Trees: The Original Green Infrastructure

How Urban Tree Canopy can be incorporated into Stormwater Management Programs, Goals and Ordinances

Green Infrastructure Center

SOUTH CAROLINA FORESTRY COMMISSION

For the American Planning Association Webinar Series

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Today's Webinar Speakers

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City of Charleston
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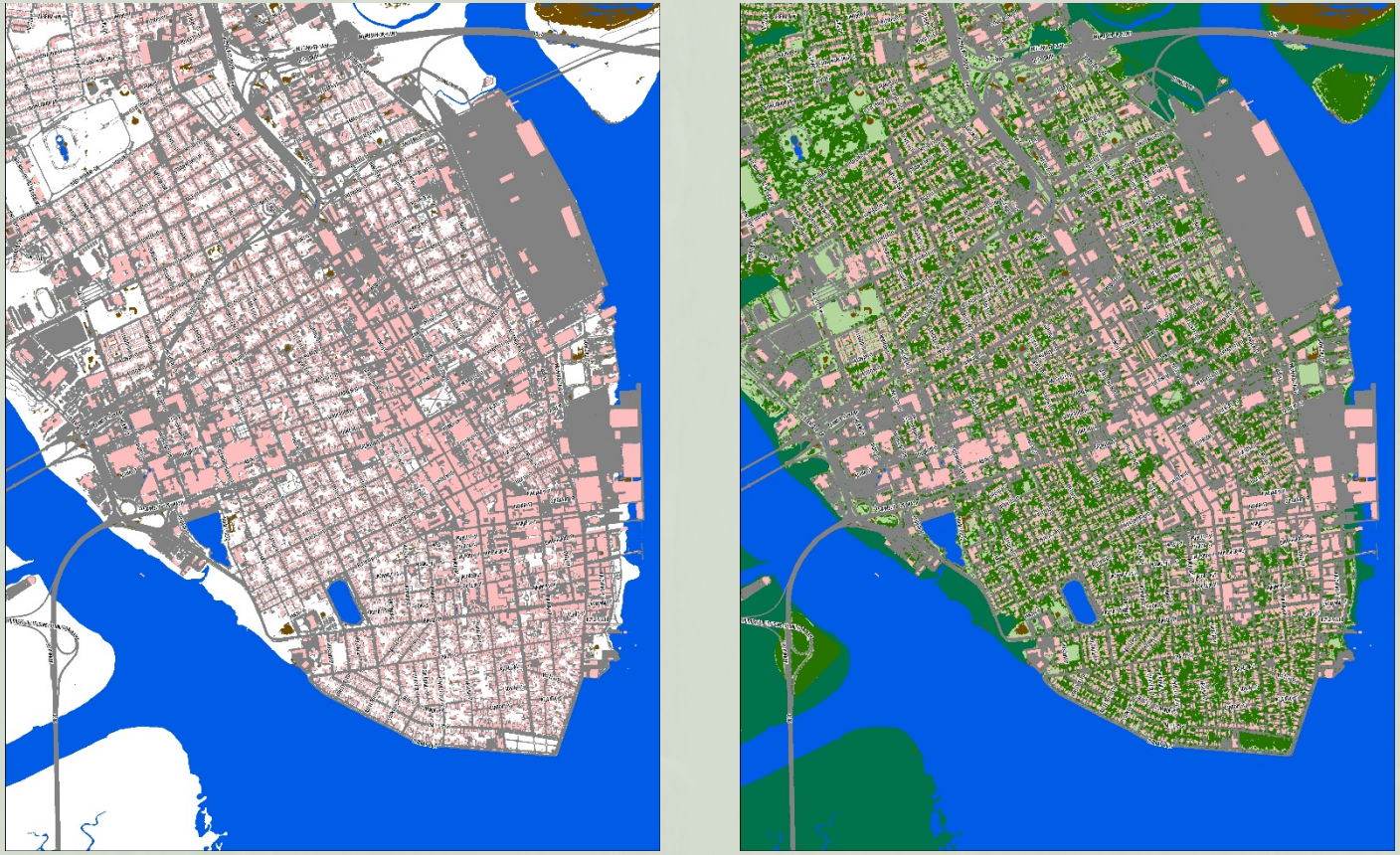
Frances Waite, Urban Forester
SC Forestry Commission
www.state.sc.us/forest/urban.htm

Today

1. Why are trees green infrastructure
2. Benefits of trees
3. Case example Charleston project overview
4. Data – how do we use it to plan for more trees?
5. Code/policy options.
6. Questions?

What is green infrastructure?



Map of a portion of Charleston showing gray infrastructure including buildings and roads (left). Classified high-resolution satellite imagery (right) adds a green infrastructure data layer (trees and other vegetation) .

Green Infrastructure Definition Expands

In 1994, Florida coined the term ***green infrastructure*** to describe its wetlands, rivers, dunes, and forest habitats. In 2006, EPA added BMPs such as raingardens to the definition. The key is to first consider natural infrastructure (trees, forests, rivers) protect them and connect them, build in the least impactful manner, then mitigate impacts.
So, ***first conservation, then mitigation.***

Rain gardens

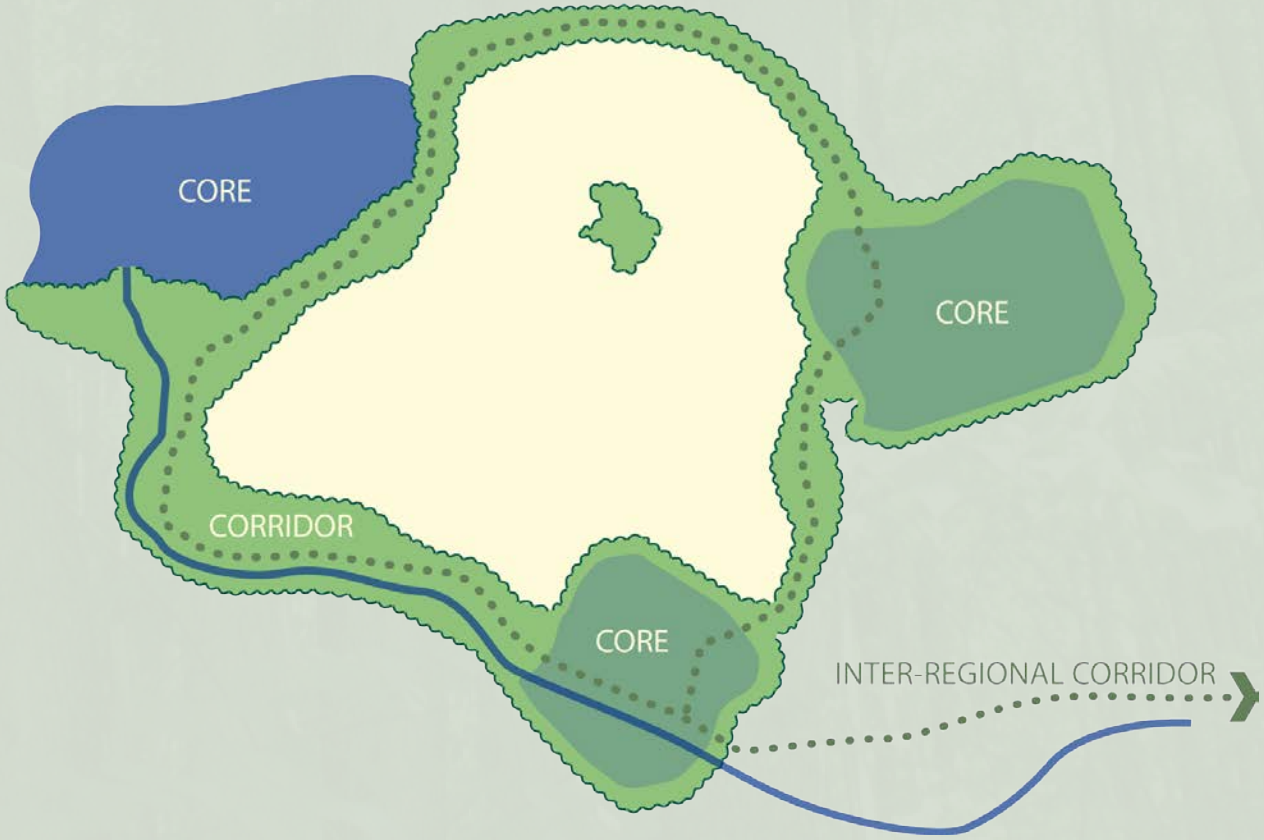
Permeable pavers

Filterra Boxes

Green Infrastructure Planning Requires Thinking About How to Connect the Landscape

It's about connecting the landscape!

Not just key habitat patches but how we connect them!



The problem of developments that protect green space without thinking about connections beyond parcel boundaries ...

Trees: the original –best – green infrastructure!

Trees give us cleaner air, shade, beauty and stormwater benefits at a cost that is far cheaper than engineered systems!

Estimates for the amount of water a typical street tree can intercept in its crown, range from 760 gallons to 4000 gallons per tree per year, depending on species.

Trees: Create Healthy Communities

- Access to fitness opportunities. (addresses obesity, nature deficit disorders)
- Clean air – trees absorb pollutants, VOCs, filter runoff, cool the city. (combat asthma)
- Well being and mental health - - people heal faster when they can see or access green. (hospitals need this for patients, reduces absenteeism of workers)
- Less crime occurs near trees. (issue especially for downtowns and public housing areas)
- Employees will exercise if they can access green where they work and on the way to work. (addresses employee health)

Urban Tree Canopy Values

Trees provide more attractive areas for development, historic districts, commercial areas opportunities for people to interact with nature.

A study by the University of Washington found that people shopped longer and more often in tree-lined retail areas and spent about 12 percent more money.

Trees = more tax revenue even in developed commercial districts!

Job Development

Small companies, especially those that are have well paid and skilled workforce place a strong importance on the “green” of the local environment.
Crompton Love and Moore, 1997

The creative class: artists, media, lawyers, analysts, make up 30 percent of the U.S. workforce and they place a premium on outdoor recreation and access to nature.
Florida, 2002

Trees and parks attract better paid jobs and thus a better tax base = $

Pilot Tree Canopy Project

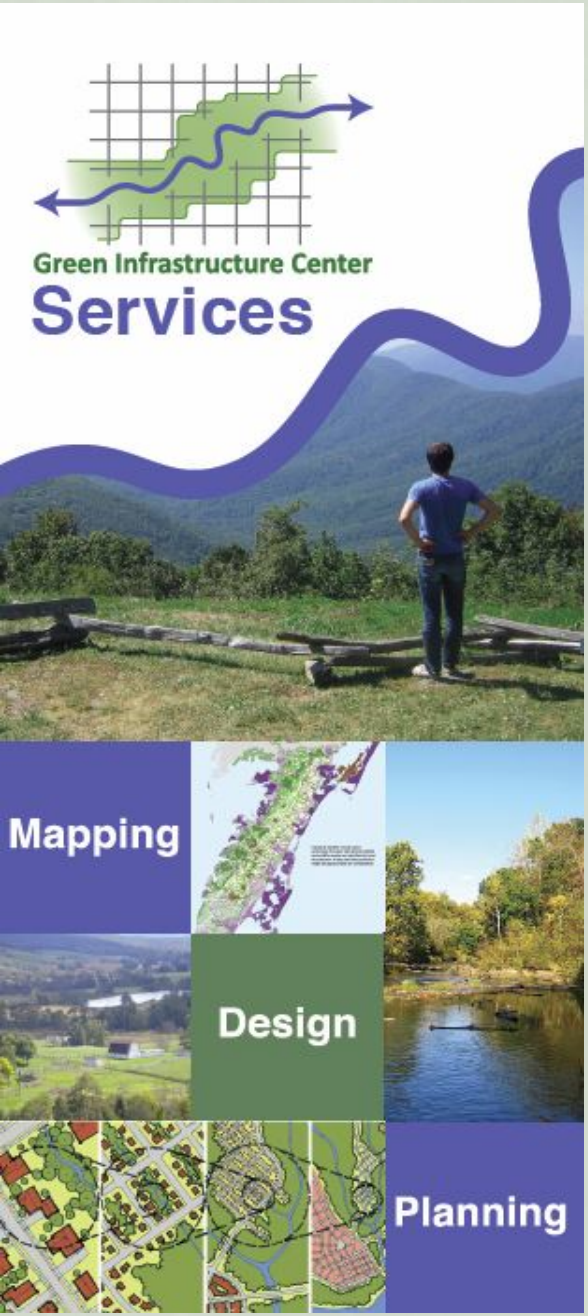
USDA Forest Service has funded 7 states to develop pilot projects to demonstrate how cities can best utilize trees for stormwater management.

Urban flooding

A partnership between **USDA FS**, **state forestry agencies** and the **GIC** developed to implement the project.

7 southern states:

SC, NC, GA, FL, AL, OK, VA



Project partner: GIC

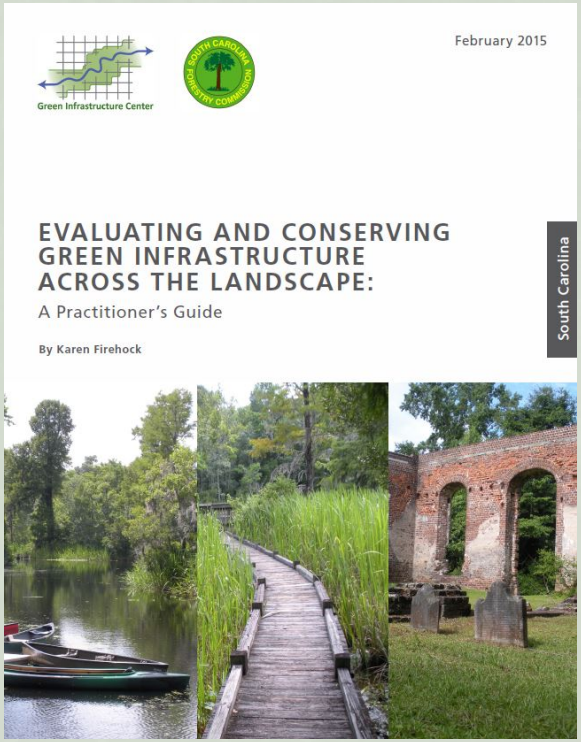
The Green Infrastructure Center and the SC Forestry Commission are helping the City of Charleston!

The GIC is the technical service provider. The GIC is a nonprofit organization that helps communities evaluate green assets and manage them to maximize ecology, economy and culture. We work across the United States.

