GREENING THE CORPORATE CAPITAL

A Vision for the City of Wilmington, Delaware

University of Delaware, 2022

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University of Delaware, Spring 2022
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EXECUTIVE SUMMARY

Wilmington, Delaware, is a historical city with an incredible legacy of innovations, one of the first industrial cities in the world. Like more than 100 other post-industrial communities in the northeast United States, Wilmington has a combined sewer and stormwater system (CSS).

In a CSS, stormwater runoff and sanitary sewers use the same underground infrastructure to convey wastewater to a wastewater treatment plant. These systems are adequate under dry conditions and during an average rainfall event. Unfortunately, during a heavy rain event, the CSS is often overwhelmed by the volume of stormwater runoff draining from the streets, discharging raw sewage into the Delaware River in a Combined Sewer Overflow (CSO) event. This occurrence will only become more problematic as climate change increases storm intensity.

Wilmington is in a period of change. Wilmington's 2028 Comprehensive Plan, Downtown Development District Plan, and various other measures propose redevelopment and improvements across the city. The Department of Public Works has recognized green infrastructure as an essential tool for urban revitalization and stormwater management. Green infrastructure is a sustainable approach to managing stormwater by reducing and treating stormwater at its source.

Green Streets are designed streetscapes that infiltrate and filter stormwater while creating more lively, livable communities. Green Street components make the city more beautiful, are associated with nearby residents' better mental and physical health, and are less costly over the system's lifespan. This book is intended to inform and inspire city workers and community members alike about the benefits of Green Streets and how they might apply to the 11th Street Bridge neighborhood and beyond.

Many cities around the country are becoming aware of the benefits of Green Streets and are beginning to implement these systems across the urban landscape. The hope of this project is that armed with the right information, Wilmington will join the Green Streets movement, adopt these systems, reap the benefits, and continue its legacy as a city of innovation.

SECTION 1

INTRODUCTION

INTRODUCTION

Once one of the most culturally, socially, and economically dynamic cities in the region, Wilmington has the opportunity to re-establish itself on the list of great cities through thoughtful revitalization efforts. Green Streets can play a vital role in this process.

HISTORY

The City of Wilmington, like most eastern U.S. cities, has been evolving for over 350 years. After periods of Swedish (1638), Dutch (1655), and British (1664) colonization, the area stabilized under British rule (with Quaker influence). It was granted a borough charter in 1739 by the King of England, which changed the name from Willington (after Thomas Willing, the first 'developer" of the land) to Wilmington, presumably after Spencer Compton, Earl of Wilmington, a favorite of the King. From the granting of the charter until the Revolution, the town developed steadily into a prosperous business and residential community. During the Revolution, its milling industries, geographic location, key leaders, and resources made Wilmington particularly strategic.

Topography and soil conditions affected residential development patterns in the city. Wilmington lies at the fall line that separates the flat coastal plain from the hilly areas to the west. Northeast Wilmington, and along both sides of the Christina River, the land is flat, low-lying, and marshy in places. The northwest is hilly and rises to a point that marks the watershed between Brandywine Creek and the Christina River.

The borough of Wilmington officially became a city in 1832, when the State legislature granted a charter. The area's economy flourished as shrewd businessmen, and a skilled labor force provided the resources for growing industries. The Industrial Revolution era was reflected in Wilmington with events such as the 1837 completion of the Philadelphia, Wilmington & Baltimore Railroad, which made the city accessible by water, road, and rail, providing easy access to most malls or markets.

The Civil War (1861) had a profound effect on the economy of the city. To meet the demands of waging war, older establishments expanded, and many new industries were attracted to the city. Wilmington products included ships, railroad cars, gunpowder, shoes, uniforms, and other war-related goods. By 1868, Wilmington was producing more iron ships than the rest of the country combined, and it rated first in the production of gunpowder. The post-war prosperity allowed the construction of many elaborate new homes and businesses, which induced residential development to the west of the existing city. More new industries developed between the Civil War and World War I, and the greatest population increases occurred. In 1860 21,250 people were living in the city. By 1920 that number had risen to 110,168.

While many corporations sought the benefits of Delaware's liberal tax structure and located themselves in or near Wilmington, firmly establishing the city as a "Corporate Capital," the burgeoning number of automobiles and roadways in the 1950s made living in the suburbs and commuting into the city to work possible. This contributed to significant population losses in Wilmington. Projects such as urban renewal in the 1960s and 70s, which cleared many housing blocks, and the construction of I-95, which cut a swath through several of Wilmington's most stable neighborhoods, also left their mark on the city.

Like many cities constructed in the late eighteenth century, Wilmington has a sewer system that combines sewage and stormwater. The emergence of paved roads for automobiles and these combined sewer systems pose two of the most significant environmental issues in older cities: polluted stormwater runoff and combined sewer overflows into waterways during large storm events.

With the recent "Back to the Cities" movement, Wilmington is at a crossroads in its redevelopment.

Plan of Wilmington, Benjamin Ferris, 1736.

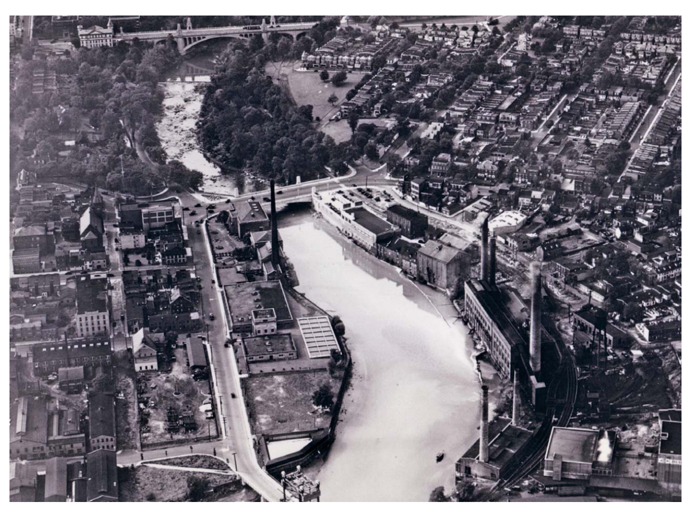
CITY OF WILMINGTON

PROBLEM & GOALS

Wilmington was planned during a period when it was considered sanitary to direct stormwater and sewage flows into the adjacent river, where it would flow "away" and be taken care of naturally. This belief led many cities, including Wilmington, to construct combined sewer and stormwater systems. While these combined flows are primarily directed to wastewater treatment plants, the system was not designed for today's higher flow volumes and heavy rainfall events, so combined sewer overflows (CSOs) into the Christina and Delaware Rivers are common. These overflows can pose significant ecological and human health risks and are subject to Environmental Protection Agency (EPA) regulations.

As a city with a highly impervious area adjacent to the Delaware River, Wilmington is interested in reducing its CSOs. The city anticipates significant revitalization in the future, and Green Streets may be a way to address the problem of CSOs and stormwater in addition to some of the other social and economic challenges facing the city.

This guidebook intends to demonstrate the effectiveness of Green Streets in addressing these problems and provide recommendations for Wilmington's streets.



Brandywine Creek and filter plant from the air, 1929.

HOW TO USE THIS GUIDEBOOK

This document aims to help city planners and policymakers advocate for Green Streets in Wilmington and serve as an initial set of design guidelines as the city transforms its streets into more ecologically, economically, and socially positive spaces.

Section 2: Making a Case for Green Streets
This section establishes the need for Green Streets in Wilmington, providing users with essential information that can be used to garner support from city departments and citizens for Green Streets.

Section 3: The Toolbox
This section provides a comprehensive breakdown of the Green Streets tools or strategies recommended in this document, including information on each tool's spatial and functional characteristics. Tools are referred to as they are used in each template and site-specific design.

Section 4: Applying Green Streets to Wilmington
This section demonstrates how this guidebook's principles, strategies, and processes can be applied to and transform a network of actual streets in Wilmington. Based on well-traveled, local streets, these designs will help readers envision the true potential of Green Streets to transform their city.

BUILDING ON EXISTING PLANS

This Green Streets Guidebook follows and builds upon several related sources, including plans and studies related to the city's context and redevelopment. These should serve as references and provide additional contextual information to users of this document. Some of the most relevant documents include:

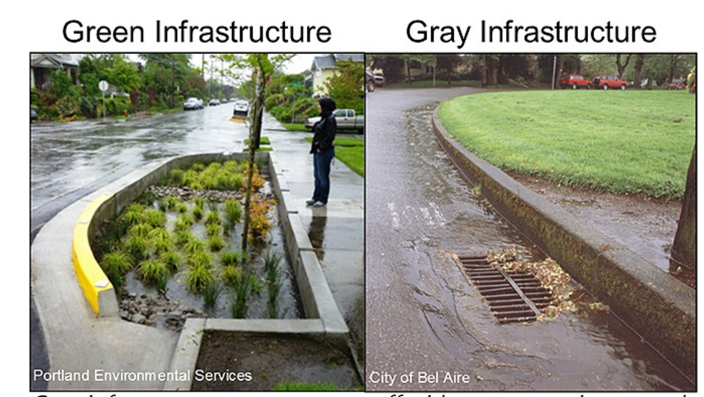
- Complete Streets in Delaware: A Guide for Local Governments
- Wilmington 2028 Comprehensive Plan
- NCC2050 Comprehensive Plan
- Northeast Brandywine Riverfront Brownfields Area-Wide Plan

WHAT ARE GREEN STREETS?

Green Streets, Green Infrastructure (G.I.), Low Impact Development (LID)... as "green" technologies have become increasingly popular in this age of climate change, the terminology has proliferated.

Whatever the name, the technique remains the same: slow water down and give it time to infiltrate into the soil. As water passes through the biological activity of the soil, toxins are broken down, and rainwater recharges the water table instead of rushing off to cause erosion and pollution downstream.

In essence, "Green Streets" are a strategy to make our urban infrastructure behave more like a natural ecosystem, with many associated benefits to all residents, human and otherwise. Most of these benefits, noted in the chart on the next page, do not occur with gray infrastructure. Furthermore, green technologies are increasingly more cost-effective than their gray counterparts.



Grey infrastructure manages runoff with sewage mains, tunnels, and wastewater treatment plants. Green infrastructure manages runoff with natural and engineered systems that mimic nature.

BENEFITS OF GREEN STREETS	
BENEFIT	EXPLANATION
Improve Air Quality	Trees uptake gaseous air pollution, remove CO2 from the atmosphere, store carbon, and filter particles out of the air, using their leaves and bark to trap them. This improves air quality and reduces respiratory illnesses, such as asthma, bronchitis, and lung infections (Feldman).
Increase Public Space	Access to green space increases walkability, physical activity, and chances for social interactions. Green Streets help physically and mentally by decreasing obesity and stress.
Increase Energy Savings	Trees and green infrastructure are able to harvest and use water, reducing the energy needed to pump it to treatment facilities (American Society of Landscape Architects). They also provide shade and therefore decrease the need for air conditioning in the warmer months.
Decrease Greenhouse Gases	As trees grow, they remove CO2, the leading cause of global warming, from the atmosphere, store it in the trees and soil, and release oxygen. A mature tree can consume up to forty-eight pounds of carbon dioxide per year. By reducing electricity costs, there is a decreased use of fossil fuel, which inherently decreases carbon in the atmosphere.
Decrease Urban Heat Island Effect	Trees and vegetation can help reduce urban heat island effect by shading buildings, deflecting sunlight, and releasing moisture back into the atmosphere.
Increase Property Value	Increased access to green space has been linked to increased property values. A study in Philadelphia demonstrated that a neighborhood with newly planted trees had a 2% increase in property values (American Society of Landscape Architects).
Create Community Cohesion	Increased vegetation encourages the use of outdoor spaces, leading to increased neighborhood interactions and higher social capital. These spaces provide a setting for people to meet, interact, and enjoy their neighbors (Platt et al).
Safety	Green infrastructure can separate pedestrians and bikers from cars to increase safety, and Green Streets have also led to decreased crime rates as neighborhoods feel as though they are cared for.
Increase Wilflife Habitat and Biodiversity	Vegetation creates habitats for birds, mammals, and insects. Slowing stormwater decreases erosion and sedimentation, which helps stabilize habitats (EPA).

GREEN STREET PRINCIPLES

Green Streets are primarily designed to infiltrate stormwater close to its source and create more vibrant, livable communities. This guidebook identifies three principles for designing Green Streets. The strategies and benefits linked with each principle contribute to sustainable streets and communities.

1. Green Infrastructure: *Using naturalized systems to treat stormwater close to its source.*

Green infrastructure uses nature-based systems to infiltrate, evapotranspire, and recycle stormwater runoff close to its source. These systems seek to complement rather than replace existing grey infrastructure, often linking green infrastructure to existing sewer and stormwater systems. Green infrastructure often uses vegetation, permeable surfaces, and engineered soils to intercept stormwater before it reaches a wastewater system, reducing the burden on the grey infrastructure system, reducing the number and volume of combined sewer overflows, and limiting the amount of polluted stormwater runoff entering waterways. Benefits of green infrastructure can include:

- Reduced and filtered stormwater, leading to reduced total suspended solids (TSS) and combined sewer overflows (CSOs)
- Reduced flooding
- Reduced wastewater pumping and treatment costs
- Added urban green space and wildlife habitat
- Sequestered CO2
- Improved air quality
- Shade and reduced urban heat island effects
- Recharged groundwater

2. Complete Streets: *Creating bicycle and pedestrian friendly streets.*

Complete streets are intended for all users, contrary to the conventional car-dominated streets most prevalent today. They foster safe, comfortable, and convenient access for all users, regardless of age, ability, income, or mode of transportation, and prioritize the health, comfort, and safety of a city's residents and visitors. By using designated bike lanes, safe pedestrian crossings, accessible transit systems, and traffic-calming elements, complete streets create healthier, more engaging streetscapes that offer opportunities to walk and bicycle daily and safely and comfortably navigate the street. Benefits of complete streets can include:

- Beautified streetscapes
- Increased bicycle, pedestrian, and vehicular safety
- Decreased car dependence and associated CO2 emissions
- Improved traffic flow
- Connected forms of transit
- Increased physical activity and improved health
- Increased social equality

3. Placemaking: *Generating a strong sense of place.*

Placemaking, or creating a strong sense of place, means strengthening connections between people and the places they share. Placemaking creates spaces that reflect the histories and identities of its residents, taking several forms, from street art to pocket parks to human-scale environments. Suitable public spaces can range from the temporary, such as streets closed off on weekends using bollards, to a permanent public park. Benefits of placemaking can include:

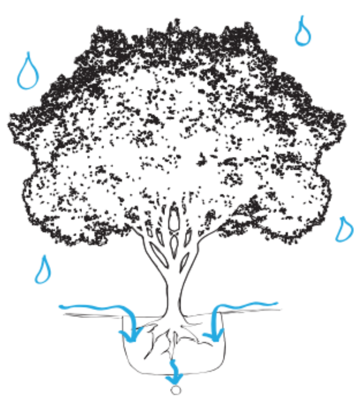
- Increased positive interactions between people
- Increased sense of inclusion, belonging, and pride
- Beautification
- Increased comfort and improved quality of life
- Economic growth

3 PRINCIPLES OF DESIGNING GREEN STREETS

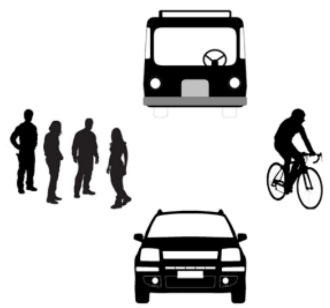
GREEN INFRASTRUCTURE
Use naturalized systems to treat stormwater close to its source

COMPLETE STREETS
Create bicycle and pedestrian friendly streets

PLACEMAKING
Generate a strong sense of place



Green infrastructure uses naturalized systems such as trees and bioswales to capture and infiltrate stormwater runoff close to its source, limiting the amount that enters into the combined sewer system.



