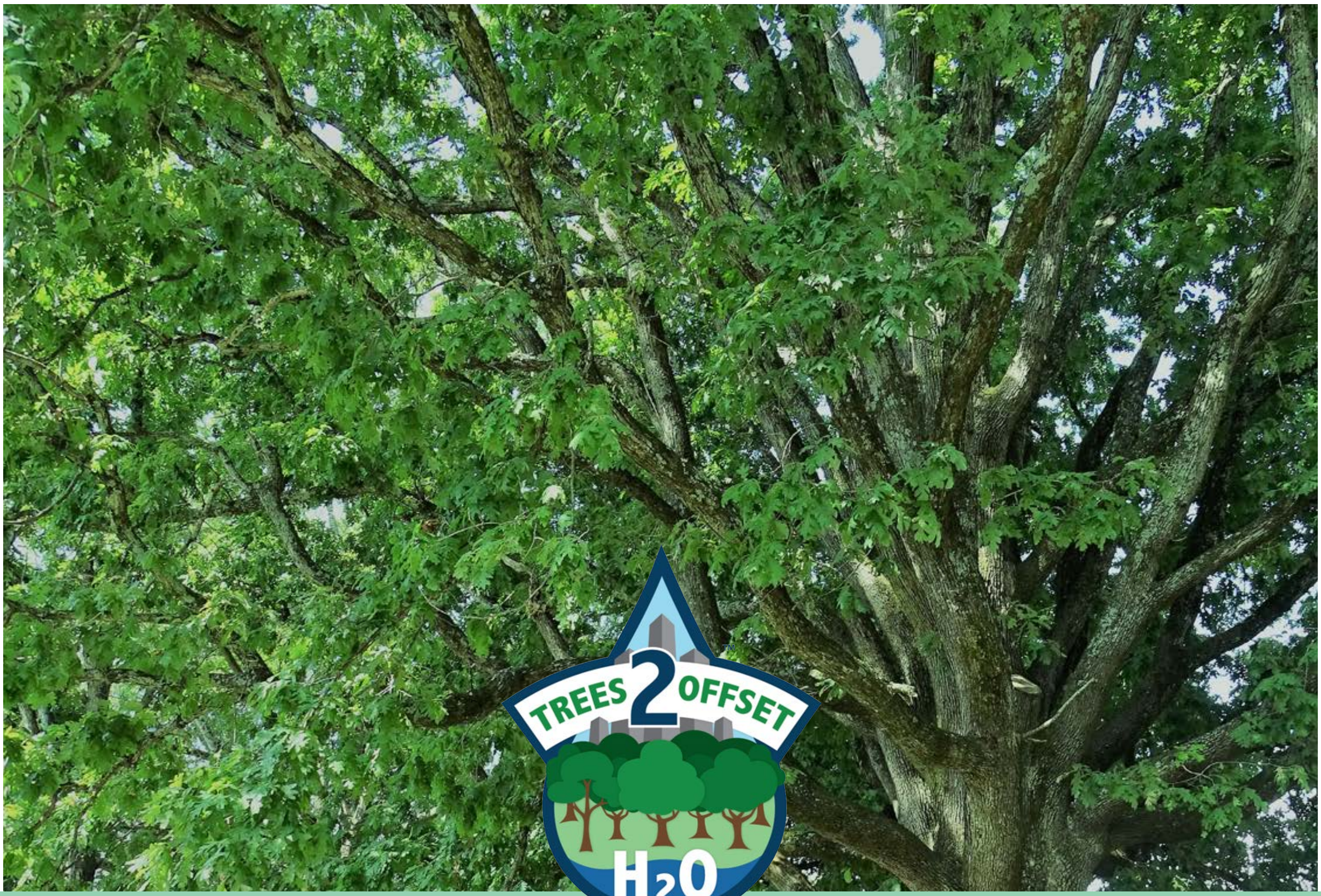

TREES TO OFFSET STORMWATER

Case Study 02: Apex, NC

July 2018

Case Study 02: Apex, NC

All images in this report are credited to the GIC unless otherwise indicated.

The work upon which this publication is based was funded, in whole, through a sub-recipient grant awarded by the USDA Forest Service from the North Carolina Forest Service to the Green Infrastructure Center and Apex. The Green Infrastructure Center is the project partner and technical services consultant. The contents do not necessarily reflect the views or policies of the USDA Forest Service or Apex Government, nor does mention of trade names, commercial productions, services or organizations imply endorsement by the U.S. Government.

Publication Date: July 2018

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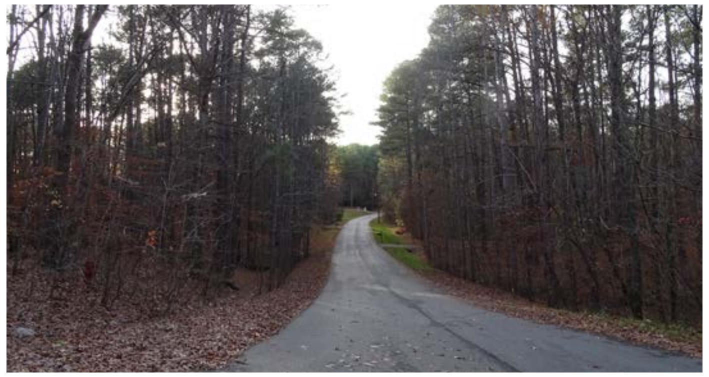
Project Overview

This project, called Trees to Offset Water, is a study of Apex's forest canopy and the role that trees play in taking up, storing and releasing water. This study was undertaken to assist Apex 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 ways in which the town can benefit from tree conservation and replanting. It also evaluated ways for the town to improve forest management as the town develops.

PROJECT FUNDERS AND PARTNERS

This is a pilot project for a new approach to estimate the role of trees in stormwater uptake. North Carolina is one of six southern states that received funding from the USDA Forest Service to study how trees can be utilized to meet municipal goals for stormwater management. The project was developed by the nonprofit Green Infrastructure Center Inc. (GIC) in partnership with the states of North Carolina, South Carolina, Virginia, Georgia, Florida and Alabama. The NC Forest Service administered the pilot studies in North Carolina. Apex was selected to be one of the two test cases in North Carolina for the project. The other North Carolina municipality selected was Wilmington.

The GIC created the data and analysis for the project. 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 and lack of tree replacement as older trees die. 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, Apex now has baseline data against which to measure canopy protection progress, measure the stormwater and water quality benefits of its urban forest, as well as to prioritize restoration of canopy where needed.



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 town codes and ordinances, and citizen input and recommendations for the future of Apex. 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 town'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 of the results of the pilot studies as a case study at the National Partners In Community Forestry Conference, and
- A case booklet and presentation detailing the pilot study methodology, as well as lessons learned and best practices.

The project began in September 2016. Apex staff members have participated in project review, analysis and evaluation. The following town departments were involved in the Technical Review Committee (TRC) which undertook project planning and review: Electric Utilities, Geographic Information Services, Planning, Water Resources, Office of the Town Manager and the Parks, Recreation and Cultural Resources Department.

COMMUNITY ENGAGEMENT

Two community meetings were held. The first meeting, held in July 2017, provided an overview of the project and an opportunity to gather public input and concerns regarding tree conservation and to review the canopy cover maps. The second meeting, held in November 2017, provided recommendations and elicited feedback on how to prioritize them.

Residents offered specific suggestions for where to plant trees and requested advice for how to properly plant and nurture street trees to maximize survival. All individual comments from the meeting were provided to the town (see Appendix B: Comment Detail). Residents expressed concern that the small town character and historic identity of Apex were being harmed because of the tree loss from new development and emphasized the importance of tree protection and replacement.

At the second community meeting, attendees were presented with seven specific code/ordinance or practice changes which GIC recommended to the Town of Apex. Meeting attendees were asked to choose the top three changes they supported. The code changes are listed in priority order below (most to least popular).

Residents learned how the tree canopy was mapped and then provided ideas for tree conservation or planting.

- Create a stormwater fee to incentivize reducing on-site impervious area.
- Increase the staff work force and budget for urban forestry.
- Create a tree list for use by the Town of Apex and add native trees.
- Increase the tree and root protection zone for trees during construction.
- Conduct proactive tree care to minimize tree hazards.
- Allow tree planting in right-of-ways.
- Have parking minimum and maximum requirements.

Additional Public Comments

Since many residents were unable to attend the first public meeting, town staff created a follow up internet survey asking residents to respond to a number of similar questions. As with the meeting survey, residents were asked to choose the top three changes they most supported. The responses following are listed from most to least popular.

- Strengthen the town's current tree protection and preservation standards.
- Allow street trees to be planted in the right-of-way where there is adequate space for viable tree growth with limited impacts to infrastructure.
- Create a stormwater fee to create an incentive for reducing impervious surface area.
- Improve the existing list of tree species to emphasize desirable native and adaptive trees and discourage invasive and nuisance species.
- Increase the town budget and staffing for urban forestry and education.
- Add maximums to the town's standards for parking spaces.
- Increase proactive tree care by the Town of Apex (for example, pruning hazardous tree limbs).

Residents made additional comments as well. These are listed in Appendix B of this report.

