



Harrisonburg

TREES TO OFFSET STORMWATER

Case Study 08: City of Harrisonburg, Virginia





Harrisonburg

Case Study 08: Harrisonburg, Virginia

The Green Infrastructure Center Inc. is the technical services consultant for this project and the case study author. Illustrations in the report are by the Green Infrastructure Center Inc. (GIC).

The contents do not necessarily reflect the views or policies of the USDA Forest Service, nor does mention of trade names, commercial productions, services or organizations imply endorsement by the U.S. Government.

The work upon which this publication is based was funded in whole or in part through an Urban and Community Forestry grant awarded by the Southern Region, State and Private Forestry, U.S. Forest Service and administered by the Virginia Department of Forestry.

In accordance with Federal law and U.S. Department of Agriculture (USDA) policy, this institution is prohibited from discriminating on the basis of race, color, national origin, sex, age, or disability.

To file a complaint of discrimination, write USDA Director, Office of Civil Rights, Room 326-W, Whitten Building, 1400 Independence Avenue, SW, Washington, DC 20250-9410 or call 202-720-5964 (voice and TDD). USDA is an equal opportunity provider and employer.

Publication Date: December 2018



December 2018





CONTENTS

Project Overview	1
Project Funders and Partners.....	1
Outcomes	1
Community Engagement.....	2
Summary of Findings.....	3
Why Protect Our Urban Forests?.....	6
Additional Urban Forest Benefits.....	9
Quality of Life Benefits.....	9
Economic Benefits	10
Meeting Regulatory Requirements	10
Natural Ecology in Urban Conditions – Changing Landscapes.....	12
Historic Land Cover	12
Growth and Development Challenges	13
Development and Stormwater	14
Analysis Performed	15
Method to Determine Water Interception, Uptake and Infiltration	15
Land Cover, Possible Planting Area, Possible Canopy Area Analysis.....	18
Codes, Ordinances and Practice Review	23
Evaluation and Recommendations.....	23
Best Practices for Conserving Trees During Development	26
Tree Planting	27
Conclusion and Next Steps	28
Appendixes	30
Appendix A: Technical Documentation	30
Appendix B: Bibliography	32
Appendix C: Community Input	34
Meeting Summary Community Orientation held May 25, 2017	34
Meeting Summary Community Wrap-Up held July 26, 2018	35
Appendix D: Tree Planting Credit Under the Chesapeake Bay Watershed Implementation Plan	36



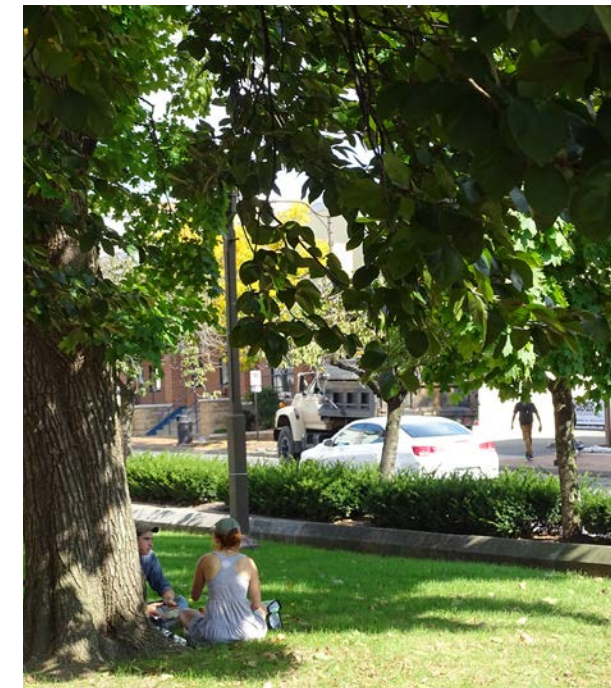
PROJECT OVERVIEW

This project Trees to Offset Stormwater is a study of Harrisonburg’s tree canopy and its role in taking up, storing and releasing water. This study was undertaken to assist Harrisonburg in evaluating how to better integrate trees into their stormwater management programs. More specifically, the study covers the role that trees play in stormwater management and shows how the city can benefit from tree conservation and replanting. It also evaluated ways for the city to improve forest management as Harrisonburg continues to develop.

PROJECT FUNDERS AND PARTNERS

The project was developed by the nonprofit Green Infrastructure Center Inc. (GIC) in partnership with the states of Virginia, Alabama, Florida, South Carolina, North Carolina and Georgia. The GIC created the data and analysis for the project and published this report. This study is one of 12 pilot projects evaluating a new approach to estimate the role of trees in stormwater uptake. The USDA Forest Service provided the funding for Virginia to determine how trees can be utilized to meet municipal goals for stormwater management. The Virginia Department of Forestry (VaDOF) administered the pilot studies in Virginia and selected Harrisonburg to be one of the three test cases. The cities of Lynchburg and Norfolk are the other municipalities selected for study.

The project was spurred by the on-going decline in forest cover throughout the southern United States. Causes for this decline arise from multiple sources including land conversion for development, storm damages, lack of tree replacement as older trees die, and for coastal cities such as Norfolk, inundation from Sea Level Rise. Many localities have not evaluated their current tree canopy, which makes it difficult to track trends, assess losses or set goals to retain or restore canopy. As a result of this project, Harrisonburg now has baseline data against which to monitor canopy protection progress, measures for the stormwater and water quality benefits provided by its urban forest, and locations for prioritizing canopy replanting.



Trees shelter residents downtown.

OUTCOMES

This report includes those findings and recommendations that are based on tree canopy cover mapping and analysis, the modeling of stormwater uptake by trees, a review of relevant city codes and ordinances, and citizen input and recommendations for the future of Harrisonburg. More specifically, the following deliverables were included in the pilot study:

- Analysis of the current extent of the urban forest through high resolution tree canopy mapping,
- Possible Planting Area analysis to determine where additional trees could be planted,
- A method to calculate stormwater uptake by the city’s tree canopy,
- A review of existing codes, ordinances, guidance documents, programs and staff capabilities related to trees and stormwater management, and recommendations for improvement,
- Two community meetings to provide outreach and education,
- Presentation about the pilot studies as a case study at regional and national conferences, and
- A case book and presentation detailing the study methods, lessons learned and best practices.

The project began in September 2016 and Harrisonburg staff members have participated in project review, analysis and evaluation. The following city divisions were involved in the project planning and review as the Technical Review Committee (TRC): Public Works Department’s Environmental Compliance Division, Stormwater Compliance; Community Development Department’s Planning and Zoning Division; Information Technology Department; Parks and Recreation Department; City Manager’s Office; the City Attorney’s Office and the Public Work’s Department.

COMMUNITY ENGAGEMENT

Two community meetings were held. The first meeting held in May 2017 provided an overview of the project. The second meeting held in July 2018 provided recommendations (listed below) for the city and elicited feedback. All individual comments from both meetings were provided to the city.

At the first meeting, residents learned about the project and offered suggestions to improve tree management and canopy coverage. At the second meeting, they learned about the project's findings, provided their opinions and made additional suggestions to conserve the city's canopy. Overall, attendees expressed great enthusiasm for helping to plant trees. Participants noted that the Boy Scouts have done plantings in Purcell Park and are working with the Parks and Recreation Department to identify riparian planting spots. Participants also suggested that there are places to plant trees at the city hall building, along Market Street, and side streets, as well as along Main Street.

The Harrisonburg Bike Stress Map was another tool suggested for use in identifying priority planting needs. In addition, participants suggested that schools lack canopy and should be prioritized as places for future planting projects. They also noted that parking lots, such as for Rose's, seem to have an oversupply of parking causing excessive impervious area in the city. Residents also wanted more education about how to properly plant and care for trees. Attendees expressed an interest in promoting more native trees and in planting urban orchards. For a full list of comments see Appendix C.

At the second meeting, community members were presented with nine specific code/ordinance or practice changes recommended by GIC to the City of Harrisonburg. Participants reviewed and discussed the following sample strategies. Each participant voted for the top three strategies they believed to be most effective for growing/protecting the urban forest.

1. Adopt a stream buffer ordinance.
2. Develop tree canopy goals by watershed.
3. Require trees over a specified Diameter at Breast Height (DBH) to be shown on development plans.
4. Tighten the development footprint (seek to reduce the amount of impervious surface during site planning).
5. Require a tree removal permit for privately owned trees over a specified DBH.
6. Use the GIC stormwater calculator tool and determine the benefit of maintaining or increasing the urban canopy.
7. Place tree protection fencing at 1.5' x DBH.
8. Perform urban forestry data collection and monitoring.



Residents learn about the extent and roles of the urban forest for stormwater management and livability.

Harrisonburg can use this report and its associated products to:

- Set goals and develop a management plan for retaining or expanding its tree canopy by watershed.
- Support grant applications for tree conservation and tree planting projects.
- Justify the need for an Urban Forester position to manage the city's tree programs.
- Educate developers about the importance of tree retention and replacement.
- Motivate private landowners (residential, commercial, and institutional) to plant and protect their trees.

SUMMARY OF FINDINGS

Satellite imagery was used to classify the types of land cover in Harrisonburg (for more on methods see page 18). This shows areas where vegetative cover helps to uptake water and those areas where impervious land cover is more likely to result in stormwater runoff. High-resolution tree canopy mapping provides a baseline that is used to assess current tree cover and to evaluate future progress in tree preservation and planting. An ArcGIS geodatabase with all GIS shape files from the study was provided to Harrisonburg.

The goal of this study was to identify ways in which water entering the city's municipal separate storm sewer system (MS4) could be reduced by using trees to intercept and soak up runoff. Tree canopy serves as 'green infrastructure' that can provide more capacity for the city's grey infrastructure (i.e. stormwater drainage systems) by absorbing or evaporating excess water before it runs off. The model created shows how the city can reduce potential pollution of its surface waters, which can impact Total Maximum Daily Load (TMDL) outcomes and watershed plans.

The detailed land cover analysis created for the project was used to model how much water is taken up by the city's trees in various scenarios. This new approach allows for more detailed assessment of stormwater uptake based on the landscape conditions of the city's forests. It distinguishes whether the trees are growing in a more natural setting (e.g. a cluster of trees in an urban forest), a lawn setting, or over pavement, such as streets or sidewalks. The amount of open space and the condition of surface soils affect the infiltration of water.

As city trees are evaluated, it's important to remember that trees within a cluster provide more value than individual trees alone because they also tend to have a more natural ground cover, more leaf litter (as they are not managed or mowed under) and less compacted soils. Thus, there is more stormwater retention for trees in a natural setting than a tree over a lawn or over pavement.



One mature tree can absorb thousands of gallons of water per year.

Trees also shelter one another from wind damages and are less likely to fall. As cities develop and lose forest, trees planted in isolation do not provide equivalent value as the same number of trees found clustered together. Therefore, when counting total trees in a city, managers should also consider the setting in which those trees are found and they should protect intact forested clusters of trees as often as possible. The Chesapeake Bay Program also provides a Best Management Practice (BMP) credit for planting trees. For more see Appendix D.

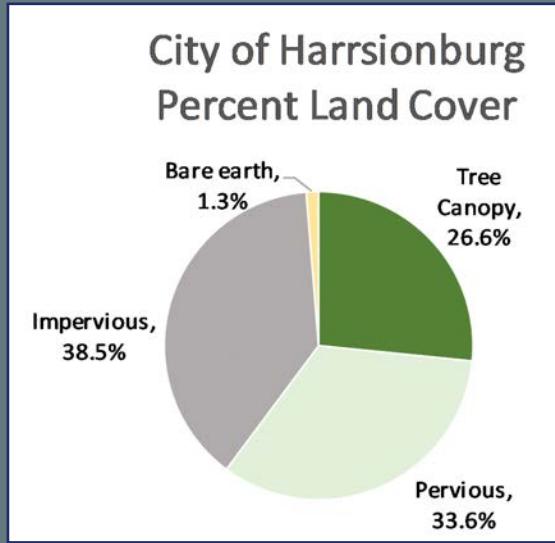
During an average high volume rainfall event in Harrisonburg (a 10-year storm), over 24 hours the city's trees are estimated to take up an average of 30 million gallons of water.

That's 45 Olympic swimming pools of water!

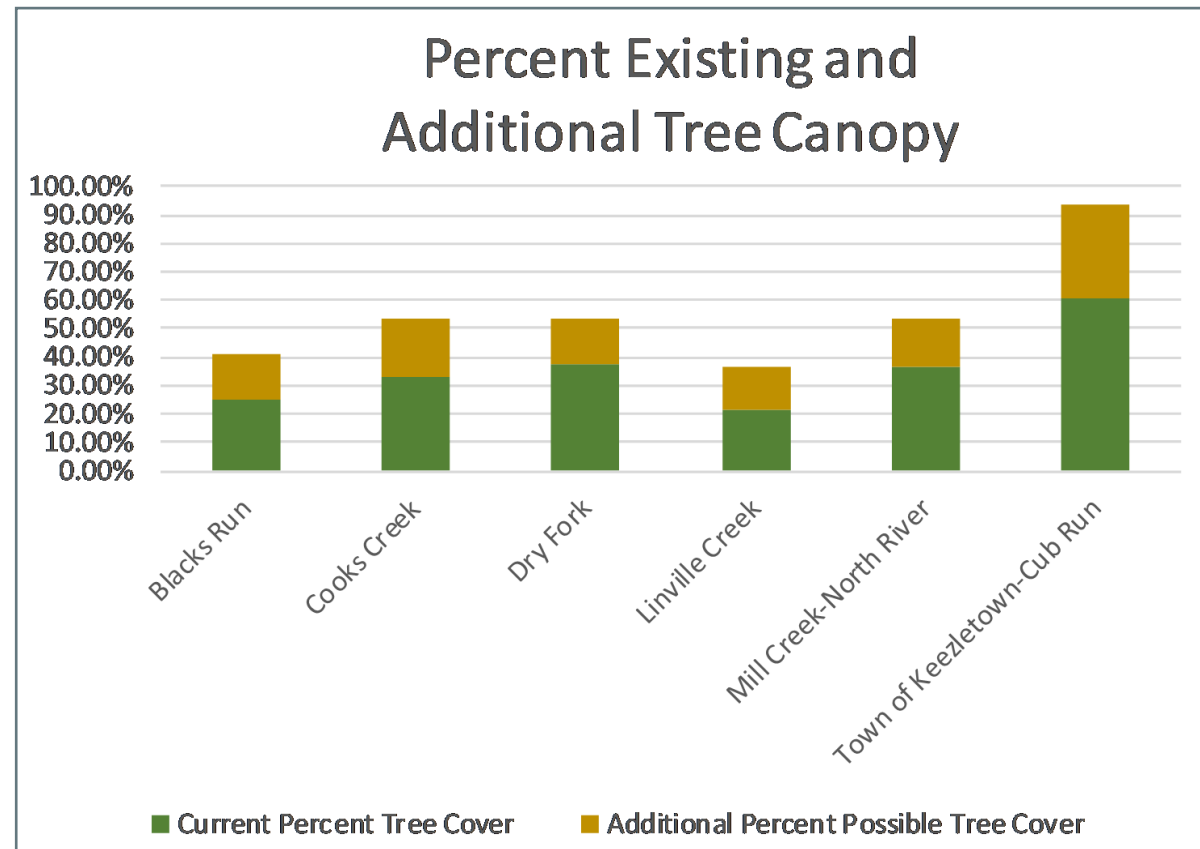
Harrisonburg: Fast Facts & Key Stats

- **Shenandoah Valley, a community in western Virginia.**
- **County:** Rockingham
- **2017 U.S. Census Population Estimate:** 54,215 people
- **City Area**
 - **Total area:** 17.45 sq. mi.
 - **Land:** 17.39 sq. mi.
 - **Water:**06 sq. mi.
 - **Streams:** 42.67 miles*
 - **Tree Canopy:** 2,946 acres (26.6%)

