URBAN FOREST MASTER PLAN

City of Columbia, Missouri

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TABLE OF CONTENTS

Tables

Figures

Appendices

A. Species List
B. New Tree Care Schedule
C. Maintenance Standards and SOPs
D. Risk Assessment Table and Information
E. UTC Methodology and Accuracy Assessment
F. Leaf Litter Methodology
G. Target Neighborhood Inventory Maps
H. Critical Forest Methodology
I. Prioritized Planting Plan Methodology
J. Tree Canopy Health Methodology
K. i-Tree Methodology

EXECUTIVE SUMMARY

Columbia has a vision that its urban forest is safe, efficient to maintain, complements its development goals, delivers equitable benefits, and enhances the livability of the city. To accomplish goals and objectives to realize this vision, a comprehensive tree management plan is required. This plan was developed to assist Columbia to better understand its urban forest's composition, structure, and tree maintenance needs as well as plan for both short-term and long-term resource allocation and develop risk management strategies.

The plan was accomplished by completing these tasks:

- Aggregating and supplementing existing tree and planting site inventories.
- Determining and mapping the citywide and target neighborhood canopy cover.
- Performing advanced analyses of the tree canopy cover data.
- Calculating tree benefits citywide and for the target neighborhoods.
- Developing a proactive tree maintenance and planting program.
- Creating a prioritized planting plan.
- Making data-driven, sustainable urban forest management recommendations.
- Presenting a multi-year budget.

A brief summary of the data and information acquired, analyses performed, and list of recommendations follows.

Columbia's Citywide Urban Tree Canopy

The urban tree canopy (UTC) was determined by classifying the land cover within the entire city boundaries; this include both public and private properties. The UTC analyses found that 35.6% of Columbia is covered by tree canopy, while 22.5% of the city is covered by impervious surfaces (roads, buildings, etc.) that repel stormwater and contribute to heat island effects. The remaining land in the city is pervious areas of low vegetation such as lawns and shrubs (36.1%); bare soil (4.3%) such as athletic fields; and open water (1.5%).

The analysis also reveals that:

- Ward 4 has the highest UTC at nearly 46%.
- Ward 1 has the lowest UTC at 25% and, as expected, has the highest percentage of impervious cover at over 51%.
- Tree canopy covers 23% of the North, 33% of the Central, and 39% of the East target neighborhoods.
- Columbia's parks have an average of 54% UTC, which represents 11% of the city's total tree cover.

Tree Benefit Analysis

Trees provide significant co-benefits to the City of Columbia. Every year, and simultaneously, trees give the city and citizens the benefits of air and water quality improvement, stormwater management, energy use reduction, and enhanced property values and aesthetics among many others.

Columbia's existing citywide tree canopy provides residents with $145 million in benefits annually. In addition to the annual benefits, the carbon stored by the current UTC contributes an additional $66 million in benefits, bringing the collective benefit amount to $211 million. Columbia's trees are an irreplaceable asset because they:

- Remove almost 925,000 pounds of pollutants from the air every year, and these air quality improvements have the impressive value of $1.2 million annually.
- Intercept 336 million gallons of stormwater annually; this important infrastructure service is valued at approximately $672,000 each year.
- Save over 16 million kilowatt hours of energy annually through decreased heating and cooling costs—a savings of over $1.8 million for consumers.
- Account for almost $139 million in property value increases, representing the largest single benefit value reported.

Columbia's street trees provide approximately $298,000 in the following annual benefits:

- Aesthetic and other benefits: valued at $112,739 per year.
- Air quality: valued at $11,575 per year.
- Net total carbon sequestered and avoided: valued at $9,141 per year.
- Energy: valued at $89,954 per year.
- Stormwater peak flow reductions: valued at $74,575 per year.

Prioritized Planting Plan

While all available planting sites in the city limits may ultimately be planted over the next several decades, the trees planted in the next several years should be installed in high-need areas and in locations that will allow the trees to provide the most benefits and return on investment. Columbia now has a prioritized planting plan to guide future tree planting. Based on a number of environmental and socio-economic factors, plantable areas were categorized as Very Low to Very High.

The distribution of the various planting priority classifications is fairly even across the city. The Low and Very Low priority sites naturally are located at the city limits away from the developed urban core where existing tree canopy is more abundant.

Based on the statistics:

- Ward Two has the greatest total number of High and Very High priority acres combined at 535 acres, and Ward Three has the second highest combined total at 495 acres. However, those acres comprise 28% and 19%, respectively, of the total plantable acres in those Wards.
- Ward 1 only has a total of 274 acres of High and Very High priority planting sites, but those comprise 43% of the plantable areas in that Ward.
- High and Very High planting sites comprise 40% of the Central Neighborhood's plantable areas, where those same classes represent only 26% in the East and 29% in the West.

Columbia's Street Tree Inventory

The tree inventory is an important planning tool that should help the City of Columbia establish a systematic program for tree care and determine budget, staff, and equipment needs. Implementation of the maintenance recommendations will improve public safety and help guide future management decisions. When properly maintained, trees return economic, environmental, and social value to the community. These benefits greatly outweigh the time and money invested in planting, pruning, protection, and removal. In 2017, Columbia's existing street tree and vacant planting site inventories were combined and updated. The following brief statistical summary of the street tree population reflects genus and species composition, condition, primary maintenance recommendations, and risk ratings:

- A total of 5,282 sites have been collected, representing 5,049 trees, 144 stumps, and 89 planting sites (Note: Planting sites were only collected in a limited area of the City and do not provide an accurate representation of available planting space).
- Generally, species diversity in Columbia is good with over 130 different species identified.
- Overall, the vast majority (74%) of Columbia's street trees are in Fair condition, with 17% of trees in Good condition. At the time of the inventory, only 9% of trees were either identified as Poor, Critical, or Dead.
- Since the majority of the street trees are in fair or better condition, required maintenance is considered routine. Recommended primary maintenance needs include: Tree Removal (6%); Stump Removal (5%); Routine Pruning (65%); Young Tree Train (21%); and Plant Tree (3%).

Columbia's Urban Forest Management Approach

To assist in strategic planning to improve urban forest management, Columbia's practices and performance were compared with those of other cities and national standards. This information gives perspective on how Columbia's program is succeeding or where improvements can be made. The benchmark information reveals both strengths of and opportunities for improvement for Columbia's urban forest and its management program.

Indicators of positive aspects of Columbia's urban forest management approach are:

- Columbia's urban tree canopy cover is greater than the national average and the majority of its peer group.
- The return on investment is positive—for every dollar of public funds spent on trees, the city and citizens receive over $4 of annual benefits.
- The city's approach compares favorably in terms of urban forest services offered, and its operations are performed in a similar manner as benchmark cities.

However, the benchmark information reveals that Columbia could improve its management approach by:

- Increasing its commitment to fund a progressive urban forest management program. In relation to the annual municipal budget, the amount dedicated to tree management is the lowest of all national and regional averages and peer city percentages.
- Increasing maintenance and using a proactive approach; the annual maintenance production rates are the lowest.
- Increasing and having a systematic planting program; the annual planting rates are the lowest.

Urban Forest Management Recommendations

Based on the analysis of the inventory and UTC data, with city staff and peer group input, and applying arboricultural industry standards and best management practices, the Columbia Urban Forest Master Plan presents recommendations in major action steps and outlines programs and procedures for achieving success for small and large tasks in both the short and long terms.

Table 1. Prioritization and Fiscal Impacts of the Urban Forest Master Plan's Primary Recommendations

Recommendation	Priority	Timeframe for Completion	Fiscal Investment	Vision, Strategy, and/or Goal # Impact
High Priority Removals	High	1 year	$64,016	3
High Priority Pruning	High	1 year	$58,875	2.1
Complete Inventory	High	Annually	$5,000	5.4.1
New Tree Maintenance	High	Annually	$12,920	2.1
Create a Risk Management Plan	High	1 year	No cost (city staff) $8,000–$15,000 for consultant	3
Create and Implement a Strategic Planting Plan – Citywide and/or by Neighborhood	High	1 year	Variable	2.1
Moderate/Low Priority Removals	Medium	3 years	$32,169	3
Routine Pruning	Medium	5 years	$578,720	2.1
Young Tree Training	Medium	5 years	$23,160	2.1
Tree Planting	Medium	Annually	$18,088	2.1
Update Inventory	Medium	5 to 10 years	$25,000	5.4.1
Plant Health Care Program/Inspection	Medium	3 years	Variable	2.1
Renew TreeKeeper®	Medium	Annually	$2,500	3.4.1
Use the UTC Analyses Citywide	Medium	1	No cost (city staff)	3.4.1; 5.2.2; 12.1.1; 12.3
Evaluate Urban Forest Management Structure	Medium	3 to 5 years	No cost (city staff)	3.4.3; 10.1.3
General Public Outreach	Medium	Annually	No cost (city staff); $2,000–$4,000 (printing and materials)	3.4.3; 8.2.1; 8.3.4
Perform Funding and Operations Reviews	Medium	3 years	No cost (city staff); $10,000–$20,000 for consultant	3.4.3
Stump Grinding	Low	1 to 3 years	$8,040	2.1
Update Ordinance(s)	Low	5 years	No cost (city staff) $10,000–$15,000 for consultant	5.3.2; 5.4; 9.1
Create a Tree Board and Volunteer Corps	Low	5 years	No cost (city staff)	2.1.1; 9.1.3
Update UTC	Low	5 to10 years	$20,000 for consultant	3.4.1

INTRODUCTION

Columbia's public and private forests combine to create an urban tree canopy that provides numerous benefits to city residents, businesses, students, and the metro region as a whole. These benefits come in the form of significant contributions to stormwater management, public health improvement, energy use reduction, air pollution abatement, and the overall quality of life. Like many communities in highly populated urban areas, the ecosystem, economic, and social services from trees become more important to Columbia each year as the population increases and economic development continues. Unfortunately, along with Columbia's growth and climate change come stressors on the urban forest that challenge the management of this dynamic, living natural resource.

Recognizing the value of the urban forest, Columbia has assessed the extent of current tree canopy and has conducted street tree inventory assessments. This Urban Forest Master Plan represents the next step in the city's effort to proactively plan for the sustainability and improvement of this valuable city asset. This plan uses the information from urban forest studies, program operations information, city goals and strategies, and benchmark data from comparable cities to understand and make recommendations for the long-term management and preservation of Columbia's valuable tree canopy cover.

This plan also provides information on the current urban forest conditions in Columbia, discusses inventory and urban tree canopy data analyses and findings, and makes short- and long-term recommendations that will strategically accomplish citywide and urban forest management goals.

ABOUT THE PROJECT

This plan was developed using an adaptive management approach, and is the result of research and analyses that centered around the following questions and topics:

What do we have now?

- How much tree canopy does Columbia have?
- How does that compare with other cities?
- Where is the tree canopy?
- How are we managing the urban forest now?
- What condition is the urban forest in currently?
- What challenges are we facing in the coming years?
- What are we doing well?

What do we want in the future?

- What is Columbia's vision for the future urban forest?
- What is the recommended canopy level?
- What does it take to move to a proactive management program and what are the associated costs?

How do we get there?

- What do we need to reach our goals?
- What steps will get us there?
- What resources will be needed?
- Where do we start?

How will we measure success?

- What benchmarks should we use to measure success over the coming years?
- How often should we take stock of our progress and re-evaluate our strategies?

To help answer these questions, urban forest data were analyzed and many sources of information were used and referenced, and included:

- An urban tree canopy (UTC) assessment;
- Examination of the existing street tree inventory data, as well as additional fieldwork to update the inventory on select streets and in three priority neighborhoods (North, Central, and East), and significant work to improve the quality of the existing inventory data was necessary;
- Interviews and meetings with Public Works staff to examine the city's approach to management of the public trees and discuss future goals;
- Review of existing plans and documents including findings from past urban forest studies, city vision, goals and strategies, Columbia's Strategic Plan, and the city's code of ordinances;
- Urban forest management data from other communities to compare with Columbia's management approach;
- GIS analysis and mapping for leaf debris; and
- Best practices sources such as American Public Works Association's Guidance Statement on Quality Management of the Urban Forest and current arboricultural industry standards and best management practices.

STRENGTHS OF COLUMBIA'S URBAN FOREST

In answer to the question "What do we have now?", Columbia's urban forest management program and the tree resource itself have many strengths.

Columbia's Urban Tree Canopy and Street Tree Population Provide Many Benefits

Photograph 1. The tree-lined streets of this Columbia neighborhood are providing benefits to the community and its residents every day.

- Over 35% of Columbia is covered with trees. This land cover percentage compares favorably with the national average of 32% (Hauer 2016) and the average of comparable size cities at 29%. The urban tree canopy provides over $200 million in a variety of ecosystem benefits annually and greatly enhances the livability of the city.
- Columbia's street tree population contains over 5,000 inventoried trees and contributes nearly $300,000 annually in benefits. The cost-benefit ratio is positive, with the city receiving over $4 in benefits for every $1 invested in the care and planting of street trees.

Regulations Exist to Protect Trees and Forests

The city has several long-standing tree ordinances, development regulations, and subsections of ordinances that address authority for public trees, protection of trees, guidelines, and standards for landscaping, and tree preservation during land development. Recently, with input from local experts and a city-appointed urban forest Task Force, the Unified Development Code was updated and gained approval from Council. The improvements made to the ordinance will advance the professional and comprehensive management of the urban forest.

Professional Staff Manage the Public Forest

The city has a highly experienced and knowledgeable arborist and a variety of crew personnel to perform important urban forest maintenance tasks, such as storm damage clean-up and correction, park tree maintenance, utility line clearance, and priority and citizen-requested street tree removals and pruning. Staff also are engaged in the development plan approval process and compliance monitoring of permits and city regulations.

CHALLENGES TO COLUMBIA'S URBAN FOREST

In answer to the question "What do we have now?", no urban forest management program is without challenges. There are several issues specific to Columbia that either affect the safety and quality of the urban forest or the staff's ability to manage the program proactively and efficiently.

Natural Threats are Increasing

- *Insects and Disease.* Many non-native, invasive insects and diseases, such as gypsy moth, emerald ash borer (EAB), and Thousand cankers disease, pose serious threats to Columbia's urban forest. In Columbia's street tree population, some of the most prevalent species are ash, maple, and oak, and these species are threatened by oak wilt and Asian longhorned beetle. As the potential for spread and establishment of these and other known and unknown invasive forest pests continues, implementing the city's EAB Plan and a more comprehensive approach to response planning and implementation is needed.
- *Severe Weather Events.* High winds, snow and ice storms, and tornadoes cannot be prevented, and these events cause significant tree damage and canopy loss. However, preventive maintenance of public trees can significantly reduce the types and amounts of storm damage. Columbia has not yet established a citywide preventive, cyclical maintenance program.
- *Climate Change.* Beyond contributing to severe weather events, climate change is causing "flash droughts," and shifts in average temperatures and moisture levels. Trees adapted to Columbia's historic climate may become stressed and more prone to insects and disease as the climate changes over time.

Photograph 2. Emerald ash borer (EAB) is a major threat to ash trees on streets, in parks, and on private properties in Columbia.

Most Trees are in Private Care

In Columbia, approximately 90% of the tree canopy is located on private lands. For this reason, success in improving or maintaining tree canopy must include a citizenry that understands: 1) the value of trees and tree canopy to the community; and 2) how to plant and care for trees. Without this awareness and information, mature trees can be removed at any time without a thought of the loss of benefits to the property owner, or overall impact on the community. And, replacement trees might not be planted, or, if they are, they may be poorly placed and selected.

Urban Forest Management is Reactive and Decentralized

As authorized in the city's code, three separate departments have responsibility for the public urban forest. As such, actions taken in Columbia's forest can be influenced by departmental missions rather than what is holistically best for the urban forest. And, providing services departmentally on a reactive basis is not an efficient use of city resources.

The Budget is not Adequate

Based on the street tree inventory data, approximately $184,000 is needed annually to address priority maintenance, achieve a cyclical maintenance program, and to have an annual planting program. The current budget for street trees falls short of this by over $110,000.

WHY PLAN FOR TREES?

Residents, businesses, and visitors of Columbia are privileged to be in an area rich in natural resources and beauty. Trees were and are a large part of the natural heritage of Columbia when the city was built near the rivers on forested foothills of the Ozark Mountains. Within the city limits, there is a wide diversity of native woodlands, stately tree-canopied parks and streets, and expertly landscaped campuses, businesses, and residences. Largely due to the high quality of life, the draw of the university and colleges, and opportunities for business success, Columbia is Missouri's fourth largest city and has experienced a steady increase in its population and economy. But some negative consequences of the city's popularity and growth may be starting, such as increasing urban heat island effects, air and water quality issues, stormwater management problems, and potential loss of tree canopy.

To reverse the trend of these growing urban and suburban issues, this Urban Forest Master Plan seeks to promote the urban forest as a solution to a variety of urban issues the city is facing. Expansion of the urban forest, support for urban forest management program improvements, and community engagement can result in a sustainable, equitable program that will help achieve some of the city's current Vision Statements, Goals, and Strategies excerpted in Figure 1.

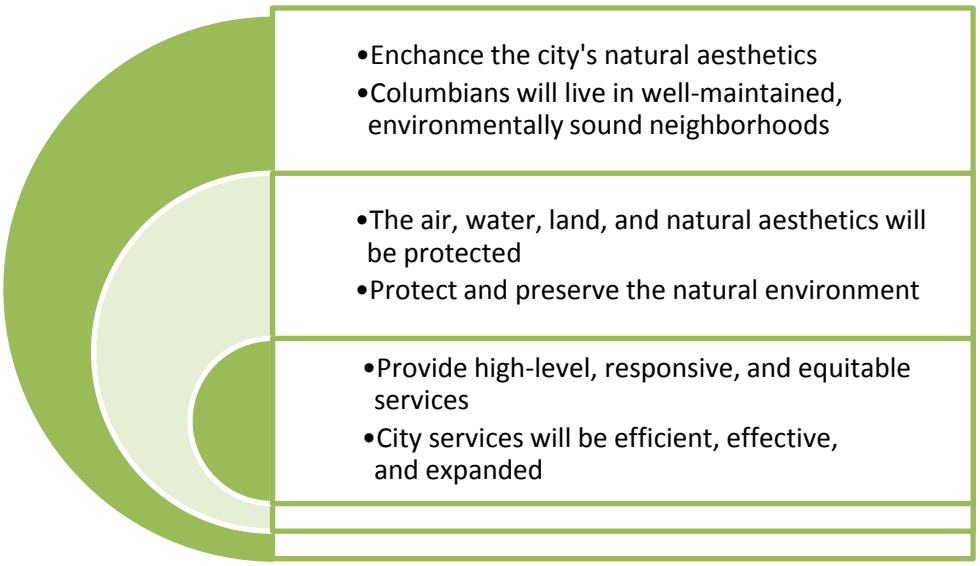


Figure 1. How the urban forest supports **the City of Columbia's** vision statements, goals, and strategies.

Additionally, this Urban Forest Master Plan is intended to assist the City of Columbia focus on improving service delivery and urban forest condition for three specific areas of the city as directed by the Strategic Plan. The neighborhood areas are: Central (Ward 1), North (Ward 2), and East (Ward 3). Therefore, this plan also presents specific conditions in and addresses the needs of these neighborhoods so that effective action can be taken to better engage the neighborhoods so that all Columbians can enjoy the benefits of trees.

STATE OF COLUMBIA'S URBAN FOREST

When examining the state of Columbia's urban forest, it is important to assess more than just the trees themselves. The following sections review existing conditions for these topics:

- Assessment of the Urban Forest
  - Overall Tree Canopy
  - Publicly-Managed Trees
- Assessment of the Existing Management Approach

Columbia's Tree Canopy

It is important to understand the overall tree canopy as well as public trees managed by the city. Whether trees are growing on private or public property, the benefits from trees extend to the entire community.

Overall Findings

The urban tree canopy (UTC) analysis found that 35.6% of Columbia is covered by trees, while 22.5% of the city is covered by impervious surfaces (roads, buildings) that repel stormwater and contribute to heat island effects.

Other land covers were also assessed on a citywide basis, and these land cover percentages are: buildings, pavement, and other hard surfaces (22.5%); pervious areas of low vegetation such as lawns and shrubs (36.1%); bare soil (4.3%); and open water (1.5%). Tree canopy analysis results are summarized and shown in Figures 2 and 3. Columbia has been provided with complete tree canopy and other land cover statistics citywide and per Ward, target neighborhoods, parcel, and parks. A detailed methodology can be found in Appendix E.

About Canopy Cover

Canopy cover is a measure of the physical coverage of the tree canopy over the land. It represents a way of expressing, as a percentage, how much of any given area is shaded or protected by trees. Canopy cover is an important way of measuring the character, location, amount, and benefits of an urban forest.

Broad calculations suggest that large mature trees provide 75% more environmental benefits than smaller trees.

As a single large tree can cover more area than several small trees, the measure of canopy cover is more valuable than simply counting the total number of trees. It is a repeatable benchmark that can be measured regularly to guide future tree planting programs and land development and help determine the successes or failures of urban forest management efforts.

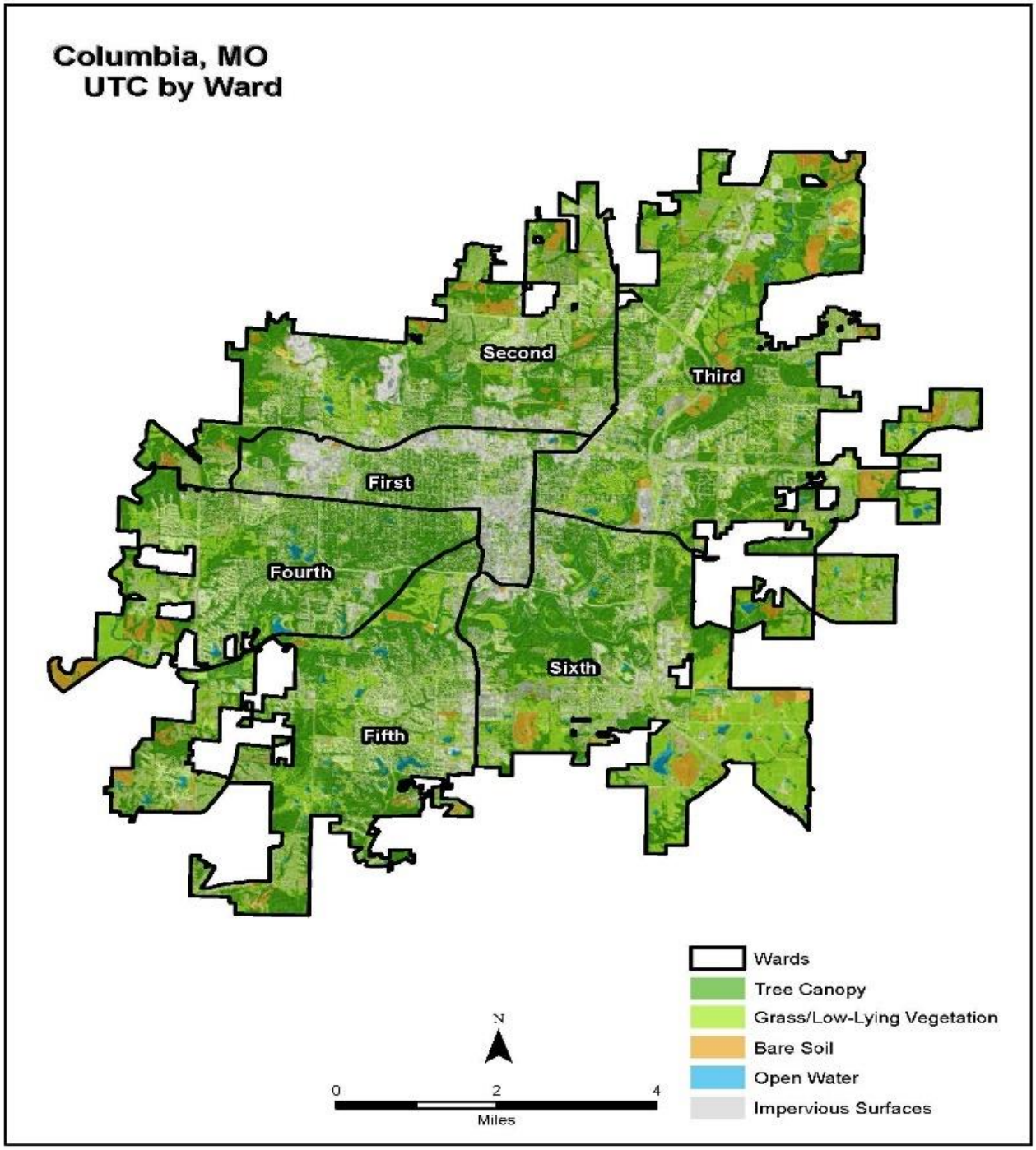


Figure 2. Columbia**'s** citywide urban tree canopy is distributed relatively equally within the city limits and among the wards.

Table 2. Tree Canopy Land Cover Metrics Within City Limits, Wards, and Parks*

Land Cover	Citywide	Parks	Ward 1	Ward 2	Ward 3	Ward 4	Ward 5	Ward 6
Tree Canopy (%)	36	54	25	36	34	46	39	31
Impervious (%)	23	13	51	25	19	20	20	18
Pervious (%)	36	29	22	35	39	29	35	44
Bare Soil (%)	4	2	1	4	6	3	3	5
Water (%)	1	3	0.2	0.5	1	2	2	2

*Data have been rounded to nearest whole percent; water to the nearest 0.1 percent.

Table 2 summarizes the land cover metrics within the city. Ward and park boundaries reveal that:

- Ward 4 has the highest UTC at nearly 46%;
- Ward 1 has the lowest UTC at 25% and, as expected, has the highest percent impervious cover at over 51%;
- Columbia's parks have an average of 54% UTC; and tree canopy in parks represents 11% of the city's total tree cover.

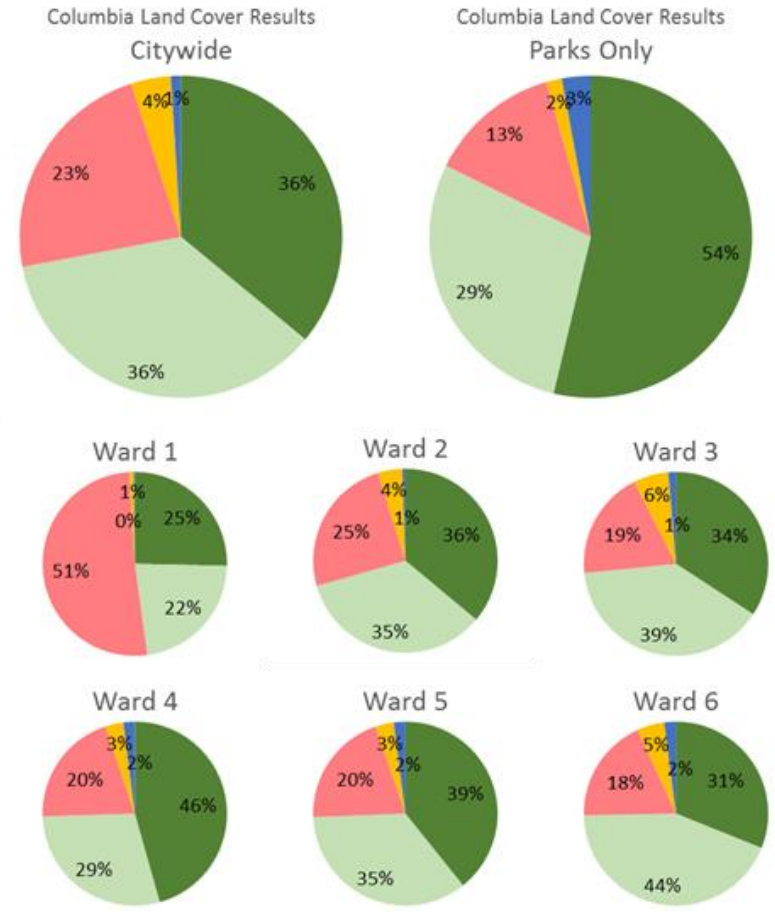


Figure 3. Citywide, park, and ward distribution of land cover.

A note about prior canopy assessment findings and accuracy. Approximately ten years ago, a Natural Resource Inventory was conducted in Columbia and it determined that the city's UTC was 57.05%. In 2016, an i-Tree Landscape project was completed and the UTC was reported as 24.19%. For this 2017 master plan study, the UTC mapping was professionally performed with high-resolution imagery and a 98.85% accuracy level was achieved by the methodology; therefore, 35.6% tree canopy cover is the statistic to be relied upon now and in the future when the UTC mapping is repeated.

What's an Ideal Canopy Cover?

American Forests, a recognized leader in conservation and urban forestry, has worked to establish baseline tree canopy goals for metropolitan areas. For many years, they have recommended an overall 40% tree canopy for cities east of the Mississippi. This included a breakdown of sub-area recommendations of 25% canopy in urban residential areas, and 15% in downtown areas. However, they have recently revised their recommendations to stress that there is not a good universal tree canopy goal that applies to all cities. Communities should instead create their own goals based on a number of factors, including what is possible given the local natural environment. Additionally, suggestions have been made to choose a canopy goal that "achieves specific objectives, such as reaching the canopy percentage necessary to reduce urban heat island temperatures to a specific range, or to reduce stormwater runoff by a projected amount." At 35%, Columbia's citywide tree canopy nearly reaches American Forests' original recommendation; the challenge now is to maintain or grow that canopy as the city and citizens desire.

Demographic and Socio-Economic Distribution of the Tree Canopy

Are there correlations between Columbia residents and their canopy cover? Analysis of multiple socioeconomic factors and tree canopy can provide the answer to that question, identify trends and priority planting areas, provide direction for establishing planting goals, and assist the city to deliver urban forest management services equitably.

Canopy coverage was determined at the census tract level (69 tracts in total) throughout Columbia and was compared to socioeconomic and demographic data collected from the 2010 U.S. Census. A summary of the findings at census tract levels follow, with full socioeconomic statistical analyses available within the data delivered.

Figure 4. Canopy and income.

- **Canopy is higher in wealthier areas.** On average, higher income areas have twice the canopy coverage as lower income census tracts in Columbia.
- **Canopy decreases as population density increases.** Not surprisingly, the percentage of canopy coverage decreases as population density (number of people per square mile) increases. Dense urban areas are made up of primarily impervious surfaces, which leave little room for large amounts of canopy.
- **Canopy is higher in areas with higher percentages of families, and lower in areas with higher percentages of young adults (ages 18–24).** Canopy was found to increase in areas with higher percentages of children (ages 0–17), as well as increasing in areas with parent-aged adults (ages 25–64). Families may purchase larger lots less close to the center of the city for raising their children. Census tracts with higher percentages of young adults (ages 18–24) had the lowest levels of canopy, which may be correlated to rental properties or proximity to colleges.
- **Canopy tends to be lower in areas dominated by rental properties and higher in areas with majority owner-occupied houses.** Higher tree canopy is strongly correlated with home ownership, which is not uncommon. This relationship is likely attributed to a number of factors: owner-occupied properties often include greater amount of green space than would typically be found in higher density rental housing such as apartments and townhomes. Homeowners also have more of a financial and emotional investment in their properties and neighborhoods, are less transient than renters, and, therefore, are more likely to plant and care for trees on their property and demand tree-lined streets.
- **Canopy is higher in areas with more educated residents.** Canopy was found to increase as the population with bachelors and advanced degrees increased, and canopy decreased as the population with associates degrees or less increased.
- **There was very little correlation between the age of homes in Columbia and the amount of canopy present.** The data suggest that there is only slightly more canopy around homes built before 1980. Typically, older homes have more mature trees and, therefore, more canopy cover.

Stormwater Runoff Analysis

Urbanization significantly alters stream flows and water quality due to increased impervious surfaces, increased pollutants emitted from various sources, and decreases in natural vegetation cover. These changes lead to increased runoff and flashiness of stream flow after storms, potential flooding issues, and poorer water quality that affect human health and well-being.

The urban tree canopy should be considered Columbia's largest green infrastructure asset. This asset is providing an extremely important public health and safety service by capturing and reducing stormwater runoff that would otherwise end up in the city's stormwater system and waterways. To quantify the amount of stormwater avoided and calculate the benefits, the i-Tree Hydro application was used to quantify the hydrologic impacts of the city's green infrastructure and particularly its urban tree canopy. The methodology for the i-Tree Hydro modeling is found in Appendix K, and the data have been delivered separately to the city for further use and reference.

The analysis showed that between the years of 2005 and 2012, Columbia has avoided, on average, over 1.2 million cubic meters of runoff due to the presence of trees. Figure 5 displays the historic impact trees have had on stormwater volume. Trees also reduced the amount of pollutants found in the urban environment that are carried by runoff, such as phosphorus, soluble organic material, and ammonia/ammonium. On average between the years of 2005 and 2012, the avoided pollutant load was more than 178 tons.

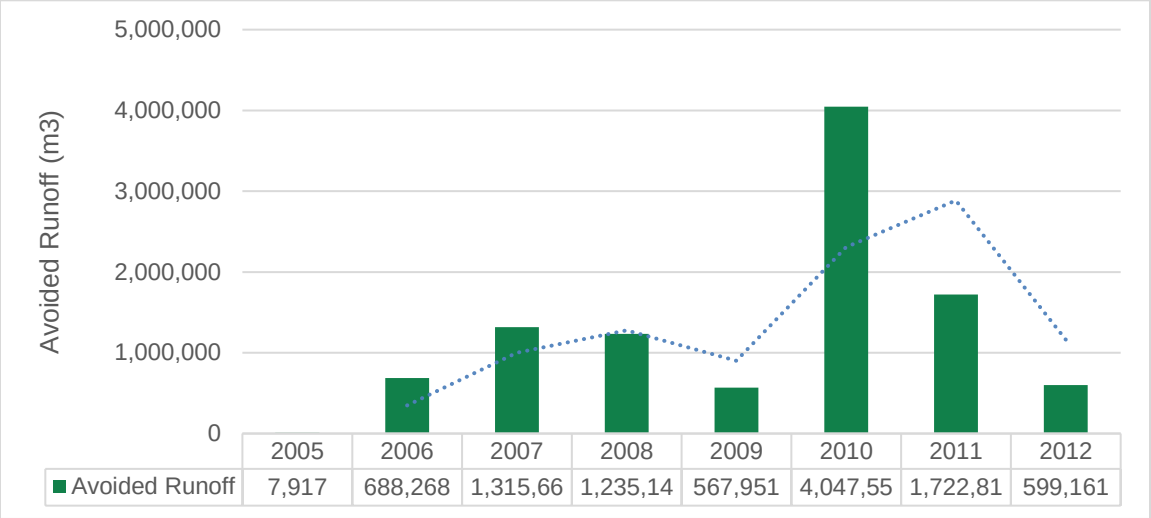


Figure 5. Avoided stormwater runoff a**ttributed to Columbia's** urban forest canopy (2005**–**99992012)

The breadth of the value of this important ecosystem service from Columbia's UTC is summarized below:

- Average annual total stormwater volume reduction = 336,306,674 gallons
- Average gallons of stormwater avoided per acre = 22,545
- Average annual stormwater benefit contribution = $672,613

Columbia should harness the power of trees to help reduce runoff and flooding and potentially be used to meet clean water regulations. The i-Tree Hydro model results can be used to inform urban forest management and urban planning and design to help improve water quality and reduce the risk of flooding. Expanding the UTC will allow Columbia to expand its ability to moderate the negative effects of stormwater in the city and neighborhoods.

Critical Forest Analysis for Water Quality

The forests in Columbia provide many public health and safety benefits, particularly related to protecting water quality and reducing flooding. Sustainable forest ecosystems provide direct benefits to not only waters of a watershed, but also to the overall quality of life for all citizens.

Trees and other vegetation in the landscape are part of a community's green infrastructure and affect both the quantity and quality of stormwater runoff. When land is left in a natural state, forests and other ecological components of the landscape decrease the quantity of stormwater runoff by allowing water to be absorbed into the soil and retained in wetlands and other areas. In concert with engineered and built solutions, preserving forests to improve water quality, reduce flooding, and lessen stormwater runoff is a strategy for many communities.

However, forest cover does not provide equal benefits. For instance, forests located on a gentle slope far from a waterbody would not provide the same stormwater and water quality benefits as forests on steep slopes adjacent to a major stream.

Therefore, it is important to determine the locations of high-quality forested areas within the city limits where features are present that significantly contribute to protecting water quality and quantity and provide the most critical public health and safety functions.

Using Columbia's land cover data, available information on stream hydrology, and other GIS data, catchment basins (or small urban watersheds) were delineated within the city. Then, headwater catchments were identified and prioritized since these upstream areas are where stormwater runoff and pollution accumulation greatly affect downstream water supplies and the potential for flooding. By combining the priority catchment map with the UTC forest data, the identification of high-functioning forests that are critical to mitigating stormwater and pollution in Columbia was accomplished. The full methodology for determining the locations of critical forestland is found in Appendix H.

The critical forest analysis revealed that a total of 2,327 acres, or 15.6% of Columbia's total UTC, are providing the most stormwater mitigation and pollution abatement services in the city. These forested areas are located primarily in the western and northern areas of the city as seen in Figures 6 and 7. The majority (30%) of them are located in Ward 3; Ward 1 has the least (8%) critical forest areas.

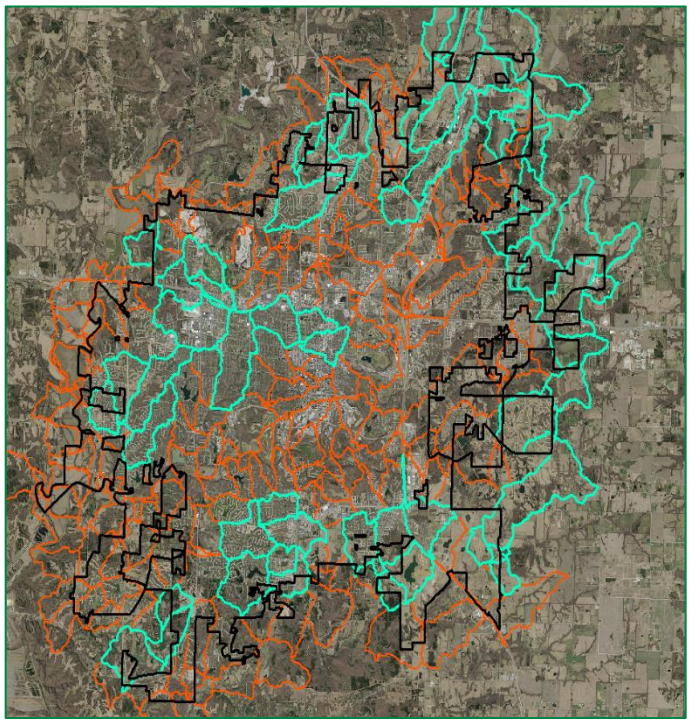


Figure 6. Citywide delineated catchments (in orange) and prioritized catchments (in teal)

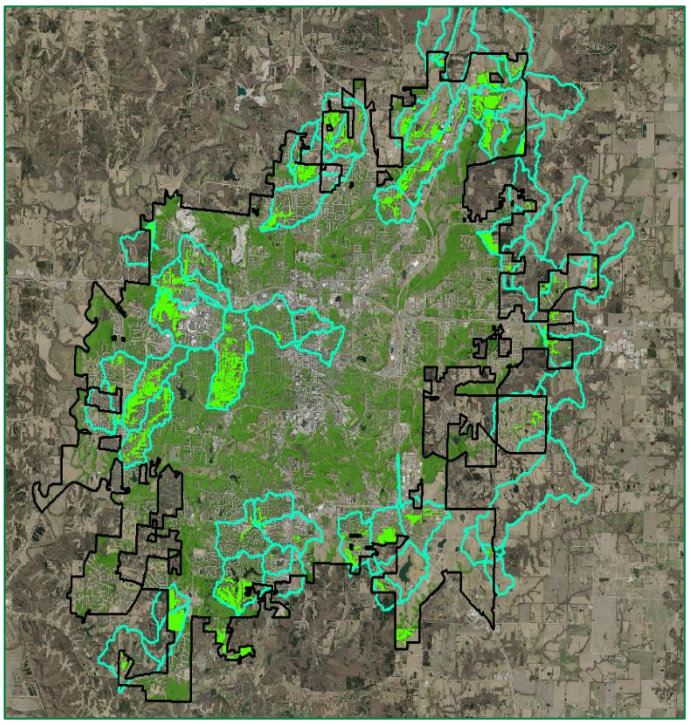


Figure 7. Critical forests (in bright green) within prioritized catchments (overall UTC in dark green)

Table 3. Critical Forest Areas by Wards

Ward	Acres	% of Total
First	194	8
Second	339	15
Third	703	30
Fourth	507	22
Fifth	357	15
Sixth	227	10
Total	2,327	

Identifying the most critical areas of forest cover in the city is essential for defensible and reasonable decision-making regarding conservation and preservation activities, as well as stormwater management policies and projects. Columbia now knows where tree protection efforts should be focused, and where low-impact land development techniques should be used. By combining the use of structural stormwater management solutions with the retention of continuous forest areas in developing areas, Columbia can realize significant benefits in public health and safety improvements and in infrastructure construction and maintenance cost reductions.