Apex can use this report and its associated products to:

- *Set goals and develop an urban forest management plan for retaining or expanding its tree canopy.*
- *Improve management practices to ensure that trees are well-planted and managed.*
- *Educate developers and landowners about the importance of tree retention and replacement.*
- *Motivate private landowners to protect their trees.*
- *Support grant applications for tree conservation projects.*

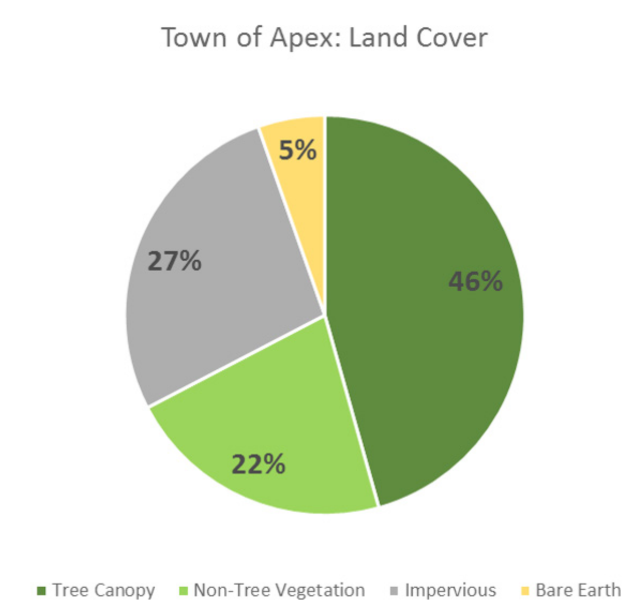
Summary of Findings

Satellite imagery was used to classify the types of land cover in Apex (for more on methods see page 14). This shows the locations for areas with vegetative cover that allow for the uptake of water and areas that are impervious and more likely to have stormwater runoff. High-resolution tree canopy mapping provides a baseline of tree canopy cover that is used to assess current tree cover and to evaluate future progress in tree preservation and planting. Apex has been provided with an ArcGIS geodatabase with all digital shapefiles produced during the study.

The goal of this study was to identify ways in which water entering the town's municipal separate storm sewer system (MS4) could be reduced by intercepting that water with trees. Tree canopy serves as green infrastructure that expands the capacity of the town to support grey infrastructure (i.e. stormwater drainage systems). It also can be used to show how the town can reduce pollution of its surface waters, which can have an impact on Total Maximum Daily Load (TMDL) requirements and Basin Management Action Plans (BMAPs).

This project created a detailed land cover analysis to evaluate how much water is taken up by the town's trees in various scenarios. This new approach allows for more detailed assessment of stormwater uptake based on the landscape conditions of the town's forests. It distinguishes whether the trees are within a forest, a lawn setting, a forested wetland or over pavement, such as streets or sidewalks. The amount of open space and the condition of surface soils affect the infiltration of water. In order to determine these conditions, a detailed land cover assessment was performed as described following.

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



Town tree canopy is 46 percent.

Apex: Fast Facts & Key Stats

2017 Census Population: **50,671**

Town Area

- **Total area: 17.7 sq. mi. incorporated area**
  (33.09 sq. mi. to Extra-Territorial Jurisdiction (ETJ)
- **Land: 16.90 sq. mi. incorporated area** (32.60 sq. mi. ETJ)
- **Water: 0.28 sq. mi. incorporated area** (0.48 sq. mi. ETJ)

Major Drainage Basins: **Cape Fear and the Neuse Rivers**

Miles of Stream: **15.8 miles** in incorporated areas (35.65 ETJ)

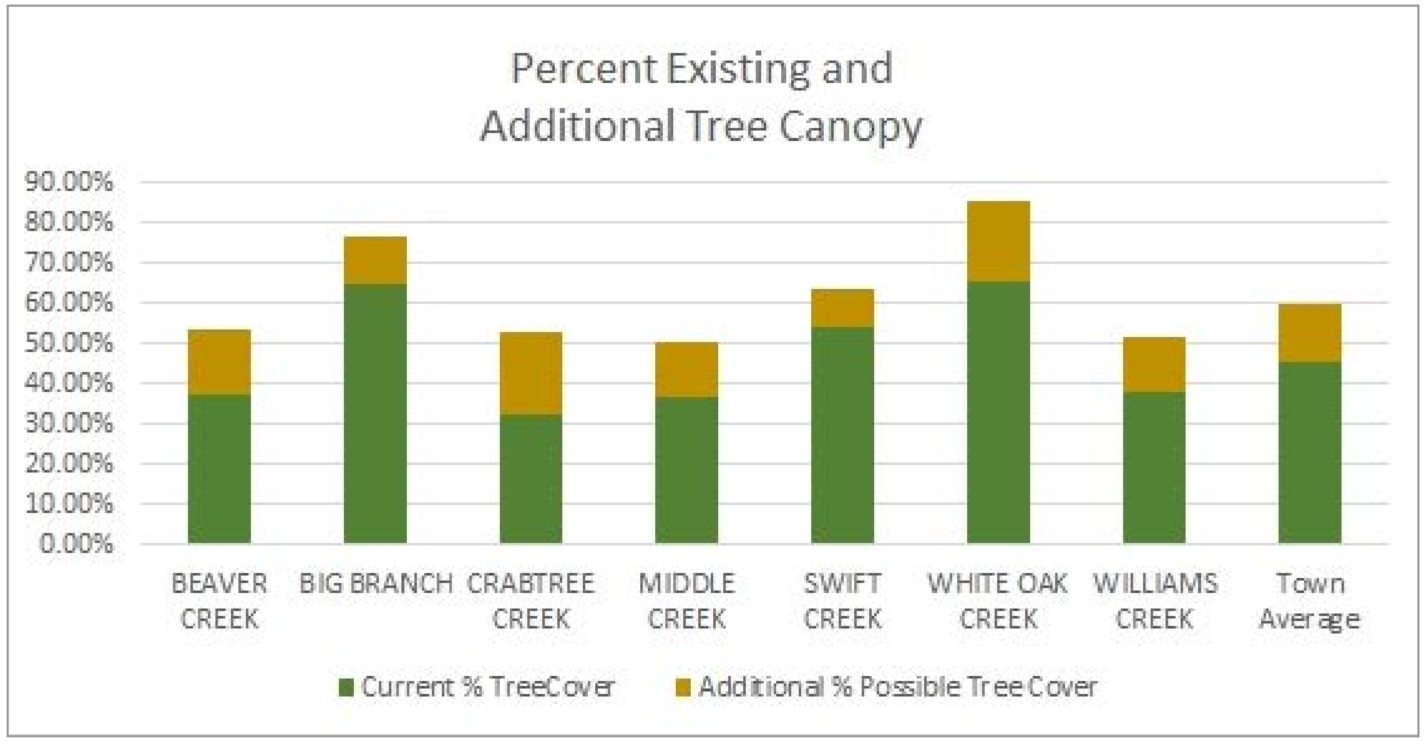
Acres of Lakes: **176.62** incorporated area (309.46 ETJ)

Tree Canopy: **46 percent** incorporated (66 percent in ETJ)

** Stats are provided for both incorporated and ETJ area since the town may annex some of these lands in the future.*

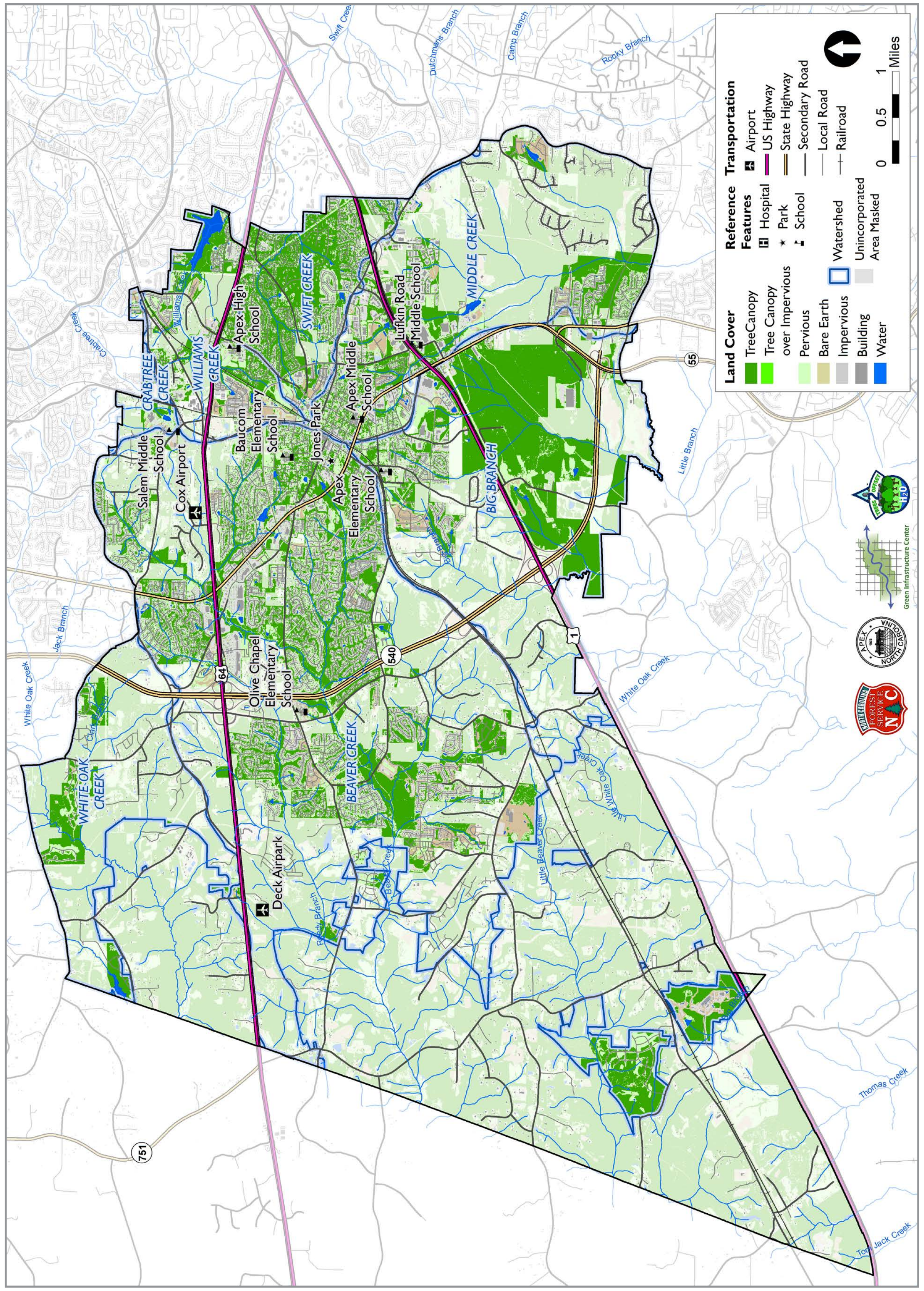
During an average high volume rainfall event in Apex (a 10-year storm), over 24 hours the town's trees take up an average of 313 million gallons of water.

