PROMOTING GREEN STREETS

A recipe for integrating water and transportation infrastructure investment



river NETWORK
connecting people · saving rivers

Hawkins Partners, Inc.
landscape architects

JULY 2016

MISSION

River Network empowers and unites people and communities to protect and restore rivers and other waters that sustain all life. We envision a future of clean and ample water for people and nature, where local caretakers are well-equipped, effective and courageous champions for our rivers. Our three strategies for focused investment are strong champions, clean water, and ample water.

LONGER TERM GREEN STREET VISION

As a best practice for achieving clean water, addressing unnatural and damaging streamflows, and investing in many other community benefits, River Network envisions a time when all cities systematically consider green street features whenever changes to the right-of-way are proposed or transportation capital improvement plans are being developed.

PROJECT PARTNERS

River Network greatly appreciates the support of the Surdna Foundation which made this project possible. In addition, the following organizations and individuals helped in numerous ways:

- Smart Growth America teamed up with River Network to develop the project concept and its application to mid-sized cities.
- Mekayle Houghton and Paul Sloan with Cumberland River Compact provided significant background, support and guidance at several stages of the project.
- Tipton Fowlkes and Kim Hawkins with Hawkins Partners, Inc. were the primary consultants who performed the analysis in Nashville's Boscobel neighborhood and provided graphics, cost data and strategic thinking to the overall project.
- Rebecca Dohn with Metro Water Services in Nashville provided valuable context, support and encouragement to the project.
- Ron Taylor with Clean Water Nashville provided information and engineering expertise from CDM Smith to the project.

Graphics and editing support provided by Riddle Design Co. and Becca Marcott with River Network. Katherine Baer and April Ingle with River Network provided strategic contributions and project support.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Purpose

To address complementary municipal goals of improved water quality and restored natural hydrology, this project focused on the development of a simple and logical methodology to promote street-based stormwater management. This methodology is guided by larger cities' analysis of and commitment to green street strategies. Cities such as Philadelphia, Boston, Chicago and New York have made intentional commitments to green street strategies to reduce stormwater runoff that contributes to combined sewer overflows.

River Network worked with Hawkins Partners, Inc. (project team) to develop a green streets methodology for mid-sized cities that may not have the same resources as the larger cities that have embraced green streets. River Network's approach ***(a)*** demonstrates a clear connection between stormwater runoff and the road system, ***(b)*** involves neighborhood, utility and local official guidance, and ***(c)*** connects green streets to established local priorities.

Analysis

River Network focused its attention on promoting green streets in mid-sized cities to take advantage of and disseminate the lessons learned from the larger cities. In particular, River Network honed in on the calculation of percent of impervious cover represented by the road system as a key factor in persuading municipalities to invest in green street strategies.

River Network chose Nashville to develop and test our methodology because of the city's commitment to green infrastructure, open space and water quality improvements in the Cumberland River. A 2010 flood caused great human and property losses throughout the city, and it has been the catalyst for recent commitment to and investment in greener solutions. In addition, Nashville was a good case study because of the city's experience with several successful green street projects and the federal mandate to reduce all combined sewer overflows into the Cumberland River.

The Boscobel neighborhood (and combined sewer basin) in East Nashville was chosen as the focus area due to its relatively small size compared to other Nashville basins, allowing for a quicker analysis. Further, this neighborhood represents a typical mid-20th century suburb with combined sewer and stormwater infrastructure. It lies close to the downtown core, is racially and socio-economically diverse, and is experiencing a revitalization as families and young professionals begin to view denser urban living as a desirable counter-point to planned suburban neighborhoods and long commutes.

The objectives of this project were to:

1. Calculate the stormwater that runs off the road network in combined sewer areas
2. Determine how much stormwater could be captured by strategically placing green street features
3. Discuss analysis with local officials and interested local parties
4. Share the process with other interested mid-sized cities

River Network worked with city officials, local organizations, a landscape architecture firm and an engineer to frame the analysis.

Lessons learned

From the experience in Nashville, River Network learned the following lessons that can be applied in other mid-sized cities:

Choice of neighborhood is important

To make a good case for green streets as an integral part of the municipal stormwater management system, the pilot neighborhood must demonstrate key criteria for success: manageable size, high percentage of impervious cover in road system, community support, sufficiently wide streets and adequately draining soils.

Need to involve neighbors in analysis of options

Residents of the neighborhood must be involved in several steps of the analysis and siting of the green street features. They will be helpful in understanding patterns of use and traffic in the neighborhood, and their support will also be critical to the replicability in other areas of the city or the watershed.

Connect different city departments

Promotion of green street strategies inherently requires communication among several municipal departments and functions (primarily stormwater management and transportation), but also wastewater management (if the systems are combined or leaky), water supply, bike and pedestrian staff, transit staff and the sustainability office (if one exists). A green street effort can open new or underutilized lines of communication that can benefit the city in additional areas.

Tradeoff and cost savings with gray infrastructure not a given

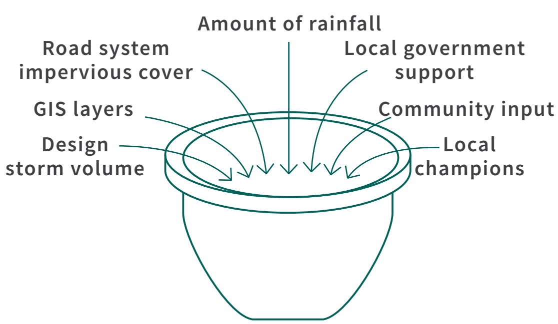
While a green street analysis may demonstrate the opportunity to capture and infiltrate a substantial volume of stormwater runoff, the municipality may be unwilling to reduce or change any of its intended investment in gray infrastructure because of the challenges in measuring and guaranteeing the same amount of capture and retention with green street elements.

GREEN STREETS RECIPE

TEST KITCHEN NOTES: *It is important to note, that soliciting input and feedback from the neighborhoods, the local agency staff and the city leadership early and often is critical to the success of this effort. In many ways, local advice and support can trump any other criteria used in the suitability analysis stage.*

INGREDIENTS

- Average local rainfall–monthly, seasonal or annual averages
- GIS layers–impervious road cover, tax lots, topography, soils (as detailed as possible), public lands, schools, etc.
- Amount of impervious cover associated with road system (can be calculated from above)
- Design storm volume
- Local government interest in and support of green infrastructure
- Community interest and input
- Local champions for green infrastructure, Complete Streets and/or Safe Routes to School



STEPS

1. Discuss project with many people in city.
2. Choose an appropriate focus area–ideally this will be a particular drainage, historic watershed or sewershed. Solicit community and local government input.
3. Calculate the impervious areas associated with roads and alleys.
4. Calculate the volume of water that runs off those impervious areas every year (seasonally or monthly if you can get more specific).
5. Tailor our suitability criteria to your area. Solicit community and local government input.
6. Apply the suitability criteria to the test area to determine which roads are best suited for green street elements.
7. Select a few green street elements that will work best along roads in the selected location. Design standardized green street elements as units that can be placed along the most suitable roads and alleys. Solicit community and local government input.

8a. Estimate the amount of runoff that can be reasonably handled by each of those units.

8b. Estimate the cost of designing and constructing each of those element units.*

9. Place the units in strategic locations, maximizing runoff capture and infiltration. Solicit community and local government input.
10. Develop a master plan that summarizes all the ideal and potential locations.
11. Estimate the total potential runoff captured under a few scenarios.
12. Estimate total cost.
13. Promote the strategy to city leadership.

*Maintenance costs will also need to be part of the discussion with city leadership.

INTRODUCTION

The stormwater that hits our streets, sidewalks and alleys in every city in the U.S. carries with it many pollutants and significant erosive energy as it searches for its original path that has been buried beneath the asphalt.

Many cities around the country are turning their streets green, for aesthetic as well as functional reasons. The Complete Streets[1] movement embraces trees and vegetation as part of the pedestrian and biking makeover encouraged for health and safety reasons. However, their laudable efforts often do not take advantage of the concurrent opportunity for better management of stormwater.

Increasing numbers of cities have decided to focus significant attention and resources on retrofitting their rights-of-way with green infrastructure to manage the stormwater running off the roadways[2]. These municipalities have recognized that "green streets" are a particularly promising opportunity because road systems represent a significant percentage, sometimes the greatest percentage, of the overall impervious cover in a city. For example, in Philadelphia, streets represent 38% of the total impervious cover[3]. Green streets can also address multiple municipal goals simultaneously, for example, stormwater management, urban revitalization, air quality, reduction of heat island effect, increased safety for walking and biking, to name a few.

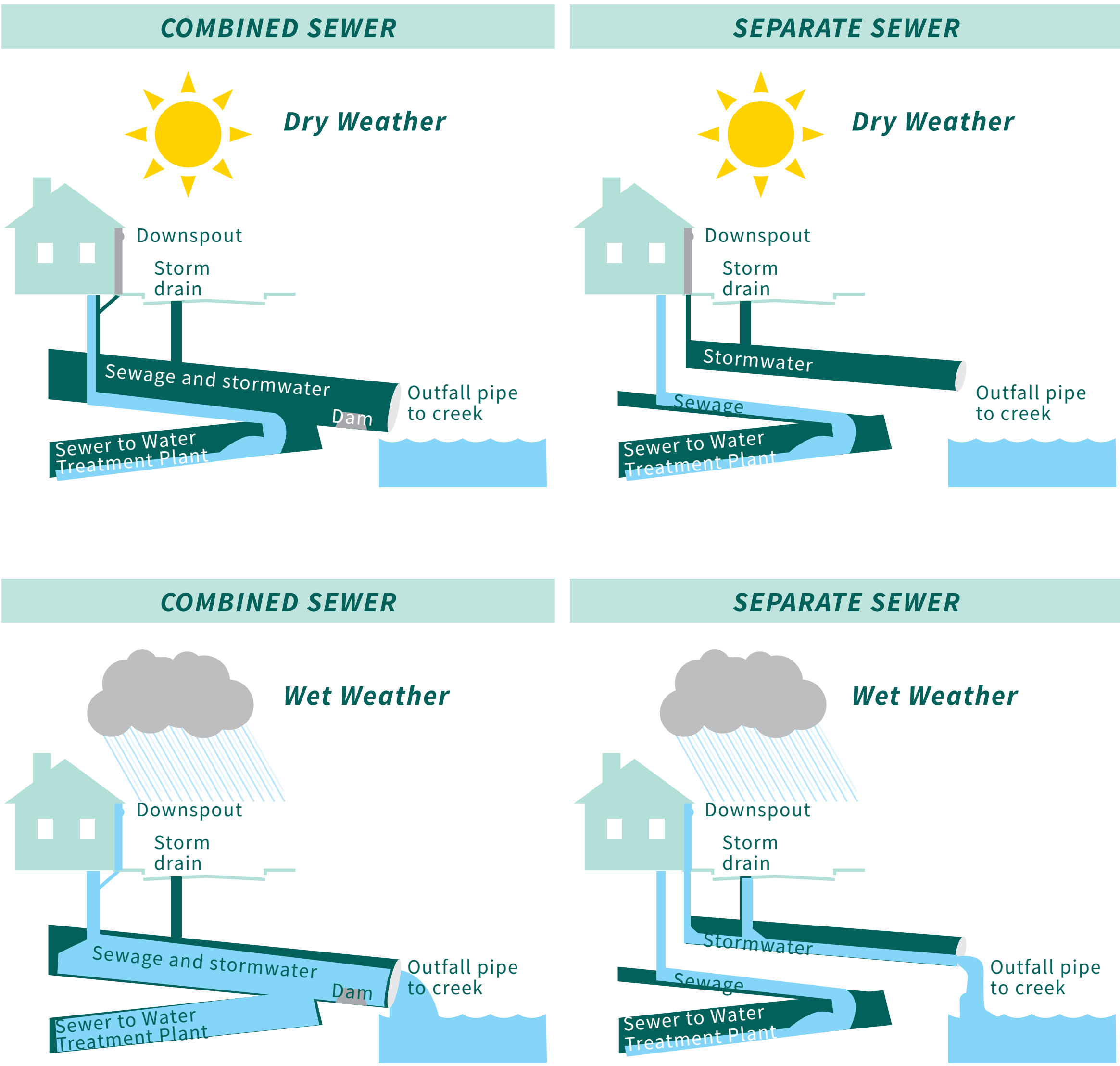
In Nashville, Tennessee the combined city and county government has experimented with green streets in three locations, all with positive public response. This is 28th/31st Avenue Connector which was completed in 2012. The blue shows where the water runs during storms.

The goal of this project is to encourage the practice of integrating stormwater and transportation infrastructure investment by developing a straightforward process for promoting the best locations for green street stormwater elements. The focus is on mid-sized cities. Our test city, Nashville, is focused on abating combined sewer overflows (CSOs), but the approach could be used in any city that is trying to effectively manage stormwater pollution and the erosive energy of the water that runs off our impervious landscape. In May 2016, the mayor signed an Executive Order formalizing a 'Complete and Green Streets' policy that added a focus on green-street infrastructure elements to the existing Complete Streets resolution to help reduce pollutant, temperature, and runoff impacts to the Cumberland River.