Complete Streets accommodate all users including pedestrians, cyclists, transit riders, and motorists through a more equitable distribution of right-of-way space.

Placemaking uses pedestrian elements such as parklets to encourage people to linger and generate a strong connection to a place.

SECTION 2

THE NEED FOR GREEN STREETS

THE NEED FOR GREEN STREETS

This section explores Wilmington's social, economic, and ecological conditions and suggests how Green Streets might address some of the city's most significant challenges today.

DRAINAGE

While the hills of Northwest Wilmington provide a breath of fresh air from Delaware's otherwise flat landscapes, drainage patterns from these elevated slopes contribute to the city's flooding issues.

These slopes flatten out as they extend eastwards, eventually becoming wetlands where the 11th Street Bridge neighborhood is located. These neighborhoods are a mix of residential and industrial, and the majority of the streets have 0 to 8 percent slopes.

As Wilmington's rivers and streams leave the hills and approach development, they are surrounded by aging grey infrastructure. In wet weather conditions, these streams increase in volume, causing flooding in low-lying communities. Flowing eastward, stormwater intersecting with development in these communities and downtown has created a few high flood-risk areas. Most of the time, precipitation falling in these riverside communities is directed into the city's combined sewer system; however, in larger storm events, surface stormwater readily floods the riverside and a portion of the downtown, which is densely covered in impervious surface.

Although flooding is most apparent near the riverside, drainage should be a primary consideration when applying Green Streets anywhere in Wilmington. It is important to treat stormwater close to its source; infiltrating stormwater upslope is as vital as treating the flood-risk areas below. Although the downtown must infiltrate stormwater to manage local flooding, neighborhood streets at higher elevations should also be prioritized as Green Streets candidates.

STORMWATER

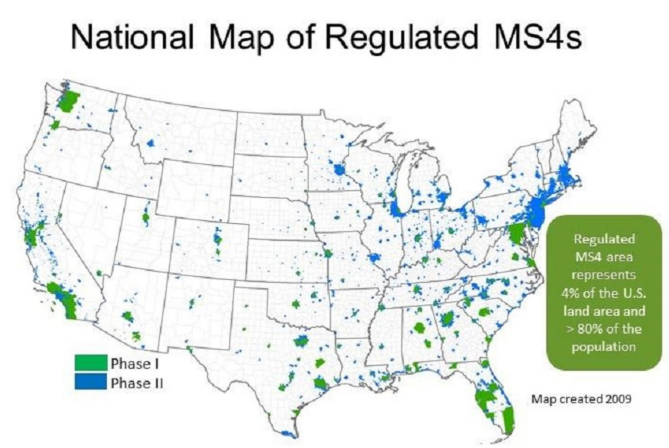
Stormwater runoff is precipitation that is unable to infiltrate into the ground due to impervious surfaces. As runoff flows over these surfaces (paved streets, parking lots, and building rooftops), it accumulates pollutants that adversely affect water quality if discharged untreated. In urban environments, these pollutants include:

- Pesticides and nutrients from lawns and gardens
- Oil, grease, and toxic chemicals from vehicles
- Bacteria and viruses from household and pet waste
- Heavy metals
- Winter road salt and sand

Drainage and flooding issues in Wilmington are compounded by the dense concentration of impervious surfaces downtown that prohibits infiltration, causing pollution. Stormwater pollution in Wilmington is not new; the city has been trying to keep pace with the EPA's stormwater regulations for decades. However, in this urban renewal era, addressing flooding issues with Green Streets may provide beautiful and ecological solutions to this ongoing struggle.

WILMINGTON'S STORMWATER HISTORY

In 1972, the Clean Water Act (CWA) enacted the National Pollutant Discharge Elimination System (NPDES) Stormwater Program to help manage growing concerns over stormwater discharges polluting water bodies in the United States. Prior to the CWA, only point source pollution (or direct, un-treated pollutant-dumping into water bodies) had been regulated, and stormwater runoff was considered a nonpoint source. Recognizing that a concentration of nonpoint source pollutant emmissions (such as a densely populated municipality's stormwater runoff discharges) behaves like point source pollution, the NPDES program redefined point source criteria, expanding regulation to incorporate Municipal Separate Storm Sewer Systems (MS4s).



Under the NPDES Stormwater Program Phase I, Wilmington was classified as an MS4 and required to protect and meet water quality requirements.

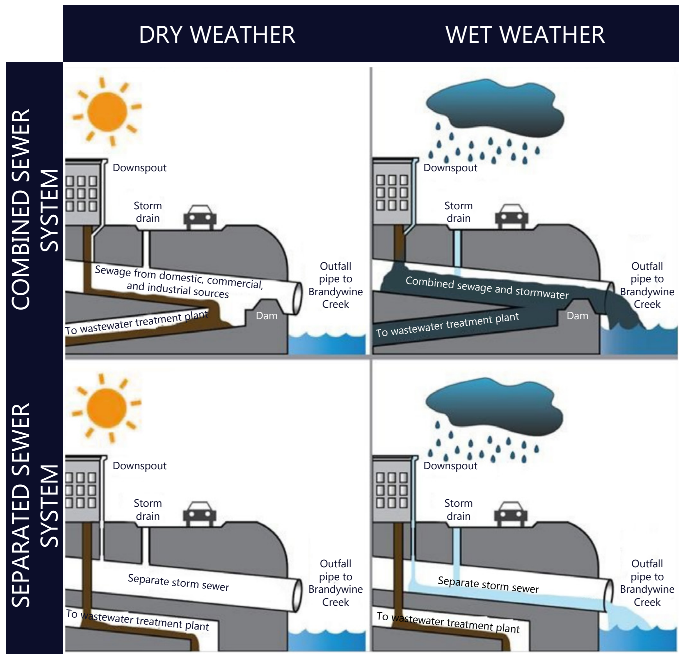
In 1990, under NPDES Stormwater Program Phase I, Wilmington was classified as an MS4 and required to protect water quality and satisfy the CWA's appropriate water quality requirements (U.S. EPA). MS4s are required to obtain an NPDES permit to discharge into water bodies. In accordance, Wilmington has developed a Storm Water Pollution Prevention and Management Program (SWPP&MP).

Wilmington is also required to evaluate the program's effectiveness and is subject to NPDES Compliance Monitoring. Recognizing the effectiveness of green infrastructure to reduce peak discharge volume and help cleanse polluted stormwater, the EPA's Region III NPDES permit for Delaware encourages municipalities to incorporate green infrastructure into their stormwater management practices and reduce impervious surfaces over time.

WILMINGTON'S STORMWATER RUNOFF TODAY

Although Wilmington has been classified as an MS4, incorporating green infrastructure has been of little priority for the city. Currently, the downtown area has a disproportionately high percentage of impervious surfaces in comparison to the outskirts of the city, with little existing green infrastructure (or opportunities to infiltrate). In the entire city, impervious surface covers 52 percent of the landscape, and open space covers 48 percent.

In conjunction with its history of industry and site contamination, Downtown Wilmington's high percentage of impervious surfaces make polluted stormwater discharges a serious matter. Most of the city's stormwater is conducted into a combined sewer system (CSS). Still, stormwater that falls in some areas is not directed into a sewershed and is instead directly discharged into the Brandywine Creek and Christina River untreated. During heavy wet weather conditions, stormwater directed into the CSS occasionally overwhelms the system and causes combined sewer overflows (CSOs) into the bodies of water.



CSO events occur in wet weather conditions when stormwater and raw sewage overwhelm the combined sewer system and are released directly into water bodies, rather than being treated at a wastewater treatment facility.

WATERSHED

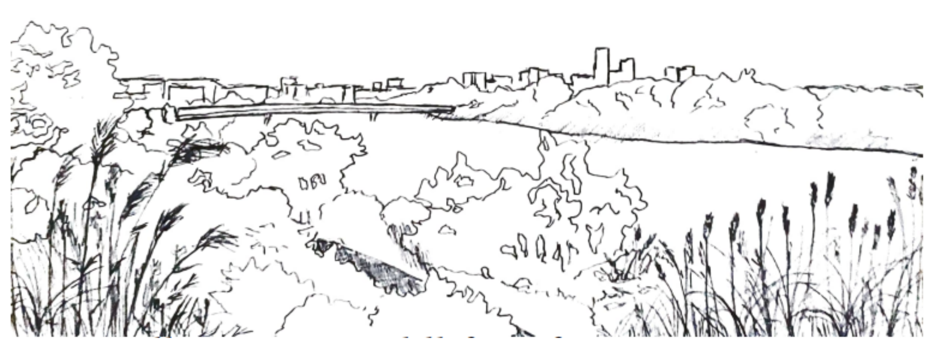
WHERE THE WATER FLOWS

The Delaware River is a major river on the Atlantic Coast of the United States, flowing from Southern New York to Southern Delaware, traversing over 300 miles through four of the nine Atlantic Coast states.

The Delaware River watershed drains an incredible 13,539 square miles of land. Wilmington is one of the largest municipalities in this watershed, meaning it has a significant influence on the overall health of the river ecosystem. Within the city, water generally flows southeast downhill through the Christina River and Brandywine Creek toward the Delaware River.

In August 1932, the City of Wilmington Board of Water Commissioners completed Hoopes Reservoir as a public works project. This has led to a drier and safer city at the expense of the local ecosystems that naturally absorb, store, and transport stormwater.

Green Street techniques restore the urbanized watershed's natural ecological function, restoring the original system's environmental integrity. By mimicking a natural ecosystem, these techniques help to infiltrate stormwater runoff on-site, reducing its displacement into the river.



City skyline over the Christina River.

IMPERVIOUS SURFACES

According to Banking on Green, "water quality becomes degraded when total impervious surface exceeds 10%" (Odefy et al., 31).
Much of the impervious surface in Wilmington is devoted to roads and parking.

A CITY OF GRAY

Wilmington's legacy of industry is manifested in the landscape, perhaps most evidently in the extremely high percentage (52%) of impervious surfaces across the urban landscape. One out of every 2 square feet is covered in road, sidewalk, driveway, or roof.

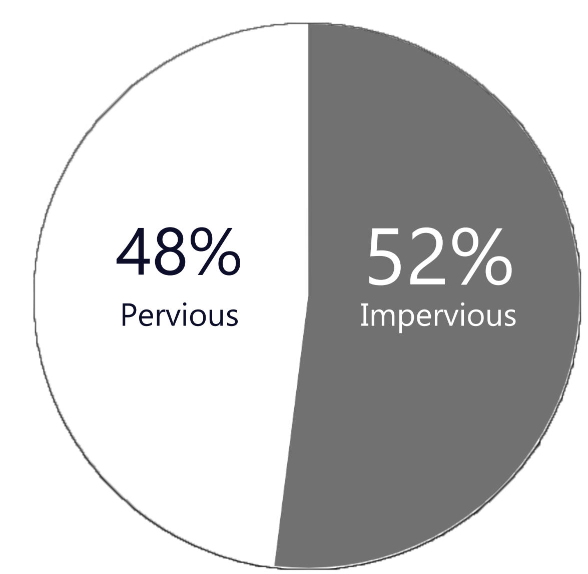
According to the Environmental Protection Agency (EPA), more than 10% of impervious cover within a watershed can damage the health of the local waterways, and over 30% is potentially irreparable.

If Wilmington is to improve its waterways' ecological vitality, the city must reduce this percentage of impervious surface. There are approximately 5,720 acres of impervious surfaces in Wilmington in Wilmington, 18% of which are roofs.

A viable technique to reduce this would be to use a constellation of Green Street components across the city to break up the asphalt street and allow water to infiltrate on-site.

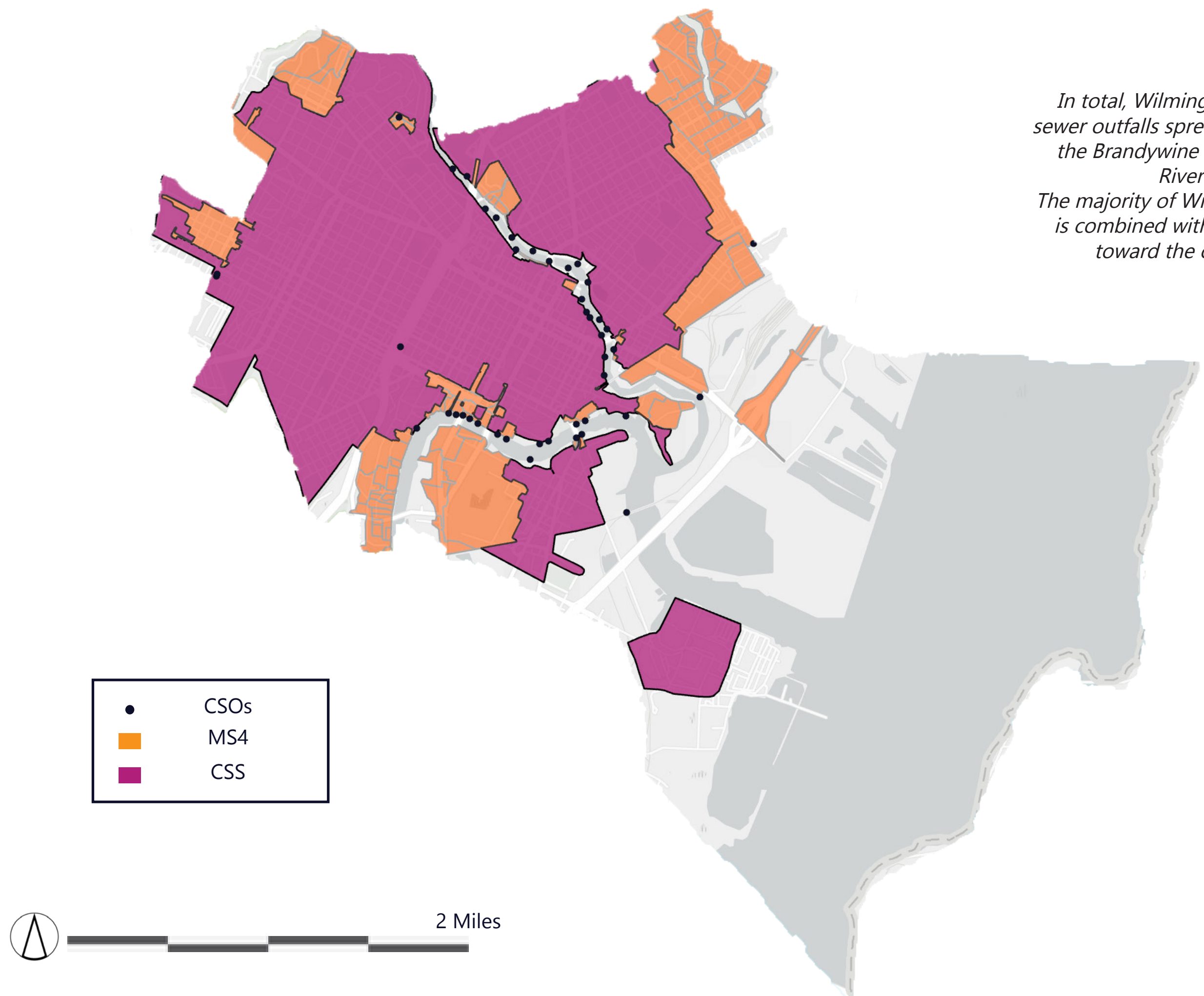
The city can reduce its total percentage of impervious surfaces by turning gray streets green.