Urban Tree Canopy Health

Where the canopy is located is now known, but what condition is it in? The overall health of trees has a direct impact on the sustainability of the urban forest. Trees in worse condition require more maintenance, are at greater risk of insect and disease problems, and can present a risk to the public. Trees in better condition require less maintenance, are less prone to storm damage, look better, and provide maximum environmental services to the city.

Using the UTC data, the general health of the city's forest canopy was determined by spectral analysis compared to established vegetation health indices. The methodology for this analysis can be found in Appendix J. Citywide, generally over 64% of the urban tree canopy was classified as in Good and Very Good health. Only 13% of the canopy was found to be in Poor health or Dead/Dying, and almost 21% was classified as in Fair health. Figure 8 displays the citywide urban tree canopy health.

It may not seem important to note, but nearly 21% of the tree canopy is in Fair health. If insects, disease, or other stressors go unmanaged, then trees in this condition could quickly fall into the Poor/Dead classification. This means that a third of Columbia's canopy would be compromised.

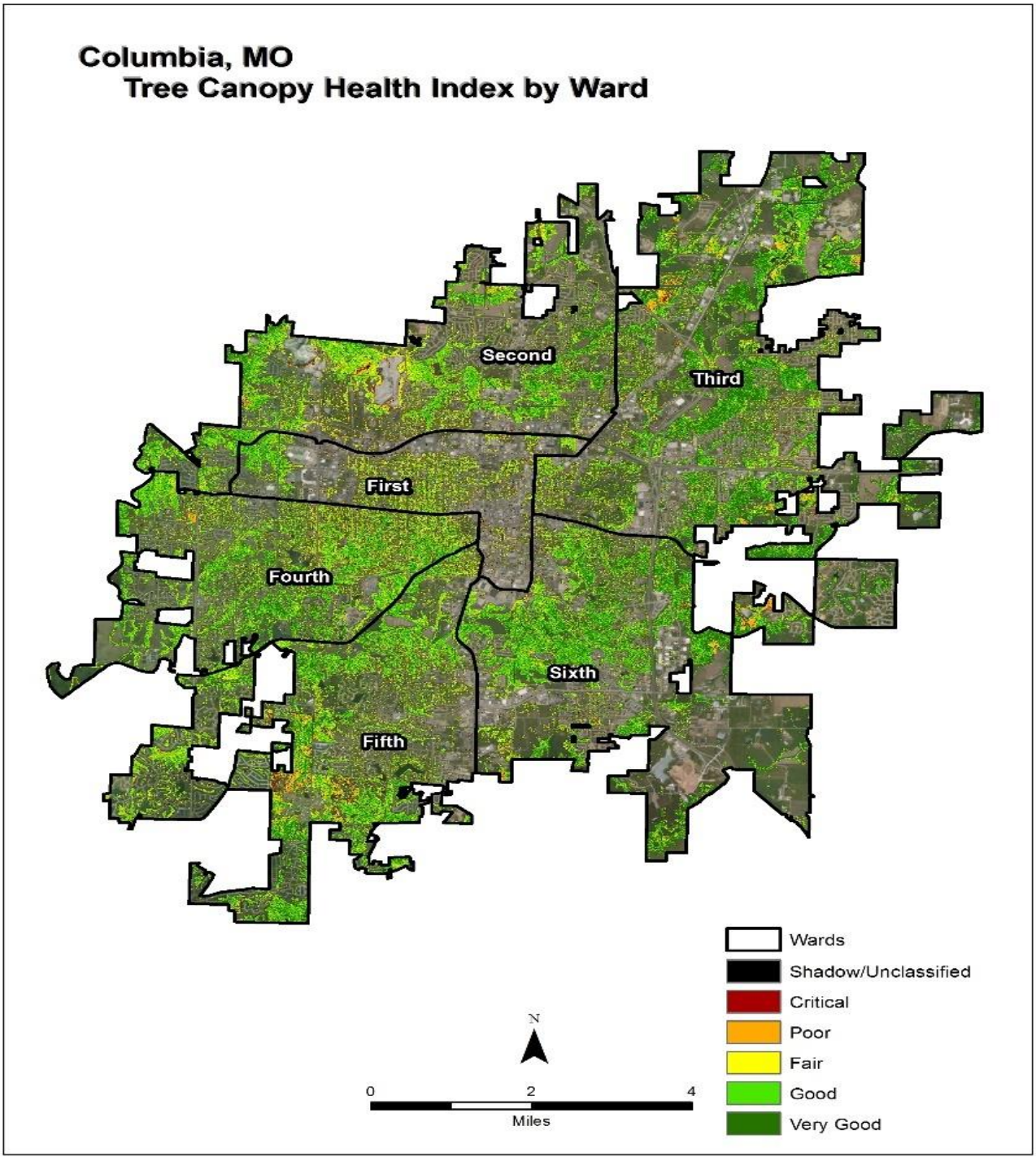


Figure 8. Citywide urban tree canopy health in Columbia.

When forest canopy health is viewed by ward, the analysis shows that the five forest health classifications are fairly evenly distributed between Wards (Figure 9). The only exception is that Ward 3 has noticeably higher percentage of trees in Very Good and Good condition (17%) than the other wards. Ward 1 has the least amount (2%) of tree canopy in Very Good and Good condition.

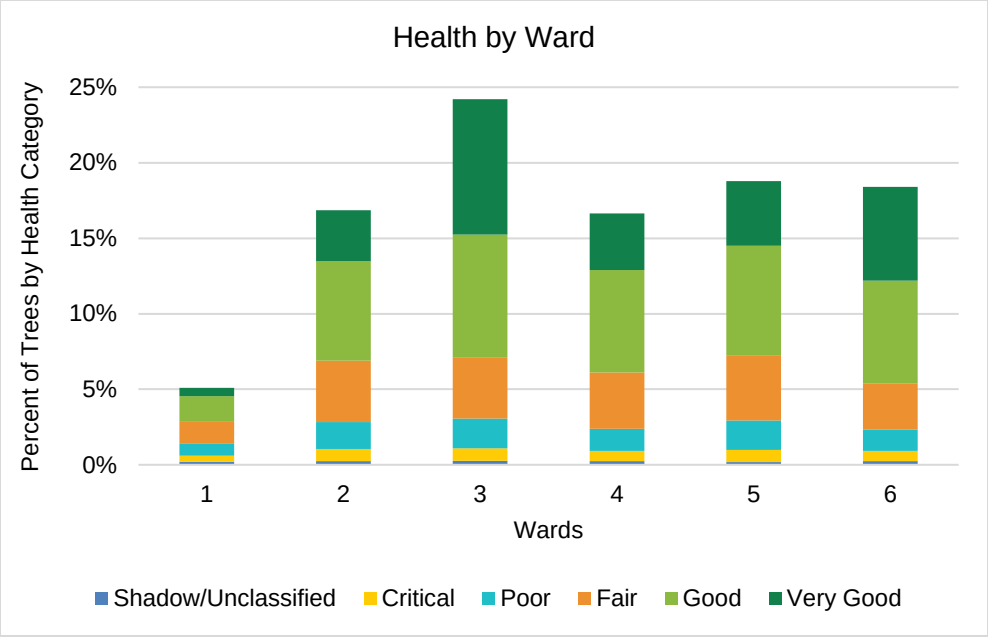


Figure 9. Forest health classification distribution between wards,

When forest canopy health is viewed by the target neighborhoods, the analysis shows that there is some significant variation of the five forest health classifications between the three neighborhoods (Figure 10). The East neighborhood had the most trees in Very Good condition (31%); the North had the most trees in Good condition (38%); and the Central neighborhood had the most trees in Fair condition (34%). The Central neighborhood also had the highest frequency of Poor (17%) and Critical (9%) trees between the three areas.

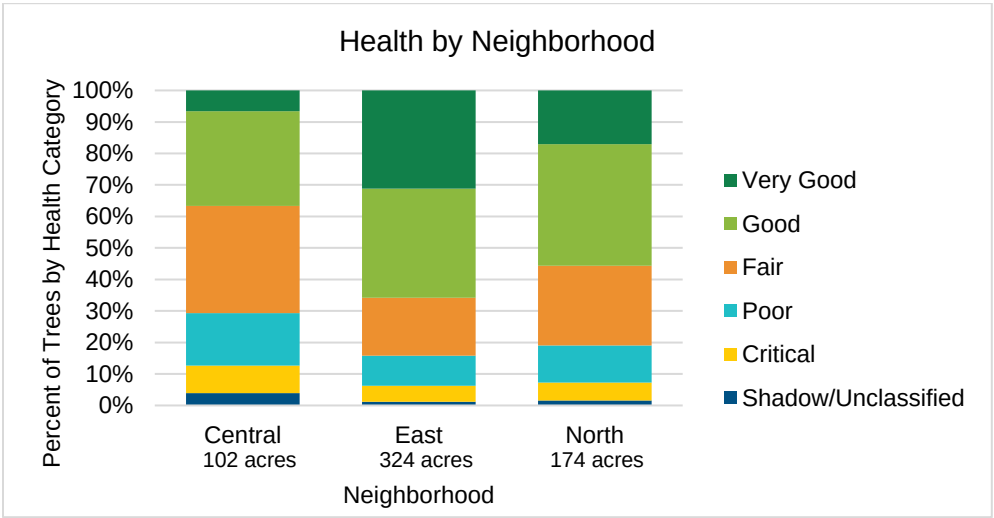


Figure 10. Forest health classification distribution in the neighborhoods.

Trees growing in an urban environment face many challenges that threaten their vigor, increase risk, and shorten their service lives—poor soil quality, restricted rooting area, air pollution, increased temperatures, construction damage, vehicular accidents, soil compaction, inadequate/inconsistent water, and stress-induced insect and disease infestations. Columbia should be aware of these many factors influencing forest health and be prepared to act if a significant threat is observed in its tree population or a nearby community, or if a significant decline in health is detected.

Integrated pest management and plant health care plans should be established that focus on identifying and monitoring threats, understanding the economic thresholds for taking action, selecting the correct treatment, properly timing management strategies, recordkeeping, and evaluating the results. The city should also make citizens aware of any threats and about actions they can take to protect the tree canopy on private property.

Forest Fragmentation

Urban forests provide numerous environmental and socioeconomic benefits to people, but the benefits to wildlife and other natural systems may not always be fully appreciated. The urban ecosystem is extremely complex and diverse, existing in a multitude of layers formed by small functional ecosystems that collectively form a larger system. The overall health of the urban ecosystem depends highly on the ability of trees, plants, wildlife, insects, and humans to interact as a whole.

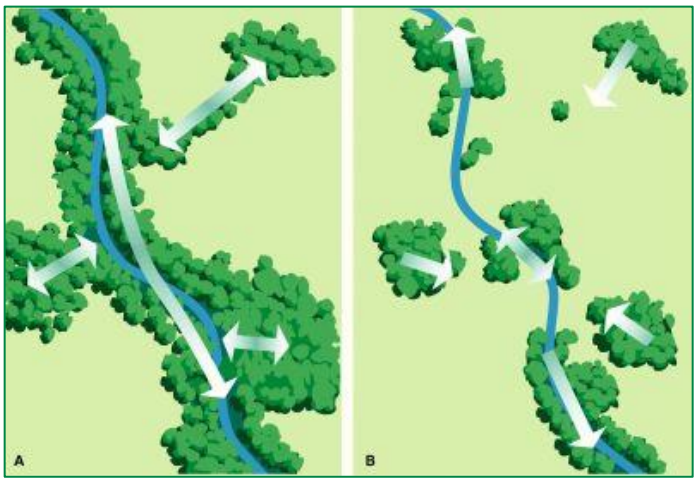


Figure 11. Wildlife corridors in area A link habitats while fragmented forests in area B lead to a decline in habitat quality. Source: Federal Interagency Stream Restoration Group.

However, a key factor in declining urban ecosystem health is urban build-up and land clearing, which often involves tree removal and a decrease in overall tree canopy cover. This effect often causes tree canopies to become isolated and fragmented from each other and leads to the degradation of ecosystem health, which in turn leads to a decline in habitat quality and canopy connectivity. This decline results in changes and imbalance to microclimates and increases the risk and susceptibility to invasive species to invade the city's woodlands and landscapes (Figure 11).

As a part of the UTC assessment, forest fragmentation was identified, mapped, and quantified. This analysis focused on how tree canopy is spatially distributed throughout the city and provided an index displaying the degree of fragmentation. Often, the health and diversity of the overall canopy can be greatly improved by creating linkages between multiple patches of forest.

The analysis found that Columbia's urban forest includes the four following categories of forest cover:

- **Core Canopy = 3,329 acres**

  Tree canopy that exists within, and relatively far from, the forest/non-forest boundary (i.e., forested areas surrounded by more forested areas). This category accounts for 22% of Columbia's canopy; this relatively large amount of high-quality, high-functioning forestland is uncommon in most U.S. cities.

- **Perforated Canopy = 1,831 acres**

  Tree canopy that defines the boundary between core forests and relatively small clearings (perforations) within the forest landscape. This category comprises 12% of Columbia's canopy.

- **Edge Canopy = 5,941 acres**

  Tree canopy that defines the boundary between core forests and large non-forested land cover features. This category accounts for 40% of Columbia's canopy indicating that the city's canopy can be described as primarily a transition between cleared land and core forests.

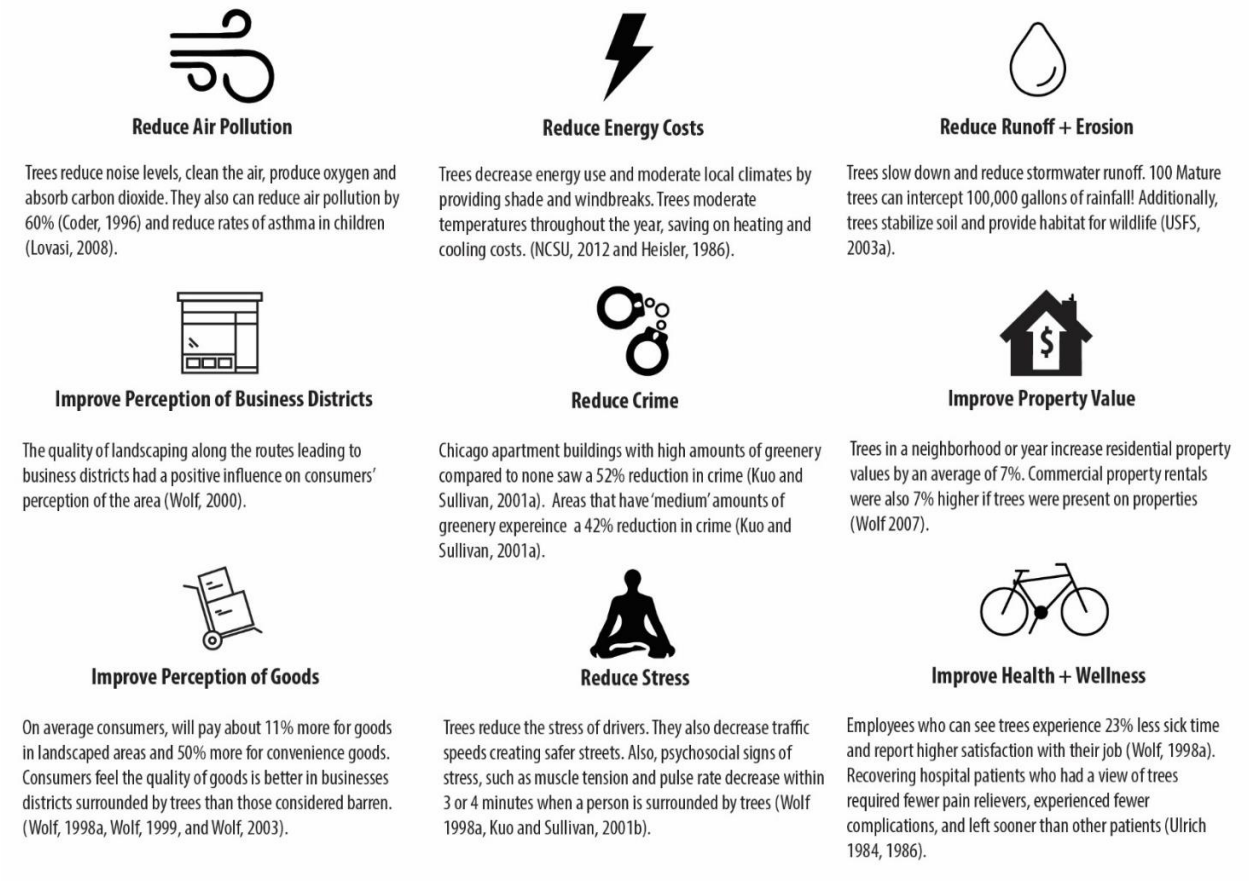
- **Patch Canopy = 3,816 acres**

  Tree canopy that comprises a small forested area that is surrounded by non-forested land cover. This category of forests is the least productive and beneficial and comprises 25% of Columbia's urban tree canopy.

Information on forest fragmentation is useful for conservation and tree planting purposes. Knowing the locations of the forest types can guide land or easement acquisition and tree planting so that these kinds of efforts are targeted in areas that can connect isolated areas of trees to create more contiguous and larger urban forests tracts.

Benefits Provided by Columbia's Tree Canopy

Trees provide a myriad of benefits to a community, some of which can be quantified currently, and some cannot. All are valuable to a community. Some of the more prominent benefits and related statistics follow.



Overall UTC Ecosystem Benefits

This study used a variety of tree canopy assessment and analytical tools to quantify and evaluate ecosystem services and benefits. The amount and value of benefits provided by Columbia's collective urban forest are calculated from trees' abilities to store carbon, clean the air, provide energy savings, intercept and absorb stormwater, and boost property values.

Overall, **Columbia's existing canopy provides its residents with $145 million in benefits annually**. In addition to the annual benefits, the carbon stored by the current UTC contributes an additional $66 million in benefits, bringing the collective benefit amount to $211 million.

The quantities and estimated value of the air pollution, carbon storage and sequestration, stormwater, energy savings, and property value benefits Columbia receives annually from trees is presented in Table 4, followed by further discussion for each category.

Table 4. Columbia's Urban Tree Canopy Benefits

	Quantity	Unit	Value
STORMWATER: Runoff Reduction	336,306,674	gallons	$672,613
ENERGY: Savings from Avoided Cooling	16,334,789	kWhs	$1,795,193
PROPERTY: Increases in Property Values	---	$	$138,852,340
AIR: Carbon Monoxide (CO) Removed	8,340	lbs.	$5,535
AIR: Nitrogen Dioxide (NO_2) Removed	68,920	lbs.	$18,632
AIR: Ozone (O_3) Removed	724,100	lbs.	$928,657
AIR: Sulfur Dioxide (SO_2) Removed	43,160	lbs.	$3,305
AIR: Dust, Soot, Other Particles Removed (Particulate Matter, PM_{10})	80,340	lbs.	$250,944
Carbon Sequestered	69,973	tons	$2,446,941
	Total Annual Benefits		$144,994,159
Carbon Storage over Canopy's Lifetime (not an annual benefit)	1,888,056	tons	$66,564,138
	Total Benefits Overall		$211,558,297

Stormwater Runoff Reduction

Trees in Columbia are able to intercept an impressive 336 million gallons of stormwater annually; this important infrastructure service is valued at approximately $672,000 each year. Intercepting and temporarily holding rainwater with leaves and in bark delays that water from reaching the ground and moderates peak runoff quantities. Tree roots also directly absorb stormwater by consuming water stored in soil pores, thereby increasing the rainwater storage capacity of local soils. Stormwater reduction rates are based on an average annual rainfall of 42 inches and equate to over 22,500 gallons of stormwater reduction per acre of tree canopy in Columbia.

Protecting and increasing the urban forest will help the city meet the goals of its *Integrated Management Plan for the Sanitary Sewer and Storm Water Utilities*, comply with city, state, and national regulations, and support the green infrastructure projects described in the city's Storm Water Manual. This specific benefit will become increasingly important as Columbia faces more severe rain storms in the future due to changes in climate.

Energy Savings

The cooling effect of shade trees is perhaps the most widely recognized benefit of trees. **Columbia's urban forest saves over 16 million kilowatt hours of energy annually —a savings of over $1.8 million for consumers**. Natural cooling provided by urban trees reduces consumer demand for electricity, which in turn also reduces harmful emissions released from the burning of fossil fuels because of the decreased demand on power plants. The cooling benefit of shade trees can also be felt at the street level where lower ambient temperatures of 5 to 15 degrees have been recorded around street trees (Miller 1997). Adding trees for their cooling benefits alone in areas with large amounts of concrete (impervious surfaces) would quickly help reduce ambient temperatures in Columbia's urbanized areas and neighborhoods.

Property Value Increases

It is widely accepted that tree-lined streets and canopied parks boost property values. In one survey by Arbor National Mortgage and American Forests, 83% of realtors indicated that large, mature trees had a "strong or moderate impact" on home sales under $150,000. For homes over $250,000, the response increases to 98%. Homes with trees were also reported to sell more quickly than those without. **Columbia's trees can be attributed to almost $139 million in property value increases**, representing the largest single benefit value reported, which in turn increases the tax revenue needed for public services.

Air Quality Improvements

Every year, Columbia's trees remove significant amounts of pollution from the air: over 8,340 lbs. of CO, 68,920 lbs. of NO_2, 724,100 lbs. of O_3, 43,160 lbs. of SO_2, and 80,340 lbs. of dust, soot, and other solid particulate matter. **Air quality improvements equate to an impressive value of $1.2 million annually**.

Ozone (O_3) pollution reduction represents the greatest benefit value to Columbia's citizens at almost $1 million annually. Reforestation efforts in and around urban areas have been shown as one of the more cost-effective and feasible methods to controlling dangerous ground-level ozone, which is known to cause increases in respiratory and cardiovascular diseases and human deaths world-wide (Kroeger et al. 2014).

Carbon Reduction

The total carbon reduction benefit provided by trees can be measured in two categories. The first is the amount of carbon dioxide absorbed by tree leaves annually, which has been calculated at over 70,000 tons. The second is the amount of carbon stored in woody tissue of living trees over its lifetime, calculated at almost 1.9 million tons. These two **carbon capturing avenues represent a total benefit value of $69 million**. This is an important benefit to Columbia's sustainability strategies as it mitigates atypical climatic patterns believed to be influenced by excess atmospheric carbon.

Neighborhood Tree Canopy Benefits

Three neighborhoods were identified for individual UTC analyses—Central (located in Ward 1), North (in Ward 2), and East (in Ward 3). Columbia is dedicated to supporting the development of these neighborhoods as vibrant places to work and live through a variety of programs and projects. Increasing the tree canopy through tree planting and mature tree care will be an integral component of those efforts.

Using similar methodologies as the citywide analyses, the UTC, other land cover, and tree benefits were calculated for each neighborhood. The results for the three target neighborhoods are summarized in Table 5 and displayed in Figures 12, 13, and 14.

Table 5. UTC, Land Cover, and Ownership Percentages, and UTC Benefit Values for the Central, North, and East Neighborhoods*

Neighborhood	Central	North	East
Land Cover			
Tree Canopy	33%	23%	39.0%
Impervious	43%	23%	23%
Pervious	24%	46%	37%
Bare Soil	0.4%	7%	0.3%
Water	0.01%	0.3%	1.1%
Tree Canopy on Public Properties	9%	1%	5%
Tree Canopy on Private Properties	91%	99%	95%
Annual Ecosystem Benefits Values			
Carbon Monoxide CO Removed	$38	$65	$120
Nitrogen Dioxide (NO_2) Removed	$127	$219	$404
Ozone (O_3) Removed	$6,310	$10,932	$20,118
Sulfur Dioxide (SO_2) Removed	$22	$39	$72
Dust, Soot, Other Particles Removed (Particulate Matter, PM_{10})	$1,705	$2,954	$5,436
Carbon Sequestered	$475	$824	$1,516
Stormwater Runoff Reduction	$4,977	$12,040	$13,318
Energy Savings from Avoided Cooling	$27,037	$65,461	$52,628
Increases in Property Values	$1,416,495	$1,653,856	$3,709,024
TOTAL ANNUAL BENEFITS	$1,473,472	$1,774,608	$3,854,564
Carbon Storage Over Canopy's Lifetime (not an annual benefit)	$452,257	$783,599	$1,442,040
TOTAL BENEFITS	$1,925,729	$2,558,207	$5,296,604

*Data have been rounded to the nearest whole percentage.

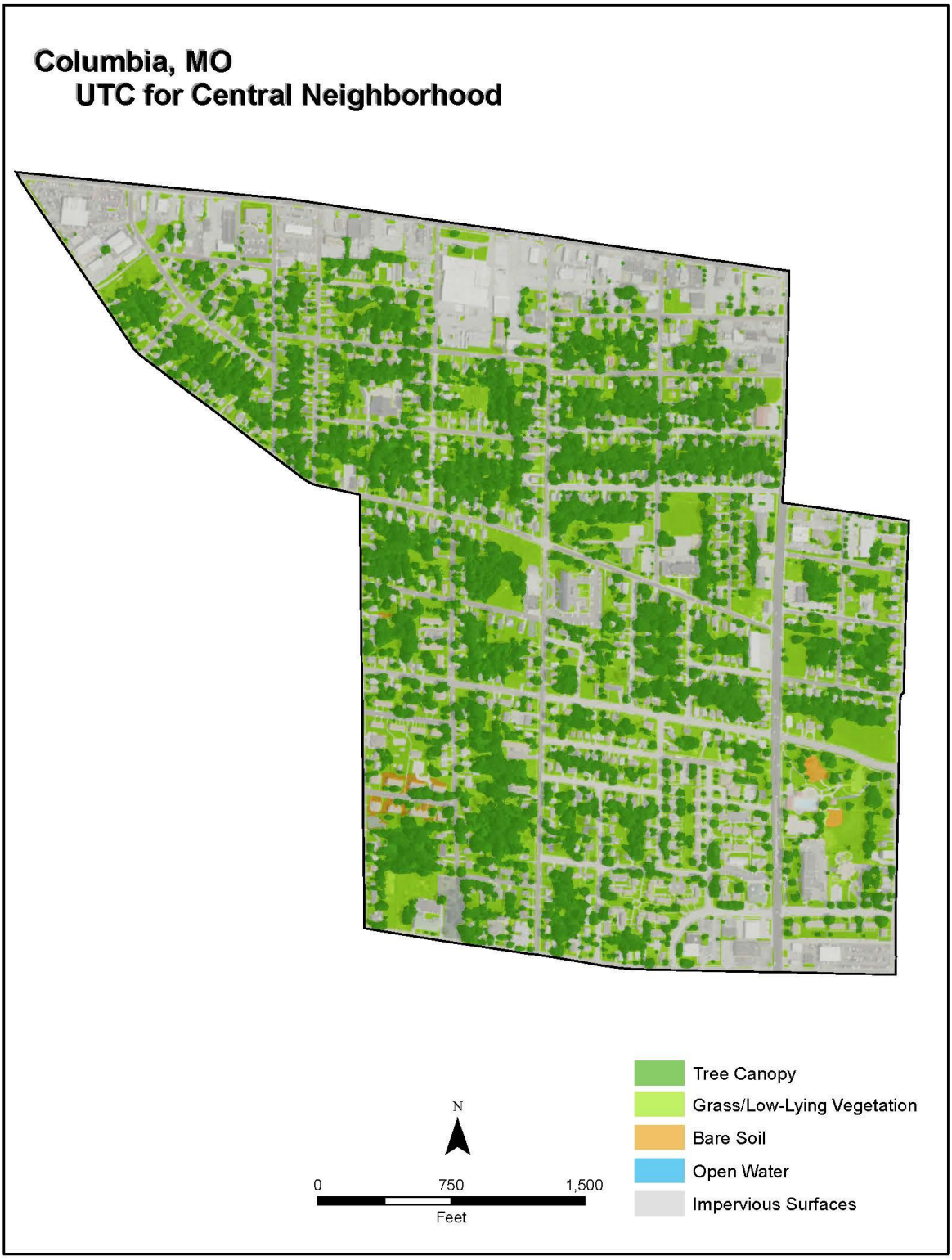


Figure 12. The Central Neighborhood has 32.82% UTC which provides over $1,473,000 in annual benefits to the residents and the city as a whole.

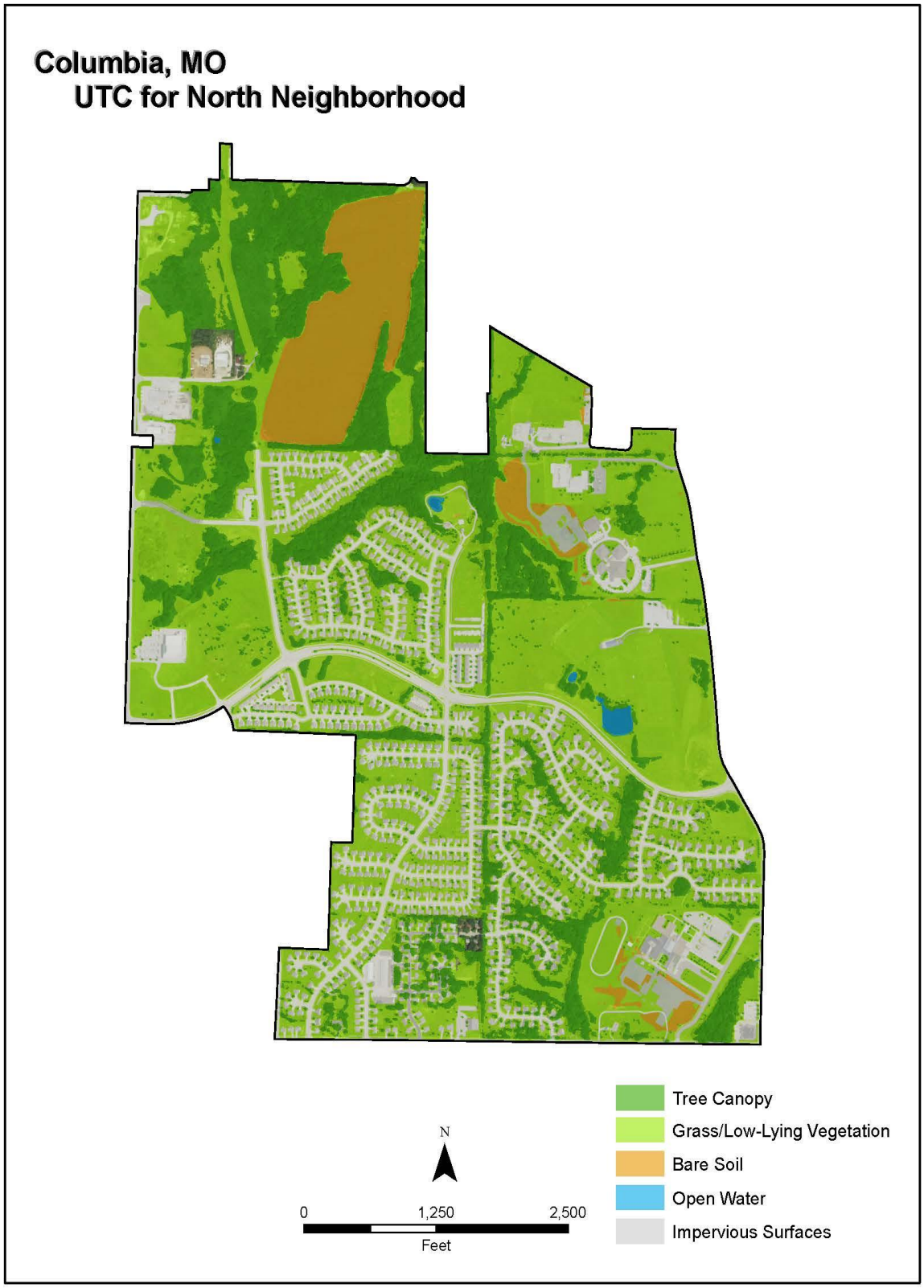


Figure 13. The North Neighborhood has 23.16% UTC which provides over $1,774,000 in annual benefits to the residents and the city as a whole.

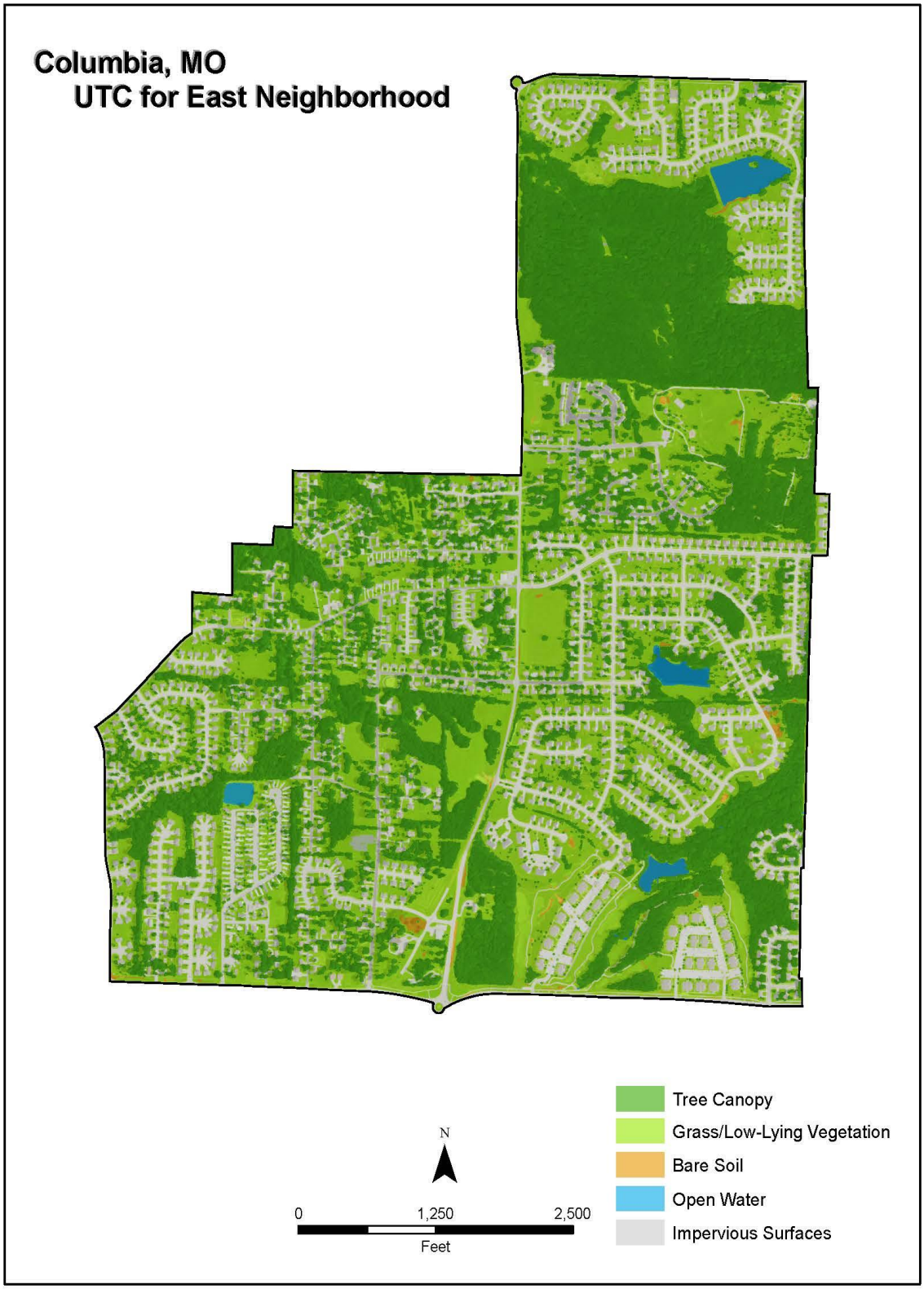


Figure 14. The East Neighborhood has 39.00% UTC which provides over $3,854,000 in annual benefits to the residents and the city as a whole.

Urban trees create healthy, safe, strong, and more vibrant neighborhoods. Tree planting and proactive maintenance in the Central, North, and East neighborhoods are no less important than other community-building services. Tree-lined streets and tree-canopied parks make neighborhoods more inviting, attract new residents and businesses, and improve public health.

One study showed that residents of apartment buildings surrounded by trees reported knowing their neighbors better, socializing with them more often, having stronger communities, and feeling safer and better adjusted than did residents of more barren, but otherwise identical areas (Kuo 2001b). According to studies released by the Pennsylvania Horticultural Society, the greening of neighborhoods increases surrounding property values, encourages investment, reduces crime and vandalism, and encourages exercise, which in turn reduces stress. All of these improvements contribute to building a better community (PHS 2015).

Final Thoughts on the City's Urban Tree Canopy

Canopy Now Benchmarked. The UTC assessment has mapped the location of tree canopy in Columbia and calculated the values of a variety of ecosystem services. This information is invaluable for an effective management program for public outreach and education, planning and prioritizing tree planting, and for generating interest and support of the program. And perhaps more importantly, these data also provide a benchmark that can be used to track future changes and trends in Columbia's tree canopy. Such a benchmark can help incorporate urban forest management goals into the broader city initiatives such as sustainability, comprehensive, and watershed plans. For the first time, Columbia's citizens, allied organizations, and government agencies have accurate tree canopy data to rely upon and formulate next steps.

Planning for Trees is Important. In an age of tight municipal budgets, aging infrastructure and competition for city resources, why should valuable funds be spent on trees? Because trees provide numerous social, economic, and environmental benefits to residents of Columbia beyond their aesthetic value. As shown in this plan, trees provide effective solutions to many urban challenges.

The UTC Provides Proven Benefits. The various ecosystem services derived from Columbia's urban tree canopy provide compelling data in support of additional tree planting and better tree preservation throughout the city and in the target neighborhoods. Trees are a proven solution and an important tool for achieving many community sustainability, public health, economic development, and pollution abatement goals.

It Pays to Increase Canopy. Columbia and its citizens are receiving benefits from its UTC valued at nearly $145 million every year (excluding stored carbon). That equates to almost $10,000 of ecosystem services per acre of tree canopy. If expanded tree planting and tree preservation and protection efforts were taken on both public and private properties, then the benefits would also increase.