[1]The Complete Streets, http://www.smartgrowthamerica.org/complete-streets/a-to-z

[2]Portland, OR, Philadelphia, PA, New York City and Seattle, WA are four notable examples. Philadelphia has committed $600 million to green infrastructure. (Abrams, Glen J. Green City, Clean Waters presentation, http://www.mwcog.org/environment/Roads_Highways/presentations/Abrams.pdf)

[3]Abrams, http://www.mwcog.org/environment/Roads_Highways/presentations/Abrams.pdf.



Source: *http://hydro-logic.blogspot.com/2012/07/urban-stormwater-and-us-epa.html*

Combined sewer system versus separated sewer system

During dry weather, a combined sewer system sends a city's waste water to a sewage plant for treatment. When it rains, stormwater is collected in the same system, combined with the wastewater and all of it is treated. However, during heavy rains, if the treatment plant capacity is exceeded, raw sewage is sent through emergency overflow pipes into streams, wetlands and rivers.

Not all cities have combined sewer systems. Similar problems can be caused by leaks in the wastewater pipes that allow stormwater to inundate the system and cause raw sewage overflows in many locations throughout the system. Even the separated stormwater systems can be overwhelmed by the volume, velocity and contamination of stormwater runoff from our increasingly impervious landscape.

How can green infrastructure help?

Green infrastructure is an approach to water management that protects, restores or mimics the natural water cycle. The goal of green infrastructure, such as green streets, is to collect water close to where it falls, treat it with a combination of soils and vegetation, and let it sink back into the earth or evapotranspire via plants back into the air. This more closely mimics the way rainfall behaves in a vegetated environment like a forest or meadow. By letting water infiltrate before it is collected in a pipe, pollution is reduced, erosion is avoided, and flooding is minimized.

INTRODUCTION

Why mid-sized cities?

Many large cities experiencing combined sewer overflows (CSOs) have committed to investment in green stormwater infrastructure and monitoring as a lower cost, longer term, multiple-benefit solution.

Securing those commitments has taken a great deal of analysis and financial investment to convince local and national officials that green alternatives can play a significant role in eliminating raw sewage releases into our water resources. With each city that submits a proposed plan including green investment, there is more analysis, data and experience from which the next city can benefit.

There are now also a number of mid-sized cities that have received EPA's approval to give green solutions a try, including Kansas City, St. Louis, Cleveland, Buffalo and Louisville. Leaders in these cities–and others like them–have benefited from guidance, analysis and explanation of what is working from the larger cities. Oftentimes, smaller cities need technical assistance to tailor solutions to their own scale, including relevant estimates of impacts and costs.

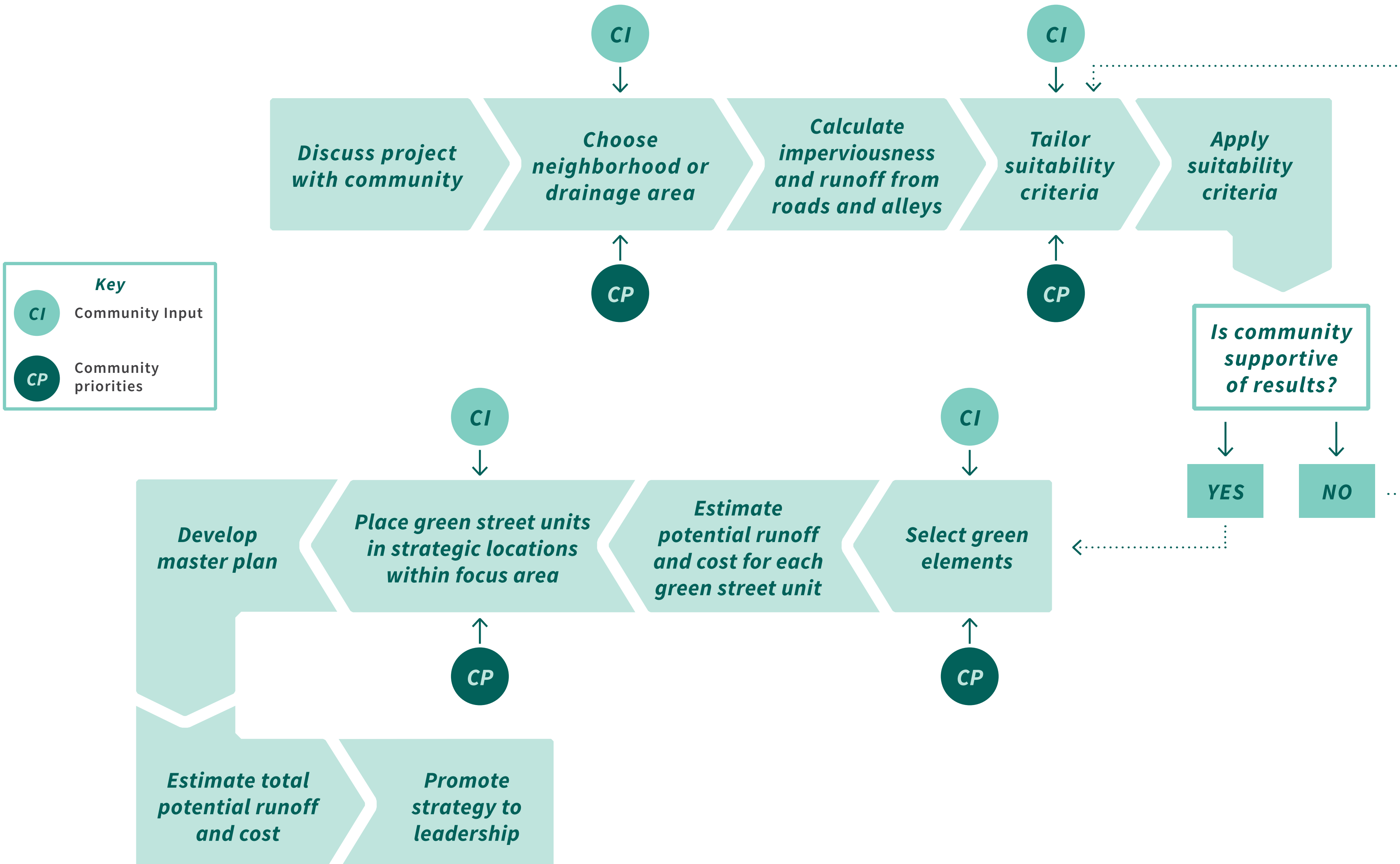
By focusing on the mid-sized cities, we hope to contribute to efforts to spur on technology transfer, investment and political support for green streets.

Kansas City Green Neighborhood Recognition Program;
For more information: http://kcmo.gov/kcgreen

Cleveland Green and Complete Streets;
For more information: https://www.neorsd.org/

A rendering of the West 65th Street Green and Complete Streets project in Cleveland, one of 12 green infrastructure projects chosen for funding in 2016 by the Northeast Ohio Regional Sewer District. Cleveland.com

RECIPE STEPS FLOWCHART



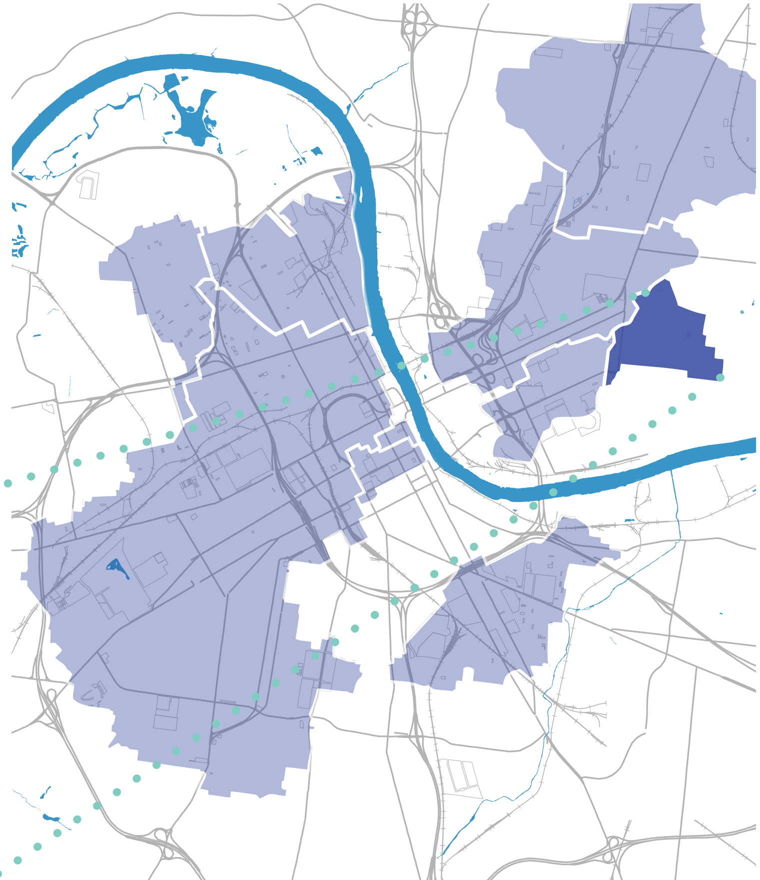
STEPS 1 & 2 | *Discuss project with community; Choose neighborhood or drainage*

Ideally, selecting an area for analysis should be undertaken with community input from neighborhoods and local government leadership. This will help ensure community acceptance and participation that is critical to a successful green streets program.

We focused our analysis on a combined sewer drainage area in Nashville, Tennessee, named after a street that falls within its boundary–Boscobel. The area was chosen for several reasons. First, the basin is relatively small compared with other basins in the urban core, as the graphic to the right demonstrates.

Secondly, it is primarily residential and therefore almost all impervious surfaces serve vehicles or pedestrians or are associated with homes. There are relatively few commercial zones or parking lots.

Thirdly, by focusing on an area that is part of Nashville's existing commitment to eliminating combined sewer overflows, we linked our strategy to a community priority area.



LESSONS LEARNED

1. Meet early and often with the local officials, local organizations and neighborhood leadership.

2. Tie into other local priorities–Combined sewer overflows, complete streets, safe routes to schools, ADA improvements.

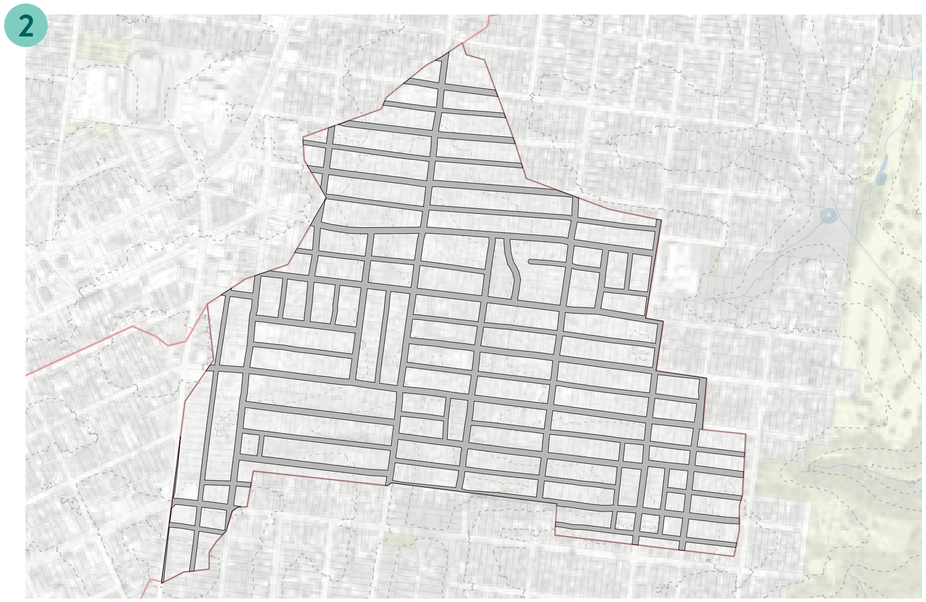
STEP 3 | *Calculate impervious area in roads and alleys*

Boscobel drainage area is **230 acres, of which over 81 acres are impervious**. Impervious areas studied (and shown below) were commercial, residential and institutional structures, roads, alleys, parking lots and sidewalks.