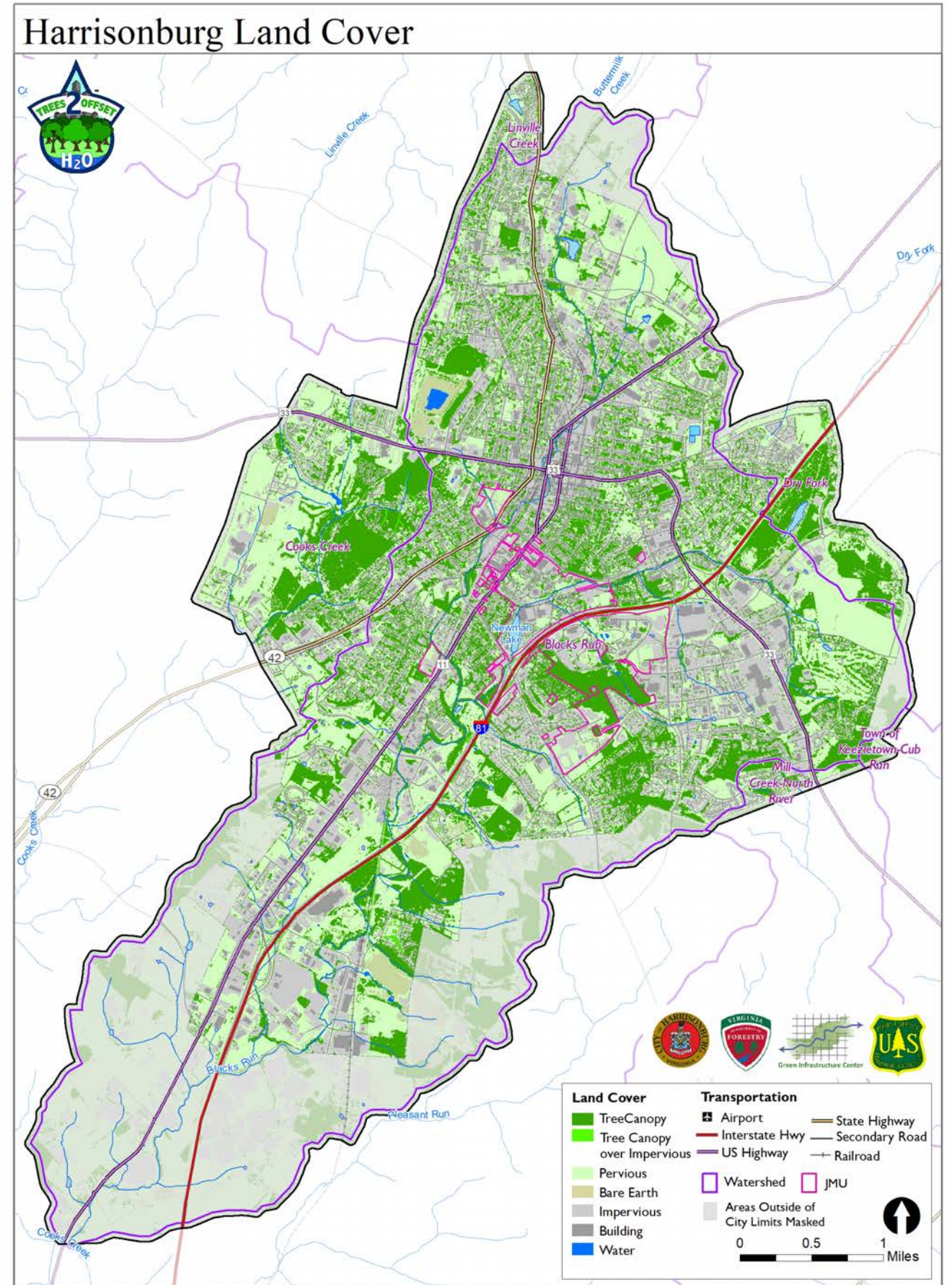
*Source: US Geological Survey



Citywide tree canopy is 26.6 percent.



Percent Tree Cover and Possible Planting Area by Watershed



This map shows the tree canopy of the city which covers 26.6 percent of the area.

WHY PROTECT OUR URBAN FORESTS?

Today, municipalities are losing their trees at an alarming rate, estimated at four million trees annually nationwide (Nowak 2010). This is due, in large part, to population growth. This growth has brought pressures for land conversion to accommodate both commercial and residential development. Cities are also losing older, established trees from the cumulative impacts of land development, storms, diseases, old age and other factors (Nowak and Greenfield 2012). At 26.6 percent canopy, Harrisonburg has only fair coverage by the urban forest, when compared to other Virginia cities.

Cities, such as Harrisonburg, have lost their natural forest cover as the city has grown. The city will continue to see losses in the future if replanting is not increased. As older trees die (or before they die), younger trees need to be planted to restore the canopy. In addition, Harrisonburg's ash trees are threatened by the Emerald Ash Borer; an Asian insect that is killing trees across Virginia. Harrisonburg is reinvigorating its urban forestry program to adopt best practices for urban forest management. For recommendations on how the city can better protect and manage its urban forests, see the Codes and Ordinances section of this report on page 23.

The purpose of this report is not to seek a limit on the city's development, but to help the city better utilize its tree canopy to manage its stormwater. Additional benefits of improved canopy include:

- cleaner air,
- aesthetic values,
- reduced heating and cooling costs,
- decreased urban heat island effects,
- buffering structures from wind damage,
- increased bird and pollinator habitat,
- fostering walkability and multimodal transportation; and,
- increased revenue from tourism and retail sales.



Assessment and inventory of trees is key to ensuring a healthy forest.



Emerald Ash Borer

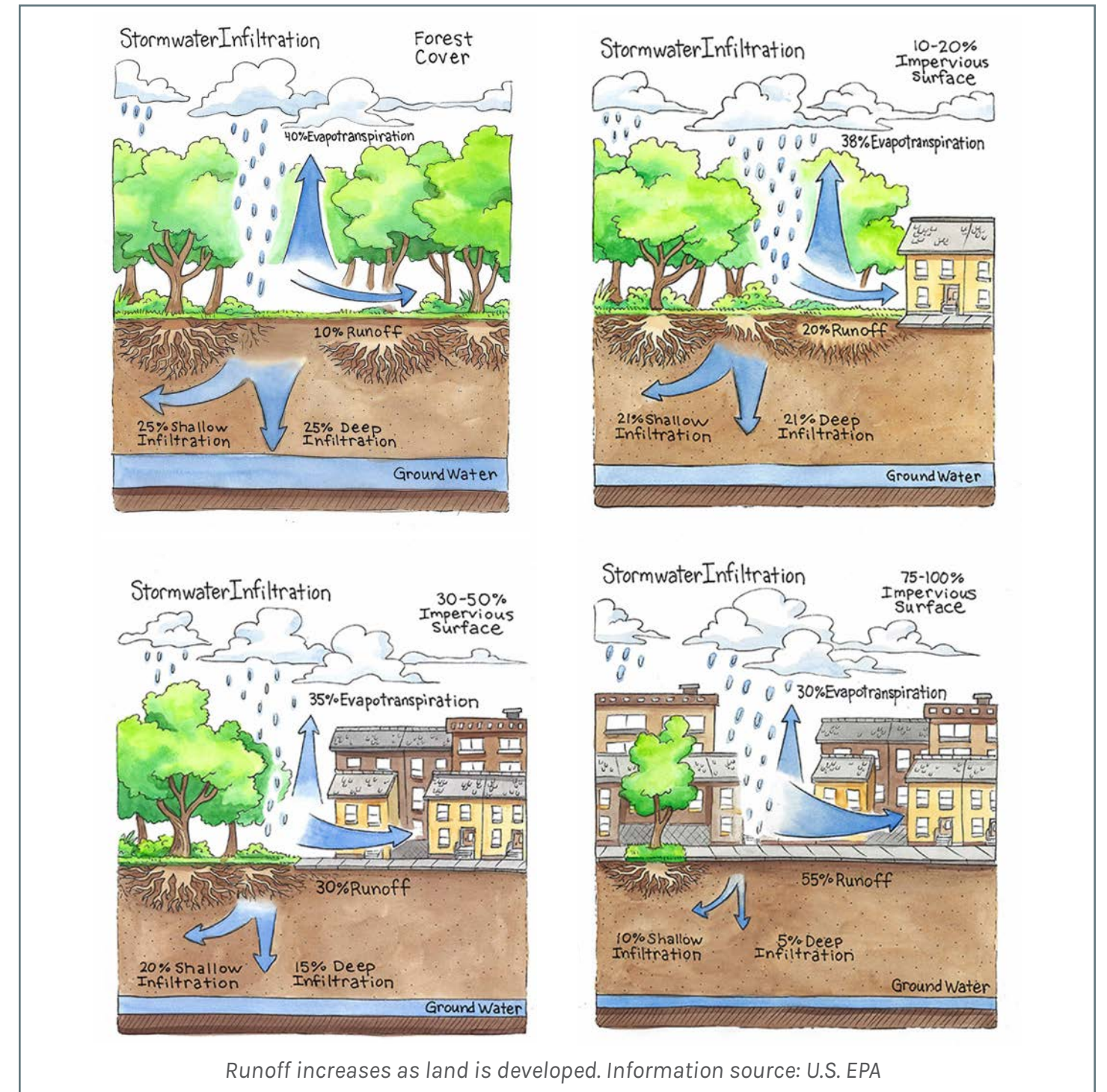


Neighborhood trees

According to the U.S. Environmental Protection Agency (EPA), excessive stormwater runoff accounts for more than half of the pollution in the nation's surface waters and causes increased flooding and property damages, as well as public safety hazards from standing water. The EPA recommends a number of ways to use trees to manage stormwater in the book *Stormwater to Street Trees*.

In evaluating runoff, the amount of imperviousness is one consideration; the other is the degree and type of forested land cover, since vegetation helps absorb stormwater and reduces the harmful effects of runoff. As their urban forest canopies have declined across the south, municipalities have seen increased stormwater runoff. Unfortunately, many cities do not have a baseline analysis of their urban forests or strategies to replace lost trees.

When forested land is converted to impervious surfaces, stormwater runoff increases. This increase in stormwater causes temperature spikes in receiving waters, increased potential for pollution of surface and ground waters and greater potential for flooding. When underground aquifers are not replenished, land subsides.



Another cause of canopy decline is the many recent powerful storms that have affected the Southeastern United States. This study was funded to address canopy decline by helping municipalities monitor, manage and replant their urban forests and to encourage cities to enact better policies and practices to reduce stormwater runoff and improve water quality.

It is not just development and storms that contribute to tree loss. Millions of trees are also lost as they reach the end of

their life cycle through natural causes. On average, for every 100 street trees planted, only 50 will survive 13-20 years (Roman et al 2014). Even in older developed areas with a well-established tree canopy, redevelopment projects may remove trees. Choosing the wrong tree for a site or climate, planting it incorrectly, or caring for it poorly can all lead to tree canopy loss. It is also important to realize that an older, well-treed neighborhood of today may not have good coverage in the future unless young trees – the next generation – are planted.

Excess impervious areas cause hot temperatures and runoff. Some older paved areas predate regulations requiring stormwater management.



Urbanizing counties and cities are beginning to recognize the importance of their urban trees because trees provide tremendous dividends. For example, urban canopy can reduce stormwater runoff anywhere from two to seven percent (Fazio 2010). According to Penn State Extension, during a one-inch rainfall event, one acre of forest will release 750 gallons of runoff, while a parking lot of the same size will release 27,000 gallons! This could mean an impact of millions of gallons during a major precipitation event. While stormwater ponds and other management features are designed to attenuate these events, they cannot fully replicate the pre-development hydrologic regime. In addition, as an older city, parts of Harrisonburg may lack stormwater management practices that are now required for new developments.

Trees filter stormwater and reduce overall flows. So planting and managing trees is a natural way to mitigate stormwater. Estimates from a Dayton, Ohio study found a seven percent reduction in stormwater runoff due to existing tree canopy coverage and a potential increase to 12 percent runoff reduction as a result of a modest increase in tree canopy coverage (Dwyer et al 1992). Conserving forested landscapes, urban forests, and individual trees allows localities to spend less money treating water through the municipal storm systems and also reduces flooding.

Each tree plays an important role in stormwater management. For example, based on the GIC's review of multiple studies of canopy rainfall interception, a typical street tree's crown can intercept between 760 gallons to 3000 gallons per tree per year, depending on the species and age. If a community were to plant an additional 5,000 such trees, the total reduced runoff per year could amount to millions of gallons of reduced runoff. This means less flooded neighborhoods and reduced stress on storm drainage pipes and decreased runoff into the city's streams.

Another compelling fiscal reason for planning to conserve trees and forests as a part of a green infrastructure strategy is minimizing the impacts and costs of natural disasters. Not only do trees reduce the likelihood of extensive flooding, they also serve as a buffer against storm damages from wind.

In urban areas, Geographic Information Systems (GIS) software is used to map the extent of the current canopy as well as to estimate how many new trees might be fitted into an urban landscape. A Possible Planting Area (PPA) map estimates areas that may be feasible to plant trees. A PPA map helps communities set realistic goals for what they could plant (this is discussed further on in the Methods Appendix).



Tree Planting in Harrisonburg



Trees in residential yards also help to soak up rainfall.

ADDITIONAL URBAN FOREST BENEFITS

Quality of Life Benefits

During Virginia's hot summers, more shade is always appreciated. Tree cover shades streets, sidewalks, parking lots, and homes, making southern urban locations cooler, and more pleasant for walking or biking. Trees absorb volatile organic compounds and particulate matter from the air, improving air quality, and thereby reducing asthma rates. Shaded pavement has a longer lifespan thereby reducing maintenance costs associated with repairing or replacing roadways and sidewalks (McPherson and Muchnick 2005).