Green Infrastructure Center

www.gicinc.org

Project partner and funder: SCFC



- ✓ Help municipalities and counties access and enjoy their urban forest
- ✓ Technical assistance with tree selection, proper planting, nursery stock
- ✓ GI model available for large landscapes to aid with planning for connectivity; guide to use on our website, and also for other states nationally through the new Esri model.
  http://www.esri.com/about-esri/greeninfrastructure
- ✓ Coming soon: How to incorporate GI & forestry into comprehensive plans

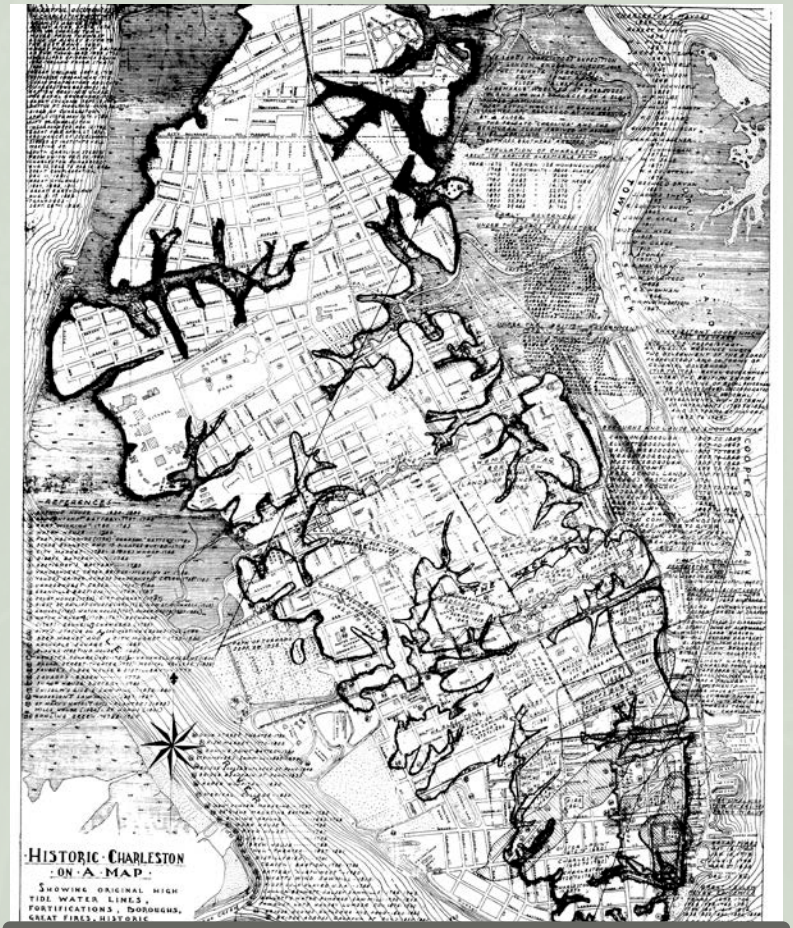
Download the guide:
https://www.state.sc.us/forest/gic-sc15.pdf

Project Partner Case Example: Charleston, SC

Project Considerations

- Major Storms
  - *Hurricanes*
  - *Flood events*
- Sea Level Rise
- Tidal Flooding
- Extreme Heat
- Staff capacity and budgetary constraints

Geography



Original High Tide Water Lines

High Tide Water Lines Over City Now

October 2015 Flood Event

Oct 3, 2015- 11.5 inches of rain recorded and highest tides since Hugo

Over 20 inches of rain in 3 days

October 2016
Hurricane Matthew

Tidal / Nuisance Flooding

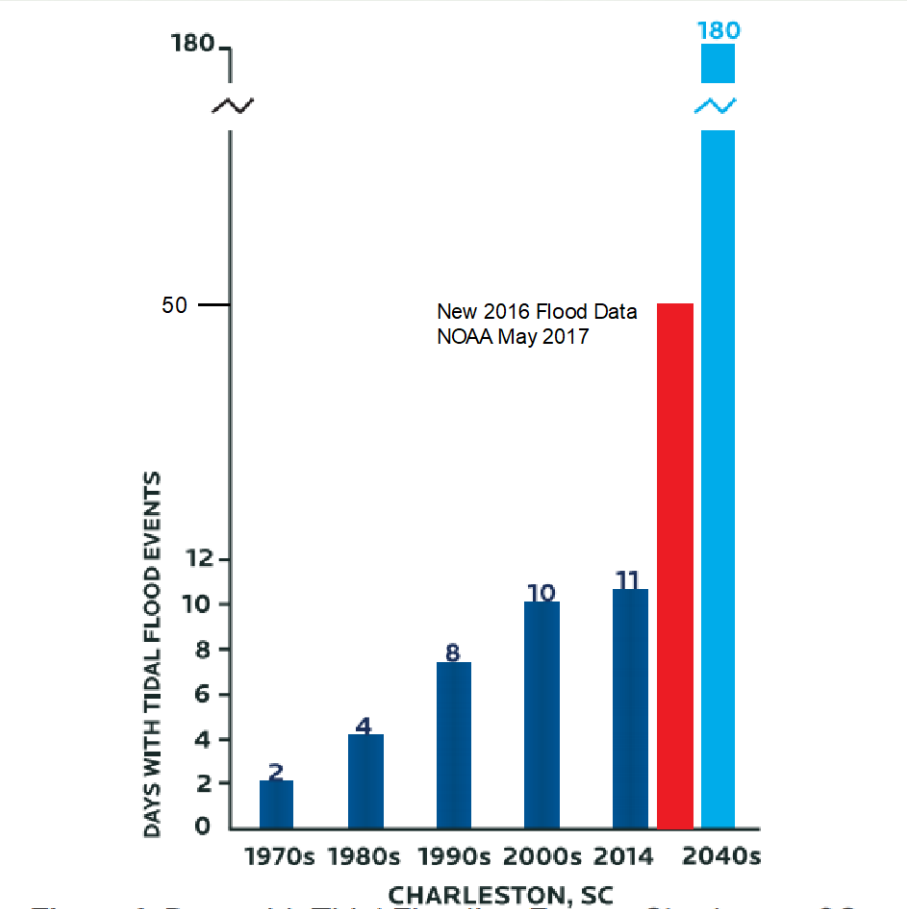


Figure 1: Days with Tidal Flooding Events, Charleston, SC


King Tide on a Sunny Day. Credit: S.C. DHEC/MyCoast

Major Drainage Improvement Projects

Gravity, Capacity and Storage

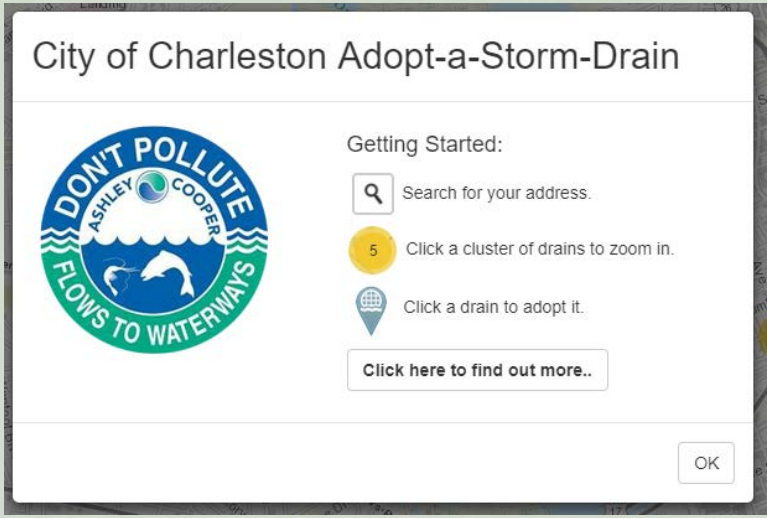
$238,000,000 Capital Investment Between 1990 and 2020

Charleston using Entire Toolbox

- Some areas won't be improved by costly engineering

- Other tools in the toolbox

  e.g. Green Infrastructure!



STORM WATER DRAIN MURAL

Project Goals

This project is helping Charleston map, evaluate, protect and restore its urban forests for improved stormwater management, flooding reduction and clean water.

Urban forests are a vital tool in managing and reducing runoff.

Charleston Excitement!

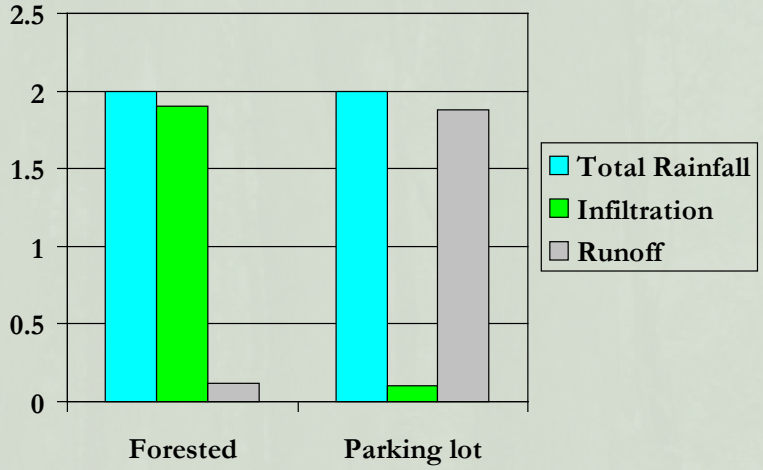
- New tree canopy and impervious land cover data
- Code audit and recommendations to strengthen current ordinances based on data and best practices
- Community input and education
- Can data help inform budget and maintenance schedules?

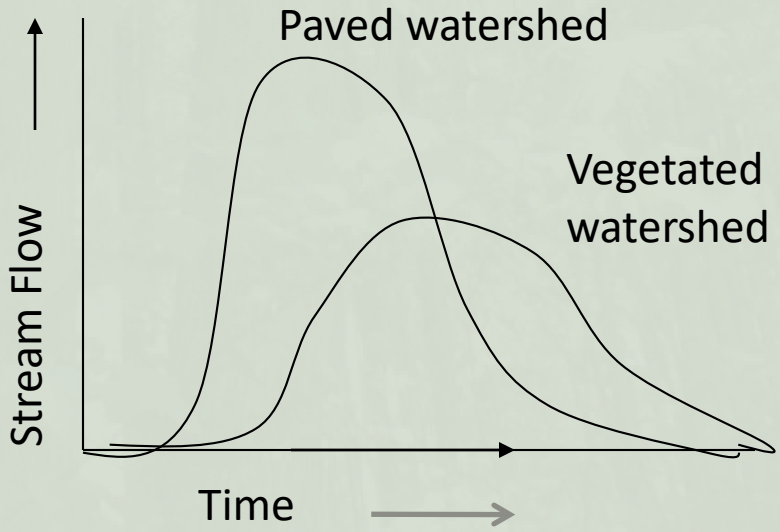
Paved Areas Can Cause Extreme Flows

1. Impervious surfaces prevent rain infiltration, causing greater runoff volume and velocity.

2. Storm flows peak sooner in the stream at higher volumes.

3. Higher volumes and velocities of runoff lead to more flooding and damages – the firehose effect!



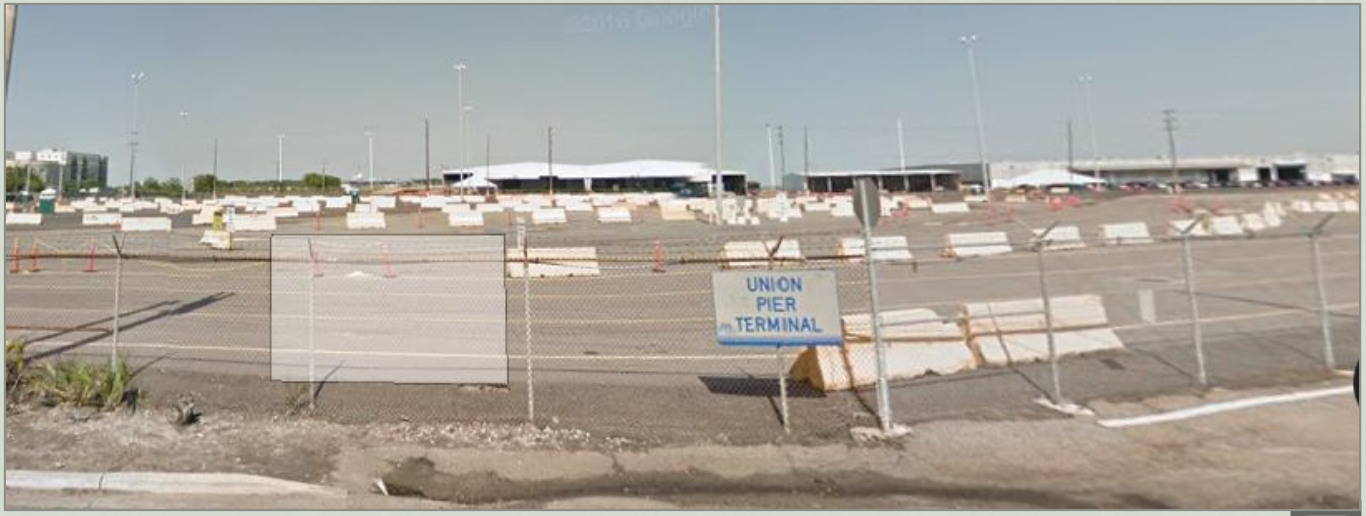


Water flow strategies

How do we make this…

function like this?

Urban Pavement Impacts



This parking lot could be retrofitted so we get less of this …

One acre of pavement releases 36 times more runoff than a forest.

During a rainfall event of one inch, one acre of forest will release 750 gallons of runoff, while a parking lot will release 27,000 gallons. (PennState Extension).

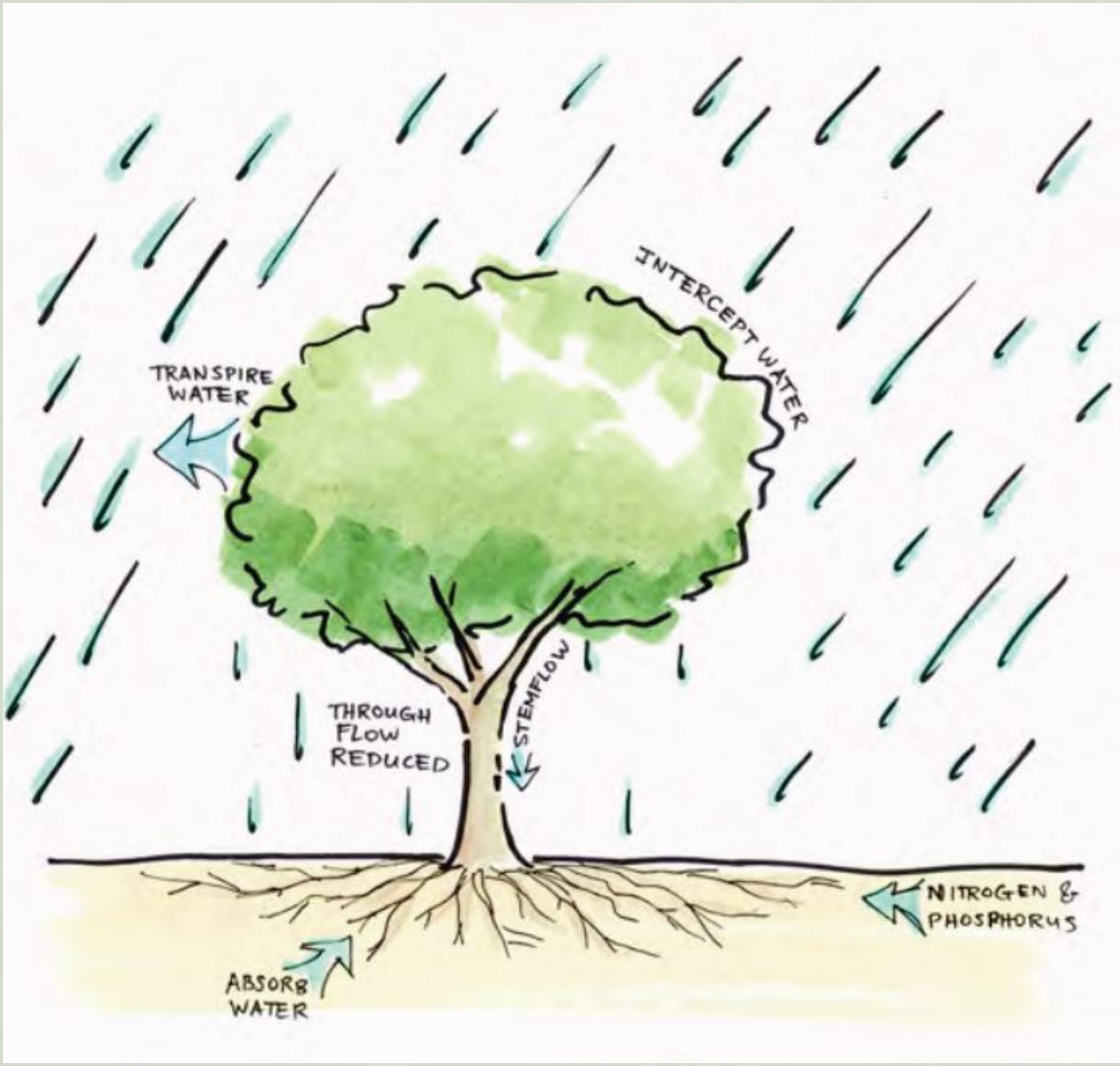
Flooding in Charleston

Urban Tree Canopy

20% of annual rainfall or > retained in crown
(Xiao et al., 2000)

Delays runoff up to 3.7 hours

↑ infiltration capacity of soils



Trees Can Reduce Flooding

- Tree canopies can temporarily detain rainfall and gradually release as throughfall
- Potentially increases soil infiltration capacity (Asadian and Weiler 2009).

throughfall – ability of tree canopy to detain rainfall & gradually release over time

As you might suspect:

Tree canopy effectiveness is

- Highest during short, low intensity storms
- Lower as rainfall amount and intensity increases

Calculating Stormwater Uptake by Trees – It's complicated!