That's 474 Olympic swimming pools of water!



Percent Tree Cover and Possible Planting Area by Watershed

Apex Tree Canopy



This map shows the study area and includes lands that are not within the incorporated area. The entire study area was analyzed because these lands may be annexed one day. Total canopy coverage within the town is 46 percent.

Why Protect Our Urban Forests?

As areas develop, natural land cover changes to urban land cover and forested land cover decreases. 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 for 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).

Towns such as Apex have lost their natural forest cover as growth pressures have led to forest losses. Apex has addressed this in part by requiring tree buffers around most developments to avoid clearing entire sites. The required buffer width varies depending on adjacent land uses. Twenty to twenty-five percent of the development site must be preserved as Resource Conservation Area for areas outside of the Small Town Character Overlay District. For more on this and other related tree protection ordinances, see the Codes and Ordinances section of this report.

The purpose of this report is not to seek a limit on the town's growth, but to help the town better utilize its tree canopy to manage its stormwater and improve water quality. Additional benefits of improved canopy include:

- fostering a healthful and vibrant community,
- cleaner air,
- aesthetic values,
- reduced heating and cooling costs,
- decreased urban heat island effects,
- increased wildlife habitat,
- fostering walkability and multimodal transportation, and
- increased revenue from tourism and retail sales.

As forested land is converted to impervious surface, stormwater runoff increases. This increase in stormwater causes temperature spikes in receiving streams, increased potential for pollution of surface and ground waters and greater potential for flooding. According to the U.S. Environmental Protection Agency (EPA), excessive stormwater runoff accounts for more than half of the pollution in the U.S.'s surface waters and causes increased flooding and property damages, as well as public safety hazards from standing water. While the Town of Apex requires the management of stormwater runoff for the 1- and 10-year storms, as land becomes more impervious, rates of infiltration decrease and runoff increases (Environmental Protection Agency

Residential trees reduce energy costs for summer cooling and improve home values.

Watershed Academy). The EPA recommends a number of ways to use trees to manage stormwater in the book Stormwater to Street Trees.

Imperviousness is one consideration; other concerns include the degree and type of forested land cover, as vegetation helps absorb stormwater and reduces the harmful effects of runoff. As urban forest canopies have declined, municipalities have seen increased stormwater runoff. Unfortunately, many cities and counties do not have a baseline analysis of their urban forests or

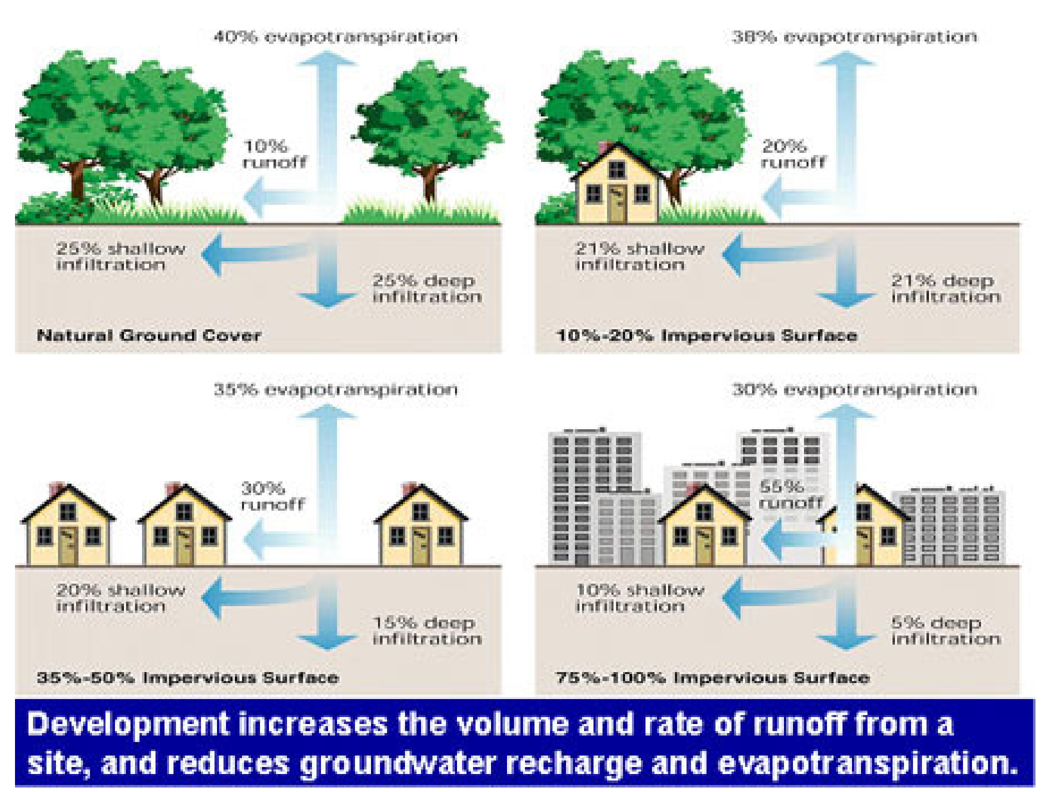
Assessment and inventory of trees is key to ensuring a healthy forest.

strategies to replace lost trees. Tree loss has been compounded by the many powerful storms that have affected the Southeastern United States in recent years, leading to high levels of tree loss. This study was funded to address these problems by helping municipalities monitor, manage and replant their urban forests and 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. 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.

Urbanizing counties and cities are beginning to recognize the importance of their urban trees because they provide tremendous dividends. For example, urban canopy can reduce urban stormwater runoff anywhere from two to seven percent (Fazio 2010). According to Penn State Extension, during a

Newly Planted Tree in Apex



Runoff increases as land is developed. Credit: U.S. EPA

one-inch rainfall event, one acre of forest will release 750 gallons of runoff, while a parking lot 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, parts of Apex are older and lack the stormwater management devices that are 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 Dayton, Ohio found a 7 percent reduction in stormwater runoff due to existing

Excess impervious areas cause hot temperatures and runoff.

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. Based on the GIC's review of multiple studies of canopy interception, estimates for the amount of water, a typical street tree can intercept in its crown range from 760 gallons to 3,000 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 could amount to tens of millions of gallons annually. This means reduced flooding in neighborhoods and less runoff into the town's streams and lakes.

Another compelling fiscal reason to conserve trees and forests as a part of a green infrastructure strategy is minimizing the impacts and costs of natural disasters. By retaining trees and forests, it is possible to reduce the likelihood or severity of flooding.

In urban areas, tree canopy should be assessed and realistic goals established to maintain or expand it. Geographic Information Systems (GIS) are 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 page 16).

One tree can absorb thousands of gallons of water annually.

Buffering surface waters from pollution

Urban forests are critical to buffering surface waters from pollution. At certain levels of urban development and related imperviousness, aquatic life begins to decline. The rate of decline is affected by factors such as land cover, lot sizes and types of land use, as well as the locations of impervious surface within the watershed. Excessive urban runoff results in pollutants such as oil, metals, fertilizers, herbicides and other contaminants reaching surface waters. High stormwater flows result in channel and bank scouring, releasing sediments that smother aquatic life and reduce stream depth, leading to yet more bank scouring and flooding, as channel capacity is lost.

ADDITIONAL URBAN FOREST BENEFITS

Quality of Life Benefits

During North Carolina's hot summers, more shade is always beneficial. Tree cover shades streets, sidewalks, parking lots, and homes, making southern urban locations cooler, walkable and bikeable. Multiple studies have found significant cooling (2-7 degrees) and energy savings from having shade trees in cities (McPherson et al 1997, Hashed, et al 2001). In addition, trees absorb volatile organic compounds and particulate matter from the air, thereby improving air quality and reducing asthma rates. Shaded pavement also has a longer lifespan so maintenance costs associated with shaded roadways and sidewalks are less (McPherson and Muchnick 2005).

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). Communities with more green 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).