Type of Surfaces



The City of Wilmington has 52% impervious (water resistant) surfaces and 48% pervious surfaces.

OUTFALL DRAINAGE AREAS



In total, Wilmington has 42 different sewer outfalls spread out primarily along the Brandywine Creek and Christina River's banks.
The majority of Wilmington's sewershed is combined with separated systems toward the city boundaries.

COMBINED SEWER OVERFLOWS

Wilmington has an aging combined sewer system with 40 outfall locations that release combined sewer overflows into the creek and river. To satisfy the EPA's mandate to reduce CSOs, the City's Department of Public Works developed an Enhanced Long-Term Control Plan (ELTCP) in 2003 to determine the feasibility of separating stormwater from sanitary sewer pipes during urban renewal projects. Sewer separation is traditionally the most expensive option to address CSO discharges in existing areas of a city.

While some parts of the city, such as the Wilmington Hospital area, can afford to take this route, the ELTCP showed that traditional infrastructure improvements necessary to achieve beyond 92% capture system-wide required costs well beyond the affordability of economically stressed urban areas. Additionally, the physical location and construction of these improvements would severely and irreparably damage the remaining green space of the city while causing significant disturbance to the city.

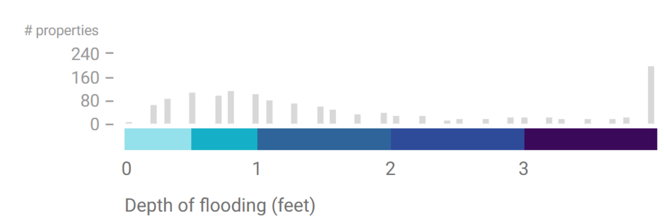
These findings provided a clear delineation of the limits of traditional infrastructure for long-term CSO control and elimination and suggested that beyond 92% capture, the city will need to identify alternative approaches to make long-term steady progress at addressing CSOs.

In cities nationwide, green infrastructure is being identified as the fundamental approach to "closing the gap" remaining after traditional infrastructure projects have been completed for CSOs. Because green infrastructure helps lessen peak discharge volumes by detaining, retaining, infiltrating, and gradually releasing stormwater after a storm's peak event, implementing Green Street strategies can help reduce CSO events without having to separate the sewers. Reducing CSOs would help Wilmington comply with the EPA's regulations and help restore the health of the Delaware River.

FLOOD RISK

BRANDYWINE CREEK FLOODING

While CSOs definitely contribute to Wilmington's flooding issues, they aren't the only problem. Floods occur naturally and can happen almost anywhere, but river and coastal flooding are two of the most common types. In this case the Brandywine Creek sometimes overtops its banks during heavy rainfall events, flooding nearby neighborhoods and putting many residents, businesses, and properties at risk.

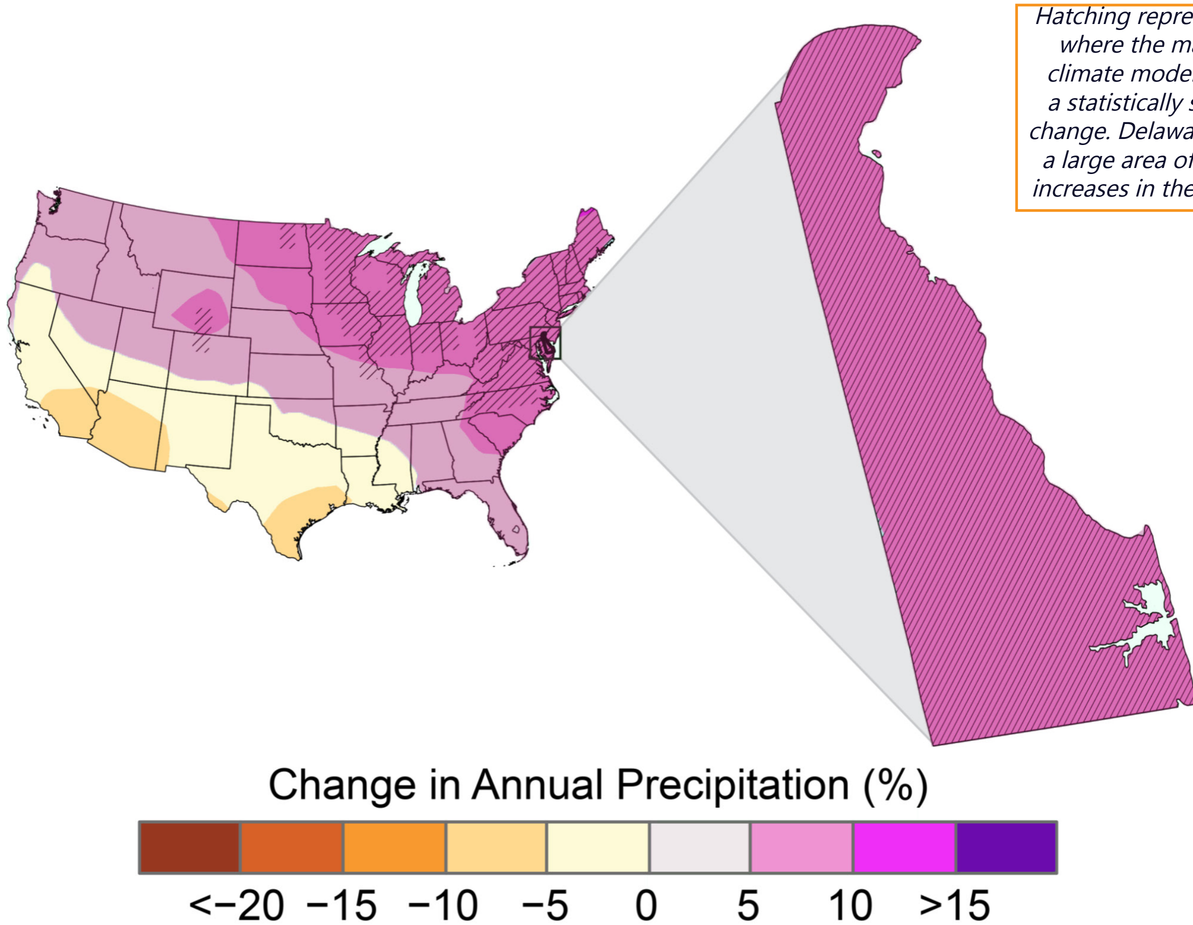


Northeast Wilmington has a hihger number of properties at risk of flood due to its proximity to the Brandywinwe Creek.

Flood Event	% chance of flooding in a given year	% chance of flooding over 30 years
100 year	1%	26%
500 year	.02%	6%

The term "flood event" is used to describe the recurrence interval of floods. The 100-year recurrence interval means that a flood of that magnitude has a one percent chance of occurring in any given year. In other words, the chances that a river will flow as high as the 100-year flood stage this year is 1 in 100.

PROJECTED ANNUAL PRECIPITATION CHANGE

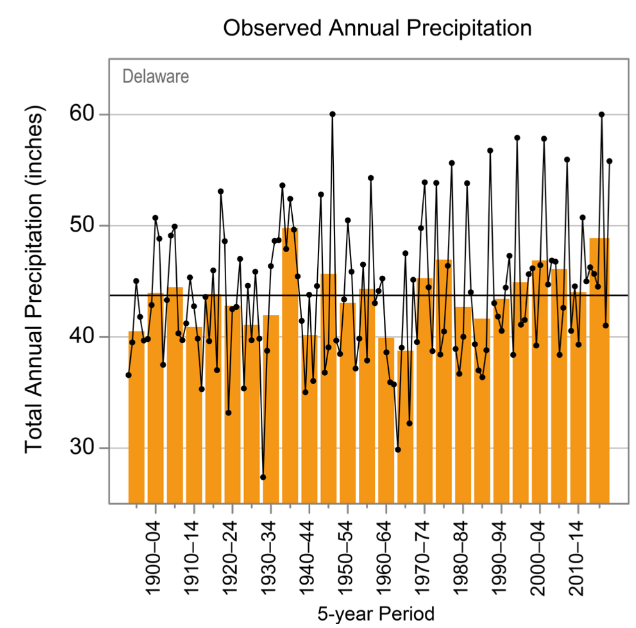


Hatching represents areas where the majority of climate models indicate a statistically significant change. Delaware is part of a large area of projected increases in the Northeast.

RAINFALL AND TEMPERATURE

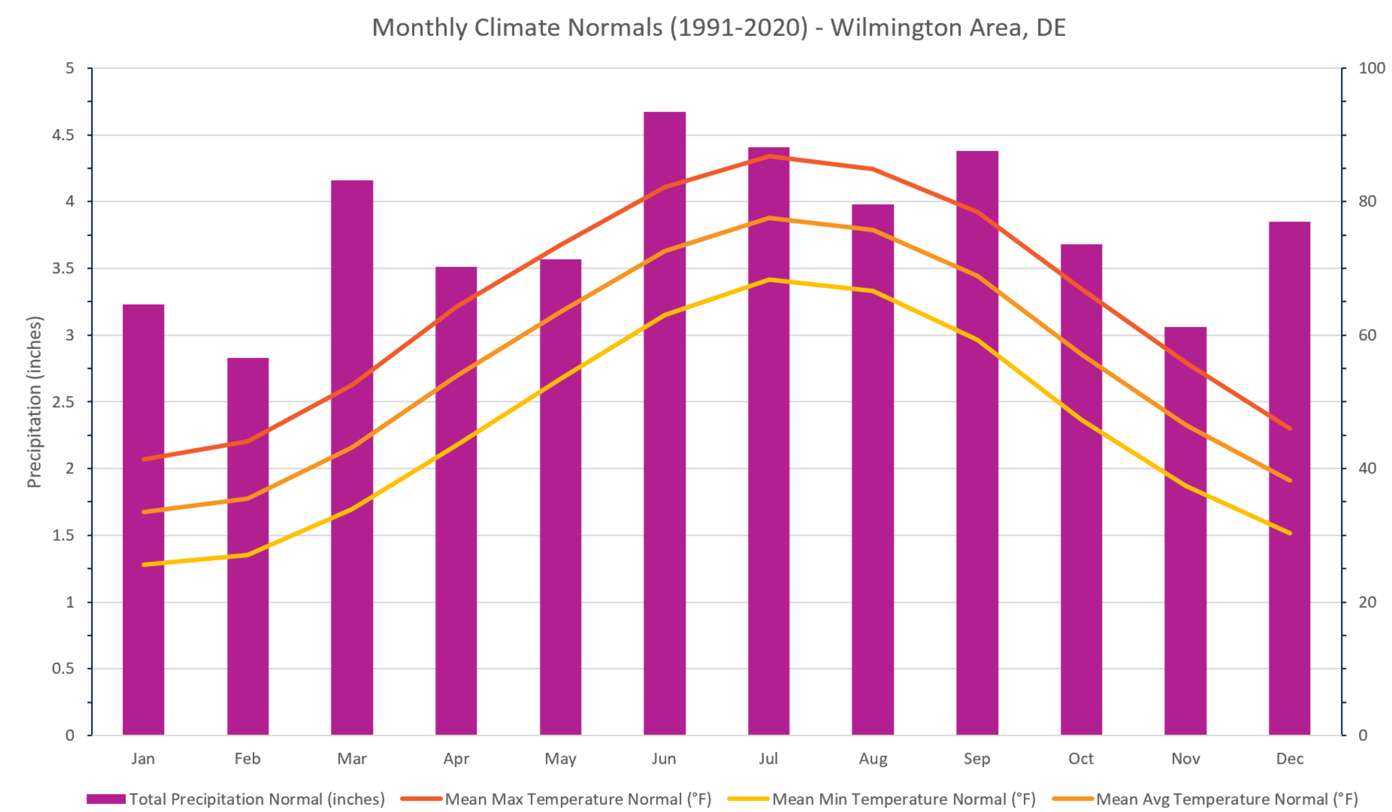
Significant temperature and precipitation fluctuations for the Northeast U.S., largely due to the release of greenhouse gas emissions, including CO2, are anticipated to destabilize our climate and lead to increased average global temperatures ("Climate Change: Basic Information"). Over the next few decades, the Northeast should expect annual mean temperatures to increase by 10 percent, producing hotter, drier summers and longer, wetter winters.

The number of extreme heat days (temperatures above 90°) are expected to double in parts of the Northeast. The region will also experience warmer winters, causing an increase in winter precipitation falling as rain and fluctuations in snowmelt, affecting peak river flow times (U.S. DOT). Scientists estimate that average precipitation will decrease in the fall and increase in the winter, yet annual precipitation will see a net increase of 10 to 15 percent. Storm events are expected to increase by 6 to 7 percent, arriving in heavier, brief pulses of rain (U.S. DOT).

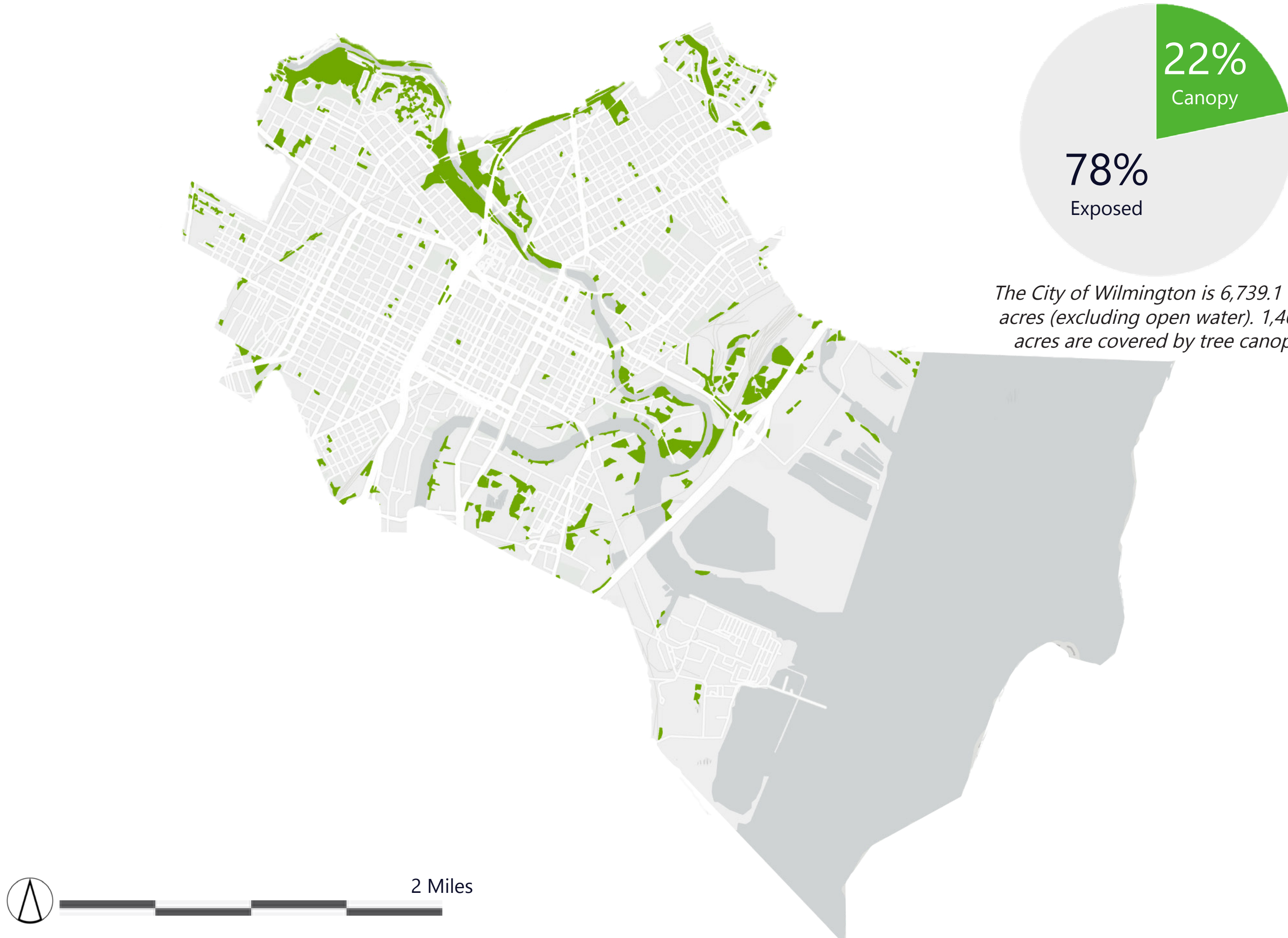


Observed total annual precipitation for Delaware from 1895 to 2020. The horizontal black lines show the long-term (entire period) average (43.7 inches).

