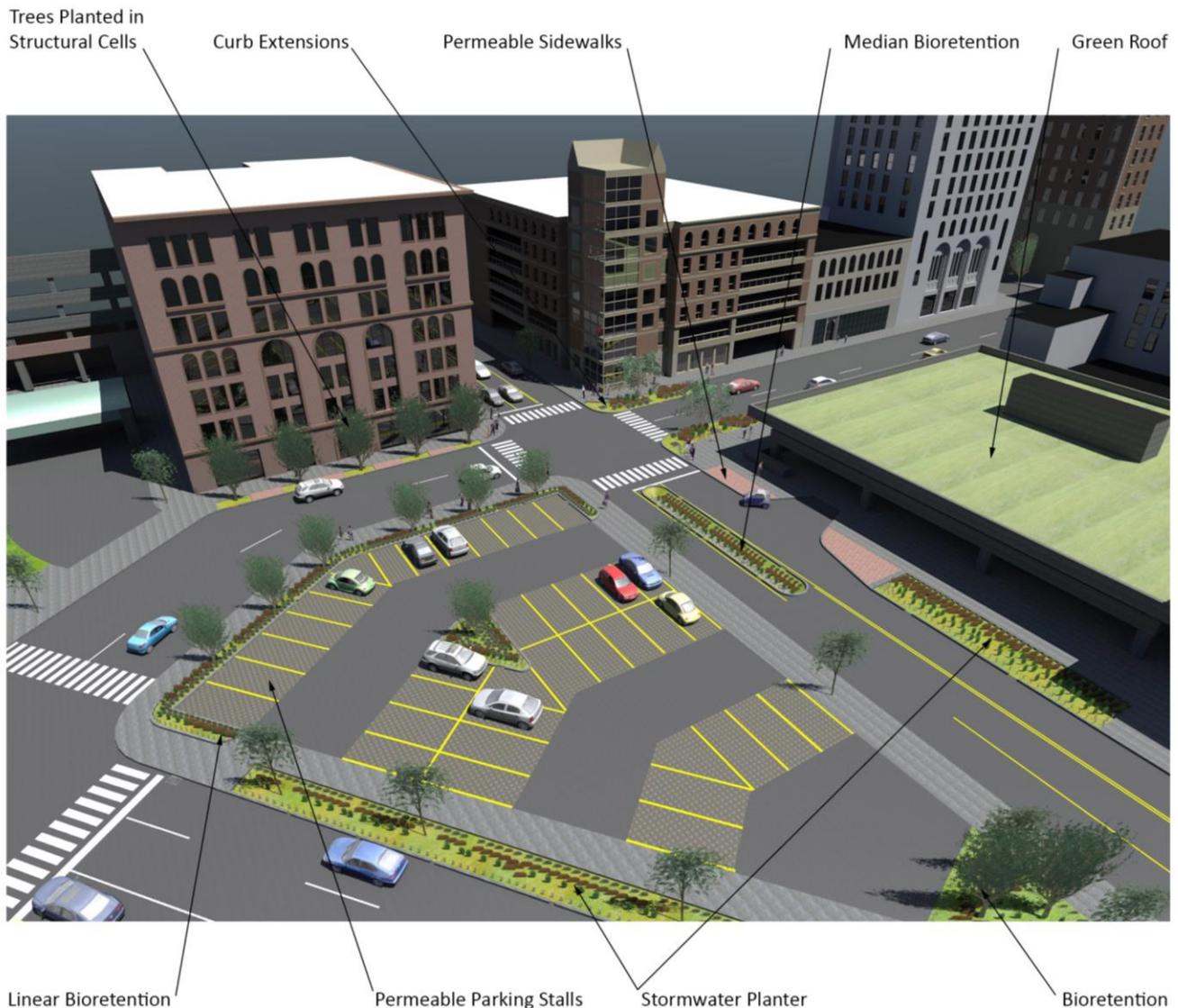


Figure 5 Example Green Infrastructure Practices in an Urban Setting

- **Linear Bioretention.** The linear bioretention in the illustration is placed around the perimeter of the parking lot. This location can typically be used to accept runoff in the form of sheet flow from the parking lot. The linear bioretention around the perimeter can usually fit within the parcel set-back requirements and fulfill screening requirements with the vegetation. Trees placed in the bioretention may reduce heat island impacts from the shading and can be used to meet tree canopy goals.
- **Permeable Parking Stalls.** Permeable parking stalls allow the runoff to seep vertically through the pavement. Permeable pavements also reduce noise pollution and keep the ground beneath the pavement warmer in the wintertime reducing the number of freeze-thaw cycles the

pavements go through. Permeable pavements use less deicing materials in the winter and don't allow surface water to refreeze thereby reducing the number of slip-fall accidents.

- **Stormwater Planter.** Stormwater planters are just another form of bioretention. In this case short retaining walls are commonly used around the perimeter of the planter. This maximizing the space and volume for stormwater management in a sidewalk setting. Planter boxes commonly accept water from the sidewalk and street surface but may also be designed to accept runoff from rooftops.
- **Bioretention.** The bioretention shown in the illustration has a large surface area that allows the soil surface to be gently graded up to the sidewalk elevation. Bioretention areas such as this may be designed as a pocket park.

Figure 6 and Figure 7 offer an enlarged view and different perspective of the urban example shown in Figure 5. Figure 6 takes a closer look at the tree trench system along the sidewalk and the bioretention bump-outs at the far end of the intersection. Figure 7 looks closer at the green infrastructure around the parking lot. In this view a bioretention island is shown situated in a triangular piece of the parking lot where the parking stalls change angles and is unusable for parking.

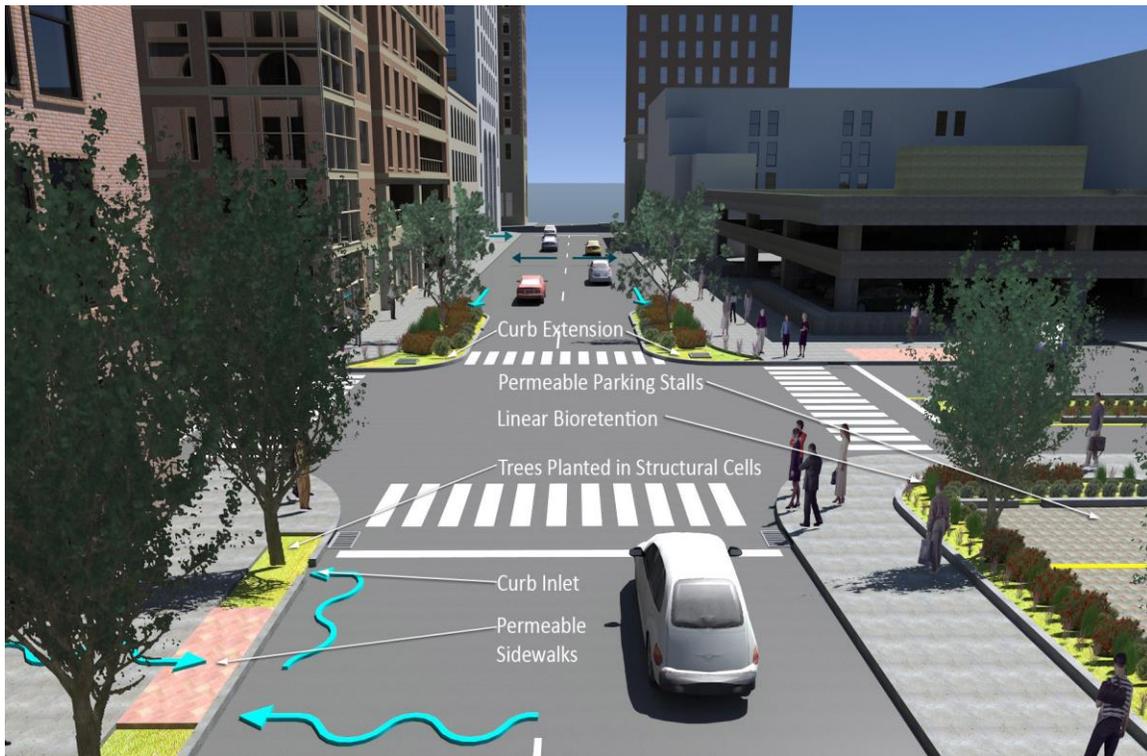


Figure 6 Urban Green Infrastructure Example - View 1



Figure 7 Urban Green Infrastructure Example – View 2

2.6 CORRELATING GREEN INFRASTRUCTURE WITH STREET AND PROPERTY CHARACTERISTICS

The matrices provided in this section correlate street right-of-way and property characteristics to green infrastructure practice type. Street right-of-way characteristics applicable to green infrastructure selection include width of street, width of median, extent of parking, presence of mature trees, age of pavement, and phase/status of development. Property characteristics applicable to green infrastructure selection include the presence of roof drains, extent of paved areas, sun exposure, availability and slope of lawn area, and the pitch of the roof. Understanding these characteristics helps in selecting appropriate green infrastructure practices for a given location at the planning level. It can also help to prioritize potential locations for green infrastructure. Figure 8 presents the characteristics of the street right-of-way and Figure 9 presents characteristics of a property.

	Street width wider than 24'	Street width lesser than 24'	Median greater than 4'	Edge of sidewalk to street less than 5'	Edge of sidewalk to street more than 5'	Premium curbside parking	Excess curbside parking	No parking zone	Many mature trees in right-of-way	Aging pavement or new street
Permeable Pavement	●	●	●	●	●	●	●	●	●	●
Curb Bulb-out Bioretention	●				●		●	●	●	●
Stormwater Planter	●	●	●		●	●	●	●	●	●
Median Bioswale	●		●		●	●	●	●		●
Linear Bioretention	●	●	●		●	●	●	●		●
Trees	●	●	●	◐	●	●	●	●	●	●
Trees with Suspended Pavement Systems	●	●	●	●	●	●	●	●		●
Leaching Basin	●	●	●	●	●	●	●	●	●	●

● Feasible ◐ Not less than 3'

Figure 8 Green Infrastructure Possibilities in the Street Right-of-Way

	Roof Drains with Downspouts	Existing Walks, Drives or Patios	Southern or Western Exposure	Gradually Sloping	Available Lawn Area	Flat or Low Pitched Roof	New Buildings in Design Phase	New Parking Lot in Design Phase	Vacant Parcel
Permeable Pavement	●	●		●	●		●	●	
Stormwater Planter	●	●		●	●		●	●	
Linear Bioretention	●	●		●	●		●	●	●
Rain Garden	●	●		●	●		●	●	●
Infiltration Trenches	●	●		●	●		●	●	●
Vegetated Filter Strip	●	●		●	●		●	●	●
Green Roof						●	●		
Reduced Pavement		●					●	●	
Reduce Lawn and Add Plantings					●		●	●	●
Plant Border or Windbreak			●	●			●	●	
Increase Solar Gain			●				●		
Curb Bulb-out Bioretention		●		●	●		●	●	
Trees	●	●	●	●	●		●	●	●
Trees with Suspended Pavement System	●	●		●			●	●	
Leaching Basin	●	●		●	●		●	●	

● Feasible

Figure 9 Green Infrastructure Possibilities in Site Development Properties

3.0 GREEN INFRASTRUCTURE PRACTICE FACT SHEETS

The last section of this document presents a series of stand-alone green infrastructure fact sheets. Each fact sheet is dedicated to one type of green infrastructure practice. The information provided in each fact sheet includes a description, objectives toward greening Grand Rapids, cost considerations, design guidelines and components, maintenance considerations, and water quality and quantity performance. The fact sheets are meant as a cursory overview of a practice to understand its applicability for a given site. Following initial planning for a site, the *Grand Rapids Green Infrastructure Standards* should be referenced.

Fact Sheets

- *Capture and Reuse Systems*
- *Curb Extensions (Bulb-Out)*
- *Detention and Retention Basins*
- *Leaching Basin*
- *Linear Bioretention*
- *Permeable Pavement*
- *Stormwater Planter*
- *Suspended Pavements*
- *Trees*
- *Underground Infiltration Basins*
- *Water Quality Structures*

Description:

Linear bioretention is located between the curb/gutter or shoulder of the road and sidewalk (or street right-of-way). They can be designed with a curb-cut opening that allows stormwater to enter the linear bioretentions from the gutters or with a grass filter strip with roads without curbs. The stormwater runoff is then captured in a depressed planting area and then either infiltrates into the soil or flows through an underdrain to the storm drain network.



NE Martin Luther King Jr. Boulevard, next to the Oregon Convention Center, Portland, OR



NE Martin Luther King Jr. Boulevard, next to the Oregon Convention Center, Portland, OR

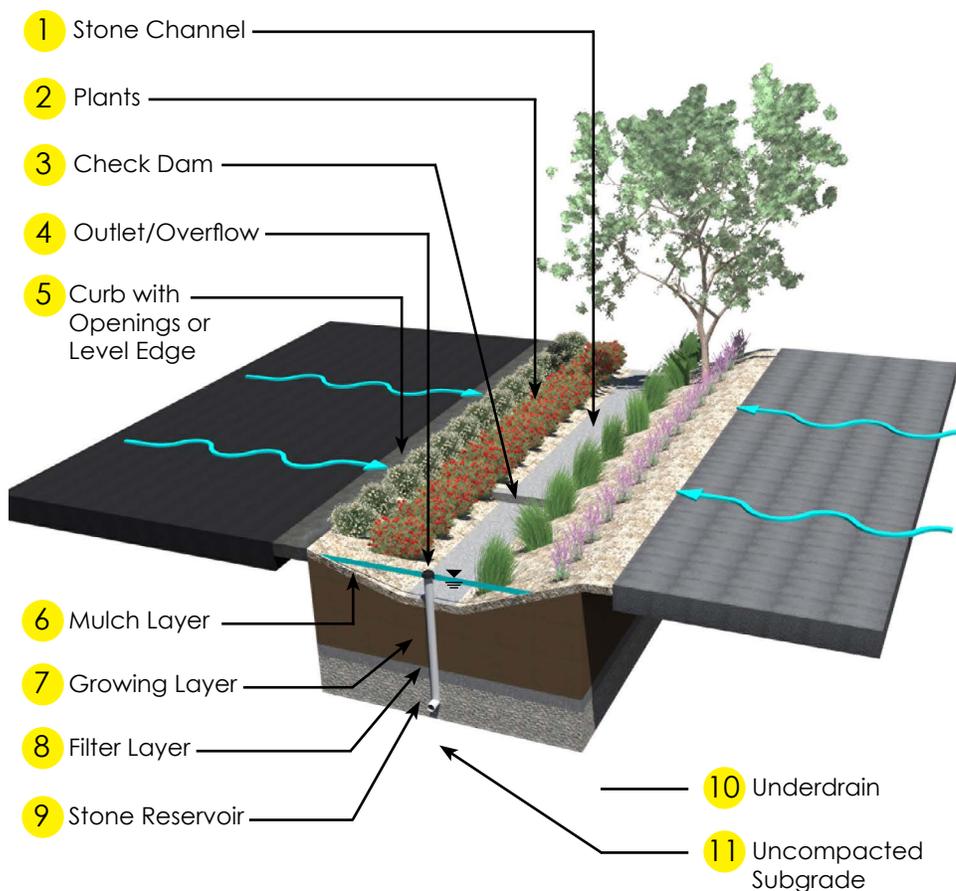
Green Objectives:

- Reduce stormwater run-off that would normally flow directly into the City's already burdened storm sewer system.
- Improve water quality by filtering pollutants.
- Reduce effective impervious area.
- Promote infiltration to the groundwater table.
- Reduce local flooding and ponding.
- Increase the quantity of green infrastructure practices throughout the City consistent with sustainability goals.
- Increase habitat for birds and butterflies.
- Increase native plantings and plant species diversity.

Key Considerations:

- Do not impede necessary pedestrian movement.
- Coordinate with bike lanes or routes.
- Avoid conflict with fire hydrants and other above ground utilities.
- Avoid conflict with existing underground utilities.
- If overhead utility lines are present, use smaller trees or shrubs.
- Work within City setback requirements.
- Use native plants when possible.
- Ensure the design does not undermine surrounding structures.