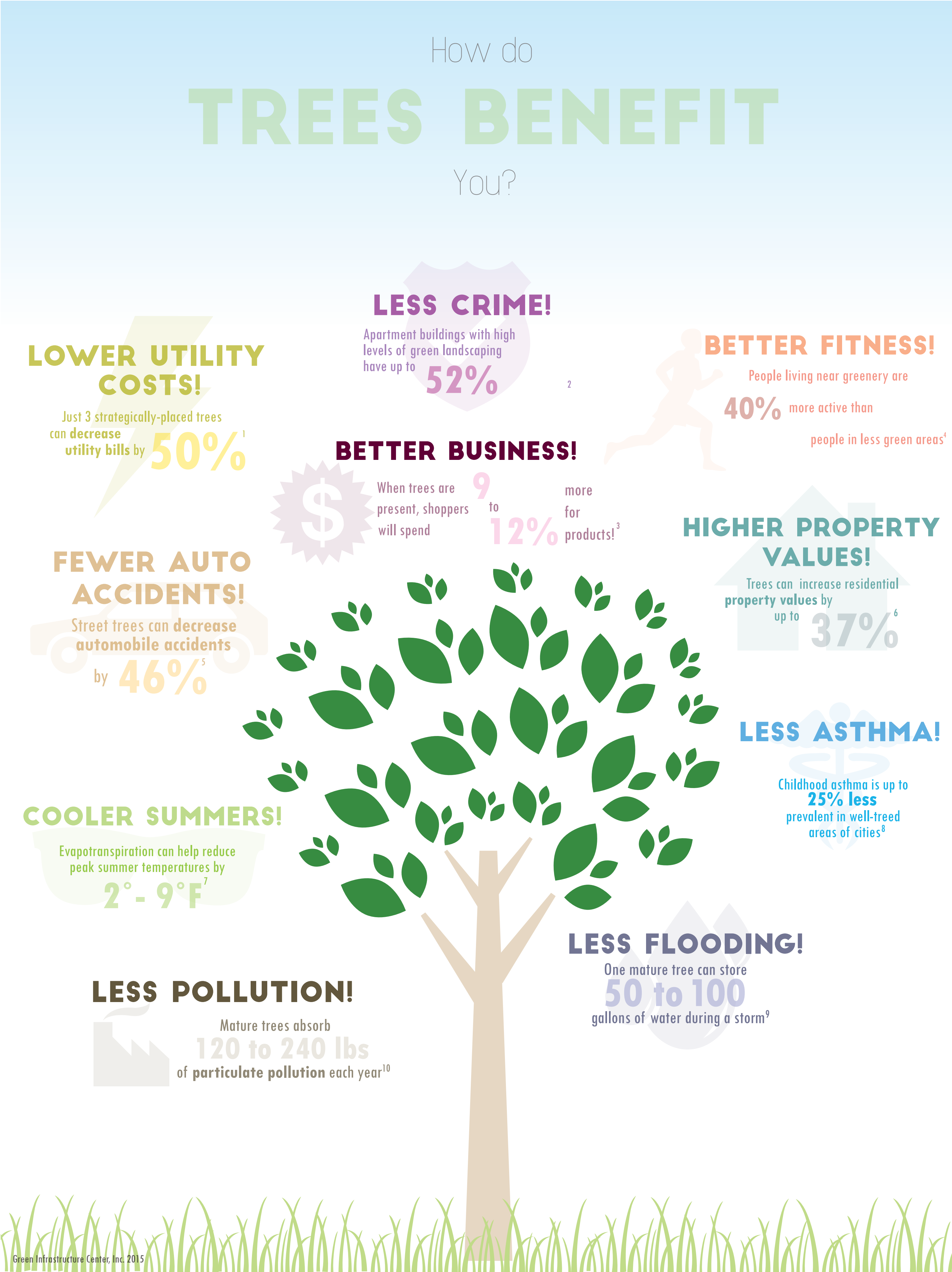
Economic Benefits

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).

A study by the National Association of Realtors 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 in Boulder, Colorado were valued 32 percent higher than those 3,200 feet away (Correll et al. 1978)

Well treed areas encourage people to walk and bike.

Trees could be added downtown.



Meeting Regulatory Requirements

Trees also help meet the requirements of the Clean Water Act. The Clean Water Act requires North Carolina to have standards for water quality. When waters are impaired, they may require the establishment of a Total Maximum Daily Load (TMDL) standard and a clean-up plan (i.e. Best Management Action Plan or BMAP) 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 town's surface and ground waters. Forest cover also reduces the cost of drinking water treatment. The American Water Works Association found that a 10 percent increase in forest cover reduced chemical and treatment costs for drinking water by 20 percent (Ernst et al. 2004).

The urban forest along the greenway provides welcome shade and recreation for Apex's residents too!

NATURAL ECOLOGY IN URBAN CONDITIONS – CHANGING LANDSCAPES

Natural history, even of an urbanized location, informs planting and other land-management decisions. Prior to conversion from natural or agricultural land cover to urban, it was Apex's geographic location that determined its flora and fauna.

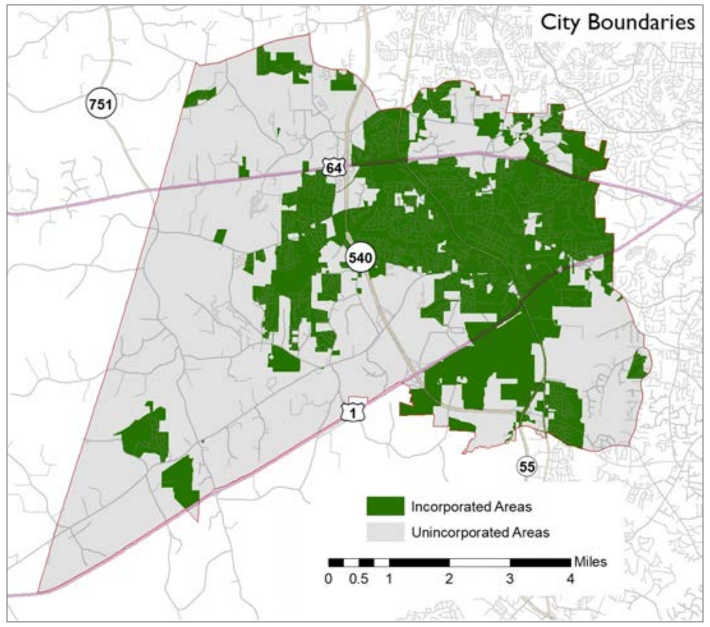
Apex is located in the Piedmont Region of North Carolina, characterized by gently rolling, well-rounded hills and long, low ridges with a few hundred feet of elevation difference between the hills and valleys. The Piedmont is characterized by early succession and scrub-shrub habitat with low, woody vegetation and herbaceous plants and periodic disturbances that result in dense understory vegetation. While the urban landscape of Apex is highly altered, the partially completed Beaver Creek greenway trail contains remnants of this landscape. The greenway supports a healthy urban forest for abundant wildlife and recreation.

A bearded Great blue heron appreciates the tree cover and water in Apex, NC

Historic Land Cover

Apex derives its charming name from the fact that the railroad station was located at the highest point along the Chatham Railroad. The 'apex' divides the Neuse and Cape Fear River watersheds. At one time, tobacco fields and horse farms dominated much of the town's landscape. This altered the existing hydrology by converting a natural forest to crop and pasture land and later to urban land uses and resulting imperviousness. Removals of existing native vegetation along with expansion of impervious surfaces have altered hydrologic regimes resulting in greater volumes and velocities of stormwater runoff now than in the past.

The 'apex' divides the Neuse and Cape Fear River watersheds at the rail crossing, the official 'apex' is just to the left corner where the white house stands.



This map shows the town's incorporated areas in green shading. The wider area was analyzed to include areas which may be annexed in the future.

Growth & Development Challenges

Apex began to boom following the construction of nearby Research Triangle Park. Numerous rankings tout Apex's small town charm, and many structures along with the downtown district are listed in the National Register of Historic Places. The town has a strong focus on culture and the arts with its Halle Cultural Arts Center.

A particular challenge for managing the town's stormwater is the pattern of ownership and jurisdiction between town and county. As Apex has urbanized and additional lands were annexed from Wake County, the resulting boundaries came to resemble the pattern of a patchwork quilt. Apex may apply stormwater control to lands within the corporate limits, but the town does not control the management of stormwater on parcels in the county (see the complex patchwork of boundaries shown earlier). In addition, much of the town was already developed prior to the 1987 Clean Water Act Amendments which required localities to treat stormwater runoff. Adding stormwater treatment for these 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 manage stormwater and vegetation are found in the section on Page 22.

Apex has one of the fastest rates of growth in the state and the resultant demand to meet the needs for housing, commercial, business, industrial uses and transportation puts strains on both the town's grey and green infrastructure. With a five year growth rate of 5.28 percent, Apex's population is projected to almost double by the year 2030 to a population of 89,477.[1] This growth will continue both through increased density within the existing town boundaries as well as annexations.

Signage such as this storm drain medallion alert residents not to pour oil or other contaminants into storm drains.

Apex's Green Future

Apex is working to develop in ways that support a quality lifestyle for residents and visitors alike, while also meeting state and federal mandates for protecting air and water quality.

Apex's Unified Development Ordinance currently requires all new development to preserve a minimum of 20-25 percent of each site as preserved open space, called a Resource Conservation Area (RCA). The RCA can include streams, stream buffers, ponds, lakes, forest, perimeter landscape buffers and historic homes, among other things. Apex is currently updating their 2030 Land Use Map and Long-Range Transportation Plan and the NC Wildlife Resources Commission has offered to review the plans with an eye towards wildlife and resource preservation.

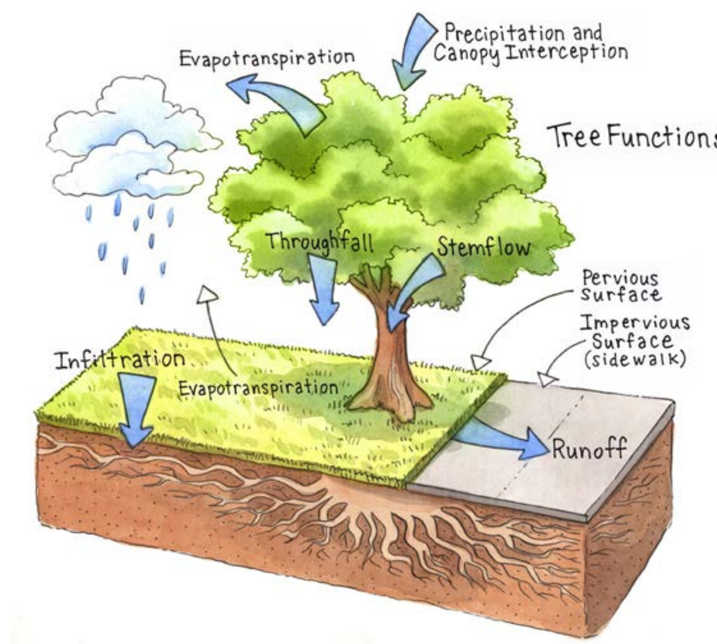
Apex also follows the NC Department of Environmental Quality's Stormwater Manual, which means that a variety of Low Impact Development stormwater control measures are allowed to be used in developments. Town staff regularly encourage the use of native species in landscaping areas, especially perimeter buffers.

[1]Apex Development Report, March 31, 2018. http://www.apexnc.org/DocumentCenter/View/405/Apex-Development-Report

Analysis Performed

This project evaluated how to calculate stormwater runoff and uptake by the town's tree canopy. Its original intended use was for planning at the watershed scale for tree conservation. An example is provided on page 15. However, new tools created for the project allow the stormwater benefits of tree conservation or additions 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 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.



Signage such as this storm drain medallion alert residents not to pour oil or other contaminants into storm drains.

METHOD

Currently, the town uses TR-55 curve numbers developed by the Natural Resources Conservation Service (NRCS) to generate expected runoff amounts for different land covers and soils. The town could choose to use the modified TR55 curve numbers (CN) for 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.