Larger variations in temperatures and precipitation patterns mean Northeast communities will have to be more resilient in an increasingly unpredictable climate. Wilmington should plan for an increase of four inches of annual rainfall over the next few decades as increased precipitation will only further contribute to stormwater pollution and strain Wilmington's combined sewer system, intensifying the issue of CSOs without appropriate intervention.



URBAN TREE CANOPY



The City of Wilmington is 6,739.1 total acres (excluding open water). 1,463.7 acres are covered by tree canopy.

NATURE'S UMBRELLA

A tree intercepts rainfall with the surface area of its leaves, absorbing some and transpiring the rest. Trees also pump water directly from the ground into the air in a process known as transpiration. This process helps break down organic chemicals present in runoff as it rehydrates the atmosphere.

Tree canopy cover is closely correlated with watershed health. At least 45% tree cover is recommended to keep the ecology of local streams and rivers intact. Not all neighborhoods in the city have an equal density of tree canopy cover. Low population density neighborhoods such as the ones near the city outskirts have much higher percentages of tree canopy cover, while neighborhoods in the dense urban core barely have any tree canopy cover.

Incorporating trees into the street infrastructure is an important strategy for increasing the overall tree canopy on public land, granting access to nature to those residents who need it most.

The surface area of leaves intercepts, absorbs, and slows down rainfall before it hits the ground, helping to reduce the flow of water draining toward the CSS.

URBAN HEAT ISLAND EFFECT

The anticipated doubling of days with extreme heat in the Northeast U.S. could have severe consequences for Wilmington. Wilmington experiences the urban heat island effect; the phenomenon of higher temperatures in cities caused by a concentration of darker, heat-trapping surfaces and little vegetative cover compared to rural areas.

Locations covered in "barren, impermeable surfaces can reach 190°F; more natural vegetated surfaces might only reach 70°F" (Gartland, 15). During high-temperature days, this can mean the difference between a hot summer day and a public health emergency, as in Western Europe, during a 2003 heatwave, when the heat-index value was significantly greater downtown compared to surrounding rural areas. The E.U. estimates that 70,000 people died due to this event.

As climate and cities warm, demand for air conditioning during sweltering days will inevitably contribute to a strained electrical grid, leading to situations similar to the 2003 blackout, when over 55 million residents across the northeastern United States lost power for days due to increased demand for urban cooling (Stone, 68). Increased storm events and temperatures are unavoidable, but cities can take precautionary measures to help lessen their effects before disaster strikes. Solutions include expanding urban forests and other vegetative covers, which cool cities through shade and evapotranspiration, and creating more spaces for water to infiltrate and evapotranspire, further cooling surfaces (Gartland, 51).

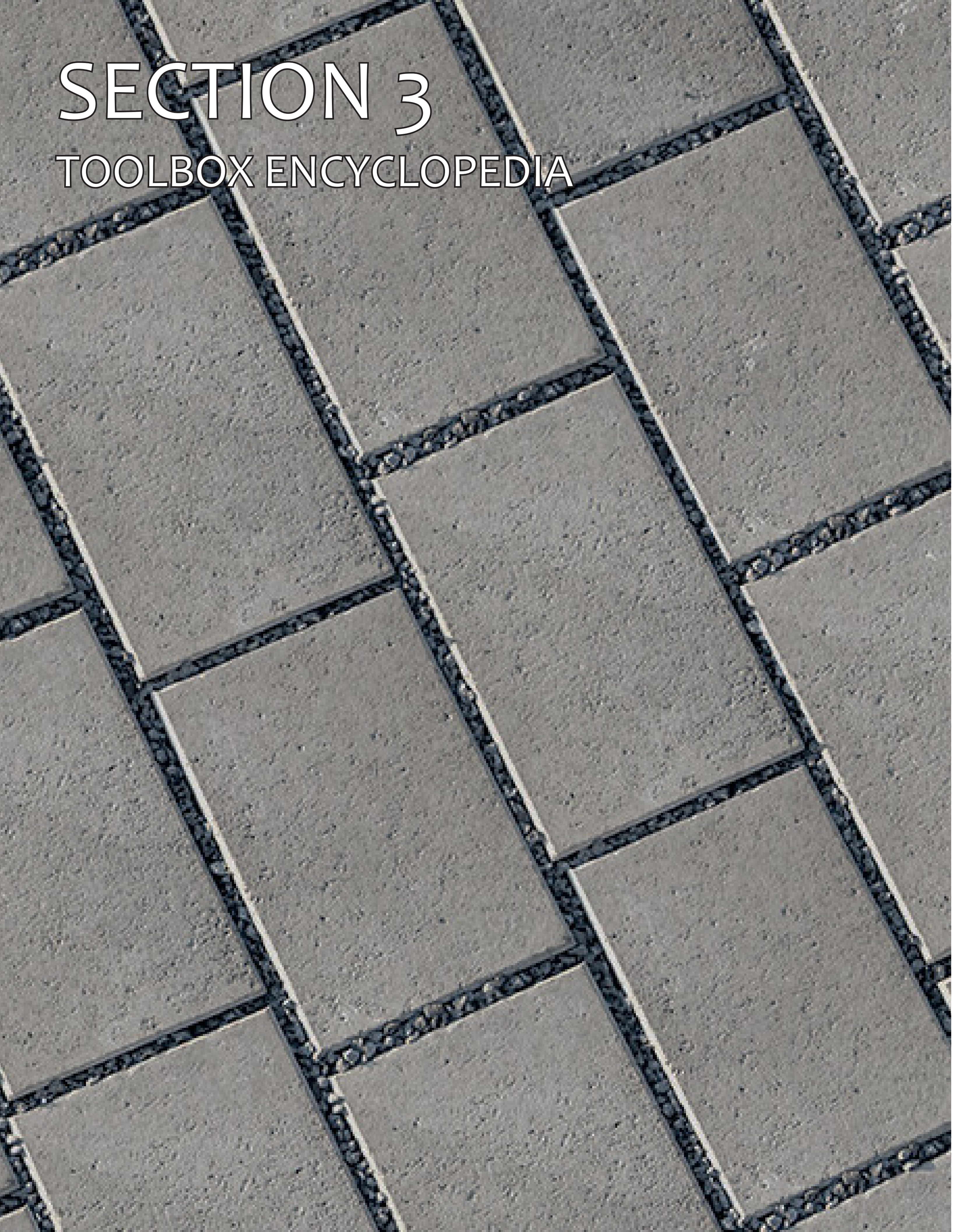
SO WHY GREEN STREETS?

Because green infrastructure helps reduce peak discharge volumes by retaining, infiltrating, and slowly releasing stormwater after the peak of a storm event, implementing Green Street strategies may reduce CSO events without necessarily having to separate the sewers. Reducing CSOs would not only help Wilmington comply with the EPA's regulations but would also help restore the health of the Delaware River.

Structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes such as forests and water bodies.

SECTION 3

TOOLBOX ENCYCLOPEDIA



TOOLBOX ENCYCLOPEDIA

WHAT IS THE TOOLBOX?

The Toolbox is a collection of recommended tools related to the three principles of Green Streets. While many relevant strategies and practices exist, the Toolbox is a compilation of those considered most effective and appropriate to Wilmington based on current research. However, as green infrastructure, complete streets, and placemaking are relatively new concepts, research and experimentation are ongoing. The successful implementation of each tool depends not only on its demonstrated efficacy but also on the site's particular ecological, social, and economic conditions.

HOW IS IT USED?

The tools within the Toolbox are divided into three categories: Green Infrastructure, Complete Streets, and Placemaking, corresponding to the three principles of Green Streets. The purpose of the Green Infrastructure tools is to capture and treat stormwater close to its source through naturalized systems such as bioswales and tree trenches. Complete Streets tools such as bike lanes emphasize the flow of traffic and issues of access, while Placemaking tools such as parklets enhance the sense of belonging of a space. Although some tools can individually or collectively address more than one Green Streets principle, each is categorized according to the principle it addresses most directly.

The Toolbox provides information on the relevant characteristics of each tool, allowing users to learn about and compare them. Each tool includes a schematic drawing, brief description, dimensions, important benefits and considerations, and a table of spatial and functional characteristics. The Toolbox is also referenced in Section 4, Applying Green Streets to Wilmington. Users seeking to implement these designs or find a suitable substitute for a tool used in these designs may refer back to the Toolbox for more detailed information.

Finding the right tool for the right place can be tricky, and in many cases there may be no one correct answer. However, it is important that, before selecting a tool for a specific street, the user properly assesses the existing conditions of the site and establishes goals for its redesign. Useful questions include:

- What is the width of the right-of-way (ROW)?
- How many lanes of traffic, and in what direction(s) do they flow?
- What is the slope of the street?
- What type(s) of land use surrounds the street? How close are buildings to the ROW?
- What is the street's speed limit and functional road classification?
- Should vehicular traffic be slowed or kept moving?
- What is the street's speed limit and functional road classification?
- Should vehicular traffic be slowed or kept moving?
- How do pedestrians, cyclists, and public transit vehicles currently move through the street? How might they be better accommodated?

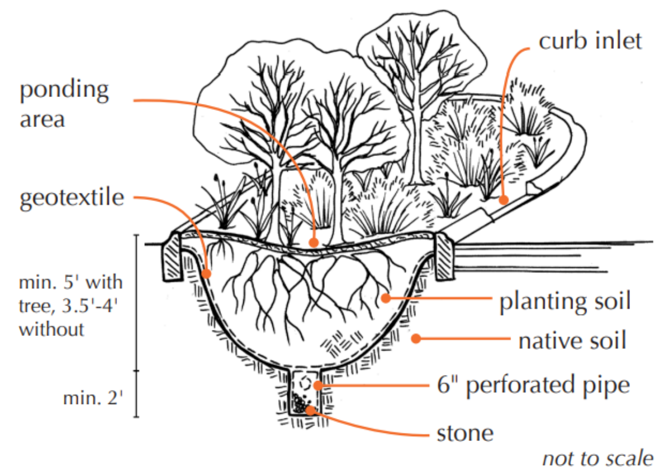
Once site assessment and goals have been conducted, the user can refer to the Toolbox to select the tool(s) most suitable for the site at hand.

BIOSWALE

Description:
A bioswale is a linear vegetated swale that channels stormwater, infiltrating and filtering it with vegetation and soils as it travels.

Benefits:
- Allows stormwater to travel and infiltrate
- Does not require energy-intensive structural walls
- Excess stormwater flows can travel to grey infrastructure system through perforated pipe
- Can be planted with a variety of wetland-tolerant vegetation

Considerations:
- Requires excavation
- Limited to slopes 6% or less
- Roadside vegetation must be wetland tolerant, hardy to salt, snow piles, and high sediment flows



Slope	Optimal Use	Dimensions	Spacing
1-6% (if greater than 5%, use check dams and dense vegetation)	Along roads, linear channels	Min. 2’ wide; min. 3.5’ deep without tree; 5’ with tree	Recommended tree spacing: 20’

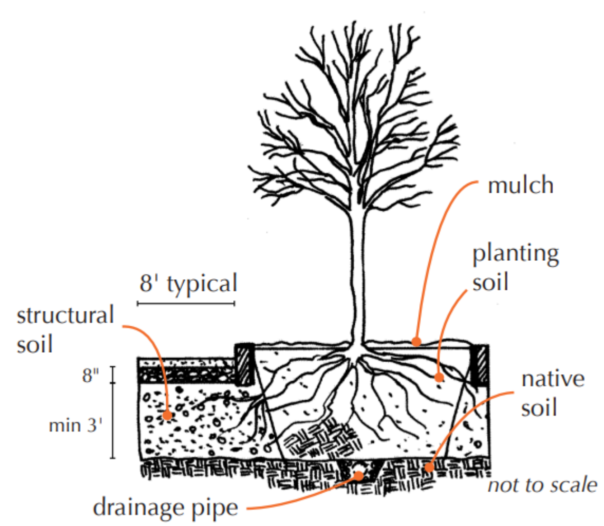
Sources: New York Department of Environmental Protection (2013)

BREAK-OUT

Description:
Break-outs are excavated areas filled with structural soil, often under sidewalks or roads. Used in combination with other green infrastructure tools such as tree trenches or stormwater planters, break-outs provide more room for tree roots to grow in tight spaces, increasing the longevity and survival rate of urban trees.

Benefits:
- Provides additional space for tree roots, improving health
- Increases amount of infiltration area by replacing compacted native soil with more porous structural soil
- Requires little maintenance after installation

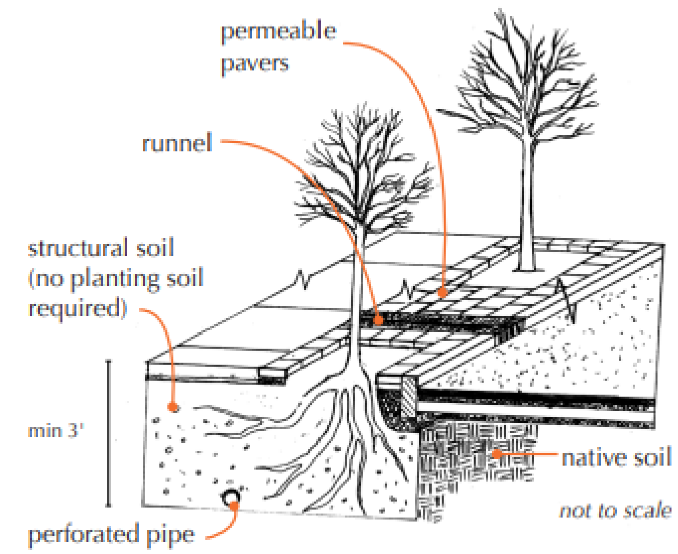
Considerations:
- Requires pavement to be ripped up and replaced for retrofits, increasing costs



Slope	Optimal Use	Dimensions	Spacing
n/a	In combination with other tools in which trees are planted	min. 3’ below paving	n/a

Sources: Bassuk et al., (2005), Bassuk et al., (1998)

COVERED TREE TRENCH



Description:
A covered tree trench is a linear system of trees connected by structural soil underground and covered with permeable pavers. Stormwater flows into the trench via inlets or runnels and through the permeable pavers, infiltrating into the soil. The continuous mass of soil combined with soil break-outs under sidewalks and streets gives roots more room, increasing vitality.