LINEAR BIORETENTION



Components

- 1 Stone Channel:** Stone or pea gravel lining at bottom of channel. Required if water velocity is high.
- 2 Plants:** Trees, shrubs, and ground covers that can withstand both wet and dry conditions.
- 3 Check Dam:** Stone or concrete barrier to slow velocity or increase ponding.
- 4 Outlet/Overflow:** Pipe riser that allows water to pond before it is collected and released into the underdrain and stone storage layer. May or may not be required.
- 5 Curb with Openings or Level Edge:** Breaks in the curb can allow stormwater to pass through into the bioretention area or if water velocity is low, edge can be level with bioretention area
- 6 Mulch Layer:** Shredded hardwood bark or other acceptable mulch (approximately 2-inch layer).
- 7 Growing Layer:** A blend of soil, compost, and sand to allow drainage and support plant growth.
- 8 Filter Layer:** Fine aggregate to prevent soil from migrating down to the stone reservoir.
- 9 Stone Reservoir:** Stone layer where water will collect until it infiltrates into the subsoil.
- 10 Underdrain:** Perforated pipe that takes excess water to the storm sewer system.
- 11 Uncompacted Subgrade:** Existing soil below the stone reservoir where stormwater infiltrates.

General Design Guidelines:

- Avoid installation of linear bioretention in areas where the water table is less than 2 feet below the bottom of the practice.
- Ensure the overflow elevation is lower than the downstream bank yet above the bottom of the linear bioretention to promote infiltration.
- Include an impermeable liner when within 10 feet of a basement.
- Side slopes should be no steeper than 3 Horizontal:1 Vertical.
- Include pretreatment sumps at the inlets with easy access for maintenance.
- Provide a stone channel or other mechanism at the inlet to slow velocities if needed.

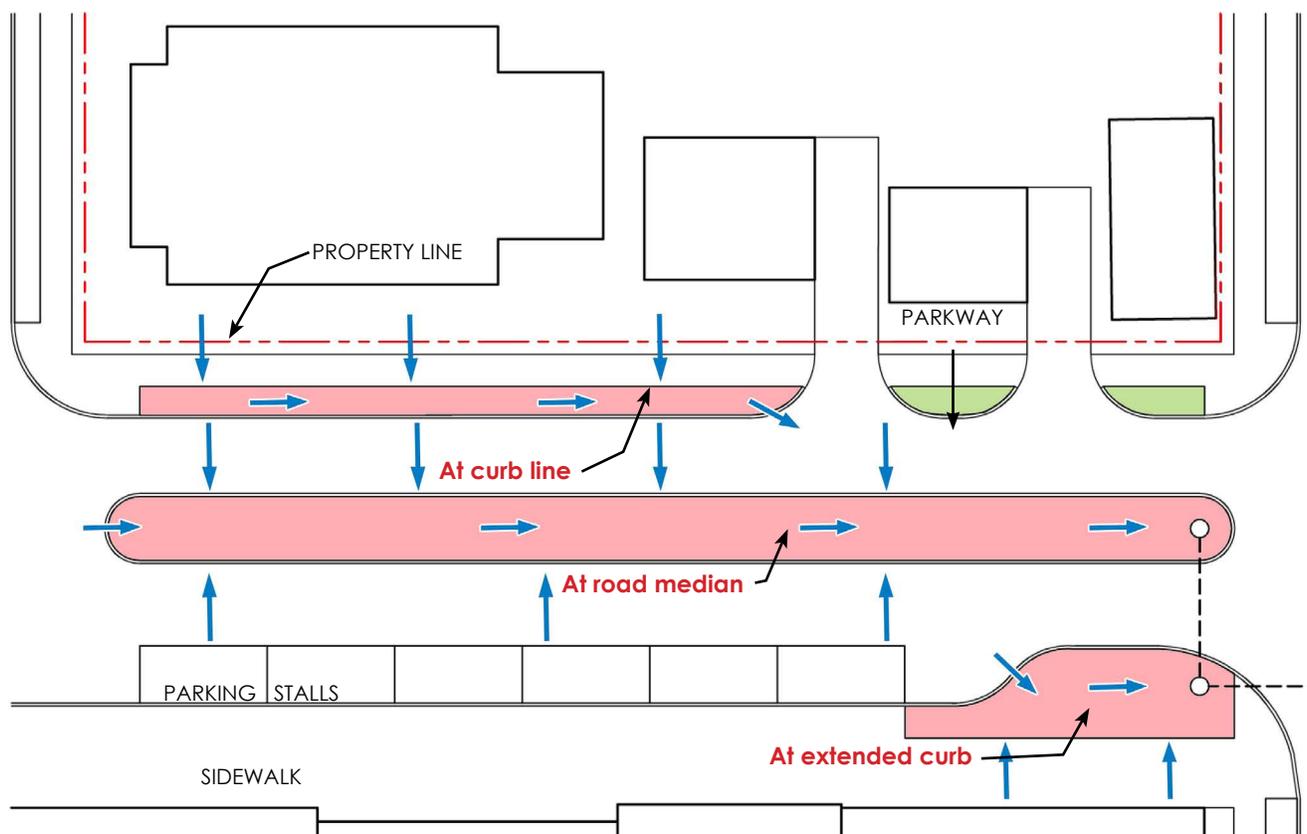
Cost Considerations:

Costs vary greatly depending on size, plant material, and site considerations. Linear bioretention is generally less expensive when used in place of underground storm sewer piping.



LINEAR BIORETENTION

Linear Bioretention Potential Locations:



Sizing Considerations:

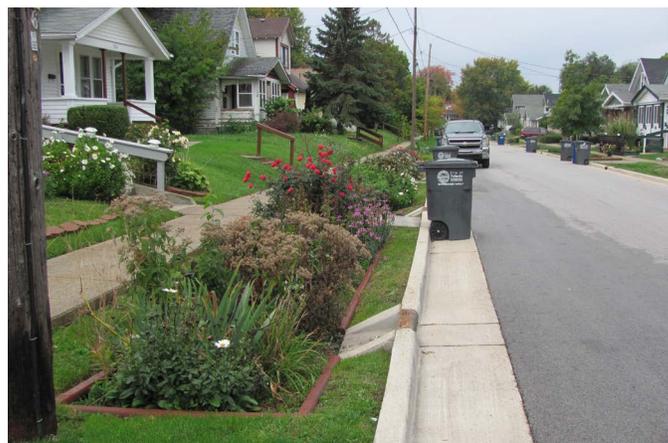
The total surface area of the linear bioretention should be around one percent of the external drainage area up to a maximum of 10 acres of tributary area. Excessive sources of sediment should be excluded from the drainage area. In-line linear bioretention should be sized to convey at least a 10-year, 24-hour storm event safely.

Maintenance:

- Clean inlets, outlets, and overflows.
- Remove accumulated debris.
- Remove weeds regularly.
- Use deep-rooted native plants for reduced maintenance.
- Add mulch when needed.
- During the one-to-two season establishment period, weed and water plants regularly.

Setback Requirements:

- From property line: No requirement.
- From parking space: No requirement.
- From building: 10-foot minimum without waterproof liner.
- From pavement: No requirement.



Residential linear bioretention, Maywood Avenue, Toledo, OH



LINEAR BIORETENTION

Where to Use:

- In locations where stormwater flows along curb line or where runoff can sheet flow from pavement.
- In locations where an overflow can be directed or connected to an appropriate outlet.
- In locations where the green space between the curb and sidewalk is at least 6-feet wide and not dominated by utilities or other public uses.



Linear bioretention in parkway, Maywood Avenue, Toledo, OH



Linear bioretention, NW 110th Street, Seattle, WA



Linear bioretention on slope, Omaha, NE

Additional Resources:

Refer to the City of Grand Rapids Green Infrastructure Standards for additional information.



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APPLICATIONS		STORMWATER QUANTITY FUNCTIONS	
Residential	Yes	Volume	Medium
Commercial	Yes	Groundwater Recharge	Medium
Ultra Urban	Yes	Peak Rate	Low
Industrial	Yes	STORMWATER QUALITY FUNCTIONS	
Retrofit	Yes	Sediment	High
Highway/Road	Limited	Temperature	High
Recreational	Yes	MAINTENANCE	
Private	Yes	Intensity	Med./High

Description:

Capture and reuse is a constructed practice of collecting and retaining runoff for later beneficial use. The system generally has four major components: collection, storage, treatment, and distribution for reuse. Runoff is collected from rooftops and other impervious surfaces and stored in a variety of above and below ground structures including cisterns, rain barrels, and tanks. The captured water may then be used for irrigation, to supplement grey water needs such as toilet flushing, or can be reused in process facility operations.



Miller Road Office Building, Lansing, MI.



Miller Road Office Building, Lansing, MI.

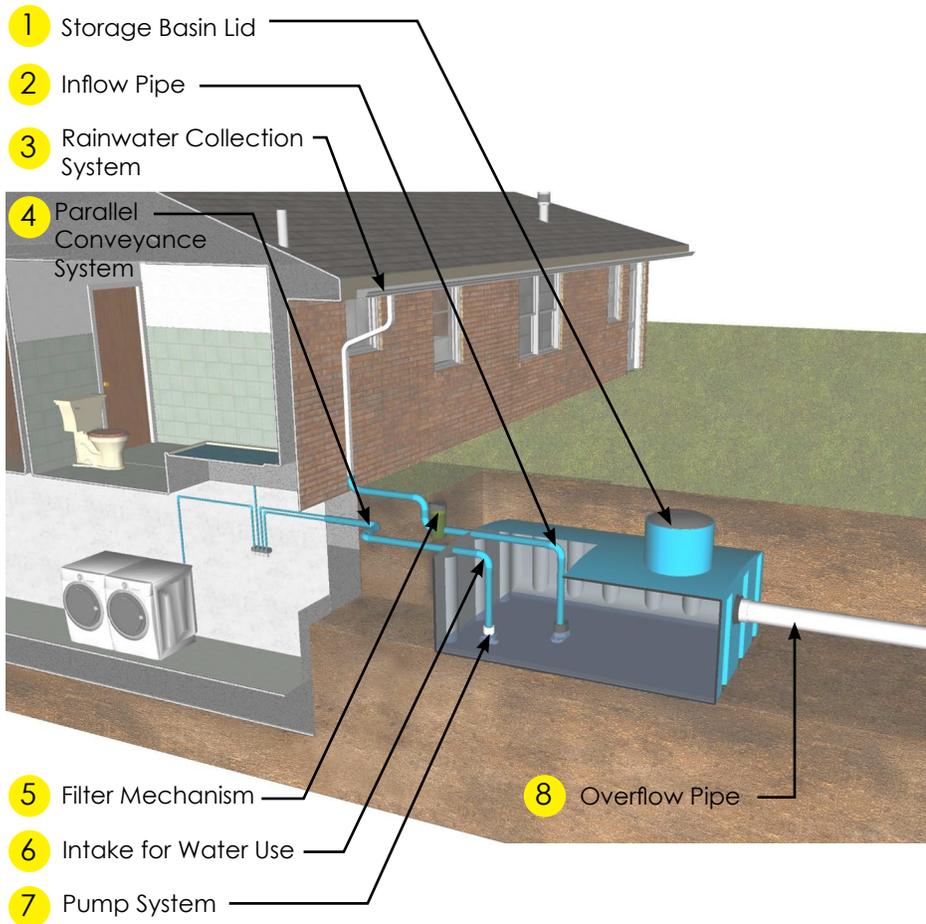
Green Objectives:

- Collect and reuse stormwater runoff to reduce potable water use.
- Provide an alternative (or supplemental) water supply that can be used for irrigation and other approved uses.
- Increase the use of grey water in households and offices.
- Reduce demand on water supplies which helps protect groundwater aquifers from drawdown.
- Increase the quantity of green infrastructure practices through the City, consistent with sustainability goals.

Key Considerations:

- Systems should be sized based on the contributing area, local rainfall patterns, and projected demand for the harvested rainwater
- Pretreatment should be provided upstream of all storage tanks to prevent leaves and other debris from clogging the system.
- Systems must comply with the Michigan Plumbing Code.

CAPTURE REUSE SYSTEMS



Components

- 1 Storage Basin Lid:** This removable lid, allows access so that the basin can be cleaned.
- 2 Inflow Pipe:** It is sized to accommodate inflow based on impervious area and rainfall amounts.
- 3 Rainwater Collection System:** Gutters collect rainwater flowing off a building or house rooftop and is connected to the storage system.
- 4 Parallel Conveyance System:** When supplementing grey water, this system is needed to separate grey water from other potable water piping systems.
- 5 Filter Mechanism:** A screen that prevents large debris from entering the storage system.
- 6 Intake for Water Use:** An outflow pipe where the water is reused for either irrigation or grey water.
- 7 Pump System:** Required in some systems to pressurize water for reuse.
- 8 Overflow Pipe:** Located below the top of the storage basin, allows for excess water to drain out.

General Design Guidelines:

- Rain barrels and cisterns should be positioned to receive rooftop runoff.
- Storage units and discharge points should be clearly marked “Caution: Untreated Rainwater, Do Not Drink.”
- Provide an outlet for overflow below the top of structure. The outlet should be sized to safely discharge appropriate design storms when the structure is full.
- The overflow pipe should be directed into an area that would allow for natural infiltration e.g. soil or natural vegetation or other approved points of disposal
- Reuse may require pressurization, therefore a pumping system may need to be installed.
- Provide leaf screens and a first flush diverter. First flush diverters direct the initial 0.02 to 0.06 inches of runoff away from the storage tank.

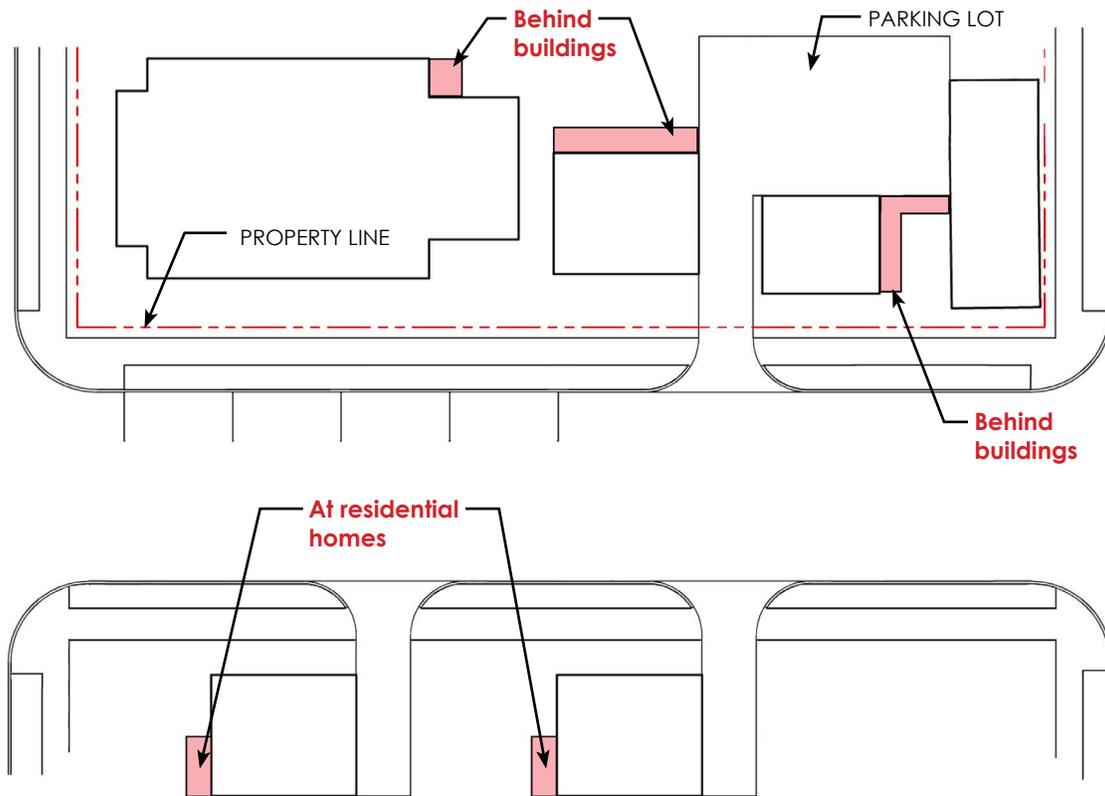
Cost Considerations:

- Cost vary depending on the size of the capture reuse system.
- A rain barrel is relatively inexpensive compared to a large cistern, but generally has less storage volume.



CAPTURE REUSE SYSTEMS

Capture Reuse System Potential Locations:



Sizing Considerations:

- The size of a capture/reuse system should be based on the available impervious collection area, annual rainfall, and intended use (or reuse) of rainfall. These factors can also determine if a site should consider a rain barrel or something larger such as a cistern.