Table 6 presents the predicted values of the total UTC benefits under the scenarios of a 5% and a 10% canopy increase citywide and in the target neighborhoods. The results reveal that there will be a 7.7% increase in benefits with only a 5% canopy increase, and a 16% increase with a 10% canopy increase.

Table 6. Total Benefit Values* for 5% and 10% Increases in Urban Tree Canopy

Area	Current	5% UTC Increase	10% UTC Increase
Citywide	$211,558,297	$227,977,177	$245,944,635
Central	$1,925,729	$2,076,289	$2,222,146
North	$2,558,207	$2,814,961	$3,080,398
East	$5,296,604	$5,681,325	$6,066,230

*Values presented include the non-annual benefit of carbon storage

Detailed descriptions of the UTC mapping methodology and models used to calculate the benefits found can be found in Appendices E and K.

PRIORITIZED PLANTING PLAN TO GUIDE AND EXPAND COLUMBIA'S UTC

Because of the many documented and quantifiable benefits trees are providing Columbia, trees should be part of the solutions for Columbia's urban growth and sustainability issues, such as heat island effect, air pollution, stormwater management, and water pollution. The city also understands that tree benefits should be afforded to people and neighborhoods equally. So, to maximize benefits and better serve all residents of Columbia, a prioritized planting plan has been developed based on the UTC information.

The UTC assessment identified all potential and realistic plantable areas in the city, but these areas were not initially prioritized. While all available planting sites in the city limits may ultimately be planted over the next several decades, the trees planted in the next several *years* should be installed in high-need areas and in locations that will allow the trees to provide the most benefits and return on investment.

To identify planting areas that will return the greatest and most diverse amount of benefits to Columbia, the tree canopy and land cover data were used in combination with information about a number of other environmental and social features that can be used to set priorities, such as soil permeability, riparian areas, urban heat island, slope, road density, and population density (Figure 15). The methodology for the prioritized planting plan is found in Appendix I.

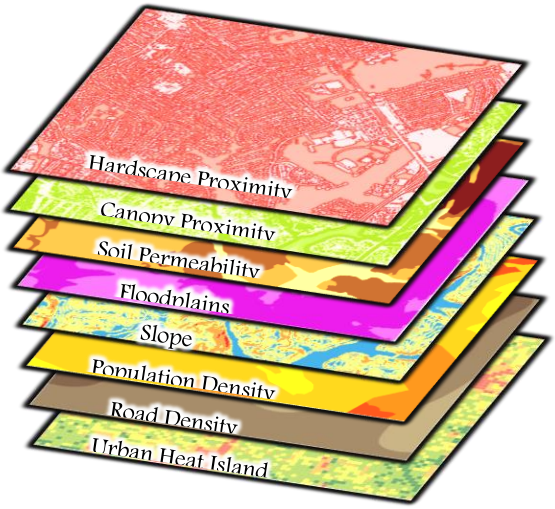


Figure 15. Features used to prioritize planting areas in Columbia.

Each of these features was used to create individual grids that were assigned a value between 0 and 4, identifying priority planting importance from Very Low to Very High. By overlaying these grid maps and adding the values at any given point, a priority planting scale was developed based on the level of need. Planting trees in areas of High and Very High need can reduce the risk of soil loss, reduce storm flooding, improve water quality, and/or reduce urban heat island effect. The GIS data analysis calculated the total acres of preferred planting sites citywide (Table 7) based on the priorities for Columbia; those areas where the greatest need is for future tree planting per Ward are displayed in Figure 16.

The distribution of the various planting priority classifications is fairly even across the city. The Low and Very Low priority sites naturally are located at the city limits away from the developed urban core where existing tree canopy is more abundant.

Table 7. Summary of Planting Site Prioritization Citywide

Priority Rank	Total Number of Locations*	Total Acres
Very Low	3,411	1,830.37
Low	11,319	3,052.97
Moderate	35,601	3,340.25
High	36,666	2,053.61
Very High	19,363	561.99
Total	106,360	10,839.18

*Locations are polygon areas measured in acres, not individual sites identified by address.

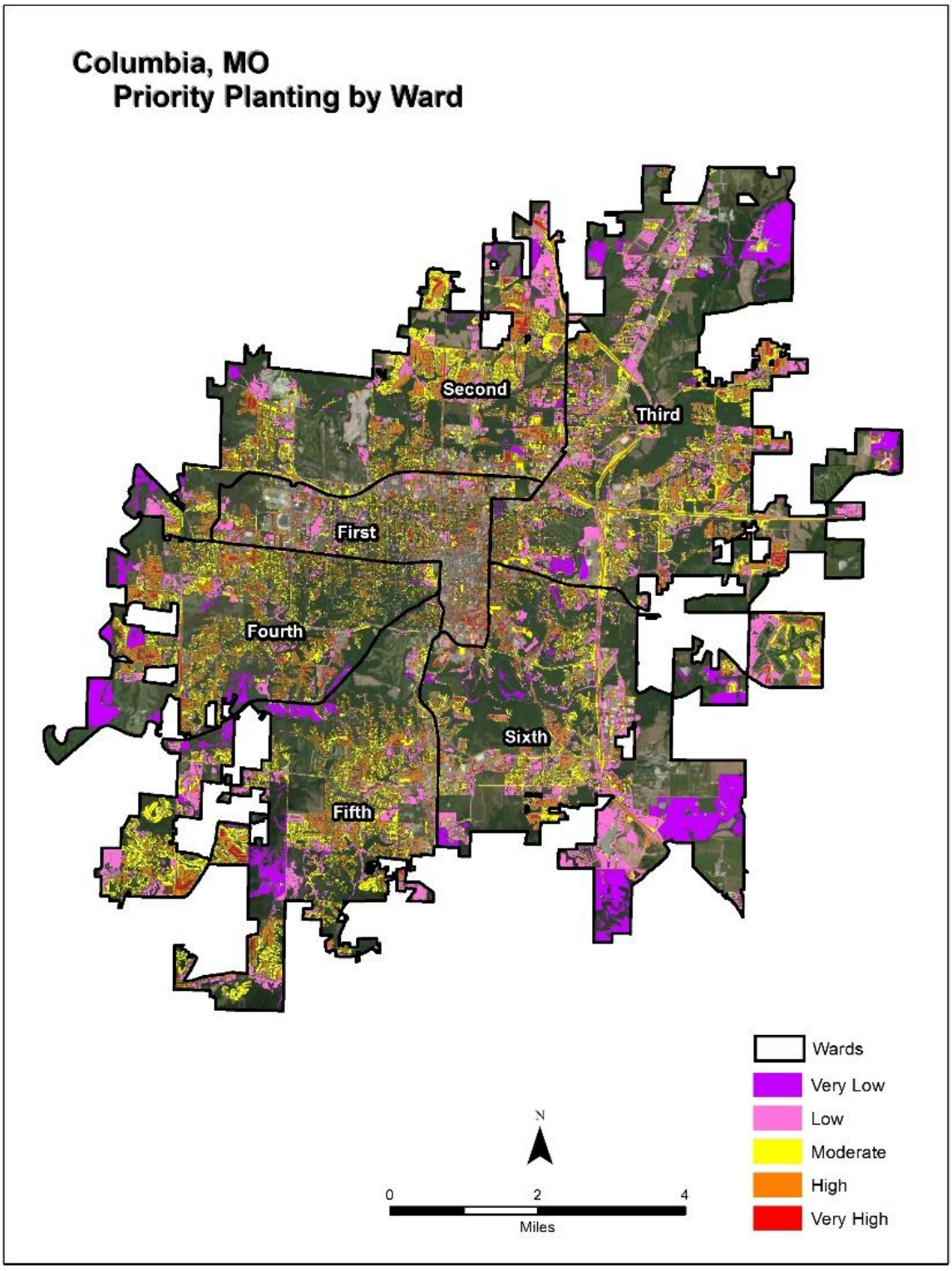


Figure 16. Citywide planting plan priority areas.

Based on the statistics, Ward Two has the greatest total number of High and Very High priority acres combined at 535 acres, and Ward Three has the second highest combined total at 495 acres. However, those acres comprise 28% and 19%, respectively, of the total plantable acres in those wards. Ward 1 only has a total of 274 acres of High and Very High priority planting sites, but those comprise 43% of the plantable areas in that ward. Figure 17 presents the distribution of the priority classifications within the Wards as a function of all the plantable sites citywide.

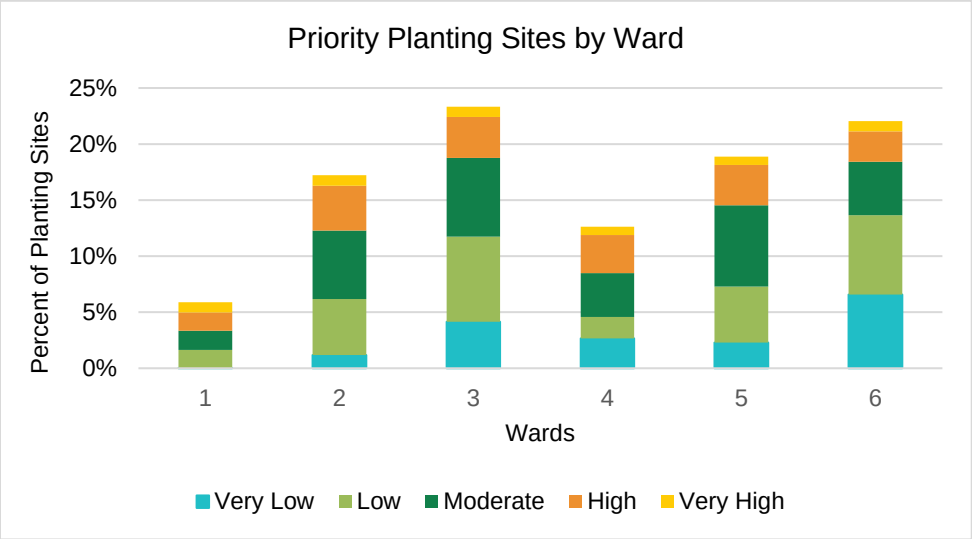


Figure 17. Distribution of the citywide prioritized planting sites by ward.

Of the total priority planting sites in the Central, East, and North Neighborhoods combined, the distribution of all priority classifications is presented in Figure 18. Further analysis of the statistics, however, reveals that High and Very High planting sites comprise 40% of the Central Neighborhood's plantable areas, where those same classes represent only 26% in the East and 29% in the West.

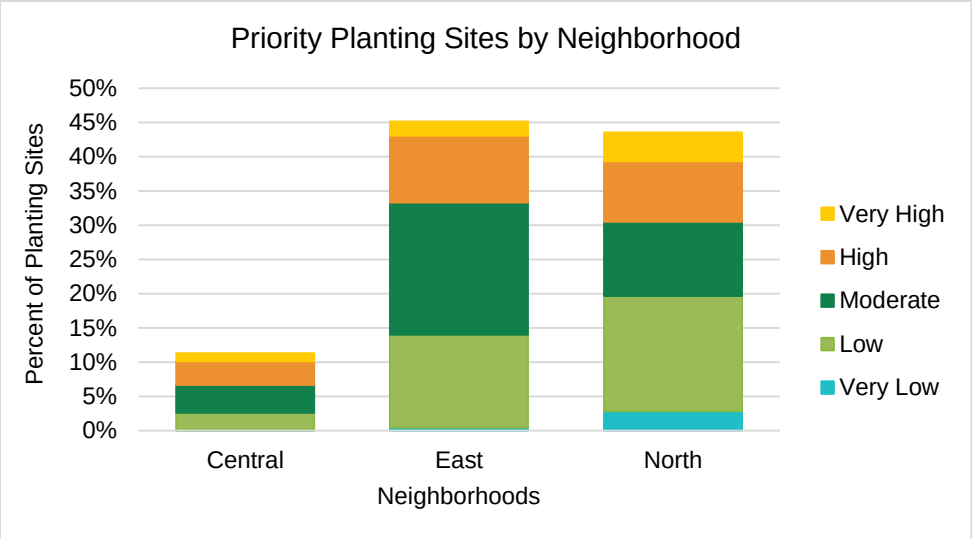


Figure 18. Distribution of target neighborhoods prioritized planting sites.

Columbia's UTC-based prioritized planting plan tool can be used for planning, budgeting, applying for grants, inter-agency project development, public education, and many other uses. With this UTC assessment and prioritization of plantable areas complete, Columbia has better information to initiate projects to achieve canopy goals which can be accomplished through landscape tree planting, reforestation, and natural regeneration.

About the Planting Plan

The prioritized planting plan should not be considered as a traditional landscape design and installation plan. It exists as an electronic GIS data layer with embedded information, and as such can be easily queried, updated, and used for project-based analyses. Tree planting areas have not been field-verified, and the statistical information provided are estimates based on the accuracy of the data provided for this project.

ASSESSMENT OF STREET TREES IN COLUMBIA

While comprehensive urban forest management considers all trees across the entire jurisdiction and takes action to improve the condition and extent of the citywide urban tree canopy, the City of Columbia's primary responsibility is to properly manage its public trees. Therefore, a key step in developing proactive management strategies is to assess the current composition and distribution of Columbia's public trees and their associated ecosystem services.

Public Tree Inventory Data Discussion

City forestry staff, other arborists, and Davey Resource Group assessed and inventoried street trees, stumps, and planting sites from the years 2006 to 2017. At this date, a total of 5,282 sites have been collected representing 5,049 trees, 144 stumps, and 89 planting sites. The public street rights-of-way were selected by Columbia for the inventory and analysis, and approximately 90% of the street trees have been inventoried to date.

Accurate analysis of Columbia's inventory data for the master plan's recommendations and budget projections was not possible due to many data-related constraints. However, every effort was made to use the available data to provide the city with reliable and actionable information in this plan. The inventory data limitations that affected the analysis included:

- The inventory data set is not a complete street tree inventory (approximately 10% of the population remains to be inventoried); and the inventory does not include parks or other public properties.
- Parts of the inventory data had not been updated or quality checked since 2006.
- Multiple duplicate sites were discovered in the data set and were deleted.
- Most sites did not have the indication of the presence of overhead utility lines.
- No diameter measurements were available for many trees in the data set; the city decided to equally assign and distribute the missing diameters to be between 3" and 9" to address this.
- No primary maintenance recommendations were available for many trees; the city decided to assign a value of "tree clean" to these sites to address this.
- No condition ratings were available for many trees; the city decided to assign a value of "Fair" to all these sites.
- Multiple sites did not have species values assigned; the city decided that no corrective action should be taken.
- Multiple sites had inaccurate location or "unassigned" addressing information; the city decided that no corrective action should be taken.

Benefits From Columbia's Street Trees

Columbia's street trees provide approximately $298,000 in the following annual benefits:

- *Aesthetic and other benefits:* valued at $112,739 per year.
- *Air quality:* valued at $11,575 per year.
- *Net total carbon sequestered and avoided:* valued at $9,141 per year.
- *Energy:* valued at $89,954 per year.
- *Stormwater peak flow reductions:* valued at $74,575 per year.

Photograph 3. *Columbia's street trees provide* approximately $297,983 in annual benefits.

The following findings, analyses, discussion, and recommendations about the public tree population should be considered in terms of the constraints and limitations of the inventory data mentioned previously. While the data can likely be relied upon to reveal trends and potential threats and opportunities in the public forest, the data requires significant updates before it can be relied upon for in-depth analytics, risk assessment, or precise budgeting.

Street Tree Population Findings

Most Trees Are In Fair Condition

Overall, the vast majority (74%) of Columbia's street trees are in Fair condition, with 17% of trees in Good condition. At the time of the inventory, only 9% of trees were either identified as Poor, Critical, or Dead (see Figure 19). Condition is an important tree attribute to know and monitor as it indicates how well trees are performing, their susceptibility to insect and disease threats, both short-term and long-term maintenance needs and costs, risk level, and the outlook for urban tree canopy cover continuity.

The city should be keenly aware of the fact that nearly three-quarters of the street trees are in Fair condition; this means that any number of stressors (i.e., climate change, construction damage, insects, disease, lack of routine maintenance, etc.) can quickly drop these street streets into the Poor condition category which may increase maintenance costs and risk levels.

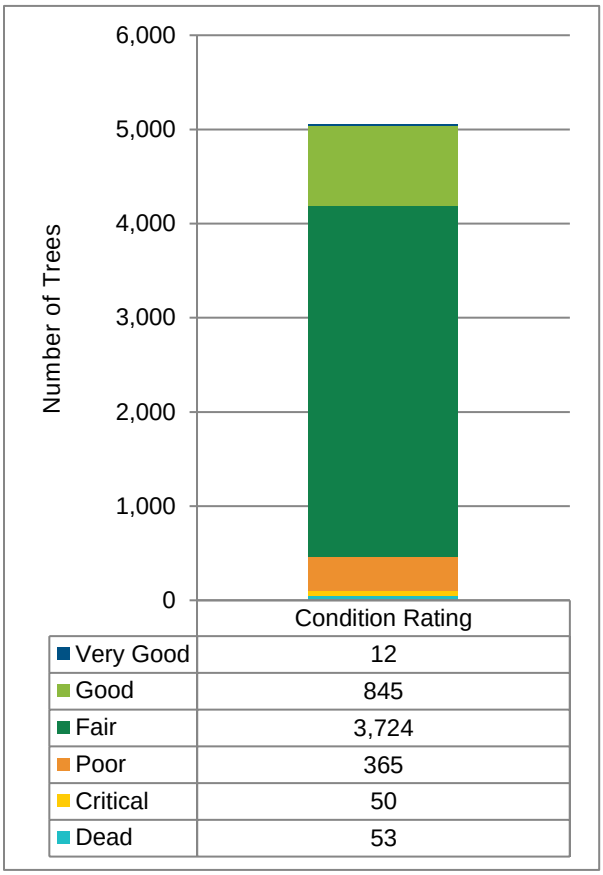
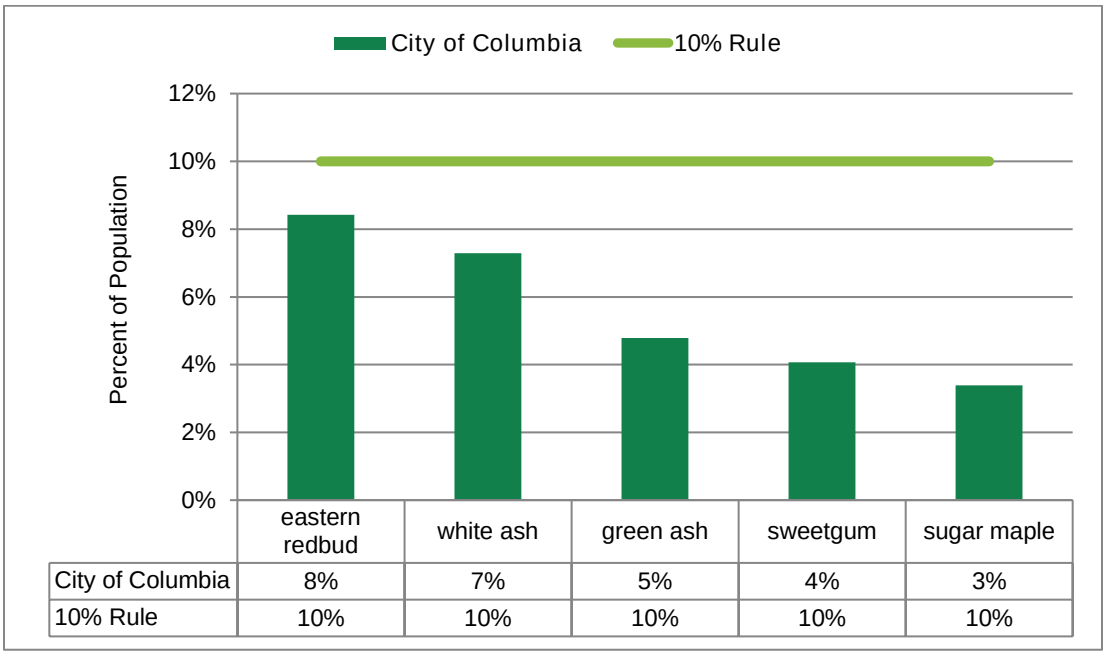


Figure 19. Street tree condition rating.

Diversity of Species is High

Species diversity, or the number and variety of species in a specific population, affects the tree population's ability to withstand threats from invasive pests and diseases. Species diversity also impacts tree maintenance needs and costs, tree planting goals, and canopy continuity and sustainability. The current industry best management practice is that a city's public tree population should follow the "10-20-30 Rule" for species diversity: a single species should represent no more than 10% of the urban forest, a single genus no more than 20%, and a single family no more than 30%.

In Columbia, the mix of species was really good with 133 species represented in the inventory data. Figure 20 uses the "10% Rule" to compare the percentages of the most common species identified during the inventory to this best management practice.



	eastern redbud	white ash	green ash	sweetgum	sugar maple
City of Columbia	8%	7%	5%	4%	3%
10% Rule	10%	10%	10%	10%	10%

Figure 20. Five most abundant species of the inventoried population compared to the 10% Rule.

Cercis canadensis (eastern redbud) and *Fraxinus americana* (white ash) are approaching the recommended 10% maximum for a single species in a population, comprising 8% and 7% of the inventoried tree population, respectively. Appendix A presents a list of recommended tree species that should aid Columbia in maintaining a high species diversity level when planning future planting projects.

Recognition of Current Age Distribution

Diameter size class distribution is the statistical distribution of a given tree population's trunk-size class and is used to indicate the relative age of a tree population. Diameter class distribution affects the valuation of tree-related benefits as well as projected maintenance needs and costs, planting goals, and canopy continuity. An ideal distribution suggests that the largest fraction of trees (approximately 40% of the population) should be young (less than 8 inches DBH), while a smaller fraction (approximately 10%) should be in the large-diameter size class (greater than 24 inches DBH) (Richards 1983). A tree population with an ideal distribution would have an abundance of newly planted and young trees, and lower numbers of established, maturing, and mature trees. Figure 21 presents the size distribution of Columbia's street trees in relation to the ideal.

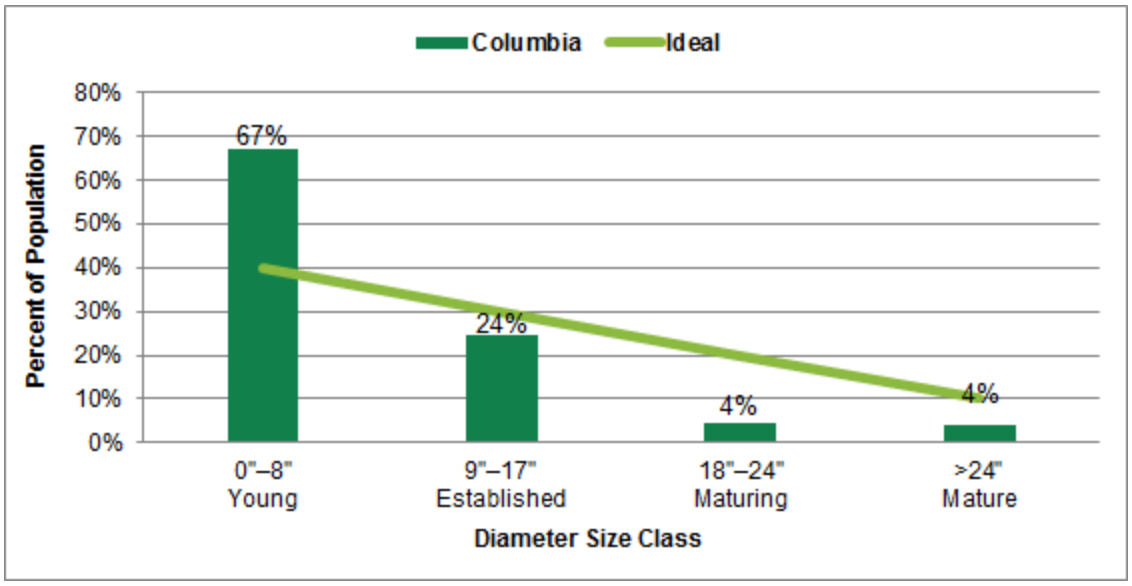


Figure 21. Comparison of diameter size class distribution for inventoried trees to the ideal distribution.

Columbia's distribution does trend toward the ideal; but young trees exceed the ideal by over 27%, and larger diameter size classes fall short of the ideal. Columbia has too few established, maturing, and mature trees, which indicates that the distribution is skewed. One of Columbia's objectives should be to have an uneven-aged distribution of trees at the citywide level. This can be accomplished with a strong planting and maintenance and the city must promote tree preservation and proactive tree care to ensure the long-term survival of older trees. Tree planting and tree care will allow the distribution to normalize over time.

Tree Maintenance Remains a Priority

Trees provide many environmental and economic benefits that justify the time and money invested in planting and maintenance. The distribution of recommended maintenance categories in Columbia's street tree forest are presented in Figure 22 and include: Tree Removal (6%); Stump Removal (5%); Routine Pruning (65%); and Young Tree Train (21%).

Maintenance should be prioritized by addressing trees with the highest risk first. The inventory noted some Extreme and High Risk trees (1% and 5%, respectively); these trees should be removed or pruned immediately to improve public safety. Low and Moderate Risk trees should be addressed after all elevated risk tree maintenance has been completed. Trees should be planted to mitigate removals and create canopy.

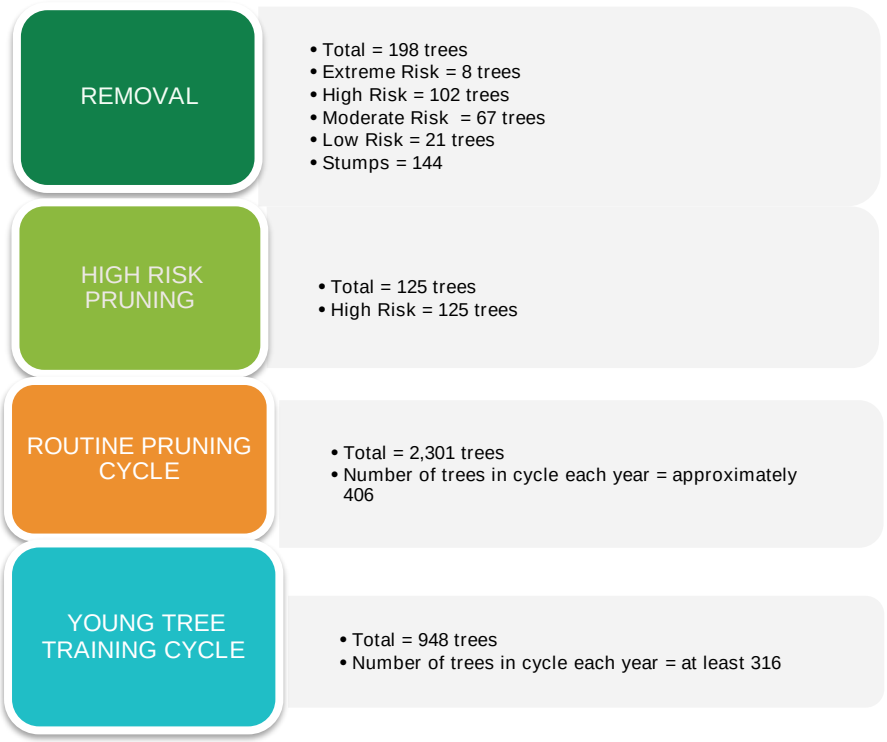


Figure 22. Current summary and **distribution of tree maintenance needs of Columbia's street trees.**

Tree and Infrastructure Conflicts Exist

In an urban setting, space is limited both above and below ground, and city trees often compete for space. If not planned and planted properly, conflicts between trees and other municipal infrastructure, such as buildings, sidewalks, and utility wires and pipes, may occur resulting in increased maintenance costs, damage to or premature loss of trees, and decreased public health and safety. Existing or possible conflicts between trees and infrastructure recorded during the inventory update included:

- *Clearance Requirements*—The inventory noted trees blocking the visibility of traffic signs or signals, streetlights, or other safety devices.
- *Overhead Utilities*—The presence of overhead utility lines above a tree or planting site was recorded.
- *Hardscape Damage*—Observed damage related to the interference between trees and curbs, sidewalks, and other hardscape features was noted.

There were 489 trees recorded with some type of clearance issue (Table 8). Most of those (89%) were related to being in conflict with vehicles. When the bottom of a tree's canopy over the road was less than 14 feet or rubbing from vehicles was noted, this clearance type was recorded. Tree canopy should not interfere with vehicular or pedestrian traffic, nor should it rest on buildings or block signs, signals, or lights. Pruning to avoid clearance issues and raise tree crowns should be completed in accordance with ANSI A300 (Part 9) (2011). Industry best management practices for street tree clearances are: 14 feet over streets; 8 feet over sidewalks; and at least 5 feet from buildings, signs, signals, or lights.

There were 569 trees with utilities directly above, or passing through, the tree canopy. Planting only small-growing trees within 20 feet of overhead utilities, medium-size trees within 20 to 40 feet, and large-growing trees outside 40 feet will help improve future tree conditions, minimize future utility line conflicts, and reduce the costs of maintaining trees under utility lines.

Hardscape damage was minimal; only 5% of the tree population had sidewalk slabs or curbs lifted in association with them. Best practices guidelines for planting trees between or near hardscape features are to give small-growing trees 4 to 5 feet, medium-growing trees 6 to 7 feet, and large-growing trees 8 feet or more between hardscape features. In most cases, this will allow for the growth of a tree's trunk taper, root collar, and large-diameter structural roots.

Table 8. Trees Noted to be Conflicting with Infrastructure

Conflict	Presence	Number of Trees	Percent
Hardscape Damage	Yes	251	4.75%
	No	3,268	61.86%
	Unassigned	1,764	33.39%
Overhead Utilities	Present	569	10.77%
	Not Present	2,945	55.74%
	Unassigned	1,769	33.48%
Clearance Requirements	Vehicle	434	8.22%
	Pedestrian	44	0.83%
	Sign/Signal	11	0%
	None Needed	3,017	57.11%
	Unassigned	1,769	33.48%

Trees are Under Threat

Insects and diseases pose serious threats to tree health. Awareness and early diagnosis are essential to ensuring the health and continuity of street and park trees. The inventory data were analyzed to provide a general estimate of the percentage of trees susceptible to some of the known pests in Missouri (see Figure 23). It is important to note that the figure only presents data collected from the street tree inventory. Many more trees throughout Columbia, including those on other public and private properties, are also susceptible to these invasive pests.

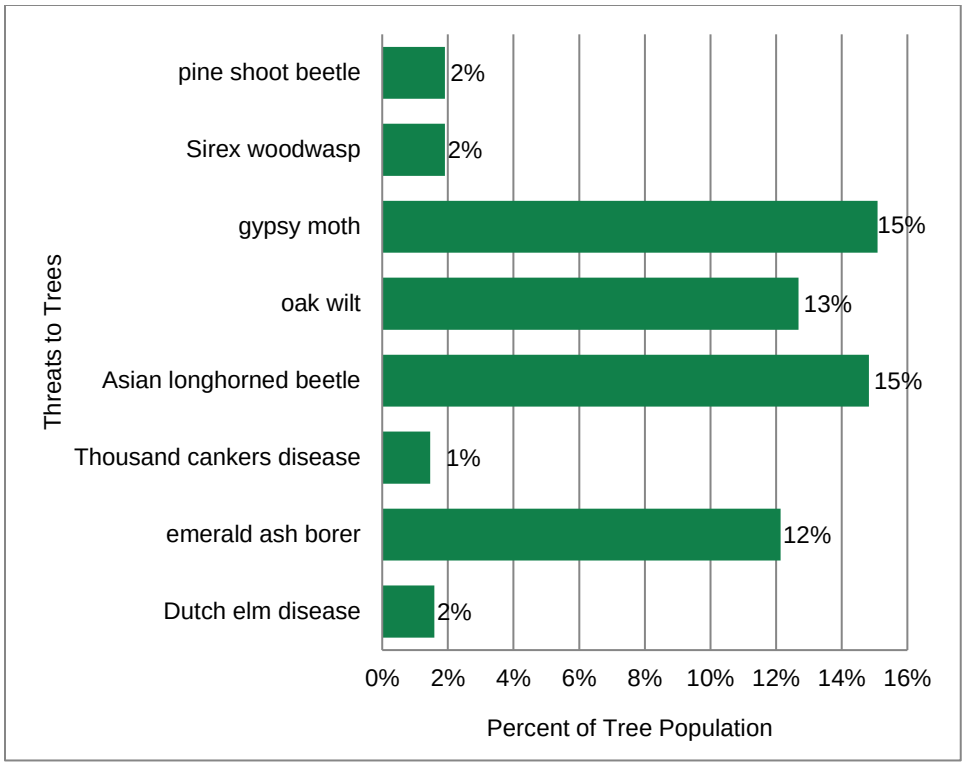


Figure 23. Potential impact of insect and disease threats noted during the inventory.

Gypsy moth (*Lymantria dispar dispar*), Asian longhorned beetle (ALB or *Anoplophora glabripennis*), and emerald ash borer (EAB or *Agrilus planipennis)* are insect threats to nearly 30% of the inventoried street trees. These pests were not detected in Columbia during the inventory, but if they were confirmed the city could see severe losses in its tree population. Oak wilt (*Ceratocystis fagacearum)* is a particularly concerning disease that is present in Missouri and threatens Columbia's tree canopy.

Columbia has an EAB Plan and should be aware of the signs and symptoms of potential infestations from other pests and diseases. The city needs to be prepared to act if a significant threat is observed in its tree population or a nearby community in the future. An integrated pest management plan should be expanded that focuses on identifying and monitoring threats, understanding the economic threshold, selecting the correct treatment, properly timing management strategies, recordkeeping, and evaluating results.

Appendix C provides information about some of the current potential threats to Columbia's trees and includes websites where more detailed information can be found.

Target Neighborhoods Street Tree Population

The inventory data were analyzed specifically for the Central, North, and East neighborhoods. As shown in Table 9, the neighborhoods' street trees follow similar trends as the citywide public tree population. The majority of trees are in Good or Fair condition; and the species diversity is good. Collectively, the trees in these three neighborhoods comprise 7.4% of the city's total inventoried population. Maps of each of the neighborhood's inventoried trees are in Appendix G.

Table 9. Select Statistical Findings of the Central, North, and East Neighborhood Street Tree Inventories

Street Tree Inventory Statistics*	Central Neighborhood	North Neighborhood	East Neighborhood
# of Trees Inventoried (% of total city inventory)	83 (1.64%)	149 (2.95%)	141 (2.79%)
# of Species	24	28	33
# of Trees in Good Condition	28	72	44
# of Trees in Fair Condition	48	72	84
# of Trees in Poor Condition	5	4	10
# of Trees in Critical or Dead Condition	0	1	2

ASSESSMENT OF EXISTING URBAN FOREST MANAGEMENT AND OPERATIONS

Public trees and the urban tree canopy are infrastructure assets, and as such should be managed efficiently and effectively to extend their service lives, maximize their benefits, and streamline operations. The key principles for successful operations management are to recognize the economic value of the asset, optimize the funding invested in that asset over its life cycle, and collaborate as an organization to ensure these public assets are functional and safe.

Current urban forest management programs and activities that directly impact the condition of the urban forest, management structure of the program, and regulations are discussed in the following sections with references to the Plan's Recommendations.

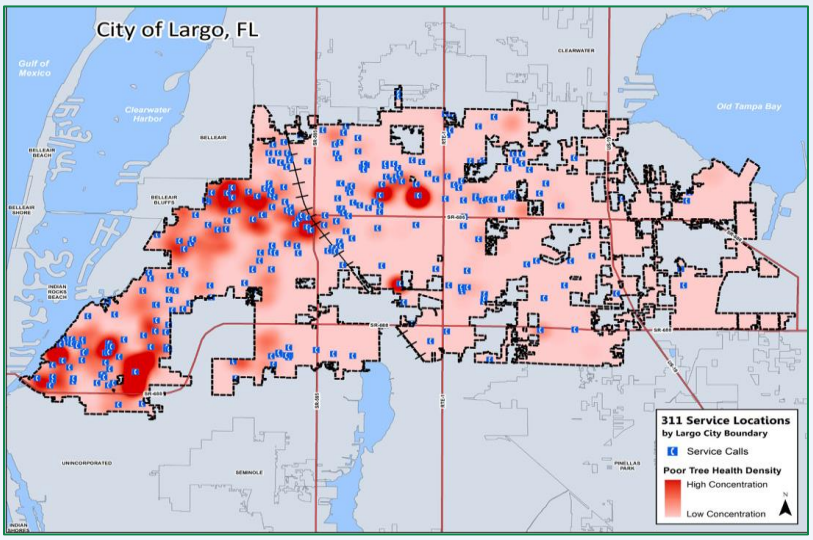
Tree Maintenance

Public tree maintenance in Columbia is generally performed on a reactive basis triggered by citizen requests, damage from severe weather and accidents, and as determined by the staff from the various departments that are responsible for public trees. Other than for utility line clearance, Columbia does not perform cyclical, preventive maintenance on its public trees.

The Case for Proactive Tree Care

The City of Largo primarily plans tree work in response to requests from citizens, often submitted via the eGov (311) system. Davey Resource Group analyzed two years of eGov tree-related service requests by comparing the requested service locations to locations of trees in poor condition.

While the map indicates that requests (blue dots) are coming from all over the city, most of the requests are not coming from the areas in highest need of pruning and other care (shown in red) according to the city's tree inventory. This suggests that Largo's reactive, request-based system does not effectively address the trees with the highest need for care and is, therefore, an ineffective method for managing the urban forest. A proactive care plan is critical for real progress and effective maintenance.



Reactive tree care is not an ideal approach. The trees in most need of maintenance for public safety reasons may not be attended to first in this approach, as shown in the case study of Largo, Florida.

The first priority to preserve and expand tree canopy in Columbia is to ensure the that all public trees are properly and proactively cared for. Proactive tree management programs have been shown to reduce long-term care costs, increase public safety, provide more predictable workloads and budgets, reduce utility outages from storms, and improve the health and appearance of the urban environment.

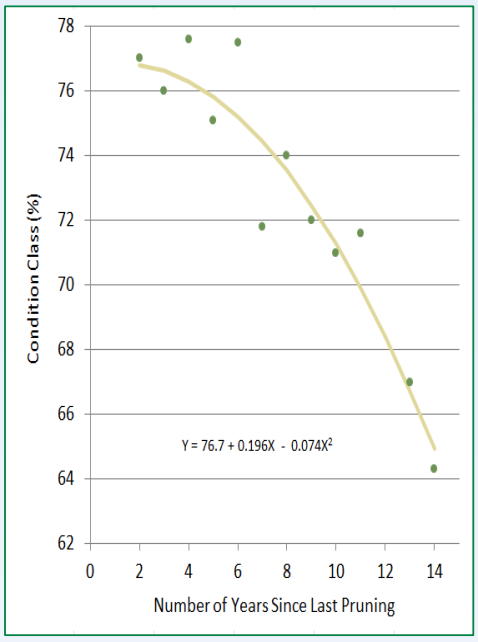
In a proactive maintenance program, tree work is typically performed as part of a cyclical care program where individual tree health, structure, and risk are assessed and addressed on a regular basis. The inspection and maintenance are performed in defined management units on an annual rotation of between 5 and 10 years.

To initiate a proactive tree management program in Columbia, it is recommended that the newly defined management zones be utilized. The city decided that the boundaries of the existing six wards will be used to begin a zone-based approach to preventive maintenance and planting. Using the inventory data and ward geographies, the budget and a multi-year work plan for a proactive, cyclical maintenance and planting program has been developed and is presented in this plan.

In the future, when the street tree inventory is complete and when park and other public trees are inventoried, or after full stocking is achieved, the management unit boundaries can be realigned or adjusted so that they all contain an equal distribution of publicly maintained trees. Using tree quantities as the basis for creating management zones is preferred because it evens out annual budget requirements, is less politically based, and can better achieve the long-term goals of urban forest sustainability and efficient use of resources.