Communities with greener landscapes benefit children by reducing both asthma and ADHD symptoms.

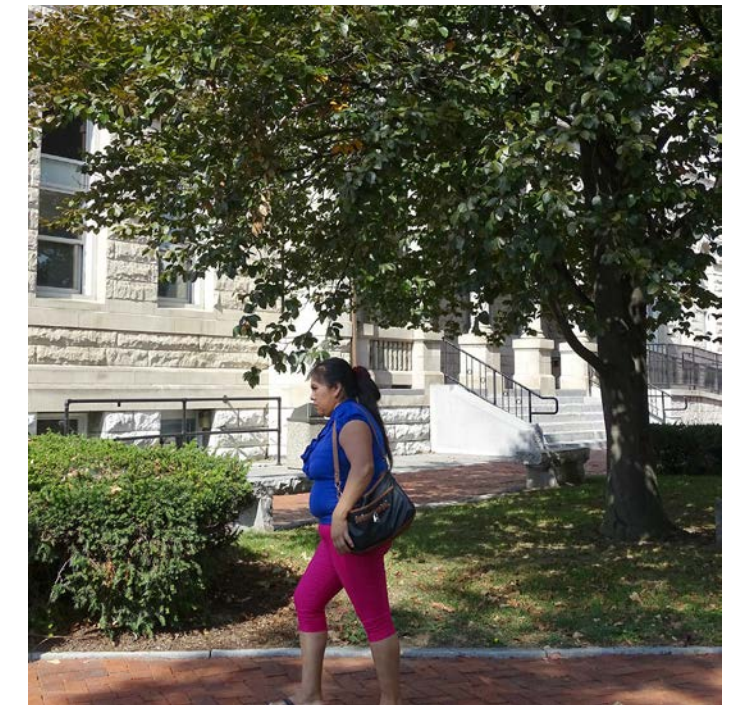


This tree has enough room to grow.



Trees provide substantial shade and beauty.

Children who suffer from Attention Deficit Hyperactivity Disorder (ADHD) benefit from living near forests and other natural areas. One study showed that children who moved closer to green areas have the highest level of improved cognitive function after the move, regardless of level of affluence (Wells 2000). Thus, communities with greener landscapes benefit children and reduce ADHD symptoms. Trees also cause people to walk more and walk farther. This is because when trees are not present, distances are perceived to be longer and destinations farther away, making people less inclined to walk than if streets and walkways are well treed (Tilt, Unfried and Roca 2007).



Well treed areas encourage people to walk.

Economic Benefits

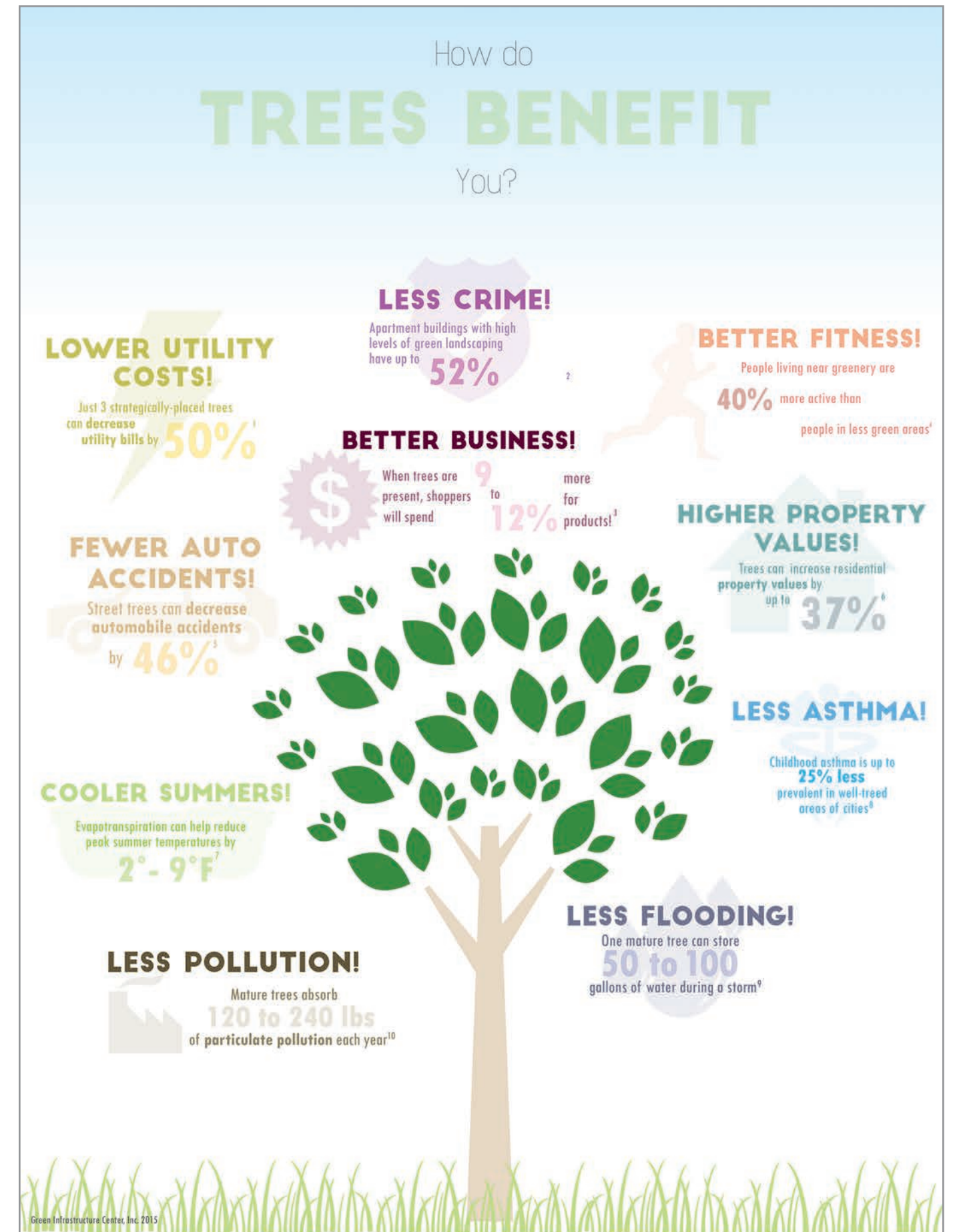
Developments that include green space or natural areas in their plans sell homes faster and for higher profits than those that take the more traditional approach of building over an entire area without providing for community green space (Benedict and McMahon 2006). This desire for green space is supported by a National Association of Realtors study which found that 57 percent of voters surveyed were more likely to purchase a home near green space and 50 percent were more willing to pay 10 percent more for a home located near a park or other protected area. A similar study found that homes adjacent to a greenbelt were valued 32 percent higher than those 3,200 feet away (Correll et al. 1978).

Meeting Regulatory Requirements

Trees also help meet the requirements of the Clean Water Act. The Clean Water Act requires Virginia to have standards for water quality. When waters are impaired they may require establishment of a Total Maximum Daily Load (TMDL) standard and a clean-up plan (i.e., Best Management Action Plan) to meet water quality standards. Since a forested landscape produces higher water quality by cleaning stormwater runoff (Booth et al 2002), increasing forest cover results in less pollutants reaching the city's surface and ground waters. Two thirds of Virginia, including Harrisonburg, are under the Chesapeake Bay TMDL and must follow the bay's Watershed Implementation Plan (WIP) to reduce the loadings of nitrogen, phosphorus and sediment reaching the Bay. The Chesapeake Bay Program has adopted a standard for tree planting to provide credit for the WIP. See Appendix D for an explanation of how to use the credit.



There are many places where trees can be added for shade and beauty.



DEVELOPMENT AND STORMWATER

As an older city, a significant amount of the city's developed area pre-dates the 1987 Clean Water Act Amendments which require the treatment of stormwater runoff. Adding stormwater treatment for older areas is achieved by either retrofitting stormwater best management practices into the landscape, or adding them as properties are re-developed. Adding more trees is a best management practice that provides other benefits beyond stormwater uptake, such as shade, air cleansing and aesthetic values. Recommendations for improvements to better utilize trees to manage stormwater and to reduce imperviousness are found in the Codes, Policies and Practices section of this report. A Stormwater Improvement Plan was developed by the city in 2017 that identifies urban tree canopy as a potential water quality best management practice suitable for Harrisonburg. This program could yield pollutant removal for the city although it should be matched with other more cost-effective pollutant removal efforts.

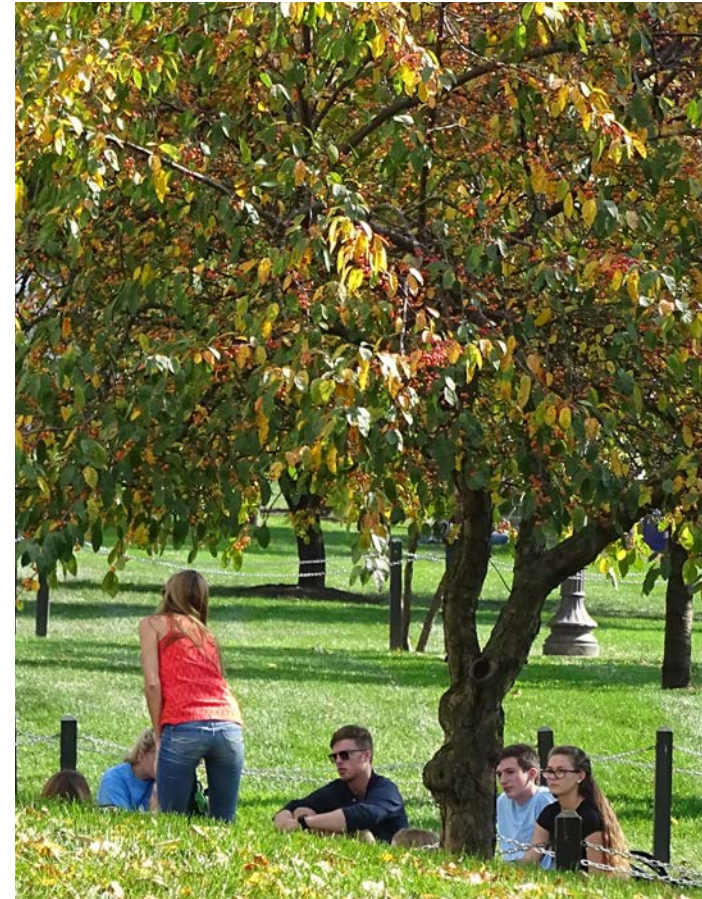


New developments require stormwater management such as ponds to hold and filter runoff.



Earth Day plantings with Landscape Manager, Mike Hott.

Reducing imperviousness and increasing vegetation are two ways to ease the frequency of flooding because this limits the amount of water that needs to be drained by the storm drainage system. Vegetation reduces water entering the stormwater system by intercepting, capturing and transpiring that water.



Trees provide places to gather.



Residents can make a difference in runoff by planting trees and other vegetation to soak up runoff.

ANALYSIS PERFORMED

This project evaluated options for how to best model stormwater runoff and uptake by the city's tree canopy. Its original intended use was for planning at the watershed scale for tree conservation. An example is provided on page 17. However, new tools created for the project allow the stormwater benefits of tree conservation or additions as to be calculated at the site scale as well.

As noted, trees intercept, take up and slow the rate of stormwater runoff. Canopy interception varies from 100 percent at the beginning of a rainfall event to about three percent at the maximum rain intensity. Trees take up more water early on during storm events and less water as storm events proceed and the ground becomes saturated (Xiao et al. 2000). Many forestry scientists, as well as civil engineers, have recognized that trees have important stormwater benefits (Kuehler 2017, 2016). See diagram of tree water flow below.

METHOD TO DETERMINE WATER INTERCEPTION, UPTAKE AND INFILTRATION

Currently, most cities use TR-55 curve numbers developed by the Natural Resources Conservation Service (NRCS) to model expected runoff amounts. The city can use the modified TR55 curve numbers (CN) from this study that include a factor for canopy interception. This project is also a tool for setting goals at the watershed-scale for planting trees and for evaluating consequences of tree loss as it pertains to stormwater runoff. The chart shows the canopy breakdown by watersheds. Blacks Run is the largest watershed in the city, spanning from the headwaters in the north all the way to the south end of the city.

This study used modified TR-55 curve numbers to calculate stormwater uptake for different land covers, since they are widely recognized and understood by stormwater engineers. Curve numbers produced by this study can be utilized in the city's modeling and design reviews. The project's spreadsheet calculator tool makes it very easy for the city to change the curve numbers, if desired. A canopy interception factor is added to account for the role trees play in interception of rainfall based on location and

Watersheds in Harrisonburg	Percent Tree Canopy Within City Limits
Blacks Run	24.9%
Cooks Creek	33.4%
Dry Fork	37.1%
Linville Creek	21.1%
Mill Creek - North River	36.5%
Town of Keezletown - Club Run	61.0%

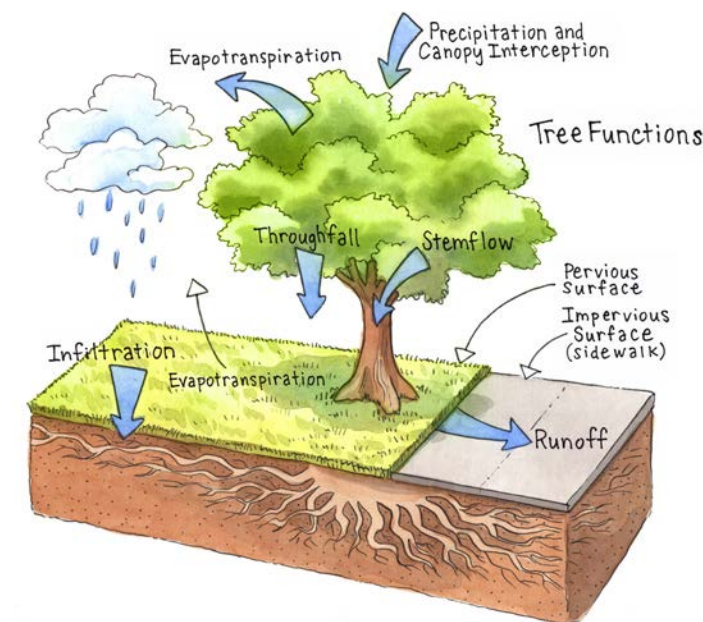
planting condition (e.g. trees over pavement versus trees over a lawn or in a forest).