Maintenance:

- To avoid damage in the winter, drain system so that water is not able to freeze inside.
- Rain barrels should be inspected four times per year and after major storm events.
- Debris should be removed from screen as needed.
- Cisterns should be flushed annually to remove sediment and twice a year the inside needs to be brushed and thoroughly disinfected.

Setback Requirements:

- Overflow devices should be designed to avoid causing ponding or soil saturation within 10 feet of building foundations.
- Storage tanks should be designed to be watertight to prevent water damage when placed near building foundations
- Recommended that underground tanks be set at least 10 feet from building foundations.

Where to Use:

- In urbanized areas where water is needed for supplemental onsite irrigation or grey water purposes such as:
 - Office Buildings
 - Other building use (commercial, light industrial, institutional, etc.)
- Residential Homes



CAPTURE REUSE SYSTEMS



Commercial rain barrel. City of Toledo Quilter Environmental Center. Toledo, OH.



Residential rain barrels. Mt. Airy Neighborhood, Cincinnati, OH.



Rainwater harvesting system reduced city water needs by approximately 1.5 million gallons per year. Sam's Club, Fayetteville, AR.



Cistern at the Chicago Center for Green Technologies (Source: Abby Hall, U.S. EPA).

Additional Resources:

Refer to the City of Grand Rapids Green Infrastructure Standards for additional information.

APPLICATIONS		STORMWATER QUANTITY FUNCTIONS	
Residential	Yes	Volume	Low
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	Yes	Peak Rate	Low
Industrial	Yes	STORMWATER QUALITY FUNCTIONS	
Retrofit	Yes	Sediment	Low
Highway/Road	Limited	Temperature	Low
Recreational	Yes	MAINTENANCE	
Private	Yes	Intensity	Medium



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Description:

Vegetated Curb Extensions (“Bump-Outs”) are planted areas that are extended into the parking zone of the street. They are designed with an opening in the curb that catches stormwater as it flows down the curb. The water is then trapped in a low planting area and is disbursed either through plant evapotranspiration or infiltration. The water that infiltrates runs through a special soil that helps clean pollutants from the water.



NE Siskiyou Street, Portland, OR



NE Siskiyou Street, Portland, OR

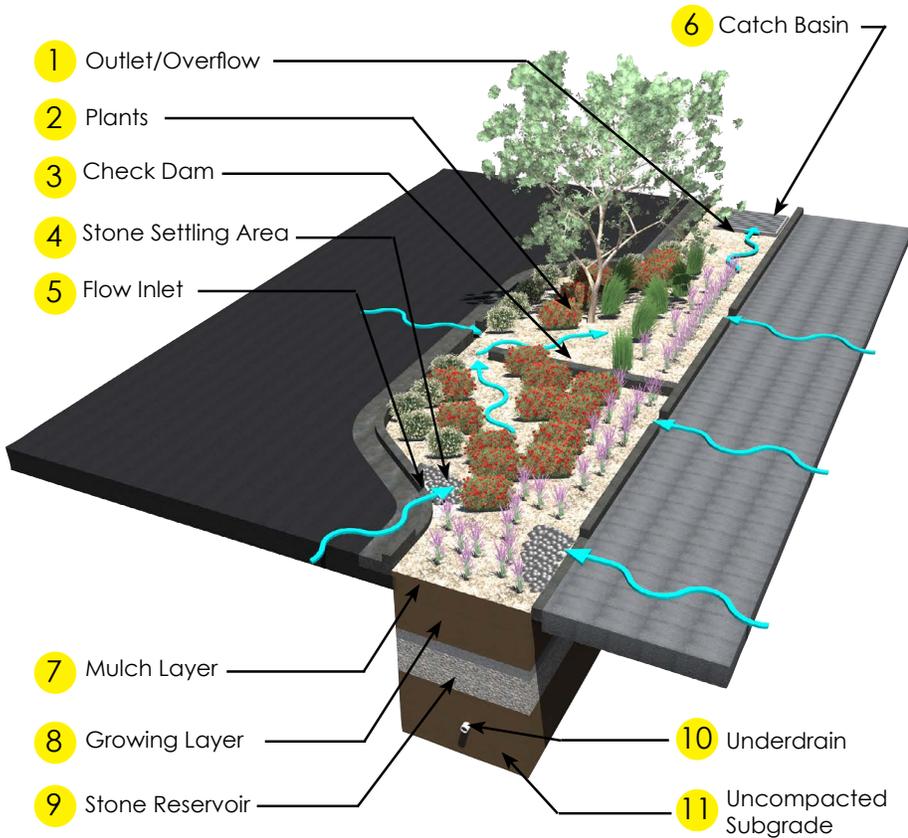
Green Objectives:

- Reduce stormwater run-off that would normally flow directly into the City’s already overburdened storm sewer system.
- Improve water quality by filtering pollutants.
- Slow stormwater run-off velocity.
- Reduce local flooding and ponding.
- Provide a “traffic calming” element and pedestrian safety.
- Increase habitat for birds and butterflies.
- Increase native plantings and plant species diversity.

Key Considerations:

- Do not impede necessary pedestrian movement.
- Coordinate with bike lanes or routes.
- Avoid conflict with fire hydrants and other above ground utilities.
- Avoid conflict with existing underground utilities.
- If overhead utility lines are present, use smaller trees or shrubs.
- Work within City setback requirements.
- Use native plants when possible.
- Meet requirements for emergency vehicle access.

CURB EXTENSIONS



Components

- 1 Outlet/Overflow:** Downstream outlet or standpipe.
- 2 Plants:** Trees, shrubs, and ground covers that can withstand both wet and dry conditions.
- 3 Check Dam:** Stone or concrete barrier to slow velocity or increase ponding.
- 4 Stone Settling Area:** Required if runoff water velocity is high (resulting from a large amount of water or a steep slope).
- 5 Flow Inlet:** An opening in the curb that allows water to flow into the planted ponding area.
- 6 Catch Basin:** An underground structure with a surface grate that temporarily holds water.
- 7 Mulch Layer:** Shredded hardwood bark or other acceptable mulch (approximate 2-inch layer).
- 8 Growing Layer:** A blend of soil, compost, and sand to allow drainage and support plant growth.
- 9 Stone Reservoir:** Stone layer where water will collect until it infiltrates into the subsoil.
- 10 Underdrain:** Collects excess water and conveys it to the storm sewer system or overflow area. May or may not be required.
- 11 Uncompacted Subgrade:** Existing soil below the stone reservoir where stormwater infiltrates.

General Design Guidelines:

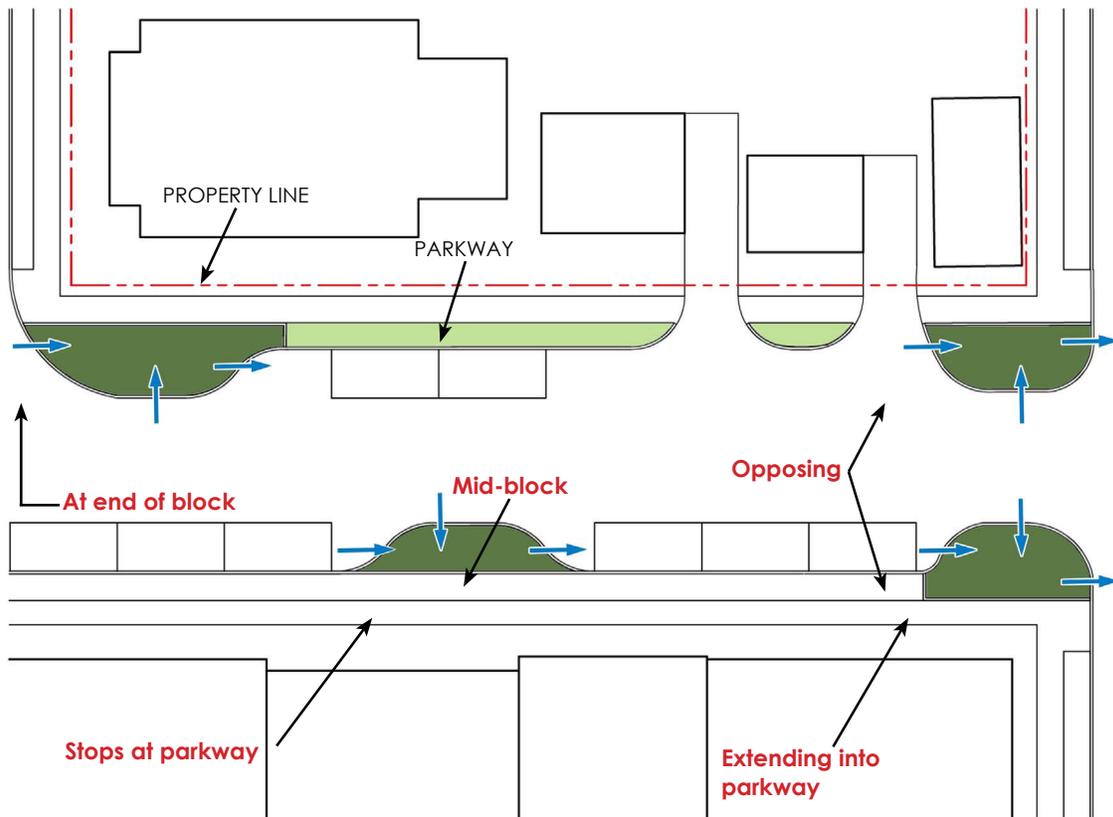
- On steep slopes, provide check dams as needed to provide flat bottoms (steps) to promote infiltration.
- For high velocity, provide stone settling area at inlets.
- Incorporate existing drainage structures into the design as overflow inlets.
- Provide signage as needed to alert motorists and pedestrians.
- Avoid in areas with less than 2 feet to water table or bedrock.
- The width of the curb extension must consider minimum lane requirements.

Cost Considerations:

- Costs vary greatly depending on size, plant materials, and site considerations. Curb extensions are generally less expensive when used in place of underground storm sewer piping.



Curb Extension Potential Locations:



Sizing Considerations:

The surface area is generally between four and seven percent of the tributary area. Excessive sources of sediment (e.g., dirt roads, gravel shoulders, gravel driveways) should be excluded from the drainage area.

Setback Requirements:

- From property line: No requirement.
- From building: 10-foot minimum without a waterproof liner.
- From pavement: No requirement.
- Two-way car travel width: 20-foot minimum.
- One-way car travel width: 18-foot minimum.

Maintenance:

- Clean inlets, outlets, and overflows.
- Remove accumulated debris.
- Remove weeds regularly.
- During the one- to two-season establishment period, weed and water plants.
- Add additional mulch when needed.



SE Sandy Boulevard, Portland, OR

CURB EXTENSIONS

Where to Use:

- At intersections or anywhere along a curb line where one or more parking spaces can be spared.
- At pedestrian crosswalks.
- In locations where stormwater flows along curb line, especially at steep slopes.
- In locations when an overflow can be directed or connected to an appropriate outlet.

APPLICATIONS		STORMWATER QUANTITY FUNCTIONS	
Residential	Yes	Volume	Low
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	Yes	Peak Rate	Low
Industrial	Yes	STORMWATER QUALITY FUNCTIONS	
Retrofit	Yes	Sediment	High
Highway/Road	Limited	Temperature	High
Recreational	Yes	MAINTENANCE	
		Intensity	Med./High



Carter Street NE, Grand Rapids, MI



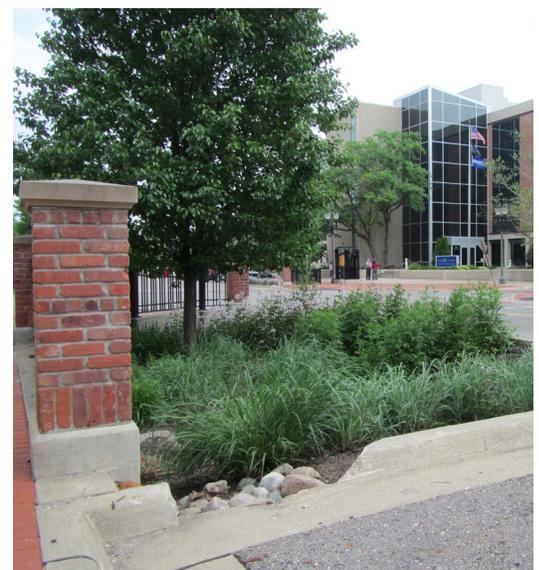
Washington Square, Lansing, MI

Additional Resources:

Refer to the City of Grand Rapids Green Infrastructure Standards for additional information.



Inlet, Washington Square, Lansing, MI



Washington Square, Lansing, MI



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Description:

Leaching (catch) basins collect roadway runoff and provide the opportunity for stormwater to infiltrate in lieu of an outlet to a storm sewer pipe. There are several types of leaching basins, including basins that contain a porous bottom consisting of loose aggregate. This type of basin allows water to infiltrate into the ground underneath the basin. Another type of basin contains both a leaching bottom and orifice holes punched along the vertical walls of the catch basin to provide additional infiltration capacity. Leaching basins can replace standard catch basins and are best suited in locations where the native soil is sandy or silty loam (Hydrologic Soil Group A and B soils).



Ponding issue, Grand Rapids, MI



Leaching basin concept, Grand Rapids, MI

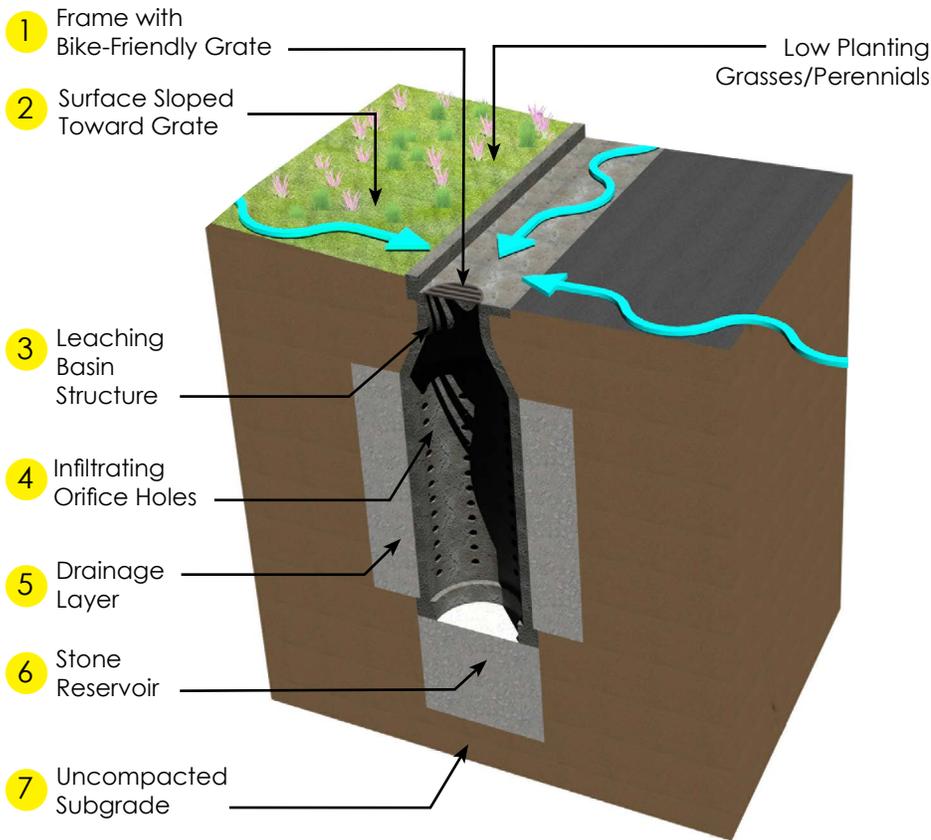
Green Objectives:

- Reduce stormwater run-off that would normally flow directly into the City's already burdened storm sewer system.
- Improve water quality by filtering pollutants.
- Reduce effective impervious area.
- Promote infiltration into groundwater.
- Reduce local flooding and ponding.
- Reduce traditional stormwater infrastructure.
- Increase the quantity of green infrastructure practices throughout the City, consistent with sustainability goals.