Why Prune Trees on a Cycle?

Miller and Sylvester (1981) examined the frequency of pruning for 40,000 street and boulevard trees in Milwaukee, Wisconsin. They documented a decline in tree health as the length of the pruning cycle increased. When pruning was not completed for more than 10 years, the average tree condition was rated 10% lower than when trees had been pruned within the last several years. Ideally, municipalities should strive towards a five-year pruning cycle, though in the real world, longer cycles are often necessary due to budget constraints.



Relationship between average tree condition class and number of years since last pruning (adapted from Miller and Sylvester 1981).

Beginning the transition from a reactive to a cyclical maintenance program by using political wards as management zones, the city will see that some units may require more time, resources, and funding to accomplish the initial tree pruning and removal needed. But after the first cycle, the city should see the budget needs normalize and equalize as the high priority work is accomplished and more trees are in better and safer conditions.

Recommendations to improve management related to tree maintenance is addressed in *Recommendation #1: Perform High Priority Care* and *Recommendation #2: Institute a Systematic Cyclical Care Program.*

Tree Planting

Trees do not last forever and like other city infrastructure assets, replacement and expansion programs should be in place. The urban forest is sustainable only if more trees are being planted than are lost to old age, insects and disease, and land development.

Currently, the city's urban forestry program does not have a structured street tree planting program. The Water & Light Department does offer two programs (Trade-A-Tree and Tree Power) that provide new trees for Columbia's urban forest. However, these programs are only for Water & Light customers and property owners and offer only one tree per address. Furthermore, there is a high level of rental and non-homeowner occupied housing within the city that limits the number of customers interested in participating in these programs.

The inventory analysis showed that the size/age distribution of the street trees in Columbia is nearly ideal. While there are currently a large number of young and small-diameter trees, there is the need and opportunity to plant more trees in Columbia's urban forest to sustain the canopy and ensure all neighborhoods and wards are equally benefiting from trees.

The UTC analysis showed that there are almost 68,000 potential planting locations along public rights-of-way in the city. Table 10 presents the potential street tree planting sites citywide, in the target neighborhoods, and in Columbia's wards as derived from the UTC analysis.

Table 10. Potential Street Tree Planting Sites in Columbia as Determined by UTC Analysis

Citywide	Estimated Planting Acres	Estimated Number of Trees
Columbia	1,098.37	67,769
Neighborhoods	**Estimated Planting Acres**	**Estimated Number of Trees**
Central	3.56	220
East	16.43	1,014
North	12.07	745
Wards	**Estimated Planting Acres**	**Estimated Number of Trees**
First	55.82	3,444
Second	197.61	12,193
Third	382.93	23,627
Fourth	63.60	3,924
Fifth	127.01	7,836
Sixth	276.60	17,066

If there are currently 5,000 to 6,000 street trees and the potential for 68,000 more, then new tree planting represents almost 90% of the goal to have a fully stocked public forest. The selection of new trees and their care will become important issues for the city and should be tasks that are included in the proactive management program.

Planting trees is necessary to increase canopy cover and replace trees lost to natural mortality (expected to be 1%–3% per year) and other threats (for example, invasive pests or impacts from weather events such as storms, wind, ice, snow, flooding, and drought). Planning for the replacement of existing trees and identifying the best places to create new canopy is critical.

Recommendations for improving Columbia's tree planting efforts into a structured, ongoing, and priority-based program are detailed in *Recommendation #6: Implement the Prioritized and Strategic Tree Planting Plan*, and in *Recommendation 7: Institute a Young Tree Care Program*.

Leaf Debris Management Can Be Optimized

Leaf debris management is one of the costs associated with the urban forest. With a current UTC cover of 35.6%, and a desire to increase that percentage in the future, the proper and efficient collection of leaf debris, from both private and public properties, should be well planned.

Analysis of the UTC data and street right-of-way widths (with a buffer of 20 feet of private property tree canopy adjacent to streets) was performed to classify areas of the city where the potential amount of leaves for pick-up could have the qualitative designations of high, medium, and low. The results of this analysis are presented in Table 11 and Figure 24; see Appendix F for the leaf litter analysis methodology.

Table 11. Statistical Summary of Leaf Litter Concentrations

Tree Canopy Zones	Linear Street Miles	Canopy Area (Acres)
High	452.62	398.16
Medium	157.60	118.17
Low	46.98	21.97

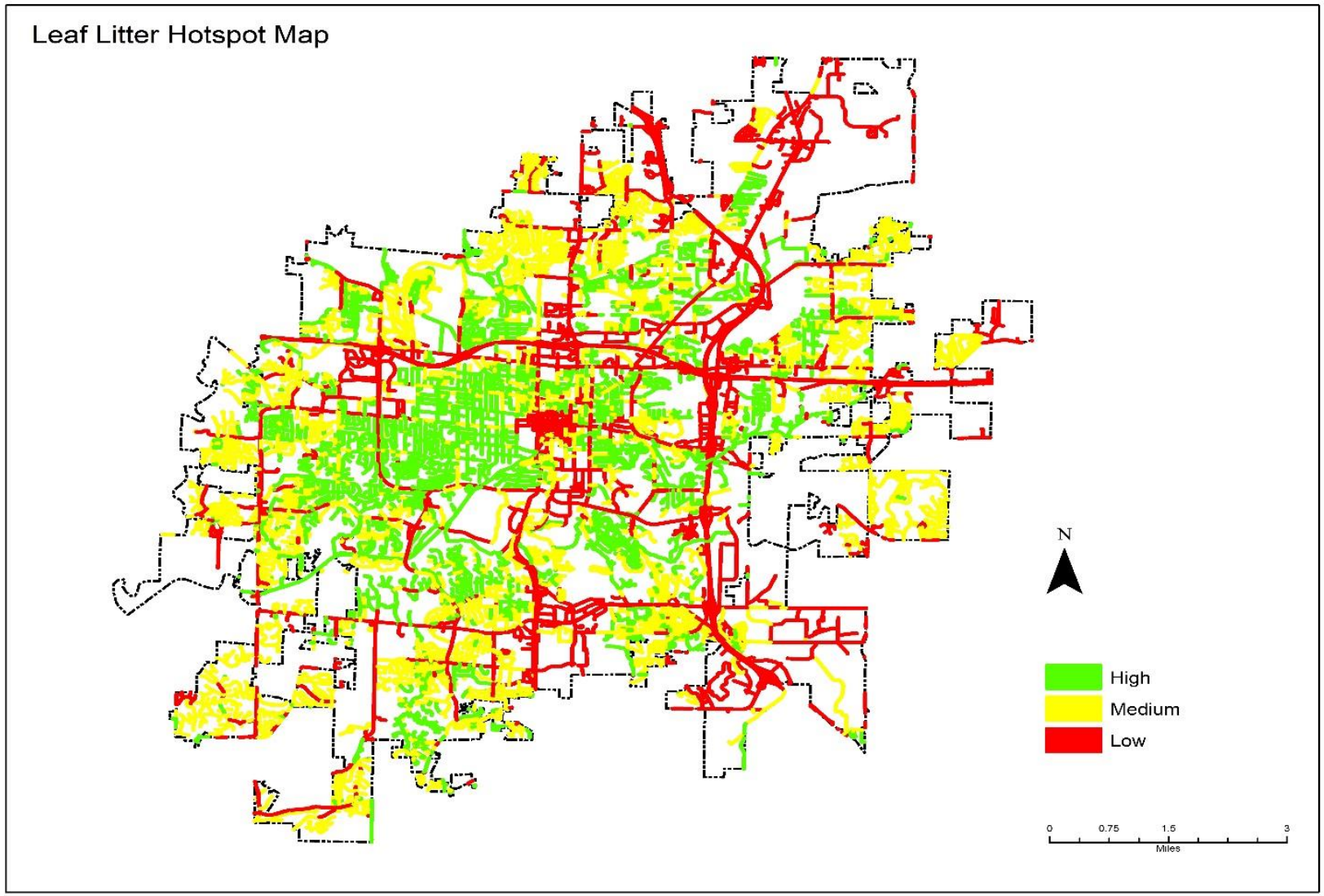


Figure 24. Qualitative leaf litter concentrations citywide.

Cities conduct curbside leaf collection and perform regular roadway street sweeping to enhance neighborhood and business district appearance, improve air quality, provide greater pedestrian and vehicular safety on public sidewalks and streets, and improve water quality. The results of the city's yard waste collection and subsequent street sweeping programs are a reflection on Columbia's community character and commitment to the environment.

Beyond the public's perception of aesthetics, an important reason to provide efficient leaf collection services is to support the city's stormwater management program and goals. Stormwater inlets and stream channels blocked by leaf debris can cause flooding. And, while the sources of nutrients to urban stormwater are many, the primary contributor is often organic debris, especially in areas with dense overhead tree canopy. An efficient and targeted leaf collection program is an effective way to remove organic detritus before it becomes entrained in stormwater runoff.

Another reason for improved leaf collection is to "fuel" the city's bioreactor landfill. Leaves and yard waste are critical ingredients for the bioreactor to produce the methane that is, and will be, used to generate electricity for the city from this renewable energy source.

Clearly, in Columbia, leaf and yard debris collection is done for more reasons than aesthetics. Given the variety of environmental and energy sustainability goals, the UTC analysis indicated that the city should prioritize and plan for leaf collection and street sweeping in the central and west central areas of the city where there is high canopy to prevent leaf litter and sediment accumulation, and, consequently, nutrient loading in stormwater systems.

The "Leaf Litter Hotspot" information was prepared as a GIS layer so that it can be used in conjunction with the city's waste/recycling collection routes and pick-up schedules to more precisely determine if certain areas should receive more frequent services. It can also be used to determine where areas could receive less frequent leaf litter pick-up and subsequently create a more tailor-made and targeted municipal leaf collection program and improve operational efficiency.

And, Columbia should continue to encourage property owners to recycle or compost leaves on site through its public education efforts and programs. An example of an educational effort the city may want to adopt or adapt is the successful "Love 'Em and Leave 'Em" public outreach campaign developed by Westchester County, New York, http://www.leleny.org/.

These results and subsequent recommended changes to the existing program are discussed in *Recommendation #5: Improve the Efficiency of Leaf and Woody Debris Collection.*

Risk Reduction

Trees provide many benefits whose values exceed the costs to plant and maintain them, but as living organisms located in areas of high human use, utilities, and valuable built structures, trees can present risks that, if unmanaged, can have catastrophic results.

With ownership comes responsibility, and one of Columbia's top priorities should be to minimize risk in the urban forest. Currently, Columbia responds to citizen requests, removes hazard trees and tree parts after storms, and performs limited visual inspections of trees as needed.

At its core, the focus of Columbia's risk management program should be to identify those features of the tree population that pose the highest potential risk to the public and property, and then concentrate available resources to reasonably mitigate risk.

The inventory data show that Columbia currently has 110 high priority removals and 125 high priority prunes. Scheduling this work should be accomplished in 12 to 18 months.

A proactive urban forest management program greatly reduces storm hazards through proper planting, preventive maintenance, and systematic risk reduction. A defensible risk management program establishes and defines the level of care that is appropriate given a community's available resources for a specified time horizon. When properly developed, documented, and executed, a tree risk management program will elevate the effectiveness and responsiveness of the city's community forestry program.

Important next steps are described in *Recommendation #3: Develop a Risk Management Program.*

Two Types of Risk from Trees

Trees pose two primary types of risk: risks specifically during and after severe weather events, and risks from poor condition and/or as a result of insect or disease infestation.

Severe Weather Events and Managing Tree Risk. When catastrophic disasters such as tornadoes, ice storms, hurricanes, and severe straight-line winds strike an urban area, thousands of cubic yards of all kinds of debris are produced. Trees and vegetation can account for approximately 30% of this debris volume. Beyond the task of collecting and disposing of tree debris, the city has additional risk management considerations, including increased threat to life from hanging limbs and uprooted trees, hindrance to life-saving efforts by blocked streets and driveways, power outages and power restoration efforts, and personal and public property damage. The impact of these additional tree-related considerations is not always quantifiable but can overwhelm public services and slow down the short- and long-term recovery process.

Non-Storm Related Tree Risk. Trees present risks when large dead wood and structural defects are present, root damage has occurred, and when insect and disease infestations weaken and damage trees. Additional risk management responsibilities and issues that are non-storm emergencies include clearing leaves and woody debris from gutters and storm drains, sidewalk, street, and building clearance, line-of-sight conflicts for street and safety signage, blockage of street lamps and traffic lights, and conflicts with overhead and underground utilities.

Public Tree and Tree Preservation Ordinances

In concert with non-regulatory efforts such as public education, incentives, and special programs, Columbia's tree ordinances and regulations are necessary to protect public property, provide a high quality of life for its citizens, and to assure that all citizens are equally benefited by trees and have access to urban tree canopy.

The recently updated Chapter 29 Zoning/Unified Development Code 29-4.4; Chapter12A Land Preservation; Article III. Tree Preservation and Landscaping Requirements; and Chapter 24 Streets, Sidewalks and Public Places Article V Landscape Planting in the Public Right-of-Way and Article VII. Trees were reviewed, and overall the city's ordinances defining the authority, and regulating the planting, maintenance, and treatment of public trees in the city, are good.

The ordinance sections are simply stated; they are not complicated or weighed down by legalese or procedural process descriptions. The city's current regulations collectively support a sustainable urban forest by requiring such actions as climax forest and significant tree preservation and protection during construction, reforestation, planting landscape trees on private property when there is insufficient right-of-way, and involving a Certified Arborist in the planning stages of land development project.

Specific recommendations to further improve Columbia's ordinances in the future are found in *Recommendation #8: Update Tree Related Ordinances.*

Organizational Structure and Resources

Uniquely, and by city code, responsibility for public trees in Columbia is shared by three separate agencies: Public Works, Water and Light, and Parks and Recreation. And, the city arborist position is in yet a fourth agency—Planning and Zoning. Generally, this organizational structure is not the norm nationwide nor regionally, as supported by the benchmarking information. Even when there is a municipal utility, overall responsibility for the urban forest is typically given to one agency. In most cases the responsibility falls to the public works department, and the position of city arborist is in that department.

In the United States, it is not uncommon that execution of tree management occurs within separate departments, i.e., parks departments plant and maintain park and street trees, public works departments do the same for street trees, etc. But more commonly, the city arborist position is designated as having the primary responsibility for managing all public trees. This leadership designation ensures that the staff member with the most arboriculture and urban ecology expertise and experience is guiding the overall management of a city's urban forest.

In Columbia, Parks and Recreation has a forestry crew but only for maintaining parks, trails, and downtown trees. Public Works has equipment operators that do minor, non-skilled forestry work along street rights-of-way; Water and Light has two foresters to manage line clearance contractors; and even Sewer/Storm Water has staff inspecting and recommending trees to be planted as part of green infrastructure projects. With the city arborist in Planning and Zoning only serving in an advisory capacity, this organizational structure appears to not only be reactive, divided, and inefficient, but also may be confusing to citizens and businesses when they are requesting services or information about trees.

Although several city departments in Columbia have been assigned responsibility for some aspect of urban forest management, planning, and/or control, this fragmented structure can contribute to inefficiencies, duplication of efforts, and inconsistent management of public trees. This happens because the individual departments naturally concentrate on only "their" part of the urban forest. Acting separately, they lack a comprehensive perspective. Fragmentation, or separation defined by organizational boundaries and agency-specific missions, may actual prevent Columbia's departments from interacting in meaningful and productive ways to protect and enhance the urban forest for the benefit of the current and future citizens.

If the current decentralized organizational structure is to continue in the foreseeable future, it would be advisable to at least have a stated administrative policy or operational philosophy that fosters greater interdepartmental support, understanding, and coordination for the benefit of the city-wide urban forest and the urban forest program. The existence of such a directive and work philosophy originating from the City Manager to department heads would help support a change away from the current problem-specific, crisis management, and reactive approach to a more proactive, holistic management response. The lack of a proactive approach to urban forest management can hinder attempts to coordinate the action of city agencies regarding the proper management of public trees and confuse citizens, businesses, utilities, and other outside entities when interacting with the city about public trees.

The effectiveness of an urban forestry program is also, in part, a function of its leadership. Without strong, supportive leadership, or if the leadership is not empowered in the organization, it will be a struggle to meet urban forestry goals. Whether in direct or indirect control, whether its centralized or decentralized, the city's administrative leadership of its urban forestry program needs to be recognized, focused, dedicated, and supported.

If the City Manager empowers the City Arborist to be the key decision-maker in setting urban forest goals and for advising on projects that affect the urban forest in any way, then no matter where the urban forestry program and responsibilities are located organizationally, the City Arborist can coordinate with other city agencies as they undertake projects in or that affect the urban forest.

General suggestions to address the management structure of Columbia's urban forest management program are found in *Recommendation #13: Evaluate the Urban Forest Management Structure*.

BENCHMARKING COLUMBIA'S URBAN FOREST MANAGEMENT AND OPERATIONS

To assist in strategic planning to improve urban forest management, it is valuable to compare Columbia's practices and performance with those of other cities. This information is provided to give perspective on how Columbia's program is succeeding or where improvements can be made. It also can be used for discussion purposes with citizens, elected officials, and other city staff to "make the case" for urban forestry program improvements.

The source of this benchmarking data is from information provided by Columbia, a recent national survey about municipal urban forestry operations, and an online survey directed to select cities. The national, regional, and other municipal benchmark data provided should not necessarily be interpreted as a goal or BMP for Columbia; the data are presented for comparison purposes only and do not mean peer groups are following industry standards or other BMPs.

Table 12 provides data (when it was available) comparing Columbia's urban forest and its urban forest management program metrics to national, regional, peer group, and select cities in the categories of urban forest quantity, funding, program management, maintenance and planting, and tree benefit values.

The benchmark information reveals both strengths and opportunities for improvement for Columbia's urban forest and its management program.

Indicators of positive trends are:

- Columbia's urban tree canopy cover is greater than the national average and the majority of its peer group.
- The return on investment is positive—for every dollar of public funds spent on trees, the city and citizens receive over $4 of annual benefits.

However, the benchmark information reveals that Columbia could improve its management approach by:

- Increasing its commitment to fund a progressive urban forest management program. In relation to the annual municipal budget, the amount dedicated to tree management is the lowest of all national and regional averages and peer city percentages.
- Increasing maintenance and using a proactive approach, the annual maintenance production rates are the lowest.
- Increasing and having a systematic planting program, the annual planting rates are the lowest.

Table 12. Benchmark Metrics for Urban Forest Management

Urban Forest & Management Program Benchmarks*	Columbia	National Averages*	Cities with Pop. 100,000-249,999 Averages*	Midwest Region Averages*	Columbia, SC	Des Moines, IA	Chattanooga, TN	Hamilton, OH	Knoxville, TN	Fort Wayne, IN	Lincoln, NE	Rochester, MN
General Statistics												
Number of public trees (estimated)	6,000	55,332	73,723	41,748	45,000	35,000	200,000	15,000	15,000	75,000	125,000	75,000
Public trees per capita	0.05	0.55	0.51	0.50	0.06	0.18	1.15	0.24	0.08	0.29	0.46	0.67
Trees per street mile	11	76	37	114	Not avail.	38.3	Not avail.	Not avail.	15.0	Not avail.	Not avail.	230.7
Existing urban tree canopy	35.6%	32%	29%	Not avail.	Unknown	29%	51%	18%	40%	29%	Unknown	26%
Urban tree canopy goal	Not determined	44%	45%	Not avail.	Unknown	32%	50%	30%	None	40%	Unknown	40%
Funding												
Average municipal tree care and program budget	$420,000**	$801,595	$1,000,000	$760,065	$500,000 - $1,000,000	$500,000 - $1,000,000	$500,000 - $1,000,000	$500,000 - $1,000,000	Not avail.	$500,000 - $1,000,000	Not avail.	$500,000 - $1,000,000
Average annual budget per public tree	$70.00	$42.59	$44.85	$32.61	$16.66	$21.43	$3.75	$50.00	Not avail.	$10.00	Not avail.	$10.00
Average annual budget per capita	$3.53	$8.76	$9.05	Not avail.	$0.92	$3.80	$4.32	$12.00	Not avail.	$2.90	Not avail.	$6.73
Tree care and management program budget percent of total municipal operating budget	0.09%	0.52%	0.48%	Not avail.	2.41%	1.22%	0.32%	3.27%	Not avail.	0.48%	Not avail.	0.48%
Program Management												
Complete public tree inventory	Yes	67% (yes)	59% (yes)	not avail.	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Staffing complement (full-time equivalent)	5***	10.0	11.8	10.0	10	15	11	1	8	6	12	13
Agency/agencies responsible for urban forestry	Public Works, Water & Light Parks and Recreation, Community Development	Public Works	Parks and Recreation	Not avail.	Public Works, Parks & Recreation	Public Works	Public Works, Parks & Recreation	Municipal Utility	Public Works	Parks and Recreation	Parks and Recreation	Parks and Recreation
Management plan	Developing	50% (yes)	66% (yes)	Not avail.	No	No	Yes	Yes	Yes	Yes	Developing	Yes
Tree preservation ordinance	Yes	54% (yes)	53% (yes)	Not avail.	Yes	No	Yes	Yes	Developing	Yes	Developing	No
Greatest challenge	Budget/Funding	Not avail.	Not avail.	Not avail.	Trained personnel	Budget/Funding	Budget/Funding	Budget/Funding	Budget/Funding	Budget/Funding	Budget/Funding	Political support
Maintenance and Planting												
Perform cyclical/preventive maintenance	No	55% (yes)	48.2% (yes)	Not avail.	No	No	No	No	No	Yes	Yes	Yes
Number of trees pruned annually	<25	2,108	3,897	1,688	Not avail.	Not avail.	Not avail.	Not avail.	Not avail.	Not avail.	Not avail.	Not avail.
Number of trees removed annually	<25	467	593	660	>100	>100	>100	>100	>100	>100	>100	>100
Number of trees planted annually	<25	629	634	552	>500	>500	110–250	250–500	>500	>500	>500	>500
Number of trees treated for insects and disease annually	<25	265	339	317	Not avail.	Not avail.	Not avail.	Not avail.	Not avail.	Not avail.	Not avail.	Not avail.
Desired cyclical maintenance cycle	8–10 years	4.8 years	5.2 years	Not avail.	5 years	5 years	8–10 years	8–10 years	6–7 years	6–7 years	5 years	8–10 years
Tree Benefit Values												
Value of public trees	$297,983	$68,665,110	$98,460,117	$30,594,006	Not avail.	Not avail.	Not avail.	Not avail.	Not avail.	Not avail.	Not avail.	Not avail.
Return on investment	1:4.26	1:85.66	1:98.46	1:40.25	Not avail.	Not avail.	Not avail.	Not avail.	Not avail.	Not avail.	Not avail.	Not avail.

* Mean statistics from Hauer R. J. and Peterson W. D. 2016. Municipal Tree Care and Management in the United States: A 2014 Urban & Community Forestry Census of Tree Activities. Special Publication 16-1, College of Natural Resources, University of Wisconsin – Stevens Point. 71 pp.
** Street tree budget = $70,000 and park trees = $350,000 as reported by Columbia.
*** Street tree staff = 1; park tree staff = 4 as reported by Columbia

Table 13 compares Columbia with eight cities and presents more details about urban forest management budgets and operations.

This more detailed, operationally-oriented benchmark information reveals that Columbia:

- Compares favorably in terms of urban forest services offered;
- Is similar in terms of its urban forest program staffing and qualifications;
- Performs its operations in a similar manner as benchmark cities;
- However, the dedicated budget is well below the peer group; and
- The annual maintenance and planting production rates are below the peer group.

Table 13. Urban Forest Budgeting and Operations Benchmark Metrics

Urban Forest Management Operations Benchmarks*	Columbia	Columbia, SC	Des Moines, IA	Chattanooga, TN	Hamilton, OH	Knoxville, TN	Fort Wayne, IN	Rochester, MN
Total budget	$25–50K	$500K–1M	$500K–1M	$500K–1M	$500K–1M	(unavail.)	$500K–$1M	$500K–$1M
Annual planting	$1–10K	$50–100K	$100–500K	$25–50K	$100–500K	$25–50K	$100–500K	$50–100K
Annual pruning	<$1K	$100–500K	$100–500K	$50–100K	$100–500K	$50–100K	$100–500K	$10–25K
Annual tree and stump removal	$1–10K	$100–500K	(unavail.)	$50–100K	(unavail.)	$50–100K	$100–500K	$10–25K
Annual pest/disease control	<$1K	(do not perform)	(do not perform)	$1–10K	<$1,000	$1–10K	(do not perform)	$100–500K
Annual infrastructure repair cost	$1–10K	(unavail.)	$25–50K	(do not perform)	$25–50K	(do not perform)	(do not perform)	(unavail.)
Annual leaf litter collection	$10–25K	(unavail.)	$100–500K	(do not perform)	$50–100K	(do not perform)	(do not perform)	<$1K
Annual storm clean-up	$25–50K	(unavail.)	$100–500K	$25–50K	$25–50K	$50–100K	$100–500K	(unavail.)
Annual average litigation settlement	$25–50K	(unavail.)	(unavail.)	(do not perform)	<$1K	(do not perform)	(do not perform)	<$1K
Annual program administration	$50–100K	$100–500K	$100–500K	$100–500K	$100–500K	$50–100K	$100–500K	$500,000-$1,000,000
Annual inspection/service calls	$10–25K	$100–500K	$100–500K	$50–100K	$25–50K	$50–100K	(do not perform)	$25–50K
Source	General fund	General fund	General fund; stormwater fund; solid waste fund	General fund	General fund; utility fund	General fund	General fund; EAB special funding	(unavail.)
Years of municipal urban forestry program with staff	>10 years	>10 years	>10 years	>10 years	1–5 years	1–5 years	>10 years	>10 years
Full-time forestry staff	5	10	15	11	1	8	6	13
Part-time forestry staff	(N/A)	(unavail.)	3	0	3	1	6	16

Urban Forest Management Operations Benchmarks*	Columbia	Columbia, SC	Des Moines, IA	Chattanooga, TN	Hamilton, OH	Knoxville, TN	Fort Wayne, IN	Lincoln, NE	Rochester, MN
Planting Program									
Annual trees planted	<25	>500	>500	110-250	250-500	>500	>500	>500	>500
Tree purchase method	Landscape installers contract	Direct purchase from local nurseries	Landscape installers contract	Direct purchase from local nurseries/landscape installers contract	Direct purchase from local nurseries	Direct purchase from local nurseries	Direct purchase from local nurseries	Landscape installers contract	Direct purchase from local nurseries
Tree planting labor types	Contractors	Employees	Contractors; volunteers	Employees; contractors; volunteers	Contractors; volunteers	Contractors	Contractors	Employees; contractors; volunteers	Employees; volunteers
Planting site selection method	Forestry staff inspections; replacements	Citizen requests; replacements	Citizen requests	Forestry staff inspections	Prioritized from tree inventory; planting plan; urban forestry staff inspections	Prioritized from tree inventory; citizen requests; UTC-based planting plan; urban forestry staff inspections	Prioritized from tree inventory; citizen requests; UTC-based planting plan; urban forestry staff inspections	Prioritized from tree inventory; planting plan; Park Supervisor's request	Prioritized from tree inventory; urban forestry staff inspections
Tree Maintenance									
New/young tree pruning program	No	No	No	Yes	Yes	Yes	(unavail.)	Yes	Yes
Routine mature tree pruning program	No	No	No	No	No	No	Yes	Yes	Yes
Annual cycle for mature tree pruning	NA	(unavail.)	(unavail.)	>15 years	>15 years	(unavail.)	8–10 years	6–7 years	>15 years
Annual cycle goal for mature tree pruning	8 years	5 years	5 years	8–10 years	8–10 years	6–7 years	6–7 years	5 years	8–10 years
Benefits realized from cyclical/preventive maintenance program	(not applicable)	(unavail.)	(unavail.)	Safer streets and public properties; more vital/healthy urban forest	Safer streets and public properties; more vital/healthy urban forest; overall maintenance budget savings; decreased citizen complaints; less storm damage	(unavail.)	Safer streets and public properties; more vital/healthy urban forest; overall maintenance budget savings; decreased citizen complaints; less storm damage; more efficient use of city staff	Decreased citizen complaints; less storm damage	(unavail.)
Number of annual removals	<25	>100	>100	>100	>100	>100	>100	>100	>100
Fertilization treatment	Never	Never	Never	As needed	As needed	Never	Never	Never	Never
Insect and disease control	Never	(unavail.)	Never	As needed	As needed	Annually	As needed	As needed	As needed
Supplemental watering	Weekly	(unavail.)	Never	As needed	Weekly	Weekly	Never	Weekly	Weekly
Mulching	As needed	(unavail.)	Never	Bi-annually	Bi-annually	Annually	As needed	As needed	As needed
Maintenance crew type	Municipal	Municipal; contractors	Municipal	Municipal; contractors	Municipal; contractors	Municipal; contractors; volunteers	Municipal	Municipal	Municipal; contractors
Leaf Collection									
Roadside leaf collection service	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Leaf collection frequency	Weekly	Weekly	Bi-weekly	Monthly	(unavail.)	Bi-weekly (seasonal)	3 times in fall	Weekly	(unavail.)
Leaf collection crew type	Municipal	Municipal	Municipal	Municipal	(unavail.)	Municipal	Municipal	Municipal	(unavail.)

URBAN FOREST MANAGEMENT BUDGET ANALYSIS

Adequate funding will be needed for the city to implement an effective urban forest management program that will provide short- and long-term public benefits, ensure that priority maintenance is performed expediently, establish proactive maintenance cycles, and plant trees to preserve and enhance the public canopy cover.

For just street trees alone, the estimated total cost for priority maintenance, routine maintenance, stump grinding, young tree maintenance, and replacement planting is $920,000 over a five-year period. This is an average of approximately $185,000 per year. Considering the city currently allocates $70,000 annually for the program, a significant budget shortfall is apparent.

High priority removal and pruning is costly; since most of this work is scheduled during the first year of the program, the budget for the first year of implementation is higher. After the high priority work has been completed, the urban forestry program should begin the preventive, cyclical maintenance (which is generally less costly) in the desired management zones. Budgets for later years are thus projected to be lower, but this cannot be assured depending on how the city decides to implement maintenance work in the wards.

Completing the inventory, and then keeping the dataset up-to-date using TreeKeeper® 8 or a similar inventory data management software, is crucial for making informed management decisions and projecting more accurate maintenance budgets.

Funding to Implement a Proactive Maintenance and Planting Program

The following suggested budget has been developed to aid in the implementation of this urban forest management plan. It is important to note that the funding needed is an estimate since the inventory data are incomplete, urban forest management is under a multi-departmental organizational structure, and full budget, staffing, and information about other resources were not available.

While a proactive program can raise budgetary needs in the short term, over the long term this level of care will reduce municipal tree care management costs and potentially minimize the costs related to other city infrastructure, such as stormwater management, energy use, etc.

Table 14 displays the budget for tree maintenance and planting within the six wards which preliminarily will be used as Columbia's management zones; a simplified summary of urban forest management activities in each ward follows Table 14.

Table 14. Urban Forest Maintenance and Planting Tasks and Total Budget by Ward

Estimated Costs for Each Activity			Ward 1		Ward 2		Ward 3		Ward 4		Ward 5		Ward 6		City-Wide Cost
Activity	Diameter	Cost/Tree	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	
Severe and High Risk Removals	1-3"	$100	0	$0	0	$0	0	$0	1	$100	0	$0	0	$0	$100
	4-6"	$100	0	$0	0	$0	0	$0	17	$1,700	1	$100	1	$100	$1,900
	7-12"	$276	1	$276	0	$0	0	$0	32	$8,832	2	$552	3	$828	$10,488
	13-18"	$628	0	$0	0	$0	0	$0	22	$13,816	2	$1,256	2	$1,256	$16,328
	19-24"	$1,210	1	$1,210	1	$1,210	1	$1,210	9	$10,890	2	$2,420	0	$0	$16,940
	25-30"	$1,650	0	$0	0	$0	0	$0	6	$9,900	0	$0	0	$0	$9,900
	31-36"	$2,090	0	$0	0	$0	0	$0	3	$6,270	1	$2,090	0	$0	$8,360
Activity Total(s)			**2**	**$1,486**	**1**	**$1,210**	**1**	**$1,210**	**90**	**$51,508**	**8**	**$6,418**	**6**	**$2,184**	**$64,016**
Moderate and Low Risk Removals	1-3"	$100	9	$900	11	$1,100	15	$1,500	22	$2,200	20	$2,000	27	$2,700	$10,400
	4-6"	$100	31	$3,100	1	$100	7	$700	18	$1,800	1	$100	5	$500	$6,300
	7-12"	$151	12	$1,812	1	$151	2	$302	12	$1,812	0	$0	4	$604	$4,681
	13-18"	$345	3	$1,035	0	$0	1	$345	3	$1,035	0	$0	3	$1,035	$3,450
	19-24"	$665	1	$665	0	$0	0	$0	3	$1,995	0	$0	0	$0	$2,660
	25-30"	$907	0	$0	0	$0	0	$0	0	$0	0	$0	1	$907	$907
	37-42"	$1,533	0	$0	0	$0	0	$0	1	$1,533	0	$0	0	$0	$1,533
	43"+	$2,238	0	$0	0	$0	0	$0	1	$2,238	0	$0	0	$0	$2,238
Activity Total(s)			**56**	**$7,512**	**13**	**$1,351**	**25**	**$2,847**	**60**	**$12,613**	**21**	**$2,100**	**40**	**$5,746**	**$32,169**
Stump Removals	1-3"	$8	1	$8	2	$16	4	$32	21	$166	1	$8	3	$24	$252
	4-6"	$16	0	$0	1	$16	0	$0	1	$16	0	$0	0	$0	$32
	7-12"	$32	7	$221	0	$0	0	$0	44	$1,389	1	$32	0	$0	$1,641
	13-18"	$55	3	$166	0	$0	0	$0	23	$1,271	0	$0	3	$166	$1,603
	19-24"	$109	0	$0	0	$0	0	$0	6	$652	0	$0	0	$0	$652
	25-30"	$136	0	$0	0	$0	0	$0	4	$544	0	$0	3	$408	$951
	31-36"	$163	0	$0	0	$0	1	$163	7	$1,142	0	$0	1	$163	$1,468
	37-42"	$190	0	$0	0	$0	0	$0	3	$571	0	$0	1	$190	$761
	43"+	$227	0	$0	0	$0	0	$0	3	$680	0	$0	0	$0	$680
Activity Total(s)			**11**	**$395**	**3**	**$32**	**5**	**$195**	**112**	**$6,429**	**2**	**$39**	**11**	**$950**	**$8,040**
Routine Pruning (5-year cycle)	4-6"	$100	0	$0	0	$0	0	$0	17	$1,700	1	$100	0	$0	$1,800
	7-12"	$225	4	$900	0	$0	2	$450	11	$2,475	1	$225	0	$0	$4,050
	13-18"	$360	3	$1,080	2	$720	5	$1,800	8	$2,880	2	$720	4	$1,440	$8,640
	19-24"	$510	0	$0	3	$1,530	2	$1,020	13	$6,630	7	$3,570	2	$1,020	$13,770
	25-30"	$675	1	$675	0	$0	4	$2,700	11	$7,425	5	$3,375	1	$675	$14,850
	31-36"	$915	1	$915	0	$0	0	$0	8	$7,320	2	$1,830	0	$0	$10,065
	37-42"	$1,140	0	$0	0	$0	1	$1,140	4	$4,560	0	$0	0	$0	$5,700
Activity Total(s)			**9**	**$3,570**	**5**	**$2,250**	**14**	**$7,110**	**72**	**$32,990**	**18**	**$9,820**	**7**	**$3,135**	**$58,875**
	1-3"	$100	137	$13,700	138	$13,800	44	$4,400	272	$27,200	222	$22,200	159	$15,900	$97,200
	4-6"	$100	296	$29,600	94	$9,400	20	$2,000	460	$46,000	44	$4,400	164	$16,400	$107,800
	7-12"	$150	176	$26,400	11	$1,650	41	$6,150	482	$72,300	107	$16,050	51	$7,650	$130,200
	13-18"	$240	45	$10,800	13	$3,120	43	$10,320	239	$57,360	21	$5,040	37	$8,880	$95,520
	19-24"	$340	9	$3,060	0	$0	8	$2,720	96	$32,640	24	$8,160	28	$9,520	$56,100
	25-30"	$550	13	$7,150	0	$0	11	$6,050	60	$33,000	8	$4,400	17	$9,350	$59,950
	31-36"	$610	3	$1,830	0	$0	3	$1,830	18	$10,980	3	$1,830	2	$1,220	$17,690
	37-42"	$760	2	$1,520	0	$0	0	$0	7	$5,320	1	$760	1	$760	$8,360
	43"+	$1,180	0	$0	0	$0	0	$0	4	$4,720	1	$1,180	0	$0	$5,900
Activity Total(s)			**681**	**$94,060**	**256**	**$27,970**	**170**	**$33,470**	**1,638**	**$289,520**	**431**	**$64,020**	**459**	**$69,680**	**$578,720**
Young Tree Training Pruning (3-year cycle)	1-3"	$20	8	$160	54	$1,080	24	$480	380	$7,600	28	$560	25	$500	$10,380
	4-12"	$30	3	$90	9	$270	6	$180	354	$10,620	33	$990	21	$630	$12,780
Activity Total(s)			**11**	**$250**	**63**	**$1,350**	**30**	**$660**	**734**	**$18,220**	**61**	**$1,550**	**46**	**$1,130**	**$23,160**
Replacement Tree Planting	Purchasing	$170	58	$9,860	14	$2,380	26	$4,420	150	$25,500	29	$4,930	46	$7,820	$54,910
	Planting	$110	58	$6,380	14	$1,540	26	$2,860	150	$16,500	29	$3,190	46	$5,060	$35,530
Activity Total(s)			**116**	**$16,240**	**28**	**$3,920**	**52**	**$7,280**	**300**	**$42,000**	**58**	**$8,120**	**92**	**$12,880**	**$90,440**
Replacement Young Tree Maintenance	Mulching	$100	58	$5,800	14	$1,400	26	$2,600	150	$15,000	29	$2,900	46	$4,600	$32,300
	Watering	$100	58	$5,800	14	$1,400	26	$2,600	150	$15,000	29	$2,900	46	$4,600	$32,300
Activity Total(s)			**116**	**$11,600**	**28**	**$2,800**	**52**	**$5,200**	**300**	**$30,000**	**58**	$5,800	**92**	$9,200	$64,600
Activity Grand Total			**886**		**369**		**297**		**3,006**		**599**		**661**		**855,420**
Five-Year Cost, Grand Total				**$135,113**		**$40,883**		**$57,972**		**$483,280**		**$97,867**		**$104,905**	**$920,020**

Ward 1 $135,113

- 2 Extreme or High Risk Removals
- 9 Extreme or High Risk Prunes
- 56 Moderate or Low Risk Removals
- 681 Moderate or Low Risk Prunes
- 11 Stump Removals
- YTT Cycle: 11 Trees
- 58 Replacement Trees Recommended for Planting and Follow-Up Care
- Newly Found Priority Tree Work (Removal or Pruning): Costs TBD

Ward 2 $40,883

- 1 Extreme or High Risk Removals
- 5 Extreme or High Risk Prunes
- 13 Moderate or Low Risk Removals
- 170 Moderate or Low Risk Prunes
- 3 Stump Removals
- YTD Cycle: 63 Trees
- 14 Replacement Trees Recommended for Planting and Follow-Up Care
- Newly Found Priority Tree Work (Removal or Pruning): Costs TBD

Ward 3 $57,972

- 1 Extreme or High Risk Removal
- 14 Extreme or High Risk Prunes
- 25 Moderate or Low Risk Removals
- 170 Moderate or Low Risk Removals
- 5 Stump Removals
- YTT Cycle: 30 Trees
- 26 Replacement Trees Recommended for Planting and Follow-Up Care
- Newly Found Priority Tree Work (Removal or Pruning): Costs TBD

Ward 4 $483,280

- 90 Extreme or High Risk Removals
- 72 Extreme or High Risk Prunes
- 60 Moderate or Low Risk Removals
- 1,638 Moderate or Low Risk Prunes
- 112 Stump Removals
- YTT Cycle: 734 Trees
- 150 Replacement Trees Recommended for Planting and Follow-Up Care
- Newly Found Priority Tree Work (Removal or Pruning): Costs TBD

Ward 5 $97,867

- 8 Extreme or High Risk Removals
- 18 Extreme or High Risk Prunes
- 21 Moderate or Low Risk Removals
- 431 Moderate or Low Risk Prunes
- 2 Stump Removals
- YTT Cycle: 61 Trees
- 29 Replacement Trees Recommended for Planting and Follow-Up Care
- Newly Found Priority Tree Work (Removal or Pruning): Costs TBD

Ward 6 **$104,905**

- **6** Extreme or High Risk Removals
- **7** Extreme or High Risk Prunes
- **40 Moderate or Low Risk Removals**
- **459 Moderate or Low Risk Prunes**
- **11 Stump Removals**
- **YTT Cycle: 46 Trees**
- **46 Replacement Trees Recommended for** Planting and Follow-up Care
- **Newly Found Priority Tree Work (Removal or Pruning): Costs TBD**

THOUGHTS ON FUNDING

True success in maintaining the city's urban forest depends on increasing support from the public sector, developers, businesses, and wider community. Columbia recognizes that effective implementation of urban forest management throughout the city depends on a coherent public policy supporting it—financially, administratively, and legally—and that a long-term funding commitment is required over the next two decades.