1. ***BUILDING FOOTPRINTS***
2. ***ROADWAY AND PARKING SURFACES***
3. ***SIDEWALKS***

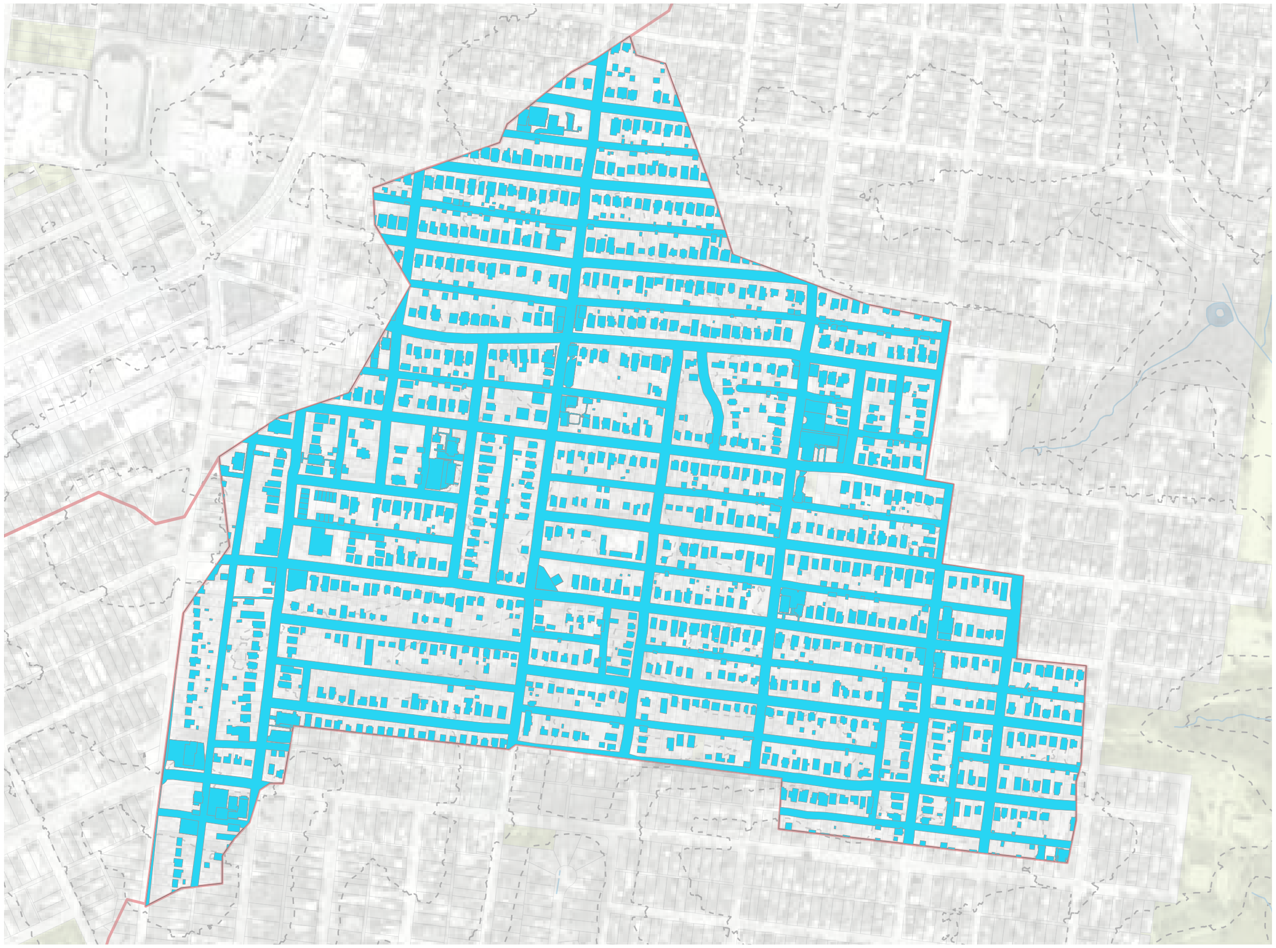
1

2



3

STEP 3 | *Calculate impervious area in roads and alleys*



Impervious surfaces in the Boscobel Combined Sewer System

To determine how much of the impervious area in the neighborhood is comprised by the road system, GIS layers were obtained from the city.

The total imperviousness was calculated (35% of the neighborhood), and the portion of that total that the road system represents (43%) was determined.

17% Buildings
15% Roads and Alleys
3% Parking

35% Impervious Cover

Roads and Alleys are 43% of Impervious Cover in the Boscobel neighborhood.

LESSONS LEARNED

1. Your municipality will likely provide all impervious cover layers.
2. It is important to clarify exactly what is included in each layer.
3. The right-of-way percentage is important to make the case for green street investment.

STEP 4 | *Calculate stormwater runoff from roads and alleys*

These equations demonstrate how to calculate the gallons of stormwater runoff per year from roads and alleys.

EQUATION 1. CALCULATING RUNOFF VOLUME FROM ROADWAY IMPERVIOUS COVER

Catchment Area (ft^2) x Avg Rainfall (ft) x Runoff Coefficient = TOTAL RUNOFF (ft^3)

- Boscobel's roadways represent approximately 35 acres, or 1,525,000 square feet of impervious surface.
- Average rainfall in Nashville is 48 inches or 4 feet. You will need to determine the average rainfall in your area.
- The widely accepted runoff coefficient for impervious surfaces is 0.95. This means that 95% of water falling on impervious surfaces is moved offsite. The remaining 5% evaporates or clings to a material's surface.

1,525,000 (ft2) x 4.0 (ft) x 0.95 = **5,795,000 cubic feet of runoff**

EQUATION 2. CONVERT CUBIC FEET TO GALLONS

Total Runoff Volume (ft^3) x 7.48 gallons per cubic foot = **TOTAL RUNOFF (Gal)**

5,795,000 (ft^3) x 7.48 gal/cu. ft. = **45,200,000 gallons of runoff**

STEP 5 | *Tailor suitability criteria to your focus area*

In order to objectively assess streets throughout an entire neighborhood, a set of metrics should be developed to compare streets to one another. Much of this work can be performed at the desktop level using publicly accessible information such as Google Maps, GIS layers from a local agency, and Web Soil Survey from the Natural Resource Conservation Service[1].

In our Nashville example, we deemed two criteria as"prerequisites" for considering particular streets as suitable for green street features: slope and right-of-way (ROW) width. Several other characteristics were identified as important to determine the viability of the street for green street investment. Those characteristics were (a) whether the soil would allow sufficient infiltration of stormwater, (b) whether utility infrastructure was underground, (c) whether there had been any citizen complaints of stormwater flooding, and (d) the number of houses along a particular street (and whether they had driveways). Each criterion used in the Boscobel suitability analysis is explained below.

Block or alley ID	Prerequisites	Slope	ROW Width	Secondary Considerations	Hydrologic Soil Group	Utility Conflict	Stormwater Customer Complaint	House Frontage	Total
1		2	2		1	1	0	0	5
2		1	2		1	1	0	0	4
3		2	2		1	0	0	0	4
4		1	2		1	2	0	1	6
5		2	2		1	2	0	1	7
6		2	2		1	0	0	0	4
7		2	2		1	0	0	0	4
8		2	2		1	0	0	0	4
9		0	1		1		0		1
10		2	2		1	1	0	0	5
11		2	2		1	1	0	1	6
12		2	2		1	1	0	0	5

Slope–Greater slope usually results in more soil erosion.

2 = Ideal (1–5%)
1 = Potential (5–7.5%)
0 = Unsuitable (7.5% or higher)

Right-of-Way Width–Must be wide enough to accommodate all uses once green infrastructure is installed. All alleys were considered ideal because we assumed they were converted to a permeable surface.

2 = Ideal (50’ foot wide)
1 = Potential (46’–50’ wide ROW)
0 = Unsuitable (< 46’–0 wide ROW)

[1] *www.websoilsurvey.sc.egov.usda.gov/App/HomePage.htm*

STEP 5 | *Tailor suitability criteria to your focus area*

Block or alley ID	Prerequisites	Slope	ROW Width	Secondary Considerations	Hydrologic Soil Group	Utility Conflict	Stormwater Customer Complaint	House Frontage	Total
1		2	2		1	1	0	0	5
2		1	2		1	1	0	0	4
3		2	2		1	0	0	0	4
4		1	2		1	2	0	1	6
5		2	2		1	2	0	1	7
6		2	2		1	0	0	0	4
7		2	2		1	0	0	0	4
8		2	2		1	0	0	0	4
9		0	1		1		0		1
10		2	2		1	1	0	0	5
11		2	2		1	1	0	1	6
12		2	2		1	1	0	0	5

Key

2 = Ideal 1 = Potential 0 = Unsuitable

Hydrologic Soil Group–This indicates how quickly water will move through native soil. Ninety-seven percent of the Boscobel neighborhood is comprised of A or B soil groups, which percolate water quickly and are ideal for green infrastructure.

Utility Conflict–Using underground water and sewer information, the team assumed the cost of working around or relocating those underground utilities would complicated retrofit efforts. The presence of these pipes was viewed as negative to retrofitting. Many cities have worked around utility conflicts, however.

Flooding Complaints–Nashville's Metro Water Service keeps track of all customer complaints in a database. The team mapped these complaints, but no complaints had been reported in the focus area. The greater the number of complaints, the more ideal the location would be for green street features that could infiltrate stormwater that is contributing to the flooding. Municipalities should consider this input as it can provide valuable information about where localized non-floodplain urban flooding occurs[1].

House Frontage–Roadway sections with fewer properties bordering the street (or more driveways) were prioritized since retrofit scenarios are less likely to displace on-street parking.

LESSONS LEARNED

1. It is very important to involve the neighborhood and the local agencies in development of suitability criteria and assignment of rankings.
2. Your community may identify more or different prerequisite criteria.

[1]For more information on this problem, see Center for Neighborhood Technology *www.cnt.org/publications/the-prevalence-and-cost-of-urban-flooding*.

STEP 5 | *Tailor suitability criteria to your focus area*

Keeping a database for organizing each of the roadway sections in the study area is critical for keeping track of values assigned. The study team used a computer-aided drafting (CAD) program and assigned a unique feature ID to every block, shown in the first column of the chart. A similar process can be accomplished in GIS.

The suitability matrix to the left is a sample of the color coding assigned to each block in the CAD program. Blocks with values of six or greater were prioritized highest and are identified in green. Yellow blocks are lower priority but still viable for retrofit, and red block were deemed unsuitable. Most of the unsuitable blocks were classified as such because they were too steep and didn't meet the first prerequisite.

Block or alley ID	Prerequisites	Slope	ROW Width	Secondary Considerations	Hydrologic Soil Group	Utility Conflict	Stormwater Customer Complaint	House Frontage	Total
1		2	2		1	1	0	0	5
2		1	2		1	1	0	0	4
3		2	2		1	0	0	0	4
4		1	2		1	2	0	1	6
5		2	2		1	2	0	1	7
6		2	2		1	0	0	0	4
7		2	2		1	0	0	0	4
8		2	2		1	0	0	0	4
9		0	1		1		0		1
10		2	2		1	1	0	0	5
11		2	2		1	1	0	1	6
12		2	2		1	1	0	0	5

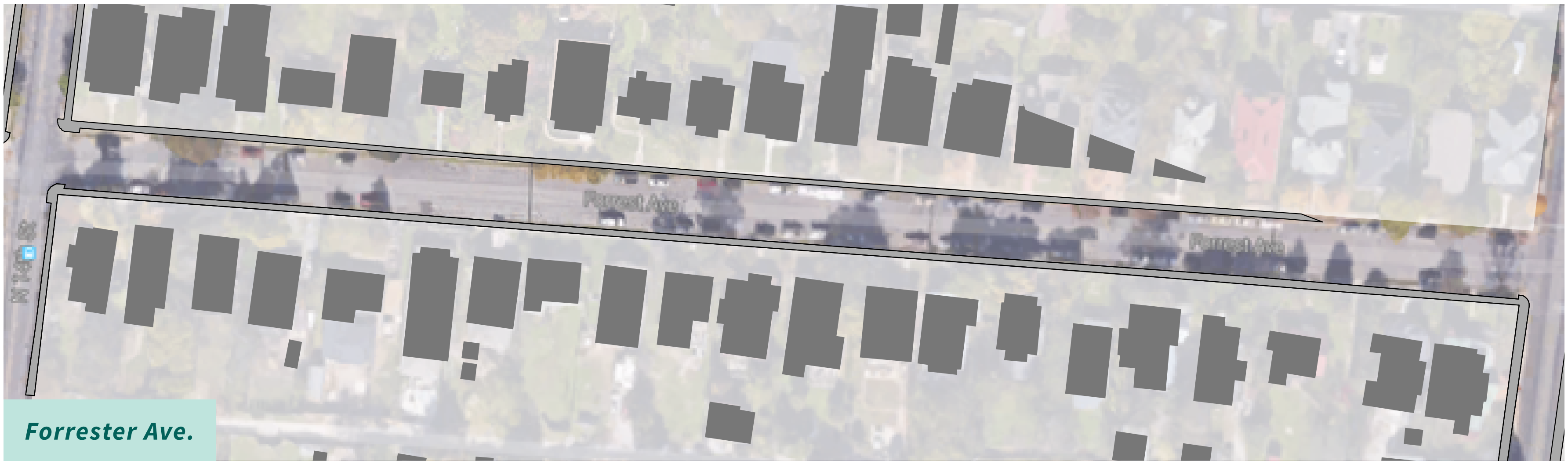
Suitability Matrix

Ideal | Potential | Unsuitable

Applying the matrix to road network

STEP 6 | *Apply suitability criteria to focus area*

The team initially tested all street and alley sections in the Boscobel neighborhood for slope and right-of-way width prerequisites. Next, the secondary considerations were tested on a 1000-foot-long stretch of Forrest Ave between 14th and 15th streets shown below. This block is close to both the local public middle school and several early childhood education schools. Proximity to schools can be used as another suitability criterion as green streets can promote traffic-calming and safer routes for children.