Tree Over Parking Lot

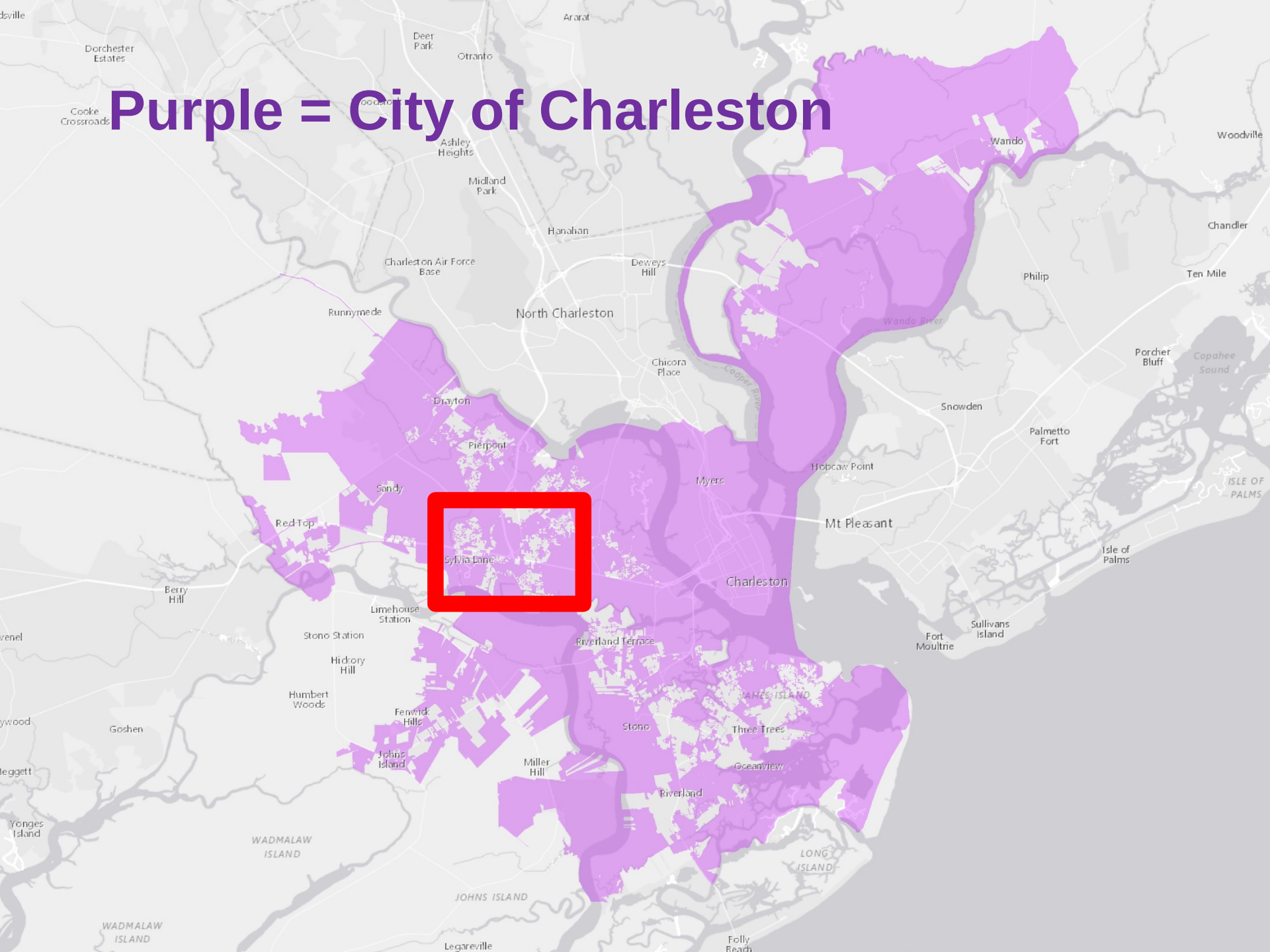
Tree in Forest

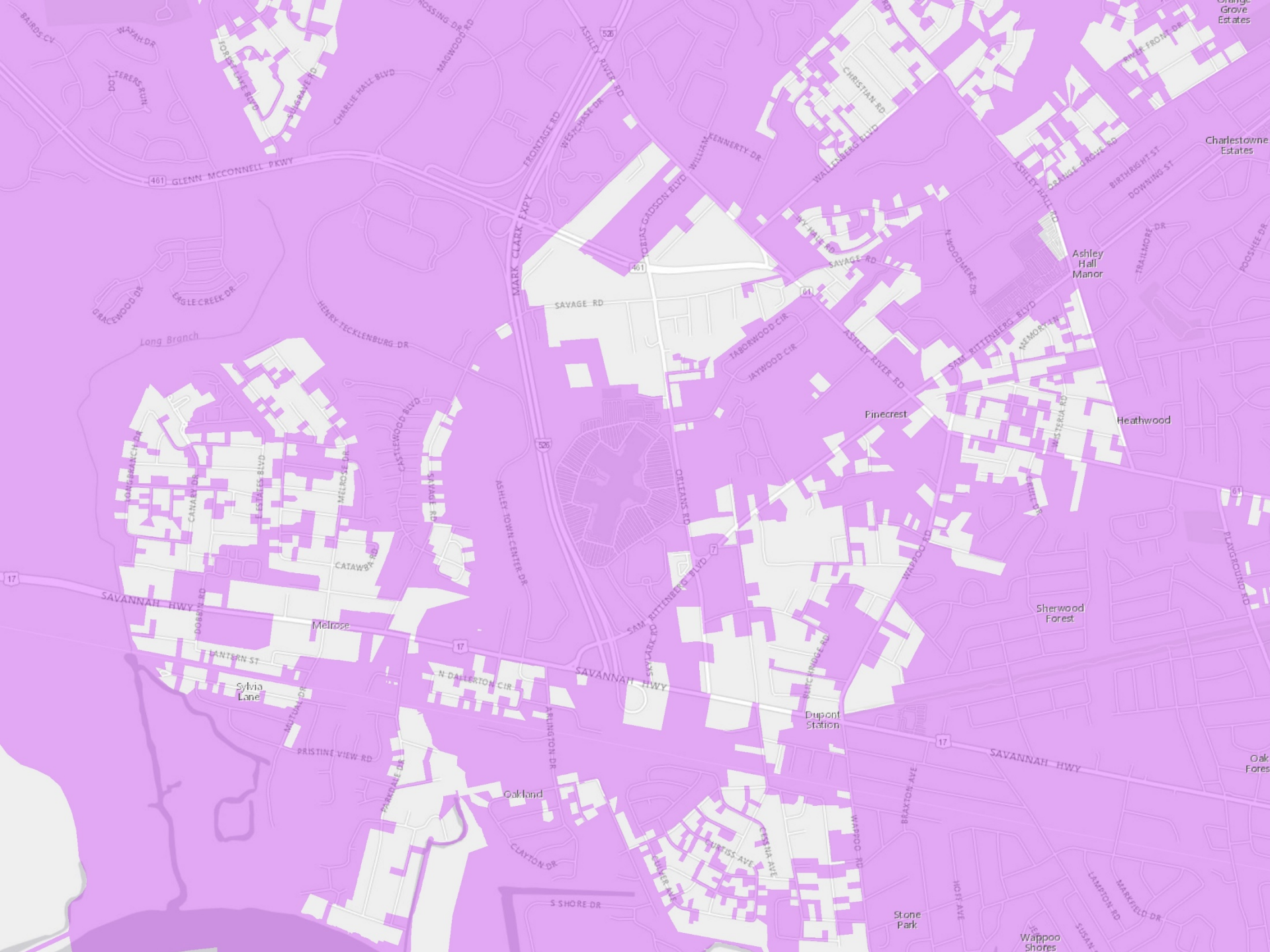
Tree Over Street and Sidewalk

Tree Over Lawn

First, How Much Canopy Do We Have? Using Image Classification

Image classification is the process of breaking an image into spatial land coverages (including tree canopy, other vegetation, impervious surfaces such as buildings, streets and parking lots).


Purple = City of Charleston
Dorchester Estates
Deer Park
Otranto
Ararat
Cooke Crossroads
Ashley Heights
Midland Park
Hanahan
Wando
Woodville
Chandler
Charleston Air Force Base
Deweys Hill
Philip
Ten Mile
Runnymede
North Charleston
Wando River
Chicora Place
Cooper River
Porcher Bluff
Copahee Sound
Drayton
Snowden
Pierpont
Palmetto Fort
Hobcaw Point
Sandy
Myers
ISLE OF PALMS
Red Top
Mt Pleasant
Sylvia Lane
Isle of Palms
Berry Hill
Charleston
Limehouse Station
Sullivans Island
Stono Station
Riverland Terrace
Fort Moultrie
Hickory Hill
JAMES ISLAND
Humbert Woods
Fenwick Hills
Goshen
Stono
Three Trees
Johns Island
Miller Hill
Oceanview
Riverland
Yonges Island
WADMALAW ISLAND
LONG ISLAND
JOHNS ISLAND
WADMALAW ISLAND
Legareville
Folly Beach


Charlestowne Estates
Ashley Hall Manor
Pinecrest
Heathwood
Sherwood Forest
Melrose
Sylvia Lane
Oakland
Dupont Station
Stone Park
Wappoo Shores
Long Branch
GLENN MCCONNELL PKWY
461
MARK CLARK EXPY
526
SAVAGE RD
SAVANNAH HWY
17
ASHLEY RIVER RD
SAM RITTENBERG BLVD
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61
ORLEANS RD
ASHLEY TOWN CENTER DR
HENRY TECKLENBURG DR
CASTLEWOOD BLVD
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PLAYGROUND RD
TRAILMORE DR
MARKFIELD DR
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ORANGE GROVE RD
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CHRISTIAN RD
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GRACEWOOD DR
EAGLE CREEK DR
CANARY DR
LONGBRANCH DR
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MELROSE DR
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MEMORY LN
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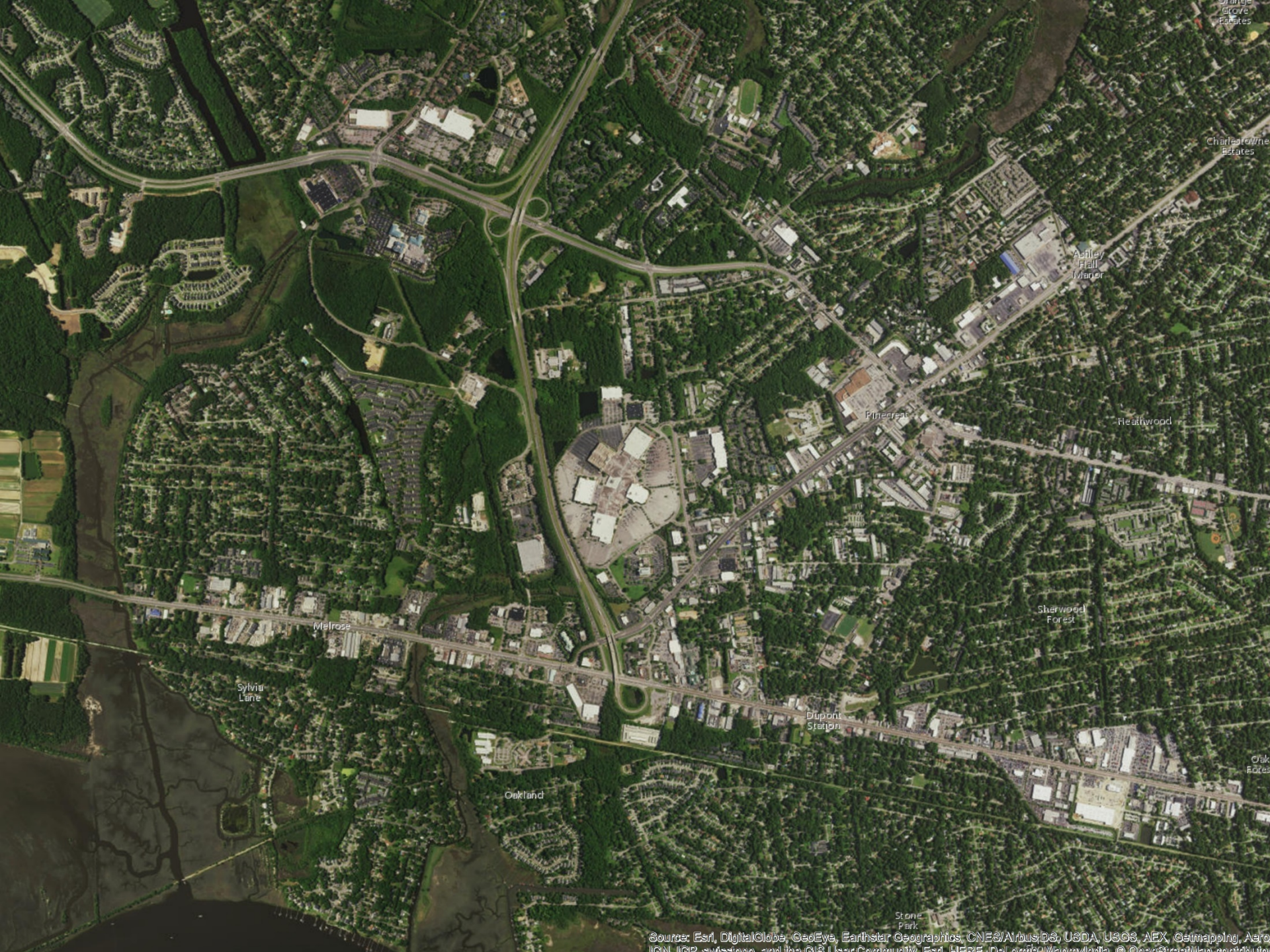
Orange Grove Estates
Charlestowne Estates
Ashley Hall Manor
Pinecrest
Heathwood
Sherwood Forest
Melrose
Sylvia Lane
Dupont Station
Oakland
Stone Park
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aero