Currently, existing public funds for urban forest management are dispersed among various departments for various tasks. The lack of adequate financial resources for the urban forestry program has likely precluded it from making significant improvements to the program. More dedicated and consistent funding is needed for increased public tree planting, new tree maintenance, routine and preventive maintenance, insect and disease monitoring and control, customer service efforts, and other necessary tasks.

To achieve the goals of this Plan, program efficiencies should be implemented along with new and creative funding sources discovered. Among traditional financing avenues, Columbia should also consider creating partnerships and focusing on demonstrating value to secure additional funding and resources for the urban forest.

Achieving funding stability ultimately depends on on-going support by the public and local leaders. Much of this support hinges on communicating and disseminating information about benefits of Columbia's urban forest in terms of reduced stormwater pollution, electricity saved, carbon and water savings from lower energy use in buildings, lower demands on power generating plants, biodiversity benefits, and temperature reductions in the city as a whole – not to mention the city's aesthetic enhancement and wide-ranging social and economic advantages.

Potential Budget Enhancement Sources

It is likely that the urban forestry program will always rely heavily on general fund allocations for its operations budget. But other options exist that can provide a revenue stream more clearly dedicated to the management of the public urban forest. And, with the ecosystem benefit information at hand, the case can be made more easily that funding urban forest management is a wise and "profitable" public investment strategy for the City of Columbia.

The following are examples of funding mechanisms used in other municipalities, and different and more creative means for enhancing the overall budget for urban forest management. Most of these funding methods/sources will require more thorough analyses; for now, they are simply being offered for consideration.

Financing Instruments

- Increased allocations from the General Fund and departmental funds
- Capital improvement fund
- Taxes, special assessments, and special tax districts
- Federal and state grants, and large regional and local private foundation grants
- Percentage of stormwater management fees

Revenue Streams

- Alternative compliance fees
- Site plan review and site inspection fees
- Tree work permit fees for non-residential applicants
- Compensatory payments for tree damage
- Sale of municipal wood products
- Voluntary donations made on utility bills

Any or all of these funding methods should be explored by city staff to determine their legality, viability, and practicality, and how one or more of these methods would help increase budgetary resources for the urban forestry program. The city should also continue to collaborate with local partners to secure funding for tree maintenance and urban forest management activities from sources that are more inclined to provide funding to nonprofit entities as opposed to the municipality directly.

With sufficient financial resources to secure professional services, equipment, and management, Columbia can accomplish its urban forestry goals, better respond to changes and challenges in the urban forest, and best serve the citizens

Urban forest project and program costs can be more easily justified when they can be linked to specific benefits derived from tree planting and maintenance, and the provision of a robust cost-benefit analysis for the urban forest will help ensure that it remains competitive as a high value land use among hard infrastructure and transportation. In other words, stable support from the community is generated by a long-term track record of documenting and disseminating those benefits.

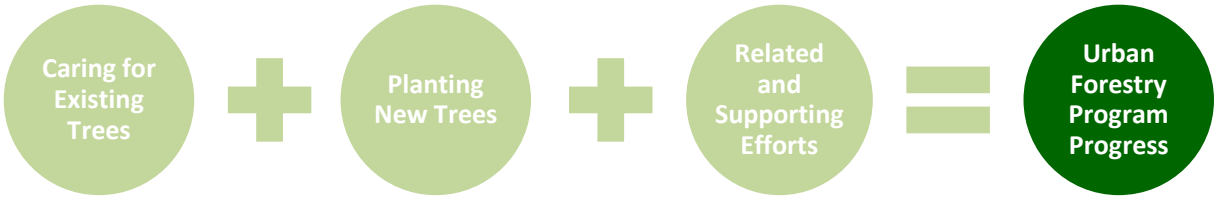
Some may ask "How much is enough for Columbia?" Urban forestry spending levels for other cities were presented in the benchmarking tables, but the real determinant of adequate funding is simply whether a proactive cyclical maintenance program and purposeful tree planting program can be implemented and sustained. Considerations for sustaining and increasing funding for Columbia's urban forestry program are found in *Recommendation 14: Analyze the Municipal Budget for Citywide Tree Management.*

NEXT STEPS

Columbia desires a healthy, diverse, and resilient urban forest that contributes to the health and well-being of the community and creates a livable city. The issues and challenges facing Columbia that directly affect the urban forest have been discussed in this plan, and the recommendations that follow are intended to be a set of practical next steps.

To achieve the desired forest of the future and leave a legacy for the generations to come requires a long-term vision and a commitment to work in "tree life-cycles", not electoral or administrative cycles. Creating a sustainable urban forest and a proactive urban forest management program requires coordination, collaboration, and expert input from multiple disciplines including planning, engineering, urban design, landscape architecture, economics, sustainability, and most importantly from the general community. The community's sense of place and capacity for change needs to be understood and included in decision-making to ensure a responsive approach is taken when managing Columbia's urban forest.

The following recommendations are made to improve long-term urban forest health in Columbia, and to provide strategies and suggestions for enhancing the city's urban forest management program. The recommendations are organized by the categories of tree maintenance/care, planting, and supporting efforts.



The recommendations have been made by analyzing and synthesizing Columbia's inventory and urban tree canopy data, the urban forest management program's current standard operating procedures, the Public Works Department's Strategic Plan, the Sustainability Plan Framework For The City of Columbia, the city's code of ordinances, the American Public Works Association's Guidance Statement on Quality Management of the Urban Forest, and current arboricultural industry standards and best management practices.

To maximize the ecosystem services, community health, and financial benefits that the urban forest provides, it is critical that Columbia's trees are healthy and safe. Recommendations have been made in an effort to achieve these objectives. The recommendations are organized by the categories of tree care, planting, and supporting efforts.

Care for Existing Canopy

1. Perform High Priority Tree Removal and Pruning
2. Institute a Systematic Cyclical Care Program
3. Develop a Risk Management Program
4. Implement a Plant Health Care and Mature Tree Care Program

Planting New Trees

5. Implement the Strategic, Prioritized Tree Planting Plan
6. Institute a Young Tree Care Program

Supporting Efforts

7. Update and Complete the Tree Inventory for All Public Trees
8. Update Tree Related Ordinances
9. Create & Implement an Outreach Plan
10. Engage the Community through Volunteerism
11. Create a Tree Board
12. Incorporate Urban Forestry into Other City Efforts
13. Consider Existing City Structure of Urban Forest Management
14. Increase the Municipal Budget for Citywide Tree Management
15. Maximize Use of Technology and Data Management Software

Caring for Existing Trees

1. Perform High Priority Tree Removal and Pruning

The updated tree inventory indicates that 110 trees are considered a high priority for removal and 125 trees are considered a high priority for pruning. Of the 225 trees requiring priority maintenance, 3 are located under utility lines. Even though large, short-term expenditures may be required, funding and expediently completing priority tree maintenance work is important to reduce risk and to promote public safety along the public streets.

Additionally, of these trees requiring priority care, three are located under utility lines. Consider that some of this expense could potentially be shared with Water & Light. Re-inspection is recommended on high priority trees where the data field for "Utility Conflicts" is incomplete. Water and Light should be presented with the inventory data for high priority trees under utility lines so they can consider assisting in high-priority maintenance work during their annual line clearance schedule/program.

Next Steps:

- Identify municipal and/or contractual resources needed to resolve the high-priority maintenance in the next one to two years.
- Re-inspect trees where the data field for "Utility Conflicts" is incomplete and record the appropriate information. Then, provide Water and Light with the inventory data for high priority trees under utility lines in GIS mapping and spreadsheet formats so they can consider assisting in the resolution of any high-priority maintenance needs during their annual line clearance schedule/program.

2. Institute a Systematic Cyclical Care Program

Reacting only to citizen service requests, or after storms, or when a tree dies is inefficient and can lead to increased liability and a decline in the condition of the urban forest. A more proactive approach to tree care is to inspect and maintain trees on a cyclical basis. In defined management units, each tree's health, risk level, and maintenance need are determined and acted upon on a regular basis. Tree inventory data are also updated at the same time.

Implementing Cyclical Care - Cincinnati Case Study

The City of Cincinnati's urban forest management program officially began in 1982. Prior to that, tree maintenance was performed only on a reactive basis. There were thousands of trees in need of maintenance, and the backlog for resolving service requests was over two years. While still responding to priority tree maintenance, resolving storm damage, and planting trees, the city began to perform inventory and preventive maintenance tasks each year on a limited basis in six management units as the budget would allow. It took approximately 15 years to complete one cycle of preventive maintenance in the six units, but now the city benefits from an established proactive maintenance cycle.

Cincinnati now has firmly established a 6-year cycle for its public tree inventory update and preventive maintenance program. The city's urban forestry staff report that the investment of time and funding for preventive tree maintenance has decreased tree-related risks and liability, decreased the incidences and severity of storm damage, increased response time for all tree maintenance requests, improved the health of public trees, and increased the benefits trees provide the city and citizens. For instance, in the year following preventive maintenance, there is an 85% reduction in emergency and routine service requests, and even after four years there is a 40% reduction in service requests.

If Columbia's public tree population is approximately 6,000 trees, then over 600 trees per year need to be inspected and maintained to have a proactive maintenance program per the minimum industry standard practice of a 10-year cycle. If the city wants to achieve an 8-year cycle, then 750 trees per year would need to be maintained, and if the goal is a 6-year cycle, then 1,000 trees would be maintained annually.

Admittedly, this amount is well over the current level of maintenance performed and more than Columbia's existing budget allocated for tree care. However, what should and can be done now is to set a goal for a 6-year preventive maintenance rotation, and start the cyclical care program, even partially, knowing that it will take time to achieve the goal but ultimately that it can be reached.

How to Initiate a Cyclical Maintenance Program at Current Funding Levels

Without a budget increase or reallocation of other city resources for public tree maintenance, the 6 defined management units can be preliminarily subdivided to create 12 or other number of smaller management units. Annually, one of these sub-units would be selected to receive the cyclical, preventive maintenance (PM) work. In this one sub-unit, every street tree would be thoroughly inspected and properly maintained (high risk removal and pruning, reactive emergency, and citizen response would still occur in the other 11 sub-units throughout the year). This approach would be followed each year until all 12 sub-units were complete.

By Year 12 there should be less tree maintenance required because of the thorough maintenance performed previously, meaning the original 6 or more units can now be used for the basis of the annual, cyclical tree maintenance work, and that the work required can be performed there without an increase in the budget. The next cycle of PM is therefore only 8 years long, and the city is now well positioned to maintain an 8-year PM rotation of 6 (or more) management units.

Once the multiple benefits of PM are demonstrated, hopefully the city's tree maintenance budget will be adjusted to meet the needs of the preventive maintenance program and accelerate its implementation, meaning the goal of an 8- to 10-year PM cycle could be achieved more quickly. It should be noted that park and other public trees should also be included in this preventive maintenance cycle.

Next Steps:

- Divide the city into 6 management units for preventive maintenance, and then further divide those into 12 or more sub-units appropriate for the current maintenance budget.
- Perform all tree maintenance work to ANSI A300 standards. These standards will ensure that trees are thoroughly maintained beyond dead wood removal, and that pruning is completed to improve structural integrity. The standards will also reduce the incidence of disease and ensure that clearance is achieved for sidewalks, streets, signs, and lights.

3. Develop a Risk Management Program

While a proactive urban forest management program greatly reduces storm hazards through proper planting, preventive maintenance, and systematic risk reduction, a well-defined risk management program and policy is strongly recommended.

Risk Management Policy. A policy should be in place that clearly defines Columbia's strategy to mitigate risk from its trees. A policy outlines the structure of a defensible program and defines the city's acceptable level of risk. Information included in this policy can include the accepted methodology to assess risk, uniformed terminology to use, authorities qualified to assess that risk, and a well-defined plan for timely implementation of corrective actions based on risk assessment results. A defensible risk management program establishes and defines the level of care that is appropriate given a community's available resources for a specified time horizon. When properly developed, documented, and executed, a tree risk management program will elevate the effectiveness and responsiveness of the city's community forestry program.

Choosing Management Zones for Columbia

Using tree quantities as the basis for creating management zones is preferred because it evens out annual budget requirements, is less politically based, and can better achieve the long-term goals of urban forest sustainability and efficient use of resources.

Note the quantity of assets to address each year in ward zones versus equal asset zones.

Public Trees by Ward

Ward 1	886
Ward 2	369
Ward 3	297
Ward 4	3,006
Ward 5	599
Ward 6	661
	5,818

Public Trees Equally Divided

Zone 1	970
Zone 2	970
Zone 3	970
Zone 4	970
Zone 5	970
Zone 6	968
	5,818

Beginning the transition into a cyclical maintenance program by using political wards as management zones, the city will see that some units may require more time, resources, and funding to accomplish the initial tree pruning and removal needed (see table above). When zones are created by equal quantity of assets, budgeting is simplified.

After the first full cycle, the city may see the budget needs normalize and equalize as the high priority work is accomplished and more trees are in better and safer conditions.

In the future, when the street tree inventory is complete and when park and other public trees are inventoried, or after full stocking is achieved, the management unit boundaries can be realigned or adjusted so that they all contain an equal distribution of publicly maintained trees.

At its core, the focus of Columbia's risk management policy should detail a system used to identify those features of the tree population that pose the highest potential risk to the public and property, and then concentrate available resources to reasonably mitigate risk.

A comprehensive tree risk management program (detailed in Appendix D) should be developed and include both regularly inspecting trees to identify risk concerns and initiating the timely performance of corrective actions to address tree risk concerns. The level and frequency of risk inspections for public trees should be guided by the location of the trees, the value of targets, and the consequences of tree failure. Appendix D presents suggested "Tree Risk Zones" categories for public trees, minimum guidelines for inspection methods, and frequency of risk inspections.

Additionally, a risk assessment is strongly recommended in parks and on other public properties, such as was performed for Stephens Park. Most of these areas have not been inventoried, yet they are often the areas with the most traffic. Tree inspections should be performed by a Certified Arborist and follow the ISA's BMPs and ANSI A300 (Part 9) "Risk Assessment" Level 2 standards. These standards will ensure the inspection reveals complete information about the health and structural stability of the trees.

Emergency Response Planning. The city should also develop an emergency response and recovery plan for the urban forest that provides information about general tree risk reduction and gives directions to city agencies during an extreme storm emergency. The plan should be based on and include information on priority tree risk zones (e.g., major road arteries, hospitals), available staff and equipment resources, and inventory analyses.

Next Steps:

- Address the 225 trees that require high priority removals or pruning. This work should be accomplished in the first 12 to 18 months.
- A comprehensive tree risk management program should be developed and include both regularly inspecting trees to identify risk concerns and initiating the timely performance of corrective actions to address tree risk concerns.
- Perform a risk assessment in parks and on other public properties.
- Tree inspections should be performed by a Certified Arborist and follow the ISA's BMPs and ANSI A300 (Part 9) "Risk Assessment" standards. These standards will ensure the inspection reveals complete information about the health and structural stability of the trees.
- The city should develop an emergency response and recovery plan for the urban forest that provides information about general tree risk reduction and gives directions to city agencies during an extreme storm emergency. The plan should be based on and should include information on priority tree risk zones (e.g., major road arteries, hospitals), available staff and equipment resources, and inventory analyses.
- To address overall tree risk in Columbia, a Tree Risk Management Manual could be developed that includes the following information:
    - Summary of the assessment of the tree population, including distributions for species, condition, diameter, and defects.
    - Summary of current practices and the fiscal, staff, and equipment resources available to the city.
    - Industry-accepted best management practices and appropriate national standards (i.e., ANSI A300 and ANSI Z133).
    - Maps of the high target areas of the community and the problem areas within the tree population.

- Maps or guidelines for monitoring and conducting visual risk assessments based on high target areas and following storms to assess impacts or changes in tree risk.
- Specific actions, procedures, and objectives to address tree risk once identified.
- Procedures for annual risk management program review.
- Reference materials for city staff use, such as forms for risk tree assessment, debris estimation, work tracking, etc.
- Training in risk assessment and management should be considered. Beyond forestry staff, multiple city departments or staff likely impact or can assist in assessing tree risk concerns. A training program on urban forest risk identification, avoidance, and reduction would benefit Columbia.

4. Implement a Plant Health Care and Mature Tree Care Program

A key responsibility of public tree management is maintaining an awareness of emerging invasive insects and diseases in the city and the region and knowing how to best manage them. Considering the species distribution from the inventory data, much of Columbia's urban forest is at risk from invasive insects or diseases. An integrated pest management (IPM) plan, as part of a plant care (PHC) program, should be established as part of the city's comprehensive urban forest management program. The plan should focus on identifying and monitoring threats, understanding the economic and political thresholds, selecting the correct treatment, properly timing management strategies, defining a method for recordkeeping, and evaluating results.

The PHC program can particularly benefit Columbia's mature trees. It is estimated that there are nearly 430 mature, large-diameter (greater than 18" DBH) trees on the public streets in Columbia. These large crown trees are producing the most environmental benefits for the city and the citizens, and they contribute greatly to Columbia's overall ambiance and sense of place. Mature trees growing in an urban environment face many challenges that threaten their vigor and increase risk—poor soil quality, restricted rooting area, air pollution, increased temperatures, construction damage, vehicular accidents, soil compaction, inadequate/inconsistent water, and stress-induced insect and disease infestations.

To protect and preserve the community forest assets, the city should consider inspection, protection, and plant health care programs, including programs specifically targeting the city's mature trees. PHC for mature trees often includes fertilization, supplemental watering, mulching, insect and disease treatments, and rooting area enhancement through radial trenching and core aeration.

Next Steps:

- Perform a Level 1 risk assessment and/or a general condition evaluation on mature trees annually, and a more detailed Level 2 assessment during the cyclical maintenance inspections. Level 3 inspections would be performed on an as-needed basis.
- Perform inspections of mature trees after severe weather events.
- Enforce current tree protection regulations and hold people accountable for damaging any mature tree.
- Identify all mature trees in Fair or better condition that should receive greater attention and care.
- Use tree growth regulators, particularly for mature street trees and trees damaged by construction, to help overcome root loss and nutrient deficiencies, and to decrease the need for/lessen the impact of frequent utility pruning.

- As with EAB, train Columbia forestry staff and contractors to detect signs and symptoms of other potential infestations and be prepared to act if a significant threat is observed in the tree population or a nearby community.
- Establish partnerships to fund and accomplish the PHC and mature tree care program. For instance, the Water & Light department may support tree growth regulator applications for trees under their lines; businesses may join an "adopt-a-tree" program for significant tree care in parks and in commercial areas; citizens may help water mature street trees during times of droughts.
- Create an Integrated Pest Management program for public trees.
- Educate property owners about significant insect and disease threats and confirmations. Since the majority of the trees that comprise the city's urban tree canopy are on private property, it is vital for the city to educate the public on how to detect insect and disease threats, provide information about management and treatment options, and relay the importance of reforestation in the event trees are removed due to insects and disease.

Planting Trees to Grow the Urban Tree Canopy

5. Implement the GIS-Based Prioritized Tree Planting Plan

Annual planting of new trees is a critical part of ensuring longevity of the urban forest. However, planting should be done with a purpose in mind—not just a random draw of what sites are available or what's easiest to fill.

Planting can have the purpose of improving diversity of species and age, or be focused on ensuring equitable tree canopy across all neighborhoods, lessening the stormwater issues in a community, or any combination of goals. Whatever the local goals are, they should be defined in advance so the annual planting projects work toward creating a more sustainable green city asset.

With the information from the computerized prioritized planting plan, Columbia is very well positioned to perform purposeful planting, and, in the near term, to plant trees where the most benefits for the most people will be derived.

Next Steps:

- For any future tree planting project in the next five years, focus on planting in areas classified as High and Very High priorities. Ward One and the Central Neighborhood should be considered first to receive additional trees.
- Based on updated and complete inventory data (including vacant planting sites), create a detailed city-wide Master Street/Park Tree Planting Plan to ensure proper species diversity, guide street tree planting by developers and citizens, and to be "shovel-ready" to take advantage of grants and donations for trees.
- Create mini-master tree planting plans for the North, Central, and West neighborhoods. Then seek out funding for planting projects that will involve and engage the residents in the planting and follow-up care of the new trees.
- Set a goal that Columbia's urban forest population will be composed of no more than 5% of one tree species, no more than 10% of one genus, and no more than 20% of any one family.
- Establish planting benchmarks, such as the number of trees planted per year or the number of trees planted in relationship to trees removed annually. An ultimate goal might be to achieve and maintain a 90% to 100% stocking level for the street tree population.

- When possible, avoid or limit planting redbud (to ensure numbers do not rise above the recommended 10% threshold), and consider planting shade tree species other than oak (due to the risk of oak wilt). Encourage property owners and developers to plant other species as well.
- Complete the city's urban forest inventory by locating and recording suitable vacant planting sites. This can be done by city staff, volunteers, or contractors.
- Update the inventory with every new tree planted.
- Plant large canopy trees on public rights-of-way and parks wherever site conditions will allow; and encourage or require land developers to do the same.
- Encourage homeowner associations to create tree or beautification boards with whom the City Arborist can communicate and provide tree care and planting information.
- Establish a "Tree Fund" for funding tree planting on streets and public property to increase and preserve the city's tree canopy. The source of funds could include insurance settlements when city trees are damaged in accidents, payments by developers submitted to compensate the city for trees that could not be planted on development sites, donations from businesses and citizens, and grants from private foundations.
- Specify that all public tree planting will follow the guidelines and standards of ANSI A300 Part 6 Planting and Transplanting Standard, the ISA *Best Management Practices for Tree Planting*, and ANSI Z60.1 American Standard for Nursery Stock.
- Encourage planting on private property that is close to the street right-of-way. This will provide the benefits of trees but decrease needed city management responsibilities.

Recommended Tree Species List. An updated tree species list for Columbia can be found in Appendix A. Recommendations have been made to include tree species selections based on current and potential threats and pressures facing Columbia's urban forest in the coming years.

Purposeful Planting Species List. A species list generated using i-Tree Species is also found in Appendix A. These lists are the top performing species for specific benefits such as air quality improvements and stormwater control.

6. Institute a Young Tree Care Program

An accelerated and dedicated public tree planting program in Columbia is needed to sustain and grow the urban tree canopy so that the city and citizens can receive the many benefits trees provide. When the cost of the tree itself and the cost of the labor and equipment used to plant each tree is considered, it is clear that each tree planted represents an investment made by the city. It is counter-productive to plant trees and then not care for them while they get established.

The more prudent and proactive action is to establish and follow a young tree care program. In this program, newly planted trees receive watering, mulching, pruning, and fertilization as needed for at least the first three years after planting.

Quality care during the first several years of a new tree's establishment is very important and has multiple tangible benefits. Most obviously it prevents wasting planting funds by lowering the mortality rate of new trees, but it also reduces the amount of care that trees need in future years. Older trees that were selected, planted, and maintained with proper care while young have fewer defects which are less costly to maintain and are longer lived in urban environments than trees that were not planted correctly or were poorly cared for.

Next Steps:

- Write planting contract specifications that include multi-year maintenance along with the initial planting, or create a separate contract specifically for that task.
- Consider creating a "Tree Stewards" program where citizens are trained to perform young tree watering, mulching, pruning, and monitoring.
- Engage local businesses, corporations, health care facilities, and schools to help care for young trees on a one-off, annual basis. These organizations are attracted to contributing to very visual projects in a neighborhood, and tree watering and mulching are very simple but important hands-on tasks for volunteers to do with immediate, quantifiable, and visual results.

See Appendix B for a multi-year young tree care schedule. This information can also be shared with individual citizens and community organizations that are planting new trees.

Supportive Actions for Enhanced Urban Forest Management

7. Update and Complete the Tree Inventory for All Public Trees

Tree inventory data are the basis for decision making and budgeting for Columbia's public trees and other data-driven actions. At this time, the street tree population has been inventoried, but little data are available for park or other public property trees or potential planting sites. With a complete inventory of public trees and potential planting sites, Columbia will be able to use the data for long-range, proactive planning to ensure the continued beauty, vitality, safety, and survival of all public trees.

Next Steps:

- Complete the inventory for existing trees and vacant planting locations on future streets, parks, and other public properties.
- The inventory data set should be immediately updated when maintenance and/or planting work is performed. The inventory, in its entirety, should be updated at least every 10 years. But a more desirable and efficient approach would be to keep it up-to-date by re-inventorying that portion of the urban forest that is receiving the annual preventive maintenance during the cyclical maintenance program.
- The city should commit to maintaining the inventory data and performing periodic quality control to ensure the accuracy of the information.
- Fully utilize the TreeKeeper® software to keep accurate records of the current inventory.

8. Update Tree Related Ordinances

Columbia's tree ordinance (Chapter 12, Article VII) generally provides for the protection and proper treatment of street and park trees, but lacks important elements that should be included to create a stronger ordinance and one that reflects the community's goals and current industry standards. The following recommendations are made for Columbia to consider to strengthen the existing ordinance structure and language in the future.

Next Steps:

- Include acceptable and unacceptable basic performance standards for the treatment of public trees. The language used to define these practices should be clear and quantifiable so that the ordinance will be enforceable.
- Make reference to these current national arboricultural industry standards: ANSI A300 Tree, Shrub, and other Woody Plant Management – Standard Practices, ANSI Z133.1 American

National Standards for Arboricultural Operations – Safety Requirements, and ANSI Z60.1 – American Standard for Nursery Stock.

- Create an official tree board and define its authority, duties, and make-up in the ordinance.
- When and if appropriate, revise the ordinance to centralize the authority for public trees into one department with the city arborist (as a designee of city manager if needed) identified as the primary position responsible for decisions regarding urban forest management. If the city desires to keep responsibility for public trees in separate departments, the city arborist should still be designated as the primary source of guidance for urban forest management.
- Since mature trees of many species provide ecosystem, economic, and social benefits, consider expanding the language in the land development code to protect all forested tracts, not just of the climax forest type.
- Columbia may want to include additional provisions in the future that are needed to reach the community's goals and address unique, local issues, such as:
    - Invasive insect and disease response: This would define the city's authority to direct removal/treatment of trees on both public and private property if a significant insect or disease threat exists in the city.
    - Incorporating a canopy goal. Once a goal has been set, insert the fact that there is canopy goal in the Purposes section. However, refrain from inserting the exact percentage to allow for future adjustments without having to change code.

Since the ordinance was just recently updated, these recommendations can be considered in five years or later. At that appropriate future point in time, the changes made recently to the ordinance can be evaluated; and the questions can be asked "Did they work?" and "Did the issues get resolved that motivated the recent changes?" If not, the ordinance can be discussed and revised again at that time, and recommended adjustments described above can be considered.

9. Create and Implement an Outreach Plan

The urban forest influences and benefits everyone in the community. Reaching out and engaging the community is not only about informing them of the importance and benefits of trees, but also communicating the role urban forests play in ensuring Columbia's livability and sustainability.

In Columbia, approximately 90% of the tree canopy is located on private lands. For this reason, success in improving or maintaining tree canopy must include a citizenry that understands: 1) the value of trees and tree canopy to the community; and 2) how to plant and care for trees. To achieve a sustainable urban forest, Columbia will rely heavily on the commitment of citizens, businesses, and other stakeholder groups to support work done in the public realm, and then translate the benefits of proactive urban forest management into action in the private realm.

Community support for the publicly-owned urban forest can include: tree-related advocacy groups and trusts; associations that lobby for more street trees and greenspaces in their neighborhoods; and others who want greater tree canopy and tree protection through better planning, new regulations, and greater investment in urban forest management. On a larger scale, business-driven civic leadership and educational institutions can incorporate urban forestry visibly into much broader planning initiatives and thus build its legitimacy as a public policy issue.

We cannot separate sustainable urban forests from the people who live in and around them. Sustainable urban forests are not born, they are made. They do not arise at random, but result from a community-wide commitment to their creation and management. Obtaining the commitment of a broad community, of numerous constituencies, cannot be dictated or legislated. It must arise out of compromise and respect."

-- Clark, et. Al., A Model of Urban Forest Sustainability, Journal of Arboriculture, 1997]

There are multiple ways to reach out to the public to improve care of and quantity of local tree canopy. Topics or messages must first be defined, prioritized, and limited in number. More effective communication occurs through choosing a few strong messages and repeating them over and over. After messages are chosen, avenues of targeted communication to deliver those messages can be determined and implemented.

Without this awareness and information, mature trees can be removed at any time without a thought of the loss of benefits to the property owner, or overall impact on the community. In addition, replacement trees might not be planted, or if they are, they may be poorly placed and selected.

Messaging. Important topics and messages that should be considered for Columbia are as follows:

Current Canopy and Value of Columbia Trees.

The message should present the current canopy level and benefits the canopy provides. This is typically the first message to send out as all other messages should connect back to this one. This can also be a way to "roll out" the urban forest master plan to the public (why Columbia needs canopy, current canopy level, and the plans to improve the management of the trees that comprise the canopy). Educating local business owners on the impact a shady commercial district can have on sales can also be a method to boost the desire for increased canopy along main thoroughfares and neighborhood streets while engaging the public. Additionally, the value of mature trees could be highlighted. People often do not realize that the large tree they have is a value to their property, the community, wildlife, and the environment.

How You Can Get Involved.

What are the next steps you want people to take? The city should decide the answer and insert this "ask" in every outreach piece or effort. This must be decided locally but options include:

- Give citizens the choice to opt-in for a tree. This could simply be a way to request a street tree. Alternatively, raise funds for a tree giveaway (usually saplings) at Arbor Day for citizens to plant on private property.
- Volunteer at a tree planting (one Saturday morning commitment).
- Join a tree tenders care corps.
- Donate funds for an upcoming planting.
- Encourage recycling or composting leaves on site.

Tree Threats

Public and private trees can die, decline, or become safety risks as a result of insect and disease infestation as well as inadequate maintenance. With education, the citizens of Columbia can become aware of the common threats to the tree canopy and what they can do to help. Particularly for EAB and oak wilt, the city should provide education on what to expect, how to identify ash and oak trees, what the city is doing about these threats on public land, and options for management on their own land. Since the majority of the trees that comprise the city's urban tree canopy are on private property, it is vital for the city to educate the public on how to detect insect and disease threats, provide information about management and treatment options, and relay the importance of reforestation in the event trees are removed due to insects and disease.

General Tree Care for Property Owners

There are a number of actions people take that are detrimental to trees at all stages of life, including improper mulching and pruning. Simple tips and tidbits of information about proper tree care and easy maintenance tasks to share with citizens for trees on their own properties are always important.

Use Multiple Avenues of Communication. There are numerous avenues that Columbia can take to convey urban forestry messages and program accomplishments to the citizens.

Social Media

Social media sites such as Facebook, Instagram, and Twitter can create buzz and promote involvement in the current urban forestry activities occurring locally. Coordinate with allied non-profits, educational institutions, and businesses to get messages posted on their social media sites as well.

Presentations to city leadership and local business and neighborhood groups

Identify key audiences, partnerships, and potential champions for the urban forestry program. Making short presentations at their regular meetings relieves individuals from having to go to yet another meeting just about the urban forest. Initial outreach could be based on letting the audience know about Columbia's urban forest and the work called for in this plan. Be sure to have an "ask" at the end of the presentation. What do you want them to do next? This work often unearths new partners and funding sources that can otherwise go untapped.

Cultivate partnerships for communication

Partnerships can be initiated with organizations that can help promote Columbia's urban forest and its management program. Organizations can include local businesses, local utilities, regional non-profits, homeowner associations, neighborhood associations, and educational institutions. Other audiences to engage can include youth groups, landscape architect firms, faith-based groups, and nurseries and landscape contractors. All these organizations have internal communication channels that get messages directly and quickly to their members or constituents. The city should leverage the reach and combined breadth of actions that can be taken by each partner.

Next Steps:

- Create a simple outreach/education plan with timely and important messages that support the city's urban forest management goals. Identify partners to help communicate the messages to the citizens.
- Focus urban forest outreach efforts and messaging through the city's website and by attending meetings and events where in-person connections can be made.
- Do a survey. Once a year, create a short online survey to identify what urban forestry issues people in Columbia are concerned or care about. The survey can also be used to gauge people's reactions to new urban forest management procedures and regulations, and their willingness to participate in volunteer work or to donate funds or other resources.
- *Publish and Promote an Annual State of the Urban Forest Report.* Using updated tree inventory data, tree planting statistics, i-Tree tools, and other program information, an annual "State of the Urban Forest Report" should be produced. It should provide information on the number and condition of public trees, and maintenance, planting, and management accomplishments. It should also present a summary of the current year's annual work plan, and identify emerging issues and budget or resource needs.

Reaching Your Audience

For important urban forest management messaging, the city should harness the power of advertising to connect with the citizens of Columbia. Recognizing the areas where people are more likely to believe the messaging and take action will help the city be more effective in its outreach efforts.

Nielsen Media Research regularly publishes results on what media outlets and sources people are more likely to rely on and believe when they look for or get information. Considering the latest survey, people are least likely to trust a newspaper article or opinions of strangers on social media and most likely to trust people they know and legitimate websites.

Therefore, the city might want to focus urban forest outreach efforts and messaging through the city's website and by arranging meetings and events where in-person connections can be made.

NIELSEN GLOBAL TRUST IN ADVERTISING SURVEY, 2015

Promoting Columbia's urban forest's benefits, educating citizens about important issues, and generating support for urban forestry projects are forms of advertising. To make the most out of communication efforts and to maximize exposure, consider using the information sources people trust the most. Direct communication is reliably the best way to spread the word about trees, but using social media sites, publishing articles in newspapers and online media, expanding the city's urban forest webpage, and sending out e-mail notices and newsletters to subscribers will be most effective ways of informing and engaging citizens.

10. Engage the Community through Volunteerism

The community can be engaged in multiple ways, but promoting volunteerism provides the city not only with labor and skills to complete urban forest projects, but also a contingent of citizens who can support the program politically.

Many cities implement a young tree care volunteer program, often called "tree stewards," to assist with new tree planting and new tree care such as watering, mulching, and pruning. The city of Columbia has the TreeKeepers program, which could be expanded do perform more service on street trees. The TreeKeepers program is an activity that provides an active engagement opportunity and encourages partnership opportunities with a variety of groups, such as neighborhood associations, master gardeners, scout troops, church affiliated groups, high school community service programs, etc., to accomplish new and young tree care tasks. Such a program does involve initial and continuing training, frequent mentoring, and overall coordination of the process and volunteers.

Particularly for street trees, the TreeKeepers can assist with a "Young Tree Care" program. Younger and smaller diameter trees sometimes have branch structures that can lead to potential problems as the tree ages, such as codominant leaders, multiple limbs attaching at the same point on the trunk, or crossing/interfering limbs. If these problems are not corrected, they may worsen as the tree grows, which increases risk and creates potential liability. Beyond pruning, young trees need watering and mulching to become established, and may require fertilization and other PHC treatments until they reach maturity.

The TreeKeepers can also be used to support the urban forest management program in other ways. Volunteers could develop and staff Arbor Day and Earth Day events; post and manage tree messages on social media; help update the inventory; and locate planting sites in neighborhoods. This program should be expanded and used to support street trees, and well as park trees, and can be modelled after similar and successful programs like those found in other states.

Volunteer Tree Care Programs Case Studies

Tree Tenders, Pittsburgh, PA. For over 15 years, Trees Pittsburgh has had a volunteer program named Tree Tenders® to help plant and care for new and small stature trees. Tree Pittsburgh requires that Tree Tenders® take an 8-hour course and learn about urban forestry practices, tree biology and health, proper planting, pruning, and maintenance. The cost of the course is $40 (scholarships are available), which includes registration, materials, light food, and instruction. Tree Tenders® participate in events organized by Tree Pittsburgh that include tree care days, pruning workshops, and tree planting. Since 2006, Tree Pittsburgh has certified over 1,300 Tree Tenders®.

CommuniTree Stewards, Syracuse, NY. Funded by the City of Syracuse and Onondaga County, the CommuniTree Steward Program started in 2002 to cost-effectively plant and maintain trees by exchanging tree maintenance classes for volunteer work on public trees. The program is run by Cornell Cooperative Extension (CCE). Students enroll in the winter and begin the required CCE courses in April. Coursework includes tree biology, tree identification, soils, matching tree species to the site, tree planting, basic pruning, structural pruning, proper mulching, and watering. Students are closely monitored and instructed during forestry projects. By the end of the summer, most students need little supervision; by the fall, CommuniTree Stewards participate in large-scale, bare-root planting events. Veteran Tree Stewards, who return annually to work on tree projects and plantings, will often pair up with new Tree Stewards and will serve as instructors. CommuniTree Stewards have planted thousands of trees in the City of Syracuse and Onondaga County villages. Volunteers are also able to serve on specialty projects such as tree inventories and invasive species mapping. Veteran CommuniTree Stewards have gone on to organize their own neighborhood projects, so the program has had an impact beyond its original intended area.

Combining Youth Employment Opportunities with New Tree Care in Indianapolis. Newly planted public trees in Indianapolis don't always have predetermined caretakers. For this reason, Keep Indianapolis Beautiful (the city's nonprofit tree partner) employs a team of young people to plant, mulch, stake, water, and prune public trees for seven weeks each summer. The Youth Tree Team program, which began in 2008, pays local high school students to take on this role of promoting new tree establishment and care. The program is supported through corporate donations, a foundation, and other donations.

11. Create a Tree Board

Focusing on just the operational management of Columbia's urban forest neglects the true owners of the resource. It is the community that makes the forest "urban" and the members of the community who can make it successful and sustainable. An official advisory tree board would provide the guidance and oversight of the urban forest management program and equitable management of this natural resource on behalf of the citizens.

12. Explore Partnerships

Development of the urban forest is an area of public planning that government does not need to tackle alone. For tree care and planting, partnerships can breach the gap from public to private lands. Along with other city departments, potential partners could include non-profits with like interests or goals, other levels of government (county, state), and local utilities.