This study used the 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 town's modeling and design reviews. The spreadsheet calculator tool provided by this study allows the town to change the curve numbers if they so choose. What is new about the calculator tool is that it generates a more realistic curve number by applying the area specific land cover conditions in which the trees are found. A canopy interception factor is added to account for the role trees play in interception of rainfall based on their locations and planting conditions (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. A study by Hynicka and Divers (2016) modified the water yield equation of the NRCS model by adding a canopy interception term (Ci) to account for the role that canopy plays in capturing stormwater, resulting in:

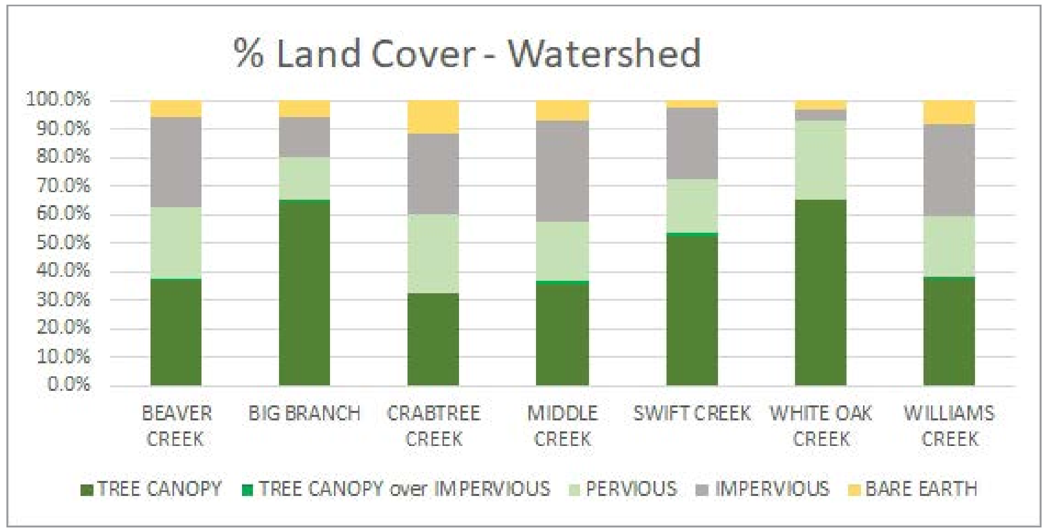
$$R = \frac{(P - C_i - I_a)^2}{(P - C_i - I_a) + S}$$

Where R is runoff, P is precipitation, Ia is the initial abstraction 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, and
- Hydrologic condition - density of vegetative cover, surface texture, seasonal variations
- Treatment - design or management practices that affect runoff

In order to use the equation and model scenarios for future tree canopy and water uptake, the project team 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.



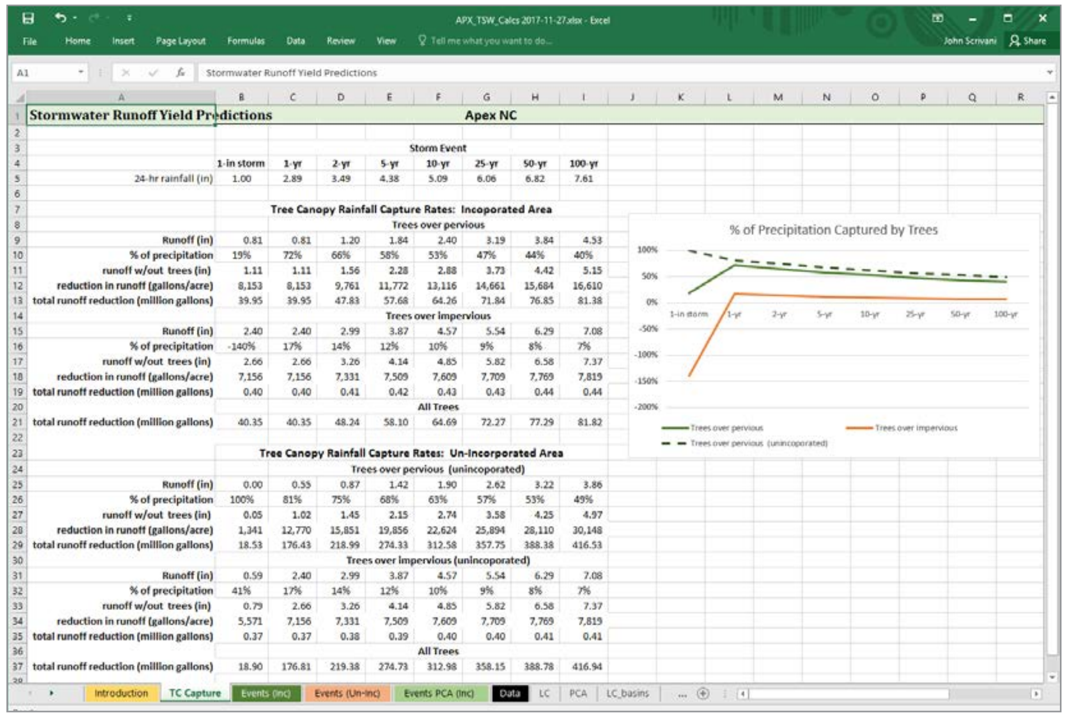
percent loss of tree canopy for incorporated Apex, which would result in an increase of 40.4 million gallons of stormwater runoff during a mean annual 24-hour storm. The model also estimates a decrease in stormwater runoff (or increase in capture) of 3.8 million gallons, if planting efforts were to increase the canopy from 46 percent to 50 percent.

This new approach allows for more detailed assessment of stormwater uptake based on the landscape conditions of the town's forests. It distinguishes whether the trees are within a forest, a lawn setting, a forested wetland or over pavement, such as streets or sidewalks. The amount of open space and the condition of surface soils affect the infiltration of water. In order to determine these conditions, a detailed land cover assessment was performed as described following. These calculations are intended to be used for analysis at the watershed scale. They can be used to create plans for where adding trees or better protecting them can reduce stormwater runoff impacts and improve water quality.

An example of how this modeling tool can be used for watershed-scale forest planning is indicated below. The actual model spreadsheet was provided to Apex for their use. It links to the land cover statistics for each type of planting area. It also allows the town to add trees or to reduce trees and to see what the effects are for stormwater capture or runoff. The key finding from this work is that removal of mature trees and existing forests generate the greatest impacts for stormwater runoff. As more land is developed in Apex, within current or future boundaries, the town should seek to maximize tree conservation to maintain surface water quality and groundwater recharge. This will also benefit the town's quality of life by fostering clean air, walkability, and attractive residential and commercial districts.

The stormwater runoff model provides estimates of the capture of precipitation by tree canopies 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.

In the graphic of the calculator tool, the model is used to estimate a hypothetical 20



Stormwater Runoff Yield Predictions — **Apex NC**

	1-in storm	1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
24-hr rainfall (in)	1.00	2.89	3.49	4.38	5.09	6.06	6.82	7.61
Tree Canopy Rainfall Capture Rates: Incoporated Area								
Trees over pervious								
Runoff (in)	0.81	0.81	1.20	1.84	2.40	3.19	3.84	4.53
% of precipitation	19%	72%	66%	58%	53%	47%	44%	40%
runoff w/out trees (in)	1.11	1.11	1.56	2.28	2.88	3.73	4.42	5.15
reduction in runoff (gallons/acre)	8,153	8,153	9,761	11,772	13,116	14,661	15,684	16,610
total runoff reduction (million gallons)	39.95	39.95	47.83	57.68	64.26	71.84	76.85	81.38
Trees over impervious								
Runoff (in)	2.40	2.40	2.99	3.87	4.57	5.54	6.29	7.08
% of precipitation	-140%	17%	14%	12%	10%	9%	8%	7%
runoff w/out trees (in)	2.66	2.66	3.26	4.14	4.85	5.82	6.58	7.37
reduction in runoff (gallons/acre)	7,156	7,156	7,331	7,509	7,609	7,709	7,769	7,819
total runoff reduction (million gallons)	0.40	0.40	0.41	0.42	0.43	0.43	0.44	0.44
All Trees								
total runoff reduction (million gallons)	40.35	40.35	48.24	58.10	64.69	72.27	77.29	81.82
Tree Canopy Rainfall Capture Rates: Un-Incorporated Area								
Trees over pervious (unincoporated)								
Runoff (in)	0.00	0.55	0.87	1.42	1.90	2.62	3.22	3.86
% of precipitation	100%	81%	75%	68%	63%	57%	53%	49%
runoff w/out trees (in)	0.05	1.02	1.45	2.15	2.74	3.58	4.25	4.97
reduction in runoff (gallons/acre)	1,341	12,770	15,851	19,856	22,624	25,894	28,110	30,148
total runoff reduction (million gallons)	18.53	176.43	218.99	274.33	312.58	357.75	388.38	416.53
Trees over impervious (unincoporated)								
Runoff (in)	0.59	2.40	2.99	3.87	4.57	5.54	6.29	7.08
% of precipitation	41%	17%	14%	12%	10%	9%	8%	7%
runoff w/out trees (in)	0.79	2.66	3.26	4.14	4.85	5.82	6.58	7.37
reduction in runoff (gallons/acre)	5,571	7,156	7,331	7,509	7,609	7,709	7,769	7,819
total runoff reduction (million gallons)	0.37	0.37	0.38	0.39	0.40	0.40	0.41	0.41
All Trees								
total runoff reduction (million gallons)	18.90	176.81	219.38	274.73	312.98	358.15	388.78	416.94

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

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 Apex Government), the Cooperative Land Cover (CLC) Map (North Carolina Natural Areas Inventory), 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.

Forested open space was identified as areas of compact, continuous tree canopy greater than one acre, not intersected by buildings or paved surfaces.

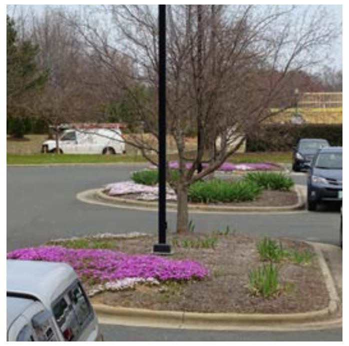
The final classification of land cover consists of nine classes (types of land cover). The Potential Planting Area (PPA) is created by selecting the land cover features that have space available for planting trees. Of the nine land cover classes, only pervious, turf and bare earth are considered for PPA.