Charlestowne Estates
Ashley Hall Manor
Pinecrest
Heathwood
Sherwood Forest
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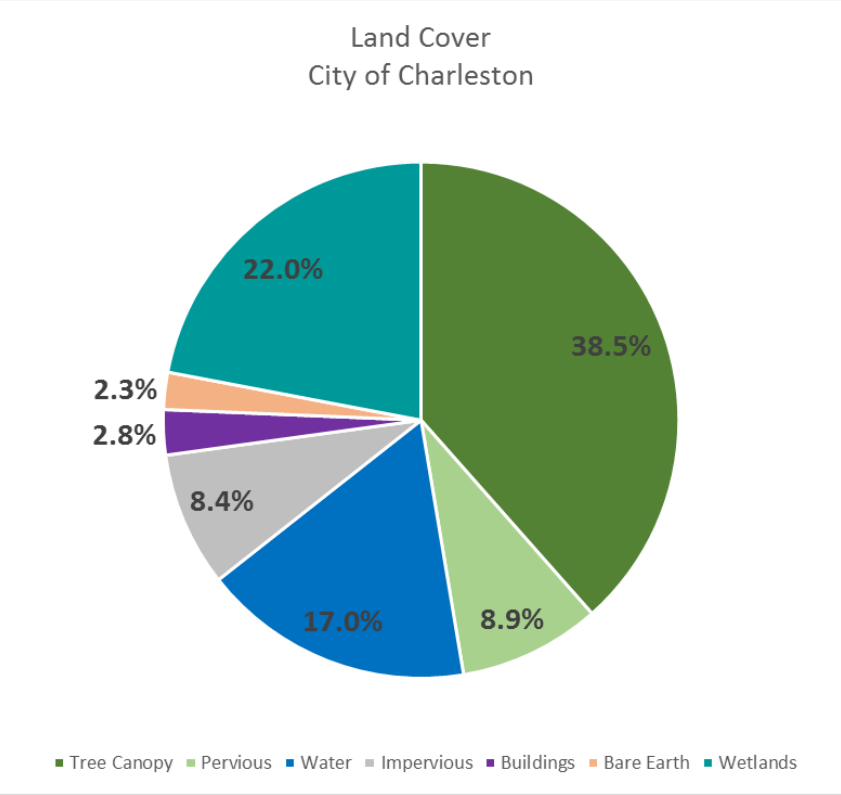
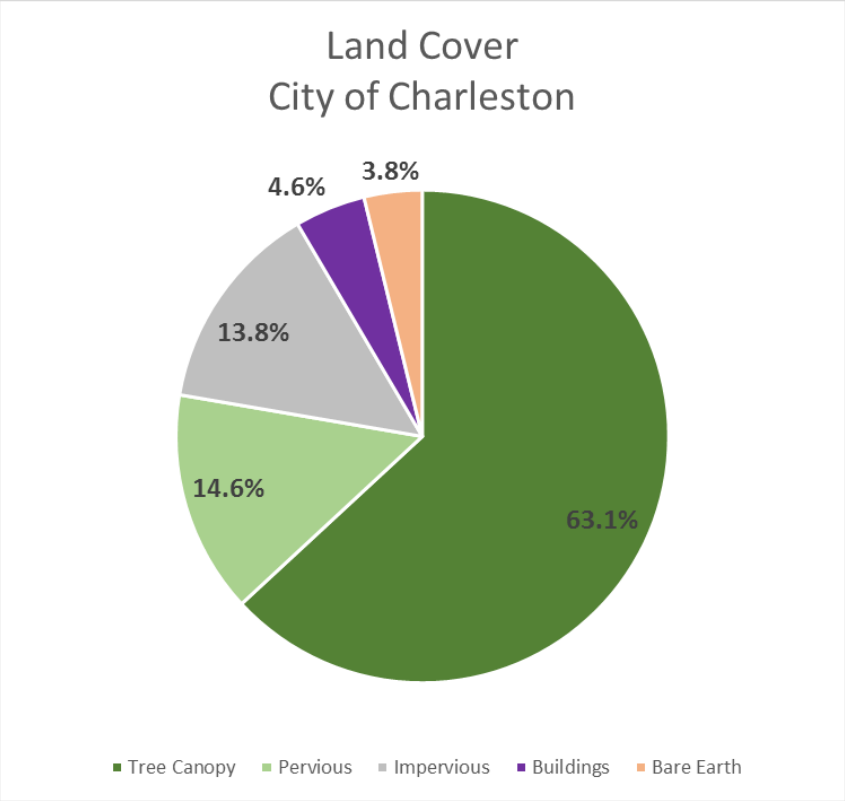
Wappoo Shores
SAVANNAH HWY
401 GLENN MCCONNELL PKWY
MARK CLARK EXPY

Results!
How well canopied are we?

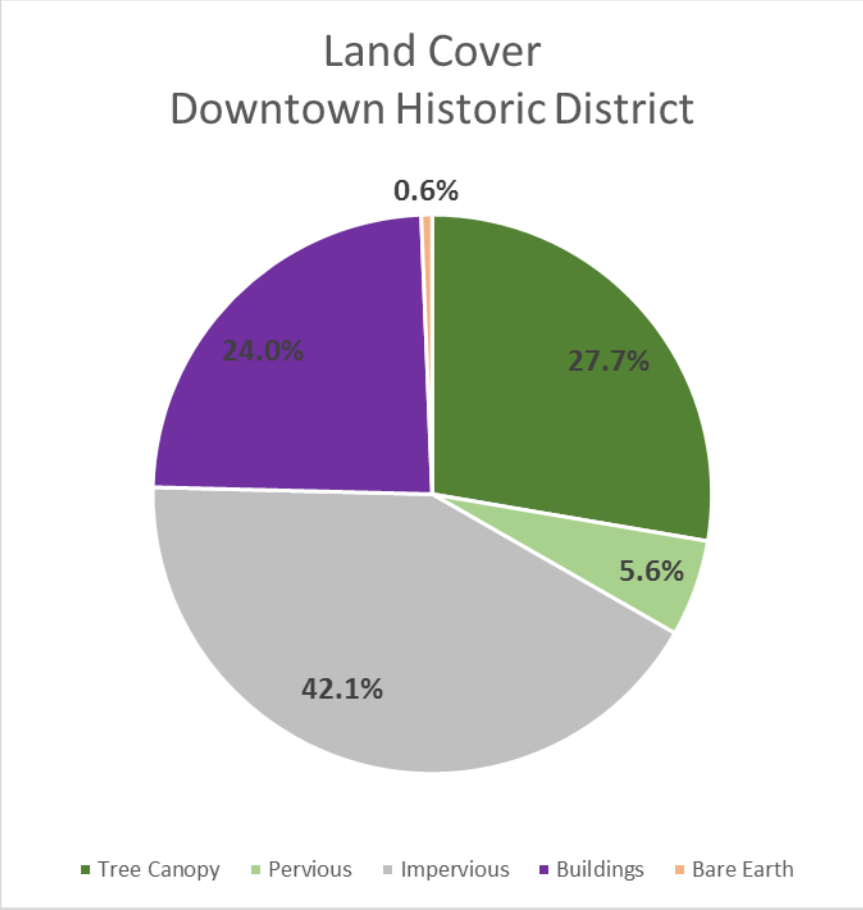


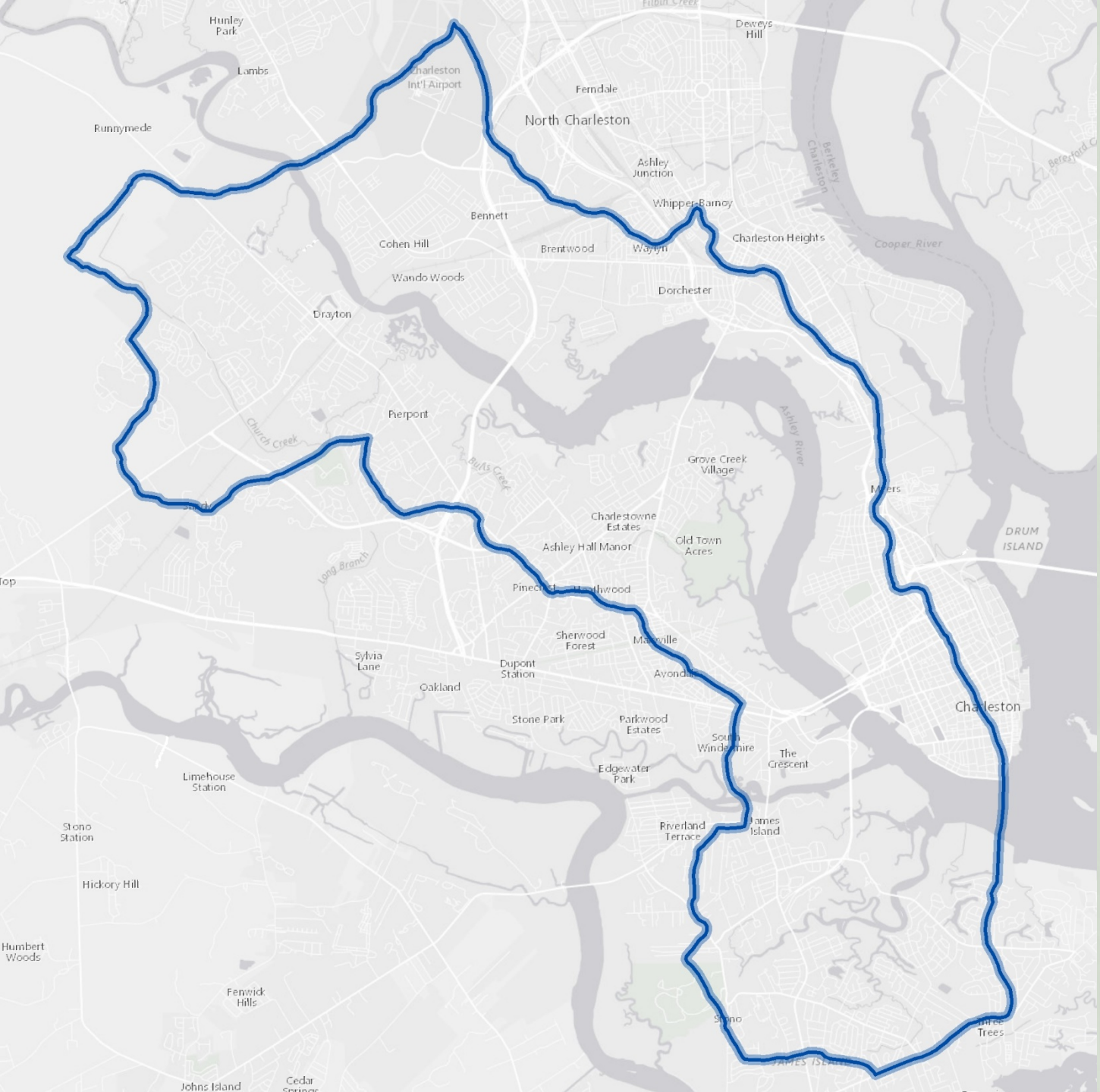
Including water and wetlands



Only land area included

Historic Downtown




Hunley Park
Lambs
Charleston Int'l Airport
Runnymede
Ferndale
North Charleston
Dewees Hill
Ashley Junction
Whipper-Barnoy
Bennett
Cohen Hill
Brentwood
Waylyn
Charleston Heights
Cooper River
Wando Woods
Dorchester
Drayton
Pierpont
Church Creek
Bulls Creek
Grove Creek Village
Ashley River
Myers
DRUM ISLAND
Charlestowne Estates
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Old Town Acres
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Charleston
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Parkwood Estates
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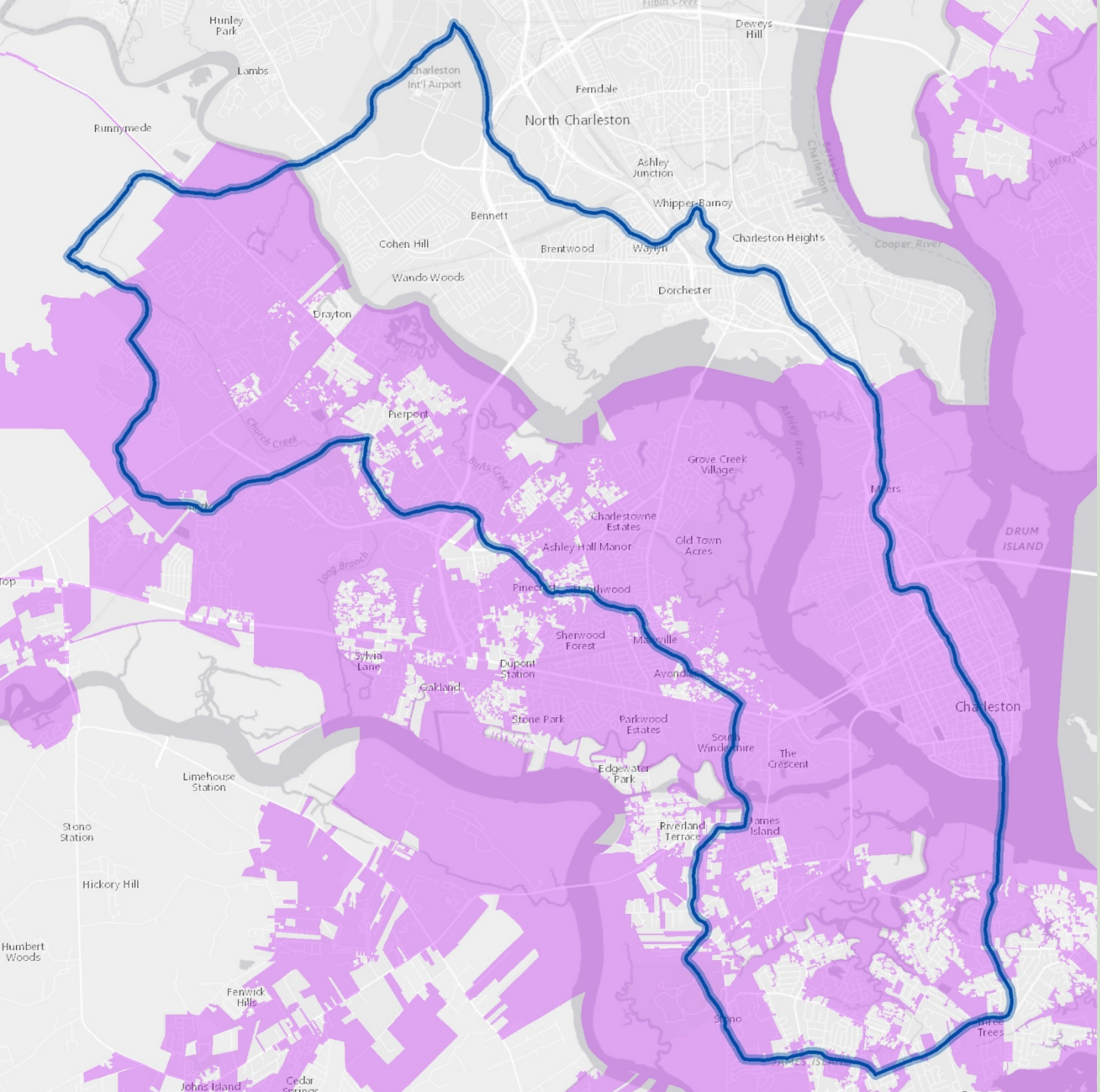
James Island
Stono Station
Hickory Hill
Humbert Woods
Fenwick Hills
Johns Island
Cedar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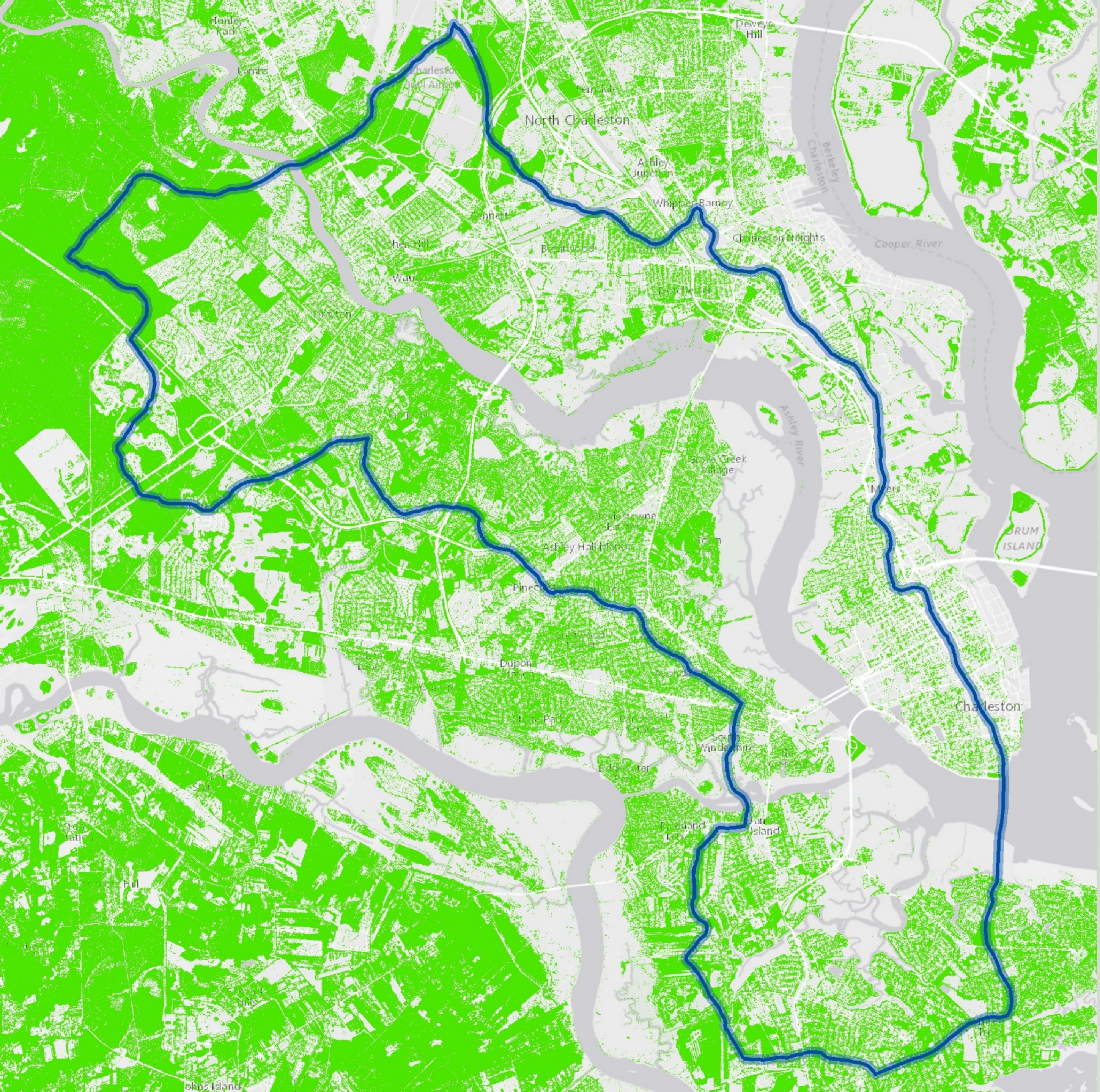