General Design Guidelines:

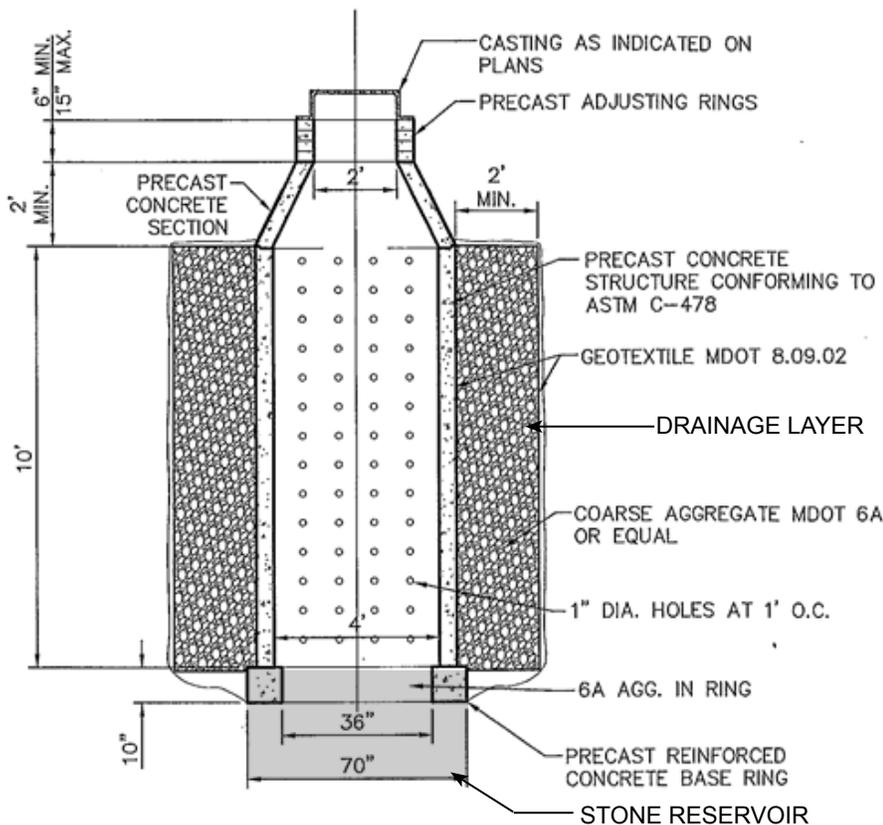
- Perform an infiltration test at the location of each leaching basin.
- Provide a deep sump per detail (next page).
- Work with City requirements to provide adequate freeboard to the roadway surface above the maximum water elevation for the design storm event.
- Avoid compaction of soils in leaching basin infiltration area.
- Provide a minimum 3-foot separation between bottom of leaching basin and seasonal high groundwater.

LEACHING BASIN



Components

- 1 **Frame with Bike-Friendly Grate:** Grated inlet allows stormwater to flow into leaching basin structure.
- 2 **Surface Sloped Toward Grate:** Sloped paved or planted surface directs stormwater toward grated inlet.
- 3 **Leaching Basin Structure:** Precast concrete structure with open bottom.
- 4 **Infiltrating Orifice Holes:** Small one-inch openings in vertical walls of structure allowing water to drain out of the structure.
- 5 **Drainage Layer:** Stone layer surrounding the structure allowing water to drain out of the structure.
- 6 **Stone Reservoir:** Stone layer where water will collect until it infiltrates into the subsoil.
- 7 **Uncompacted Subgrade:** Existing soil below the stone reservoir where stormwater infiltrates.



An example of a leaching basin

Cost Considerations:

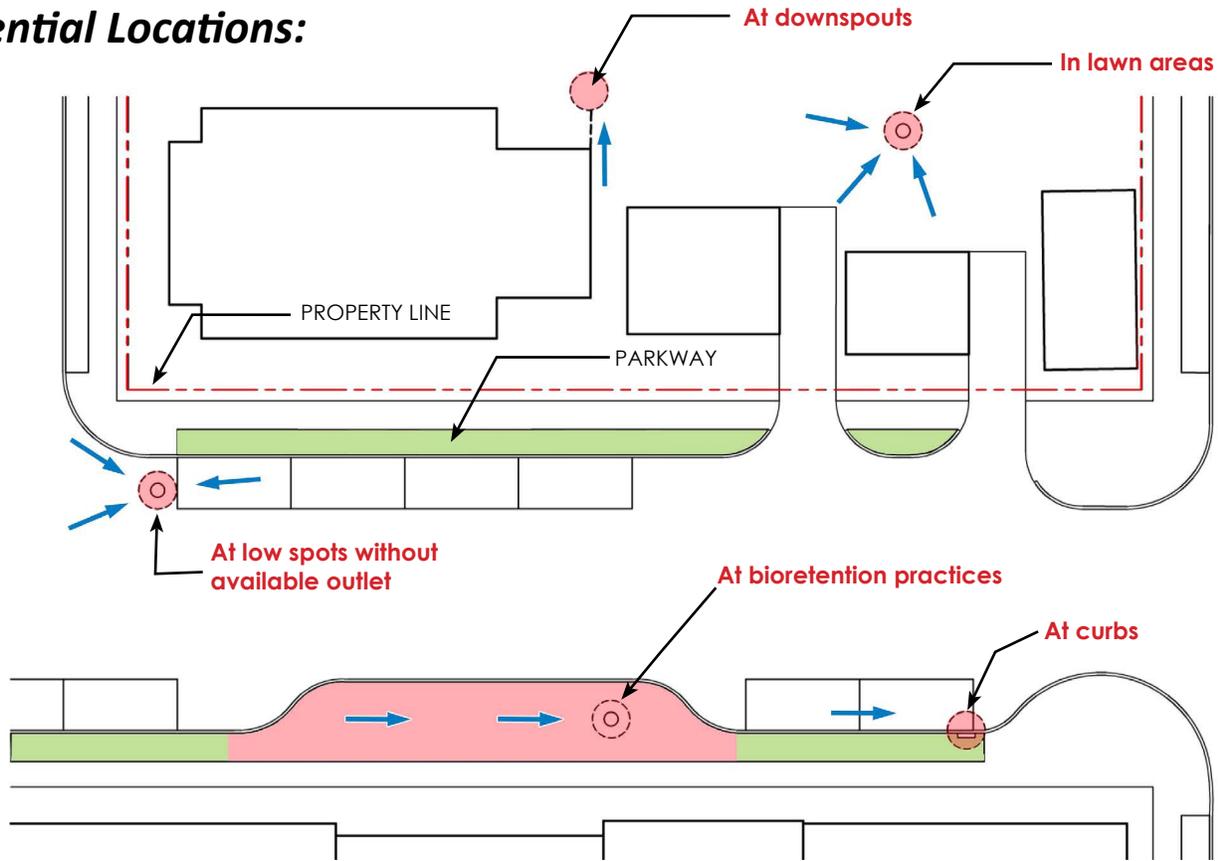
- Leaching basins are slightly more expensive compared to a standard catch basin.
- Installing leaching basins could reduce the amount of storm sewer infrastructure required.



LEACHING BASIN

Leaching Basin

Potential Locations:



Sizing Considerations:

The tributary area to each leaching basin should be based on typical spacing of basins along a roadway. Soil infiltration and depth to groundwater must be investigated to determine the feasibility of a leaching basin in a particular area.

Maintenance:

- Inspect structure annually (or more frequently as indicated by structure performance).
- Clean leaching basin grates where water enters the structure as needed.
- Remove accumulated debris in the sump to ensure drainage through structure.

Setback Requirements:

- From property line: No requirement.
- From parking space: No requirement.
- From building: 10-foot minimum.
- From pavement: No requirement.
- From right-of-way: No requirement.



Leaching basin installed in place of standard catch basin, Grand Rapids, MI

LEACHING BASIN



Installation of a leaching catch basin. The large diameter openings are for storm sewer pipes. Grand Rapids, MI



Installing the base of a leaching basin, Grand Rapids, MI

Where to Use:

- In place of standard catch basins where native soils are well drained.
- At the upstream points (beginning of system) along a stormwater drainage system.
- Best suited at locations with no inlet pipes, i.e., off-line with only an inlet grate.
- Not recommended where sediment loading is likely to result in clogging of infiltration surface.

Additional Resources:

Refer to the City of Grand Rapids Green Infrastructure Standards for additional information.



Stone backfill surrounding a leaching basin, Grand Rapids, MI

APPLICATIONS		STORMWATER QUANTITY FUNCTIONS	
Residential	Yes	Volume	Low
Commercial	Yes	Groundwater Recharge	High
Ultra Urban	Yes	Peak Rate	Low
Industrial	Limited	STORMWATER QUALITY FUNCTIONS	
Retrofit	Yes	Sediment	High
Highway/Road	Yes	Temperature	High
Recreational	Yes	MAINTENANCE	
Private	Yes	Intensity	High



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Description:

Permeable pavement allows stormwater to pass through the pavement to a stone storage layer. The water then either infiltrates into the soil or flows through an underdrain to the storm drain network. It is effective in storing, infiltrating, and treating runoff from impervious surfaces. There are a variety of permeable pavements including concrete pavers, paving grids, pervious concrete, porous asphalt, porous rubberized asphalt, and glass porous paving. Permeable pavement can be used in parking lots, parking lanes, low-volume roads, alleys, sidewalks, and plazas.



Eastown Hub Lot, Wealthy Street SE at Ethel Avenue SE, Grand Rapids, MI (looking south)



Eastown Hub Lot, Wealthy Street SE at Ethel Avenue SE, Grand Rapids, MI (looking northwest)

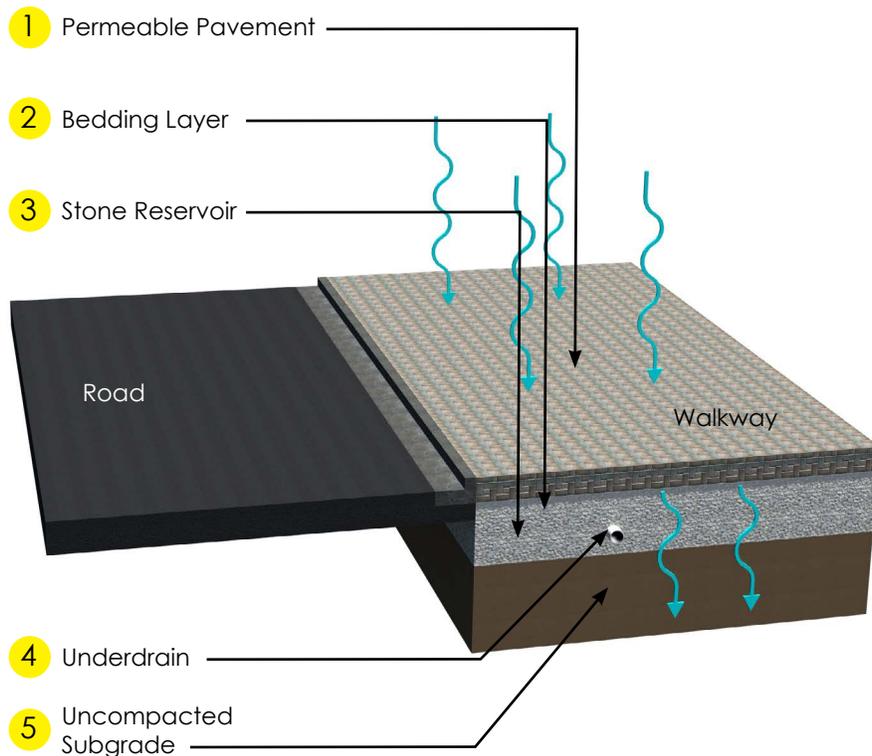
Green Objectives:

- Reduce stormwater run-off that would normally flow directly into the City's already burdened storm sewer system.
- Improve water quality by filtering pollutants.
- Reduce impervious area.
- Promote infiltration into groundwater.
- Reduce local flooding and ponding.
- Enhance aesthetics with decorative permeable pavements.
- Increase the quantity of green infrastructure practices throughout the City, consistent with sustainability goals.

Key Considerations:

- Ensure that the drainage area has no significant sediment sources (e.g., gravel shoulders, gravel driveways, dirt roads) that will clog pavement.
- Design the system so that the storage layer drains within 24 to 48 hours by infiltration or an underdrain.
- Select permeable pavement conducive to bike traffic in the area.
- Coordinate review by an arborist or forester for impacts to nearby trees.

PERMEABLE PAVEMENT



Components

- 1 Permeable Pavement:** Pavement that allows stormwater to pass through to be temporarily detained or infiltrated through the soil.
- 2 Bedding Layer:** Aggregate layer for leveling and stabilizing permeable pavement.
- 3 Stone Reservoir:** Stone layer where water will collect until it infiltrates into the subsoil or is released into the underdrain.
- 4 Underdrain:** Perforated pipe that takes excess water to the storm sewer system.
- 5 Uncompact Subgrade:** Existing soil below the stone reservoir where stormwater infiltrates.

General Design Guidelines:

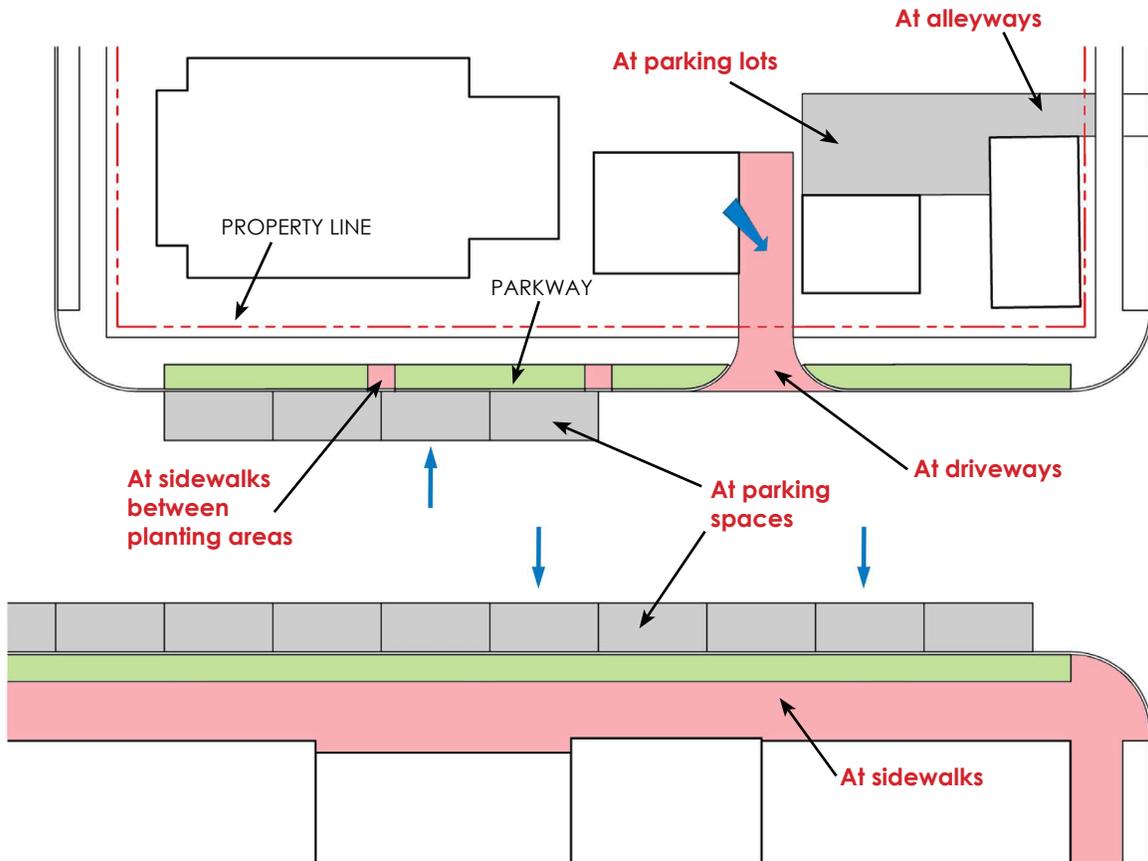
- Consider the potential for shifting pavement (especially modular systems) on slopes greater than five percent.
- Allow porous concrete to cure for a minimum of three months before applying salt.
- Specify a geotextile separator between the storage layer and adjacent soils to prohibit migration of fine soils into the storage layer.
- For concrete paver systems, incorporate a concrete header between the paver are and adjacent asphalt to decrease paver shifting.
- Size the stone drainage layer to meet local design standards.