Business partners can be powerful contributors to the expansion and success of urban forestry through financial support, planting, and maintenance of trees on residential and commercial properties, and support of civic organizations involved in forestry. Some businesses have a direct stake in urban forestry as a function of their own enterprises. Others may be interested in contributing to urban forestry projects to off-set the environmental impacts of their operations.

Partnerships can be used for mature tree care, and not just for tree planting. For instance, businesses may join an "adopt-a-tree" program for significant trees in parks and in commercial areas near their businesses or customers; citizens can help water mature street trees during times of droughts; and Water & Light could be a proactive partner for mature trees under utility lines if they are presented with the inventory data for trees under utility lines so they can consider assisting in high-priority maintenance work during their annual line clearance schedule/program.

Next Steps:

- *Expand the TreeKeepers program for street trees*. Partnerships can be initiated with organizations that can help promote, enhance, and preserve Columbia's urban forest. Organizations can include local businesses, local utilities, regional non-profits, homeowner associations, neighborhood associations, and educational institutions. Other audiences to engage can include youth groups, landscape architect firms, faith-based groups, and nurseries and landscape contractors. Actions that can be taken by each partner should be defined before approaching them for support.
- *Encourage and support the University of Missouri to become a Tree Campus USA.* The University of Missouri's over 1,200-acre campus comprises much of the city's urban core. The University is not yet a Tree Campus, USA. If they were to pursue this distinction and join the city's Tree City, USA legacy, then two powerful entities would be supporting Columbia's urban forest. One Tree Campus, USA standard the University would need to achieve annually is for students to participate in one or more Service Learning Projects. These projects are intended to provide an opportunity to engage the student population with trees and can be part of a larger community initiative. University students could help the city's urban forestry program perform many tasks, such as tree planting, tree care, and public outreach. For instance, University students could organize, manage, and participate in the volunteer tree corps program.
- *Establish a permanent, officially recognized, and appointed urban forestry board*. This commission would guide the urban forestry program and advise City Council, the City Manager, city departments, and the citizens of Columbia on the urban forestry priorities. Members of the Tree Board should at least include city staff from the various city departments that affect the urban forest, citizen representatives from each ward, and the City Arborist.
- C*reate a relationship with a non-profit organization.* A non-profit organization can more easily solicit funds and accept grants that will benefit the urban forest management program.

13. Integrate Urban Forestry into Other City Plans and Efforts

As shown in the tree benefits discussion, urban tree canopy is a tool for achieving or solving many of the challenges that face cities today. Leveraging the benefits of trees and urban forest management best practices should be included in other city programs/efforts/improvements when possible.

Street Enhancement and Traffic Calming

Urban trees make streets safer and more walkable. Trees are a natural complement to Columbia's *Neighborhood Traffic Management Program* and the city's efforts to make its streets safer and improve neighborhoods through its Vision Zero goal. Planting trees on residential streets encourages people to drive more slowly, as well as improve neighborhood livability and the environment for pedestrians.

Street trees can complement Columbia's Level 1, 2, and 3 traffic calming devices as they provide visual cues that encourage people to drive more slowly. Yet, trees are not currently acknowledged in the *Neighborhood Traffic Management Program Handbook*. According to the Federal Highway Administration, tree canopy along a street provides a narrowing speed control measure by creating a "psycho-perceptive sense of enclosure" that discourages speeding (U.S. Department of Transportation 2015). Additionally, multiple studies have shown that traffic speeds and driver stress levels have been reported to be lower on tree-lined streets, contributing to a reduction in road rage and aggressive driving (Wolf 1998, Kuo and Sullivan 2001). The buffers between walking areas and driving lanes created by trees also make pedestrians and cyclists feel safer.

As an added value, more walkable communities can help strengthen retail businesses by the increased foot traffic along storefronts and lower CO_2 emissions by increasing the number of walkers and cyclists, reducing vehicular traffic. A study in Toronto, Canada found that street landscape improvements reduced accidents by 5% to 20% (generating significant public costs savings) and boosted pedestrian use of urban arterials (Rosenblatt Naderi 2003).

To maximize the traffic calming benefits of the urban forest, it is essential to incorporate street trees into Columbia's roadway redesign projects, plant more streets trees in residential areas, and to include trees as a Level 1 traffic calming device in Columbia's transportation enhancement program.

Sustainability Plans and Projects

Because of the diverse number and value of benefits provided by trees and urban tree canopy, urban forestry forest management is increasingly recognized as a vital component of sustainable communities. Sustainability offices are in the opportunistic position of influencing policy, planning, and perception regarding how to better incorporate trees as solutions to meeting municipal sustainability goals, and to facilitate a collaborative approach to urban forest management.

Sustainability offices have the mission, authority, and resources to assist with integrating trees and urban forests into citywide programs, plans, and projects; and sustainability offices recognize the importance of cooperative, productive relationships and can influence important stakeholders such as elected officials, private sector entities, and non-profits. Columbia's Office of Sustainability states that it "works with all city departments and the community to optimize resource use efficiency and improve economic, environmental, and social well-being" and is a logical champion for trees and tree canopy in the city, and for the urban forest management program in general.

Next Steps:

- Include trees as a Level 1 traffic calming device in Columbia's transportation enhancement program.
- Explore how tree planting can strategically support the efforts of implementing the transportation goal of Vision Zero.

- Columbia's urban forestry program should work more closely with the Office of Sustainability to integrate trees and tree-related policies into city strategic plans and projects for the goal-oriented areas of focus of energy, sustainable economy, sustainable land management, and stormwater.
- Communicate directly with Office of Sustainability staff—the Community Conservationist, Stormwater Educator, and Energy Educator—to share the value of trees in achieving their short- and long-term goals and objectives.
- Specifically link and promote the air quality improvement, carbon sequestration, and pollution reduction benefits of trees and the urban tree canopy in terms of the Mayors for Climate & Energy agreement and the city's Climate Action Plan.
- Work cooperatively with the Office of Sustainability and Water & Light to enhance the Tree Power program and public outreach concerning the energy reduction benefits of trees and greater tree canopy. Consider joining the National Arbor Day Foundation's Energy Saving Trees program to encourage more strategic tree planting on private property and to quantify energy savings more accurately (https://energysavingtrees.arborday.org/).
- The urban forestry program should partner with and support the Office of Sustainability's public education efforts. Provide tree information which can be available on the sustainability webpage and at public meetings. Be an active participant at the annual Sustainable Living Fair by having a booth and/or conducting a workshop.

14. Evaluate the Urban Forest Management Structure

A comprehensive, progressive, and proactive urban forest management program requires the coordination of professional talents in land use planning, public works, forestry, parks, and other public services. It requires all political, administrative, and private actors to be educated about and involved in urban forestry matters. It also requires sufficient funding to allow for professional management responses to a comprehensive urban forestry policy.

The reaction of progressive local governments to these requirements has been to reevaluate and/or reorganize the structure and organization of urban forest management so that appropriate solutions might be developed, tested, and implemented to better manage and maintain municipal forest resources.

Urban forest management can be as complex, vibrant, diverse, and fragile as the urban forest ecosystem itself. Just as one silvicultural technique is best suited for a particular forest stand, that same technique can fail when applied to a different stand. And so it is with urban forestry management. Columbia should not simply duplicate what other cities have done. The ultimate and best management for a particular urban forest is determined by its unique political climate, its social soil and grassroots factors, the capabilities of its administrative timber, and the other resources that define the municipality's ecosystem.

Next Steps:

- *The City Arborist and urban forest management operational duties, resources, authority, and responsibility should be centralized in one department.* Currently, and by the ordinance, the public urban forest, and to a degree private trees, is controlled and managed by multiple departments with separate missions. In this decentralized structure, public tree management is divided by departmental lines with each agency making decisions, spending resources, and taking action (or inaction) on the public trees in the properties and projects under their control. The City Arborist and future program staff should be in the department that has the most immediate impact on the public urban forest and the implementation of the management plan. In most U.S. cities, urban forestry management is assigned to the public works department; park departments are the second most common location for the program.
- *The city should find the means to increase interdepartmental communication and cooperation for plans and projects that may affect the urban forest.* If decentralization of urban forest management responsibilities is the structure desired by the city, then interdepartmental coordination with the involvement of City Arborist is crucial if the city wants to properly and professionally manage public trees. If the City Arborist does not have information on public and private projects affecting public trees, and enough time to review and comment on these plans and projects, potential problems may occur, and opportunities will be missed that have immediate and long-term impacts on the urban forest. The city should at least create a policy or operational philosophy that fosters greater interdepartmental support, understanding, and coordination for the benefit of the citywide urban forest and the urban forestry program.
- *Columbia should formalize interdepartmental communication by creating a citywide departmental review and approval system for major projects.* Plans or project descriptions of new construction or major repair projects (not routine departmental tasks) are circulated through each department for review and comment. Each department can weigh the impact the particular project has upon its responsibilities and comment on the project. The project cannot be implemented until all departments have approved the project as planned or requests for changes have been satisfied. Another mechanism to increase communication is for representatives from all departments (as needed) to be invited to pre-construction meetings for large infrastructure projects. At this meeting, the City Arborist can personally interact with city staff and private contractors who will be involved in the project. It is important that the City Arborist is officially designated as part of the review, comment, and recommendation process, and is supported by the City Manager. Ideally, the City Manager should enable the City Arborist to be the key decision-maker in projects that affect the urban forest in any way.
- *The staffing levels and resources for urban forest management should be increased.* A truly proactive and comprehensive urban forest management program requires trained and dedicated staff to oversee management and operational activities. The important duties of tree planting, tree maintenance, emergency response, plan review, development site inspection, project management, contract administration, interagency assistance and coordination, and citizen education, among others, require a sufficient level of staffing, equipment, and other program resources.

An adequate complement of professionals who, individually or collectively, understand the technical, operational, and administrative factors in urban forest management is needed to prescribe and monitor the city's urban forestry activities, enforce policies and regulations, apply technical standards and practices, and review plans that affect the forest resource. Without this professional component in sufficient numbers, urban forest management decisions and actions often default to inadequately prepared decision-makers, which can have long-term, negative consequences for the urban forest resource.

Columbia has dedicated, trained professional staff. However, to accomplish many of the short- and long-term goals of the Plan, additional public and/or contractual professional staff may be required.

- *Consider performing a job analysis and/or operational review specifically for urban forest management.* A job analysis could be performed to determine if new or existing job classifications should be created, whether existing staff could be trained and reassigned or if new hiring is needed, and what level of funding is needed to support the positions. The job analysis could also reveal if contracting various urban forest management functions and tasks would be beneficial or more cost-effective.

  And, an operational review of urban forestry activities could be performed to document work processes, work quantities, personnel, use or absence of arboricultural standards, and to inventory existing equipment, tools, and office equipment. The findings and recommendation of both the job analysis and operational review are critical sources of decision-making information and baseline data for judging future success or shortcomings of the urban forestry program.

Technical Support and Tree Work Staffing Options

Whether addressing the backlog of priority maintenance work and need for neighborhood tree planting, or performing technical site plan review, utility coordination, or construction monitoring, the City Arborist's need for assistance is high.

Increasing the number of tree maintenance and inspection personnel could happen almost immediately, since these job classifications exist. However, classifications don't exist for technical support staff, and time may be needed to decide whether some of the technical support staff should be full- or part-time and exactly what the job duties should entail. Additionally, committing to increasing full-time or part-time staff and buying and maintaining required vehicles and equipment will call for time and funding that doesn't currently exist.

Contracting crews and technical support is an option for supplementing existing staff in the short term. Using contracted labor and equipment on a temporary basis in conjunction with existing staff could be a viable solution to accomplish the quantity and diversity of work that the urban forestry program will face in the next several years.

As reported by the American Public Works Association, below is a summary of the advantages and disadvantages of using contracted and in-house staff for forestry operations:

Contracted Technical Support Staff

Advantages

- Very experienced and knowledgeable on a wide array of topics.
- Can provide a high level of knowledge in a specific area, such as hazard tree identification, tree valuation, ordinances and technical specifications, tree preservation.
- Can be more easily released from service.
- Usually is fully and pre-equipped with a vehicle and computer.
- All certifications, licensing, and continuing education are already in place and separately provided.
- Contracted personnel do not require long-term pension obligations that are remunerated to retired city workers upon retirement without any production value.

Disadvantages

- Contract agreement may limit flexibility in job assignments.
- If used regularly, and for an extended period of time, contract staff can be more expensive in the long term.
- Administrative time must be provided for contract writing, monitoring, and invoice processing.
- Administrative time is required for contract writing, monitoring, and invoice processing.

In-House Technical Support Staff

Advantages

- Ties within the community.
- Has or will build "institutional knowledge".
- Available at a moment's notice to perform a wider variety of tasks.
- Directly accountable to the citizens and the Public Works Director.
- Fringe benefit costs and long-term pension obligations represent cost barriers to staff expansion.

Technical Support and Tree Work Staffing Options (Continued)

Disadvantages

- May only be experienced in limited aspects of arboriculture and urban forest management.
- Investment must be made in equipment for this position, such as a vehicle, computer, and diagnostic tools.
- City must invest time and funding for obtaining and maintaining certifications, licenses, and other training.
- Not easily removed from the position if performance is substandard.

Contractual Crews and Work Production

Advantages

- Funds are only paid for work performed and when completed to the specifications and satisfaction of the Public Works Department.
- Labor is available for peak demands and special projects; there is cancellation and no cost when work is not needed or when the weather is poor.
- Contractor provides all required equipment, tools, and supplies; repair, maintenance, and downtime of equipment are not the responsibility of the Public Works Department.
- All insurance and workers' compensation are the responsibility of the contractor.
- Contractor provides employee supervision, training, and certifications.
- Liability for damage to public and private property is the responsibility of the contractor.

Disadvantages

- Contractors are bound by the specifications of the contract; their work assignments are not as flexible.
- May not be as quick to respond to emergencies as in-house crews.
- Administrative time is required for contract writing, monitoring, and invoice processing.

In-house Crews and Work Production

Advantages

- More flexible for other work assignments.
- Quality can be perfected over time to meet community standards through training.
- May respond more quickly to emergencies.
- Workforce is more stable.
- Staff can be more knowledgeable about the community and can be motivated by pride and residency.
- More control over training and specializations.
- No administrative time is needed to write and oversee contracts.

Disadvantages

- Large investment in equipment and maintenance per crew.
- Workers are paid regardless of work production quantity, efficiency, and quality.
- Difficult to release from employment.
- Public Works Department is responsible for damage caused by crew actions.
- Public Works Department is responsible for on-the-job injuries and workers' compensation.

Most public works agencies have the option of performing urban forestry tasks using in-house staffing and equipment, or using contractors who specialize in various arboricultural disciplines and services. Often, using a combination of in-house personnel and contractors is chosen to ensure that the urban forest management services provided are performed at the lowest possible cost, as efficiently as possible, and with the greatest level of expertise.

15. Analyze the Municipal Budget for Citywide Tree Management

It is reported that the budget for public tree management in Columbia (excluding utility-related tree clearance and removal) is approximately $420,000 annually. This represents only 0.09% of the total municipal budget. Since over 80% of the tree management budget is funding for strictly Parks and Recreation tree maintenance and planting, funding for street trees, especially in neighborhoods, is woefully inadequate. As the benchmark tables showed, overall Columbia is below national, regional, and peer group averages for public tree funding.

The inventory analysis reveals that on average, $150,000 will be required to perform annual priority and routine maintenance, and $31,000 should be allocated annually for neighborhood tree planting; this totals $181,000 needed each year for Columbia to have a proactive urban forest management program. This annual average budget is only for tree maintenance and replacement planting. It does not include expanded tree planting, plant health care, outreach efforts, staff salaries, or equipment costs; therefore, annual expenditures could approach $250,000 for a comprehensive urban forestry program.

To achieve the goals of this plan, funding levels for increased staffing levels, expanded public tree planting and maintenance programs, and public outreach efforts should be increased.

Next Step:

- A budget analysis should be considered to aid in determining how to increase funding to the appropriate level that includes:
    - Identifying all city resources spent on urban forestry activities to clearly understand the current level of funding for urban forestry related activities;
    - Determining if future budget reallocations and efficiencies can occur;
    - Determining the amount of the actual shortfall to achieve the goals of the plan, and;
    - Identifying potential and best sources of increased financial resources.

16. Maximize the Use of Technology and Data Management Software

Many technological tools exist to help Columbia manage its urban forest assets more effectively and efficiently. And, Columbia has a significant amount of inventory, tree canopy, and GIS data. Using technology and data leads to insights that urban forest managers can turn into decisions and actions that improve the urban forest and customer service. Columbia's urban forestry program is poised to successfully begin taking a data-driven approach to management and using technology for public engagement.

Next Steps:

- *Commit to using TreeKeeper®8 software.* The city has the latest version of TreeKeeper® software. This tree inventory data management software has extensive capabilities for record keeping, reporting, work order generation and tracking, expenditure analysis, and mapping. city forestry, administrative, and IT staff should be trained to use TreeKeeper® so that the inventory can be kept up-to-date, accomplishments can be tracked, and reports on a variety of issues can be generated. The city should consider obtaining the TreeKeeper® mobile app to make field data collection easier and the myTreeKeeper® program that allows the public to see the benefits of trees in their neighborhoods or citywide, and give them access to public tree and UTC information.

- *Put the UTC analyses and data to work citywide*. Other city departments should be made aware of the UTC data layer and access it when planning projects and making decisions that might affect the city's tree canopy. Beyond Parks and Recreation and Public Works, the staff of the Sustainability Office, Utilities, and Community Development should be aware of this information and data and access it routinely when planning for land development, construction and repair projects, and infrastructure improvement projects.
- *Update the UTC GIS layer*. Every 5 to 10 years, the UTC should be updated to detect trends and document changes in the tree canopy. The existing UTC GIS layer can be used as a baseline that the city can compare subsequent years to and gauge the success or failure of urban forest program initiatives, the impact of serve weather events, and the effects of invasive insect, disease, and plant infestations.
- *Use GIS technology and information for public outreach.* Beyond using GIS technology for tree location, UTC mapping, and spatial data management, GIS information can be used to support public outreach goals. "Pictures speak 1,000 words," so Columbia can create informative maps and interactive imagery with the GIS data for use on the city's website, at neighborhood or other public meetings, and to give to allied non-profits and partners to get messages out about urban forest issues and projects. Columbia should promote the Plan's Story Map, the priortized planting plan, and other GIS data to help make the case for trees, showcase the city's plans and projects, protect and enhance the urban tree canopy, engage the public, and educate decision-makers.
- *Develop a CoMobile App for trees.* The city has various mobile apps available to make living in and visiting Columbia a better experience. Creating a CoMo Trees app specifically for the urban forest is recommended. The app could have simple, informative, and fun features such as a series of neighborhood-based "landmark" or historic tree trails; tree care and planting tips; tree identification information; and contact information for tree care in the city.
- *Enhance Online Service Requests and Problem Reporting.* Columbia makes it easy for citizens to report problems ranging from crime to pot holes and to request services ranging from various city departments. Tree issues or service requests have no online or e-mail system in place other than to report street and sidewalk clearance issues. An online reporting form should be created so citizens and business can report tree issues and/or request tree maintenance or planting. It is recommended that it be its own form and be placed on both the Public Works webpage and the Citywide Problem Reporting webpage. A link to this form should also be made available on the CoMoGOV mobile app.

FISCAL AND VISION IMPACTS OF URBAN FOREST MASTER PLAN RECOMMENDATIONS

Table 15 summarizes the primary recommendations made in this master plan and presents them in terms of a low, medium, or high priority, a suggested timeframe for initiating or completing the tasks, a best estimate of the fiscal impact of the activity, and the specific Vision, Strategy, and/or Goal statement of Columbia that the urban forest management recommendation supports.

Table 15. Prioritization and Fiscal Impacts of Urban Forests Master Plan Primary Recommendations

Recommendation	Priority	Timeframe for Completion	Fiscal Impact	Vision, Strategy, and/or Goal # Impact
High Priority Removals	High	1 year	$64,016	3
High Priority Pruning	High	1 year	$58,875	2.1
Complete/Update Inventory	High	Annually	$5,000	5.4.1
New Tree Maintenance	High	Annually	$12,920	2.1
Create a Risk Management Plan	High	1 year	No cost (city staff) $8,000–$15,000 for consultant	3
Create and implement a Strategic Planting Plan – citywide and/or by neighborhood	High	1 year	Variable	2.1
Moderate/Low Priority Removals	Medium	3 years	$32,169	3
Routine Pruning	Medium	5 years	$578,720	2.1
Young Tree Training	Medium	5 years	$23,160	2.1
Tree Planting	Medium	Annually	$18,088	2.1
Plant Health Care Program/Inspection	Medium	3 years	Variable	2.1
Renew TreeKeeper®	Medium	Annually	$2,800	3.4.1
Use the UTC Analyses Citywide	Medium	1	No cost (city staff)	3.4.1; 5.2.2; 12.1.1; 12.3
Evaluate Urban Forest Management Structure	Medium	3 to 5 years	No cost (city staff)	3.4.3; 10.1.3
General Public Outreach	Medium	Annually	No cost (city staff); $2,000–$4,000 (printing and materials)	3.4.3; 8.2.1; 8.3.4
Perform Funding and Operations Reviews	Medium	3 years	No cost (city staff); $10,000–$20,000 for consultant	3.4.3
Stump Grinding	Low	1 to 3 years	$8,040	2.1
Update Ordinance(s)	Low	5 years	No cost (city staff) $10,000–$15,000 for consultant	5.3.2; 5.4; 9.1
Create a Tree Board and Volunteer Corps	Low	5 years	No cost (city staff)	2.1.1; 9.1.3
Update UTC	Low	5 to 10 years	$20,000 for consultant	3.4.1

CONCLUSION

The overall health and long-term management of the urban tree canopy is an important component for achieving environmental sustainability in a community. Urban forests provide numerous environmental services, including reducing surface water runoff, sequestering carbon and improving overall air quality, mitigating urban heat island effect, buffering noise and visual impacts between developments, providing habitat for local wildlife, and adding to the aesthetic appeal of the urban landscape. Securing these same benefits for the citizens of Columbia through engineered "grey" infrastructure, single function solutions rather than through trees and green infrastructure usually result in services with less capacity and much greater cost-benefit ratio.

If Columbia envisions a sustainable future that unites the three pillars of economic development, social equity, and environmental protection through actions that meet the needs of the present without compromising the ability of future generations to meet their own needs, then the city simply cannot afford to lose its tree canopy.

The management of public trees is challenging to say the least. Urban forest managers have the daunting task of balancing the recommendations of experts, the wishes of council members and other elected officials, the needs of citizens, the pressures of local economics, concerns for liability issues, the physical aspects of trees, the forces of nature and severe weather events, and the desire for all of these needs to be met all at once.

The recommendations of this plan are ambitious but are achievable. This plan contains both short- and long-term goals and objectives that Columbia can implement incrementally until the urban forest management program is providing the level of service desired by staff and citizens. This plan has established a clear set of priorities and objectives related to program enhancement and tree canopy expansion that are based on defensible data and a reasonable use of municipal funds and resources.

By implementing this master plan, the City of Columbia can begin to make progress toward reaching the goals of:

1. Managing a diverse, sustainable, safe, and beneficial community forest;
2. Maintaining and expanding the urban tree canopy for both today and for future generations;
3. Using professional urban forestry leadership and staff, proper maintenance and planting techniques, more efficient management of city resources, and public education and support so that the city's urban forest is viewed as an important community asset; and
4. Having the urban forest uniquely define the city's character and be a major factor in the continued growth and livability of Columbia.

Columbia's Urban Forest Master Plan should be considered a "living" working document. The goals and recommendations presented should be reviewed annually and adjustments made appropriately for the following year. The entire document itself should be reviewed on a five- or ten-year basis to determine if management and urban forest conditions have changed significantly.

Benchmarks for a Sustainable Urban Forest

Columbia will have achieved and created a sustainable urban forest when these "benchmarks" have been reached:

- Elected officials pass and enforce favorable ordinances protecting Columbia's trees, and fully fund the urban forestry program.
- Planning agencies include trees in comprehensive plans, encourage conservation easements and low-impact development, and enforce codes to protect trees.
- Public works and engineering staff value trees equally with other municipal infrastructure and include tree planting and protection in their projects.
- Economic and community development staff advocate for trees and greenspace to increase property values, shopping revenues, attract new business investments, and understand that trees are an incentive, not an obstacle, to economic investment.
- Health departments and the medical community recognize and promote the value and benefits of trees for personal and societal health benefits.
- Citizens volunteer for tree commissions, appear before city leaders and elected officials to support trees, and provide planting and maintenance labor for special projects.

GLOSSARY

aesthetic report: The i-Tree Streets Aesthetic/Other Report presents the tangible and intangible benefits of trees reflected by increases in property values in dollars ($).

air quality report: The i-Tree Streets Air Quality Report quantifies the air pollutants (ozone [O_3], nitrogen dioxide [NO_2], sulfur dioxide [SO_2], coarse particulate matter less than 10 micrometers in diameter [PM_{10}]) deposited on tree surfaces and reduced emissions from power plants (NO_2, PM_{10}, Volatile Oxygen Compounds [VOCs], SO_2) due to reduced electricity use measured in pounds (lbs.). Also reported are the potential negative effects of trees on air quality due to Biogenic Volatile Organic Compounds (BVOC) emissions.

American National Standards Institute (ANSI): ANSI is a private, nonprofit organization that facilitates the standardization work of its members in the United States. ANSI's goals are to promote and facilitate voluntary consensus standards and conformity assessment systems, and to maintain their integrity.

ANSI A300: Tree care performance parameters established by ANSI that can be used to develop specifications for tree maintenance.

arboriculture: The art, science, technology, and business of commercial, public, and utility tree care.

canopy: Branches and foliage that make up a tree's crown.

canopy cover: As seen from above, it is the area of land surface that is covered by tree canopy.

carbon dioxide report: The i-Tree Streets Carbon Dioxide Report presents annual reductions in atmospheric CO_2 due to sequestration by trees and reduced emissions from power plants due to reduced energy use in pounds. The model accounts for CO_2 released as trees die and decompose and CO_2 released during the care and maintenance of trees.

condition: The general condition of each tree rated during the inventory according to the following categories adapted from the International Society of Arboriculture's rating system: Excellent (100%), Very Good (90%), Good (80%), Fair (60%), Poor, (40%), Critical (20%), Dead (0%).

cycle: Planned length of time between vegetation maintenance activities.

defect: See structural defect.

diameter: See tree size.

diameter at breast height (DBH): See tree size.

extreme risk tree: Applies in situations where tree failure is imminent, there is a high likelihood of impacting the target, and the consequences of the failure are "severe." In some cases, this may mean immediate restriction of access to the target zone area in order to prevent injury.

failure: In terms of tree management, failure is the breakage of stem or branches, or loss of mechanical support of the tree's root system.

further inspection: Notes that a specific tree may require an annual inspection for several years to make certain of its maintenance needs. A healthy tree obviously impacted by recent construction serves as a prime example. This tree will need annual evaluations to assess the impact of construction on its root system. Another example would be a tree with a defect requiring additional equipment for investigation.

genus: A taxonomic category ranking below a family and above a species and generally consisting of a group of species exhibiting similar characteristics. In taxonomic nomenclature, the genus name is used, either alone or followed by a Latin adjective or epithet, to form the name of a species.

geographic information system (GIS): A technology that is used to view and analyze data from a geographic perspective. The technology is a piece of an organization's overall information system framework. GIS links location to information (such as people to addresses, buildings to parcels, or streets within a network) and layers that information to provide a better understanding of how it all interrelates.

grow space size: Identifies the minimum width of the tree grow space for root development.

high risk tree: The High Risk category applies when consequences are "significant" and likelihood is "very likely" or "likely," or consequences are "severe" and likelihood is "likely." In a population of trees, the priority of High Risk trees is second only to Extreme Risk trees.

inventory: See tree inventory.

i-Tree Streets: i-Tree Streets is a street tree management and analysis tool that uses tree inventory data to quantify the dollar value of annual environmental and aesthetic benefits: energy conservation, air quality improvement, CO_2 reduction, stormwater control, and property value increase.

i-Tree Tools: State-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban forestry analysis and benefits assessment tools. The i-Tree Tools help communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the structure of community trees and the environmental services that trees provide.

management costs: Used in i-Tree Streets, they are the expenditures associated with street tree management presented in total dollars, dollars per tree, and dollars per capita.

moderate risk tree: The Moderate Risk category applies when consequences are "minor" and likelihood is "very likely" or "likely"; or likelihood is "somewhat likely" and consequences are "significant" or "severe." In populations of trees, Moderate Risk trees represent a lower priority than High or Extreme Risk.

monoculture: A population dominated by one single species or very few species.

net annual benefits: Specific data field for i-Tree Streets. Village-wide benefits and costs are calculated according to category and summed. Net benefits are calculated as benefits minus costs.

ordinance: See tree ordinance.

overhead utilities: The presence of overhead utility lines above a tree or planting site.

right-of-way (ROW): See street right-of-way.

risk: Combination of the probability of an event occurring and its consequence.

species: Fundamental category of taxonomic classification, ranking below a genus or subgenus, and consisting of related organisms capable of interbreeding.

street right-of-way (ROW): A strip of land generally owned by a public entity over which facilities, such as highways, railroads, or power lines, are built.

street tree: A street tree is defined as a tree within the right-of-way.

structural defect: A feature, condition, or deformity of a tree or tree part that indicates weak structure and contributes to the likelihood of failure.

sulfur dioxide (SO_2): A strong-smelling, colorless gas that is formed by the combustion of fossil fuels. Sulfur oxides contribute to the problem of acid rain.

summary report: A report generated by i-Tree Streets that presents the annual total of energy, stormwater, air quality, carbon dioxide, and aesthetic/other benefits. Values are reflected in dollars per tree or total dollars.

tree: A tree is defined as a perennial woody plant that may grow more than 20 feet tall. Characteristically, it has one main stem, although many species may grow as multi-stemmed forms.

tree benefit: An economic, environmental, or social improvement that benefits the community and results mainly from the presence of a tree. The benefit received has real or intrinsic value associated with it.

tree height: If collected during the inventory, the height of the tree is estimated by the arborist and recorded in 10-foot increments.

tree inventory: Comprehensive database containing information or records about individual trees typically collected by an arborist.

tree ordinance: Tree ordinances are policy tools used by communities striving to attain a healthy, vigorous, and well-managed urban forest. Tree ordinances simply provide the authorization and standards for management activities.

tree size: A tree's diameter measured to the nearest inch in 1-inch size classes at 4.5 feet above ground, also known as diameter at breast height (DBH) or diameter.

urban forest: All of the trees within a municipality or a community. This can include the trees along streets or rights-of-way, in parks and green spaces, in forests, and on private property.

urban tree canopy (UTC) assessment: A study performed of land cover classes to gain an understanding of the tree canopy coverage, particularly as it relates to the amount of tree canopy that currently exists and the amount of tree canopy that could exist. Typically performed using aerial photographs, GIS data, or Lidar.

young tree train: Data field based on ANSI A300 standards, this maintenance activity is characterized by pruning of young trees to correct or eliminate weak, interfering, or objectionable branches to improve structure. These trees can be up to 20 feet tall and can be worked with a pole pruner by a person standing on the ground.

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APPENDIX A
SPECIES LIST

Common Name	Scientific Name	Street Tree	Parking Lot or Island	Screen or Landscape	Under Power Lines	Mature Height	Size Class	Comment
SMALL TREES								
Crabapple, Centurion	Malus 'Centzam'	yes	yes	yes	yes	20–25	S	disease resistant
Crabapple, Harvest Gold	Malus x 'Harvest Gold'	yes	yes	yes	yes	20–25	S	disease resistant
Crabapple, Prairiefire	Malus 'Prairiefire'	yes	yes	yes	yes	20–25	S	disease resistant
Crabapple, Snowdrift	Malus 'Snowdrift'	yes	yes	yes	yes	15–20	S	disease resistant
Crabapple, Sugar Tyme	Malus 'Sutyzam'	yes	yes	yes	yes	15–20	S	disease resistant
Fringetree	Chionanthus virginicus	yes	yes	yes	yes	25–30	S	
Hawthorn, Thornless	Crataegus punctata'Ohio Pioneer'	yes	yes	yes	yes	15–20	S	
Hawthorn 'Crimson Cloud'	Crataegus laevigata 'Superba'	yes	yes	yes	yes	15–20	S	
Lilac, Japanese tree	Syringa reticulata	yes	yes	yes	yes	25–30	S	messy flowers
Magnolia, Saucer	Magnolia x soulangiana		yes	yes	yes	20–30	S	
Magnolia, Sweetbay	Magnolia virginiana		yes	yes	yes	15–25	S	
Maple, Amur	Acer ginnala		yes	yes	yes	20–25	S	
Maple, Shantung	Acer truncatum	yes	yes	yes	yes	20–25	S	
Maple, Tatarian	Acer tataricum	yes	yes	yes	yes	15–25	S	
Smoketree	Cotinus obovatus	yes	yes	yes	yes	15–25	S	
MEDIUM TREES								
Blackhaw, Rusty	Viburnum rufidulum		yes	yes	yes	25–35	M	
Buckeye, Yellow	Aesculus flava		yes	yes	yes	25–35	M	
Buckeye, Red	Aesculus pavia		yes	yes	yes	25–35	M	
Cherry, Flowering	Prunus 'Kwanzan'		yes	yes	yes	25–35	M	
Cherry, Sargent	Prunus sargentii 'Columnaris'		yes	yes	yes	30–40	M	
Cherry, Yoshino	Prunus yedoensis		yes	yes	yes	30–40	M	
Chesnut, Red Horse	Aesculus x carnea		yes	yes	yes	25–35	M	
Corktree, Amur	Phellodendron amurense	yes	yes	yes	no	35–40	M	tolerant of dry sites
Dogwood, Kousa	Cornus kousa		yes	yes	yes	15–25	S	
Dogwood, Flowering	Cornus florida		yes	yes	yes	15–25	S	
Goldenraintree	Koelreuteria paniculata		yes	yes	no	25–40	M	
Hawthorn 'Winter King'	Crataegus viridis 'Winter King'	yes	yes	yes	yes	25–35	M	
Honeylocust, Thornless	Gleditsia triacanthos 'Impcole' Imperial	yes	yes	yes	no	30–40	M	
Honeylocust, Thornless	Gleditsia triacanthos 'Suncole' Sunburst	yes	yes	yes	no	30–40	M	
Hophornbeam	Ostrya virginiana	yes	yes	yes	yes	30–40	M	tolerant of dry sites
Hornbeam, American	Carpinus caroliana	yes	yes	yes	no	20–35	M	
Hornbeam, European	Carpinus betulus 'Fastigiata'	yes	yes	yes	no	35–40	M	narrow upright form
Maple, Hedge	Acer campestre	yes	yes	yes	no	20–40	M	

Common Name	Scientific Name	Street Tree	Parking Lot or Island	Screen or Landscape	Under Power Lines	Mature Height	Size Class	Comment
Maple, Pacific Sunset	Acer truncatum x platanoides 'Warenred'	yes	yes	yes	no	20–40	M	
Maple, Paperbark	Acer griseum		yes	yes	no	20–40	M	
Maple, State Street	Acer miyabei 'Morton' State Street	yes	yes	yes	no	30–40	M	
Maple, Trident	Acer buererianum	yes	yes	yes	yes	20–30	M	
Parrotia, Persian	Parrotia persica		yes	yes	no	20–40	M	
Pawpaw	Asimina triloba		yes	yes	no	20–35	M	
Redbud, Eastern	Cercis canadensis	yes	yes	yes	yes	25–30	M	
Redbud, 'Forest Pansy'	Cercis canadensis 'Forest Pansy'	yes	yes	yes	yes	25–30	M	
Redbud, 'Oklahoma Red'	Cercis reniformis	yes	yes	yes	yes	25–30	M	
Serviceberry, Spring Flurry	Amelanchier laevis		yes	yes	yes	25–30	M	
Serviceberry, Downy	Amelanchier arborea		yes	yes	yes	25–30	M	
LARGE TREES								
Alder, Black	Alnus glutinosa	yes	yes	yes	no	45+	L	
Baldcypress	Taxodium distichum	yes	yes	yes	no	45+	L	
Basswood	Tilia americana	yes		yes	no	45+	L	
Beech, American	Fagus grandifolia	yes		yes	no	45+	L	
Beech, European	Fagus sylvatica	yes		yes	no	45+	L	
Birch, River	Betula nigra 'Heritage' or 'Dura Heat'	yes	yes	yes	no	45+	L	
Blackgum	Nyssa sylvatica	yes		yes	no	45+	L	
Bloodgood Planetree	Platanus x acerifolia 'Bloodgood'			yes	no	45+	L	
Elm, 'Allee'	Ulmus parvifolia 'Allee'	yes	yes	yes	no	45+	L	
Elm, American	Ulmus americana 'Valley Forge'	yes	yes	yes	no	45+	L	subject to DED
Elm, 'Emerald Prairie'	Ulmus parvifolia 'Emerald Prairie'	yes	yes	yes	no	45+	L	
Elm, Hybrid	Ulmus 'Frontier', 'Homestead', 'Pioneer'	yes	yes	yes	no	45+	L	DED resistance
Elm, Lacebark	Ulmus parvifolia	yes	yes	yes	no	45+	L	
Gingko	Gingko biloba	yes	yes	yes	no	45+	L	male or cultivars only
Hackberry	Celtis occidentalis 'Prairie Pride'	yes	yes	yes	no	45+	L	
Hornbeam, European	Carpinus betulus	yes	yes	yes	no	45+	L	
Katsuratree	Cercidiphyllum japonicum	yes	yes	yes	no	45+	L	
Kentucky coffeetree	Gymnocladus dioicus	yes	yes	yes	no	45+	L	
Linden, Littleleaf	Tilia cordata 'Chancellor', 'Greenspire'	yes	yes	yes	no	45+	L	upright
Linden, Silver	Tilia tomentosa 'Green Mountain'	yes	yes	yes	no	45+	L	
Magnolia, Cucumbertree	Magnolia acuminata	yes		yes	no	45+	L	
Maple, Autumn Blaze	Acer x freemanii 'Jeffersred'	yes		yes	no	45+	L	
Maple, Autumn Flame	Acer rubrum 'Autumn Flame'	yes		yes	no	45+	L	
Maple, Legacy	Acer saccharum 'Legacy'	yes	yes	yes	no	45+	L	
Maple, Red	Acer rubrum	yes		yes	no	45+	L	
Maple, Red Sunset	Acer rubrum 'Franksred'	yes		yes	no	45+	L	
Maple, Scarlet Sentinel	Acer x freemanii 'Scarsen'	yes		yes	no	45+	L	
Maple, Sugar	Acer saccharum	yes		yes	no	45+	L	
Maple, Sugar 'Green Mnt'	Acer saccharum 'PNI 0285'	yes		yes	no	45+	L	
Oak, Bur	Quercus macrocarpa			yes	no	45+	L	

Common Name	Scientific Name	Street Tree	Parking Lot or Island	Screen or Landscape	Under Power Lines	Mature Height	Size Class	Comment
Oak, Chinkapin	Quercus muehlenbergii			yes	no	45+	L	
Oak, English	Quercus robur 'Fastigiata'	yes	yes	yes	no	45+	L	narrow upright
Oak, Northern Red	Quercus rubra	yes		yes	no	45+	L	
Oak, Pin	Quercus palustris	yes		yes	no	45+	L	
Oak, Sawtooth	Quercus acutissima	yes		yes	no	45+	L	
Oak, Scarlet	Quercus coccinea	yes		yes	no	45+	L	
Oak, Shumard	Quercus shumardii	yes		yes	no	45+	L	
Oak, Swamp Chestnut	Quercus michauxii	yes		yes	no	45+	L	
Oak, Swamp White	Quercus bicolor	yes		yes	no	45+	L	
Oak, White	Quercus alba	yes		yes	no	45+	L	
Pagodatree, Japanese	Sophora japonica	yes	yes	yes	no	45+	L	
Planetree, London	Platanus x acerfolia	yes		yes	no	45+	L	
Rubbertree, Hardy	Eucommia ulmoides	yes		yes	no	45+	L	
Tulip Tree	Liriodendron tulipifera	yes		yes	no	45+	L	
Tupelo, Black	Nyssa sylvatica	yes		yes	no	45+	L	
Tupelo 'Forum'	Nyssa sylvatica 'Forum'	yes		yes	no	45+	L	
Tupelo 'Red Rage'	Nyssa sylvatica 'Red Rage'	yes		yes	no	45+	L	
Yellowwood	Cladrastis kentukea	yes		yes	no	45+	L	
Zelkova, Japanese	Zelkova serrata	yes	yes	yes	no	45+	L	
EVERGREEN TREES								
Holly, American	Ilex opaca		yes	yes	N			
Pine, Austrian	Pinus nigra		yes	yes	N			
Spruce, Colorado (blue)	Picea pungens		yes	yes	N			
Cedar, Eastern red	Juniperus virginiana		yes	yes	Y			
Pine, Eastern White	Pinus strobus		yes	yes	N			
Fir, Concolor	Abies concolor		yes	yes	N			
Juniper, Chinese	Juniperus chinensis		yes	yes	Y			
Spruce, Norway	Picea abies		yes	yes	N			
Pine, Limber	Pinus flexilis 'Vander woolf'		yes	yes	N			
UNDESIRABLE TREES (restricted use for public planting)								
Ash - all species	emerald ash borer							
Boxelder	weak wood							
Catalpa	weak wood							
Crabapple	disease prone varieties and cultivars							
Ginkgo	female or any non-cultivar							
Hawthorn, Washington	disease issues							
Honeylocust	species with thorns							
Maple, silver	weak wood							
Pear - all cultivars	highly invasive; weak branch unions							
Pine, Scotch	disease issues							
Plum, Cherry	borers							

Purposeful Planting – Species Recommendations

To increase the benefits the urban forest provides, the city should prioritize planting large-crown, large-statured tree species that manage the most stormwater, absorb the most CO_2, and remove the most air pollutants. The following list of tree species, generated specifically for Columbia using i-Tree Species, is recommended for maximizing important environmental benefits and contributing to the city's overall sustainability.