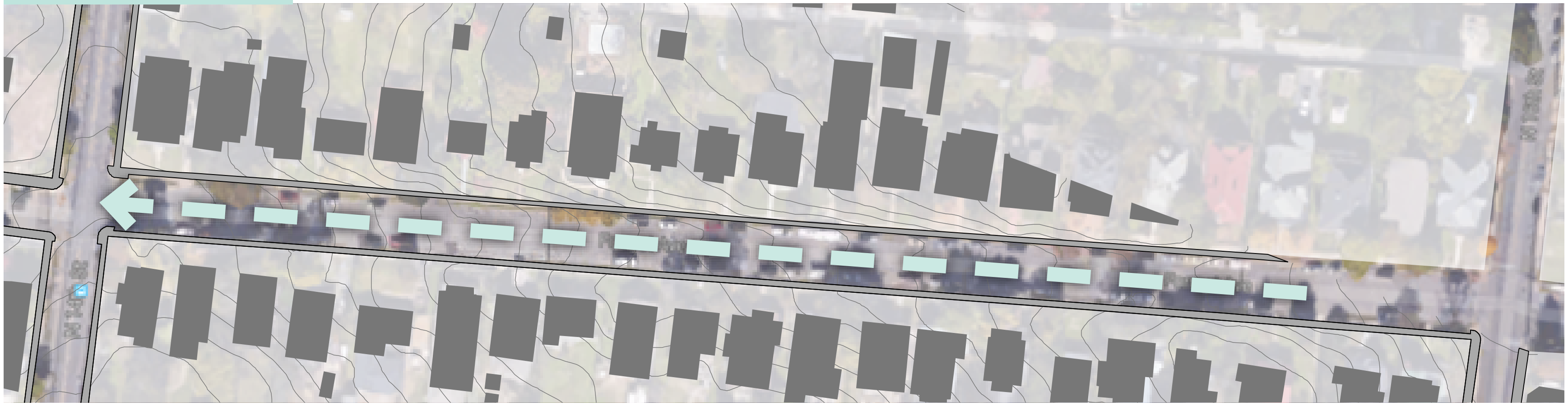
Forrester Ave.

Forrester and Lockeland

Lockeland Springs Elementary

STEP 6 | *Apply suitability criteria to focus area*

SLOPE ASSESSMENT

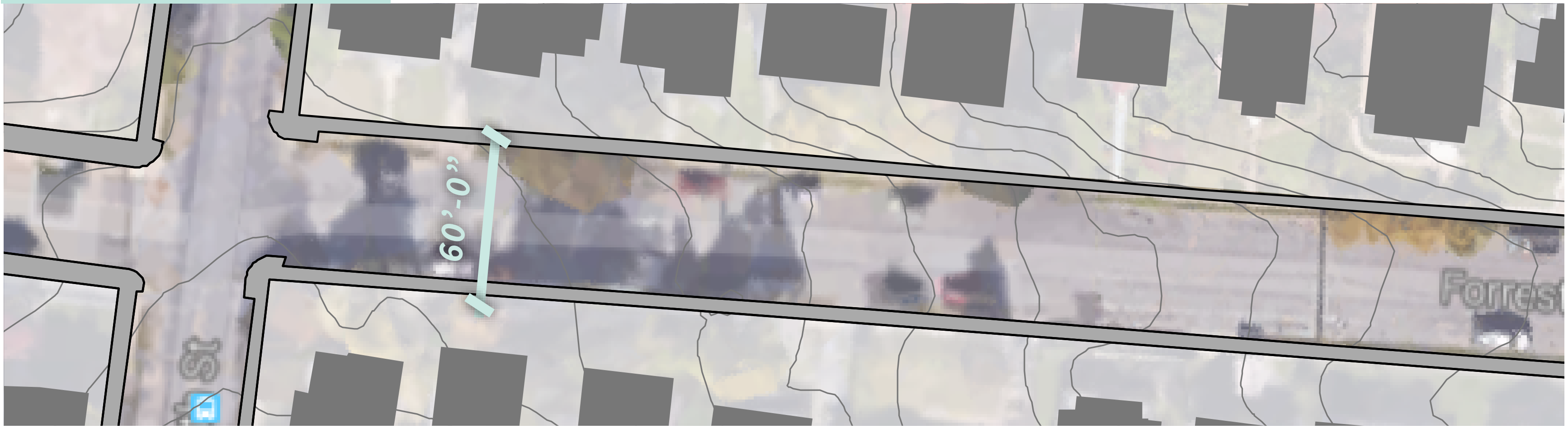


The slope on this block averages 3.8% from the high point at the right of the image to the low point at the left.

This block has a slope of less than 2%.

This block has a slope of over 9%.

RIGHT-OF-WAY ASSESSMENT



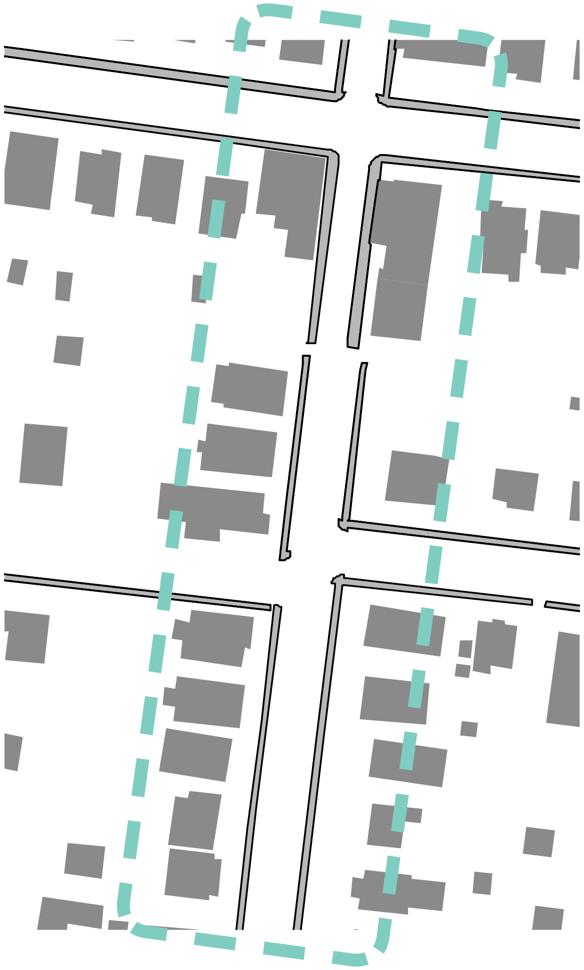
ROW width is approximately 60'–0". Nashville's Metro Public Works department defines this road as a Medium Density Local Road with a minimum standard with of 50'–0".

This block has a 50-foot right-of-way which allows room for stormwater features.

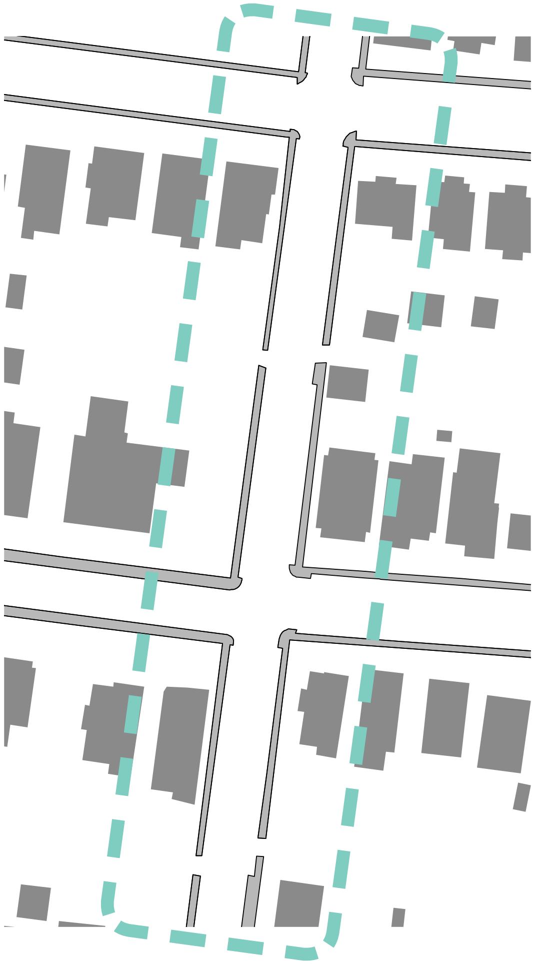
This block has a 45-foot right-of-way which is the minimum width for installing green features and maintaining standard drive lanes.

STEP 6 | *Apply suitability criteria to focus area*

LOT FRONTAGE ASSESSMENT



Example A: In this neighborhood many of the lots are narrow and deep, with the short side (typically 50’–0” wide) fronting the street. This means most homeowners do not have driveways and therefore are likely to park a vehicle on these streets.



Example B: Along this street, the lots have much wider frontages and would not displace as much parking. Including a driveway layer if it exists might help with this assessment. It will also be informed by community feedback.

STEP 6 | *Apply suitability criteria to focus area*

PEDESTRIAN AND BICYCLE TRAFFIC

When examining suitability, the study team also considered the pedestrian and bicycle traffic on different streets and the proximity to public services such as schools, parks, libraries and commercial areas. Data on busy pedestrian and bicycle routes can help prioritize traffic-calming needs that can be addressed with green street features.

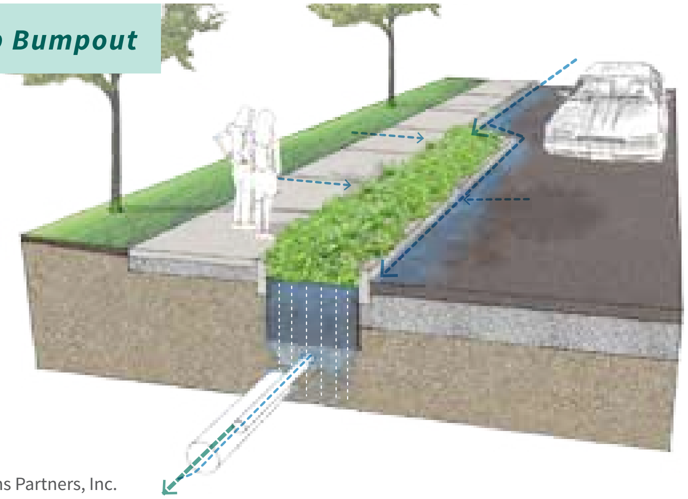
LESSONS LEARNED

1. Additional considerations for prioritizing streets may include proximity to schools, parks, and commercial activity to promote walking.
2. Consider researching flooding complaints to target investment where stormwater management improvements are more critical.

STEP 7 | *Select green street elements suited to your focus area*

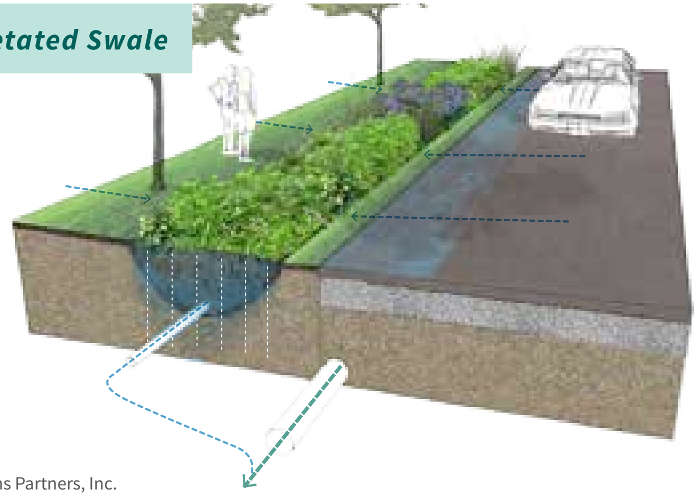
With input from the neighborhood and relevant local government departments, a suite of green street elements appropriate to the neighborhood and the ecoregion should be selected. We chose four particular elements for the Boscobel neighborhood: curb bumpout, vegetated swale, tree trench and permeable pavement. In the following pages, each element is described along with its advantages and limitations.

Curb Bumpout



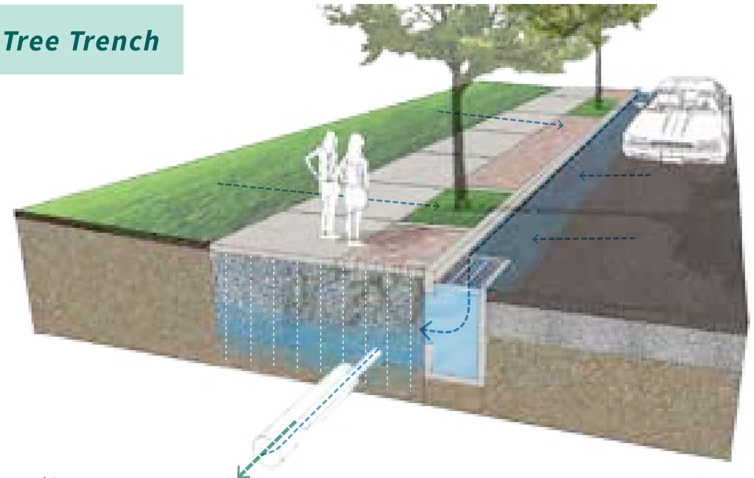
© Hawkins Partners, Inc.

Vegetated Swale



© Hawkins Partners, Inc.