Tree canopy reduces the proportion of precipitation that becomes stream and surface flow, also known as water yield. In a study, Hynicka and Divers (2016) modified the water yield equation of the NRCS model by adding a canopy interception term (C_i) to account for the role that canopy plays in capturing stormwater, resulting in:

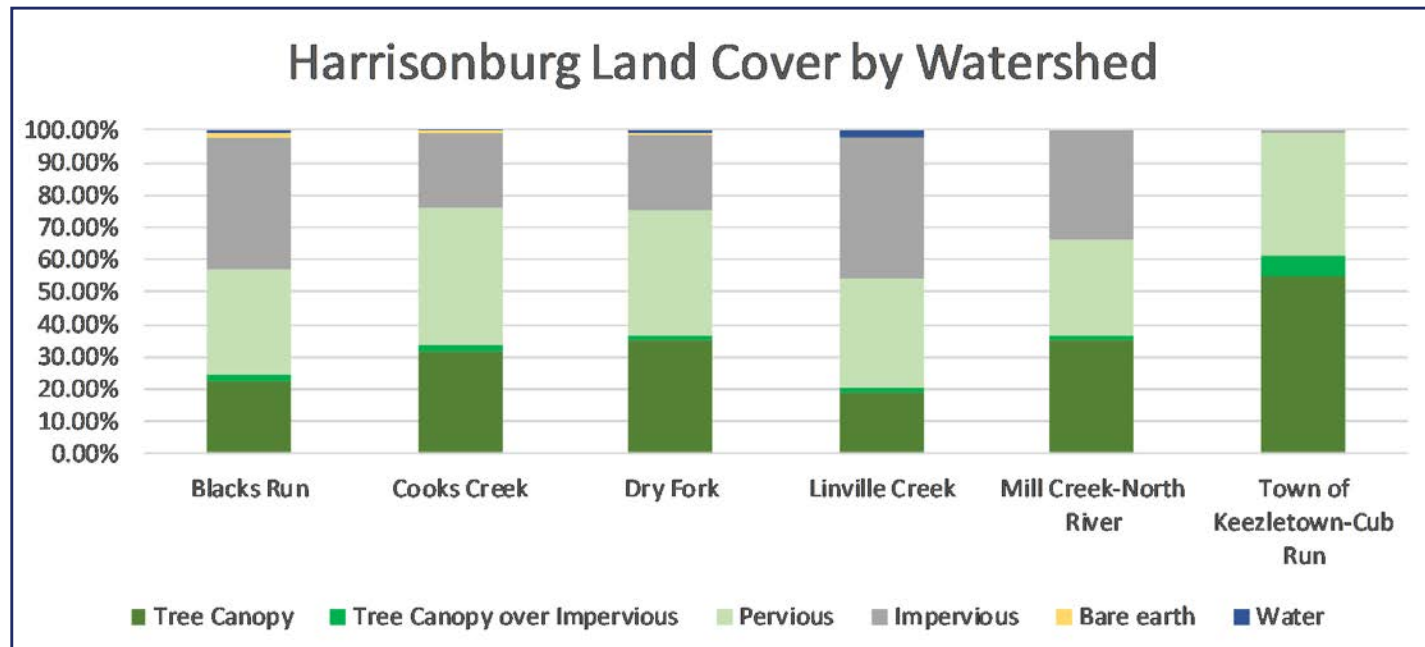
$$R = \frac{(P - C_i - I_a)^2}{(P - C_i - I_a) + S}$$

Where R is runoff, P is precipitation, I_a is the initial abstraction for captured water, which is the fraction of the storm depth after which runoff begins, and S is the potential maximum retention after runoff begins for the subject land cover ($S = 1000/CN - 10$). Major factors determining CN are:

- The hydrologic soil group (defined by surface infiltration rates and transmission rates of water through the soil profile, when thoroughly wetted)
- Land cover types
- Hydrologic condition – density of vegetative cover, surface texture, seasonal variations
- Treatment – design or management practices that affect runoff



Trees and the Water Cycle



What is new about the calculator tool is that the curve numbers relate to the real land cover conditions in which the trees are found. In order to use the equation and model scenarios for future tree canopy and water uptake, the GIC first developed a highly detailed land cover analysis and an estimation of potential future planting areas, as described following. These new land cover analyses can be used for many other projects, such as looking at urban cooling, walkability (see map of street tree coverage on following pages), trail planning and for updating the comprehensive plan.

The actual model spreadsheet was provided to Harrisonburg. It links to the land cover statistics for each type of planting area. It also allows the city to hypothetically add or reduce tree canopy to see what are the effects for stormwater capture or runoff. The key finding from this work is that removal of mature trees generates the greatest impacts for stormwater runoff. As more land is re-developed in Harrisonburg, the city should maximize tree conservation for maintenance of surface water quality and groundwater recharge. This will also benefit the city's quality of



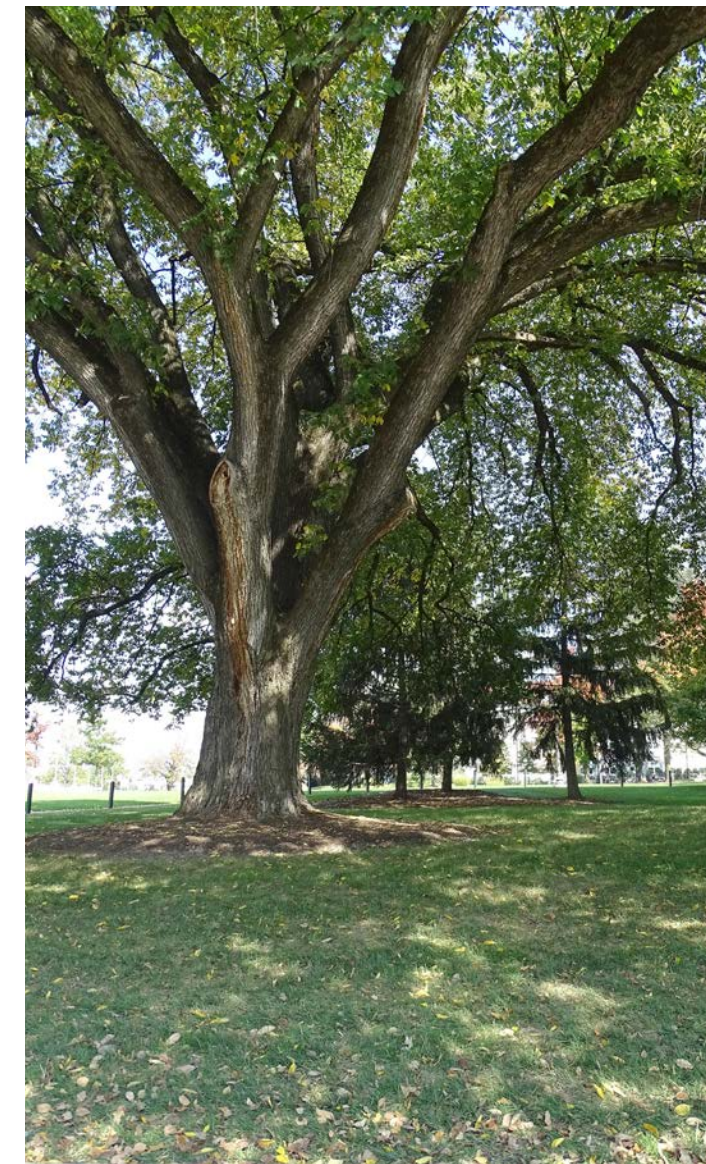
The key finding from this work is that removal of mature trees generates the greatest impacts for stormwater runoff.

life by fostering clean air, walkability, and attractive residential and commercial districts. Several studies have shown that higher tree canopy percentage is associated with lower overall hospitalization numbers and also with lower hospital visits from asthma.

The stormwater runoff model provides estimates of precipitation capture by tree canopy and the resulting reductions in runoff yield. It takes into account the interaction of land cover and soil hydrologic conditions. It can also be used to run 'what-if' scenarios, specifically losses of tree canopy from development and increases in tree canopy from tree planting programs.

An example of how this modeling tool can be used for watershed-scale forest planning is indicated following. The trees and stormwater model can be used to estimate the impact of the current canopy, possible losses to that canopy, and potential for increasing that canopy. As shown below, for a 10-year,* 24-hour storm, a loss of 10 percent of the urban tree canopy would increase runoff by 5.8 million gallons, while increasing canopy coverage from the current 27 to 30 percent will decrease runoff by almost 2.4 million gallons for that storm event.

This new approach allows for more detailed assessments of stormwater uptake based on the landscape conditions of the city's forests. It distinguishes whether the trees are within a tree cluster, a lawn setting, a forested wetland or over pavement, such as streets or sidewalks. Tree setting is considered because the conditions in which the tree is living affect the amount of water the tree can intercept. The amount of open space around the tree and the condition and type of surface soils affect the infiltration of water. In order to determine these conditions, a detailed land cover assessment was performed as described following. The analysis can be used to create plans for where adding trees or better protecting them can reduce stormwater runoff impacts and improve water quality.



Harrisonburg, VA Urban Tree Canopy Stormwater Model version October 18, 2018																
The Green Infrastructure Urban Tree Canopy Stormwater Model estimates stormwater runoff yields for current and potential land cover. The methodology is based upon the NRCS TR-55 method for small urban watersheds. It is used to provide better estimates using GIC's high-resolution land cover and modeling of potential canopy area.																
TOTALS																
		26.6%	38.4%	29.7		5.8	-	26.6%	Variable							Variable
		Statistics by Drainage Basin (current settings)						Variable			Variable					
Area	Current Tree Cover	Current Impervious Cover	Tree H2O Capture	Increased H2O w/xx% tree loss	Added H2O Capture w/xx% PPA	Tree Cover Goal	Pick an Event	Pick a loss scenario	Converted Land	Canopy Added	Enter % to be planted					
	%	%	million gallons	million gallons	million gallons	%	Event	% UTC loss	% FOS Loss	% Imperv	PCA	PPA	% of Land	% of PPA		
1 Blacks Run	24.9%	41.6%	22.18	4.74	-	25%	10 yr / 24 hour	10%	0%	40%	40.9%	15.9%	0.0%	0%		
2 Cooks Creek	33.4%	23.3%	6.02	0.71	-	33%	10 yr / 24 hour	10%	0%	40%	53.2%	19.8%	0.0%	0%		
3 Dry Fork	37.1%	23.4%	1.18	0.24	-	37%	10 yr / 24 hour	10%	0%	40%	53.7%	16.6%	0.0%	0%		
4 Linville Creek	21.1%	44.4%	0.16	0.08	-	21%	10 yr / 24 hour	10%	0%	40%	36.4%	15.3%	0.0%	0%		
5 Mill Creek-North River	36.5%	34.2%	0.28	0.05	-	36%	10 yr / 24 hour	10%	0%	40%	53.5%	17.0%	0.0%	0%		
6 Town of Keezletown-C	61.0%	0.7%	(0.08)	0.00	-	61%	10 yr / 24 hour	10%	0%	40%	93.9%	32.9%	0.0%	0%		

The calculator tool developed for this project allows the city to see the water uptake by existing canopy and model impacts from changes, whether positive (adding trees) or negative (removing trees).

* A 10-year storm refers to the average recurrence interval, or a 10 percent chance of that level of rainfall occurring.

LAND COVER, POSSIBLE PLANTING AREA, POSSIBLE CANOPY AREA ANALYSIS

The land cover data were created using 2016 leaf-on imagery from the National Agriculture Imagery Program (NAIP) distributed by the USDA Farm Service Agency. Ancillary data for roads (from Harrisonburg government), and hydrology (from National Wetlands Inventory and National Hydrography Dataset) were used to determine:

- 1) Tree cover over impervious surfaces, which otherwise could not be seen due to these features being covered by tree canopy; and
- 2) Wetlands not distinguishable using spectral/feature-based image classification tools.

In cities studied for this project, forested open space was identified as areas of contiguous tree canopy greater than one acre, not intersected by buildings or paved surfaces.

The final classification of land cover consists of six classes listed below. The Potential Planting Area (PPA) is created by selecting the land cover features that have space available for planting trees (i.e., areas where the growth of a tree will not affect or be affected by existing infrastructure). Of the seven land cover classes, only pervious (grass and scrub vegetation) is considered for PPA.

- Tree Canopy
- Tree Canopy over Impervious
- Pervious
- Impervious
- Bare earth
- Water

Next, these eligible planting areas are limited based on their proximity to features that might either interfere with a tree's natural growth (such as buildings) or places a tree might affect



Adding more canopy can help alleviate flooding.

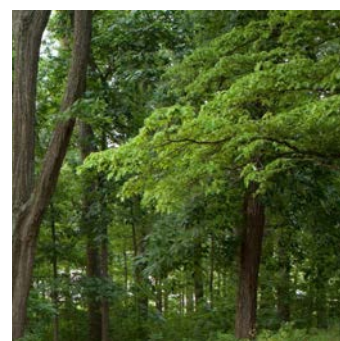


This shows what is currently treed (green) and areas where trees could be added (orange).

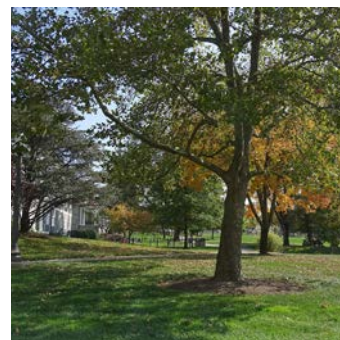
the feature itself such as power lines, sidewalks or roads. Playing fields and other known land uses that would not be appropriate for tree cover are also avoided. However, there may be some existing land uses (e.g., soccer fields or golf courses) that are unlikely to be used for tree planting areas, but that may not have been excluded from the PPA. In addition, the analysis did not take into account proposed future developments (e.g., planned developments) that would not likely be fully planted with trees. Therefore, the resulting PPAs represent the maximum potential places trees can be planted and grow to full size. A good rule is to assume about half the available space could be planted with trees.