Cost Considerations:

- Cost of permeable pavement tends to be higher than traditional pavement. Costs vary with location and contractor familiarity of the installation.
- Concrete pavers and articulating concrete blocks tend to be more expensive than porous asphalt or pervious concrete.
- Use of permeable pavements can provide cost savings by reducing the amount of other storm treatment systems required.
- For roads and parking lots, permeable pavement can be incorporated within parking lanes and stalls to intercept flow from driving lanes. This is more cost-effective than using permeable pavement across the entire paved area.

PERMEABLE PAVEMENT

Permeable Pavement Potential Locations:



Sizing Considerations:

To reduce the amount of sediment that collects on the permeable pavement, the area that drains to the permeable pavement should be largely impervious. The impermeable surface can be two to five times the surface area of the permeable pavement depending on the extent of sediment in the runoff.

Setback Requirements:

- From property line: No requirement.
- From building: 10-foot minimum without a waterproof liner.
- From pavement: No requirement.

Maintenance:

- Remove accumulated sediment and particulates from the permeable pavement void spaces with a high efficiency vacuum sweeper at least twice per year. Pressure washing pavement is not recommended as particulates could further embed.
- Stone between pavers will need to be replaced after vacuuming as needed.
- Use of sand and fine aggregate for winter road conditions will quickly clog permeable pavement and should not be used.



Image depicts porous aggregate set between the pavers.

PERMEABLE PAVEMENT

Where to Use:

- Roadway parking lanes
- Parking lots
- Low-volume roads and alleys
- Plazas, paths, and sidewalks
- In areas where impervious space is highly utilized and cannot be spared for vegetated green infrastructure practices



Porous rubberized asphalt sidewalk



Permeable pavement, Farmington Hills City Hall parking lot, Farmington Hills, MI



Permeable pavement in business district, Ionia Avenue SW, Grand Rapids, MI



Permeable asphalt paving in parking zone, Carrier Street NE, Grand Rapids, MI

Additional Resources:

Refer to the City of Grand Rapids Green Infrastructure Standards for additional information.

APPLICATIONS		STORMWATER QUANTITY FUNCTIONS	
Residential	Yes	Volume	Medium
Commercial	Yes	Groundwater Recharge	Medium
Ultra Urban	Yes	Peak Rate	Low
Industrial	Yes	STORMWATER QUALITY FUNCTIONS	
Retrofit	Yes	Sediment	High
Highway	Yes	Temperature	Medium
Recreational	Yes	MAINTENANCE	
Local Roads	Yes	Intensity	Medium
Private	Yes		



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Description:

Detention basins are excavated surface stormwater facilities that provide temporary storage of stormwater runoff with a controlled discharge to prevent downstream flooding. This includes both retention basins, which hold a permanent pool of water, and detention basins, which empty completely after each rainfall event. These basins create storage of stormwater by allowing large amounts of stormwater to fill the basin and limiting the outflow with a riser structure and orifice openings.



Traditional Detention Basin.



Traditional Retention Basin.

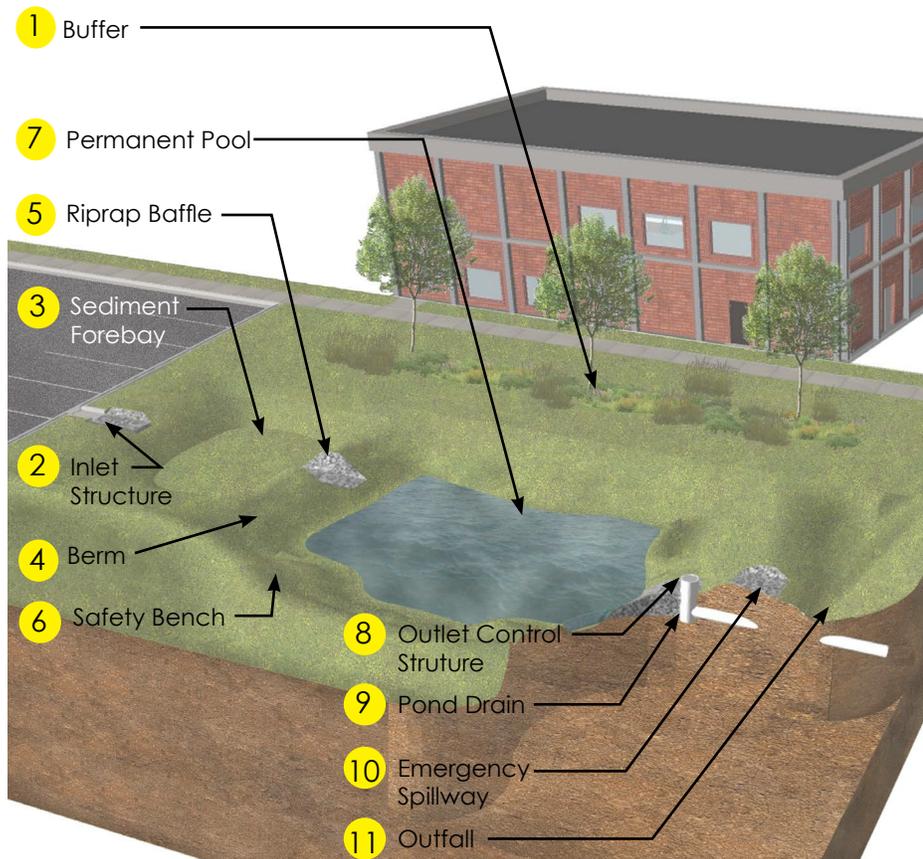
Green Objectives:

- Reduce local flooding by storing large, infrequent runoff volumes and slowly releasing the water.
- Retention basins can be effective for sediment and pollutant removal.
- Detention basin may be modified by adding a permanent wet pool for water quality treatment and adapting the outlet structure for channel protection. This is desirable because dry ponds have limited effectiveness for pollutant removal.
- Increase the quantity of green infrastructure practices throughout the City, consistent with sustainability goals.

Key Considerations:

- For a retention basin, the bottom of the basin should be at or below or the groundwater table level to retain water.
- For a detention basin, the bottom of the basin should be above the groundwater table.
- Use native plants to surround the basin when possible.
- Detention and retention basins are typically installed at the downstream end of the treatment train.
- Sized for local flood control by storing and slowly releasing large infrequent storm events.

TRADITIONAL STORMWATER DETENTION/RETENTION BASINS



Components

- 1 **Buffer:** A 25 ft boundary to enhance habitat value, water temperature and health of the basin.
- 7 **Permanent Pool:** Found only in retention basins, this is the water remaining in the basin (can be between 6-8 feet).
- 5 **Riprap Baffle:** A pervious rock barrier that slows the inflow and helps reduce erosion.
- 3 **Sediment Forebay:** A basin designed to capture coarse sediment to prevent buildup in the main basin.
- 2 **Inlet Structure:** Either a spillway or a pipe that conveys water into the basin.
- 4 **Berm:** Separates the forebay from the main basin.
- 6 **Safety Bench:** A sloped perimeter around the basin to prevent overflows and to keep pedestrians out of the basin. Native plants and vegetation are recommended here.
- 8 **Outlet Control Structure:** Usually an orifice, this structure is designed to discharge stored runoff in a timely manner.
- 9 **Pond Drain:** Allows for a permanent pool to be completely drained for maintenance.
- 10 **Emergency Spillway:** Designed to capture excessive depths that can occur during extreme events.
- 11 **Outfall:** Composed of rocks, this helps prevent erosion in the outflow area.

General Design Guidelines:

- Storage areas should be adequately sloped towards outlets to ensure complete drainage after storm events.
- Side slopes should be no steeper than 4 Horizontal:1 Vertical
- Basins should have a sediment forebay to trap larger coarse sediment.
- To maximize the settling of smaller sediments, basins should have a length to width ratio of 2L:1W
- The outlet opening (orifice) should be no smaller than 3 inches in diameter.
- All basins deeper than 4 feet should have a safety bench.
- A retention basin must be able to receive and retain enough flow from rain, runoff, and groundwater.

Cost Considerations:

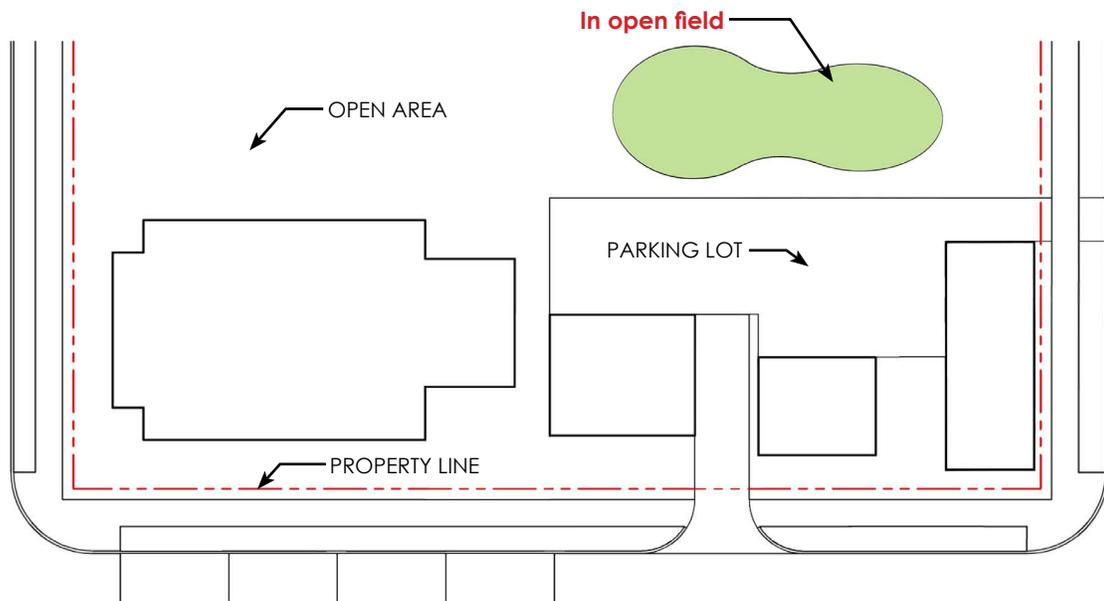
The cost of each basin can vary depending on size, depth of extraction, and site characteristics.



TRADITIONAL STORMWATER DETENTION/RETENTION BASINS

Traditional Stormwater Detention/Retention Basins

Potential Locations:



Sizing Considerations:

The total surface area of the basin is generally between one and three percent of its drainage area, which has a maximum of 50 acres. The basin should also be designed to provide an emergency overflow for larger storms.

Setback Requirements:

- From property line: 10 foot minimum
- From private well: 50 foot minimum
- From septic system: 50 foot minimum
- From building: 10 foot minimum without a waterproof liner.

Maintenance:

- Clean inlets, outlets, and overflows
- Check outlet for clogging
- Mow and trim vegetation surrounding to pond. Inspect and remove any invasive species.
- Remove accumulated sediment and debris.



Kreiser Pond, Grand Rapids, MI.



TRADITIONAL STORMWATER DETENTION/RETENTION BASINS

Where to Use:

- In a plaza or athletic field where the recreation areas can be designed for temporary detention through the use of flow control structures and berms.
- In large open areas such as a field which would provide enough acreage for the basin.
- In a low area in a residential subdivision.



An outlet control structure at a detention basin. Armada Township, MI.



A dry detention basin that manages the stormwater from surrounding buildings. Chandler Crossings, East Lansing, MI.



Neighborhood retention basin. Macomb, MI.



Neighborhood retention basin. Tower Gardens, Meridian Township, MI.

Additional Resources:

Refer to the City of Grand Rapids Green Infrastructure Standards for additional information.

APPLICATIONS		STORMWATER QUANTITY FUNCTIONS	
Residential	Yes	Volume	Low
Commercial	Yes	Groundwater Recharge	None or Low
Ultra-Urban	Yes	Peak Rate	High
Industrial	Yes	STORMWATER QUALITY FUNCTIONS	
Retrofit	Yes	Sediment	Medium
Highway/ Road	Yes	Temperature	Low
Recreational	No	MAINTENANCE	
Private	Yes	Intensity	Low/Medium



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Description:

A stormwater planter is a vegetated green infrastructure practice relying on specified soils and vegetation to treat and absorb stormwater that drains to it. It is different from other vegetated practices as it typically has concrete vertical side walls allowing it to be incorporated into congested street corridors or attached to the perimeter of a building. Planter boxes are often categorized either as flow-through planter boxes or infiltrating planter boxes. Infiltrating planter boxes have an open bottom to allow infiltration into the underlying soils. Flow-through planter boxes are completely lined and have an underdrain system to convey flow that is not taken up by plants to drainage areas.



Before

Ionia Avenue SW, Grand Rapids, MI



After

Image rendering for Ionia Avenue SW, Grand Rapids, MI

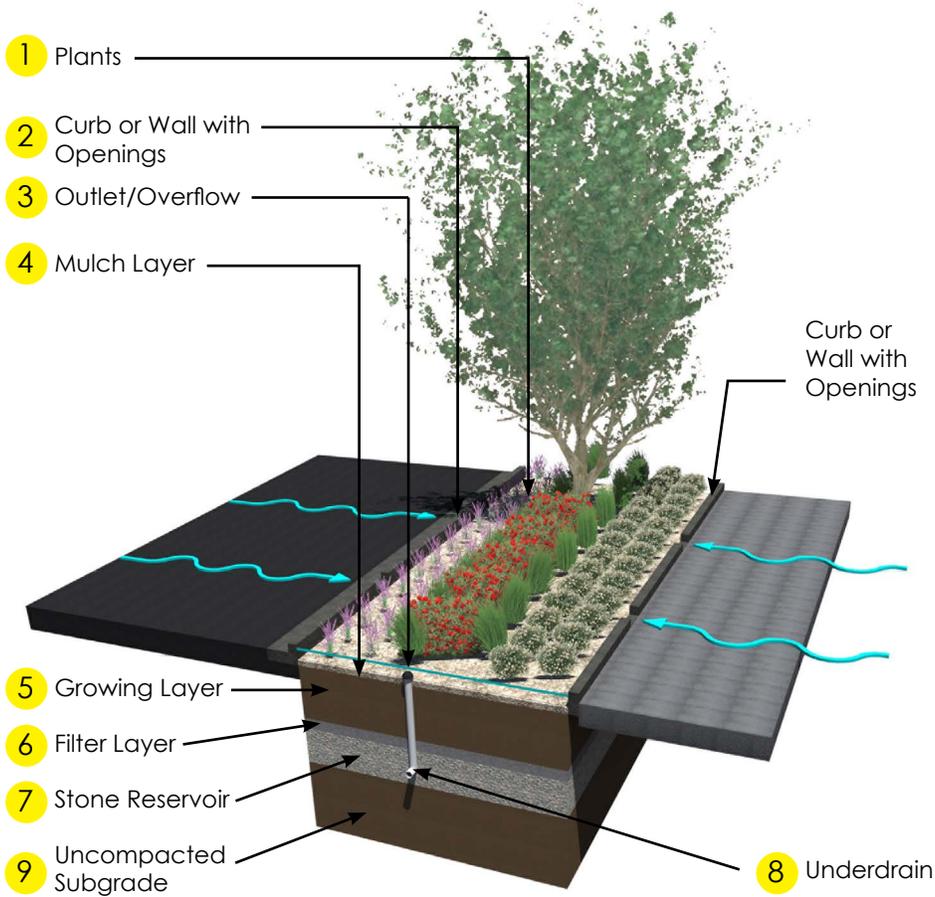
Green Objectives:

- Reduce stormwater run-off that would normally flow directly into the City's already burdened storm sewer system.
- Improve water quality by filtering pollutants.
- Reduce effective impervious area.
- Promote infiltration to the groundwater table.
- Increase the quantity of green infrastructure practices throughout the City, consistent with sustainability goals.
- Increase habitat for birds and butterflies.
- Increase native plantings and plant species diversity.

Key Considerations:

- If the stormwater planter walls are taller than curb height, place outside the reach of open car doors.
- Provide pedestrian walkways or "bridges" from roadside parking to store fronts.
- Work around existing underground and above ground utilities.
- Ensure that ADA access is maintained if taking up sidewalk space.
- Do not locate a stormwater planter downstream of sediment sources (e.g., gravel shoulders, gravel driveways, dirt roads).