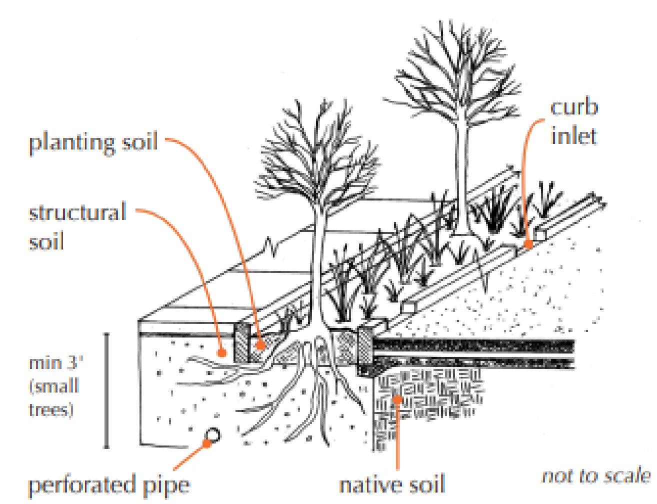
Benefits:
- Maximizes infiltration area,
- Increases life-span of trees
- Allows pedestrian access between sidewalk and road

Considerations:
- Requires considerable excavation, especially in combination with break-outs; may be expensive
- Limited to slopes less than 5%
- Sensitive to heavy compaction over root systems

Slope	Optimal Use	Dimensions	Spacing
<5%	Along roads and sidewalks, to promote pedestrian crossings	2.5’ minimum width, 3’ minimum depth	Recommended tree spacing: 20’ (varies by species)

Sources: City of Milwaukee (2013): Boston Transportation Department

OPEN TREE TRENCH



Description:
Like a covered tree trench, an open tree trench is a linear system of trees connected by structural soil underground, but it is filled with vegetation, not covered with permeable pavers. Stormwater flows into the trench via inlets and infiltrates into the soil. The continuous mass of soil in combination with soil break-outs into sidewalks and streets gives roots more room, increasing vitality.

Benefits:
- Maximizes infiltration, especially with break-outs
- Increases life-span of trees
- Allows for variety of wetland plantings

Considerations:
- Requires considerable excavation, especially in combination with break-outs; may be expensive
- Limited to slopes less than 5%
- Limits pedestrian access between sidewalk and road

Slope	Optimal Use	Dimensions	Spacing
<5%	Along roads and sidewalks to protect pedestrians and cyclists	2.5’ minimum width, 3’ minimum depth	Recommended tree spacing: 20’ (varies by species)

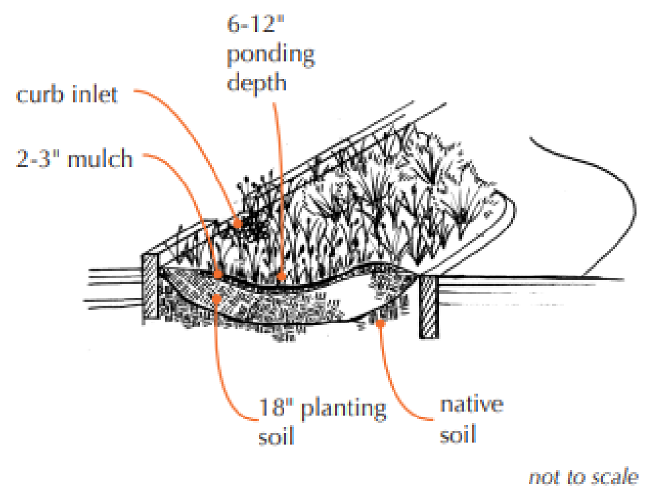
Sources: City of Milwaukee (2013); Boston Transportation Department

RAIN GARDEN

Description:
A rain garden is typically a moderately depressed, vegetated area designed to capture, pond, and gradually infiltrate stormwater within 72 hours. It is different from most other green infrastructure tools because it is often not connected to the grey infrastructure system and requires less excavation.

Benefits:
- Easy to incorporate into retrofit projects
- Can vary in size and shape
- Effective at removing pollutants
- Can double as snow storage area

Considerations:
- Because they are disconnected from the grey infrastructure system, rain gardens must either be located where soils can drain within 72 hours, or soil must be amended
- Plants must be wetland tolerant



Slope	Optimal Use	Dimensions	Spacing
>1%	To replace traditional landscaping; residential and school settings	Flexible in shape and size; ideally 18" deep and allow for 6-12" ponding depth	

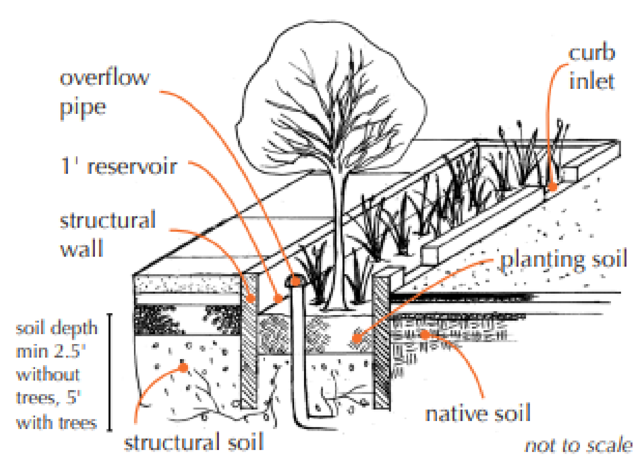
Sources: "Simple Infiltration Rain Garden"

STORMWATER PLANTER

Description:
A stormwater planter is usually a rectangular, vegetated planter, sometimes planted with trees. Its four concrete sides double as a curb and structure for the planter and allow water to pool up to 1' before overflowing into another planter or the grey infrastructure system, storing and infiltrating water over time.

Benefits:
- 1' ponding depth increases capacity during peak stormwater flows and allows for infiltration over time
- Effectively buffers pedestrians and cyclists from vehicles with curb and vegetation strip

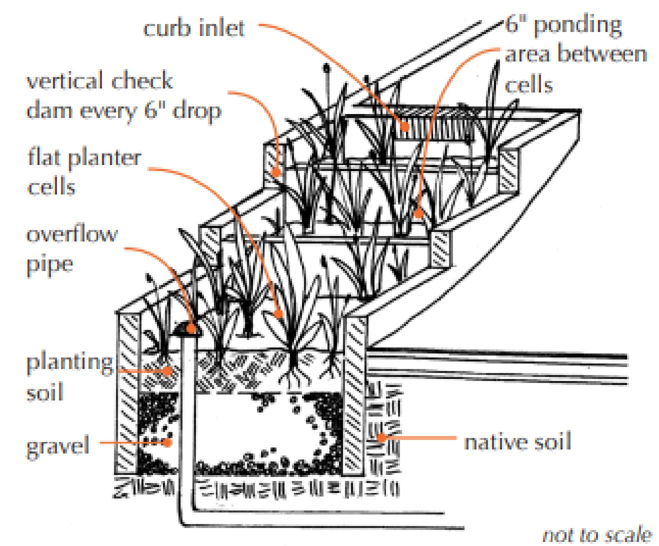
Considerations:
- Water must be able to infiltrate into the soil within 48 hours of a storm event
- If planted with trees, additional excavation for soil and break-outs may be necessary; use wetland-tolerant plants



Slope	Optimal Use	Dimensions	Spacing
<5%	Along roads and sidewalks to protect pedestrians and cyclists	Length & width vary; soil depth & width min. 2.5' without trees, 5' with trees	Spacing depend on access needs; recommended tree spacing 20' (varies)

Sources: "Section of Stormwater Planter"

STEPPED STORMWATER PLANTER



Description:
Ideal for sloped sites, stepped stormwater planters consist of walled, vegetated cells that allow stormwater to pond and infiltrate over time. For every six inch drop in elevation, a vertical check dam is placed between each level cell, allowing for overflowing water to travel downslope from cell to cell.

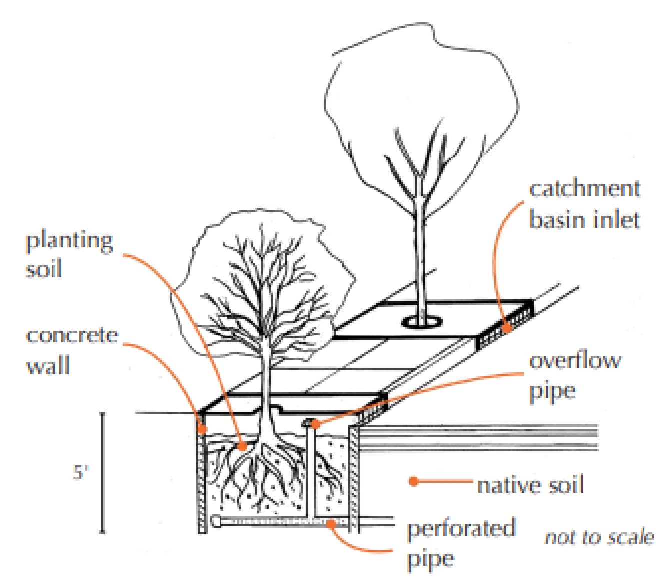
Benefits:
- Adaptable to varying slopes
- 6" ponding depth (1' in bottom cell) provides large capacity during peak flows and allows infiltration over time

Considerations:
- Water must be able to infiltrate into the soil within 48 hours of a storm event
- If planted with trees, proper examination of vertical check dam locations, additional excavation of soil, and break-outs may be necessary; use wetland-tolerant plants

Slope	Optimal Use	Dimensions	Spacing
>5%	Steeper slopes; along roads and sidewalks, to protect pedestrians and cyclists	Length & width vary; soil depth & width min. 2.5' without trees, 5' with trees	Spacing depends on access needs; recommended tree spacing: 20' (varies)

Sources: Environmental Protection Agency (2009); Milwaukee Office of Environmental Sustainability (2013)

TREE BOX FILTER



Description:
A tree box filter is a bioretention container filled with soil and planted with a tree or shrub. Stormwater runoff from roads enters the system through a catchment basin inlet, is infiltrated and treated by the soil and tree, and overflows into a perforated pipe below. It is ideal for small urban spaces and retrofits, where little hardscape can be removed. Tree box filters can have open or closed bottoms, depending on soil type and infiltration goals. Closed bottoms are ideal for contaminated sites.

Benefits:
- Highly effective at water quality treatment
- Can be used in place of or adjacent to catchment basins

Considerations:
- Costly ($3,000 per unit, $3,000 for installation) (UNH)
- Only suitable for smaller trees; use wetland-tolerant plants
- A relatively new technology; may require additional research

Slope	Optimal Use	Dimensions	Spacing
<5%	Retrofit projects; tight spaces	Can vary; suggested 5' x 5' x 5' for tight spaces; consider tree or shrub sizes	Recommended tree spacing: 20' (varies by species)

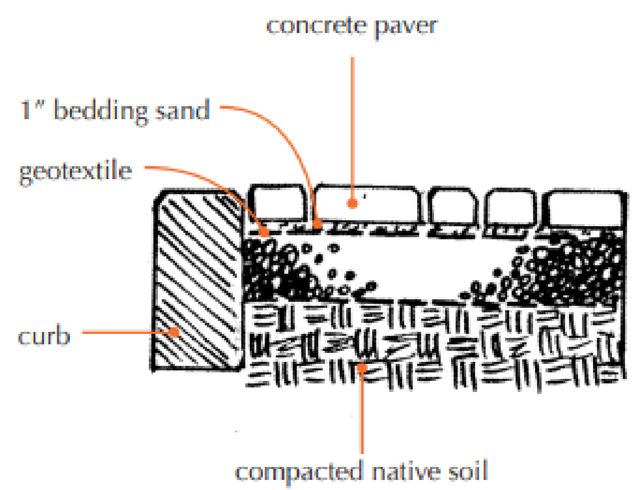
Sources: "Tree Box Filter"

PERMEABLE PAVERS

Description:
Permeable pavers are any type of paver laid on sand and gravel that allows runoff to flow through the pavers into an infiltration area below.

Benefits:
- Allows water to infiltrate through traditionally impervious surfaces, reducing the amount of impervious surfacewithout necessarily reducing hardscape
- Reduces ice accumulation, the need to plow and salt

Considerations:
- Periodic vacuuming of surface is required to prevent loss of permeability; sensitive to snow plowing regime
- If using in bike lanes or sidewalks, ensure material meets ADA accessibility requirements
- Not ideal for high vehicular-traffic areas
- Where infiltration is not desired, use impervious membrane



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Slope	Optimal Use	Dimensions	Spacing
<5% optimal	Sidewalks, local streets, parking lanes, parking lots, alleys	3' above water table; 2' above bedrock	n/a

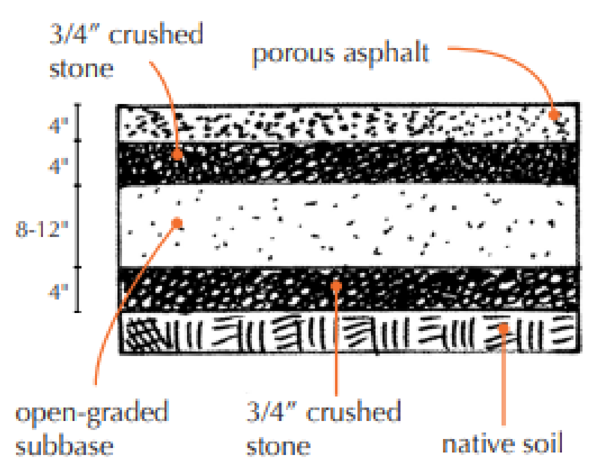
Sources: "Patio/Sidewalk/Plaza On Compacted Aggregate Base"

POROUS ASPHALT

Description:
Porous asphalt allows water to infiltrate through usually impervious hardscape, increasing infiltration and temporary storage of stormwater during peak flows.

Benefits:
- Allows water to infiltrate while maintaining hardscape
- Reduces ice accumulation, the need to plow and salt
- Blends well with traditional hardscape material

Considerations:
- Maintenance requires periodic vacuuming of surface or fills with sediment and permeability is lost
- Not ideal for high vehicular-traffic areas
- Where infiltration is not desired, use impervious membrane



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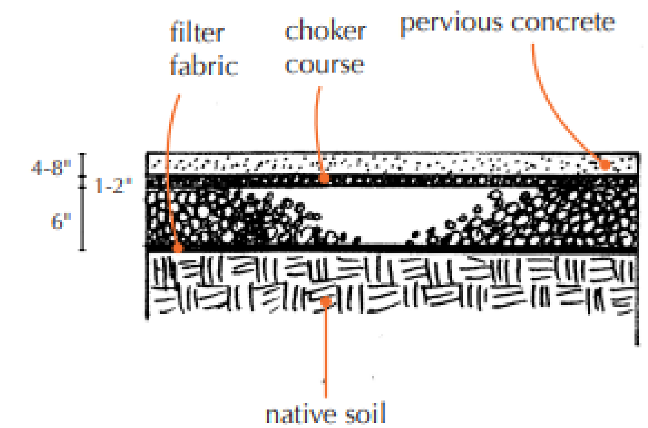
Slope	Optimal Use	Dimensions	Spacing
<5% optimal	Sidewalks, local streets, parking lanes, parking lots, alleys	3' above water table; 2' above bedrock	n/a

Sources: "Porous Asphalt Pavement for Stormwater Management"

PERVIOUS CONCRETE



not to scale

Description:
Pervious concrete allows water to infiltrate through usually impervious hardscape, increasing infiltration and temporary storage of stormwater during peak flows.