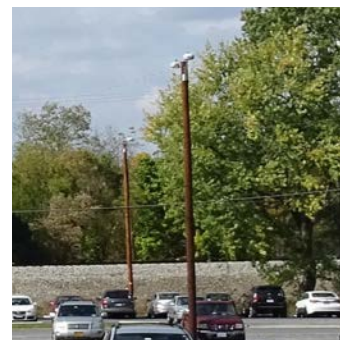
Tree over street



Trees over forest

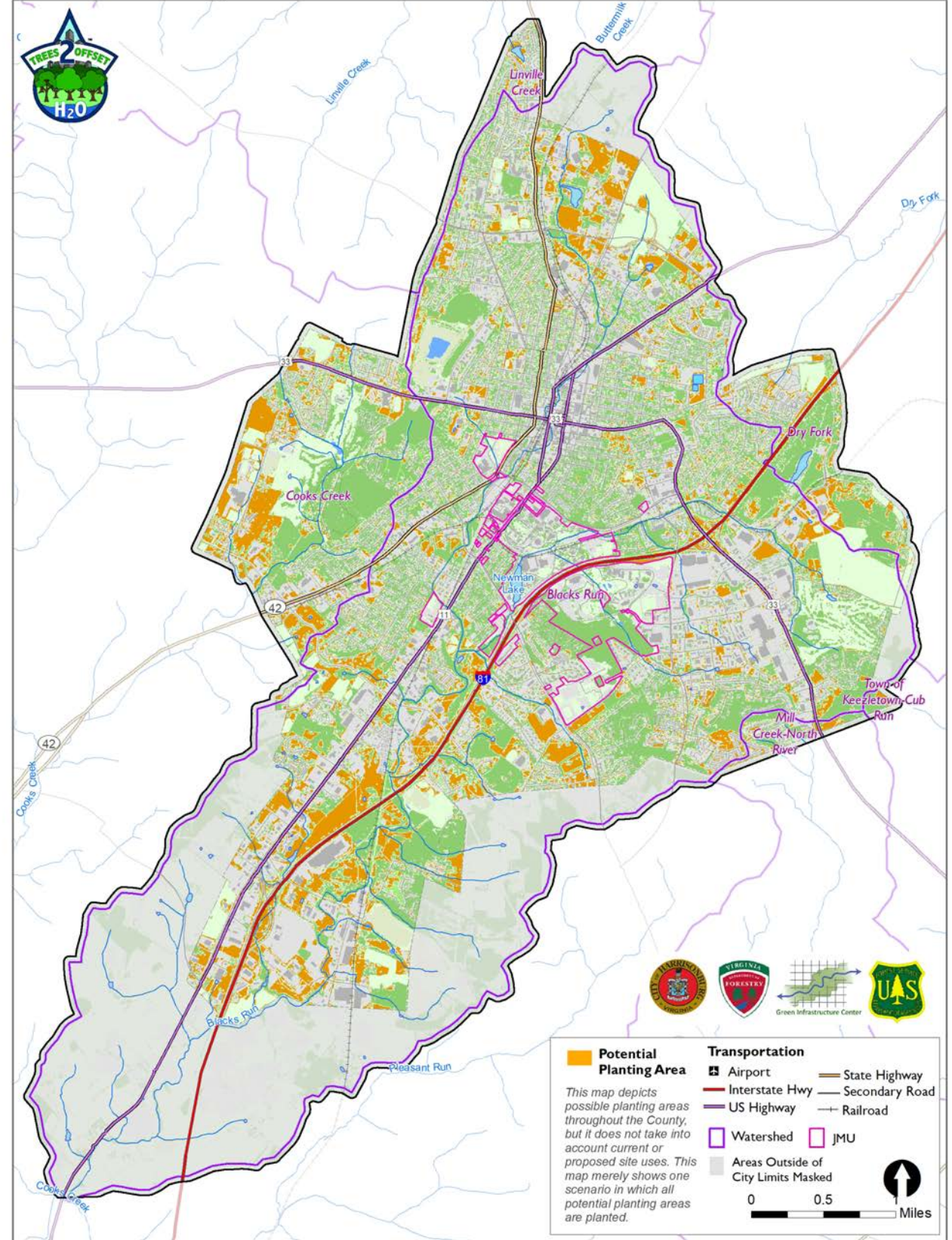


Tree over lawn



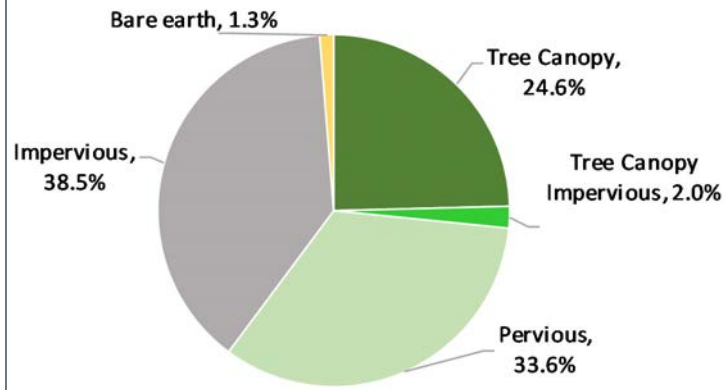
Tree over parking lot

Harrisonburg Potential Planting Area

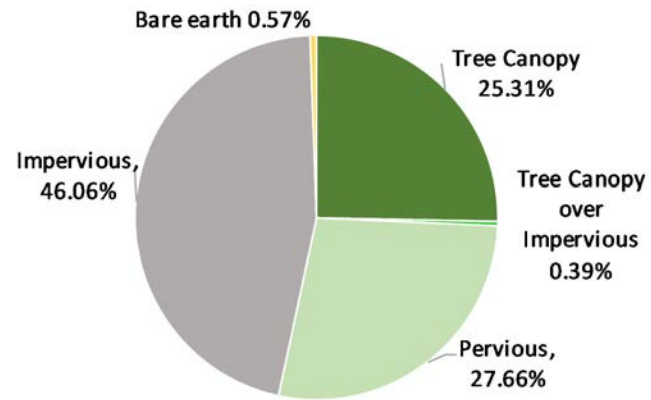


Potential Planting Area (PPA) shown in orange depicts areas where it may be possible to plant trees. All sites would need to be confirmed in the field and may be on private or public lands.

Percent Land Cover - City Limits



Percent Land Cover - JMU



These pie charts show the land cover divided by tree setting for the entire city and for James Madison University.



Potential Planting Spots (PPS)



Potential Canopy Area (PCA)

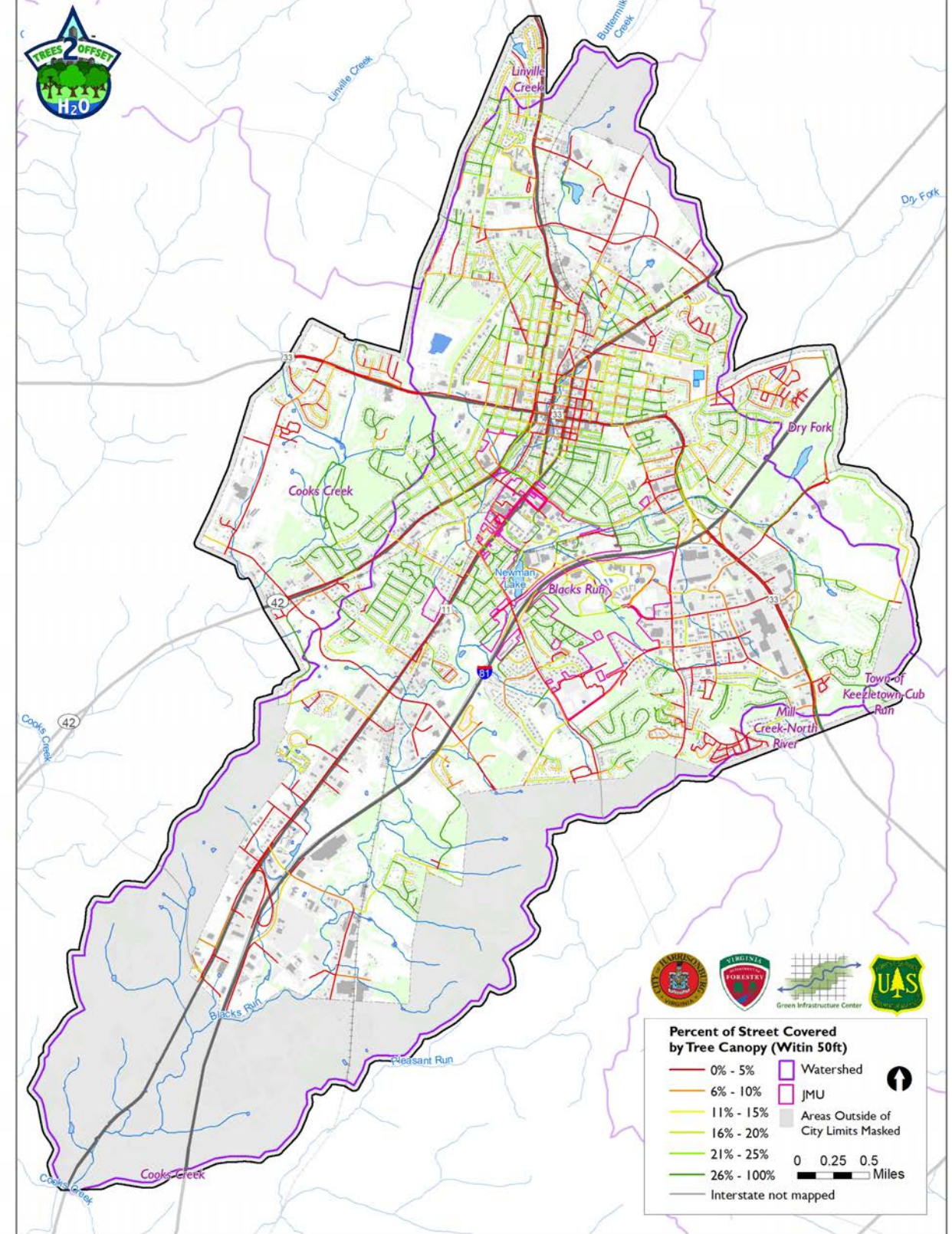
The Potential Planting Spots (PPS) are created from the PPA. The PPA is run through a GIS model that selects those spots where a tree can be planted depending on the size of trees desired. For this analysis, expected sizes of both 20 ft. and 40 ft. diameter of individual mature tree canopy were used with priority given to 40 ft. diameter trees (larger trees have more benefits). It is expected that 30 percent overlap will occur as these trees reach maturity. The result demonstrates a scenario where, if planted today, once the trees are mature, their full canopy will cover the potential planting area and overlap adjacent features, such as roads and sidewalks.



The Potential Canopy Area (PCA) is created from the PPS. Once the possible planting spots are selected, a buffer around each point that represents a tree's mature canopy is created. Similarly, the tree buffer radius is 20 ft. or 40 ft. diameter canopy for each tree. These individual tree canopies are then dissolved together to form the potential overall canopy area.

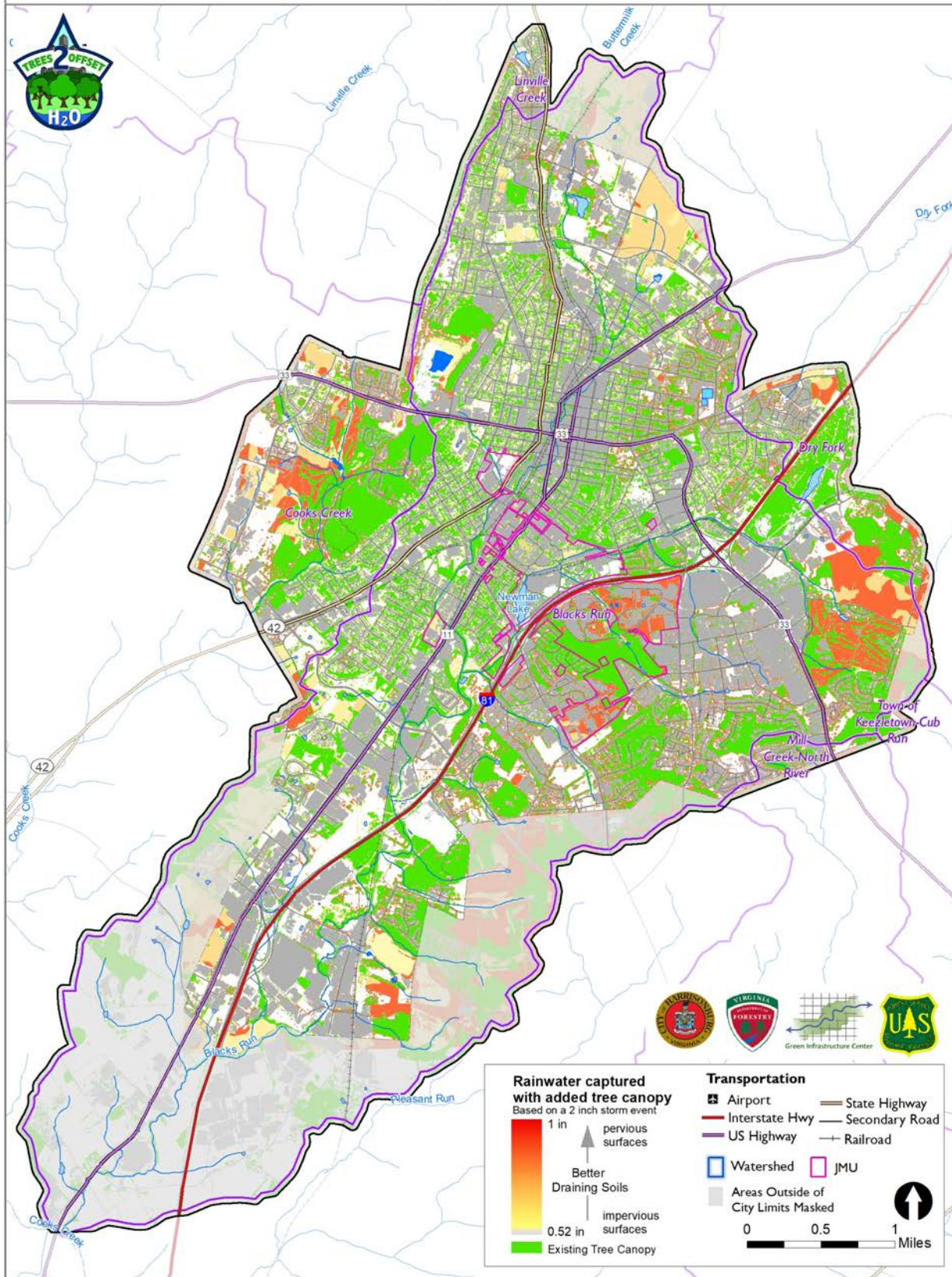
Percent Street Trees is calculated using the Land Cover Tree Canopy and road centerlines, which are buffered to 50 ft. from each road segment's centerline. The percent value represented is the percentage of tree cover within that 50 ft. buffer.

Harrisonburg Percent Street Tree Canopy



The street trees map shows which streets have the most canopy (dark green) and which have the least (red). Streets lacking good coverage can be targeted for planting to facilitate uses, such as safe routes to school or beautifying a shopping district.

Harrisonburg Optimal Tree Planting Locations for Stormwater Infiltration



This map shows where tree planting will yield the greatest benefits for stormwater infiltration (darkest orange).

See the Appendix A for more details on technical details for mapping.