North Charleston
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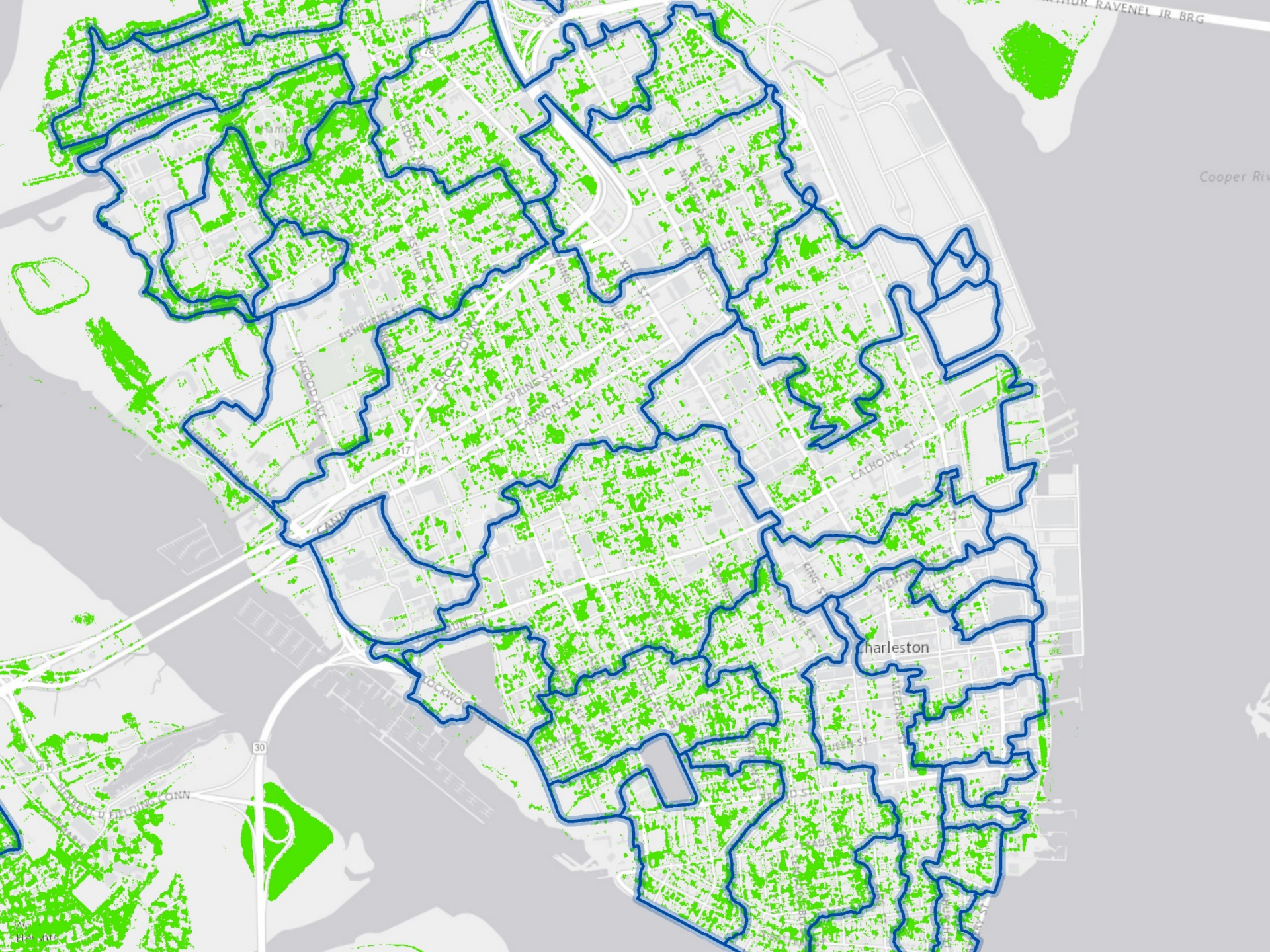
Cooper River
Ashley River
Berkeley
Charleston
Charleston Heights
Deweys Hill


Charleston
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MEETING ST
RAGSDALE AVE
CANNON ST
SPRING ST
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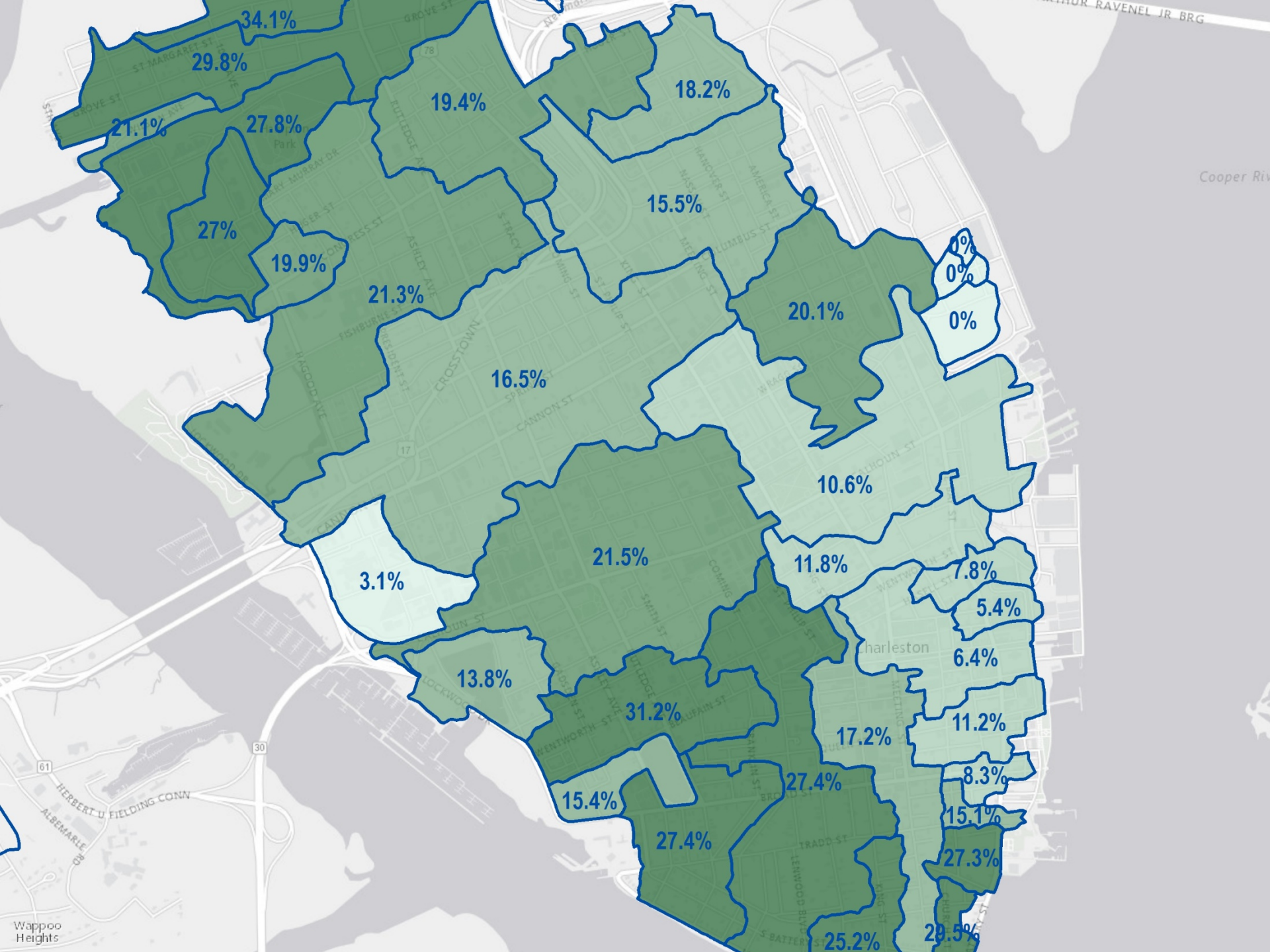
30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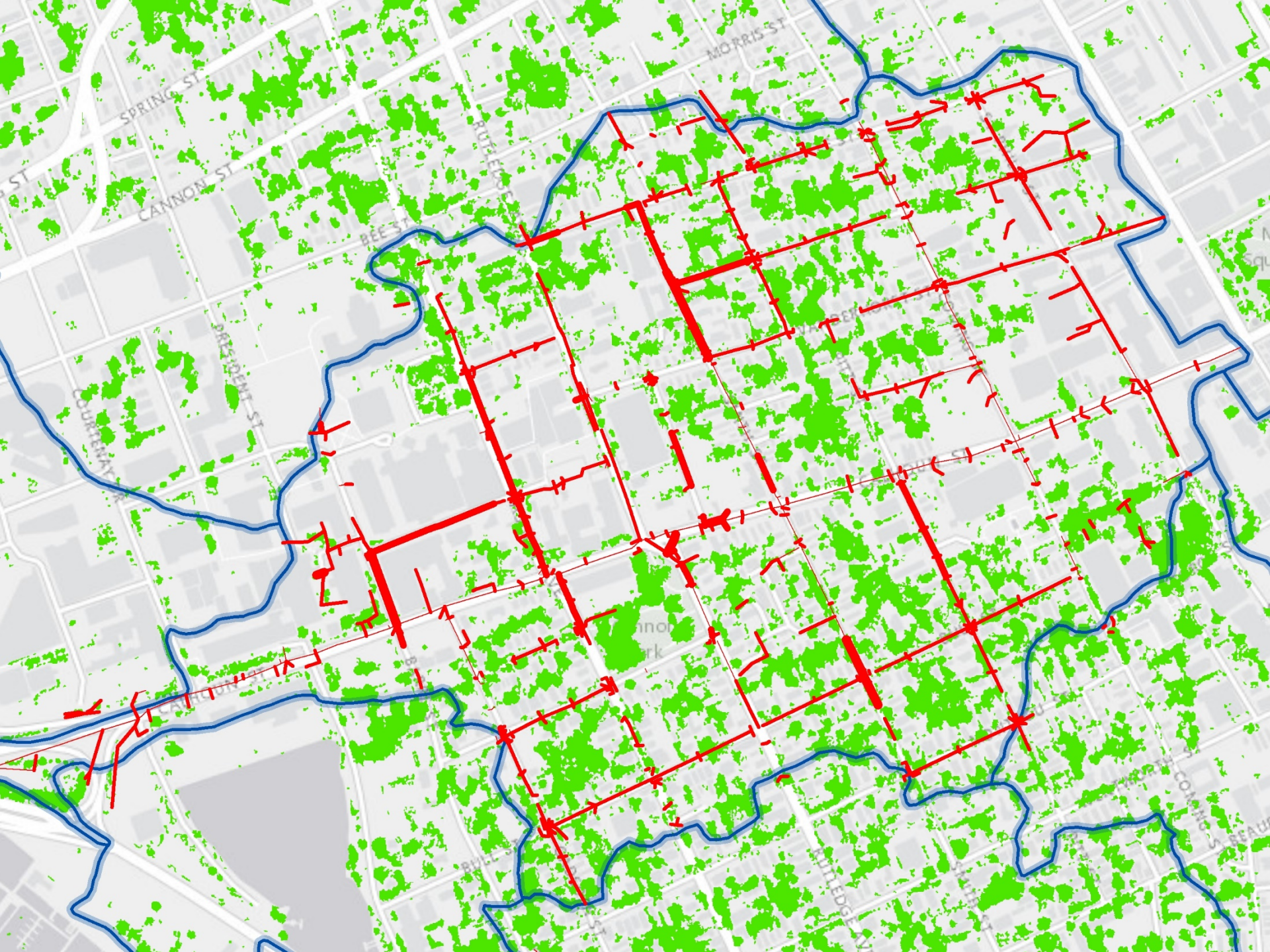