STORMWATER PLANTER



Components

- 1 Plants:** Trees, shrubs, and ground covers that can withstand both wet and dry conditions.
- 2 Curb or Wall with Openings:** Breaks in the curb or openings in the wall can allow stormwater to pass through into the bioretention area.
- 3 Outlet/Overflow:** Pipe riser that allows water to pond before it is collected and released into the underdrain and stone storage layer.
- 4 Mulch Layer:** Shredded hardwood bark or other acceptable mulch (approximate 2-inch layer).
- 5 Growing Layer:** A blend of soil, compost, and sand to allow drainage and support plant growth.
- 6 Filter Layer:** Fine aggregate to prevent soil from migrating down to the stone reservoir.
- 7 Stone Reservoir:** Stone layer where water will collect until it infiltrates into the subsoil.
- 8 Underdrain:** Perforated pipe that takes excess water to the storm sewer system.
- 9 Uncompacted Subgrade:** Existing soil below the stone reservoir where stormwater infiltrates.

General Design Guidelines:

- Keep the elevation of the top of the overflow lower than the adjacent sidewalk or road.
- Provide a pretreatment sump at the inlets with easy access for maintenance.
- Design so that the storage layer drains within 24 to 48 hours by an underdrain or infiltration.
- Avoid installation where the water table is less than 2 feet below the bottom of the storage layer.
- Use retaining walls, geotextile separators, or impermeable liners to avoid undermining adjacent structures.
- Incorporate native plants when possible.

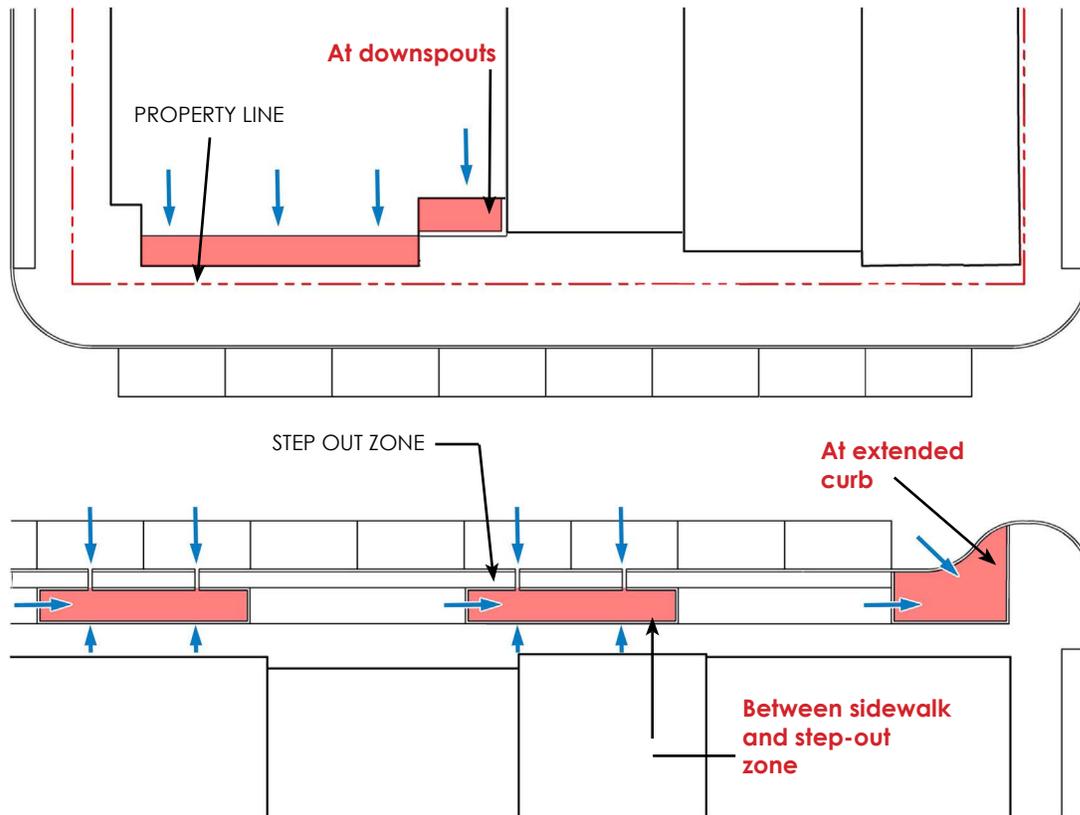
Cost Considerations:

- Although they have similar function and components, stormwater planters are generally more expensive than curb-line bioswales due to the sidewalks, construction practices, and restoration typical in congested urban areas.
- Costs vary greatly depending on size, plant material, and site considerations.



STORMWATER PLANTER

Stormwater Planter Potential Locations:



Sizing Considerations:

The sizing of the stormwater planter varies depending upon the goals for infiltrating stormwater, but generally the surface area should be about 5 to 7 percent of the drainage area. If the goal is to treat the stormwater rather than infiltrate it, there are patented high flow rate engineered media available that can decrease the required stormwater planter footprint.

Maintenance:

- Clear debris from inlets and overflow grates.
- Remove accumulated sediment.
- Remove weeds during plant establishment and annually thereafter.
- Water plants during plant establishment.
- Use deep-rooted native plants for reduced maintenance.
- Remove trash and debris weekly.

Setback Requirements:

- From property line: No requirement.
- From parking space: No requirement.
- From building: 10-foot minimum.
- From pavement: No requirement.



Stormwater planter in Columbus Square, Philadelphia, PA

STORMWATER PLANTER

APPLICATIONS		STORMWATER QUANTITY FUNCTIONS	
Residential	Yes	Volume	Medium
Commercial	Yes	Groundwater Recharge	Medium
Ultra Urban	Yes	Peak Rate	Low
Industrial	Yes	STORMWATER QUALITY FUNCTIONS	
Retrofit	Yes	Sediment	High
Highway/Road	No	Temperature	High
Recreational	Yes	MAINTENANCE	
Private	Yes	Intensity	Med./High



Stormwater planter with fence, Michigan Avenue, Lansing, MI



Stormwater planter with curb, Portland, OR

Where to Use:

- In locations where stormwater flows along a curb line.
- Attached to a building to accept downspout discharge water.
- In locations where an overflow can be directed or connected to an appropriate outlet.
- In locations that are at least 6-feet-wide and where site conditions allow.

Additional Resources:

Refer to the City of Grand Rapids Green Infrastructure Standards for additional design information.



Stormwater planter, Ionia Avenue SW, Grand Rapids, MI



Stormwater planter attached to a building, Portland, OR



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Description:

Suspended pavement is a connectable cell structure that can support heavy loads and creates a subsurface void space that is most commonly filled with uncompacted soil ideal for root growth. This additional soil filled area provides enough space for the root system of mature tree(s). Larger trees help reduce urban heat islands and air pollution while improving the aesthetics of the area. The soil can also be engineered for on-site rainwater storage, further reducing the amount of runoff.



Suspended pavement systems on Ionia Street, Grand Rapids, MI.



Tree trenches along Palmer St, Shissler Recreational Center, Philadelphia, PA.

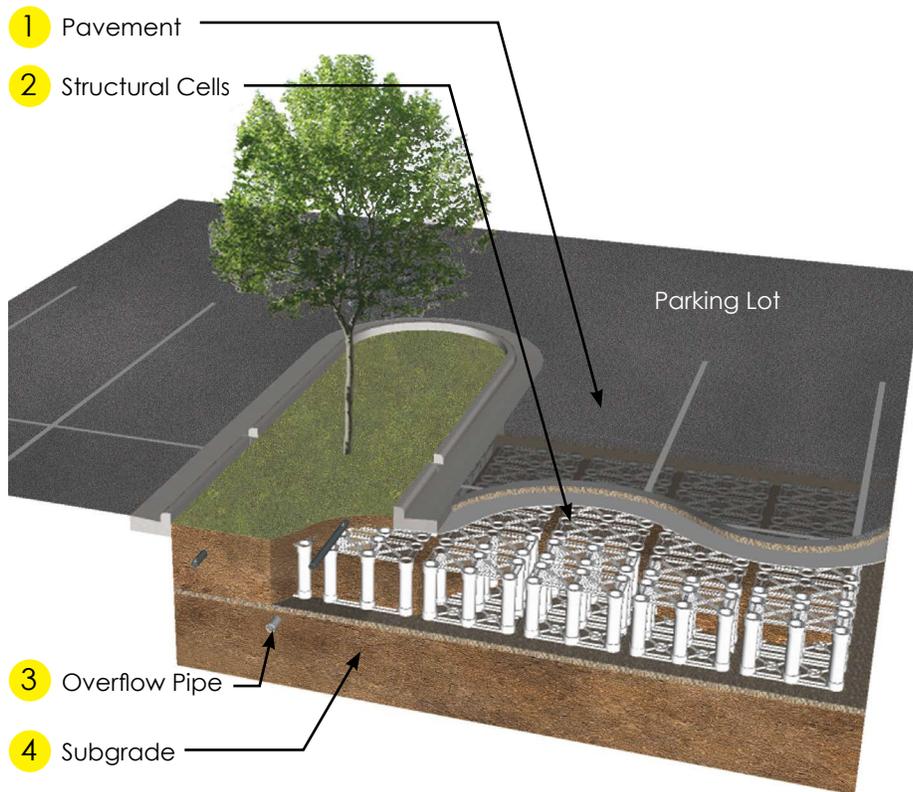
Green Objectives:

- Reduce stormwater runoff that would normally flow directly into the City's already burdened storm sewer system.
- Reduce local flooding and ponding.
- Increase the number of mature trees in urban areas consistent with the City's Tree Canopy Goals.
- Increase the amount rainfall intercepted by trees with more mature and larger trees.
- Improve water quality by filtering pollutants.

Key Considerations:

- Avoid conflict with existing underground utilities.
- Do not impede necessary pedestrian movement.
- Coordinate with other infiltration practices, such as permeable pavement, that will allow for water to drain into soil.

SUSPENDED PAVEMENTS



Components

- 1 Pavement:** Layer covering structural cells that can support varying surface loads, including vehicles.
- 2 Structural Cells:** These stackable polypropylene cells create space for soil, tree roots, and stormwater storage.
- 3 Overflow Pipe:** Pipe that takes excess water to the storm sewer system.
- 4 Subgrade:** A blend of soil that is designed to store stormwater and help trees grow.

General Design Guidelines:

- The individual cells vary by manufacturer however many are able to support concrete, pavers, asphalt, and permeable pavements.
- With a bioretention soil mix, about 20% of the total soil volume is available to hold stormwater.
- To prevent lifting of pavement, a root barrier should be installed with the cell system in order to guide roots to uncompacted soil.
- Stormwater can be directed into the system using pervious pavers, curb cuts, catch basins, or slot drains.
- Recommend 1 to 3 cubic feet of soil for each 1 square foot of projected tree canopy diameter (1,000 cubic feet of soil will grow a 16-inch diameter tree with a 32 foot canopy).
- Trees in shared beds do not need as much soil as trees in individual planters.

Cost Considerations:

- Cost of suspended pavement tends to be higher than traditional tree planting with the additional materials and construction however the larger trees have additional benefits.
- Total cost will vary depending on the manufacturer of the cells, the number of cells needed, and the type of trees being planted.

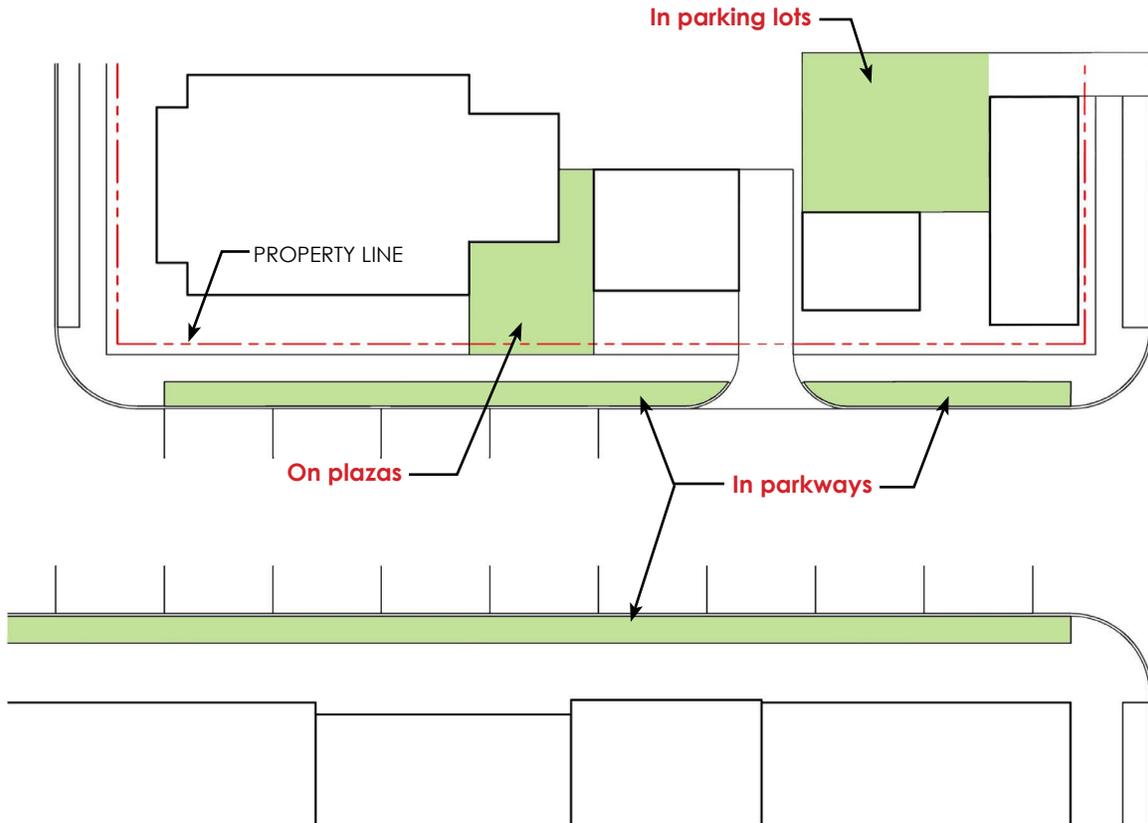
Additional Guidelines:

- Use impermeable liner as needed to separate tree trenches and boxes from roads, parking lots, sidewalks and adjacent walls or building foundations.
- Media infiltration rates should be provided to allow adequate filtration of stormwater. Infiltration rates should not be so high as to limit tree growth or water quality treatment. Infiltration rates between 1 and 4 inches per hour are recommended.



SUSPENDED PAVEMENTS

Suspended Pavements Potential Locations:



Sizing Considerations:

- The suspended pavement units come in a variety of sizes. Therefore depending on the tree root and soil space needed, the cell can range from 10-30 cubic feet.
- If intending to use these structures for stormwater storage, the larger cells are most efficient.

Maintenance:

- Mature trees will lose a significant amount of leaves in the fall and therefore may require clean up.
- Trees may require water in times of drought.

Limitations or Constraints:

- Setback from curb: 18 inch minimum
- Above ground space limitations such as utilities, lighting, signs, and structures.
- Regulations regarding types and locations of trees planted in public right of way such as minimum sight distances and setbacks from street corners.



Suspended pavements coordinated with permeable pavement

SUSPENDED PAVEMENTS

Where to Use:

- Sidewalk areas
- In parking lot islands and around the perimeter of the lot.
- On roofs
- Plazas



Mature trees in a suspended pavement system on S. Martin Luther King Drive, Chicago, IL.



Deconstructed structural cells ready to be built and installed, Defiance, OH.



Suspended pavements used in a plaza with permeable pavement.



Flow diversion manhole shown distributing flow to tree box, Defiance, OH.

Additional Resources:

Refer to the City of Grand Rapids Green Infrastructure Standards for additional information.

Article II- Landscaping and Green Infrastructure of the zoning ordinances for tree canopy provisions.

APPLICATIONS		STORMWATER QUANTITY FUNCTIONS	
Residential	Yes	Volume	Low/Medium
Commercial	Yes	Groundwater Recharge	Low/Medium
Ultra Urban	Yes	Peak Rate	Low
Industrial	Yes	STORMWATER QUALITY FUNCTIONS	
Retrofit	Yes	Sediment	Medium
Highway/Road	Limited	Temperature	Low
Recreational	Yes	MAINTENANCE	
Private	Yes	Intensity	Low/Medium



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Description:

Mature trees provide significant stormwater quantity and rate control benefits through soil storage, interception, and evapotranspiration. A tree with a 25-foot diameter canopy can hold the 1-inch, 24-hour storm event from 2,400 square feet of impervious surface. Interception and evapotranspiration also decrease runoff volume with larger trees providing exponentially more benefit than smaller trees.