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 such as power lines, sidewalks or roads which a tree might impact by interfering with pavement or overhead wires. Playing fields, cemeteries and other known land uses that would not be appropriate for tree cover were also avoided. However, there may be some existing land uses (e.g., golf courses, agricultural lands that are expected to remain in agricultural use, etc.) that are unlikely to be used for tree planting areas, but that were not 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 area for potential places trees can be planted and grow to full size.

Tree over street

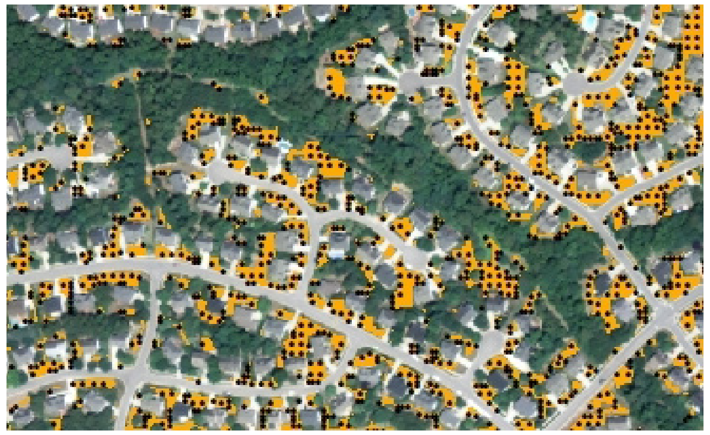
Trees over forest

Tree over lawn



Tree over parking lot

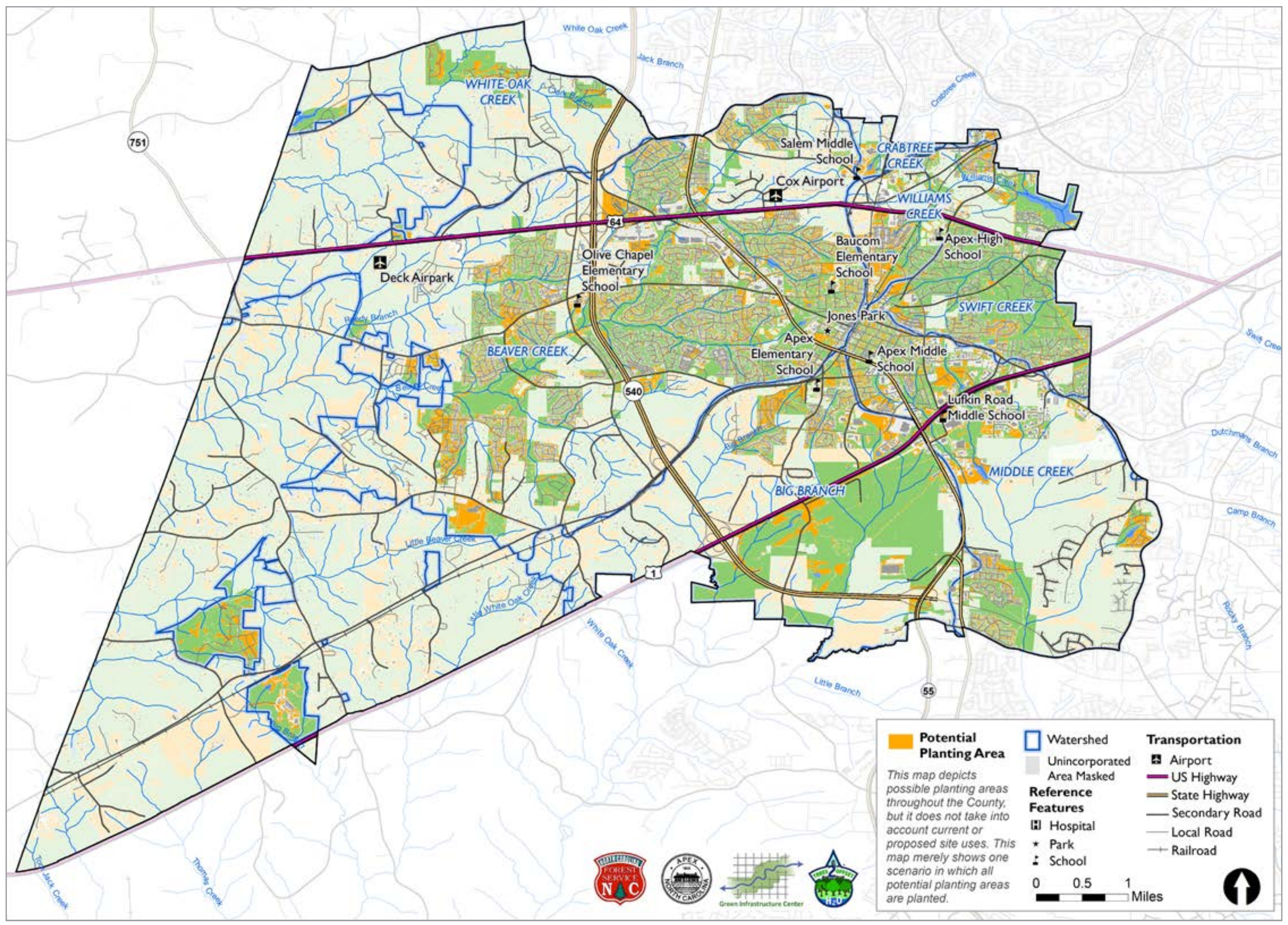
This shows what is currently treed (green) and areas where trees could be added (orange).



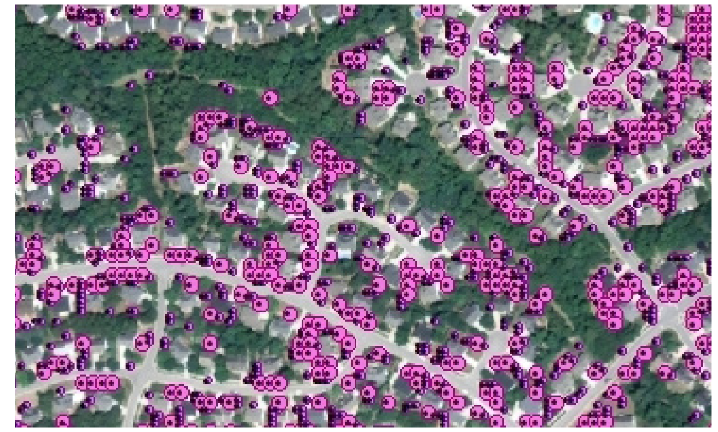
Potential Planting Spots (PPS)

The Potential Planting Spots (PPS) are created from the PPA. The PPA is run through a GIS model that selects those spots 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 mature and fill out to their fullest canopy spread they will overlap the potential planting area and adjacent land cover, such as roads and sidewalks.

Apex 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.

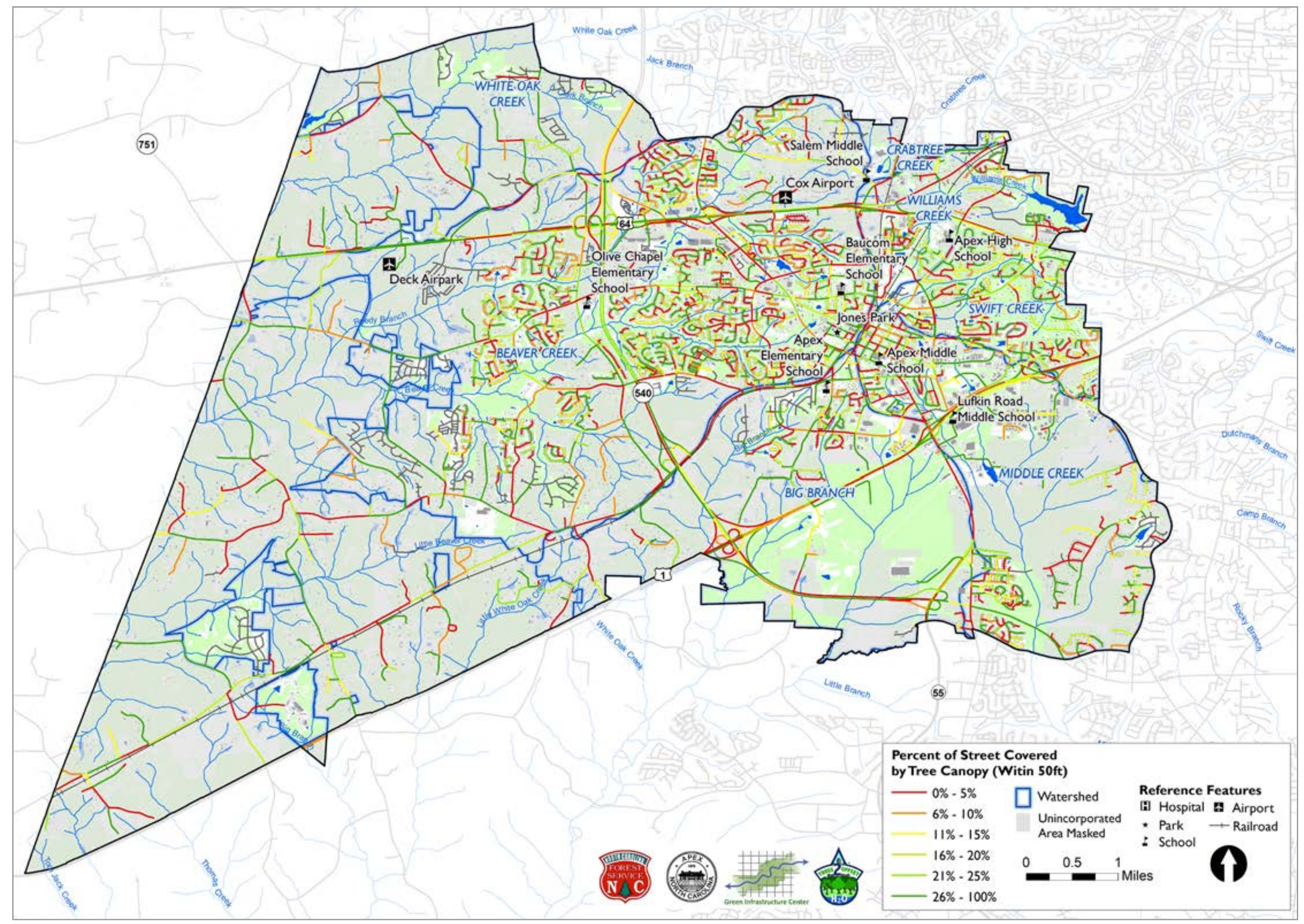


Potential Canopy Area (PCA)

The Potential Canopy Area (PCA) is created from the PPS. Once the PPS are selected, a buffer around each point that represents a tree's mature canopy is created. For this analysis, that buffer radius is either 10 ft. or 20 ft., which result in either a 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. See the Methods Appendix for more details on mapping methodology.