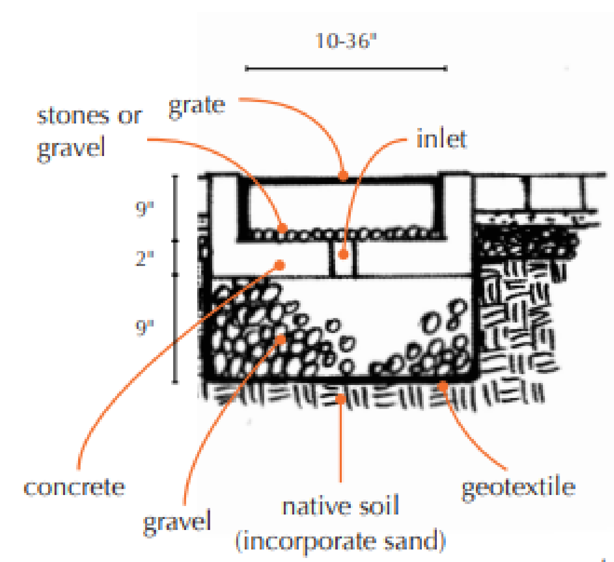
Benefits:
- Allows water to infiltrate through traditionally impervious surfaces, reducing the amount of impervious surface without necessarily reducing hardscape
- Reduces ice accumulation, the need to plow and salt
- Visually blends with existing materials

Considerations:
- Maintenance requires periodic vacuuming of surface or fills with sediment and permeability is lost
- Not ideal for high vehicular-traffic areas
- Where infiltration is not desired, use impervious membrane

Slope	Optimal Use	Dimensions	Spacing
<5% optimal	Sidewalks, local streets, parking lanes, parking lots, alleys	3' above water table; 2' above bedrock	n/a

Sources: "Pervious Concrete Pavement"

RUNNEL



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Description:
Runnels are depressed channels designed to direct stormwater to other green infrastructure tools or directly to a drain. Though they can vary in shape and materiality, runnels are commonly constructed using concrete or stone and often covered with grates or filled with stone to reduce tripping hazards.

Benefits:
- Quickly and unobtrusively directs water where desired
- Can provide aesthetic and educational interest
- Easily combined with other green infrastructure tools

Considerations:
- For ADA compliance, runnels must include an ADA compliant cover like a steel grate (also called trench drain)
- Must be slightly sloped in order to move water effectively

Slope	Optimal Use	Dimensions	Spacing
0.5-3% desired slope toward outlet	To direct stormwater to other green infrastructure tools; sidewalks and plazas	Typically 10-36" wide	n/a

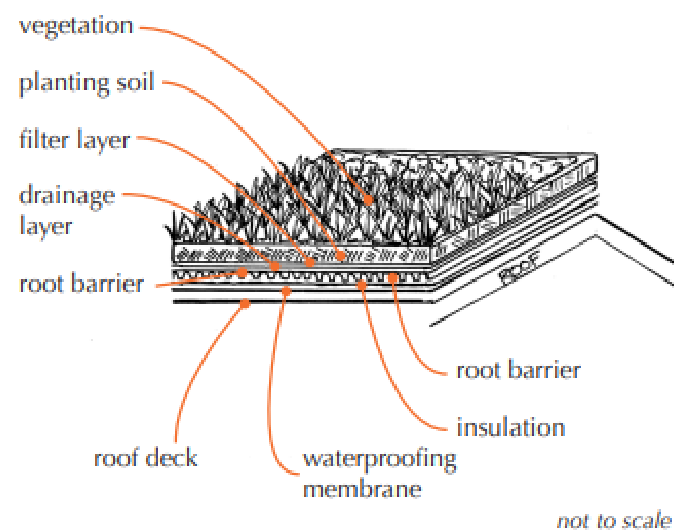
Sources: Channels and Runnels"

GREEN ROOF

Description:
Though not traditionally considered part of the streetscape, green roofs are an important green infrastructure strategy. Just like paved areas replaced with vegetation, green roofs placed on structurally sound, often flat roofs intercept and retain stormwater before it reaches the street.

Benefits:
- Intercepts and treats stormwater, improving water quality
- Regulates building temperatures, reducing energy demand for heating and cooling
- Provides wildlife habitat and pollution mitigation
- Increases lifetime of roofing material

Considerations:
- Roof must be able to bear additional weight of green roof
- Initial costs are often greater, though savings can be achieved over time through increased building efficiency



Slope	Optimal Use	Dimensions	Spacing
Roofs 0-30º	Building roofs, bus shelters, pocket park awnings	Extensive system <6″ soils; intensive system >6″ soils	n/a

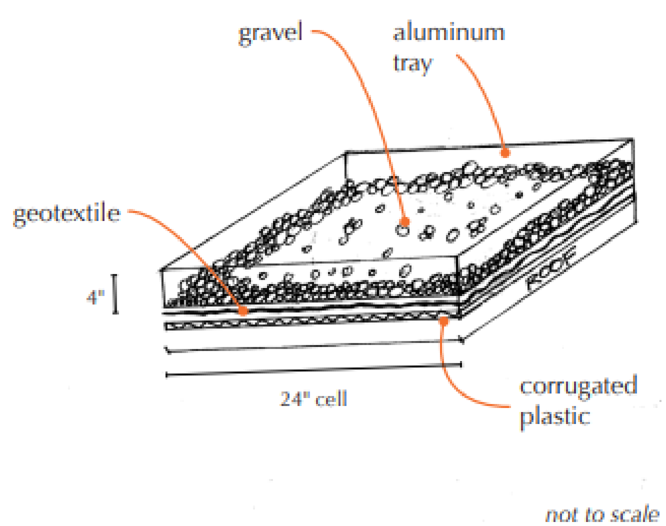
Sources: "Green Roofs/Blue Roofs"

BLUE ROOF

Description:
Blue roofs consist of non-vegetated cells that temporarily detain stormwater during peak flows and slowly release it over time into the grey infrastructure system or adjacent green infrastructure.

Benefits:
- Reduces peak stormwater flows
- Less expensive than green roofs
- Coupled with lightly colored materials, can reduce cooling demand

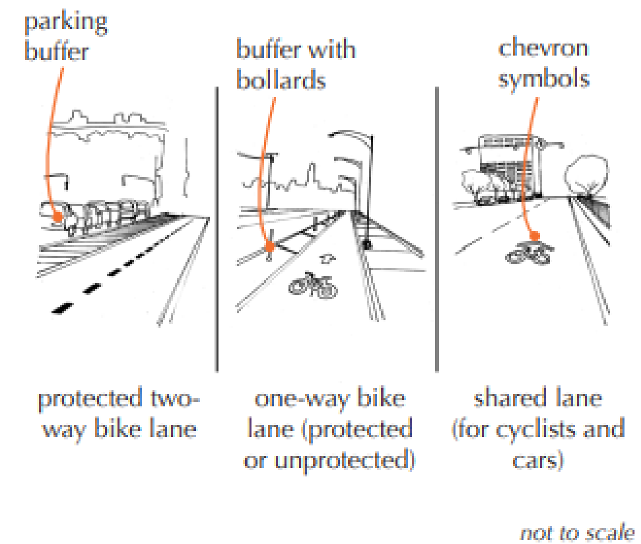
Considerations:
- Does not reduce overall stormwater runoff as effectively as green roof
- Roof must be able to bear additional weight of blue roof



Slope	Optimal Use	Dimensions	Spacing
Usually flat roofs	Building roofs	Typical cell 24″ x 24″ x 4″	n/a

Sources: "Green Roofs/Blue Roofs"

BIKE LANE



Description:
Bike lanes are roadside areas designated only for cyclists to increase safety and comfort of cycling. They can come in a variety of forms, including protected two-way bike lanes, which allow for two-way bicycle travel protected from vehicular traffic either by parking, a 2-3′ buffer, or bollards; one-way bike lanes, which often travel in the same direction as vehicular traffic on roadsides; and shared lanes, which are travel zones shared by both cyclists and motorists, designated by chevron symbols in the lane.

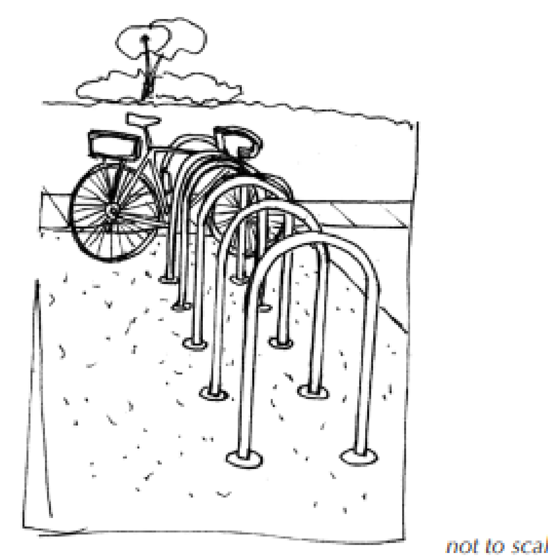
Benefits:
- Increased bicycle safety and use, especially with lanes protected by bollards, buffers, or vegetation
- Increased bicycle visibility and awareness

Considerations:
- Adding bike lanes to existing roads means lanes, parking, or sidewalks may have to be narrowed or removed
- Painted lanes increases visibility and awareness of cyclists, but increases costs

Slope	Optimal Use	Dimensions	Spacing
n/a	Along roadsides	Lanes 4-6′ wide	n/a

Sources: New York City Department of Transportation (2013), NACTO (2013)

BIKE PARKING



Description:
An important complement to bike lanes, bike parking provides safe, designated areas for cyclists to lock up their bikes. They can come in a variety of forms and can double as aesthetic streetscape elements.

Benefits:
- Promotes cycling as form of transportation, potentially decreasing dependence on motorized transportation and reducing carbon emissions and pollution
- Provides an opportunity to engage local artists in the design of bike racks and parking areas

Considerations:
- May require the displacement of vehicular parking or sidewalk space

Slope	Optimal Use	Dimensions	Spacing
n/a	Along roadsides, parklets, in place of vehicular parking	Typically accommodates a 6′ long bike	n/a

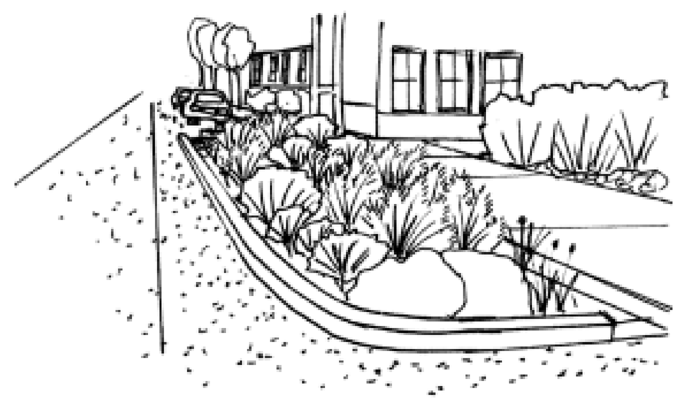
Sources: New York City Department of Transportation (2013), NACTO (2013)

BUMP OUT

Description:
Bump-outs extend the sidewalk toward the center of the street, visually and physically narrowing the roadway and providing space for pedestrians, plantings, and other street amenities. Bump-outs may be applied at intersections to increase pedestrian visibility and decrease crossing distances, mid-block to calm traffic, or at bus stops as “bus bulbs” to increase efficiency of bus travel and the safety of waiting riders.

Benefits:
- Slows traffic; increases pedestrian visibility
- May be planted and paired with green infrastructure strategy or paved

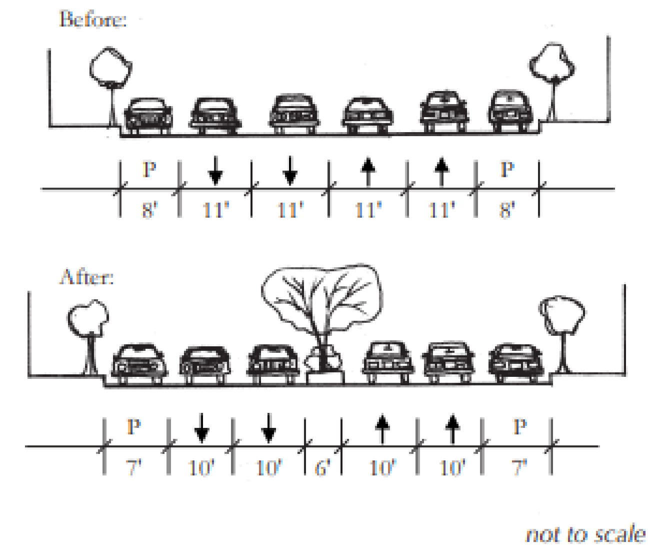
Considerations:
- Bus bulbs should be at least the length of one bus and 6-10’ wide
- When combined with plantings, maintain sight lines



Slope	Optimal Use	Dimensions	Spacing
Any slope	Mid-block; intersections; bus stops (bus bulb)	Varies by use; often size of on-street parking space or 2’ narrower	Varies

Sources: National Association of City Transportation Officials; New York City Department of Transportation (2013); NACTO (2013)

LANE DIET



Description:
A lane diet is the process of reducing lane widths while retaining the existing number of lanes. Vehicular lanes are often wider than necessary, which promotes higher speeds and allocates more right-of-way space to vehicles.

Benefits:
- Calms traffic
- Reduces street crossing widths for pedestrians and cyclists, promoting safety
- Provides space for other road uses
- Can be applied to road reconstruction, resurfacing, or restriping projects

Considerations:
- If the road has a truck or bus route, lanes must be a minimum of 11’ wide

Slope	Optimal Use	Dimensions	Spacing
n/a	Streets with lanes wider than 10’	11-12’ driving lanes for truck and bus routes, 10’ for local roads	n/a

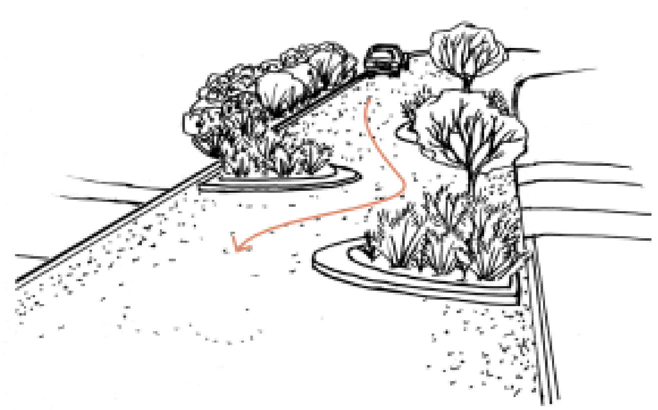
Sources: New York City Department of Transportation (2013), NACTO (2013)

CHICANE

Description:
A chicane is a traffic-calming tool that uses often vegetated bump-outs to create an “S” curve that drivers must maneuver through, slowing speeds as they approach and travel through. Chicanes also provide an opportunity to increase the amount of green infrastructure and sidewalk space available on a street.

Benefits:
- Slows traffic
- Increases opportunity for stormwater infiltration
- Increases aesthetic appeal of street

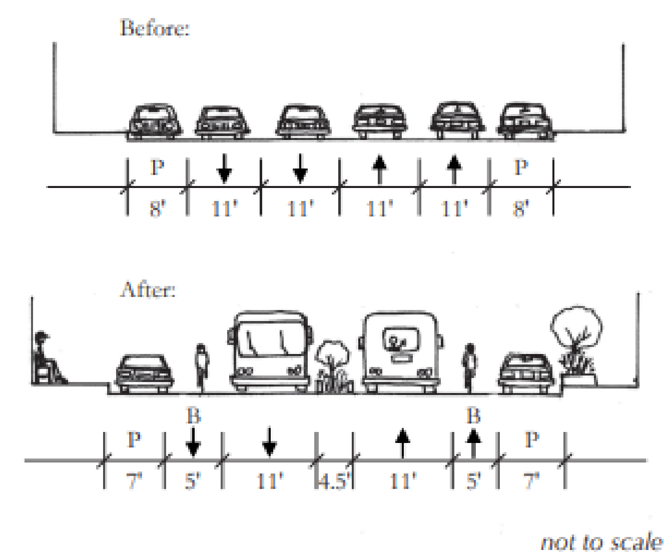
Considerations:
- Low vegetation is recommended to preserve sight lines
- Other traffic-calming tools such as speed tables or speed bumps may be a desirable alternative
- Consider cyclists and snow removal systems



Slope	Optimal Use	Dimensions	Spacing
Adaptable; consider limitations of green infrastructure tool used	To calm traffic; 1 or 2 way streets	Varies based on desired vehicular speed	Varies based on desired vehicular speed

Sources: New York City Department of Transportation (2013), NACTO (2013)

ROAD DIET



Description:
A road diet is the process of removing vehicular lanes from a right-of-way to make room for other uses such as bicycle lanes, green infrastructure, widened sidewalks, or parking.