SPRING ST
CANNON ST
BEE ST
MORRIS ST
PRESIDENT ST
CURRENAY ST

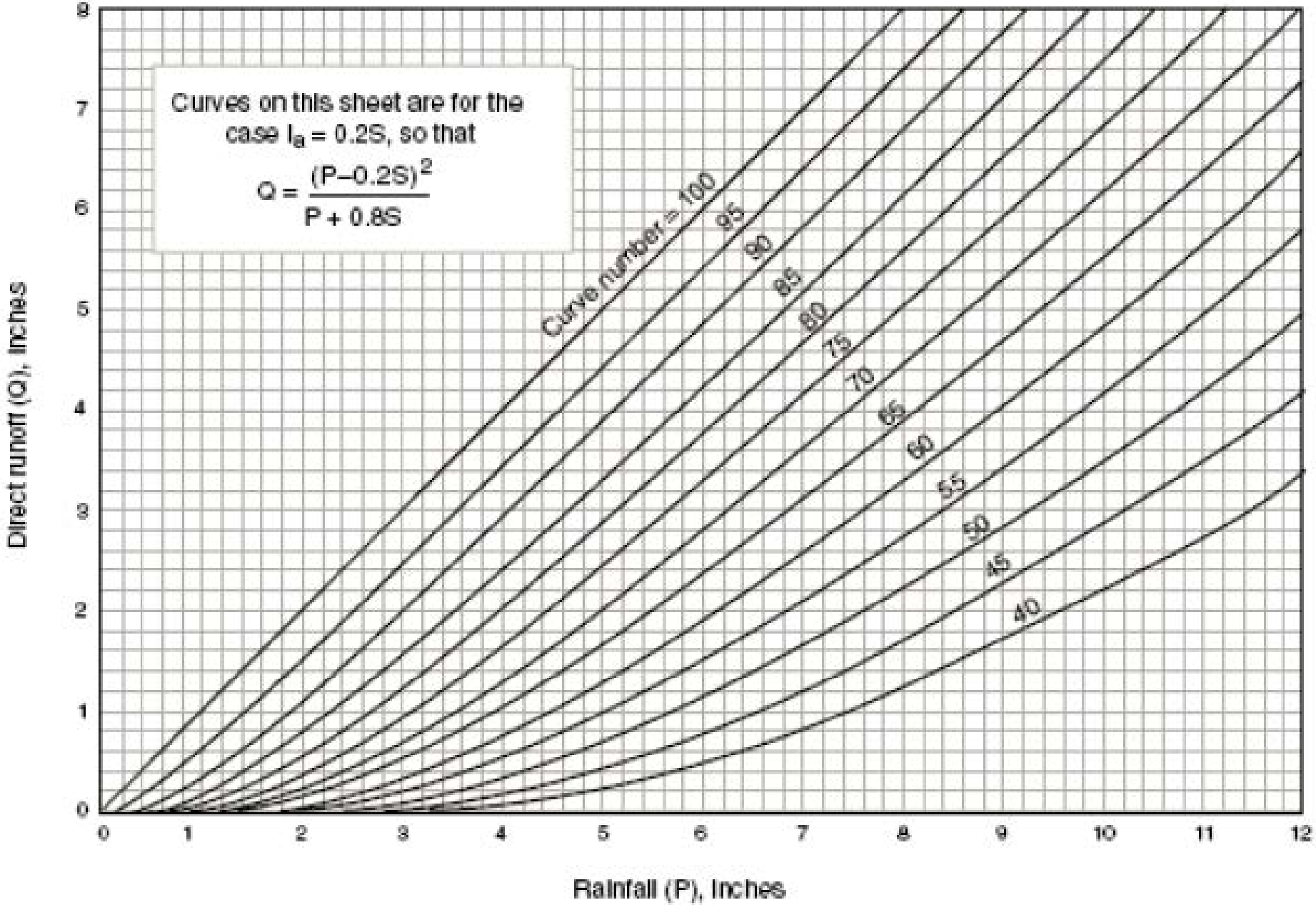
Field Checking Photo Recon

How much stormwater do the trees take up?

The NRCS Runoff Curve Number (CN)

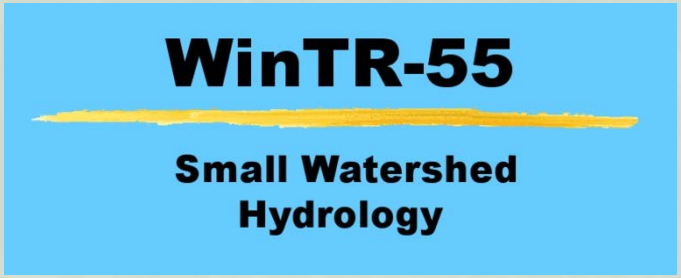
- ✓ A coefficient used to estimate runoff from precipitation, accounting for losses due to canopy interception, surface storage, evaporation, transpiration and infiltration
- ✓ Curve numbers have been developed for a variety of land covers and soil conditions

Figure 2-1 Solution of runoff equation.



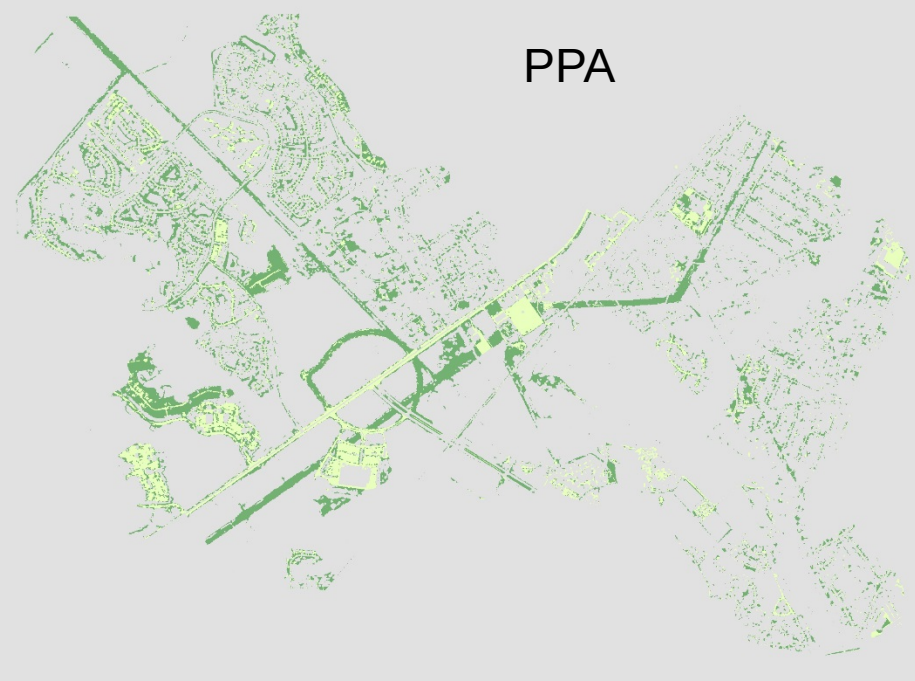
Method Overview

- Using GIC's high-resolution land cover / tree canopy maps to better estimate a composite CN for each watershed
- Estimating how increasing tree canopy according to our PPA can decrease (i.e. improve) the composite CN
- Using WinTR55 to estimate peak stormwater overland flows using current and projected composite CNs
- Using pollutant load reductions estimates from the Chesapeake Bay Progam to get rough estimates of water quality benefits provide by tree canopy



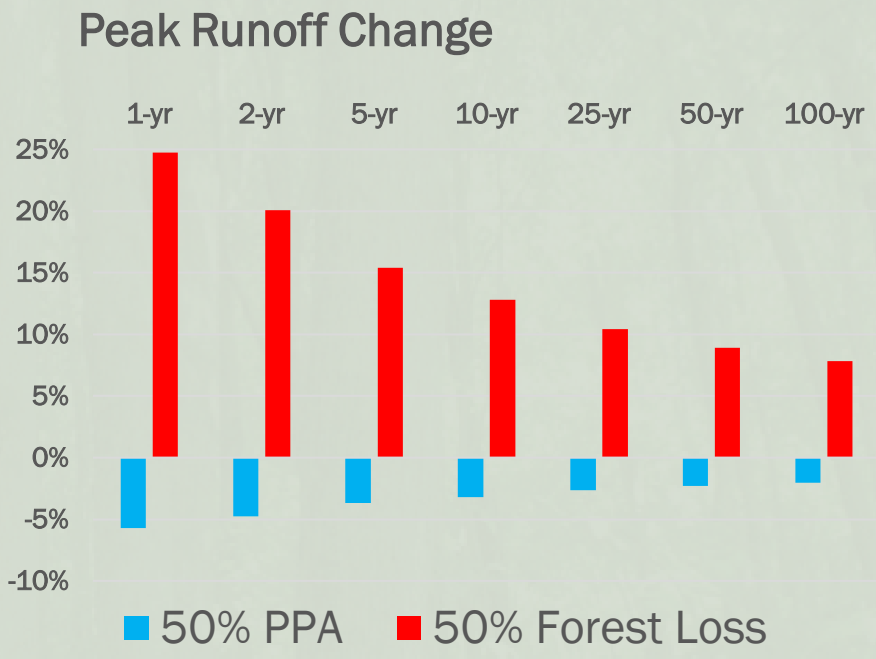
Church Creek

- 3,069 acres
- Tree canopy 56%
  - *Developed over pervious 35%*
  - *Developed over impervious 2%*
  - *Forest areas 19%*
- Pervious 22%
- Impervious 13%
- Bare earth 3%
- Wetlands 3%
- Water 3%



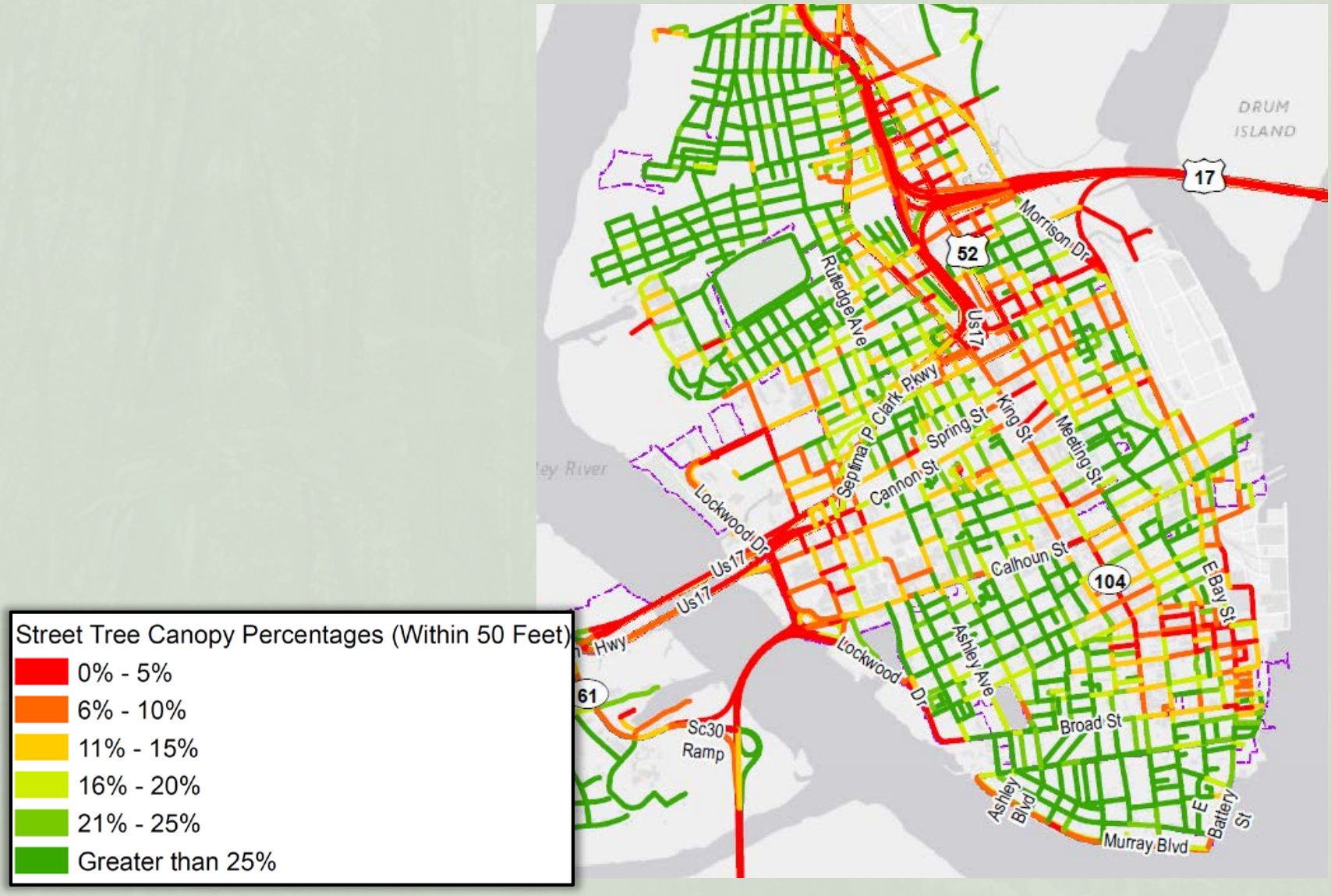
Preliminary results
Church Creek

- During a 5-yr storm (5.25 in) tree cover in this drainage can intercept, infiltrate and evapo-transpire about 147 million gallons of water
- Planting 50% of the PPA reduces 1-yr storm runoff by 1,200 gallons per minute and captures an additional 5.4 million gallons of water in a 5-yr storm
- 50% tree canopy loss increases 1-yr peak runoff by 25%

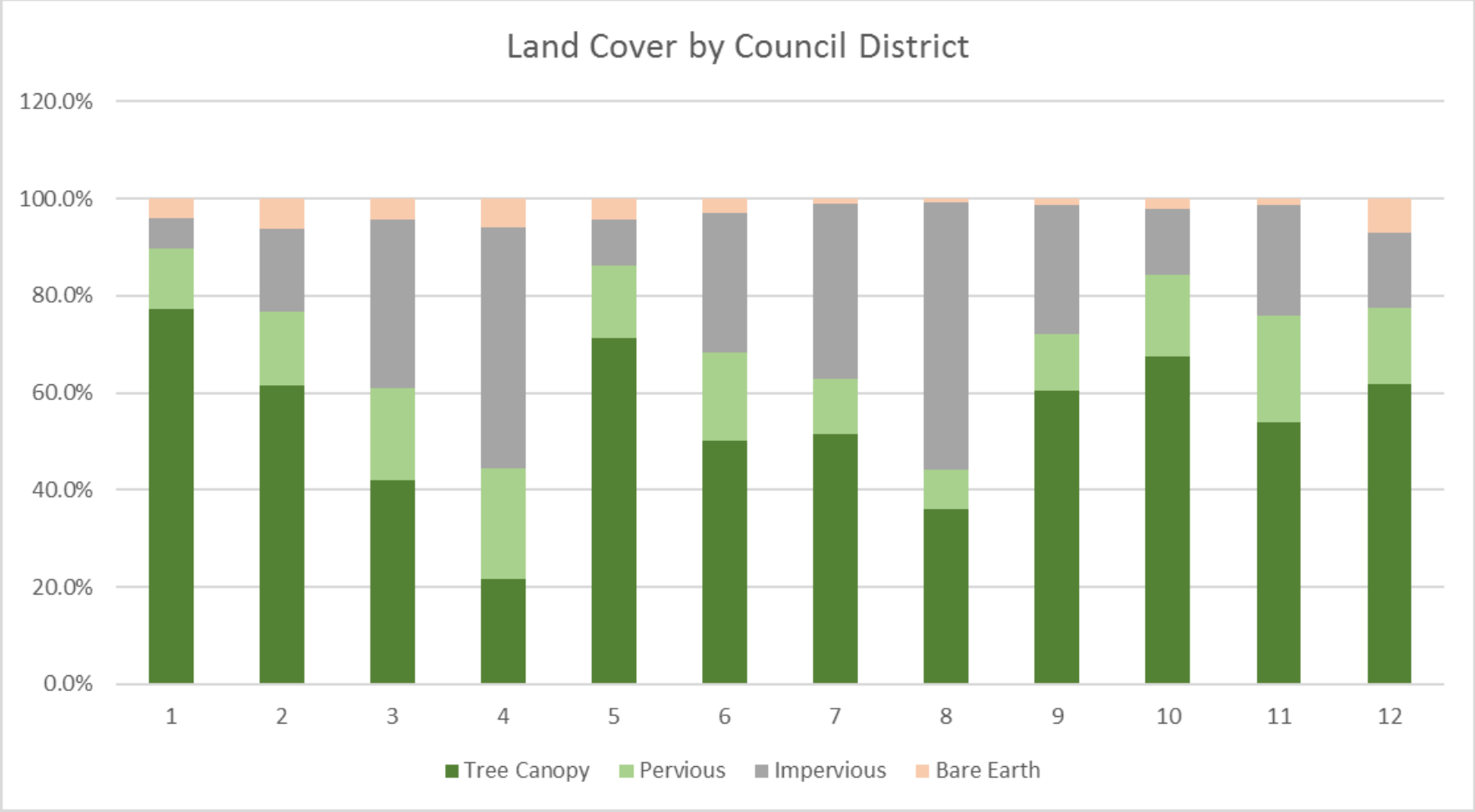


- Water Quality benefits of current urban canopy
  - 9.2% N & P loading reductions
  - 2.2% loading reductions
- Water Quality benefits of trees with 50% PPA
  - 10.5% N & P loading reductions
  - 2.6% loading reductions

Street by street analysis. How green are the city's streets?