Apex 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.

Trees create a vibrant and attractive downtown.

Codes, Ordinances and Practice Review

This review is designed to determine which practices make the town 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 portion of the project include relevant sections of the town's current code and UDO. Data were gathered through analysis of town codes and policies, as well as interviews with town staff, whose input was incorporated directly on the spreadsheet summary prepared by the GIC. The spreadsheet provided to the town lists all the codes reviewed, interviews held and relevant findings. A more detailed memo submitted to the town by GIC provides additional ideas for improvements.

EVALUATION AND RECOMMENDATIONS

Points were assigned on a spreadsheet to indicate what percentage of urban forestry and planning best practices have been adopted by the town. The spreadsheet can also serve as a tracking tool and to determine other practices or policies the town may want to adopt in the future to strengthen the urban forestry program or to reduce impervious land cover. As other places are studied, they will be compared to the town, and vice versa.

Apex invests a great deal of staff time and energy into protecting trees and caring for the local environment. In fact, the town just celebrated its first year of being recognized as a 'Tree City USA' by the Arbor Day Foundation, which means that it spends adequate funds per capita on tree care, that it has a tree ordinance and practices tree management.

The recommendations provided in this report are a way to increase the protections for, and size of, the forest in Apex. In a perfect world, a town or city would score 100 percent by utilizing all the various practices suggested. However, each locality is unique and not all practices or policies are needed or appropriate.

Top recommendations for the town of Apex listed in priority order include the following:

1. Use the GIC's stormwater uptake calculator to determine the benefits of maintaining or increasing tree canopy goals by watershed. The calculator, provided to Apex, allows the town to determine the stormwater benefits or detriments (changes in runoff) from adding or losing trees and calculates the pollution loading reductions for nitrogen and phosphorus, and sediment.

2. Work with developers to shrink the development footprint to minimize impervious surfaces. Apex requires a pre-application meeting between developers and staff representatives from each department. More emphasis needs to be placed on exploring ideas to preserve trees at these meetings.

3. Conduct a land cover assessment every four years to catalog and compare tree canopy change. Keeping tree canopy coverage 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 occur and to address negative trends and take preventative actions.

4. Require tree removal permits on lots with single family homes. Requiring tree removal permit for large trees (over 24" DBH) on all lots is a strategy for retaining tree canopy coverage in a community.

5. Include software to track the condition of public trees as well as their removal or addition as part of an urban forestry program. Site-scale landscape changes are easily seen with imagery but information about the urban forest that could be used for planning is lacking. Instead, urban forestry data collection should provide detailed, quantifiable information.

6. Require tree canopy coverage percentages by land use. To assure the community's quality of life, add a requirement for minimum tree canopy coverage based on the land use (e.g. residential, commercial).

7. Allow tree plantings in ROWs. As long as sufficient soil volume and separation from utilities is provided, allow planting in the ROW to provide shade, walkability and longer pavement lifespans. Note that trees are not allowed in small triangle areas, as they may impair sight lines.

8. Require and enforce 600, 1,000 and 1,500 cubic feet soil volume planting requirements for small, medium, and large trees respectively. Apex currently requires minimal tree well sizes based on area rather than volume. Providing more room or better structure to grow will ensure that trees have adequate root volume and can live longer.

9. Prioritize funding for essential forestry maintenance activities. Forest management should continue, even during economic slowdowns. Critical tree care activities, such as watering and risk management, should be carried out. A contingency budget can be developed for essential tree maintenance items to be met, even during difficult budget cycles.

10. Develop an Urban Forestry Management Plan (UFMP) which includes statistics on the values that trees provide to the community, measurable and achievable urban forestry goals, and action steps required to achieve those goals, along with a detailed list of maintenance items and frequencies. Apex does not currently have a UFMP, but many of its codes and ordinances include typical UFMP components. These components can be divided into several sections including documentation of the community values of trees, outlining urban forestry goals and developing a maintenance item schedule.

11. Develop a forestry emergency response plan. The town does not have a plan for replacing trees lost to natural disasters such as hurricanes or other storms. This means that canopy will decrease over time. Given the many benefits that trees provide, the town should plan for funding and replacement tree plantings to be implemented following natural disasters.

12. Revitalize the TreeCAP program and hold regular meetings with TreeCAP members. Apex currently has a Citizen Advisory Panel for Tree City USA, but it rarely meets. Increasing the frequency of meetings and enlarging the focus of the TreeCAP will foster better tree care and planting. Citizen input is highly encouraged in urban forestry best practices, especially as private sector lands are where most trees can and will be planted. The more effort put into community engagement, the greater the investment in tree planting by the private sectors.

13. Adopt a complete, green streets policy. Complete green streets allow for integration of stormwater management and aesthetic goals. Incorporating vegetation as an integral part of the designs provides for creation and connection of habitats, reduced urban heat island effect, air pollutant removal, and promotion of walking and biking.

14. Remove the extra spaces requirement for variable space sizing in parking lots. Add parking maximums to the current minimums required by the UDO. Excessive parking standards have exponential negative effects on stormwater volume generation, especially in urban environments. Parking allotments may exceed actual demand. Apex is currently reviewing an update to their parking requirements, which includes parking maximums for some uses.

15. Adopt a stormwater utility and associated fee which provides offset credits for tree planting. Stormwater utility fees are a mechanism for funding stormwater management based on the amount of impervious surfaces generated for land cover by parcel. Trees can be planted as an incentive for reducing impervious areas to lessen the fee.

16. Adopt best practices for fencing and signage to protect trees during construction. Unless careful avoidance measures are taken, earth moving activities can damage trees and they may not survive following construction. Apex can expand requirements for tree protection practices during construction.

17. Develop a program for heritage or witness trees. Protection of heritage and witness trees adds a cultural and aesthetic component to urban forestry, while also protecting additional trees. Heritage and witness trees can commemorate historical events which hold great significance to a community.

BEST PRACTICES FOR CONSERVING TREES DURING DEVELOPMENT

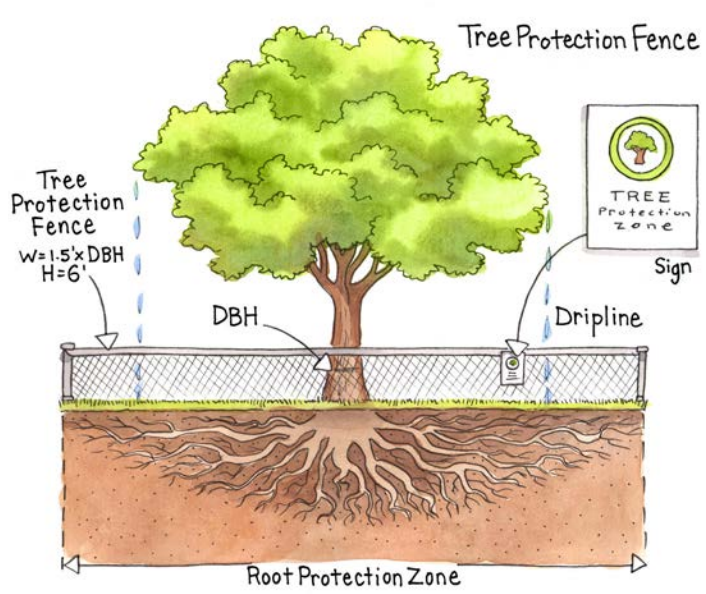
Tree planting or preservation opportunities can be realized throughout the development process. A first step is to engage in constructive collaboration with developers. The Town of Apex currently holds pre-application meetings, monthly review committee meetings and pre-construction meetings with representatives from each town department, developers and civil engineers. These meetings could be used to identify more opportunities to preserve trees on development sites. Many developers are willing to cooperate in such ventures, as houses often sell for a premium in a well-treed development.

There are many tree protection mechanisms, each one designed for a specific purpose. Many developers don't know which tree protection mechanism is best to use in a particular site situation and need guidance. Apex could provide additional best practice guidance beyond the current, general requirement of 'protection measures must adhere to generally accepted good design standards and practices.'

Tree Protection Fencing and Signage

The most common form of tree protection is fencing. It is a physical barrier that keeps people and machines out of a tree's critical root zones during construction. However, some municipalities only require plastic orange fencing and wooden stakes. This type of fencing can be removed or trampled easily and makes tree protection efforts less effective. Trees slated for protection may suffer development impacts, such as root compaction and trunk damage. Instead, sturdy metal chain link fencing can be required in high risk areas (such as near heavy construction equipment and active site grading) and orange plastic fencing can be used for lower risk areas (such as along woodlands at the edge of a development property). Apex requires plastic orange fencing with metal stakes, but has used larger chain-link fencing on select projects that require more protection. Small roots at the radial extent of the tree root area uptake water and absorb nutrients. Protection of the small fibrous roots is critical for the optimal health of a tree. The Apex UDO (Unified Development Ordinance) requires tree protection fence to extend only to one foot per inch of tree diameter measured at breast height (DBH), omitting protection for part of the tree most involved in stormwater uptake. GIC recommends that Apex change their requirement so that tree protection fencing is placed at a distance of 1.5' from the tree trunk per DBH inch of the tree, in order to better protect trees and their functions.