CODES, ORDINANCES AND PRACTICES REVIEW

This review is designed to determine which practices make the city more impervious (e.g. too much parking required) and which make it more pervious (e.g. conserving trees or requiring open spaces). Documents reviewed during the codes, ordinances and practices analysis for the project include relevant sections of the city's current code that influence runoff or infiltration. Data were gathered through analysis of city codes and policies, as well as interviews with city staff, whose input was incorporated directly on the spreadsheet summary prepared by the GIC. The spreadsheet provided to the city lists all the codes reviewed, interviews held and relevant findings. GIC also provided the city with a more detailed memo "Maximizing Stormwater Benefits Using GI in Harrisonburg VA: A Codes and Ordinances Audit for Integrating Trees into Stormwater Management Programs and Reducing Imperviousness" which offers additional ideas for improvement.

EVALUATION AND RECOMMENDATIONS

Points were assigned to indicate what percentage of urban forestry and planning best practices have been adopted to date by the city. The spreadsheet tool created for city codes can also serve as a tracking tool and to determine other practices or policies the city may want to adopt in the future to strengthen the urban forestry program or to reduce impervious land cover. A final report comparing all studied localities will be issued by GIC in 2019.

Harrisonburg invests staff time and funds to manage its urban forest. The city just re-enrolled in the Tree City USA program as a 'Tree City USA' by the Arbor Day Foundation, which means that it spends adequate funds per capita on tree care, it has a tree ordinance, and it practices tree management. The city currently has one arborist on staff in the Parks and Recreation Department.

The recommendations provided in this report are a way to increase the protections for, and size of, the urban forest in Harrisonburg. As noted earlier, the city's canopy is only 26.6 percent and it is not distributed equally citywide. Even just maintaining this level of coverage will require new plantings annually. Harrisonburg is one of 12 localities in a six-state area of the Southeastern U.S. to be studied and the eighth to be completed. As other places are studied, they will be compared to the city, and vice versa.



The tree planting team.



Arbor Day, celebrated annually, includes tree planting and community education.



Top recommendations to improve forest care and coverage in Harrisonburg listed in priority order include the following:

- 1) **Create an Urban Forestry Division and hire staff for urban forestry community outreach and enforcement.** Municipal arborists and foresters educate community members about trees, care for city-owned trees, educate developers and landowners in caring for privately owned trees, and work in collaboration with planners, engineers, and GIS staff to plan for the future urban tree canopy. Arborists and foresters are essential to any urban forestry program, regardless of municipality size, to ensure the canopy is well cared for. Although the city has an arborist on staff, GIC recommends hiring additional staff to carry out an urban forestry program.
- 2) **Use the GIC's stormwater uptake calculator to determine the benefits of maintaining or increasing tree canopy goals by watershed and to set urban forestry goals.** The calculator provided to Harrisonburg allows the city to determine the stormwater benefits or detriments (changes in runoff) from adding or losing trees and calculates the pollution loading reductions for nitrogen, phosphorus, and sediment. Once tree canopy goals are established, city staff can also determine if tree plantings can be used to meet the new urban tree planting BMPs for the Chesapeake Bay TMDL (for more see Appendix D).
- 3) **Use the urban forestry budget calculator to determine funds needed to achieve tree planting goals.** Planting and maintaining more trees costs additional money, but is well worth the outcomes for ecosystem services provided by trees. The city should determine the goal for its tree canopy coverage level and allocate funds to achieve it over time.
- 4) **Conduct a land cover assessment every four years to determine and allow for comparison of tree canopy coverage change over time.** Keeping tree canopy coverages at levels that promote public health, walkability, and groundwater recharge is vital for livability and meeting state water quality standards. Regular updates to land cover maps allow for this analysis and planning to take place.
- 5) **Develop codes/ordinances that regulate and protect both privately and publicly owned trees.** The majority of Harrisonburg's urban forest is privately owned. Protection of the urban forest can only be accomplished through regulation of both private and publicly owned trees. The city can require permits for tree removals on private lands and provide additional standards for protecting trees on public properties and other publically managed spaces.

- 6) **Perform tree risk assessments and increase assessment intervals in densely populated portions of the city.** Tree risk assessments help proactively manage the urban forest. Diseased or damaged trees can be pruned, treated or, if necessary, removed to ensure public safety. Tree risk assessments are typically performed only on public properties. However, city staff may recommend homeowners hire an arborist to assess risk on trees of concern on private property. For those trees that may fall onto a public space or right of way, the city can require that the tree at risk be maintained or removed for public safety.
- 7) **Work with developers to shrink the development footprint to minimize impervious surface.** Holding a pre-development conference allows all parties to explore ideas for tree conservation before extensive funds are spent on land planning. For example, parking lots can be reduced in size depending on the permitted land uses and building can be built higher, rather than wider. Variable space sizing is another way to shrink surface parking lots while still meeting demand.



This split trunk signals a danger of failure.

- 8) **As part of the development process, require inventory of hardwood trees 18" diameter at breast height (DBH) and over, softwood trees 24" DBH and over, and understory trees 8" DBH and over on private property.** Tree protection begins with tree inventory. A tree inventory contains information about the type, age, and caliper of existing trees on a site. Impose tree inventory requirements for lands proposed for development.
- 9) **During construction, ensure enforcement of best management practices for public and privately**

owned trees that have been designated for protection. Trees are often lost during construction due to damage from construction equipment, soil compaction, root loss etc. Enforcing best management practices during construction includes requiring a standard tree protection zone of 1.5' per 1" tree DBH for trees designated for protection on the site plan, using root pruning where appropriate, and using root matting to protect pore spaces in soil can all help save more trees during the development process. More trees on a site post development translates to higher property values and lower vacancy rates.

- 10) **Hold inter-departmental meetings about proposed projects to discuss and minimize site conflicts resulting in excess tree loss.** Often, requirements such as curb/gutter, sidewalks, driveways, parking pads, etc. require tree removals. Many of these requirements are managed by city departments such as Planning and Community Development and Public Works. As requirements are managed by more than one department, inter-departmental communication is a critical component of achieving a site designs which minimize tree canopy coverage loss and maximize livability and connectivity of habitats.
- 11) **Develop an Urban Forest Management Plan (UFMP) for the city.** Include the current condition of the urban forest, the current maintenance costs, and options to achieve the urban tree canopy coverage goals. A UFMP details a vision for urban tree canopy. It meshes local government and community interests to proactively manage the urban canopy and provide long term benefits. The city should develop an UFMP which describes the condition of the urban forest, the current maintenance costs, the urban tree canopy coverage goals and how they can be achieved.
- 12) **Determine urban forestry data needs and which software will best collect urban forestry data and implement data collection to inform the urban forestry program.** Monitoring urban forest composition and health is necessary for maintaining a thriving urban forest that serves both people and wildlife. Urban forest technologies exist which make data collection far less arduous than it was in the past. Use of these software systems allow urban forest managers to make data informed decisions.
- 13) **Permit the use of bioswales instead of curb and gutter in appropriate areas of the city.** Bioswales allow for infiltration of stormwater and can beautify a city. Bioswales are recessed planting beds filled with a filter media and amended soils and plants that are designed to infiltrate and clean stormwater. Trees can be used in bioswales to soak up, clean and transpire stormwater. Use bioswales along roads instead of curb and gutter when possible.

- 14) **Prioritize essential urban forestry maintenance activities and develop a contingency budget.** The city should work towards approval of an urban forestry maintenance and contingency budget. During economic downturns, urban forestry often is one of the first programs to be cut from a municipal budget. To ensure funds remain in the budget, the city should set aside a contingency budget which funds maintenance for critical tree care activities, such as watering and emergency and risk management, to be carried out while less critical items, such as sucker pruning, are allowed to be completed at a later date. Some cities, such as Lynchburg, engage trained citizens to prune city trees.
- 15) **Assign or hire a staff member whose job responsibilities include management of urban forestry and conservation activities grants as half of their staff time.** Grants can fund urban tree projects such as planting and performing GIS analysis. Partial staff time devoted to grant management can allow completion of urban forestry projects that may otherwise not be funded by the municipality.
- 16) **Develop a Harrisonburg Tree Stewards group.** Provide this group with resources and guidance and allow the public help build and maintain the urban forest. Tree Stewards are a vital part of any municipality's urban forestry program. They can carry out tree planting projects, provide tree care trainings, and increase the public's awareness of the value and care of trees. Expand the existing Public Tree Advisory Board to include people who can conduct education, instruction and tree planting tasks or create a new Tree Stewards group to tackle hands-on activities for urban forestry.
- 17) **Re-use urban waste wood.** Establishing an urban waste wood program is an excellent way to engage community members and re-use a valuable product. Launch a city-wide campaign encouraging the re-use of waste wood and let citizens know how they can get involved. Proceeds from sale of urban waste wood can fund tree plantings. For ideas see <http://www.treesvirginia.org/outreach/virginia-urban-wood-group>.
- 18) **Adopt a complete green streets policy.** Complete green streets allow for integration of stormwater management and aesthetic goals. By incorporating vegetation as an integral part of the design, green streets create and connect habitat, reduce urban heat island effect, help remove air pollutants, and promote walking and biking. The city should develop a green streets policy that includes the following elements: green infrastructure (trees and other vegetation), pedestrian space, bicycle lanes, and stormwater management.

BEST PRACTICES FOR CONSERVING TREES DURING DEVELOPMENT

Tree planting or preservation opportunities can be realized throughout the development process. A first step is to engage in constructive collaboration with developers. The City of Harrisonburg can hold planning concept reviews at the pre-development stage. These meetings and funding for the city's urban forestry program could expand the options for conservation of the city's trees.

Encouraging Tree Conservation

It is also necessary to actively promote the implementation of development designs that minimize the loss of urban forest canopy and habitat. While the city encourages site layouts that conserve trees, developers may not always agree to implement staff suggestions. The GIC has found that economic arguments (real estate values for treed lots, access to open spaces, and rate of sales) are usually the most compelling way to motivate developers to take the extra effort and care to design sites and manage construction activities to promote tree conservation. This will facilitate site designs which save more trees and thereby require less constructed stormwater mitigation. Many developers are willing to cooperate in such ventures, as houses often sell for a higher premium in a well-treed development and occupancy rates are higher for commercial spaces on well treed lots.

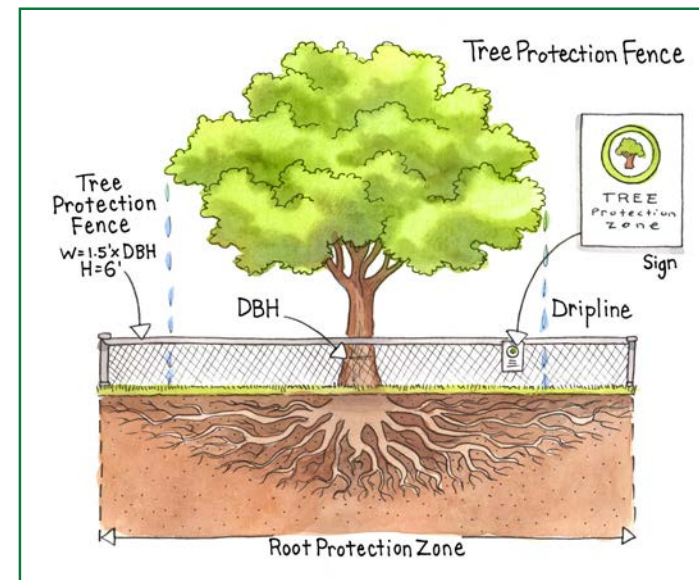


Tree Protection Fencing and Signage

Small roots at the radial extents of the tree root area, uptake water and absorb nutrients. Protection of these roots is critical for the optimal health of a tree. While protection at the dripline is an accepted practice, it does not adequately protect the roots.

Trees slated for protection may still suffer development impacts such as root compaction and trunk damage. The most common form of tree protection during construction is tree protection fencing. It is a physical barrier that keeps people and machines out of tree's critical root zones during land disturbance.

Tree protection signage communicates how work crews should understand and follow tree protection requirements. It also informs crews and citizens about the consequences of violating city code. The city does not have requirements for tree protection or for signage. It is important that building materials are not placed in tree protection zones and that protective fences are not removed.



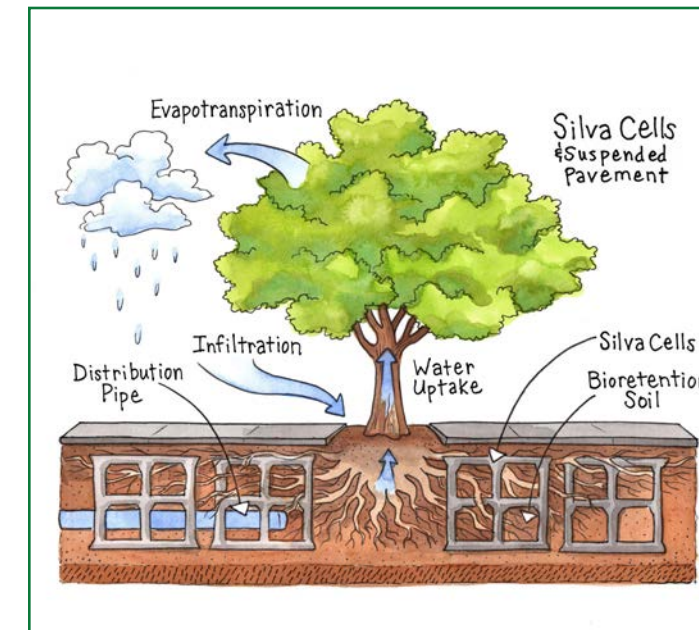
Tree Protection Fence and Signage



TREE PLANTING

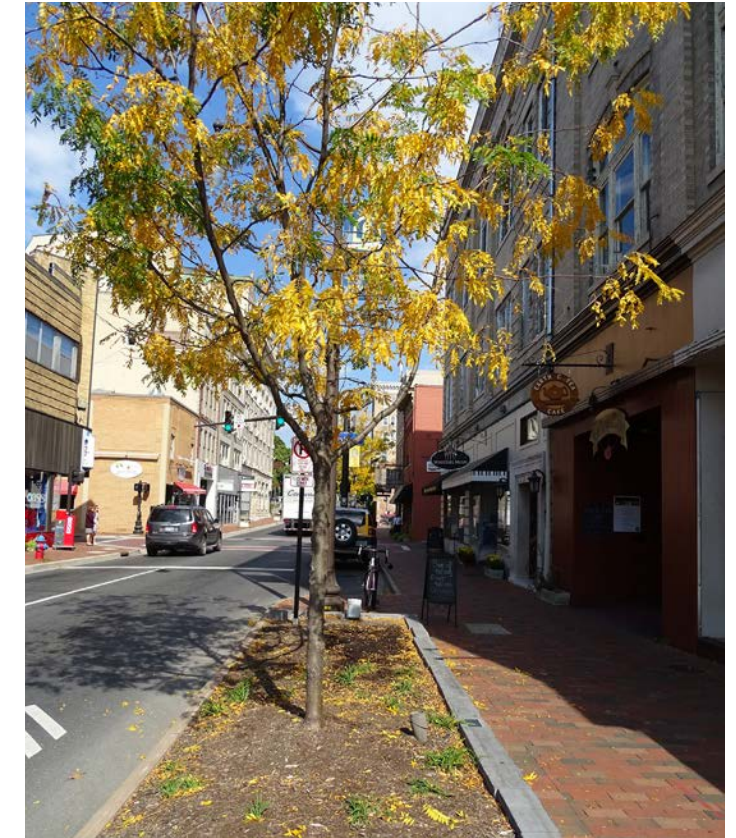
In urban environments, many trees do not survive to their full potential life span. Factors such as lack of watering or insufficient soil volume and limited planting space put stresses on trees, stunt their growth and reduce their lifespans. For every 100 street trees planted, only 50 will survive 13-20 years (Roman et al 2014). This means that adequate tree well sizing standards are a critical factor in realizing the advantages of a healthy urban forest. At a minimum, canopy trees require 1000 cubic feet of soil volume to thrive. In areas where space is tighter or where heavy uses occur above roots, 'Silva cells' or other trade technologies can be used to stabilize and direct tree roots towards areas with less conflicts (e.g. away from pipes). Silva cells have been used downtown at 1 Court Square (for more information see https://www.vwrrc.vt.edu/swc/documents/MTD/SilvaCell_Document%201.pdf).