Tree Trench



© Hawkins Partners, Inc.

Permeable Pavement

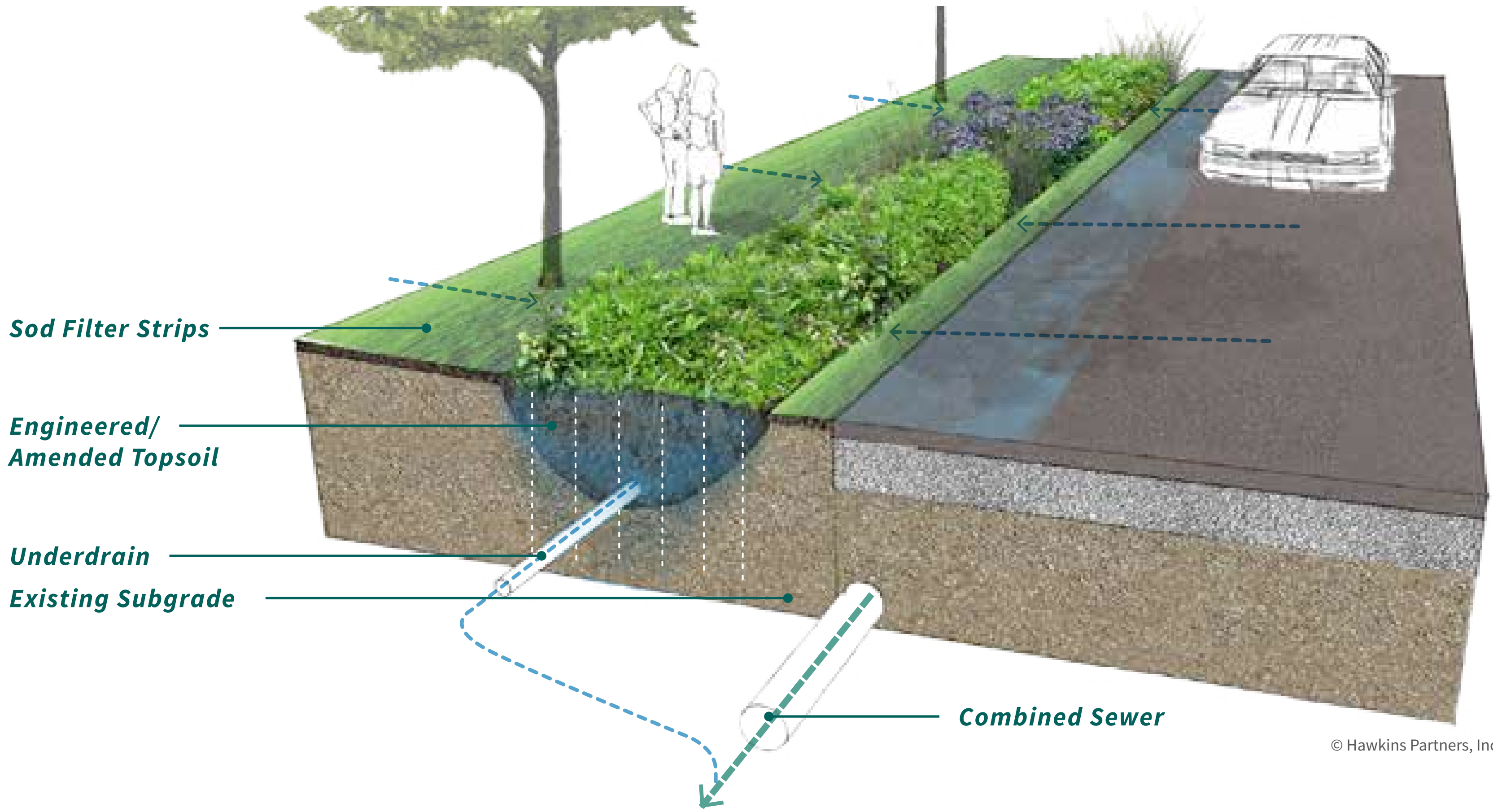
© Hawkins Partners, Inc.

VEGETATED SWALE

Components:
- Best on slopes of less than 2%
- Level spreaders needed every 50 feet
- Filter bed of engineered/amended soils
- Underdrain for impermeable soils

Advantages:
- Less expensive than curb and gutter
- Reduces runoff velocity
- Promotes infiltration
- Conveyance and stormwater treatment

Limitations:
- Cannot be used on steep slopes
- Higher land requirement
- Higher maintenance than curb/gutter

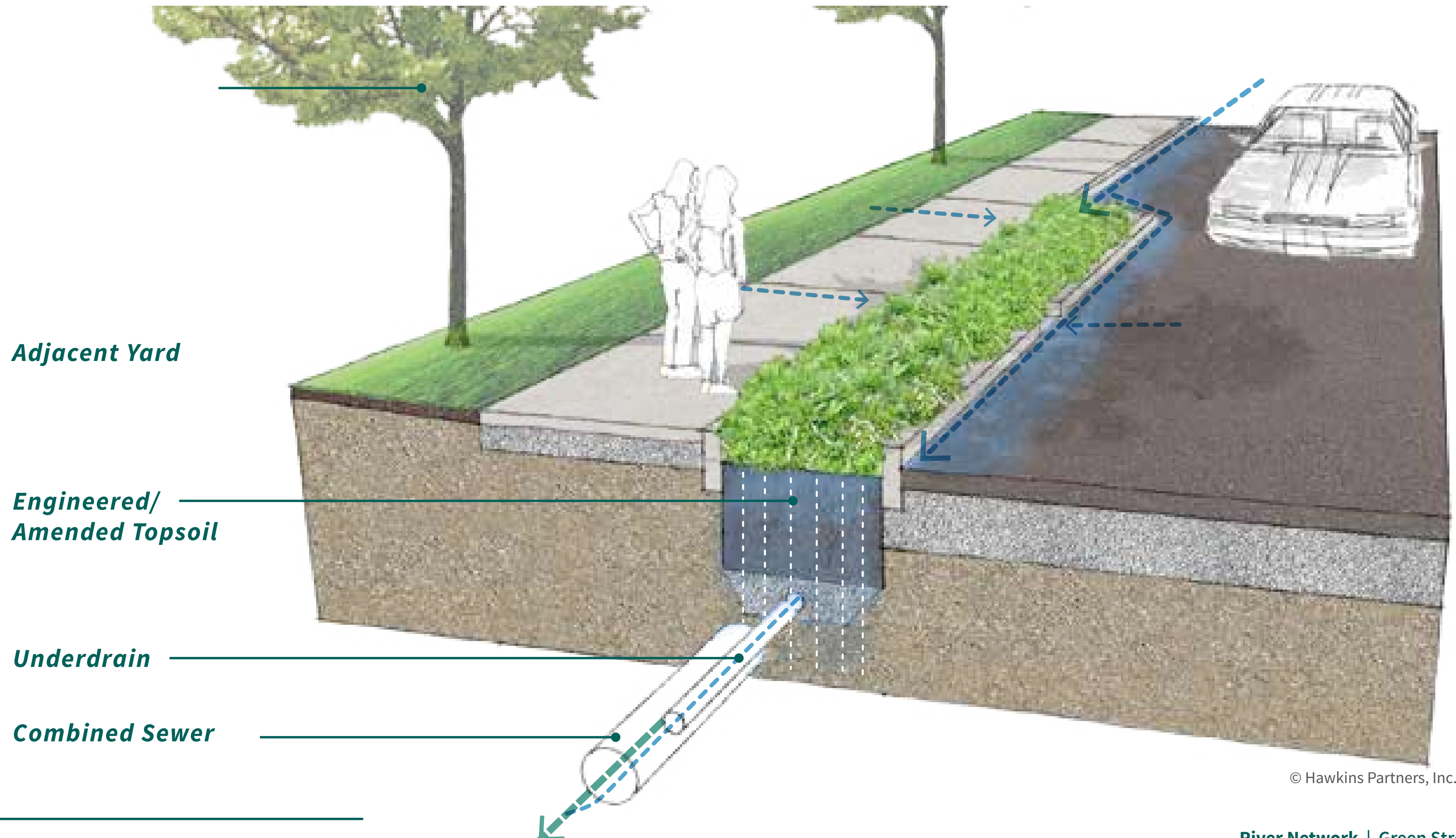


CURB BUMPOUT

Components:
- Best on slopes of 3% or less
- Curb cuts to allow water flow
- Filter bed of engineered/amended soils
- Designed to drain within 24 hours

Advantages:
- Reduced volume, peak discharge, and TSS
- Enhanced site aesthetics
- Traffic calming
- Displaces existing paved surfaces

Limitations:
- Cannot be used on steep slopes
- Higher land requirement
- Higher maintenance than curb/gutter



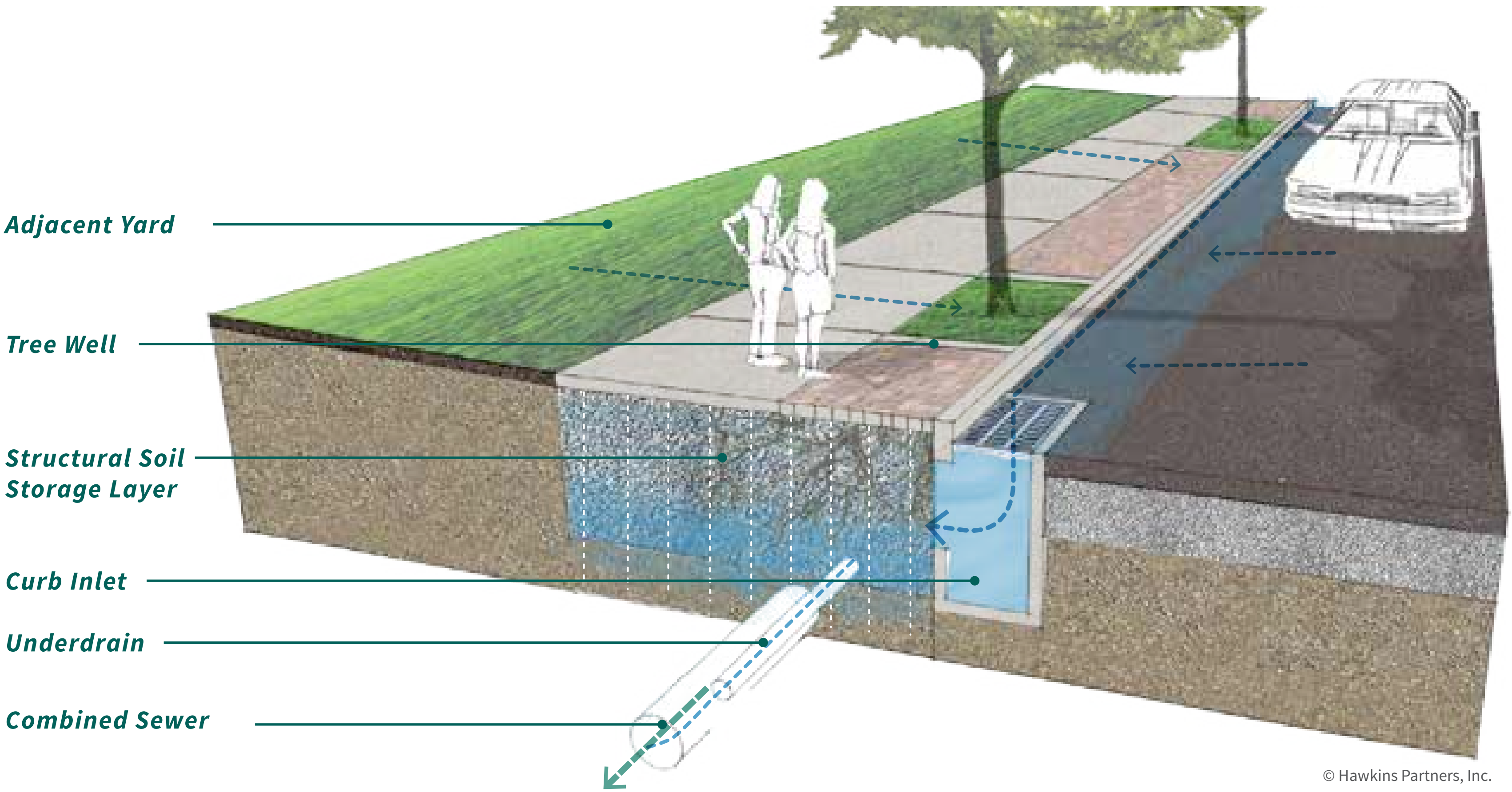
STEP 7 | *Select green street elements suited to your focus area*

TREE TRENCH

Components:
- Curb, gutter, and inlet
- Structural soils
- Pervious pavement

Advantages:
- Utilizes space below sidewalk
- Improves tree health with large rootzone
- Reduces peak discharge, and promotes infiltration

Limitations:
- Expensive; to be considered as part of a larger capital project.
- Difficult to repair if problems arise