Tree protection signage communicates how work crews should understand and follow tree protection requirements. It also



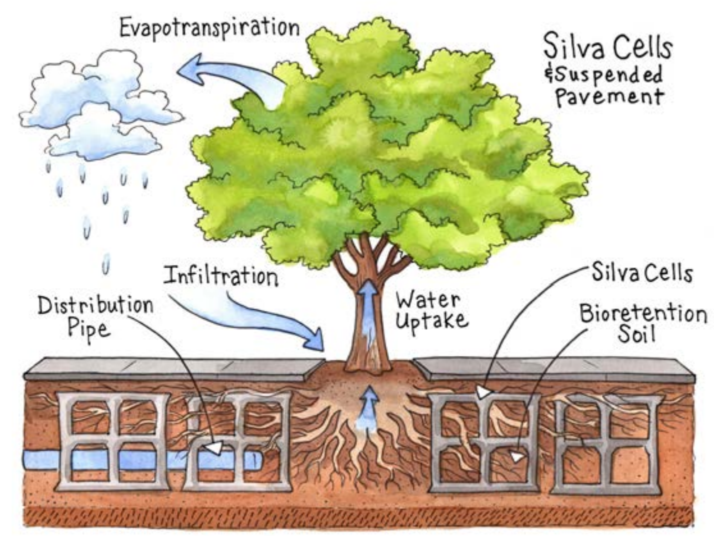
Tree Protection Fence and Signage

informs crews and citizens about the consequences of violating town code. Construction crew members may not understand that building materials may not be placed in tree protection zones and that moving the protective fencing around the tree is never permitted. The town has a tree protection sign that prohibits entering the tree protection area. Spacing should be at 50 feet so ensure the signage is seen more readily.

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, stunts their growth and reduces 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 1,000 cubic feet of soil volume to thrive. In areas where space is tighter or where heavy uses occur above, Silva cells can be used to stabilize and direct tree roots towards areas with less conflicts (e.g. away from pipes).

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 town trees will pay dividends for reducing stormwater runoff as well as clean air and water, lower energy bills, higher property values and natural beauty long into the future.



Tree Protection Fence and Signage

Shade trees would make this public seating space more comfortable.

Trees added to new development enhance home values.

Conclusion

Adapting codes, ordinances and municipal practices to use trees and other native vegetation for greener stormwater management will allow Apex 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.

Apex should use the canopy map and updates to track change over time. Apex can use the canopy data, analysis and recommendations and stormwater calculator tool to continue to create a safer, cleaner, cost-effective and more attractive environment for all.

Appendices

APPENDIX A: METHODS APPENDIX - 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 Apex.

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 imagery) 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:

Projection: Lambert_Conformal_Conic
False_Easting: 2000000.002616666
False_Northing: 0.0
Central_Meridian: -79.0
Standard_Parallel_1: 34.33333333333334
Standard_Parallel_2: 36.16666666666666
Latitude_Of_Origin: 33.75
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

The imagery was then clipped to the area of interest (Apex Town boundary).

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 the 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)

Initial Inclusion selected from GIC created land cover:

- Pervious surfaces
- Bare Earth

Exclusion Features (buffer distance):

- Existing tree cover
- Water
- Wetlands
- Ball Fields (i.e.: Baseball, Soccer, Football) where visually identifiable from NAIP imagery. (Digitized by GIC)

Impervious surfaces setback:

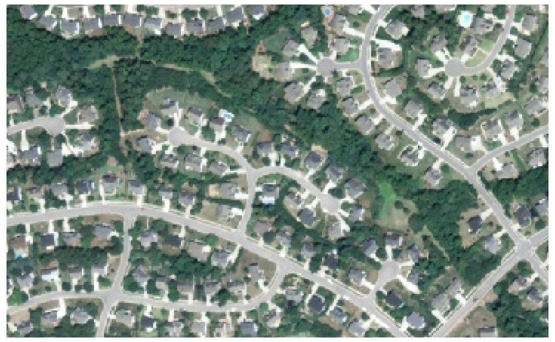
- Roads (based on road width estimate from centerlines) (5ft)
- Sidewalks (5ft)
- Railroads (10ft)
- Buildings (15ft) acquired from imageryWetlands (10ft)
- Hydrological Features (10ft)
- Active Airport Area (near and around runways)
- Stormwater pipes (5ft)
- Sewer pipes (5ft)

Potential Planting Spots

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

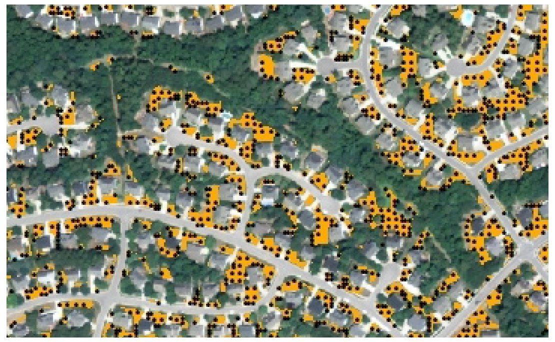
Potential Canopy Area

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 spread.



NAIP Image 2016

Potential Planting Area (PPA)



Potential Planting Spots (PPS)

Potential Canopy Area (PCA)

APPENDIX B: SECOND COMMUNITY MEETING – DETAILED COMMENTS

The second community meeting about The Trees and Stormwater Grant was held in order to solicit public comments following the project's findings. A select number of codes, ordinances and practices recommendations for the town were also presented. Public input and comment was solicited for the codes/ordinances and general urban forestry comments were welcomed.

Codes/Ordinances/Practices Feedback and Suggestions:

1. Develop standards for maintaining a certain percentage of mature trees in development areas. No clear cutting. Make developers pay for what they destroy.
2. Discourage chemicals/fertilizers for all plantings.
3. Stop crowning median planting strips and planting trees on top. Instead create concave areas in the center to capture water and plant the water loving trees in the center. They would live instead of slowly dying.
4. Stop planting Bradford Pear Trees.
5. No more impervious parking lots.
6. Plant trees and vegetation that people will come to value in public areas. For example, plant fruit and nut trees and allow collection for personal use.
7. Work with Boy Scouts – Eagle Projects to continue tree planting projects.
8. Work with local nurseries to have tree planting incentives for homeowners (i.e. tax-free native trees).
9. Adopt a Tree Retention Ordinance to eliminate clear cutting.
10. Set town goals for tree canopy as a part of town planning.
11. Give developers incentives to retain trees on lots they develop above and beyond RCA requirements.
12. Look at Raleigh's ordinance for Apex ordinance revisions.

Funding Sources:

1. Solicit local businesses to sponsor the urban forestry program. Do not rely on the government for all funding.
2. It's easy to say we need more money and staff but the town needs some ideas on how to make this happen. Are there any other sources of funding besides a tax increase, which would not be popular?
3. Promote citizen donations for tree purchase and use signs to acknowledge donation. Civic groups, churches, etc. might also make contributions.

Urban Forestry Approaches:

1. Kids in young families need to experience growing up with trees. They improve mood and incentivize going outside and exercising. Healthy environment, healthy community. It is common for students (high school level) to discuss the need for more tree planting in Apex and their disdain for the practice of clear cutting.
2. Make tree preservation and protection a development priority.
3. Builders must be held to task with any ordinances. No trade-offs. Create financial incentives/disincentives to drive home the importance of the program.
4. Charge every development/zoning inspector/staffer with being aware and protective of trees.
5. Education is needed. A nature center where programs are held to teach about trees and other green infrastructure is desired.
6. Integrate tree planting efforts with Apex festivals (PeakFest etc.) Use the public events to promote the program and educate residents.
7. Add forestry classes to the electives offerings at local high schools.
8. Engage in more planting on private properties.
9. Keep the canopy the town currently has.
10. Provide a tax credit for maintaining tree canopy.

Flooding:

1. Residents downstream of Lawrence Prong Branch are suffering because of excess runoff.

Pollutants:

1. Residents downstream of Lawrence Prong Branch are suffering because of excess runoff.

Miscellaneous:

1. Make sure the overall objectives and long term outcomes are clearly stated in the final report. Describe how each idea or investment contributes to the objectives.
2. Can we save trees on the currently approved 12,000 housing development site?
3. Were there better landscaping standards in the 1980s?
4. Engage in more outreach about the importance of this project.
5. Engage in more green initiatives – bike sharing, geothermal etc.
6. Apex likes curb and gutter (piping stormwater directly to the drain without allowing for infiltration).

Vegetated stormwater pond helps detain and clean runoff.

Community Input on Specific Code Changes:

Community members were presented with seven specific code/ordinance or practice changes which GIC is recommended to the Town of Apex. Meeting attendees were asked to choose the top three changes they felt would most benefit the urban forest. The code changes were as below and are followed by brackets which show the total 'votes' for each change.

1. Have parking minimum and maximum requirements [3].
2. Create a stormwater fee to incentivize reducing on-site impervious area [25].
3. Conduct proactive tree care to minimize tree hazards [6].
4. Increase the staff force and budget for urban forestry [19].
5. Allow tree planting in right-of-ways [6].
6. Increase the tree and root protection zone for tree protection during construction [11].
7. Create a tree list for use by the Town of Apex. Add native trees [17].

Special note on youth concerns:

Adolescents and teenagers in the Town of Apex show an outspoken vested interest in the urban forest. They wrote about their frustrations with the practice of clear cutting, their willingness to be actively involved in growing the urban forest, their understanding of the benefits of trees, and their concern over ensuring that trees are properly cared for (watering, pruning etc.). Students specifically expressed an interest in participating in local tree planting days.

APPENDIX C: 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/ >

______ Climate Project.” Urban ecosystems 1, no. 1 (1997): 49-61.

______ 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-13-001Web 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).

Li, Y. C., A. K. Alva, D. V. Calvert, and M. Zhang. “Chemical composition of throughfall and stemflow from citrus canopies.” Journal of plant nutrition 20, no. 10 (1997): 1351-1360.

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. Resource Bulletin NRS-1. Newtown 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. Scatena. “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 behavior32, 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.