Putting a Political Lens on Canopy …

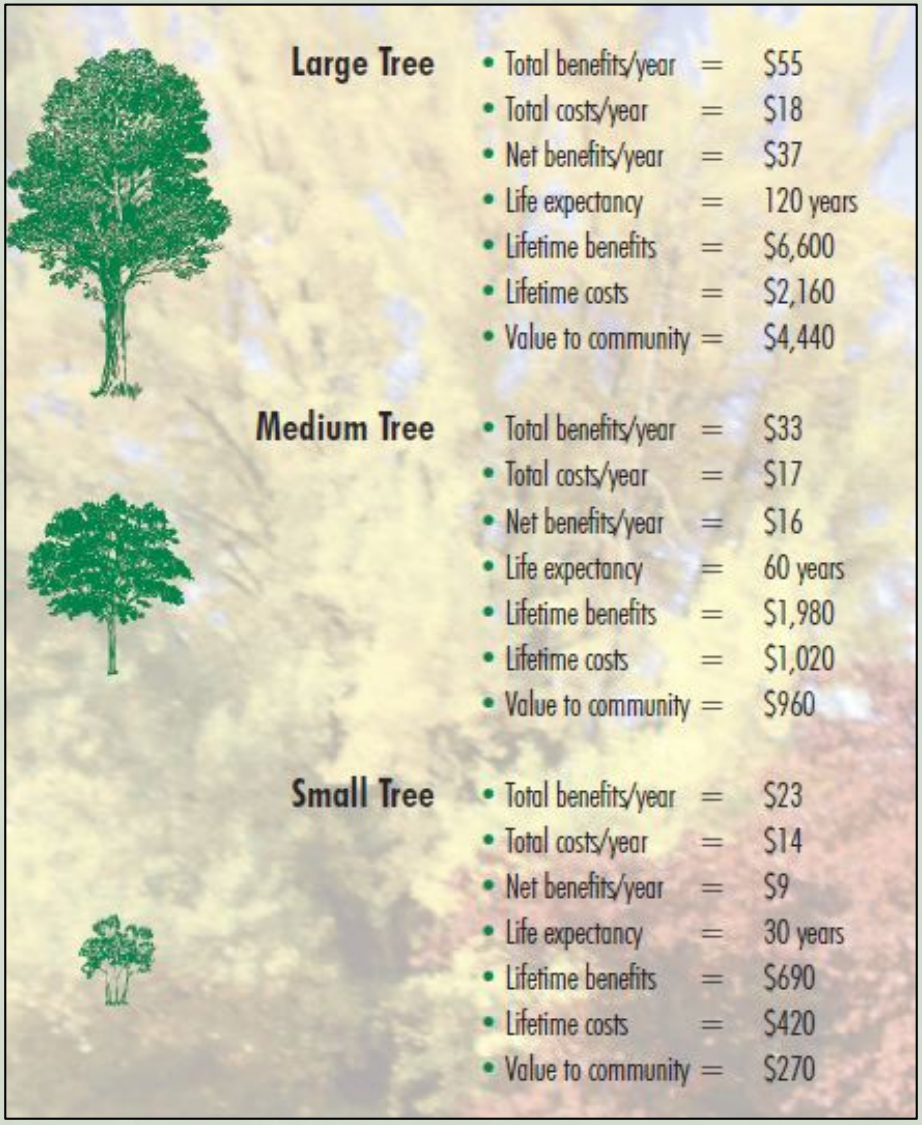


Where Can We Fit Trees?

Possible Planting Areas

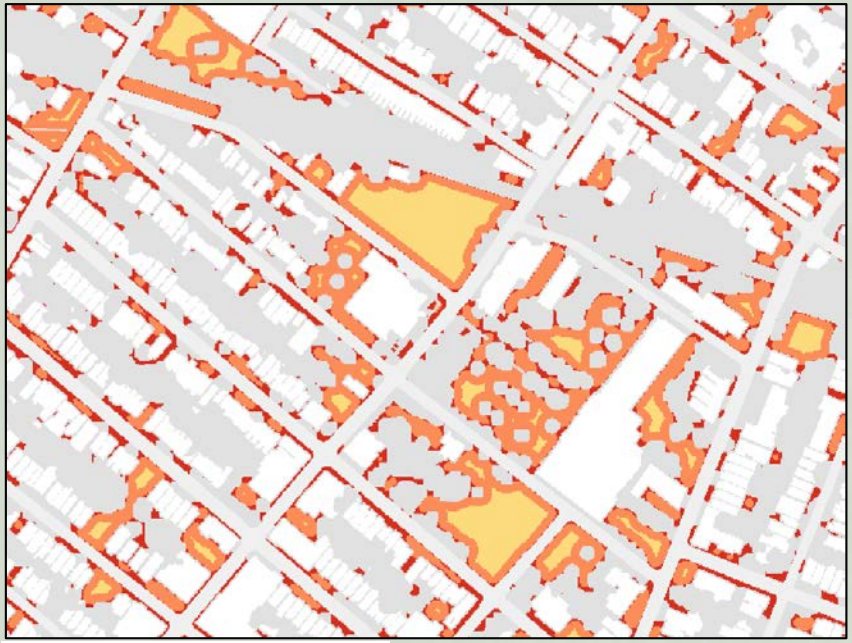
Lots of room to add trees

Annual Average Benefits



USDA Forest Service, Center for Urban Forest Research

Using GIS, we can estimate where it's possible to plant trees, and the benefits of doing so.



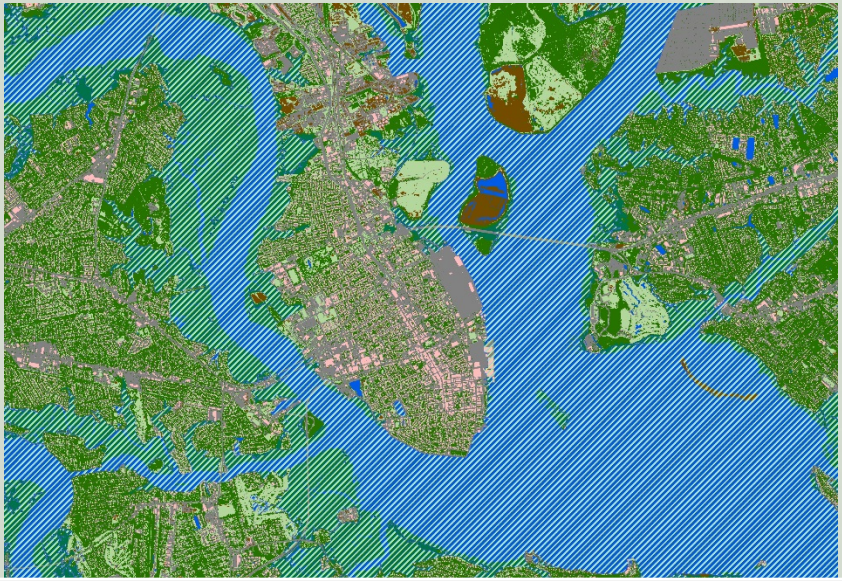
Possible Planting Area vs. Potential Tree Canopy

What would it take to reach certain canopy goals?

(example from a GIC Study neighborhood)

Percent of PPA Covered	New Neighborhood TC %	Small Trees	Medium Trees	Large Trees	Total Trees
1%	15.04%	4	9	1	14
2%	15.60%	8	19	3	30
3%	16.16%	12	28	5	45
4%	16.72%	16	38	6	60
5%	17.28%	20	47	8	75
6%	17.84%	25	57	10	92
7%	18.40%	29	66	12	107
8%	18.96%	33	76	13	122
9%	19.52%	37	86	15	138
10%	20.08%	41	95	17	153
11%	20.64%	46	105	18	169

Impacts of Sea Level Rise



Land Cover Inundated by 1.5 ft. SLR		
	Acres	*% of cover*
Wetlands	19,540	83.2%
Trees	820	1.6%
Impervious	222	1.7%
Pervious	166	1.2%
Bare earth	106	2.4%
Buildings	15	0.4%

Data: GIC Landcover, NOAA Coastal Services Center Sea Level Rise Data: 1-6 ft Sea Level Rise Inundation Extent, City of Charleston Sea Level Rise Strategy (2015)

Now: Codes and Policy Audits

This will answer two main questions:

Do city policies allow too much impervious area?

For example does the city mandate excessive parking area?

Does it provide incentives to reduce impervious area?

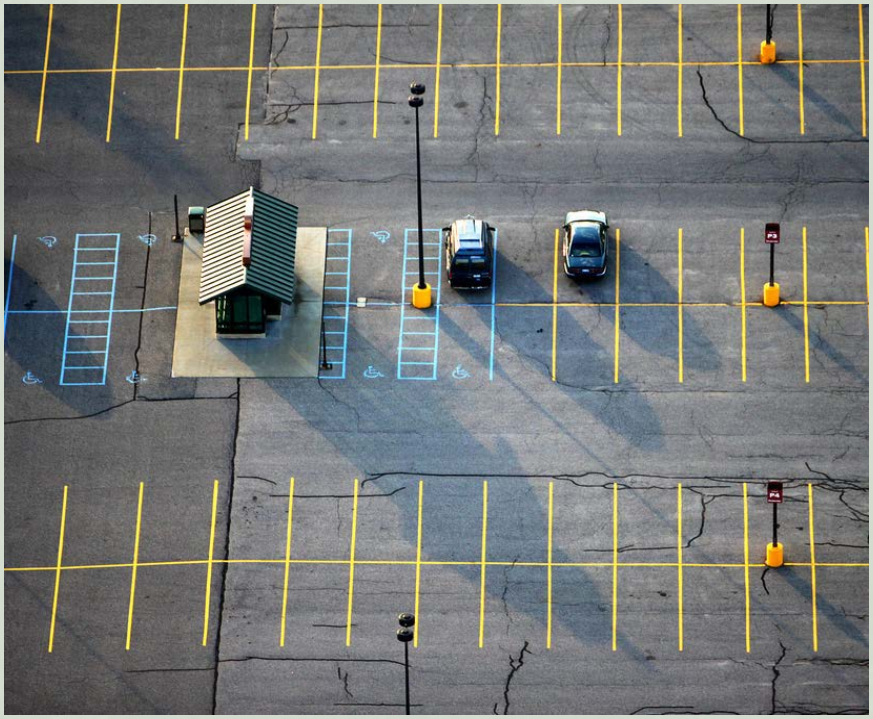
Can the city manage and expand the urban forest?

For example, are tree care and management well funded and implemented?

Does the city have a strategy for planting trees in areas most in need?

Low Impact Development Best management practice – parking lot bioswale!

Changing Codes Example: Reduce Imperviousness in Parking Lots



How?

- Match parking requirements to demand requirements
- Incentivize permeable pavement especially at city's higher elevations

Variable Space Sizing

Not all of us drive this →

← Some of us drive this.

Reduce Supersized Streets

- Increase imperviousness
- Decrease stormwater uptake
- Increase urban heat island effect

Supersized Streets

Example from a pilot city:

- Street widths based on average daily trips (ADTs)
- ADTs based on suburban driving habits (i.e. drive everywhere)
- Suggest increasing ADT ranges and allowing more narrower streets
- Geared toward redevelopment

Current Street Classifications to Reduce Widths

Residential Street Classification	Projected Traffic Volume (ADT)
Low Density	< 400
Medium Density	401-2000
High Density	2001-4000

Proposed Street Classifications to Reduce Widths

Residential Street Classification	Projected Traffic Volume (ADT)
Low Density	< 600
Medium Density	600-1600
High Density	1601-3000

Mature Tree Preservation

Versus

Mature v. Immature

Clearing Land

Example from a pilot city:

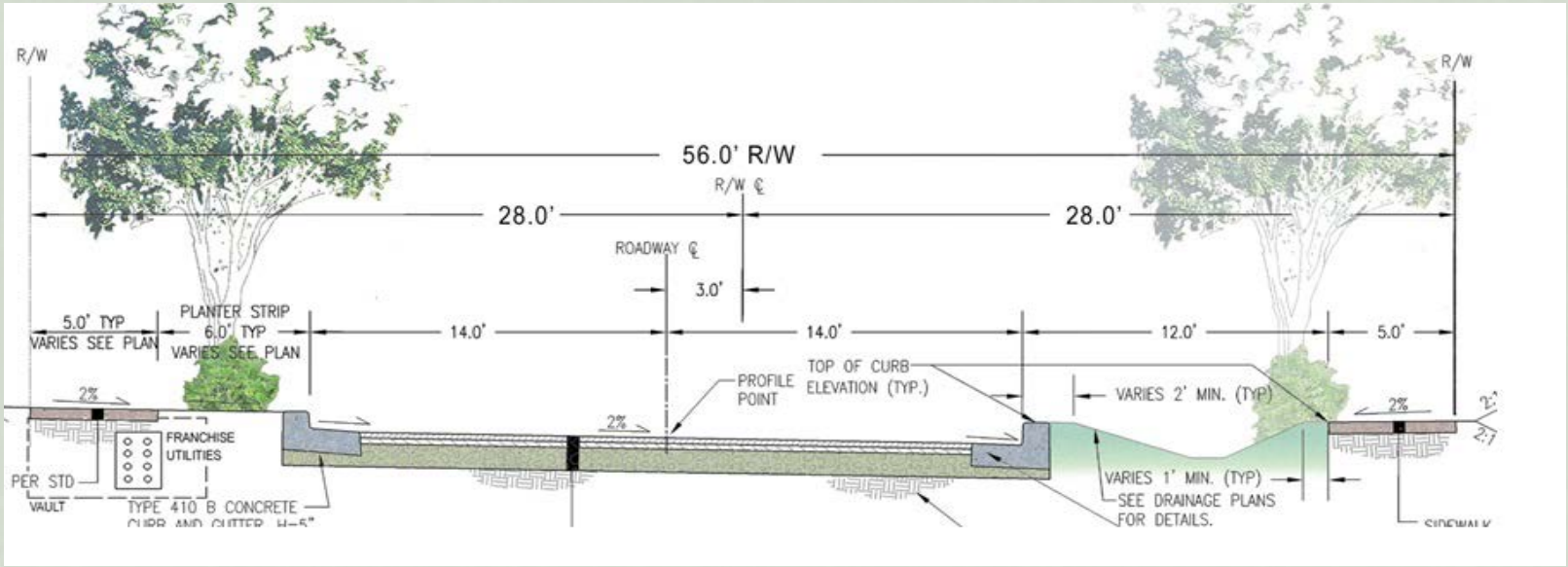
- Ordinance allowed lot line to lot line clearing
- Revised ordinance proposes tree canopy requirements by district
  - *0% Downtown District*
  - *10% Traditional Character District*
  - *25% Suburban Character District*
  - *15% Coastal Character District*

While this is better than before, the downtown should not be 0!