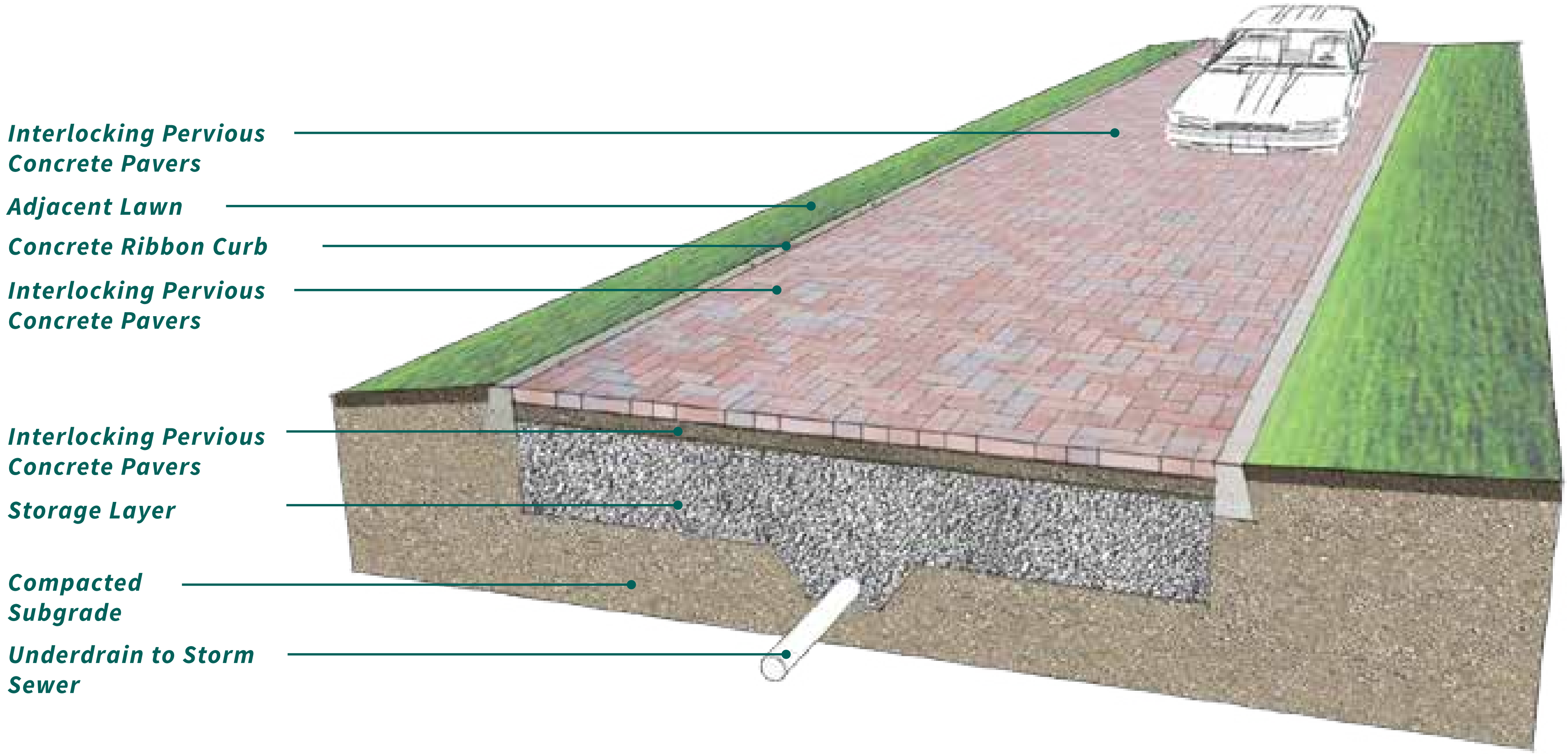


PERMEABLE PAVEMENT

Components:
- Pervious surface material
- Bedding layer
- Reservoir/storage layer
- Drainage
- Filter layer

Advantages:
- Runoff reduction
- Can increase aesthetic value
- Provides water quality treatment

Limitations:
- Cost
- Maintenance
- Limited to low traffic areas
- Not effective on steep slopes



STEP 8a | *Estimate potential runoff captured by each green street element*

The process for calculating the potential runoff captured by each green street element will require collection of local information and decisions about the site of each element. The Center for Neighborhood Technology summarized variables and factors involved in calculating potential runoff capture of different green infrastructure elements in their 2010 publication, *The Value of Green Infrastructure*[1].

Vegetated swale and curb bumpout

Information needed:

- *Area and depth of the swale or bumpout*
- *Relevant drainage area contributing runoff to the infiltration area*
- *Average annual precipitation data*
- *Expected percentage of retention*

Factors affecting capture:

- *Rainfall amount and distribution*
- *Site irrigation practices*
- *Temperatures and humidity*
- *Soil infiltration rate*


arlingtonva.us

Tree trench

Information needed:

- *Number, size and type of trees planted*
- *Average annual interception (gal) per tree*

Factors affecting capture:

- *Climate zone*
- *Precipitation levels*
- *Seasonal variability affecting evapotranspiration rates*


Architectural Record, captured from www.dot.ca.gov

Permeable pavement

Information needed:

- *Average annual precipitation data*
- *Square footage of the green infrastructure feature*
- *Percentage of precipitation that the feature is capable of retaining*

Factors affecting capture:

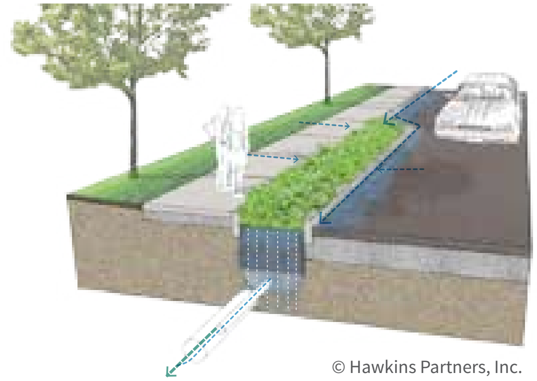
- *Slope of the pavement*
- *Soil content & aggregate depth below pavement*
- *Size and distribution of storm events*
- *Infiltration rate*
- *Frequency of surface cleaning*


Permeable pavement

[1]Center for Neighborhood Technology, The Value of Green Infrastructure, A Guide to Recognizing Its Economic, Environmental and Social Benefits, 2010, *www.cnt.org/publications/the-value-of-green-infrastructure-a-guide-to-recognizing-its-economic-environmental-and*.

STEP 8b | *Estimate cost of each green street element*

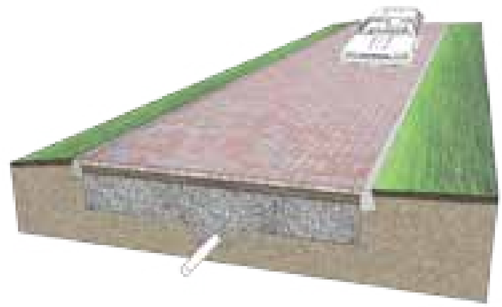
Costs of each green street element are estimated on a per square foot basis derived from Nashville components and pricing. Details of these costs can be found in the Appendix. It will be necessary to (a) tailor these estimates with the available materials and prices in your area and (b) determine appropriate standard-sized units (length and width) for your focus area.



© Hawkins Partners, Inc.

Flow Through Planter
(35 ft long x 6 ft wide, typ.)

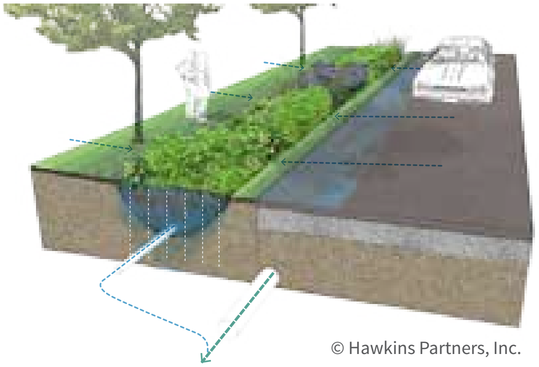
Traditional Infrastructure Improvements Total	$8,283.60
Green Infrastructure Improvements Total	$3,237.00
Overall Total	$11,520.60
Price Per Square Foot	$54.86



© Hawkins Partners, Inc.

Alley Permeable Paving
(750 ft x 12 ft) based on typical E-W block length

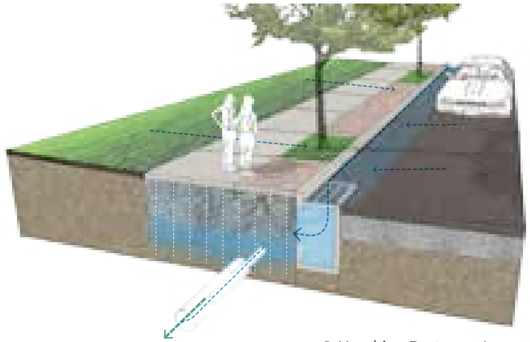
Infrastructure Improvements Total	$208,562.90
Price Per Square Foot	$48.28



© Hawkins Partners, Inc.

Vegetated Swale
(100 ft long x 6 ft wide, typ.)

Traditional Infrastructure Improvements Total	$12,675.00
Green Infrastructure Improvements Total	$10,608.00
Overall Total	$23,283.00
Price Per Square Foot	$38.81



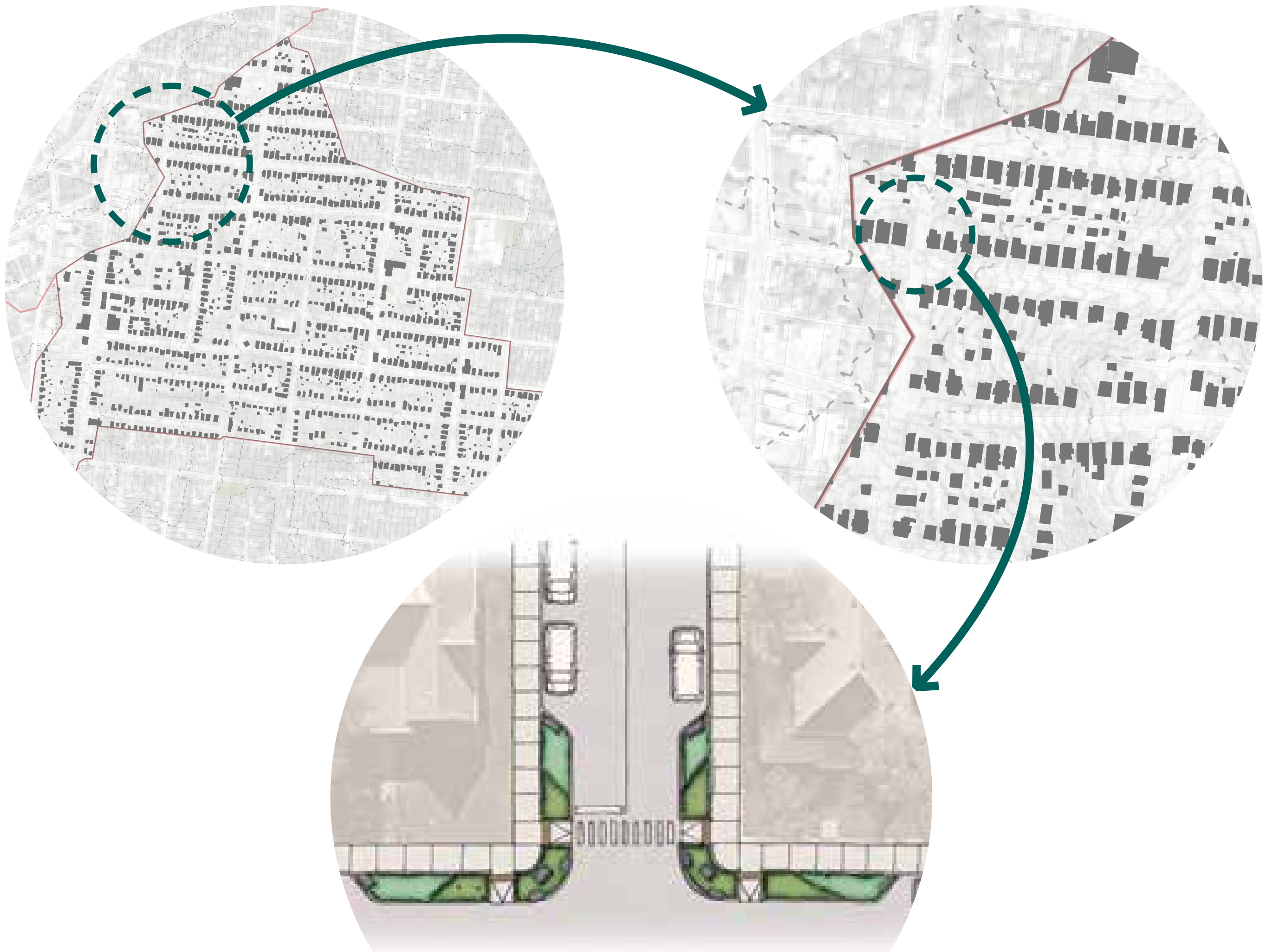
© Hawkins Partners, Inc.