Benefits:
- Provides space for other road uses
- Can be applied to road reconstruction, resurfacing, or restriping projects
- Can increase road safety for all users

Considerations:
- A capacity analysis should be conducted to determine if a street is a candidate for a road diet
- Only applies to streets with more than one lane traveling in a given direction
- Can be combined with lane diet (see above)

Slope	Optimal Use	Dimensions	Spacing
n/a	Multi-lane roads not at capacity	11-12’ driving lanes for truck and bus routes, 10’ for local roads	n/a

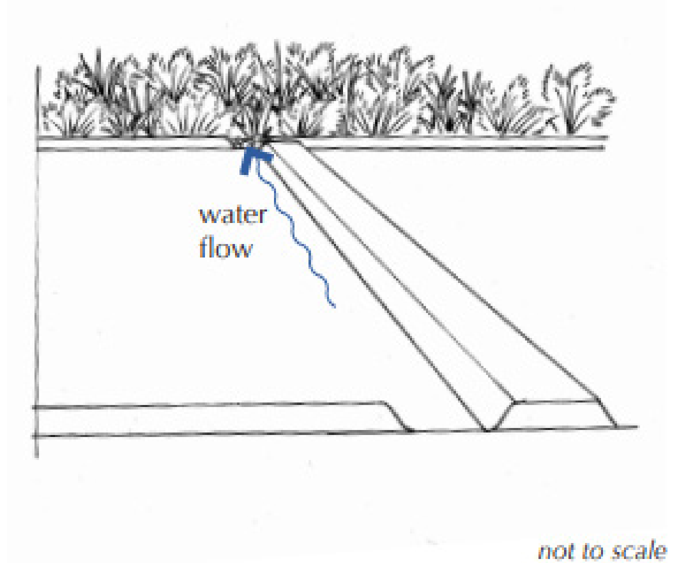
Sources: New York City Department of Transportation (2013), NACTO (2013)

SPEED BUMP / WATER BAR

Description:
A speed bump / water bar is a bump in the road that serves both to slow vehicular traffic as well as direct stormwater to adjoining green or grey infrastructure systems. It is recommended for lower-traffic roads where water needs to be channeled.

Benefits:
- Calms traffic
- Directs stormwater to adjacent green or grey infrastructure
- Good for moderately steep slopes where stormwater interception is necessary

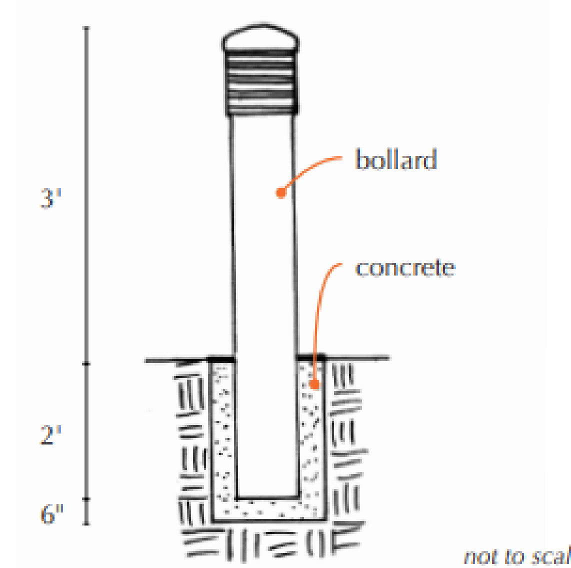
Considerations:
- For higher-traffic or commercial areas, consider using the speed table (below) as an alternative



Slope	Optimal Use	Dimensions	Spacing
n/a	Sloped low-traffic roads where green infrastructure tools will be implemented	n/a	n/a

Sources: New York City Department of Transportation (2013), NACTO (2013)

BOLLARD



Description:
A bollard can be a permanent or removable fixture in the street that provides a boundary between different modes of travel or different zones of use within a right-of-way. They can protect cyclists, pedestrians, and specific areas from vehicle use. As removable features, they can redefine the use of a space for weekends or events, or can be removed in the winter for snow removal or emergency vehicle access.

Benefits:
- Increased legibility and safety of different zones of use
- Temporary bollards can diversify the uses of a street space

Considerations:
- Can be expensive
- Requires maintenance to uninstall and reinstall removable bollards and to fix damaged bollards

Slope	Optimal Use	Dimensions	Spacing
Any	Between bike & road lanes, to block off streets, around pedestrian-only zones	Typically 3' tall, 4" diameter, with 2' encased below ground	Enough to prevent vehicular access

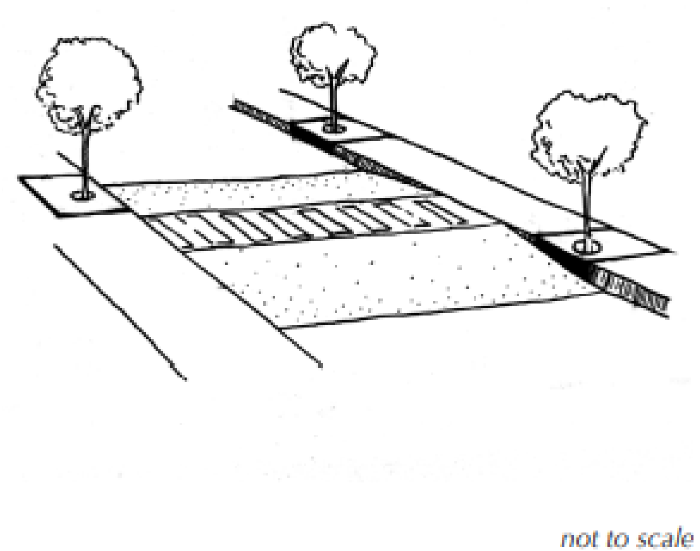
Sources:

SPEED TABLE

Description:
A speed table is an elongated speed bump, often doubling as a crosswalk, that calms traffic and increases visibility of pedestrian crossings. It provides a more comfortable crossing for vehicles than a speed bump while also effectively reducing travel speeds.

Benefits:
- Reduces travel speeds
- Provides safer crossing opportunities

Considerations:
- Consider snow removal operations
- Avoid placing at the bottom of a steep hill, where cyclists traveling at fast speeds may be endangered
- Speed tables are most effective when applied with other traffic-calming tools such as increased vegetation, chicanes, or lane diets.



Slope	Optimal Use	Dimensions	Spacing
Adaptable; avoid at bottom of steep slopes	To calm traffic; for speeds of 25-30 mph; best utilized in series	Typically 22' long, 3-6" higher than roadway	Varies

Sources: New York City Department of Transportation (2013), NACTO (2013)

PARKLET

Description:
Often installed on busier commercial streets, a parklet converts one or more on-street parking spaces to a small park open to the public. They serve to extend the pedestrian zone and encourage people to linger and interact.

Benefits:
- Temporary parklets can test the success of the feature in an area and make way for more permanent installations
- Often engages adjacent businesses, residents, and artists in maintenance and design

Considerations:
- Not suitable for all areas; consider parking restrictions, fire lanes, and bus stops as well as adjacent land use (commercial is preferred)
- May require maintenance agreements with local businesses and residents

Slope	Optimal Use	Dimensions	Spacing
Minimal preferred for seating comfort, designs can adjust to slopes	Commercial streets with high pedestrian activity; extend businesses to street	Width of parking lane, length dependent on amount of parking removed	Varies

Sources: New York City Department of Transportation (2013), NACTO (2013)

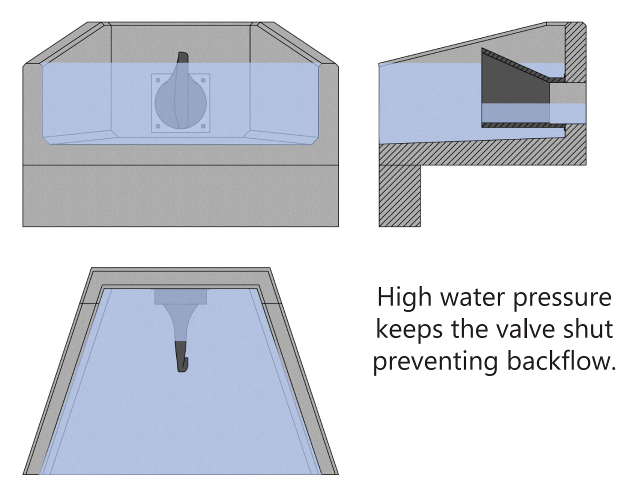
SECTION 4
APPLYING GREEN STREETS TO WILMINGTON

APPLYING GREEN STREETS

This section conveys the potential for Green Streets to be applied to culturally and commercially important right-of-ways (ROW) located within the 11th Street neighborhood area. Each ROW's unique criteria in conjunction with a set of hypothetical goals determined which Green Streets strategies were selected for each street-specific ROW design. For each ROW design, hypothetical goals were envisioned, based on each site's combined criteria, and listed in order of priority. Then, strategies from each principle of Green Streets (utilize green infrastructure, design for complete streets, and generate a sense of place) were selected based on their appropriateness to achieve each of the ROW's identified goals.

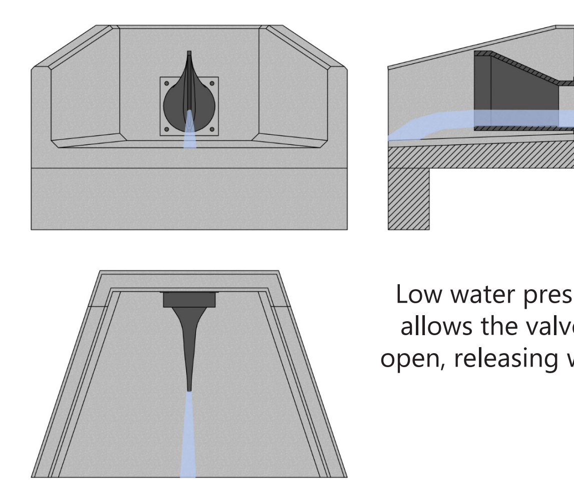
To ensure the sustainability of the implemented green infrastructure and to provide additional support to combat the flooding issue plaguing Wilmington, check valves will be placed over local sewer outfalls to prevent water backflow into the sewershed during Brandywine Creek flooding events. Check valves are one-way valves, in which the water flow can run freely one way, but if the flow turns or outside water pressure increases, the valves will close to protect the piping.

Closed Position



High water pressure keeps the valve shut preventing backflow.

Open Position

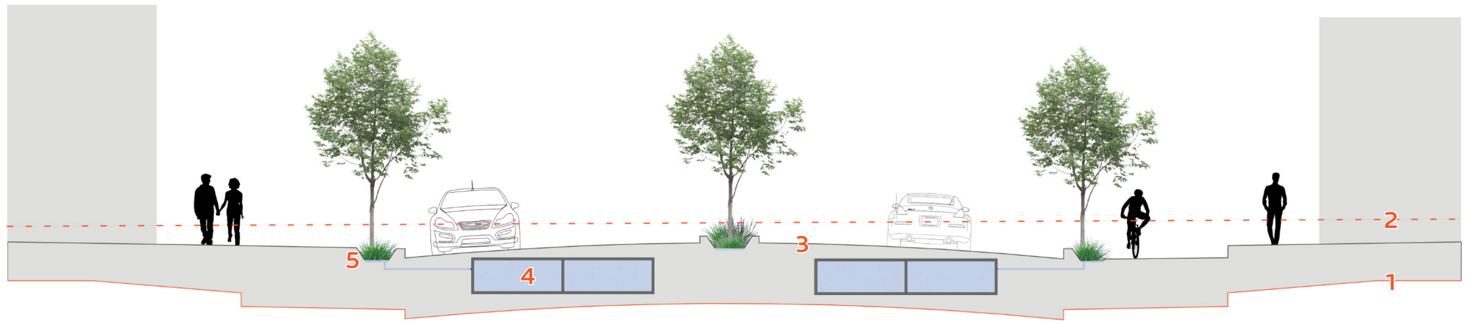


Low water pressure allows the valve to open, releasing water.

NORTHEAST BOULEVARD

The primary commercial street in northeast Wilmington, Northeast Boulevard, hosts a variety of street-level shops and acts as an important cultural center for the neighborhood. With the largest total road width in the northeast, there is ample opportunity for Green Infrastructure improvements. This design adds small interventions such as pedestrian amenities, protected bike lanes, and bioswales to improve the pedestrian experience, accommodate cyclists, and infiltrate stormwater.

In addition to adding increased green infrastructure to Northeast Boulevard, a more intensive street raising initiative can help reduce water from flowing into the neighborhood during a major flooding event. By elevating Northeast Boulevard by just a few feet, it can become a floodwater barrier, providing protection from water flowing from downstream as well as water that may overtop the Brandywine Creek banks.