In addition, large trees should not be planted where they may interfere with overhead transmission lines. These and other practices, implemented to provide long term care, protection and best planting practices for the urban forest, will help ensure that investments in city trees will pay dividends for reducing stormwater runoff, as well as cleaner air and water, lower energy bills, higher property values and natural beauty long into the future.

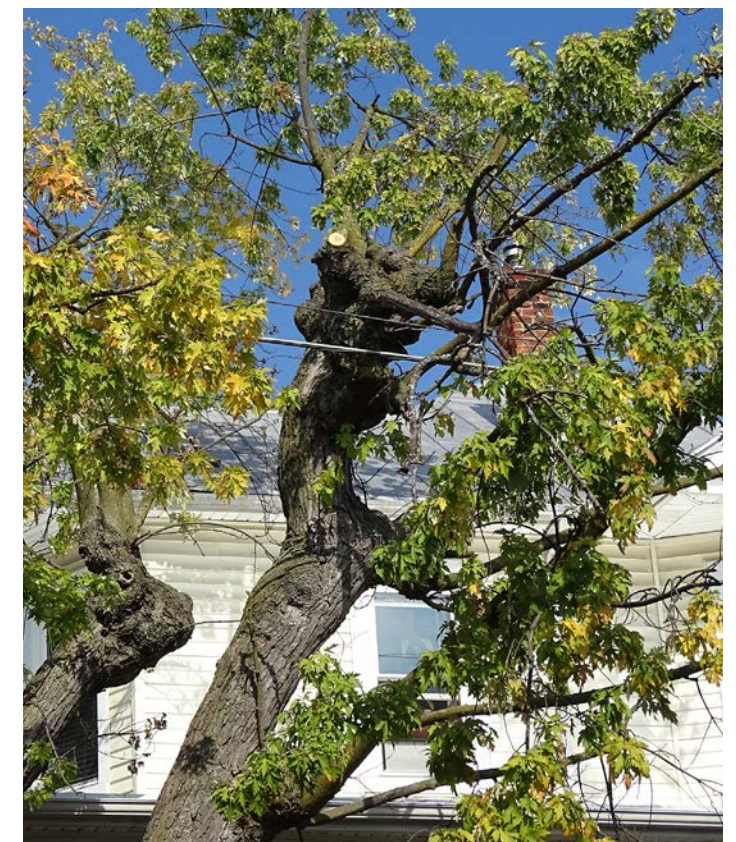


Silva Cells and Suspended Pavement

² The downtown master plan also contains recommendations for tree planting considerations. For more see: <https://www.harrisonburgva.gov/sites/default/files/PublicWorks/files/downtown-plan/Harrisonburg%20Downtown%20Streetscape%20Plan%20%282014%29.pdf>



Newly planted trees downtown are not in the way of power lines.



Power line conflicts require damaging cuts to mature trees.

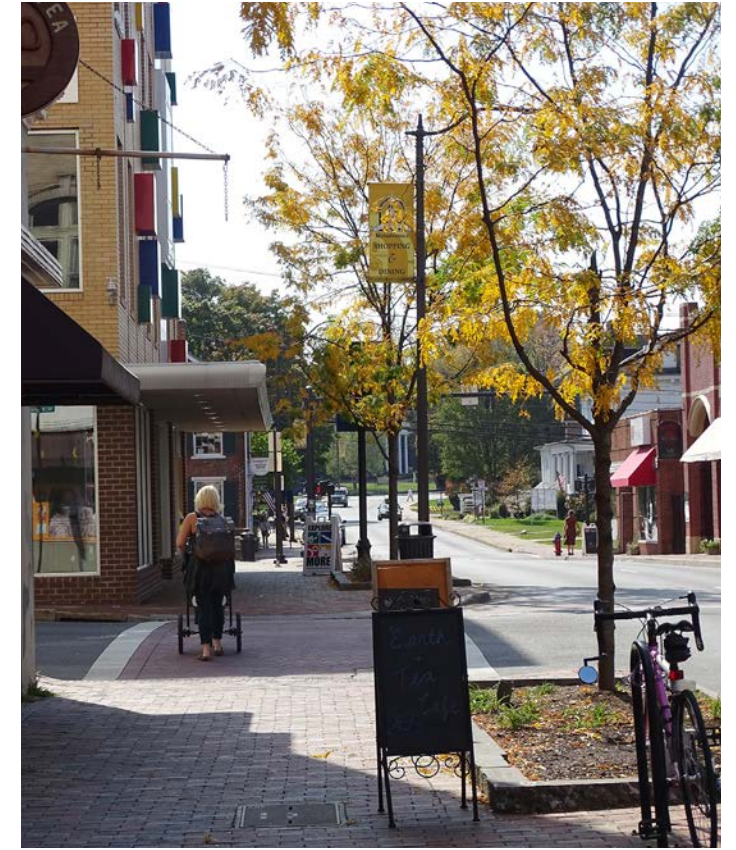
CONCLUSION AND NEXT STEPS

Adapting codes, ordinances and municipality practices to use trees and other native vegetation for greener stormwater management will allow Harrisonburg to treat stormwater more effectively. Implementing these recommendations will significantly reduce the impact of stormwater sources (impervious cover) and benefit the local ecology by using native vegetation (trees and other vegetation) to uptake and clean stormwater. It will also lower costs of tree cleanup from storm damages, since proper pruning or removal of trees deemed to be 'at risk' can be done before storms occur.

The city can also consider working to increase the canopy coverage. Based on the analysis performed for this project, the Harrisonburg technical advisory committee for this project has discussed the possibility of creating an urban tree canopy goal to include an increase in tree canopy coverage from 27 to 30 percent; a 3 percent increase over the next 20 years. This would require planting approximately 32,000 trees (canopy and understory) and would cost the city approximately \$118,000 per year for trees on public lands while private landowners (which own the majority of land in the city) would need to plant the remaining private lands.

In addition, the city hopes to implement a GIS assessment of its urban canopy every four years to compare urban tree canopy levels and better plan for the urban forest. Performing an inventory of all city owned trees, hiring at least one Public Works inspector for tree protection on city projects, and performing tree risk assessments on publicly owned trees are also urban forestry items staff have identified as potential goals for city adoption. The city also can use its urban forest to meet pollution reduction goals under the Chesapeake Bay Watershed Implementation Plan.

Next steps are for the city to move forward with planning for whether and how to implement the recommendations in this report. Harrisonburg should use the canopy map and update it to track change over time and to set goals for increasing or maintaining canopy by neighborhood. The city can use the canopy data, analysis, recommendations and stormwater calculator tool to continue to create a safer, cleaner, cost-effective and more attractive urban forest to benefit all community members.



Images credit: City of Harrisonburg



APPENDIXES

APPENDIX A: TECHNICAL DOCUMENTATION

This section provides technical documentation for the methodology and results of the land cover classification used to produce both the Land Cover Map and Potential Planting Scenarios for Harrisonburg.

Land cover classifications are an affordable method for using aerial or satellite images to obtain information about large geographic areas. Algorithms are trained to recognize various types of land cover based on color and shape. In this process, the pixels in the raw image are converted to one of several types of pre-selected land cover types. In this way, the raw data (i.e. the images) are turned into information about land cover types of interest, e.g. what is pavement, what is vegetation? This land cover information can be used to gain knowledge about certain issues; for example: What is the tree canopy percentage in a specific neighborhood?

Land Cover Classification

NAIP 2016 Leaf-on imagery (4 band, 1-meter resolution) was used for the land cover classification. The full set of NAIP data was acquired through the Earth Resources Observation and Science (EROS) Center of the U.S. Geological Survey.

Pre-Processing

The NAIP image tiles were first re-projected into the coordinate system used by the city.

NAD_1983_StatePlane_Virginia_North_FIPS_4501_Feet
WKID: 2283 Authority: EPSG

Projection: Lambert_Conformal_Conic
False_Easting: 11482916.666666666
False_Northing: 6561666.666666666
Central_Meridian: -78.5
Standard_Parallel_1: 38.03333333333333
Standard_Parallel_2: 39.2
Latitude_Of_Origin: 37.66666666666666
Linear Unit: Foot_US (0.3048006096012192)

Geographic Coordinate System: GCS_North_American_1983
Angular Unit: Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0)
Datum: D_North_American_1983
Spheroid: GRS_1980
Semimajor Axis: 6378137.0
Semiminor Axis: 6356752.314140356
Inverse Flattening: 298.257222101

Supervised Classification

The imagery was classified using an object based supervised classification approach. The ArcGIS extension Feature Analyst was used to perform the primary classification with a “bull’s eye” object recognition configuration was used to identify features based on their surrounding features. Feature Analyst software is an automated feature extraction extension that enables GIS analyst to rapidly and accurately collect vector feature data from high-resolution satellite and aerial imagery. Feature Analyst uses a model-based approach for extracting features based on their shape and spectral signature.

For better distinction between classes an NDVI image was created using Raster Calculator used instead of ArcGIS’ Imagery Analyst menu for consistency. The NDVI image along with the source NAIP bands (primarily 4, 1 and 2) were used to identify various features where they visually matched the imagery most accurately.

Post-Processing

The raw classifications from Feature Analyst then went through a series of post-processing operations. Planimetric data were also used at this point to improve the classification. Roads, sidewalks, and trails were “burned in” to the raw classification (converted vector data to raster data, which then replaced the values in the raw classification). The ‘tree canopy’ class was not affected by the burn-in process, however, because tree canopy can overhang streets. These data layers were also used to make logic-based assumptions to improve the accuracy of the classification. For example, if a pixel was classified as ‘tree canopy,’ but that pixel overlaps with the roads layer, then it was converted to ‘Tree Cover over Impervious.’ The final step was a manual check of the classification. Several ArcGIS tools were built to automate this process. For example, the ability to draw a circle on the map and have all pixels classified as “tree canopy” to ‘non-tree vegetation,’ which is a process usually requiring several steps, is now only a single step.

Potential Planting Area Dataset

The Potential Planting Area dataset has three components. These three data layers are created using the land cover layer and relevant data in order to exclude unsuitable tree planting locations or where it would interfere with existing infrastructure.

1. Potential Planting Area (PPA)
2. Potential Planting Spots (PPS)
3. Potential Canopy Area (PCA)

The Potential Planting Area (PPA) is created by selecting the land cover features that have space available for planting trees, then eliminating areas that would interfere with existing infrastructure.

■ Initial Inclusion (selected from GIC created land cover)

- Pervious surfaces
- Bare earth

■ Excluded Land Cover Features

- Existing tree land cover
- Water
- Wetlands
- Imperious surfaces
- Ball fields (i.e.: baseball, soccer, football) where visually identifiable from NAIP imagery. (Digitized by GIC)

■ Exclusion Features: (buffer distance)

- Roads areas (10ft)
- Roads areas (10ft)
- Driveways (10ft)
- Railroads (10ft)
- Structures (10ft)
- Storm pipes (10ft)
- Water lines (10ft)
- Sewer lines (10ft)
- Power lines and other identifiable utilities (10 ft.)

Potential Planting Spots

The Potential Planting Spots (PPS) are created from the PPA. The potential planting areas (PPA) is run through a GIS model that selects spots a tree can be planted depending on the size tree’s that are desired. Tree planting scenario was based on a 20 ft. and 40 ft. mature tree canopy with a 30 percent overlap.

Potential Canopy Area

The Potential Canopy Area (PCA) is created from the PPS. Once the possible planting spots are given a buffer around each point, this represents a tree’s mature canopy. For this analysis, they are given a buffer radius of 10 or 20 ft. that results in 20 and 40 ft. tree canopy.



NAIP Image 2015



Potential Planting Area (PPA)



Potential Planting Spots (PPS)



Potential Canopy Area (PCA)

APPENDIX B: BIBLIOGRAPHY

_____. Appendix: Hynicka, Justin, and Marion Divers. "Relative reductions in non-point source pollution loads by urban trees." in Cappiella, Karen, Sally Claggett, Keith Cline, Susan Day, Michael Galvin, Peter MacDonagh, Jessica Sanders, Thomas Whitlow, and Qingfu Xiao. "Recommendations of the Expert Panel to Define BMP Effectiveness for Urban Tree Canopy Expansion." (2016).

_____. Runoff and infiltration graphic. EPA Watershed Academy Website. Accessed February 19, 2019: https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=170

_____. Complete Green Streets. Smart Growth America. Web site accessed February 20, 2018 <https://smartgrowthamerica.org/resources/complete-and-green-streets/>

_____. Penn State Extension, Trees and Stormwater <http://extension.psu.edu/plants/green-industry/landSCaping/culture/the-role-of-trees-and-forests-in-healthy-watersheds>

_____. Stormwater to Street Trees. U.S. Environmental Protection Agency. September 2013. EPA report # EPA 841-B-13-001 Web site accessed June 01, 2016: <https://www.epa.gov/sites/production/files/2015-11/documents/stormwater2streettrees.pdf>

Akbari, Hashem, Melvin Pomerantz, and Haider Taha. "Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas." *Solar energy* 70, no. 3 (2001): 295-310.

Benedict, Mark A., and Edward T. McMahon. 2006. *Green Infrastructure: Linking Landscapes and Communities*. Washington, D.C.: Island Press.

Benedict, Mark A. and McMahon. "Green Infrastructure: Smart Conservation for the 21st Century." Washington, D.C., Sprawl Watch Clearing House, May 2002. Accessed February 2018 <http://www.sprawlwatch.org/greeninfrastructure.pdf>

Booth, Derek B., David Hartley, and Rhett Jackson. "Forest cover, impervious surface area, and the mitigation of stormwater impacts." *JAWRA Journal of the American Water Resources Association* 38, no. 3 (2002): 835-845.