Wide greenway, Maywood Avenue, Toledo, OH



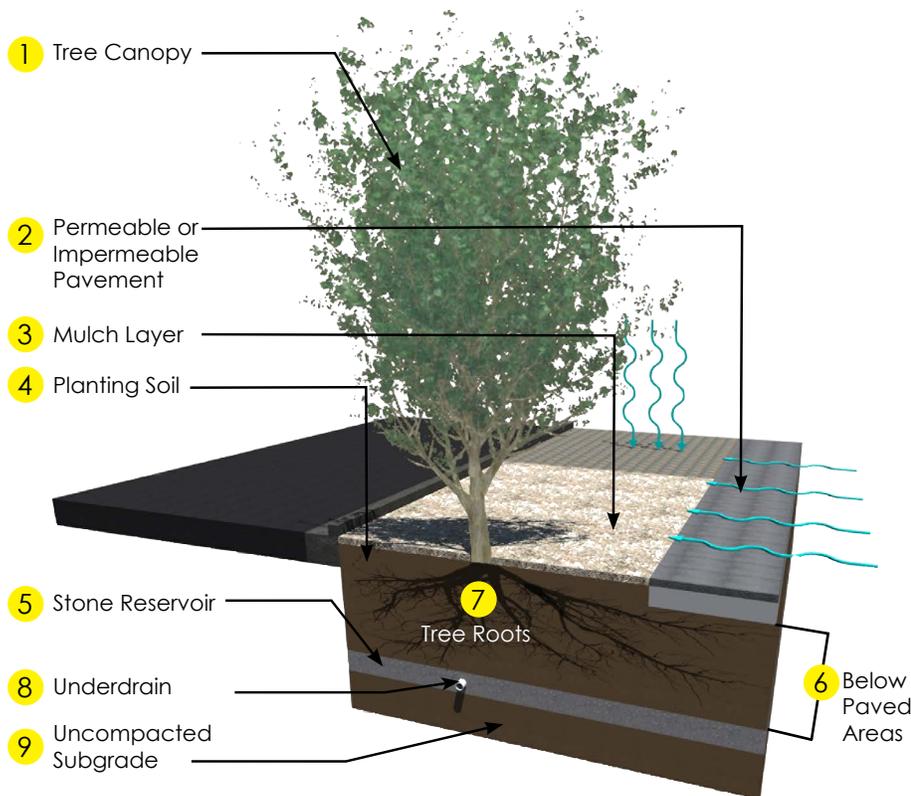
Trees and linear bioretention, Maywood Avenue, Toledo, OH

Green Objectives:

- Reduce stormwater run-off that would normally flow directly into the City's already burdened storm sewer system.
- Improve water quality by filtering pollutants.
- Reduce effective impervious area.
- Promote infiltration to the groundwater table.
- Reduce urban heat island effect.
- Improve air quality.
- Reduce energy usage.
- Increase tree canopy, tree species diversity, and aesthetics city-wide.

Cost Considerations:

- The environmental and aesthetic benefits of trees are an average of three times greater than tree care costs.
- Tree canopy can reduce building air conditioning costs and energy demand.
- Shady streets need to be repaved less frequently than streets with little or no shade.
- Trees increase residential property values and attract shoppers to commercial districts.
- Trees can provide stormwater benefits while meeting landscape requirements.



Components

- 1 Tree Canopy:** Intercepts rainwater, which slows the accumulation of runoff and allows some of it to evaporate.
- 2 Permeable or Impermeable Pavement:** Directs runoff into the tree planting zone.
- 3 Mulch Layer:** Shredded hardwood, compost, or other mulching material retains water and filters pollutants.
- 4 Planting Soil:** Loose soil mix designed to meet the needs of the tree species and to encourage infiltration of stormwater.
- 5 Stone Reservoir:** Stone layer where water will collect until it infiltrates into the subsoil.
- 6 Below Paved Areas:** If additional space is needed for tree roots, extend the planting soil area by providing structural cells, suspended sidewalks, or structural soil under adjacent paved areas.
- 7 Tree Roots:** Stormwater runoff is directed downwards through tunnels created by the roots. Some of the water is then absorbed by the roots, which provides the tree with needed moisture and helps dissipate excess stormwater.
- 8 Underdrain:** Perforated pipe that takes excess water to the storm sewer system.
- 9 Uncompacted Subgrade:** Existing soil below the stone reservoir where stormwater infiltrates.

General Design Guidelines:

- Identify trees to be protected and preserved during the site planning process (i.e., greater than 4 inches in diameter per City standard).
- Seek advice from a professional on the health of each tree and the effects of planned construction. Determine what procedures should be followed to protect the trees.
- Preserve trees on slopes and riverbanks to prevent soil erosion.
- Design green infrastructure practices (e.g., permeable pavement, bioretention) adjacent to new or mature trees to take advantage of the water absorbing properties of the root system.
- Plant trees within green infrastructure practices to enhance the hydrologic performance of the practice.
- Provide a curb cut from the street to allow water from the surrounding area to drain to the tree. Care must be taken to not drown the tree.
- Do not store any equipment or materials within the drip line of a tree.
- Consider pervious flexible sidewalks (e.g., rubber or plastic) to replace concrete sidewalks that are cracked due to tree roots. The porous material allows water and oxygen to reach the roots, is flexible to accommodate the growing tree roots, and can be lifted to allow for tree root trimming.
- Trees with a caliper less than 8 inches can be removed and replaced with City approval.

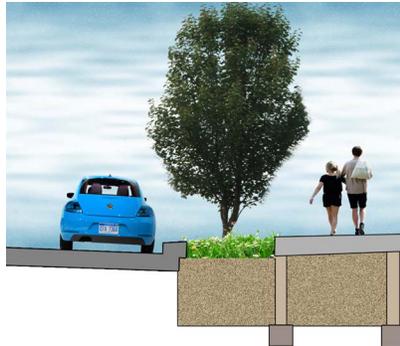
Structural Cells

Modular manufactured cells that support pavement and are filled with loose soils that encourage root growth.



Suspended Sidewalks

Sidewalks with a supporting understructure that allows loose root-friendly soils to be continued under the walk.



Structural Soils

A blend of crushed rock and soil that is able to support pavement and can also support root growth.



Help Trees Survive:

Street trees are usually short-lived, surviving an average of 7 to 10 years and in some areas less than 3 years. The two main reasons for low survival rates are:

- 1. Lack of adequate soil volume:** The roots of trees in the natural environment will spread out to two to four times the diameter of the canopy of the tree. Roots are critical for healthy tree development as they absorb the essential nutrients, water, and oxygen the tree needs. Therefore, it is important to provide adequate soil volume to accommodate healthy roots.

Solution: Provide adequate soil volume.

Preferred Soil Volumes:

- Small Tree: 600 cubic feet
- Medium Tree: 1,000 cubic feet
- Large Tree: 1,500 cubic feet
- Multiple Trees: Provide a continuous tree trench at least 8-feet-wide by 3-feet-deep

Minimum Soil Volume:

- Per Tree: Provide at least 500 cubic feet of soil

- 2. Lack of moisture:** Trees may not receive enough moisture because of a space that is too small or the ground is too compacted for water to be absorbed.

Solution: Provide adequate moisture.

Provide a loose organic soil and where feasible direct stormwater into tree planting zones. If oversaturation is a potential problem, provide a stone storage layer and/or a porous underdrain pipe.



Stormwater planter with trees, Bagby Street, Houston, TX

Maintenance:

Please refer to guidance for street tree care at <http://grcity.us/parks/Pages/Caring-For-Your-Street-Tree.aspx>. Information includes: watering, weeding, mulching, and uncompacting soil.

The City of Grand Rapids Forestry division provides numerous tree services not limited to: emergency response for tree-related emergencies; pruning; removal of diseased, dead, and dying trees; and administering a tree planting and maintenance program.



Residential bioretention with trees, Houston, TX



Bioretention in parking lot with trees, Fayetteville Manlius School Manlius, NY



Trees planted in structural soil that extends under the sidewalk to encourage healthy roots, Philadelphia, PA

Tree Ordinance Considerations:

Reference ordinances for new development:

- Minimum number and size of trees planted in common space.
- Overlay district tree planting requirements.
- Landscaping requirements (prohibited trees).
- Tree protection/replacement requirements.
- Street tree planting requirements.

Additional Resources

Refer to the City of Grand Rapids Green Infrastructure Standards for recommended trees and prohibited species.

Johnson, G. R. 2013. Protecting Trees from Construction Damage: A Homeowner's Guide. University of Minnesota Extension. Last Accessed: March 24, 2015 <http://www.extension.umn.edu/garden/yard-garden/trees-shrubs/protecting-trees-from-construction-damage/>



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APPLICATIONS		STORMWATER QUANTITY FUNCTIONS	
Residential	Yes	Volume	Medium
Commercial	Yes	Groundwater Recharge	Medium
Ultra Urban	Yes	Peak Rate	Low
Industrial	Yes	STORMWATER QUALITY FUNCTIONS	
Retrofit	Yes	Sediment	High
Highway/Road	Limited	Temperature	High
Recreational	Yes	MAINTENANCE	
Private	Yes	Intensity	Low/Med.

Description:

Underground facilities are designed to capture and temporarily store stormwater from the tributary drainage area. Curb inlets, surface drains, or over flow from upstream practices direct stormwater to underground tanks/vaults or systems of large diameter subsurface storage pipes. The stormwater is then released directly through an outlet pipe back into a stormwater drainage system or allowed to infiltrate into the soil. Examples of these underground facilities include arch storage, concrete vault storage, cube storage, and stackable columns.



Subsurface storage and infiltration under Joe Taylor Park, Grand Rapids, MI.



Subsurface storage and infiltration under Joe Taylor Park, Grand Rapids, MI.

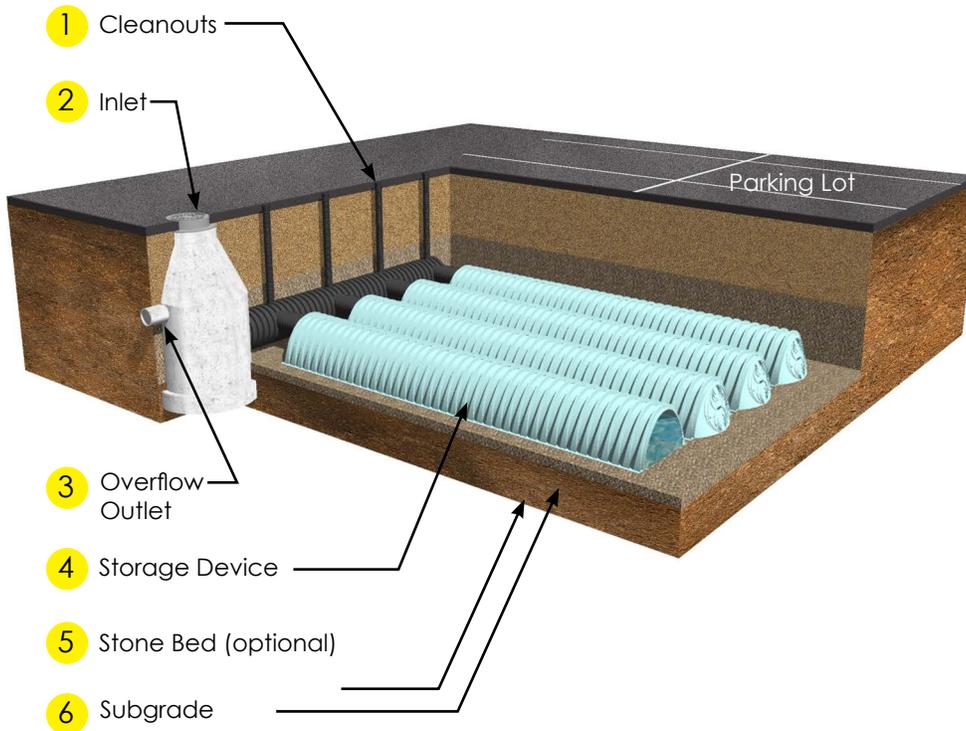
Green Objectives:

- Reduce volume of runoff from a drainage area by promoting infiltration through the subgrade.
- Promote groundwater recharge.
- Infiltration is a preferred method for stormwater management where appropriate site conditions and soils exist.
- By infiltrating stormwater onsite, downstream impacts resulting from stormwater flows are reduced or in some cases eliminated.

Key Considerations:

- Do not infiltrate in areas with soil contaminations or areas of unstable soil.
- Needs ample space to build, however may not utilize above ground space.
- Pretreatment should be incorporated for maximizing performance. (Refer to Water Quality Structures Factsheet)
- May be cited under lawns, parking areas, and recreational areas.
- Maintain minimum distance from building foundations (typically 10 feet).
- Storage is provided within voids of open graded aggregate or other approved materials.

SUBSURFACE INFILTRATION PRACTICES



Components

- 1 Cleanouts:** Pipes that allow access to the network for inspections and cleanout of accumulated sediment.
- 2 Inlet:** The structure into which water from the pipes and catch basins flows into. The water is then distributed into the system.
- 3 Overflow Outlet:** Pipe that takes excess water to the storm sewer system.
- 4 Storage Device:** Storage may be accomplished in open graded aggregate, pipes, arched vaults, modular plastic cubes, large concrete vaults or other approved materials. The storage system allows for infiltration of water into the subgrade.
- 5 Stone Bed:** An optional open graded aggregate layer to promote infiltration from the storage device and provide a stable base.
- 6 Subgrade:** Water spread out from the storage slowly infiltrates into the subgrade.

General Design Guidelines:

- Avoid installation of underground facility in area where the water table is less than 2 feet below the bottom of the practice.
- Include a pretreatment device upstream of the main practice to increase the functional life of system. Acceptable forms of pretreatment include: filters, bioretention, filter strips, appropriate prefabricated and propriety designed systems (see Water Quality Devices Factsheet) and sumped inlets with traps.
- Provide a mechanism to dewater if needed.
- Ensure cover material is suitable for proposed surface use conditions
- Perform an infiltration test at the location and proposed elevation of underground practice.
- Underground infiltration practices may meet USEPA definition of a Class V Injection Well.

Cost Considerations:

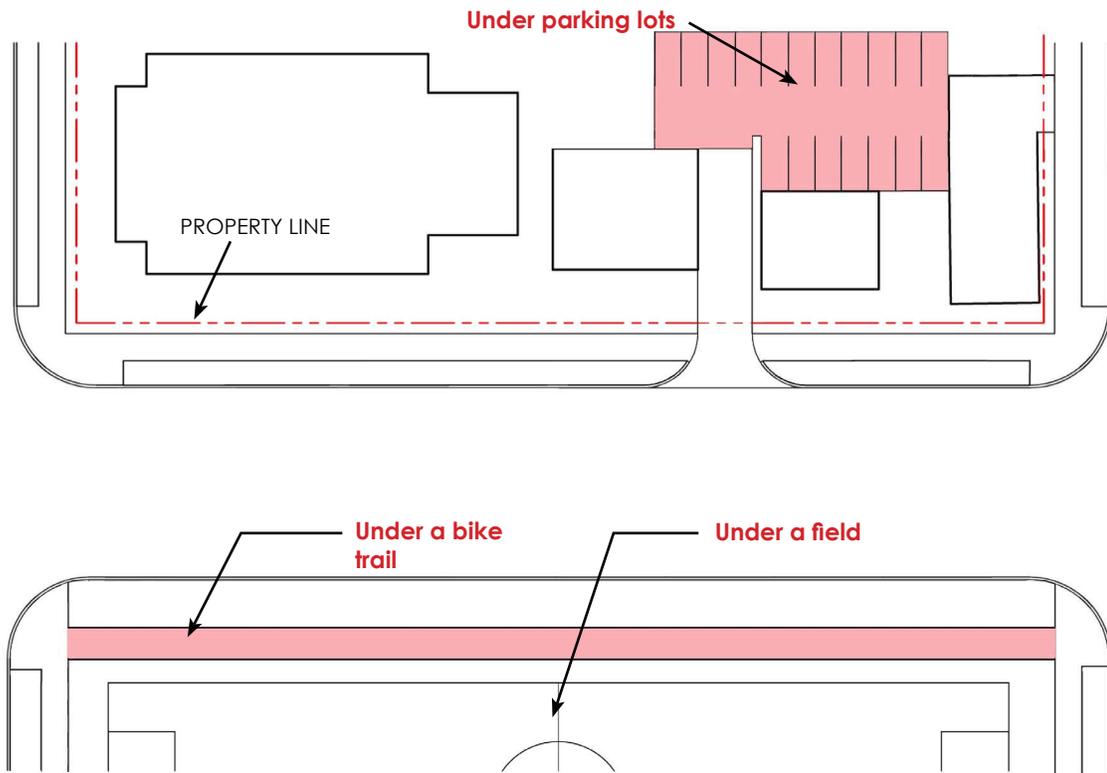
- The cost will vary depending on the size of the infiltration bed.
- Other factors include the type of storage media chosen and if piping and other drainage structures are included in the design.