Tree Trench
(100 ft long x 9 ft wide)

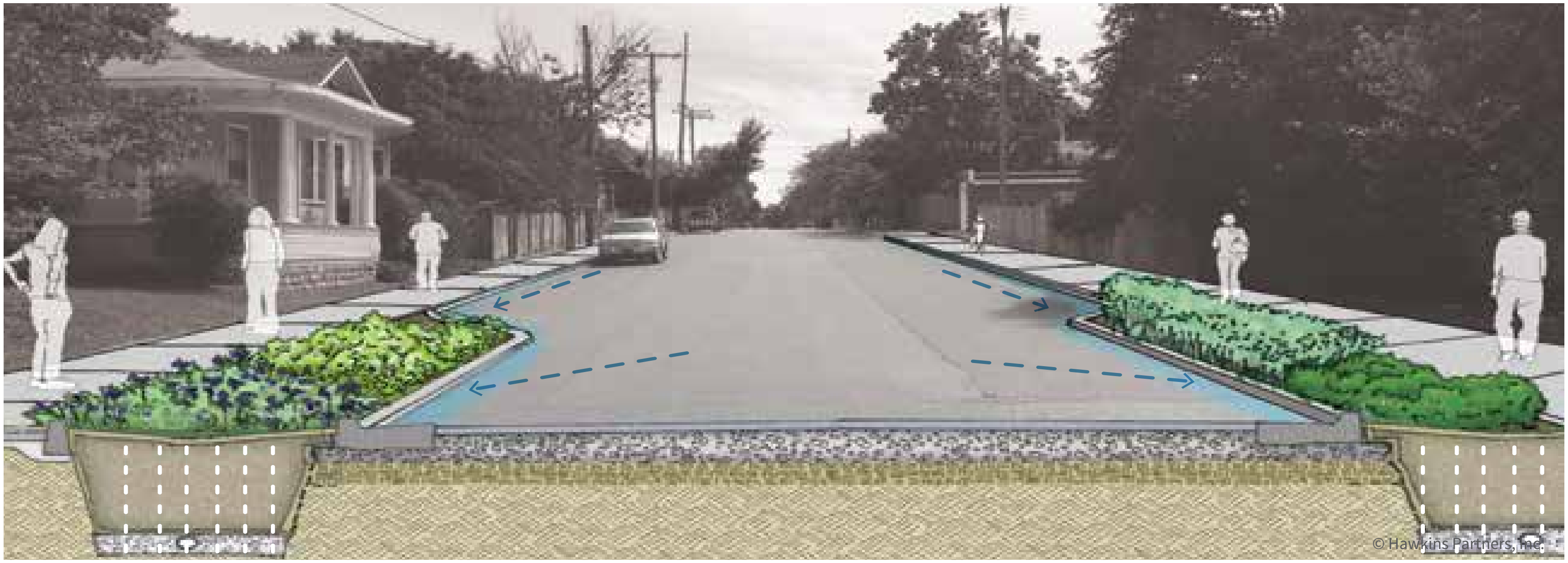
Traditional Infrastructure Improvements Total	$31,850.00
Green Infrastructure Improvements Total	$12,601.00
Overall Total	$74,451.00
Price Per Square Foot	$82.72

STEP 9 | *Place elements along most suitable roads and alleys*

Once you have determined which roads and alleys are suitable for green street features and selected the appropriate green street elements, it is time to place the elements throughout the neighborhood. This process will again require input from the residents and local officials, and it will need to take into consideration community priorities for the neighborhood such as creating safer walking and biking routes to schools and town centers.

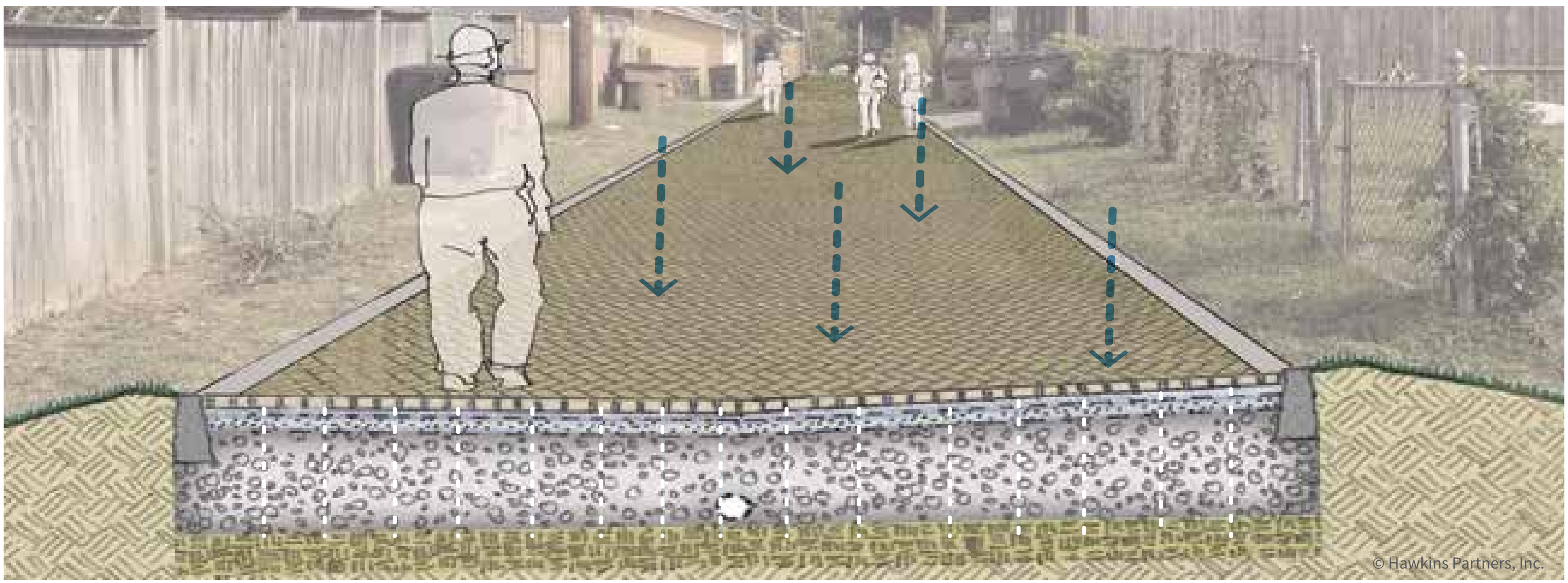


STEP 9 | *Place elements along most suitable roads and alleys*

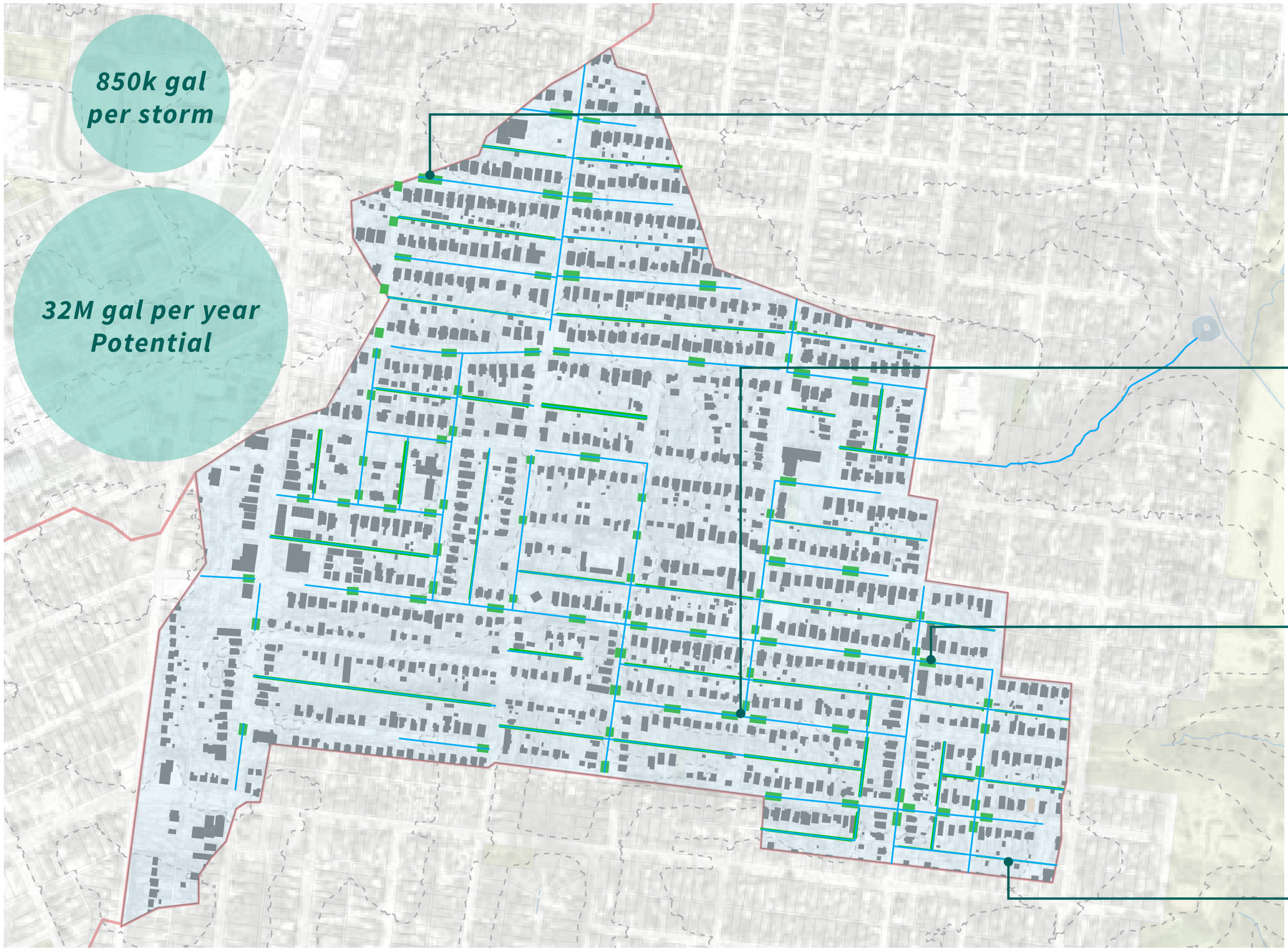


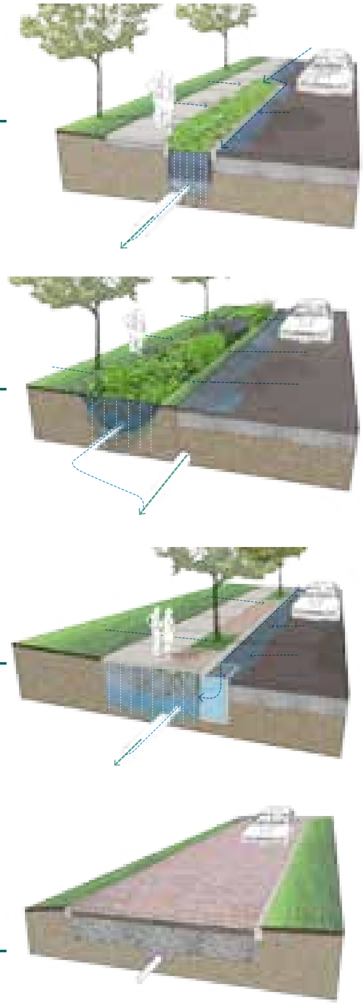
This before and after sequence demonstrates how the installation of a curb bumpout can help reduce speeding from motorists while providing an improved pedestrian experience. Water runs downhill and enters the bumpout at multiple points. If the soil becomes saturated, the additional volume overflows to the combined sewer.

STEP 9 | *Place elements along most suitable roads and alleys*



This before and after sequence illustrates the potential improvement of an alley through installation of permeable pavers. The layers below a permeable alley can retain and infiltrate the rain that falls on it.





This diagram highlights in green all roadway or alley segments that were deemed ideal or potential in the analysis phase of the process. If green infrastructure were implemented in all of these locations, the watershed could potentially retain **850,000 gallons in a 1.2" storm or thirty-two million gallons of stormwater runoff over the course of a year. (See p.32)**

STEP 11 | *Estimate total potential runoff captured*

These equations demonstrate how to calculate the annual runoff from all the streets that resulted in ideal or potential scores from the suitability analysis.

EQUATION 1. ESTIMATE POTENTIAL RUNOFF CAPTURED FROM SUITABLE STREETS (CUBIC FEET)

Rainfall Depth (in) x Runoff Coefficient x Contributing Drainage Area (SF) / 12 inches = TOTAL RUNOFF (ft^3)

- The design team used a 1.2” storm volume for this equation (90th percentile storm)
- The widely accepted runoff coefficient for impervious surfaces is 0.95. This means that 95% of water falling on impervious surfaces is moved offsite. The remaining 5% evaporates or clings to a material’s surface.
- The total contributing drainage area for ideal and potential roadway segments is 1.2 million square feet.

1.2 x 0.95 x 1,200,000 / 12 = **114,000 cubic feet of runoff**

EQUATION 2. CONVERT CUBIC FEET TO GALLONS

Total Runoff Volume (ft^3) x 7.48 gallons per cubic foot = **TOTAL RUNOFF (Gal)**

114,000 (ft^3) x 7.48 gal/cu. ft. = **852,700 gallons of runoff**

STEP 12 | *Estimate total cost*

Once elements are placed in suitable areas, it will be possible to add up the estimated cost per square foot or per standard unit to arrive at an estimate for the whole focus area. The combinations below are examples of what might be installed in a focus area.