Cappiella, Karen, Sally Claggett, Keith Cline, Susan Day, Michael Galvin, Peter MacDonagh, Jessica Sanders, Thomas Whitlow, and Qingfu Xiao. "Recommendations of the Expert Panel to Define BMP Effectiveness for Urban Tree Canopy Expansion." (2016).

Correll, Mark R., Jane H. Lillydahl, and Larry D. Singell. "The effects of greenbelts on residential property values: some findings on the political economy of open space." *Land economics* 54, no. 2 (1978): 207-217.

Dwyer, John F., E. Gregory McPherson, Herbert W. Schroeder, and Rowan A. Rowntree. "Assessing the benefits and costs of the urban forest." *Journal of Arboriculture* 18 (1992): 227-227.

Ernst, Caryn, Richard Gullick, and Kirk Nixon. "Conserving forests to protect water." *Am. Water W. Assoc* 30 (2004): 1-7.

Fazio, James R. "How trees can retain stormwater runoff." *Tree City USA Bulletin* 55 (2010): 1-8.

Gregory, J.H., Dukes, M.D., Jones, P.H. and Miller, G.L., 2006. Effect of urban soil compaction on infiltration rate. *Journal of soil and water conservation*, 61(3), pp.117-124.

Gregory, Justin H., Michael D. Dukes, Pierce H. Jones, and Grady L. Miller. "Effect of urban soil compaction on infiltration rate." *Journal of soil and water conservation* 61, no. 3 (2006): 117-124.

"Climate Project." *Urban ecosystems* 1, no. 1 (1997): 49-61.

Kuehler, Eric, Jon Hathaway, and Andrew Tirpak. "Quantifying the benefits of urban forest systems as a component of the green infrastructure stormwater treatment network." *Ecohydrology* 10, no. 3 (2017).

McPherson, E. Gregory, and Jules Muchnick. "Effect of street tree shade on asphalt concrete pavement performance." *Journal of Arboriculture* 31, no. 6 (2005): 303.

McPherson, E. Gregory, David Nowak, Gordon Heisler, Sue Grimmond, Catherine Souch, Rich Grant, and Rowan Rowntree. "Quantifying urban forest structure, function, and value: the Chicago Urban Forest"

Nowak, David J., E. Robert III, Daniel E. Crane, Jack C. Stevens, and Jeffrey T. Walton. "Assessing urban forest effects and values, Washington, DC's urban forest." *Assessing urban forest effects and values, Washington, DC's urban forest. Resour. Bull. NRS-1. Newcity Square, PA: US Department of Agriculture, Forest Service, Northern Research Station. 24 p. 1 (2006).*

Nowak, D.J., and E.J. Greenfield. 2012. "Tree and impervious cover change in U.S. cities." *Urban Forestry & Urban Greening*, Vol. 11, 2012; pp 21-30. <http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1239&context=usdafsfacpub>

Nowak et al. 2010. *Sustaining America's Urban Trees and Forests*: https://www.fs.fed.us/openspace/fote/reports/nrs-62_sustaining_americas_urban.pdf

Roman, Lara A., John J. Battles, and Joe R. McBride. "Determinants of establishment survival for residential trees in Sacramento County, CA." *Landscape and Urban Planning* 129 (2014): 22-31.

Roman, Lara A., and Frederick N. Catena. "Street tree survival rates: Meta-analysis of previous studies and application to a field survey in Philadelphia, PA, USA." *Urban Forestry & Urban Greening* 10, no. 4 (2011): 269-274.

Souch, C. A., and C. Souch. "The effect of trees on summertime below canopy urban climates: a case study Bloomington, Indiana." *Journal of Arboriculture* 19, no. 5 (1993): 303-312.

Tilt, Jenna H., Thomas M. Unfried, and Belen Roca. "Using objective and subjective measures of neighborhood greenness and accessible destinations for understanding walking trips and BMI in Seattle, Washington." *American Journal of Health Promotion* 21, no. 4_suppl (2007): 371-379.

Wang, Jun, Theodore A. Endreny, and David J. Nowak. "Mechanistic simulation of tree effects in an urban water balance model." *JAWRA Journal of the American Water Resources Association* 44, no. 1 (2008): 75-85.

Wells, Nancy M. "At home with nature: Effects of "greenness" on children's cognitive functioning." *Environment and behavior* 32, no. 6 (2000): 775-795.

Xiao, Qingfu, E. Gregory McPherson, Susan L. Ustin, Mark E. Grismer, and James R. Simpson. "Winter rainfall interception by two mature open-grown trees in Davis, California." *Hydrological processes* 14, no. 4 (2000): 763-784.

Meeting Summary Community Orientation held May 25, 2017

Brief Description

The Trees and Stormwater grant is a partnership between the Virginia Department of Forestry, Harrisonburg, VA, and the Green Infrastructure Center (GIC). This community forum invited public comment on the mapping that had been done so far for the project as well as solicited public comment on the urban forest in Harrisonburg, VA.

PUBLIC COMMENTS

Tree Plantings and Care

1. Boy Scouts have been doing tree plantings in Purcell Park.
2. Boy Scouts have an interest in riparian buffer plantings. They have been working with Jeremy Harold, the Superintendent of Parks, to find potential planting sites.
3. There is an interest from the community in using tree species that provide the most habitat in addition to providing stormwater benefits.
4. There are opportunities to plant trees at the city municipal building.
5. Market Street needs more trees. Also, focus on the feeder streets such as Dogwood.
6. Main Street needs more trees.
7. The Harrisonburg Bike Stress Map could inform where trees should go, e.g. more stress = more need to calm traffic.
8. Schools are lacking tree canopy coverage. The Simms School is planning to start a community garden which will include trees. The Waterman School is leaving pine branches on the ground for children to play with.

Bike/Pedestrian Suitability

1. Add bike infrastructure (racks etc.) to the maps?
2. Bike and pedestrian safety is a big deal. Should coordinate the percent canopy over streets map with the bike plan.
3. There is a plan for a new separated bike/walkway trail at the north end of the greenway. The construction has not begun yet but the plan is finalized and the funding has been at least partially secured.

Overly-large Streets and Parking Lots

1. Rose's parking lot is very overbuilt (too much impervious surface).
2. The main street through Quadrant Four has lots of extra lanes. Some city streets are overly wide.
3. Main Street is too wide.

Community Engagement and Education

1. It was recommended that the local chapter of the VA Master Naturalists be notified before the next meeting.
2. The project and the city should liaison with James Madison University.
3. Need to educate residents and tree care companies about not topping trees.

Harrisonburg Codes/Ordinances

1. There is a lack of replacement requirements for trees removed during city projects.

Mowing and Tree Succession/Growth

1. The Mennonites are very interested in trees. They have stopped mowing some of their property so that it re-grows into a wild landscape.
2. Why are some city parks mowed?

Other

1. What is the process for migrating your urban forest? If the yard is shaded by a large tree, how can one plant the next tree when it will not have enough light yet?
2. On the maps, grey out the interstate because we won't likely be planting there and the city does not control that.
3. The northern section of Black's Run floods frequently. ½-1" of rainfall and the streets are closed.
4. The Virginia Mennonite Retirement Community (VMRC) owns some idle farmland in the city. It is currently unused but there is no way to get across the street safely.
5. Vine and Fig are looking to expand to a small city owned parcel near the Salvation Army. They want to start an urban tree farm growing fruit and nut trees.
6. There is an interest from community members in having a map of PPA for their own neighborhood to encourage tree planting. It was stated that roads often form the de facto boundaries for 'neighborhoods' so these may be able to be used to approximate neighborhoods. GIC will work with the Planning Division to identify the best neighborhood boundaries.

Meeting Summary Community Wrap-Up held July 26, 2018

General Comments

- Concern over parking lots downtown; thinks there are too many.
- Confusion as to who funds tree planting, and can they get more trees for small local businesses?
- Concern over the development of the new school near South Gate: is there a green report? Concerned with runoff
- Desire to expand sapling donation into a sort of community plant-donation and adoption program Desire for people to donate their saplings to the city (e.g., white oaks)
- About 7 voters were confused by the "development footprint" option and 3 needed further explanation on 'stream buffers' – what are they and how are they enforced?
- Food forests (urban orchards) we should promote this. John Munsell at Virginia Tech is doing research on this.
- Should revise city tree planting lists to include more natives.
- Provide more tree planting guidance/information to homeowners.
- Pay for tree installations
- Begin a tree voucher program
- Revitalize the Harrisonburg Tree Stewards group
- Port Republic ramps are being re-done. Is there an option to plan more trees along there?



Tree Canopy Over Streets Map

- Identified the co-op as wanting to attract foot traffic, thinks the strips along the street could use more trees
- Wants incentive to businesses to commit to a certain canopy percentage
- Concern that tree cover is not as extensive in real life as on the map (streets in question were green, two citizens disagreed); said road isn't very shady, and lots of overhead lines that would prevent trees (along Central Avenue and Sunrise Drive)

Northwest Canopy and Planting Maps Comments (Photo location provided to GIC and city).

- 1) Sawmill Avenue viewshed is important to the city
- 2) Federal Street: add more trees since the street is being converted to 'one-way' and there is now room for additional landscaping!
- 4) New elementary school – can more trees be planted there?

Northeast Canopy and Planting Maps (Photo location provided to GIC and city).

- 1) Plant more trees at the Rockingham County Complex
- 2) Plant more trees at the Roses parking lot
- 3) Reach out to the Woodbine Cemetery and plant trees there
- 4) Plant more trees at the Poultry Industry

Votes on key strategies:

Several strategies were presented for participants to show support for. Each participant voted for the top three strategies they believed to be most effective for growing/protecting the urban forest.

- 1) Use the GIC stormwater calculator tool and determine the benefit of maintaining or increasing the urban canopy. (5 votes)
- 2) Require a tree removal permit for privately owned trees over a specified diameter at breast height (DBH). (6 votes)
- 3) Require trees over a specified DBH to be shown on development plans. (9 votes)
- 4) Tighten the development footprint. (8 votes)
- 5) Develop tree canopy goals by watershed. (12 votes)
- 6) Perform urban forestry data collection and monitoring. (2 votes)
- 7) Place tree protection fencing at 1.5'xDBH. (3 votes)
- 8) Adopt a stream buffer ordinance. (14 votes)

APPENDIX D: TREE PLANTING CREDIT UNDER THE CHESAPEAKE BAY WATERSHED IMPLEMENTATION PLAN

Introduction:

The Chesapeake Bay Program (CBP) is a regional organization that coordinates Chesapeake Bay restoration and protection for federal agencies and state partners along with local governments, non-profit organizations, and academic institutions. CBP developed over 200 best management practices (BMPs) for accreditation in the Phase 6 Implementation Chesapeake Bay Watershed Model. Many BMPs, including urban tree planting, are eligible for nitrogen, phosphorus, and sediment reductions toward their Phase III Watershed Improvement Plan (WIP) targets. This appendix explains how to calculate nitrogen, phosphorus, and sediment reductions through urban tree planting BMPs. This is derived from “Quick Reference Guide for Best Management Practices, Nonpoint Source BMPs to Reduce Nitrogen, Phosphorus and Sediment Loads to the Chesapeake Bay and its Local Waters” (Pub. CBP/TRS-323-18)³

Types of Urban Tree Planting BMPs

CBP developed three classes of urban tree planting BMPs. Each one yields a different nitrogen, phosphorus, and sediment reduction per acre and loading reductions vary by state as well. See below for a description of each.

Urban Tree Canopy Expansion

The Urban Tree Canopy Expansion BMP credits planting of urban trees. Trees do not need to be planted in a contiguous manner but cannot be part of a riparian forest buffer or a structural BMP. For the BMP, 300 trees planted is equivalent to one acre of urban tree canopy expansion.

Urban Forest Planting

The Urban Forest Planting BMP offers credit for conversion of developed turf grass to urban forest. For credit to be granted, trees must be planted contiguously and urban forest plantings must be documented in a planting and maintenance plan that meets state planting density and associated standards for establishing forest conditions. These standards must include no fertilization and minimal mowing to aid tree understory establishment.

Urban Forest Buffer

The Urban Forest Buffer BMP credit is for contiguous forest planted in a recommended buffer of 100' or a minimum buffer of 35'.

Note: Trees may not be double credited. For example, if an acre of trees is planted along a stream in a developed area as an urban forest buffer, the same acre of trees may not be credited as urban forest planting or urban tree canopy expansion.

Calculating Nitrogen, Phosphorus, and Sediment Reductions

Trees are credited based on the standard that 300 trees comprise one acre of trees. This is based on the Bay panel's recommendation of 144 square foot average of canopy trees planted. To calculate credit, first determine the type of urban tree planting BMP performed (Urban Tree Canopy Expansion, Urban Forest Planting, or Urban Forest Buffer). Calculate the number of trees planted (note that some BMPs require trees to be planted contiguous while others do not). Divide the number of trees planted by 300 and multiply by the corresponding nitrogen, phosphorus, and sediment reduction coefficient.

For example, if 600 trees were planted throughout an urban area in a noncontiguous fashion and not as part of a riparian forest buffer, these trees would be credited under the Urban Tree Canopy Expansion BMP. To determine the acres of trees planted, divide the number of trees planted (600) by 300. This yields two acres of Urban Tree Canopy Expansion. Multiply the nitrogen, phosphorus and sediment average reductions/acre for Urban Tree Canopy Expansion (see Table below) by two to find total nitrogen, phosphorus, and sediment reductions for the BMP. Thus,

- Total nitrogen reduction is 3.64 lb. (1.82 lb./ac x 2 ac).
- Total phosphorus reduction is 0.30 lb. (0.15 lb./ac x 2 ac).
- Total sediment reduction is 445 lb. (223 lb./ac x 2 ac).

³ https://www.chesapeakebay.net/documents/BMP-Guide_Full.pdf

Jurisdiction	BMP	Nitrogen Average reduction per acre, Edge of tide (lbs/ac)	Phosphorus Average reduction per acre, Edge of tide (lbs/ac)	Sediment Average reduction per acre, Edge of tide (lbs/ac)
Virginia	Forest buffer	8.77	1.61	854
	Forest planting	7.33	1.16	451
	Tree planting - canopy	1.82	0.15	223

Above values are from Table D-7-1. Bay-wide average nitrogen, phosphorus and sediment reductions per acre of implementation. Pounds reduced edge-of-tide (EOT). TN and TP rounded to nearest hundredth of a pound; TSS rounded to nearest whole pound. Values derived in Phase 6 version of CAST and available by county or state. These values provided as useful estimates but the actual reductions for specific BMPs will be different from these average estimates. Source: BMP Pounds Reduced and Cost by State, July 13, 2018 version, available under “Cost Effectiveness” section at <http://cast.chesapeakebay.net/Documentation/DevelopPlans>