Pollutant Removal

- *Tsuga cannadensis* (eastern hemlock)
- *Ulmus americana* (American elm – resistant varieties)
- *Liriodendron tulipifera* (tuliptree)
- *Betula alleghaniensis* (yellow birch)
- *Tilia americana* (American linden)

Carbon Storage

- *Platanus hybrida* (London planetree)
- *Platanus occientalis* (American sycamore)
- *Zelkova serrata* (Japanese zelkova)
- *Ulmus americana* (American elm – resistant varieties)
- *Betula alleghaniensis* (yellow birch)

Stormwater Reduction

- *Liriodendron tulipifera* (tuliptree)
- *Ulmus americana* (American elm – resistant varieties)
- *Tilia americana* (American linden)
- *Betula alleghaniensis* (yellow birch)
- *Magnolia acuminata* (cucumber magnolia)

Energy Reduction

- *Liriodendron tulipifera* (tuliptree*)*
- *Ulmus americana* (American elm – resistant varieties)
- *Tilia americana* (American linden)
- *Betula alleghaniensis* (yellow birch)
- *Platanus occientalis* (American sycamore)

Heat Island Effect/Temperature Reduction

- *Liriodendron tulipifera* (tuliptree)
- *Ulmus americana* (American elm – resistant varieties)
- *Tilia americana* (American linden)
- *Betula alleghaniensis* (yellow birch)
- *Platanus occientalis* (American sycamore)

Energy Reduction

- *Liriodendron tulipifera* (tuliptree)
- *Ulmus americana* (American elm – resistant varieties)
- *Tilia americana* (American linden)
- *Betula alleghaniensis* (yellow birch)
- *Platanus occientalis* (American sycamore)

Top 10 Tree Species for Overall Benefits

- *Liriodendron tulipifera* (tuliptree)
- *Ulmus americana* (American elm – resistant varieties)
- *Tilia americana* (American linden)
- *Betula alleghaniensis* (yellow birch)
- *Tsuga canadensis* (eastern hemlock)
- *Ulmus glabra* (Wych elm)
- *Magnolia acuminata* (cucumber magnolia)
- *Picea abies* (Norway spruce)
- *Platanus occientalis* (American sycamore)
- *Zelkova serrata* (Japanese zelkova)

APPENDIX B
NEW TREE CARE SCHEDULE

DAVEY Resource Group

Multi-Year Maintenance Plan for Newly Planted Trees

YEAR 1

At Planting

- Prune tree for co-dominate stems and broken or dead branches only.
- Create a watering dish or berm at the edge of the root ball, not the planting hole.
- Mulch a 4-foot diameter area under the tree—Maximum of 3-inches deep and nothing against the trunk of the tree.
- Water thoroughly. 20 gallons per tree within eight hours of planting.

The Summer Following Planting, from Leaf -On to Leaf-Off - Once a Week

- Water - 10 to 15 gallons: Applied at a rate less than 3 gallons per minute.

  Note: Watering will only be skipped if more than 1 inch of rainfall during that week.

Fall After Planting, After Leaf Fall (late October, early November)

- Control weeds in mulched area.

YEAR 2

Spring, Before Leaf Out (late March)

- Remove any staking, and all wire, tags, and twine.
- Control weeds in mulch bed.
- Refresh mulch to 3 inches. Mulch should be rotting about 33% per year by volume. Each tree should require about 1-inch of fresh mulch.
- Remove suckers, dead and broken branches.

Fall, After Leaf Fall (late October, early November)

- Control weeds in mulch bed.

YEARS 3, 5, 6, 8, and 9

Spring, Before Leaf Out (late March)

- Control weeds in mulch bed.
- Refresh mulch to 3 inches. Mulch should be rotting about 33% per year by volume. Each tree should require about 1-inch of fresh mulch.
- Remove suckers, dead and broken branches.

Fall, After Leaf Fall (late October, early November)

- Control weeds in mulch bed.

YEARS 4, 7, and 10

Spring, Before Leaf Out (late March)

- Control weeds in mulch bed.
- Refresh mulch to 3 inches. Mulch should be rotting about 33% per year by volume. Each tree should require about 1 inch of fresh mulch.
- Begin structural pruning practices: prune to establish central leader; raise lower branches so the crown of the tree is on the upper 2/3 of the tree; establish good branching structure and remove suckers, dead and broken branches.

Fall, After Leaf Fall (Late October, early November)

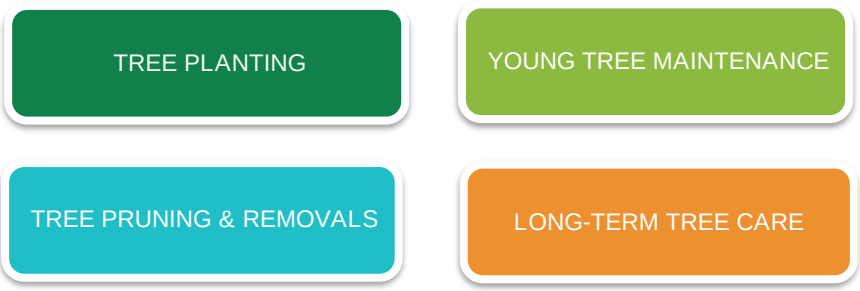
- Control weeds in mulch bed.
- Fertilize, as necessary

APPENDIX C
MAINTENANCE STANDARDS AND SOPs

Standard Operating Procedures

The following recommendations have been developed for the City of Columbia, Public Works Department by DRG with a focus on best addressing short-term and long-term maintenance needs for public trees. The City of Columbia has an understanding of the needs of the existing community forest and has identified specific protocol (standard operating procedures) to best address these needs. Analysis of inventory data and information about Columbia's existing program and vision for the community forest were utilized to develop these *Standard Operating Procedures*.

These Standard Operating Procedures or SOP's include all activities associated with the maintenance of The City of Columbia's community forest. These affect all trees, stumps, and planting sites along public street rights-of-way (ROW), and in specified parks and public facilities. Common community forestry activities pivotal to SOP's include, but are not limited to, the following:



Approach to Community Forestry Management

The best approach to managing your community forest is to develop an organized, proactive program using tools to set goals and measure progress. These tools can be utilized to establish tree care priorities, generate strategic planting plans, draft cost-effective budgets based on projected needs, and ultimately minimize the need for costly, reactive solutions to crises or urgent hazards.

Trees provide many environmental and economic benefits that justify the time and money invested in planting and maintenance. Over the long term, supporting proactive management of trees through funding will reduce municipal tree care management costs and potentially minimize the costs to build, manage, and support certain city infrastructure. Keeping the inventory up-to-date using TreeKeeper® 8 or similar software is crucial for making informed management decisions and projecting accurate maintenance budgets.

Columbia has many opportunities to improve its community forest. Consistent implementation of the following SOP's, such as planned tree planting and a systematic approach to tree maintenance, will help ensure a cost-effective, proactive program. Investing in this tree management program will promote public safety, improve tree care efficiency, and increase the economic and environmental benefits the community receives from its trees.

Tree Planting

Planting trees is necessary to maintain and increase canopy cover, and to replace trees that have been removed or lost to natural mortality (expected to be 1–3% per year) or other threats (for example, construction, invasive pests, or impacts from weather events such as drought, flooding, ice, snow, storms, and wind).

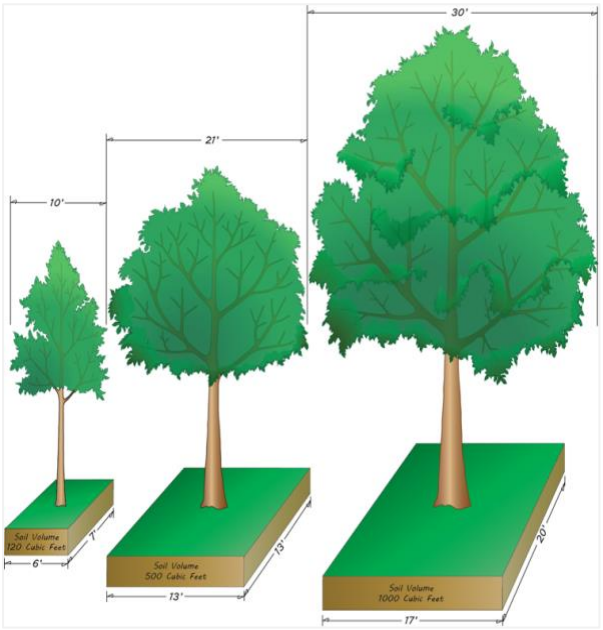
City-wide tree planting should focus on replacing tree canopy recommended for removal and establishing new canopy in areas that promote economic growth, such as business districts, recreational areas, trails, parking lots, areas near buildings with insufficient shade, and areas where there are gaps in the existing canopy. Various tree species should be planted and the city's existing planting list (located in Appendix A) offers smart choices for species selection. Due to the species distribution and impending threats from emerald ash borer (EAB, *Agrilus planipennis*), all *Fraxinus* spp. (ash) trees have been removed from the planting list or planted only when a landscape plan is in place.

Planting trees is a valuable goal as long as tree species are carefully selected and correctly planted. When trees are planted, they are planted selectively and with purpose. Without proactive planning and follow-up tree care, a newly planted tree may become a future problem instead of a benefit to the community.

The goal of tree planting is to have a vigorous, healthy tree that lives to the limits of its natural longevity. That can be difficult to achieve in an urban growing environment because irrigation is limited and the soils are typically poor quality. However, proper planning, species selection, tree planting techniques, and follow-up tree maintenance will improve the chance of tree planting success.

When planting trees, it is important to be cognizant of the following:

- Consider the specific purpose of the tree planting.
- Assess the site and know its limitations (i.e., confined spaces, overhead wires, and/or soil type).
- Select the species or cultivar best suited for the site conditions.
- Examine trees before buying them, and buy for quality.



Minimum recommended requirements for tree sites is based on tree size/dimensions. This illustration is based on the work of Casey Trees (2008).

Tree Species Selection

Selecting a limited number of species could simplify decision-making processes; however, careful deliberation and selection of a wide variety of species is more beneficial and can save money. Planting a variety of species can decrease the impact of species-specific pests and diseases by limiting the number of susceptible trees in a population. This reduces time and money spent to mitigate pest- or disease-related problems. A wide variety of tree species can help limit the impacts from physical events, as different tree species react differently to stress. Species diversity helps withstand drought, ice, flooding, strong storms, and wind.

Columbia is located in USDA Hardiness Zone 6a, which is identified as a climatic region with average annual minimum temperatures between −10°F and −5°F. Tree species selected for planting in Columbia should be appropriate for this zone.

Tree species should be selected for their durability and low-maintenance characteristics. These attributes are highly dependent on site characteristics below ground (soil texture, soil structure, drainage, soil pH, nutrients, road salt, and root spacing). Matching a species to its favored soil conditions is the most important task when planning for a low-maintenance landscape. Plants that are well matched to their environmental site conditions are much more likely to resist pathogens and insect pests and will, therefore, require less maintenance overall.

The Right Tree in the Right Place is a mantra for tree planting used by the Arbor Day Foundation and many utility companies nationwide. Trees come in many different shapes and sizes, and often change dramatically over their lifetimes. Some grow tall, some grow wide, and some have extensive root systems. Before selecting a tree for planting, make sure it is the right tree—know how tall, wide, and deep it will be at maturity. Equally important to selecting the right tree is choosing the right spot to plant it. Blocking an unsightly view or creating some shade may be a

priority, but it is important to consider how a tree may impact existing utility lines as it grows taller, wider, and deeper. If the tree's canopy, at maturity, will reach overhead lines, it is best to choose another tree or a different location. Taking the time to consider location before planting can prevent power disturbances and improper utility pruning practices.

A major consideration for street trees is the amount of litter dropped by mature trees. Trees such as *Acer saccharinum* (silver maple) have weak wood and typically drop many small branches during a growing season. Others, such as *Liquidambar styraciflua* (American sweetgum), drop high volumes of fruit. In certain species, such as *Ginkgo biloba* (ginkgo), female trees produce large odorous fruit; male ginkgo trees, however, do not produce fruit. Furthermore, a few species of trees, including *Crataegus* spp. (hawthorn) and *Gleditsia triacanthos* (honeylocust), may have substantial thorns. These species should be avoided in high-traffic areas.

Seasonal color should also be considered when planning tree plantings. Flowering varieties are particularly welcome in the spring, and deciduous trees that display bright colors in autumn can add a great deal of appeal to surrounding landscapes.

Planting trees is necessary to increase canopy cover and replace trees lost to natural mortality (expected to be 1%–3% per year) and other threats (for example, invasive pests or impacts from weather events such as storms, wind, ice, snow, flooding, and drought). Planning for the replacement of existing trees and identifying the best places to create new canopy is critical.

Tips for Planting Trees

To ensure a successful tree planting effort, the following measures should be taken:

- Handle trees with care. Trees are living organisms and are perishable. Protect trees from damage during transport and when loading and unloading. Use care not to break branches, and do not lift trees by the trunk.
- If trees are stored prior to planting, keep the roots moist.
- Dig the planting hole according to the climate. Generally, the planting hole is two to three times wider and not quite as deep as the root ball. The root flair is at or just above ground level.
- Fill the hole with native soil unless it is undesirable, in which case soil amendments should be added as appropriate for local conditions. Gently tamp and add water during filling to reduce large air pockets and ensure a consistent medium of soil, oxygen, and water.
- Stake the tree as necessary to prevent it from shifting too much in the wind.
- Add a thin layer (1–2 inches) of mulch to help prevent weeds and keep the soil moist around the tree. Do not allow mulch to touch the trunk.

Additional Recommendations

- Residents of Columbia can apply for Right-of-Way planting permits through the city's Public Works Department (located at the end of this section; Appendix C).
- Planting only small-growing trees within 20 feet of overhead utilities, medium-size trees within 20–40 feet, and large-growing trees outside 40 feet will help improve future tree conditions, minimize future utility line conflicts, and reduce the costs of maintaining trees under utility lines.
- When planting around hardscape, it is important to give the tree enough growing room above ground. Guidelines for planting trees among hardscape features are as follows: give small-growing trees 4–5 feet, medium-growing trees 6–7 feet, and large-growing trees 8 feet or more between hardscape features. In most cases, this will allow for the spread of a tree's trunk taper, root collar, and immediate larger-diameter structural roots.
- To prolong the useful life of street trees, small-growing tree species should be planted in tree lawns 4–5 feet wide, medium-size tree species in tree lawns 6–7 feet wide, and large-growing tree species in tree lawns at least 8 feet wide. The useful life of a public tree ends when the cost of maintenance exceeds the value contributed by the tree. This can be due to increased maintenance required by a tree in decline, or it can be due to the costs of repairing damage caused by the tree's presence in a restricted site.

Young Tree Maintenance

Caring for trees is just as important as planting them. Once a tree is planted, it must receive maintenance for several years.

Watering

Initially, watering is the key to survival; new trees typically require at least 60 days of watering to establish. Determine how often trees should be irrigated based on time of planting, drought status, species selection, and site condition.

Mulching

Mulch can be applied to the growspace around a newly planted tree (or even a more mature tree) to ensure that no weeds grow, that the tree is protected from mechanical damage, and that the growspace is moist. Mulch should be applied in a thin layer, generally 1 to 2 inches, and the growing area should be covered. Mulch should not touch the tree trunk or be piled up around the tree.

Post-Establishment Young Tree Care

After the tree is established, it will require routine tree care, which includes inspections, routine pruning, watering, plant health care, and integrated pest management as needed.

The city should employ qualified arborists to provide most of the routine tree care. An arborist can determine the type of pruning necessary to maintain or improve the health, appearance, and safety of trees. These techniques may include: eliminating branches that rub against each other; removing limbs that interfere with wires and buildings or that obstruct streets, sidewalks, or signage; removing dead, damaged, or weak limbs that pose a hazard or may lead to decay; removing

diseased or insect-infested limbs; creating better structure to reduce wind resistance and minimize the potential for storm damage; and removing branches—or thinning—to increase light penetration.

An arborist can help decide whether a tree should be removed and, if so, to what extent removal is needed. Additionally, an arborist can perform—and provide advice on—tree maintenance when disasters such as storms or droughts occur. Storm-damaged trees can often be dangerous to remove or trim. An arborist can assist in advising or performing the job in a safe manner while reducing further risk of damage to property.

Plant Health Care, a preventive maintenance process that keeps trees in good health, helps a tree better defend itself against insects, disease, and site problems. Arborists can help determine proper plant health so that the city's tree population will remain healthy and provide benefits to the community for as long as possible.

Integrated Pest Management is a process that involves common sense and sound solutions for treating and controlling pests. These solutions incorporate basic steps: identifying the problem, understanding pest biology, monitoring trees, and determining action thresholds. The practice of Integrated Pest Management can vary depending on the site and based on each individual tree. A qualified arborist will be able to make sure that the city's trees are properly diagnosed and that a beneficial and realistic action plan is developed.

The arborist can also help with cabling or bracing for added support to branches with weak attachment, aeration to improve root growth, and installation of lightning protection systems.

Educating the community on basic tree care is a good way to promote the city's community forestry program and encourage tree planting on private property. The city should encourage citizens to water trees on the ROW adjacent to their homes and to reach out to the city if they notice any changes in the trees, such as signs or symptoms of pests, early fall foliage, or new mechanical or vehicle damage.

Additional Recommendations

- The Community forest will benefit greatly from a three-year young tree training cycle. Proactive pruning cycles improve the overall health of the tree population and may eventually reduce program costs. In most cases, pruning cycles will correct defects in trees before they worsen, which will avoid costly problems.
- Younger trees in Fair or Poor condition may benefit from improvements in structure that may improve their health over time. All Pruning should follow *ANSI A300 (Part 1)* (ANSI 2008).
- Proper tree care practices are needed for the long-term general health of the urban forest. Many of the newly planted trees were improperly mulched or had staking hardware attached to them long after they should have been removed. Following guidelines developed by ISA and those recommended by *ANSI A300 (Part 6)* (ANSI 2012) will ensure that tree maintenance practices ultimately improve the health of the community forest.

- Staking should only be installed when necessary to keep trees from leaning (windy sites) or to prevent damage from pedestrians and/or vandals. Stakes should only be attached to trees with a loose, flexible material. Installed hardware that has been attached to any tree for more than one year, and hardware that may no longer be needed for its intended purposes, should be inspected and removed as appropriate.

Tree Pruning and Removals

Pruning consists of *selectively* removing branches (living and dead) from woody plants, ranging from pinching off a bud at the end of a twig to removing large limbs.

Proper pruning benefits trees, shrubs, and vines, and the associates of woody plants (including humans). Pruning branches can be one of the most beneficial or the most damaging practices arborists do to trees.

A basic principle of pruning is that the removal of any live stems, branches, twigs, and buds affects the growth of the plant. Proper pruning prevents and corrects defective form that could result in branch or stem failure. Thus, knowledge of plant biology is essential for the correct methods of The Davey Tree Expert Company pruning.

Most tree species evolved in competitive forest communities. Consequently, trees developed efficient branching systems to capture the energy of available light for photosynthesis.

Woody plants also evolved the ability to get rid of inefficient energy resources by *shedding* shaded branches (cladaptosis). A branch is naturally shed from its base. As natural shedding occurs, the wood tissue around the branch core within the stem protects against decay. The Davey Tree Expert Company's limb removal cuts imitate natural branch shedding (natural target pruning).

Many people equate woody plant pruning to amputation, but there should be no fear of wise and careful use of pruning equipment. A properly pruned tree, shrub, or vine is a combination of art, science, and skill.

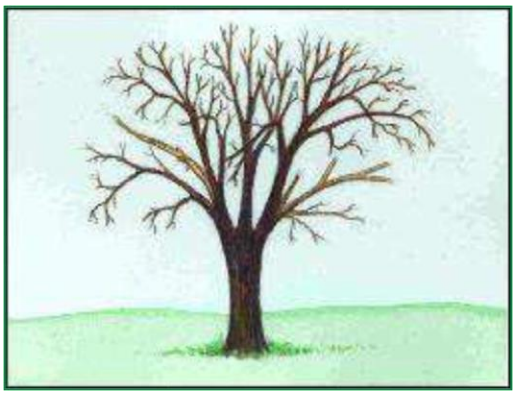
The City of Columbia adheres to industry pruning standards. In the arboriculture industry, the current standard approved by the ISA and the NAA is *The American National Standards Institute* (ANSI) A300 issued in 1995. Other acceptable standards include the National Arborist Association (NAA) *Pruning Standards for Shade Trees* (revised 1988) where four classes of pruning are defined.

Reasons for Pruning

The first rule in pruning is **do not cut without a reason**. Too often arborists tend to over-prune to meet client expectations. Proper pruning is an effort to *direct* new growth rather than ‘control’ growth.

Most pruning cuts are of a *preventive* or *corrective* nature to be beneficial to woody plant health.

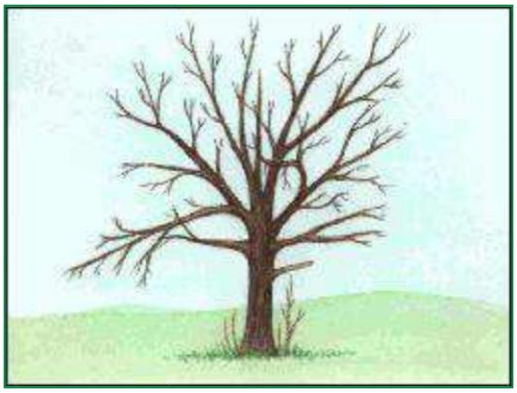
Health



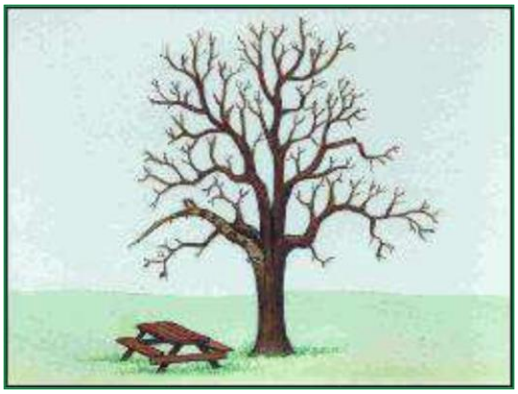
- *Sanitation* by removing dead, broken, decayed, diseased, or insect-infested wood (crown cleaning).
- *Thinning* to improve penetration of light and air, and to reduce wind resistance and potential storm damage.
- Reduction of the number of poorly attached *epicormic branches.*
- *Girdling root* removal.
- Correct and/or redirect *structural growth* that may cause future problems (weak crotches, branches growing out of proportion, etc.).

Appearance

- Shape for aesthetic purpose, natural forms, growth habit (training).
- Influence flowering, fruiting, promotion of shoots, canes, bark color.
- Direct new growth and/or correct improper prior pruning (crown restoration).

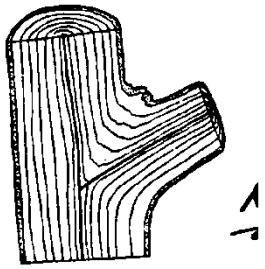


Convenience or Safety of Property and People



- Correct or modify storm-damaged, neglected, or poorly pruned woody plants.
- Identify and remove potential hazard limbs, stems, and deadwood (hazard reduction pruning).
- Line clearance (directional pruning).
- Raise or lower obstructive canopies over or near roads, sidewalks, playgrounds, buildings, pools, satellite dishes, etc. by removing interfering limbs (crown reduction and/or crown raising).
- Provide access to more light for understory plants and turf (crown thinning).
- Vista pruning (alter crowns to allow views of something beyond tree screens).

Pruning Methods and Techniques



Branch Attachment to Stems

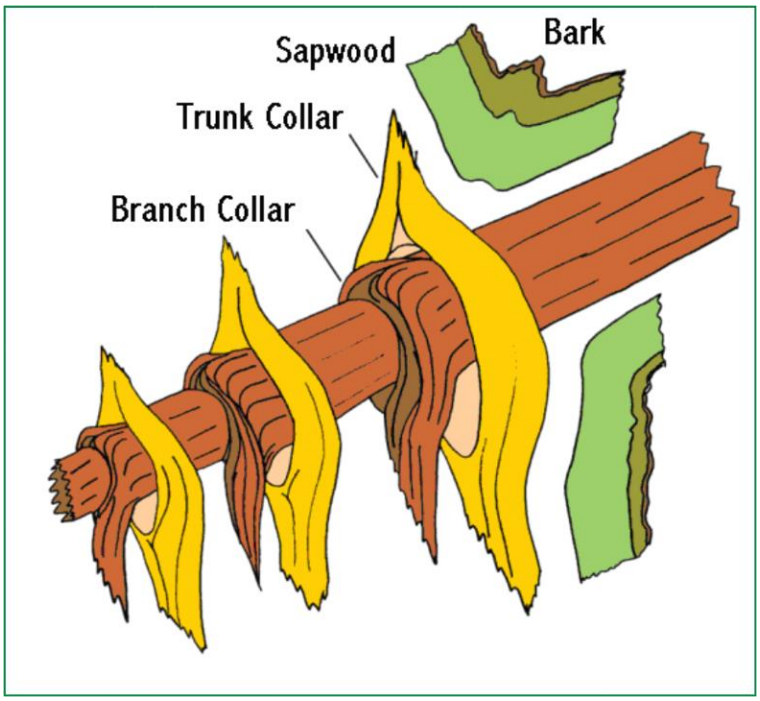
New branch tissues generated by the vascular cambium usually start growth before trunk tissues. As current-year branch tissue develops from branch ends toward the trunk, it turns abruptly downward at the branch base to form a *collar*.

Trunk branch tissues grow later and form a trunk collar over the branch collar (trunk collars and branch collars are collectively called the *branch collar*).

The collar is where wood and bark of the branch and the trunk come together, like an overlapping tissue 'switching zone'. All true branches on woody plants have branch collars.

The *branch bark ridge* (BBR) is raised bark developing in the branch crotch and shows the angle of the branch core in the tree.

If a branch dies or is removed, the trunk collar continues to grow over the thin belt of branch tissue below the collar junction. The wood core of the branch is walled off (compartmentalized) in the trunk.



Proper Pruning Cuts (Natural Target Pruning)

Location of *branch bark ridges* and *branch collars* determines the location of a pruning cut. Cuts must be made *outside* of the branch bark ridge, angling away from the trunk outward as close as possible to the collar.

- There is no set or standard angle for a proper collar cut.
- The proper angle depends on the shape of the collar.
- Conifers often have flat collars where a straight cut close to the collar is correct.
- Sometimes the angle of the cut will necessitate an upstroke cut with a handsaw or chainsaw.

Do not cut into the collar to stimulate callus production and rapid closure. Although closure is desirable for appearance, such a cut promotes decay and future hazards. Never put a pruning tool behind the branch bark ridge.

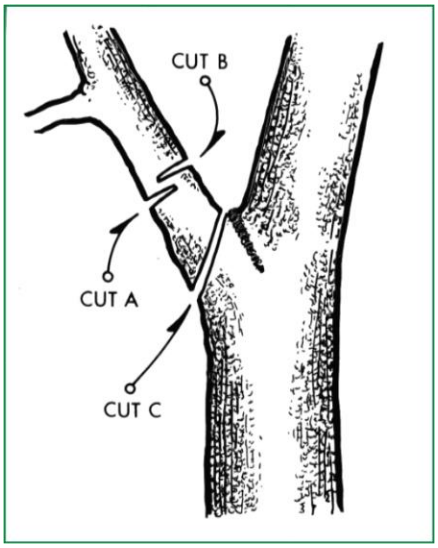
Whether a branch collar is obvious or not, the position of the final or finish cut should:

- Minimize the branch stub that is an entryway for decay fungi.
- Retain the natural decay protection present in the branch core. The intact branch collar is the first line of defense in preventing decay within the trunk.
- Minimize the overall size of the pruning wound and direct damage to the stem.

Always **stub cut** the branch first. Limbs that cannot be controlled must be removed using at least **three** cuts. Roping of limbs may be necessary to prevent damage to other parts of the tree if they cannot be controlled by hand.

- The first cut (Cut A) **undercuts** the limb one or two feet out from the parent branch or trunk. A properly made undercut will eliminate the chance of the branch 'peeling' or tearing bark as it is removed.

- The second cut (Cut B) is the **top cut** which is usually made slightly further out on the limb than the undercut. This allows the limb to drop smoothly when the weight is released.
- The third cut (Cut C) or **finish cut** is to remove the stub.



Each finish cut should be made carefully, outside of the branch bark ridge and the evident collar, leaving a smooth surface with no jagged edges or torn bark.

There are some situations where the cambium dies back beneath a branch collar after a correct cut:

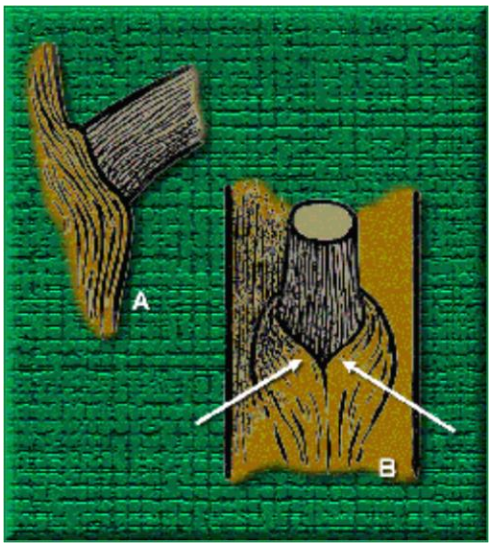
- The trunk collar did not join the branch collar directly below the branch. Sunken spots under branches are a sign of this condition.
- Winter cuts may result in undercollar dieback.
- Problem tends to increase with size of branches removed.

Callus and Woundwood

Callus is undifferentiated meristematic tissue that forms at wound margins from the cambium.

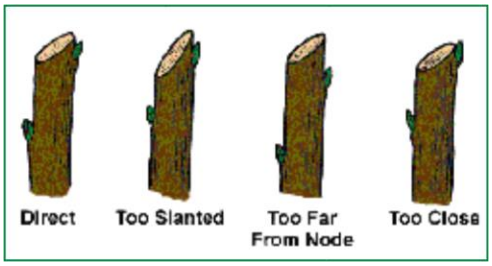
Callus differentiates into *woundwood* over time. Woundwood is 'new wood' and has the different cell components of periderm, cambium, phloem, and xylem.

A *complete* ring of callus and subsequent woundwood will develop around and eventually over proper cuts. Woundwood forms only to the sides of improper cuts (flush cuts), which means the collar and branch protection zone is damaged and the trunk is wounded.



A proper pruning cut results in a smaller wound area, and more rapid callus and woundwood movement over the wound. Cuts on dead limbs that have trunk collars moving up the dead branch wood must also be made just outside of the evident collar.

- Appropriate only for small woody plants or one- to two-year-old branches (twigs, branchlets) on trees.
- Cut back to a bud (lateral bud) or lateral branchlet, slanting at a 45° angle above the bud *node* on alternately arranged branches and stems.
- Two or more buds at a node (opposite, whorled) require a *transverse* cut just above the bud tips or a 45° angle cut, removing one of the buds and leaving the other(s) to elongate in a desired direction.
- Cut 1/8" higher above the bud tips when pruning in cold weather to prevent winter injury to the bud (tissue around a winter cut is more vulnerable to desiccation).



- Leaving a majority of *inward* facing buds produces growth towards center.
- Leaving a majority of *outward* facing buds results in more open growth.

Pruning Tools

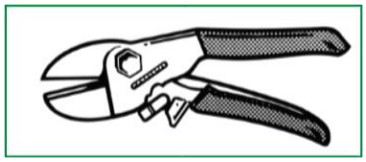
Use **well-sharpened** tools for both your safety and to help reduce tearing of wood and cambial tissues. Wear specified protective equipment.

Pruning Shears

Hand shears, secateurs, hand pruners, one-hand shears:

- Remove branches, stems up to 1/2" diameter.
- By-pass (hook and blade, scissors, drop-forge, curve blade): make closer cuts than anvil-type.

- Anvil (straight-blade): good for only soft-tissued wood; will crush harder wood (inappropriate per A300 standards).



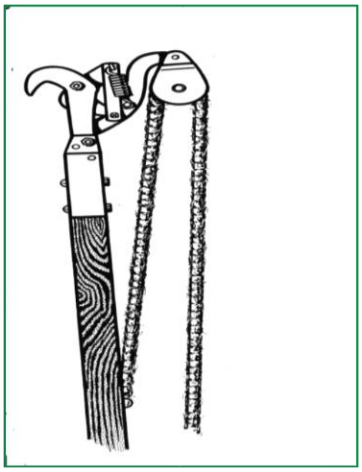
Lopping Shears

Two-hand shears:

- Remove branches, stems up to 1-3/4" diameter.
- Most useful in rejuvenation.
- By-pass, hook, and blade, etc.
- Anvil, straight-blade.
- Ratcheting.

Pole Pruners

- Wood and insulated poles (round and squared).
- Cut like by-pass shears.
- Important to keep blade side in toward the cut.



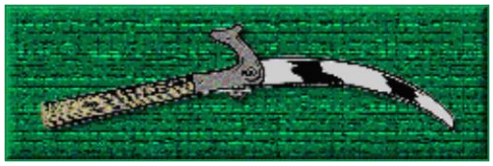
Cut at the outer side of the branch bark ridge at a slightly outward angle so as not to injure or remove the branch collar. Hook the pruner head around the limb to be cut with the blade side against the lateral branch or stem to remain. The arborist must be in a safe working position and the pruner handle positioned so the blade will not jam in the wood. You should not cut off a limb directly above yourself if there is any chance that it could fall and hit you.

Change your working position before completing the cut; place the hook so you have a straight pull on the rope and the lever arm can move far enough to complete the cut. An experienced tree surgeon can give a limb a flip with the side of the pruner head, just as the cut is completed, so that the limb will fall in the desired direction.

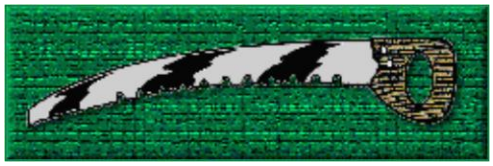
Saws

Pole saws:

- Hook cast onto pole-head.
- Wood poles (round and squared).
- Insulated poles (foam core).
- Difficult to make clean, accurate cuts.



Fine-tooth saw blades (more points per inch):



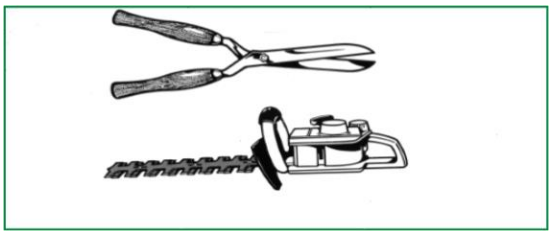
- On folding, rigid, and grip handles.
- *Needlepoint* teeth.
- Razor-tooth, Japanese, or *tri-edge-style teeth* (*Fanno™ 1311, Felco™, Corona™*); narrow, curved blades facilitate getting into tight spots.

Arborist saws cut on the *pull* stroke:

- Davey-issue speed saw.
- Raker and gullet saws.
- Needle-tooth saws Fanno™ series.
- Scabbards, blade lengths.
- Pole saw blades now available with tri-edge teeth.

Hedge Shears

Clippers/trimmers:



- Manual (sometimes called 'pruning' shears).
- Powered (electric, gasoline).
- Cut off growth ‘in line’ with no regard for node locations or branch bark ridges.
- Provide time and labor savings at expense of overall plant health.
- Dull blades compound problems and make you work harder!

Crown Thinning and Cleaning

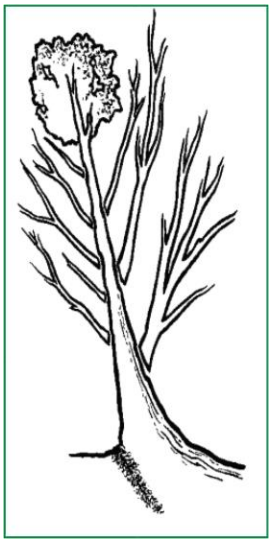
A proper thinning cut removes a branch at its point of attachment, or back to a lateral branch large enough to assume a terminal role.

Learn to foresee the need for removing live branches while they are small. Avoid large cuts. Direction can be influenced by removal of short portions of growth or even by removal of individual buds.

Thinning of lower branches can ‘raise’ a limb. If after crown raising the remaining leaf material is insufficient for limb size, consider complete removal. The client's opinion is important.

Never perform excessive thinning, which is stressful, especially on thin-barked or young trees prone to sunscald.

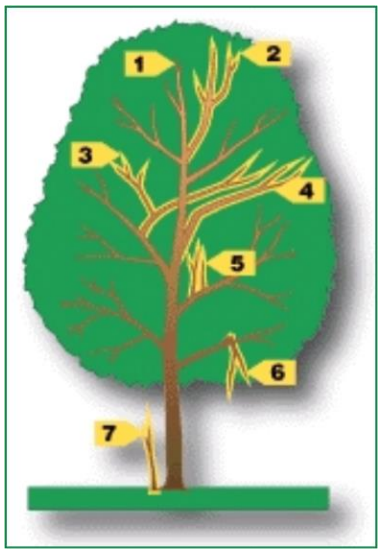
Avoid removing more than 1/4 of the live branches on a tree. Older or overmature trees should have an absolute minimum of living branches removed.