Cost of 10 standard-sized

VEGETATED SWALES

+

Cost of 15 standard-sized

CURB BUMPOUTS

+

Cost of 20 standard-sized

TREE TRENCHES

+

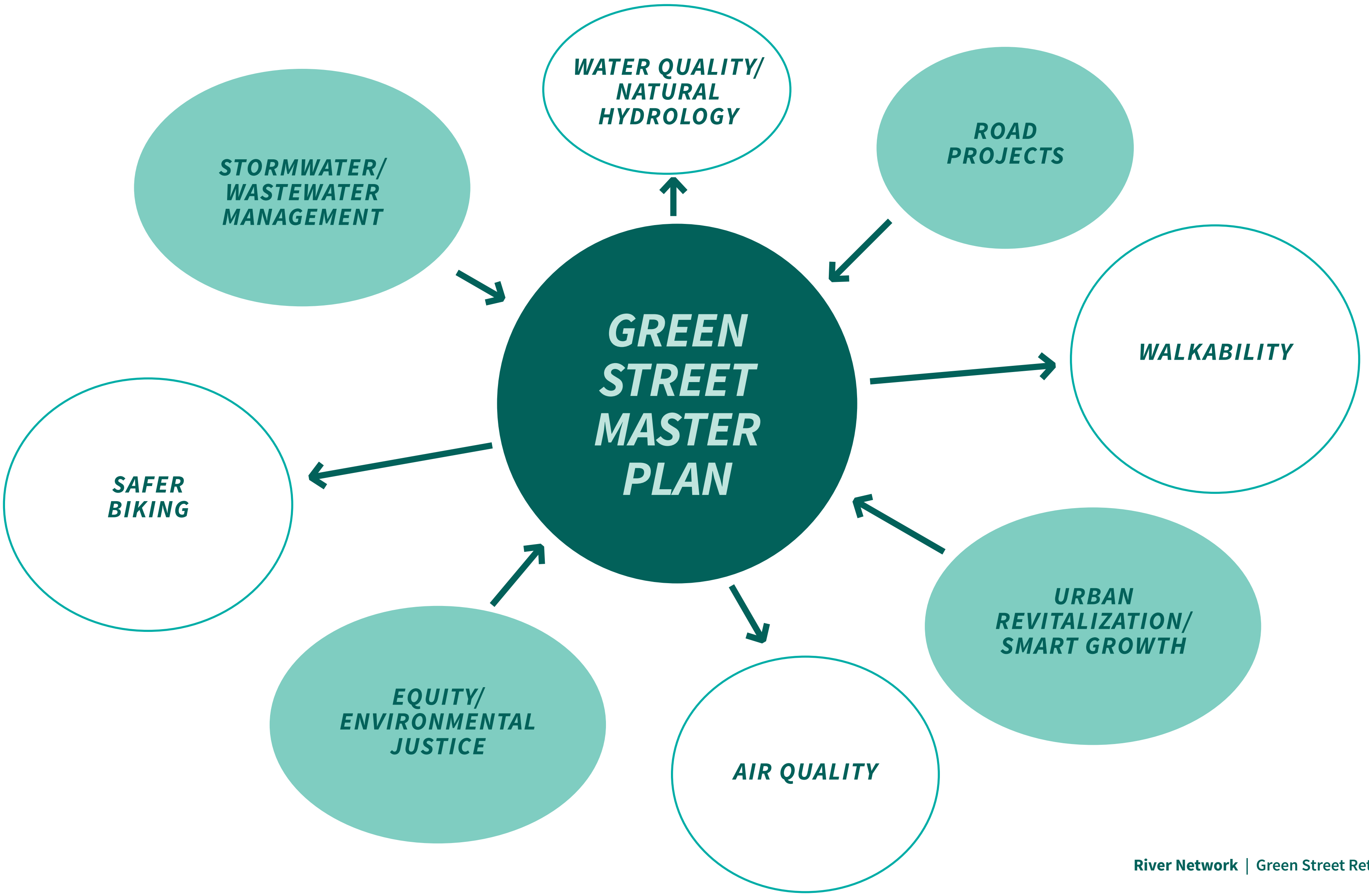
Cost of 30 parking spaces of

PERMEABLE PAVEMENT

= ESTIMATED TOTAL COST OF GREEN STREET FEATURES

STEP 13 | *Promote strategy to leadership*

Ideally, the local officials have been engaged every step of the way. At this point, however, you will have an analysis and a plan that can be used to bring additional individuals, groups and departments together to discuss what community priorities have gone into the development of the plan and what benefits are likely to come out of its implementation. With any luck and skill, these conversations will lead to the examination of opportunities to implement the master plan.



RECOMMENDATIONS


Villanova University, Philadelphia Water


Landscape Architects Network, California

Gayle Killam, Portland, Oregon

1. Leverage existing community priorities

Hitch your green street ideas to community initiatives, road projects, municipal resolutions, or revitalization efforts. The goal should be that whenever road infrastructure is planned or slated for improvements, the opportunities for green street elements are considered.

2. Work with neighborhood and municipal leadership

Be sure to find the champions both in the neighborhoods and within the municipal departments who will listen and thoughtfully consider the green street analysis and ideas. It is through those champions that your ideas will be carried forward into existing plans and investment.

3. Attract attention with road imperviousness and runoff calculations

Use your analysis of the road imperviousness percentage and the amount of runoff attributed to that significant part of the city to capture the attention of the leaders and champions of other related municipal priorities. Managing this significant amount of stormwater will be important for cities with combined sewer systems as well as those implementing stormwater controls under municipal separate storm system permits. Many cities have to answer to both programs.

4. Determine which parts of the recipe have already been developed/calculated locally

Don’t reinvent any wheels. Start by looking for the useful GIS layers (e.g., impervious cover, soil, slope, utilities, tax lots, school locations), typical local rainfall amounts, preferred (and potentially more locally effective) green infrastructure elements, locally-derived costs of constructing those elements, and any green infrastructure planning that has already been done. You may be surprised at how much you can track down for the recipe, and that similar conversations promoting green streets are already in progress. They might just need YOU to catalyze the action.

5. Tackle challenges head-on and creatively

You will encounter challenges in gathering your ingredients and following the recipe. The challenges may be unique to your city or region or they may be typical. Maintenance costs and responsibilities are a typical (and very real) concern that is raised regarding any green infrastructure investment. It is important to tackle that challenge from the beginning and secure commitments from city departments, non-governmental organizations or neighbors themselves for stewardship and maintenance of the green street elements. When needed, seek guidance from those who are implementing green street programs in other cities (*www.rivernetwork.org/resource/municipal-green-streets-projects-resources/*).

APPENDIX | *Cost data*

The cost data summarized in Step 8b is explained in more detail below. These data reflect 2015 costs in the Nashville, TN area[1]. Local economic factors, labor costs and material availability should be taken into account when developing an implementation plan.

FLOW THROUGH PLANTER (35ft LONG x 6ft WIDE, TYP.)				
TRADITIONAL INFRASTRUCTURE IMPROVEMENTS				
DEMOLITION				
Demolition of rigid pvmt	c.y.	$200.00	10	$2,000.00
Excavation	c.y.	$65.00	31	$2,015.00
Sawcutting concrete pavement	l.f.	$2.85	20	$57.00
PAVEMENT				
Concrete curb driveway ramp	s.f.	$9.00	0	$0.00
4″ light broom finish concrete	s.f.	$4.50	200	$900.00
Asphalt Resurfacing (1/2 block)	s.y.	$32.00	85	$2,720.00
CONCRETE WORK				
Concrete Curb and Gutter	l.f.	$30.00	0	$0.00
Concrete Post Curb	l.f.	$20.00	70	$1,400.00
Sub-total				$6,372.00
Contingency (30%)				$1,911.60
TRADITIONAL TOTAL				$8,283.60
GREEN INFRASTRUCTURE IMPROVEMENTS				
PAVEMENT				
Bioswale dissapators–pavers	s.f.	$23.00	10	$230.00
Trench Drain (grate and frames for Bioswales)	ea.	$500.00	1	$500.00
PLANTING				
Trees 3″	ea.	$500.00	0	$0.00
Trees 2″	ea.	$350.00	0	$0.00
Bioswale Planting	s.f.	$6.00	150	$900.00
Sod	s.y.	$5.50	0	$0.00
Seed & straw	s.f.	$0.05	0	$0.00
MISC				
Engineered Soil	c.y.	$40.00	15	$600.00
6″ perforated underdrains	l.f.	$5.00	0	$0.00
Non-woven Filter Cloth	s.y.	$4.50	0	$0.00
Mulch	c.y.	$40.00	2	$60.00
2′ open graded base material/porous fill	c.y.	$25.00	8	$200.00
IRRIGATION				
Sub-total				$2,490.00
Contingency (30%)				$747.00
GI TOTAL				$3,237.00
TOTAL				$11,520.60
Price per square foot	s.f.			$54.86

ALLEY PERMEABLE PAVING (750ft x 12ft)				
INFRASTRUCTURE IMPROVEMENTS				
DEMOLITION				
Demolition of rigid pvmt, sidewalk, etc.	c.y.	$200.00	120	$24,000.00
Excavation	c.y.	$65.00	814	$52,910.00
Sawcutting asphalt pavement	l.f.	$3.29	300	$987.00
PAVEMENT				
Previous Concrete Pavers–Vehicular	s.f.	$7.00	4,320	$30,240.00
Concrete curb driveway ramp	s.f.	$9.00	200	$1,800.00
2′ open graded base material/porous fill	c.y.	$25.00	650	$16,250.00
Bedding layer	c.y.	$20.00	120	$2,400.00
Filter fabric	s.f.	$0.17	8,800	$1,496.00
6″ perforated underdrains	l.f.	$5.00	750	$3,750.00
CONCRETE WORK				
Flush Concrete Header–Ribbon curb	l.f.	$15.00	1,540	$23,100.00
Sub-total				$160,433.00
Contingency (30%)				$48,129.90
TOTAL				$208,562.90
Price per square foot	l.f.		4,320	$48.28

[1]Hawkins Partners, Inc., A Review of the Green Infrastructure Integration Plan Process for Nashville, Tennessee, 2015.

APPENDIX | *Cost data*

VEGETATED SWALE (100ft LONG x 6ft WIDE, TYP.)				
TRADITIONAL INFRASTRUCTURE IMPROVEMENTS				
UTILITIES				
New single sump inlet with casting	ea.	$2,500.00	1	$2,500.00
Water line 6″ Cl	l.f.	$145.00	50	$7,250.00
Sub-total				$9,750.00
Contingency (30%)				$2,925.00
TRADITIONAL TOTAL				$12,675.00
GREEN INFRASTRUCTURE IMPROVEMENTS				
PLANTING				
Trees 3″	ea.	$500.00	2	$1,000.00
Bioswale Planting	s.f.	$6.00	600	$3,600.00
Sod	s.y.	$6.00	55	$330.00
MISC				
Engineered Soil	c.y.	$40.00	50	$2,000.00
6″ perforated underdrains	l.f.	$5.00	150	$750.00
Mulch	c.y.	$40.00	7	$280.00
2′ deep linear gravel diaphragm	c.y.	$25.00	8	$200.00
Sub-total				$8,160.00
Contingency (30%)				$2,448.00
GI TOTAL				$10,608.00
TOTAL				$23,283.00
Price per square foot	s.f.		600	$38.81

TREE TRENCH (100ft LONG* x 9ft WIDE)				
TRADITIONAL INFRASTRUCTURE IMPROVEMENTS				
DEMOLITION				
Excavation	c.y.	$65.00	100	$6,500.00
HARDSCAPE				
4″ Pervious Concrete Pavement–Pedestrian	s.f.	$6.00	900	$5,400.00
(2) Concrete curb driveway ramp, typ.	s.f.	$9.00	150	$1,350.00
4″ standard white concrete pavement	s.f.	$5.00	900	$4,500.00
CONCRETE WORK				
Concrete Curb and Gutter	l.f.	$30.00	100	$3,000.00
UTILITIES				
New single curb inlet for tree trench	ea.	$1,200.00	2	$2,400.00
MISC				
4′ x 8′ Metal Tree Grate	ea.	$450.00	3	$1,350.00
Sub-total				$24,500.00
Contingency (30%)				$7,350.00
TOTAL				$31,850.00
GREEN INFRASTRUCTURE IMPROVEMENTS				
HARDSCAPE				
4″ Pervious Concrete Pavement–Pedestrian	s.f.	$6.00	400	$2,400.00
PLANTING				
Trees 3″	ea.	$500.00	3	$1,500.00
Seed & straw	s.f.	$0.05	500	$25.00
MISC				
Structural Soil for Tree Trench	c.y.	$150.00	40	$6,000.00
6″ perforated underdrains	l.f.	$5.00	150	$750.00
Sub-total				$16,385.00
Contingency (30%)				$9,831.00
TOTAL				$42,601.00
COMBINED TOTAL				$74,451.00
Price per square foot	s.f.		900	$82.72

P.O. Box 21387, Boulder, Colorado 80308 || 303.736.2724 || www.rivernetwork.org