Cube storage system installed at Hope College, Holland, MI.

SUBSURFACE INFILTRATION PRACTICES

Subsurface Infiltration Potential Locations:



Sizing Considerations:

The area of the underground infiltration bed is dependent on the drainage area and the design storm that the bed is intended to store. Infiltration practices should be designed to dewater within approximately 72 hours.

Maintenance:

- Clean inlets, pretreatment devices, outlets and overflows.
- Remove accumulated debris.
- Periodically test the infiltration rate of the subgrade.

Setback Requirements:

- From Property Line: 10-foot minimum
- From Building foundation: 10-foot minimum without a waterproof liner.
- From Private Well: 50-foot minimum
- From Public Water Supply: 50-foot minimum
- From Septic Drain field: 100-foot minimum
*50 feet for septic systems with a design flow of less than 1,000 gallons per day

Limitations:

- Not recommended if the infiltration practice receives runoff from vehicle fueling or maintenance areas.
- Not recommended if the infiltration practice is within 200 feet of an edge of a slope that exceeds 20%.

SUBSURFACE INFILTRATION PRACTICES

Where to Use:

- In locations where available surface space is constrained but adequate underground space is available.
- In locations where an overflow can be directed to an appropriate outlet.



Installation of a 36-inch HDPE under roadway Middle Blue River Green Solutions Pilot Project, Kansas City, MO.



Post-construction Middle Blue River Green Solutions Pilot Project, Kansas City, MO.



Installation of subsurface storage and infiltration system, Field Club Trail, Omaha, NE.



Post-construction subsurface storage and infiltration system, Field Club Trail, Omaha, NE.

Additional Resources:

Refer to the City of Grand Rapids Green Infrastructure Standards for additional information.

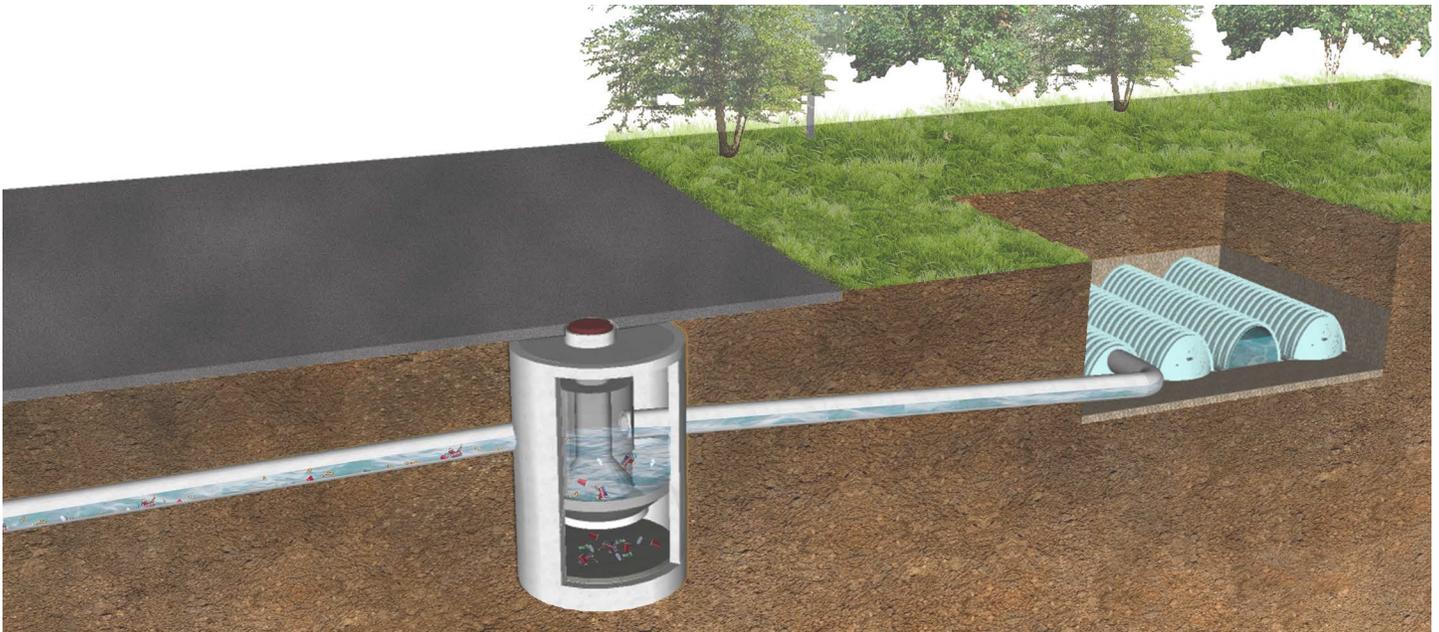


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Residential	Yes	Volume	Medium
Commercial	Yes	Groundwater Recharge	Medium/High
Ultra Urban	Yes	Peak Rate	High
Industrial	Yes	STORMWATER QUALITY FUNCTIONS	
Retrofit	Yes	Sediment	Low/Medium
Highway/ Road	Limited	Temperature	High
Recreational	Yes	MAINTENANCE	
Private	Yes	Intensity	Low/Medium

Description:

Water quality structures are below ground, flow-through treatment devices that use multiple treatment technologies to remove sediments, solids, oil, and other pollutants from stormwater. The systems can be added to stormwater conveyance systems as a retrofit option and are very effective as pretreatment for other green infrastructure systems. There are a variety of water quality structures including filter beds, screens, baffles, and hydrodynamic separators that offer a range of treatment options.



An example of a hydrodynamic separator being placed upstream of a green infrastructure practice as a pretreatment. The device settles out sediment and trash so that the longevity of the subsurface practice is maximized.

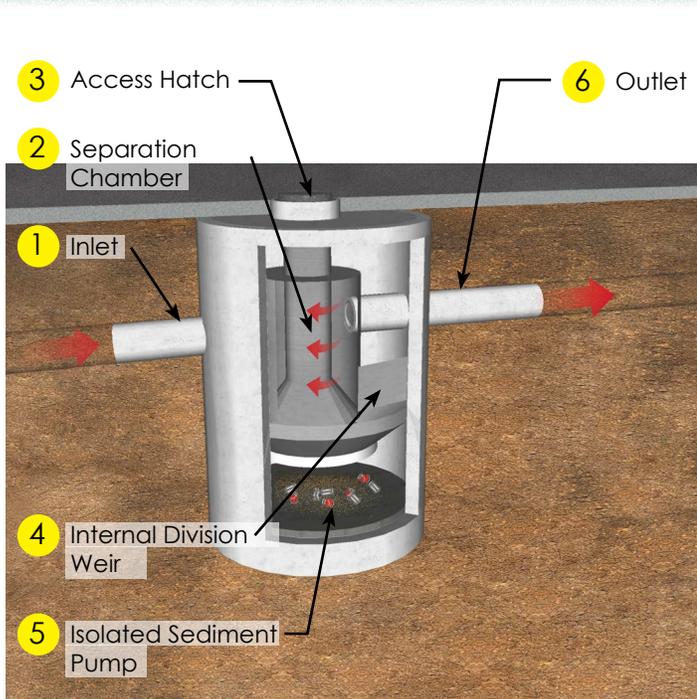
Green Objectives:

- Improve water quality by settling or filtering sediments and removing the pollutants attached to the sediment particles.
- Pretreat the runoff so that a downstream green infrastructure practices receive less debris and sediment.
- Increase the quantity of green infrastructure practices through the City, consistent with sustainability goals.

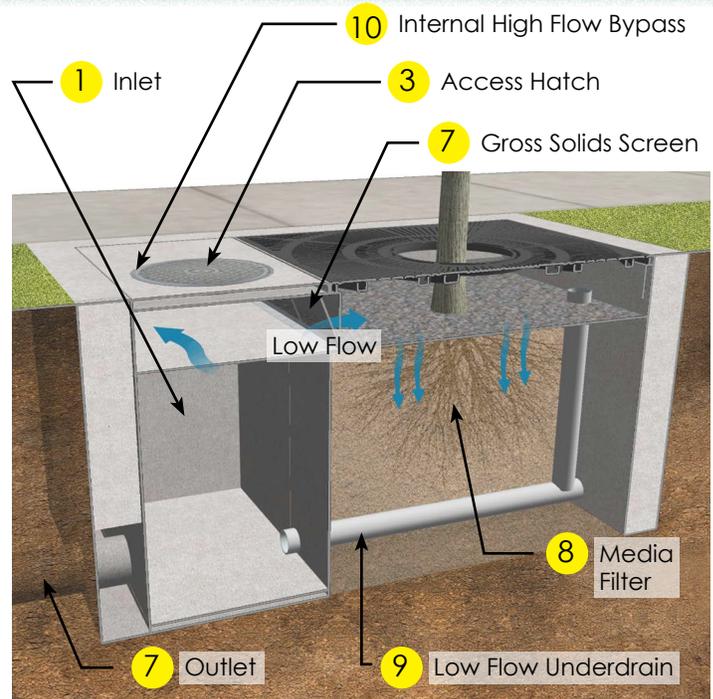
Key Considerations:

- Placement of device should ensure easy access for people and maintenance.
- Can be used as a water quality retrofit to existing stormwater systems.
- Avoid conflict with existing underground utilities.
- Ensure device is properly sized to handle the design storm peak flow rates.

WATER QUALITY STRUCTURES



Typical Hydrodynamic Separator



Filter Media Device

Components

- 1 **Inlet:** Pipe that brings stormwater into system.
- 2 **Separation Chamber:** The area specially designed to settle out sediment and trash. Varies by device and can consist of baffles, a swirl chamber, filters, or screens.
- 3 **Access Hatch:** Allows access to the internal system for maintenance.
- 4 **Internal Diversion Weir:** Allows excessive flows to bypass around separation chamber.
- 5 **Isolated Sediment Sump:** Area where the settled-out sediments are captured for removal and disposal.
- 6 **Outlet:** Pipe conveys treated water into storm sewer or a stormwater management practice.
- 7 **Gross Solids Screen:** Runoff passes through a screen prior to entering the media filter.
- 8 **Media Filter:** Low flow is filtered through a customizable media filter.
- 9 **Low Flow Underdrain:** After filtering, runoff is collected and routed through an underdrain pipe.
- 10 **Internal High Flow Bypass:** Runoff flow rates in excess of what the media filter can handle are bypassed to the outlet system.

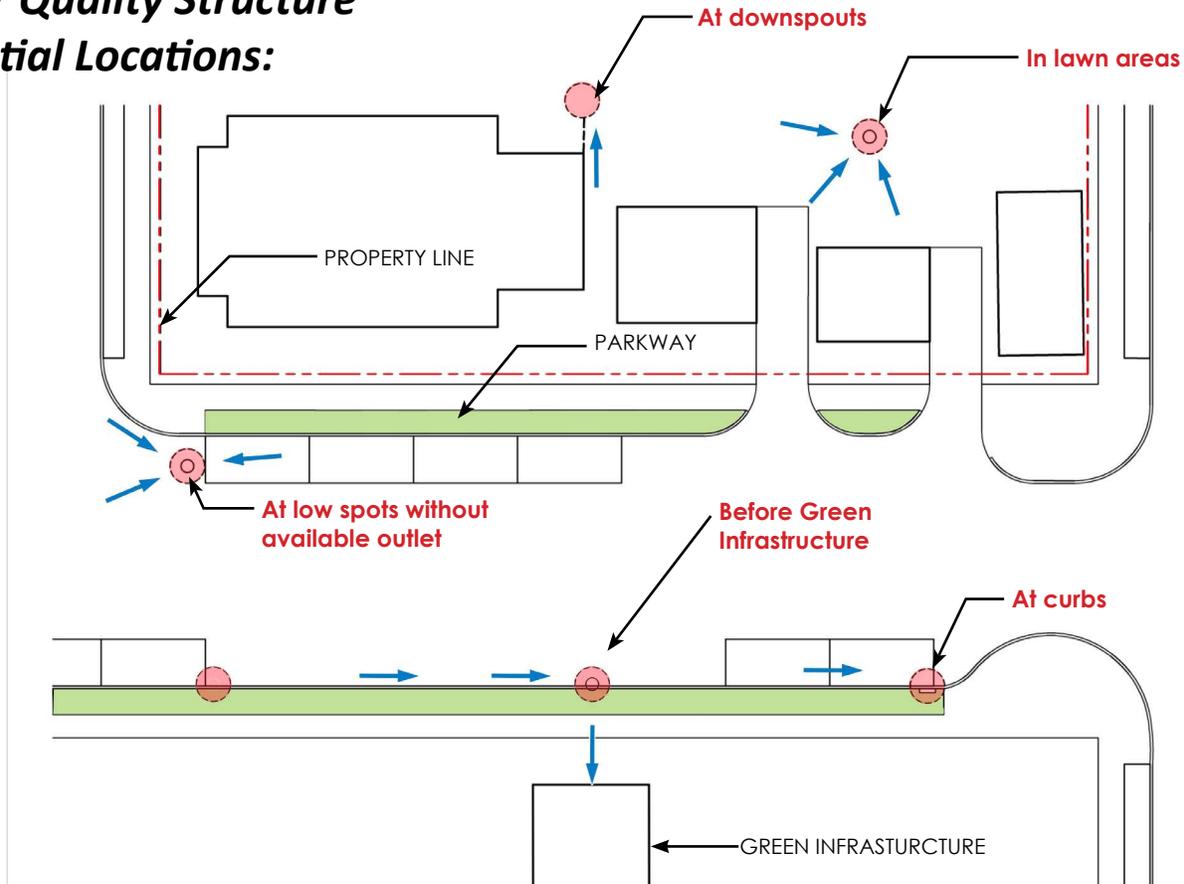
General Design Guidelines:

- Match site considerations with manufacturer's guidelines and specifications.
- Overflow should be designed so that large storms bypass the treatment device.
- Maximize the system's capacity by connecting multiple inlets, including catch basins.
- Properly select and design water quality devices to prevent re-suspension of captured sediments during storm events that exceed system capacity.
 - Media filtration units may be customized to target removal of specific pollutants.



WATER QUALITY STRUCTURES

Water Quality Structure Potential Locations:



Sizing Considerations:

- Systems are typically sized by the manufacturer based on the device and tributary area.
- System should be sized to accommodate the peak flow for an appropriate design storm.
- Systems work best for small to medium tributary areas.

Performance Information:

- With the large variety of devices, each with multiple models, it is important to review the devices' performance data.
- New Jersey Corporation for Advanced Technology has developed standards by which to test these devices and is a good source for performance reports. Refer to www.njcat.org.

Maintenance:

- Inspect device at regular intervals and if possible after major storms.
- Use vacuum pump to remove floatables and sediment from the separation chamber and sediment sump.
- If capturing runoff from a nearby hotspot, special disposal of debris may be required.
- Regular maintenance is crucial to the effectiveness of these devices.

Cost Considerations:

- Costs vary widely according to manufacturer, type, and size.
- The larger devices are relatively high in cost in terms of cost per tributary area, however, there are low cost pretreatment options.



WATER QUALITY STRUCTURES

Where to Use:

- In existing or proposed conveyance systems that have/expected to have significant levels of sediment or debris.
- In conveyance systems near pollutant hot spots.
- Within: parking lots, gas stations, golf courses, streets, and driveways.
- Upstream of green infrastructure practices.



Rapid media filtration unit, Lansing, MI (winter time).



Zeolite based media filtration, San Diego, CA.



Hydrodynamic separator during construction, Grand Rapids, MI.



Hydrodynamic separator during construction, Grand Rapids, MI.

Additional Resources:

Refer to the City of Grand Rapids Green Infrastructure Standards for additional information.



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Industrial	Yes	STORMWATER QUALITY FUNCTIONS	
Retrofit	Yes	Sediment	Medium
Highway/Road	Yes	Temperature	None
Recreational	Yes	MAINTENANCE	
Private	Yes	Intensity	Medium