Benefits of Trees In Developed Areas

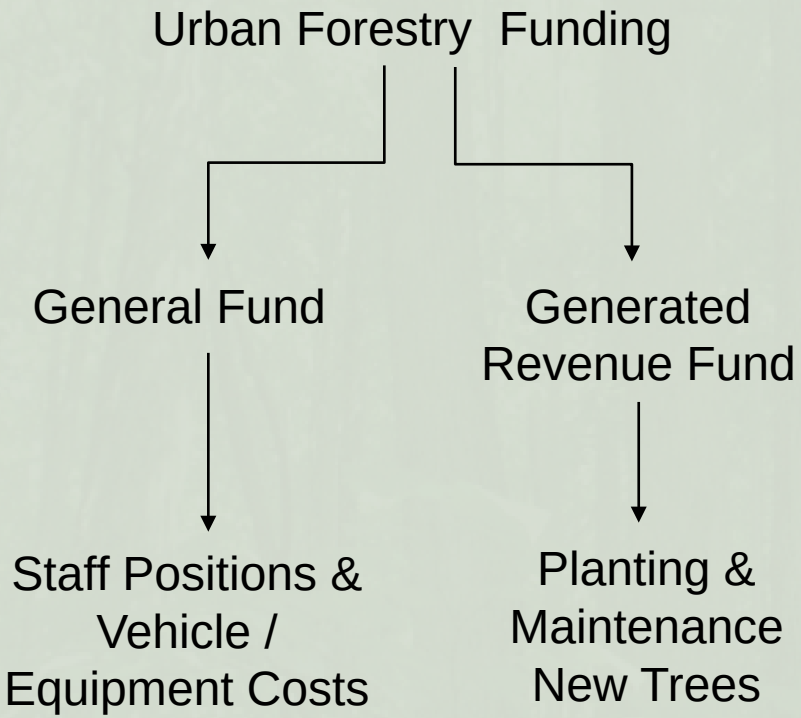
- Stormwater flow can be integrated into the streetscape in a way that provides multiple benefits – traffic calming, pedestrian safety and landscaping.
- Think outside the box:
  - *Allow flexibility for not meeting canopy requirements by planting projects such as pocket parks*

Water Flow Strategies



- Widen and deepen planting strip
- Streets may drain to one side
- Planting strips can be mown lawn or include perennials

Urban Forestry Budget



- Does the locality have a dedicated budget for tree planting and maintenance?
- For example, it is common that resources allocated for trees are through fines and fees only.
- Cities often only practice reactive forest management because of limited resources.
- Resiliency can be increased by allocating funds and acting in a proactive management mode, e.g. prune before storms, remove hazards, plant buffers.

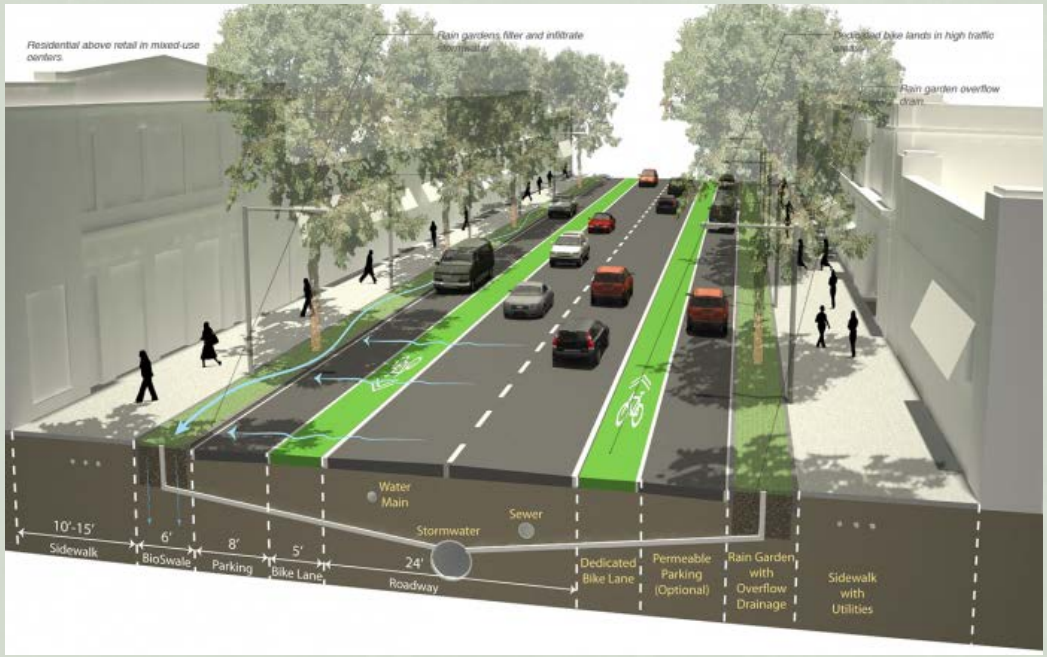
Grants May be Difficult if All Approvals are by City Council

- It is common, that City Council requires that all grants be approved by them
- Delays lasting longer than a year have been experienced
- This restriction should be eliminated; this would allow the forestry department to apply for and implement more grants
- GIC suggests that City Council only be required to approve grants greater than $20,000. Some cities don't bother councils with grants less than $50,000.

Redesign Streets as Complete ‘Green’ Streets

Complete green streets allow for

- ✓ Treatment of stormwater on site
- ✓ Reduction of urban heat island effect
- ✓ Beautification: increase in downtown foot traffic
- ✓ Habitat corridors



Infiltration and Trunks – need more room to allow water to reach roots!

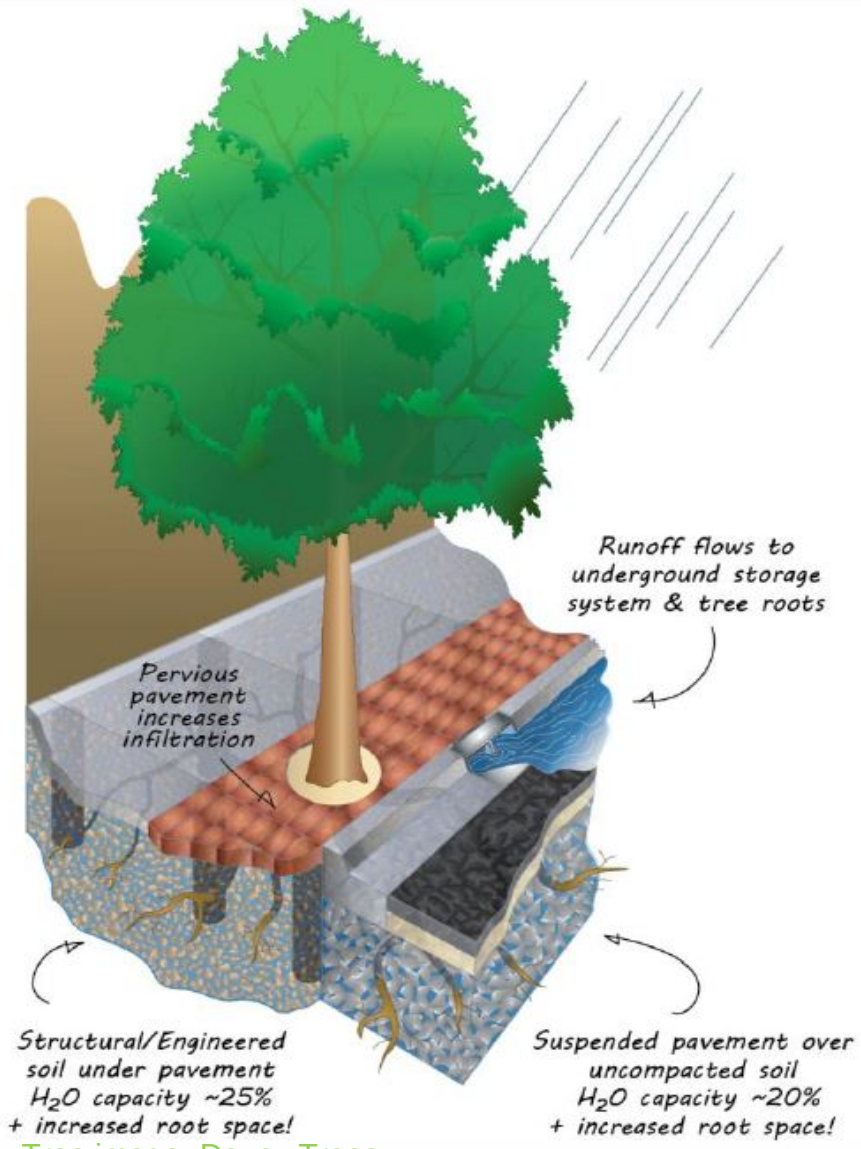
Adequate Planting Area

This small tree has permeable pavers for high traffic areas.

The pavers can be removed as the trunk grows, while air and water can still reach the roots.

A general rule: 1000 cubic feet soil vol. per tree.

Accommodate Large Trees



Tree image, Davey Trees.

Larger trees offer greater benefits – so think carefully when setting planting goals for streets!

Consider using structural soils and permeable pavement, rather than just choosing small trees! Trees will pay back your investment!

Charleston is working to provide options to live with its street trees.

This walkway was built to go over the roots so this live oak and people can co-exist!

Charleston Tree Planting Program

Charleston City Arborist Danny Burbage leads tour of amazing Charleston Trees

- Upon request, the city plants trees within city right-of-ways
- Planting fee depends on the tree species and whether the sidewalk must be opened
- Resident who requested the tree is responsible for keeping the tree watered
- After the tree has been in the ground for one year, the city takes over pruning and maintenance of the tree

Example: Type of Analysis for Private Sector

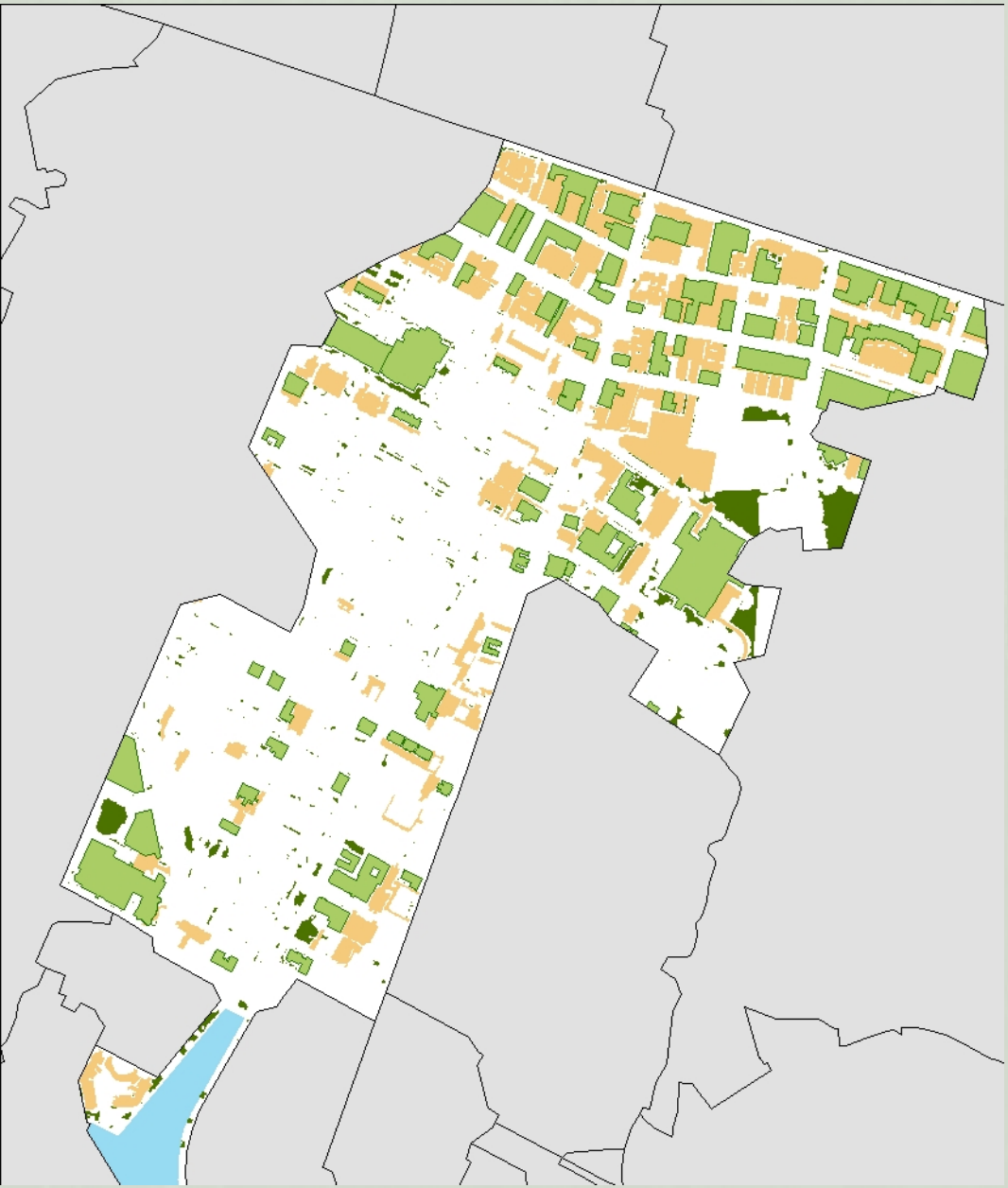
Individuals actions can make a big impact!

- ~**47,500** parcels with single family homes
- ~**31,000** of these have room for at least 1 tree
- If everyone planted a single tree, they would intercept **62 million gallons** of rainwater every year (1.5 million bathtubs!)

Each tree icon represents a possible tree planting location that avoids buildings, underground utilities, and other infrastructure. Tree spacing is 30 feet.

This example is for Norfolk, VA and we will do similar analysis for Charleston.

Example: Adding infiltration on roof tops when not much room to plant



- Example scenario:
  Green roofs reduce runoff from rooftops by 21 million gallons annually (assuming 70% capture)
- 50% of parking covered by shade trees – intercepts an additional 700,000 gallons annually (based on interception of 20 year old hardwood).

- What incentives to make this happen? For ex., locality allows tax incentives, density bonuses, fee reductions, expedited permitting etc.

Project Outcomes for 13 cities…

- ✓ Map of the city's urban forest and possible planting areas.
- ✓ Written step by step methodology for linking urban forest systems to urban stormwater management.
- ✓ Calculating stormwater uptake by trees
- ✓ Recommendations for how the city can adopt new programs, codes, processes to better integrate the county's trees as part of stormwater management
- ✓ Sharing the work – a case booklet and presentation detailing methodology, lessons learned, best practices

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End