1	EXISTING GRADE	3	REBUILT ELEVATED ROAD	5	BIOSWALE
2	100 YR FLOOD ELEVATION	4	STORMWATER STORAGE		

GOALS

- Maximize stormwater infiltration
- Calm traffic and improve vehicular flow
- Provide protected two-way bike route
- Protect pedestrians from traffic
- Create welcoming canopied boulevard, potentially for entrances into the city
- Prevent oncoming vehicular accidents

ADDITIONAL CONSIDERATIONS

- Suitable for gateways into the city.
- Bike lanes could be one-way on both sides.
- Visible mid-block crosswalks can be incorporated where needed.
- Parking could replace buffer where needed.
- Lanes could be removed or bottlenecked to calm traffic and provide space for parking.
- Median could be reduced and/or planted with herbaceous plants for increased visibility.
- When selecting trees, consider those that allow for clear sight lines

TOOLS

Bioswale
(page 29)

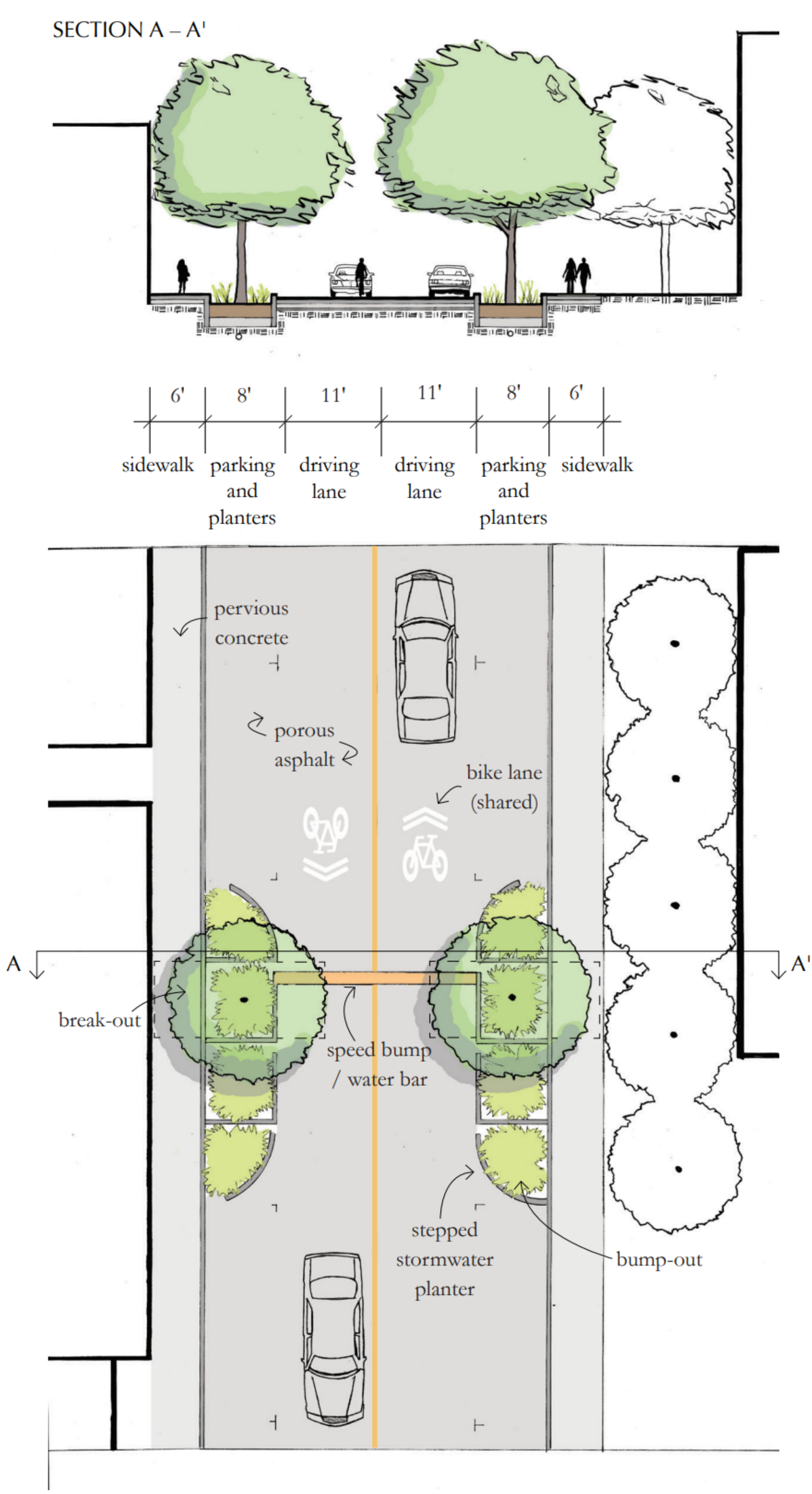
Pervious Concrete
(page 34)

Pourous Asphalt
(page 33)

Bike Lane
(page 36)

N HEALD STREET

Heald Street is a major connector from the commercialized NE Blvd to the adjacent residential neighborhoods. With the addition of a shared bike lane, vegetated bump-outs, and a speedbump/water bar, drivers are encouraged to slow down as they transition from the highway into a residential area. Bump-out stormwater planters placed at the midpoint of a street along with a speed bump that intercepts and directs stormwater on steep slopes calm traffic while maximizing stormwater infiltration.



GOALS

- Infiltrate and direct stormwater on steep slope
- Calm traffic
- Maintain most of the on-street parking for residents

TOOLS

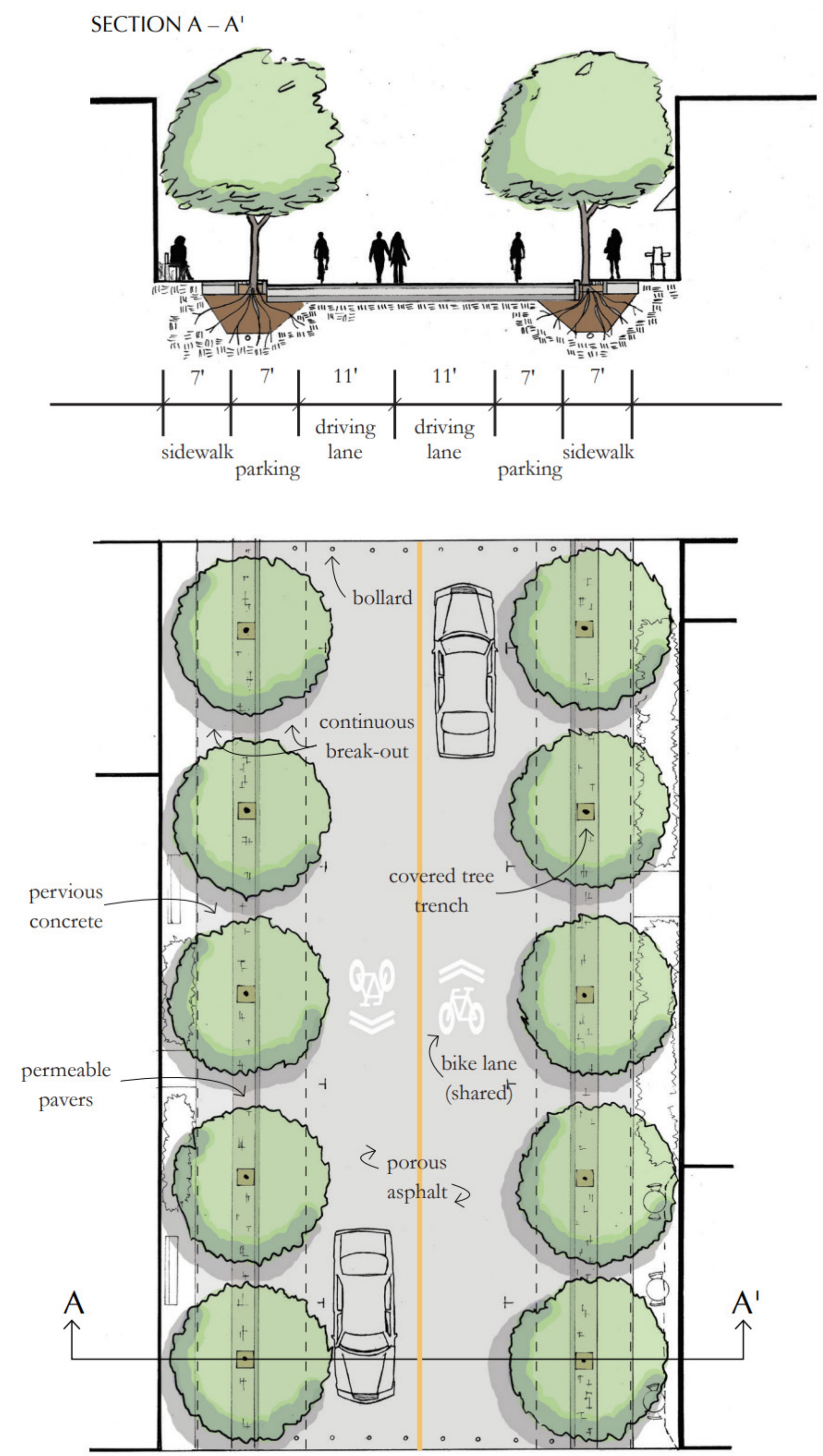
- Stepped Stormwater Planter (page 32)
- Pervious Concrete (page 34)
- Pourous Asphalt (page 33)
- Speed Bump / Water Bar (page 39)
- Bike Lane (page 36)
- Bump-Out (page 37)

ADDITIONAL CONSIDERATIONS

- If slope is 5% or less, consider replacing the stepped stormwater planter with another green infrastructure tool such as a stormwater planter.
- If ROW is wider, consider adding designated bike lanes or widening the sidewalk.
- When trees are planted in stepped stormwater planters, increase depth of soil in stormwater planters and add break-outs.

E 12TH STREET

As another primary community connector, 12th Street links surrounding communities together. There are future plans to extend this connector farther west along Brandywine Creek. This design adds space for bike lanes and creates a framed vista with a protected pedestrian corridor, which also maximizes stormwater infiltration. Using removable bollards, the street can be temporarily closed off to vehicular traffic, restricting use to pedestrians and cyclists for weekends and special events such as farmers markets or art walks. Covered tree trenches maximize stormwater infiltration.



GOALS

- Provide flexible pedestrian-only on-street weekend and event space
- Infiltrate stormwater
- Provide shade for pedestrian

TOOLS

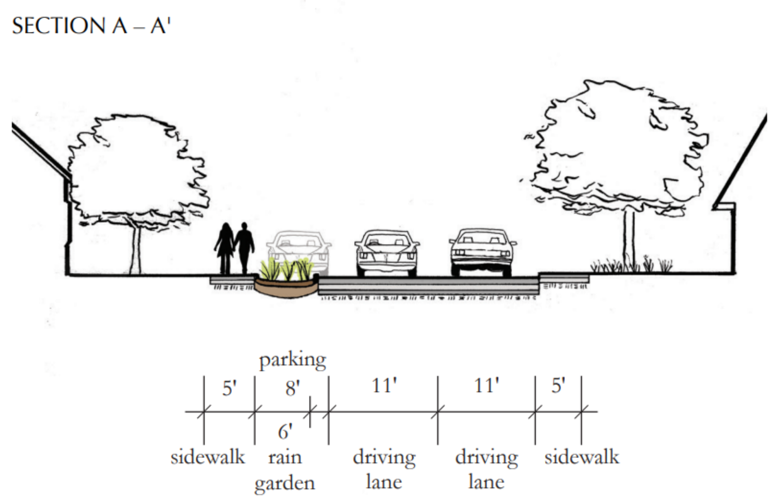
- Covered Tree Trench (page 30)
- Permeable Pavers (page 33)
- Pourous Concrete (page 34)
- Porous Asphalt (page 33)
- Break Out (page 29)
- Bike Lane (page 36)
- Bollard (page 40)

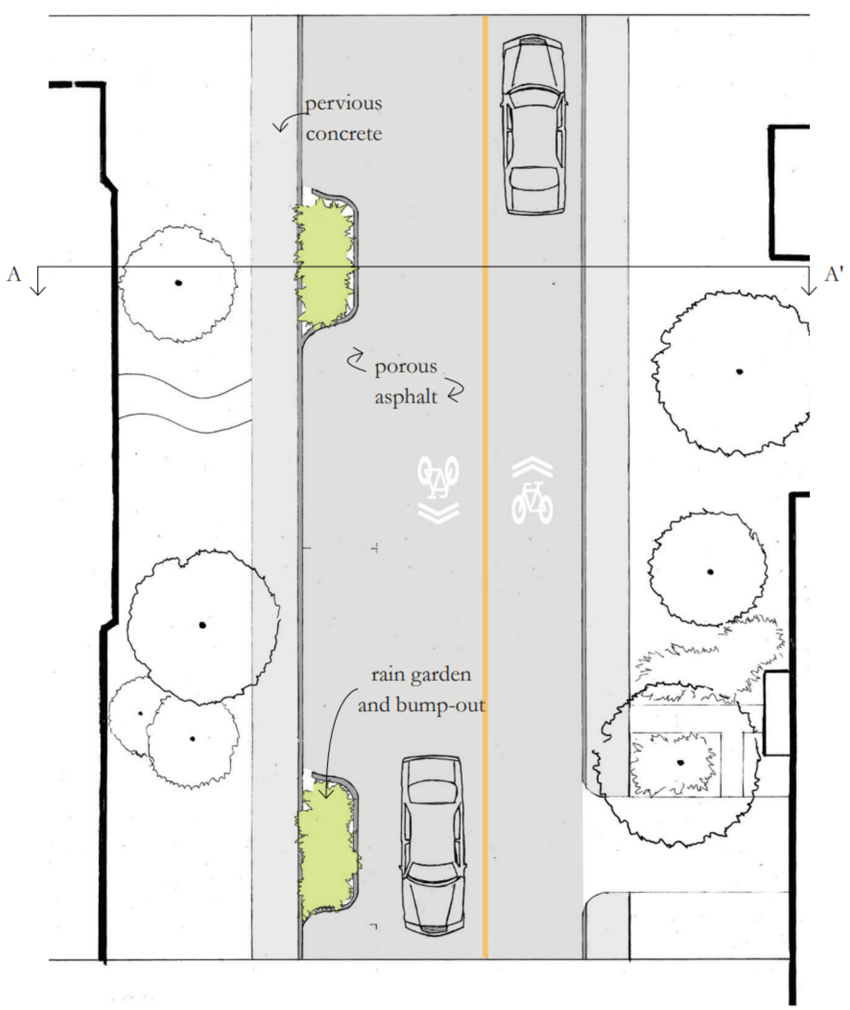
ADDITIONAL CONSIDERATIONS

- Ensure trees have enough room to grow unimpeded when buildings directly about the sidewalk.
- Flexible streets are most successful with strong community support.
- This pedestrian-friendly alternative should be prioritized in arts and commercial areas.
- On streets with slopes greater than 5%, stepped stormwater planters may be more appropriate.
- For wider streets, consider widening the sidewalk or including designated bike lanes

14TH STREET

14th Street, a narrow two-way residential street, can benefit from Green Infrastructure as well. This simple design preserves parking and adds rain garden bump-outs to enhance the neighborhood streetscape and capture stormwater runoff. Rain gardens with strategically placed inlets can provide stormwater infiltration without connecting to the existing grey infrastructure system while maintaining most on-street parking and calming traffic.





GOALS

- Retain most on-street parking
- Infiltrate stormwater without connecting to grey infrastructure system; minimal excavation
- Calm traffic
- Accommodate cyclists
- Provide community-building opportunities

TOOLS

- Rain Garden (page 31)
- Pervious Concrete (page 33)
- Porous Asphalt (page 33)
- Bump-Out (page 37)
- Bike Lane (page 36)

ADDITIONAL CONSIDERATIONS

- Rain gardens can be implemented in areas where least excavation is desired.
- When siting rain garden, consider provisions for stormwater overflow
- For slopes above 5%, consider stepped stormwater planter.
- If road is wider, bump-outs may be placed on both sides of the road.
- Also consider including designated bike lanes.
- Encourage neighboring residents to volunteer to help maintain bioswales and to install additional green infrastructure on their own properties.

CONCLUSION

WHY GREEN STREETS IN WILMINGTON?

Northeast Wilmington has its fair share of obstacles. Excess stormwater runoff, CSOs, and riverine flooding are causing degradation of Northeast Wilmington communities. In addition, substantial impervious cover and disproportionately little open space and tree cover are concentrated within this area. These residents need more access to open space and a greener, healthier environment. It is anticipated that climate change will only add to these issues: increased precipitation and warming will increase stormwater pollution and CSOs; impervious surfaces will get hotter, exponentially contributing to the urban heat island effect; fossil-fuel independence and alternative transportation will become more critical; less affluent people will be the first to be subject to environmental injustices. Green Streets are designed to treat stormwater at its source and to create more vibrant and livable communities. Green Streets in Wilmington have the potential to begin the process of addressing the interconnected complexities of these issues.

WILMINGTON'S FUTURE STREETSCAPES

Wilmington's streets were created well before the automobile, some wide enough to accommodate horses and carriages. Most of the tracks were paved over, leaving the city with wide, paved streets covered in impervious surfaces, transforming the city into the thriving industrial center it later became. Now, over one hundred years later, those same streets have the potential to transform the city again, but this time serving to bring Wilmington into a brighter future.

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As awareness of green and grey infrastructure has grown, many cities around the country are implementing these systems in urban environments. This project is intended to inspire and inform City of Wilmington officials and community members alike about the benefits of green and grey infrastructure, primarily Green Streets, and how they might serve as a preliminary set of design guidelines to transform the 11th Street Bridge neighborhood, Wilmington, and beyond into more ecologically, socially, and economically positive spaces.

Special thanks to Jules Bruck and Andrew Hayes.