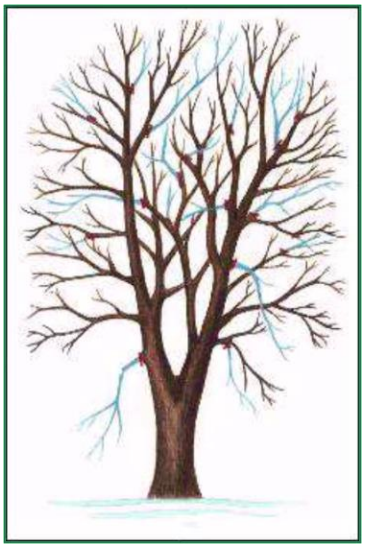


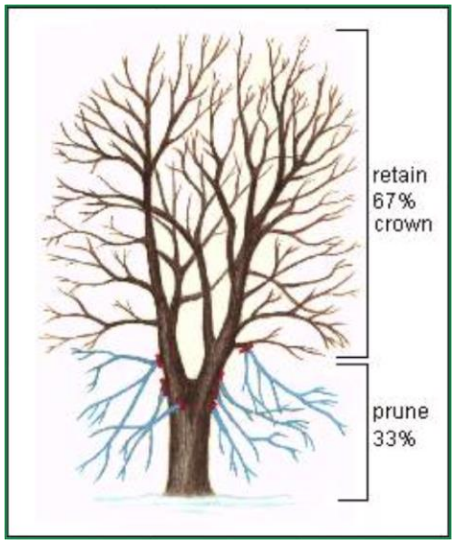
Lion-tailing

Always avoid ‘skinning’ or ‘hollowing' out the center of a tree's canopy. The majority of thinning cuts should be made along the outer crown. Proper thinning requires a good deal of limb-walking and deft use of a pole-pruner when and where aerial lifts are not used.

When thinning laterals from a limb, maintain well-spaced inner branches to achieve more distribution of foliage along the branch.







Caution must be taken to avoid creating an effect known as *lion-tailing*:

- Caused by removing all of the inner laterals and foliage.
- Displaces foliar weight to the ends of the branches.
- May result in sunburned bark tissue, renewed and excessive epicormic branches, weakened branch structure, and breakage.
- Wind whippage.

Removal of Diseased or Insect-Infested Branches

Sanitation or 'eradicative' pruning (crown cleaning):

- Cut out diseased limbs back to collars, appropriate lateral branches, or a scaffold branch at least one foot below infected portion.
- Disinfect tools *during* or *after* pruning diseased branches with bleach solution (1-part bleach to 10-parts water) or Lysol.
- Do not use any form of alcohol to sterilize pruning tools *during* the work. Use alcohol to disinfect auger-bits, injection tees, or pruning tools *after* the job, especially plants with wetwood or fireblight bacterial infections.

Removal of Weak, Rubbing, or Competing Stems

Remove, if possible, but avoid large holes in the canopy.

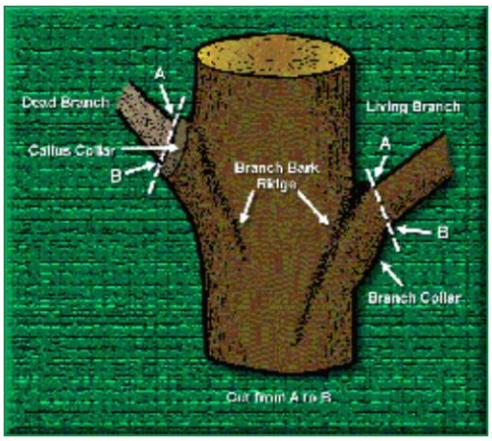
The life of large limbs, weakened by decay or cracks, can often be extended by "shortening" or weight removal using highly selective thinning cuts. Cabling and/or rigid bracing may be required to secure limbs or codominant stems if removal is not possible.

Deadwood Removal

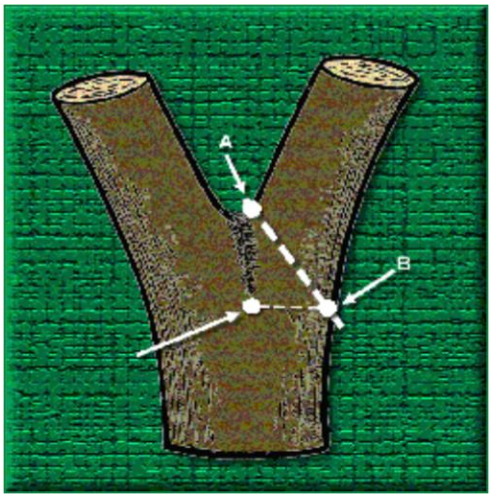
Sanitation and hazard reduction pruning:

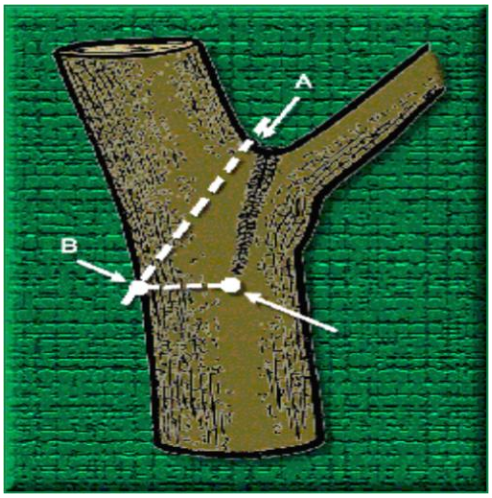
- Dead branches and stubs are an energy source (cellulose, glucose).
- Decay fungi.
- Boring insects.

Again, do not remove the branch collar around dead branches. Cut as close as possible to the collar of good wood surrounding the branch base.



Locate Target Points





Codominant Stem or Branch Removal

Always *stub cut* the stem to be removed, and then make the *finish* cut with care.

Some defect (discoloration) will develop in the remnant stem 'core' in the main stem:

- Usually not attached like a true branch with protective collar.
- Barrier zone should develop and confine defect if correct cut is performed.

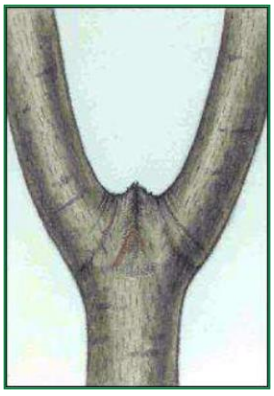
Never remove both stems!

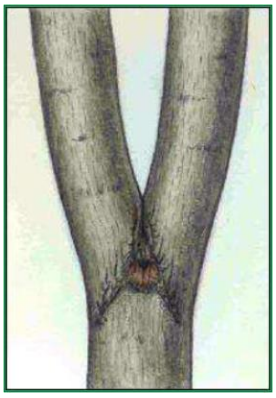
When the bark plates on the stem bark ridge turn upward, the union of the stems is usually *strong.*

When the bark between the stems turns inward, the union of the stems is *weak.*

It is the *union* of the stems or upright branches more than the *angle* that determines whether attachment is weak or strong.

The stems have *included bark* squeezed or embedded *between* them.

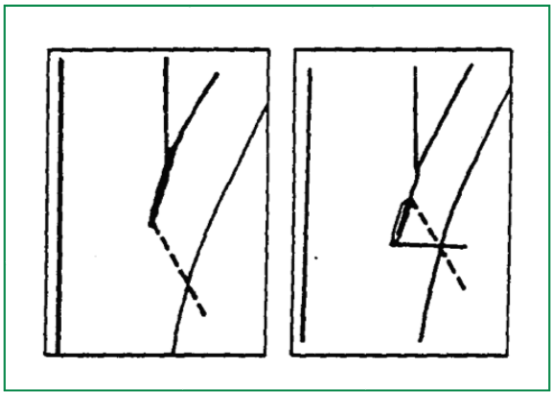




Remedies

To *remove*, stub cut the stem first and then cut where the dotted line is with care; avoid cutting into the remaining stem.

If the saw cannot complete this cut, tap a small wedge into the kerf and cut the remainder of the wood with a flat chisel and mallet.



To *strengthen* stems on older trees, a cable can be attached; place at a point approximately two-thirds of the distance from the crotch to the ends of the stems.

When a cable is used to strengthen stems, the cable and hardware must be checked regularly. When the risk of stem fracture becomes high, the weaker stem should be removed.

Davey Residential Operations employs four general classes of pruning. Classes 1, 2, and 3 are classified as maintenance pruning, which is recommended when the primary objective is to maintain or improve tree health and structure, including hazard reduction pruning:

- Class #1 - *Fine Pruning*: consists of the removal of dead, dying, diseased, interfering, objectionable, and weak branches (crown cleaning), as well as selective thinning to lessen wind resistance. Some deadwood up to ½ inch in diameter may remain within the main leaf area where it is not practical to remove such. Girdling roots will be monitored and removed where possible.
- Class #2 - *Medium Pruning*: consists of the removal of dead, dying, diseased, interfering, objectionable, and weak branches (crown cleaning). Some deadwood up to one inch in diameter may remain within the leaf canopy.
- Class #3 - *Hazard Reduction*: pruning is recommended when the primary objective is to reduce the danger to a specific target, caused by visibly defined hazards in a tree, by removing dead, diseased, or obviously weak branches two inches in diameter or greater.
- Class #4 - *Crown Reduction Pruning*: consists of reducing canopy tops, sides, under branches, or individual limbs at appropriate lateral limbs and stems for purposes of clearance of storm damage repair. Some crown reduction pruning incorporates hazard reduction pruning.

Epicormic Branches

Epicormic branches may be needed to fill in the canopy where trees have been excessively thinned or storm damage has occurred (crown restoration).

Epicormic branches (shoots, watersprouts, suckers) arise from two types of "buds":

- Adventitious buds.
- Latent (dormant) buds or meristematic points.

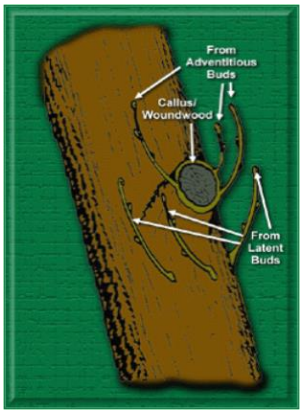
Adventitious epicormics come from meristematic tissue generated anew by the cambium. Most adventitious buds develop from callus tissues moving over a wound, or from root tissue.

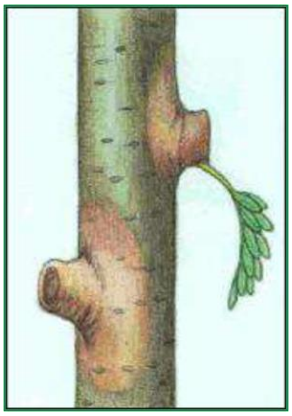
Latent (dormant) buds or *meristematic points* are formed at an earlier time in the life of a woody plant but do not 'release' or grow. Latent buds are 'carried along' in rays in the cambial zone year after year, as the tree increases girth, and are usually released upon injury or stress. Epicormic sprouts from latent meristematic points are often found in the vicinity of pruning cuts, usually below the wound.

Epicormic branches are *stimulated* on a much larger scale by winter or early spring pruning rather than by late spring-summer pruning (desirable in shrub renewal or rejuvenation).

A *watersprout* is an epicormic branch growing from branch and stem parts, or <u>above</u> a graft union.

A *sucker* is an epicormic branch growing from root tissue or <u>below</u> a graft union.





Apical Dominance and Control

Woody plant natural shapes, forms, or habits are governed by species' inherent (genetic) determination of:

- Leaf and flower bud locations.
- Budbreak patterns along stems.
- Branching angles.
- How buds and branches elongate.

Apical dominance = terminal bud(s) suppress lateral buds along an elongating shoot.

Excurrent and *decurrent* branching patterns:

- Decurrent woody plants have overall weak apical control, but strong apical dominance while shoots are elongating.
- Random-branching excurrent plants have weak apical dominance and overall strong apical control.
- Whorl-branching excurrent trees have both strong apical dominance and control.

Excurrent

Decurrent

Plant growth regulators are substances that enhance or alter the growth and development process of a plant. In most cases, these chemicals either increase or decrease normal growth, flowering, and/or fruiting of plants.

Selective growth control and/or branch release by natural growth regulators:

- Auxins
- Abscisic acid (ABA)
- Cytokinins
- Gibberellins (gibberellic acid = GA)
- Ethylene

Branch terminals – auxin source

Roots – cytokinin source

Low auxin = axillary bud release,

High cytokinin energy storage drain

High auxin = bud suppression,

Low cytokinin initiate new roots

Plant growth regulators are substances that enhance or alter the growth and development process of a plant. In most cases, these chemicals either increase or decrease normal growth, flowering, and/or fruiting of plants.

Utility arborists use synthetic growth regulators to *control* the growth of trees and other vegetation beneath utility lines. Growth *inhibitors* can be:

- Sprayed on the foliage.
- Painted on pruning wounds.
- Banded on the bark.
- Soil applied.
- Injected into trees.

Antigibberellins are growth regulators that counter the effects of naturally occurring *cell-elongation* hormones (gibberellin). Ideal formulations are being sought that would minimize phytotoxicity while reducing utilities' pruning expenses.

Another use of growth inhibitors is to suppress epicormic branch production on trees:

- Not yet widely used by arborists.
- Must be applied annually.
- Client concern over the use of chemicals.
- Applicator safety concerns.
- Epicormic branch growth can be minimized with proper cuts.
- Retarded woundwood development.

Painting of Cuts

Proper cuts negate the "need" for wound dressings. Wound dressings will not *prevent* decay; wound dressings have been evaluated to often *promote* wood decay or cause cambium damage.

Cuts or wounds in certain species during the growing season may attract insects that carry diseases or allow fungus invasion. Native oaks or elms and European elms should be pruned during dormant periods in regions where wilt disease conditions are known to exist.

If pruned in summer, pruning wounds on wilt-susceptible oaks and elms should be treated with the current wound dressing recommended by The Davey Institute.

Pruning Phenology

The ideal or optimal times to prune most woody plants are:

- Late in the dormant season.
- After leaves are fully formed and expanded.

Client concerns with excessive *sap flow* (birches, maples):

- Avoid pruning during height of sap flow (just before growing season) if possible.
- Sap flow may be unsightly but does not cause definite injury.
- Prune immediately after leaves are fully expanded if client cannot be convinced.

Avoid pruning birches after leaf expansion, as the wounds may be attractive to boring insects.

Dead, broken, or weak limbs may be removed at any time with little effect, except in wilt-susceptible oaks and elms.

Pruning before the spring leaf budbreak period can enhance stimulated growth and rapid wound closure. Pruning during the period after leaf expansion will result in suppressed growth and maximum ‘dwarfing’.

Avoid pruning those woody plants undergoing budbreak and early leaf expansion, especially in the period where bark ‘slips’ (cambial development of unlignified wood).

Flowering can be reduced or enhanced by pruning at the appropriate time of the year. Woody plants that bloom on current season's growth (‘summer-flowering’ such as crapemyrtle or butterfly-bush) are best pruned to enhance flowering:

- During the dormant season.
- Just prior to or immediately after leaf expansion.
- In late summer (post-bloom).

Plants that bloom on last season's wood ('spring-flowering') should be pruned *just after bloom.*

- Fruit trees are often pruned during the dormant season to enhance structure and distribute fruiting wood, and after bloom to thin fruit-load.

Pruning Selection

Ideal pruning technique begins with planting the right tree in the right place (PHC selection).

Maintaining tree size or allowing for limited crown growth is possible with a regular pruning schedule begun early in the tree's life.

- Consider the extent of mature branches and crown.
- Select good stock with proper growth form.
- Imagine how form will continue to develop; there is no way to turn a large tree back into a small tree.
- Don't expect to improve form with future prunings.

Avoid obtaining saplings with included bark; the stem union becomes weaker rather than stronger as the plant grows. Failure of one or both stems of the fork frequently occurs when the tree is mature, especially during snow and ice storms (loading events).

Structural Pruning

Structural pruning principles are used when training young woody plants or working with a tree that has not been pruned in many years. Properly trained shrubs and young trees will develop into structurally strong plants that should require little corrective pruning as they mature.

Trees that will be large at maturity should have a sturdy, tapered trunk, with well-spaced branches smaller in diameter than the trunk.

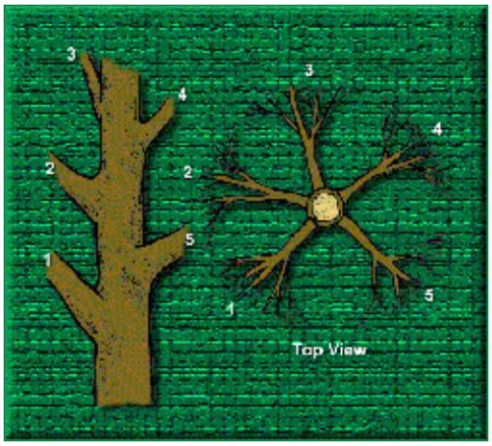
If two branches develop from apical buds at the tip of the same stem, they will form *codominant* branches or, eventually, codominant stems. Each codominant branch is a direct extension of the stem. It is best if one is removed when the tree is young.

Branches with narrow angles of attachment and codominant branches may tend to break if there is *included bark* that gets enclosed inside the crotch as the two branches develop girth and length.

The relative *size* of a branch in relation to the trunk is usually more important for strength of branch attachment than is the *angle* of attachment. Scaffold branches' diameters should not be more than 1/2 the stem or trunk diameter.

Select main branches to give *radial distribution*. Discourage branches growing directly over another unless spaced well apart.

On large-growing trees, except whorl-branching conifers, branches that are more than 1/3 the diameter of the trunk in size should be well spaced along the trunk (at least 18 inches apart).



Maintain one-half the foliage on branches arising in the lower 2/3 of younger trees.

- Increases trunk taper.
- More uniformly distributes weight and wind stress along the trunk.

This rule of thumb also holds true for an individual limb:

- Leave lower and inside branches along the limb.
- Limb can develop taper and strength.
- Stress and weight can be evenly distributed along the length.

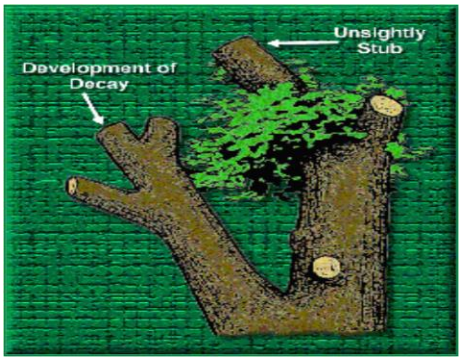
The height of the lowest scaffold branch will depend on the intended function of the tree: screen an unsightly view, provide a windbreak, shade a patio, installed as a walkway or street tree.

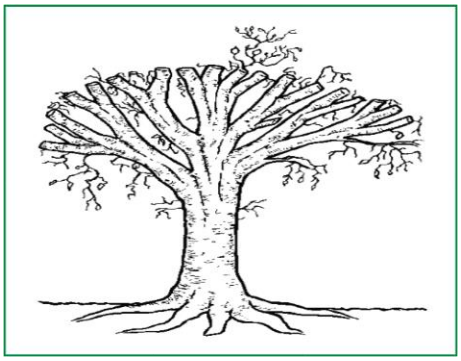
Pruning at Planting

For years, the conventional wisdom was that trees should be severely pruned at time of transplant to compensate for root loss and to "balance" the crown with the root system (especially bare-root trees). This practice has since been discovered to prolong *transplant shock.*

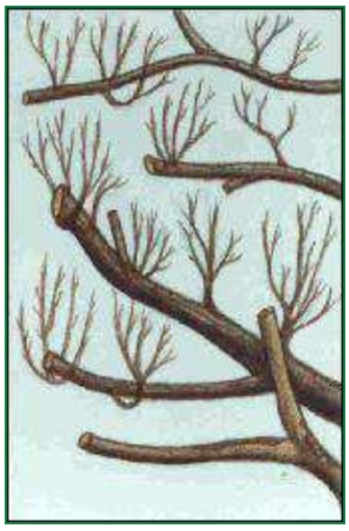
- Transplant pruning should be limited to removal of dead, broken, diseased, or interfering branches.
- Leave small shoots along the trunk for later removal.
- Protect the trunk from ‘sunburn’.
- Aid in development of proper trunk taper.
- Leave as many terminal buds as possible.
- Stimulate root growth triggered by hormones in these buds.

Topping, Tipping, and Roundover

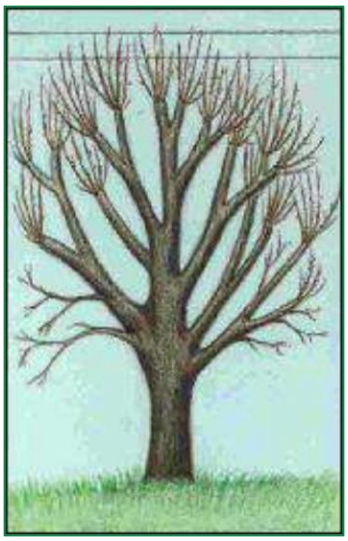




Topping: cutting vertical branches and stems back to inadequate nodes (heading) or to internodes (stubbing).



Tipping: heading side or horizontal branches to stubs or weak laterals.



Roundover: topping + tipping.

Many people have the misconception that cutting or heading the main branches of a tree back to stubs to 'reduce the height' is the proper way to prune.

Apparently, a short tree is thought to be safer and healthier than a tall tree regardless of how the result is attained. Heading back to stubs or inadequate laterals permanently disfigures and weakens a tree. Topping is one of the worst things humans do to trees.

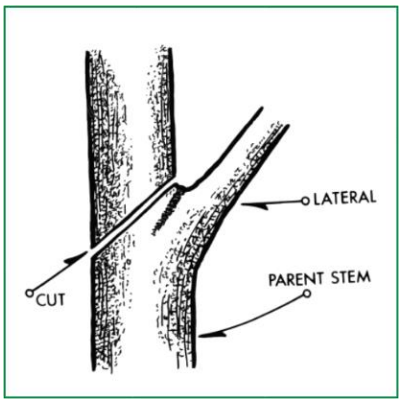
The International Society of Arboriculture (ISA) and the National Arborist Association (NAA) consider heading-back to stubs an unacceptable arboricultural practice. Modern pruning standards do not include heading-back as any sort of a recommended technique.

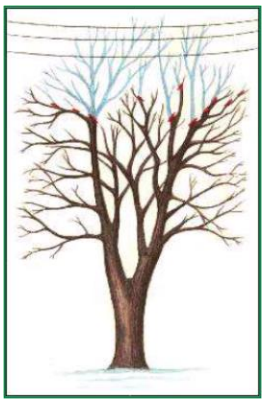
- Topping removes a major portion of a tree's leaves that are necessary for the production of carbohydrates.
- Stimulation of epicormic branches at or just below an internodal stub cut causes a topped tree to grow back to its original height faster and denser than a properly pruned tree. The sprouts are weakly attached and easily broken off in storms.
- Bark within the canopy can become scalded by sudden exposure to direct sunlight.
- Stubs attract wood-boring insects and sustain wood decay organisms.
- Topping, tipping, and roundover cuts permanently disfigure a tree.

Crown Reduction, Restoration, and Raising

If the height or width of a tree has to be reduced because of storm damage or interference with structures or utility lines, it is performed correctly by a method called *crown reduction* or *drop-crotch* pruning (NAA Class IV Crown Reduction). This procedure involves the removal of a main leader, scaffold, or branch at its point of attachment with a lateral branch large enough to assume a terminal or leader role.

The final cut should begin or end somewhat *parallel* to the remaining lateral branch and offset slightly above the branch bark ridge (without cutting into the bark ridge). The remaining lateral branch must be at least one-half to one-third the diameter of the branch or leader that is being removed.





If a tree has been topped previously and now has epicormic sprouts, crown restoration can improve its structure and appearance. Decayed, rotting stubs, and tipped branches are cut back to appropriate laterals or entirely removed. One to three sprouts on main branch stubs are retained to become permanent branches and reform a more natural appearing crown. Selected epicormic branches may need to be thinned to a lateral to control length and ensure adequate attachment for the size of the sprout. Restoration usually requires several prunings over a number of years.

Trees in urban and landscape settings may need to have lower limbs removed. *Crown raising* or elevating removes the lower branches of a tree in order to provide clearance for buildings, vehicles, pedestrians, and vistas. Excessive removal of lower limbs should be avoided so that the development of trunk taper is not affected and structural stability is maintained.

Additional Recommendations

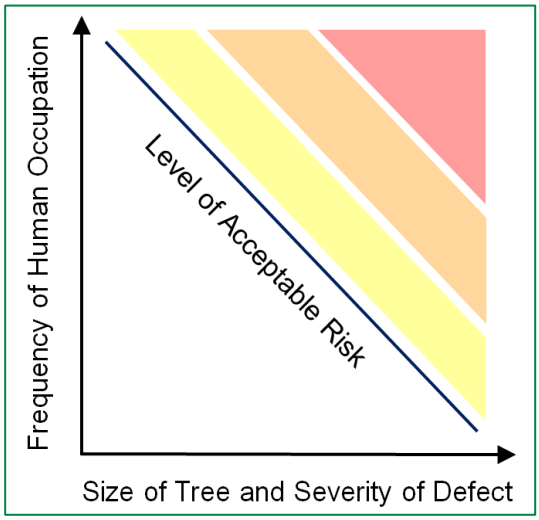
- The costs for treating deficient trees must be considered to determine whether removing and replacing the tree is the more viable option.
- Dead trees and trees in Critical condition should be removed because of their failed health; these trees will likely not recover, even with increased care.
- Tree canopy should not interfere with vehicular or pedestrian traffic, nor should it rest on buildings or block signs, signals, or lights. Pruning to avoid clearance issues and raise tree crowns should be completed in accordance with ANSI A300 (Part 9) (2011). Davey Resource Group's clearance distance guidelines are as follows: 14 feet over streets; 8 feet over sidewalks; and 5 feet from buildings, signs, signals, or lights.
- Extreme and High Risk trees should be removed or pruned immediately to promote public safety. Low and Moderate Risk trees should be addressed after all elevated risk tree maintenance has been completed.
- Poor condition among mature trees were generally due to visible signs of decline and stress, including decay, dead limbs, sparse branching, or poor structure. These trees will require corrective pruning, regular inspections, and possible intensive plant health care to improve their vigor.

Long-Term Tree Care

Multiple entities including natural decline and insects & disease pose serious threats to long-term tree health. Awareness and early diagnosis are essential to ensuring the health and continuity of street and park trees. Proper risk assessment methodology and information about some of the current potential threats to Columbia's trees will serve to help mitigate some of these threats.

Risk Assessment

Every tree has an inherent risk of tree failure or defective tree part failure. During the inventory, DRG performed a Level 2 qualitative risk assessment for each tree and assigned a risk rating based on the ANSI A300 (Part 9), and the companion publication *Best Management Practices: Tree Risk Assessment* (ISA 2011). Trees can have multiple failure modes with various risk ratings. One risk rating per tree will be assigned during the inventory. The failure mode having the greatest risk will serve as the overall tree risk rating. The specified time period for the risk assessment is one year.



- **Likelihood of Failure**—Identifies the most likely failure and rates the likelihood that the structural defect(s) will result in failure based on observed, current conditions.
  - Improbable—The tree or branch is not likely to fail during normal weather conditions and may not fail in many severe weather conditions within the specified time period.
  - Possible—Failure could occur but is unlikely during normal weather conditions within the specified time period.
  - Probable—Failure may be expected under normal weather conditions within the specified time period.
- **Likelihood of Impacting a Target**—The rate of occupancy of targets within the target zone and any factors that could affect the failed tree as it falls towards the target.
  - Very low—The chance of the failed tree or branch impacting the target is remote.
    - Rarely used sites
    - Examples include rarely used trails or trailheads
    - Instances where target areas provide protection
  - Low—It is not likely that the failed tree or branch will impact the target.
    - Occasional use area fully exposed to tree
    - Frequently used area partially exposed to tree
    - Constant use area that is well protected
  - Medium—The failed tree or branch may or may not impact the target.
    - Frequently used areas that are partially exposed to the tree on one side
    - Constantly occupied area partially protected from the tree
  - High—The failed tree or branch will most likely impact the target.
    - Fixed target is fully exposed to the tree or tree part

- **Categorizing Likelihood of Tree Failure Impacting a Target**—The likelihood for failure and the likelihood of impacting a target are combined in the matrix below to determine the likelihood of tree failure impacting a target.

Likelihood of Failure	Likelihood of Impacting Target			
	Very Low	Low	Medium	High
Imminent	Unlikely	Somewhat likely	Likely	Very Likely
Probable	Unlikely	Unlikely	Somewhat likely	Likely
Possible	Unlikely	Unlikely	Unlikely	Somewhat likely
Improbable	Unlikely	Unlikely	Unlikely	Unlikely

- **Consequence of Failure**—The consequences of tree failure are based on the categorization of target and potential harm that may occur. Consequences can vary depending upon size of defect, distance of fall for tree or limb, and any other factors that may protect a target from harm. Target values are subjective and should be assessed from the client's perspective.
  - Negligible—Consequences involve low value damage and do not involve personal injury.
    - Small branch striking a fence
    - Medium-sized branch striking a shrub bed
    - Large tree part striking structure and causing monetary damage
    - Disruption of power to landscape lights
  - Minor—Consequences involve low to moderate property damage, small disruptions to traffic or communication utility, or very minor injury.
    - Small branch striking a house roof from a high height
    - Medium-sized branch striking a deck from a moderate height
    - Large tree part striking a structure, causing moderate monetary damage
    - Short-term disruption of power at service drop to house
    - Temporary disruption of traffic on neighborhood street
  - Significant—Consequences involve property damage of moderate to high value, considerable disruption, or personal injury.
    - Medium-sized part striking a vehicle from a moderate or high height
    - Large tree part striking a structure resulting in high monetary damage
    - Disruption of distribution of primary or secondary voltage power lines, including individual services and street-lighting circuits
    - Disruption of traffic on a secondary street
  - Severe—Consequences involve serious potential injury or death, damage to high-value property, or disruption of important activities.
    - Injury to a person that may result in hospitalization
    - Medium-sized part striking an occupied vehicle
    - Large tree part striking an occupied house
    - Serious disruption of high-voltage distribution and transmission power line disruption of arterial traffic or motorways

- **Risk Rating**—The overall risk rating of the tree will be determined based on combining the likelihood of tree failure impacting a target and the consequence of failure in the matrix below.

Likelihood of Failure	Consequences			
	Negligible	Minor	Significant	Severe
Very likely	Low	Moderate	High	Extreme
Likely	Low	Moderate	High	High
Somewhat likely	Low	Low	Moderate	Moderate
Unlikely	Low	Low	Low	Low

Trees have the potential to fail in more than one way and can affect multiple targets.

Tree risk assessors will identify the tree failure mode having the greatest risk, and report that as the tree risk rating. Generally, trees with the highest qualitative risk ratings should receive corrective treatment first. The following risk ratings will be assigned:

- None—Used for planting and stump sites only.
- Low—The Low Risk category applies when consequences are "negligible" and likelihood is "unlikely"; or consequences are "minor" and likelihood is "somewhat likely." Some trees with this level of risk may benefit from mitigation or maintenance measures, but immediate action is not usually required.
- Moderate—The Moderate Risk category applies when consequences are "minor" and likelihood is "very likely" or "likely"; or likelihood is "somewhat likely" and consequences are "significant" or "severe." In populations of trees, Moderate Risk trees represent a lower priority than High or Extreme Risk trees.
- High—The High Risk category applies when consequences are "significant" and likelihood is "very likely" or "likely," or consequences are "severe" and likelihood is "likely." In a population of trees, the priority of High Risk trees is second only to Extreme Risk trees.
- Extreme—The Extreme Risk category applies in situations where tree failure is imminent and there is a high likelihood of impacting the target, and the consequences of the failure are "severe." In some cases, this may mean immediate restriction of access to the target zone area to avoid injury to people.

Trees with elevated (Extreme or High) risk levels are usually recommended for removal or pruning to eliminate the defects that warranted their risk rating. However, in some situations, risk may be reduced by adding support (cabling or bracing) or by moving the target away from the tree. DRG recommends only removal or pruning to alleviate risk. But in special situations, such as a memorial tree or a tree in a historic area, Manchester may decide that cabling, bracing, or moving the target may be the best option for reducing risk.

Determination of acceptable risk ultimately lies with city managers. Since there are inherent risks associated with trees, the location of a tree is an important factor in the determination and acceptability of risk for any given tree. The level of risk associated with a tree increases as the frequency of human occupation increases in the vicinity of the tree. For example, a tree located next to a heavily traveled street will have a higher level of risk than a similar tree in an open field.

Priority Maintenance

Identifying and ranking the maintenance needs of a tree population enables tree work to be assigned priority based on observed risk. Once prioritized, tree work can be systematically addressed to eliminate the greatest risk and liability first (Stamen 2011).

Risk is a graduated scale that measures potential tree-related hazardous conditions. A tree is considered hazardous when its potential risks exceed an acceptable level. Managing trees for risk reduction provides many benefits, including:

- Lower frequency and severity of accidents, damage, and injury
- Less expenditure for claims and legal expenses
- Healthier, long-lived trees
- Fewer tree removals over time
- Lower tree maintenance costs over time

Regularly inspecting trees and establishing tree maintenance cycles generally reduce the risk of failure, as problems can be found and addressed before they escalate.

In this plan, all tree removals and Extreme and High Risk prunes are included in the priority maintenance program.

Proactive Maintenance

Proactive tree maintenance requires that trees are managed and maintained under the responsibility of an individual, department, or agency. Tree work is typically performed during a cycle. Individual tree health and form are routinely addressed during the cycle. When trees are planted, they are planted selectively and with purpose. Ultimately, proactive tree maintenance should reduce crisis situations in the community forest, as every tree in the inventoried population is regularly visited, assessed, and maintained. DRG recommends proactive tree maintenance that includes pruning cycles, inspections, and planned tree planting.

Further Inspection

Inspections are essential to uncovering potential problems with trees. They should be performed by a qualified arborist who is trained in the art and science of planting, caring for, and maintaining individual trees. Arborists are knowledgeable about the needs of trees and are trained and equipped to provide proper care.

Perform Level III risk inspections, as needed, in accordance with ANSI A300, Part 9 (ANSI, 2011), or periodic inspection due to particular conditions that may cause it to be a safety risk and, therefore, hazardous.

An ISA-Certified Arborist should perform additional inspections. If it is determined that these trees exceed the threshold for acceptable risk, the defective part(s) of the trees should be corrected or removed, or the entire tree may need to be removed.

Insect and Disease Diagnosis

Many pests target a single species or an entire genus. Assess and update inventory data to provide a general estimate of the percentage of trees susceptible to some of the known pests in Missouri. Many more trees throughout Columbia, including those on public and private property, may be susceptible to pests.

In today's worldwide marketplace, the volume of international trade brings increased potential for pests and diseases to invade our country. Many of these pests and diseases have seriously harmed rural and urban landscapes and have caused billions of dollars in lost revenue and millions of dollars in clean-up costs. Keeping these pests and diseases out of the country is the number one priority of the United States Department of Agriculture's (USDA) Animal and Plant Inspection Service (APHIS).

Although some invasive species enter the United States naturally via wind, ocean currents, and other means, most enter with some help from human activities. Their introduction to our country is a byproduct of cultivation, commerce, tourism, and travel. Many species enter the United States each year in baggage, cargo, contaminants of commodities, or mail.

Once they arrive, hungry pests grow and spread rapidly because controls, such as native predators, are lacking. Invasive pests disrupt the landscape by pushing out native species, reducing biological diversity, killing trees, altering wildfire intensity and frequency, and damaging crops. Some pests may even push species to extinction. The following sections include key pests and diseases that adversely affect trees in America at the time of this plan's development. This list is not comprehensive and may not include all threats.

It is critical to the management of community trees to routinely check APHIS, USDA Forest Service, and other websites for updates about invasive species and diseases in your area and in our country so you can be prepared to combat their attack.

Asian Longhorned Beetle

The Asian longhorned beetle (ALB, *Anoplophora glabripennis*) is an exotic pest that threatens a wide variety of hardwood trees in North America. The beetle was introduced in Chicago, New Jersey, and New York City, and is believed to have been introduced in the United States from wood pallets and other wood-packing material accompanying cargo shipments from Asia. ALB is a serious threat to America's hardwood tree species.

Adult Asian longhorned beetle
Photograph courtesy of New Bedford Guide 2011

Adults are large (3/4- to 1/2-inch long) with very long, black and white banded antennae. The body is glossy black with irregular white spots. Adults can be seen from late spring to fall depending on the climate. ALB has a long list of host species; however, the beetle prefers hardwoods, including several maple species. Examples include: *Acer negundo* (box elder); *A. platanoides* (Norway maple); *A. rubrum* (red maple); *A. saccharinum* (silver maple); *A. saccharum* (sugar maple); *Aesculus glabra* (buckeye); *A. hippocastanum* (horsechestnut), *Betula* (birch), *Platanus* × *acerifolia* (London planetree), *Salix* (willow), and *Ulmus* (elm).

Dutch Elm Disease

Considered by many to be one of the most destructive, invasive diseases of shade trees in the United States, Dutch elm disease (DED) was first found in Ohio in 1930; by 1933, the disease was present in several East Coast cities. By 1959, it had killed thousands of elms. Today, DED covers about two-thirds of the eastern United States, including Illinois, and annually kills many of the remaining and newly planted elms. The disease is caused by a fungus that attacks the vascular system of elm trees blocking the flow of water and nutrients, resulting in rapid leaf yellowing, tree decline, and death.

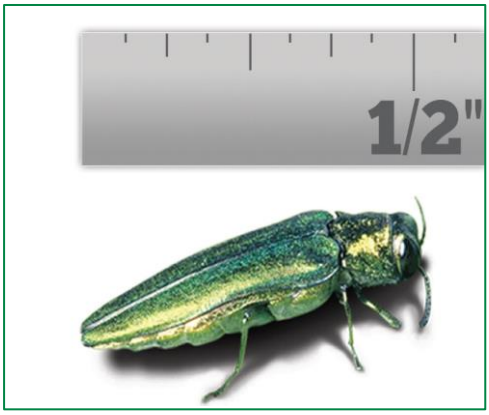
Branch death, or flagging, at multiple locations in the crown of a diseased elm
Photograph courtesy of Steven Katovich, USDA Forest Service, Bugwood.org (2011)

There are two closely-related fungi that are collectively referred to as DED. The most common is *Ophiostoma novo-ulmi*, which is thought to be responsible for most of the elm deaths since the 1970s. The fungus is transmitted to healthy elms by elm bark beetles. Two species carry the fungus: native elm bark beetle (*Hylurgopinus rufipes*) and European elm bark beetle (*Scolytus multistriatus)*.

The species most affected by DED is the *Ulmus americana* (American elm).

Emerald Ash Borer

Emerald ash borer *(EAB) (Agrilus planipennis*) is responsible for the death or decline of tens of millions of ash trees in 14 states in the American Midwest and Northeast. Native to Asia, EAB has been found in China, Japan, Korea, Mongolia, eastern Russia, and Taiwan. It likely arrived in the United States hidden in wood-packing materials commonly used to ship consumer goods, auto parts, and other products. The first official United States identification of EAB was in southeastern Michigan in 2002.



Close-up of the emerald ash borer
Photograph courtesy of APHIS (2011)

Adult beetles are slender and 1/2-inch long. Males are smaller than females. Color varies but adults are usually bronze or golden green overall with metallic, emerald-green wing covers. The top of the abdomen under the wings is metallic, purplish-red and can be seen when the wings are spread.

The EAB-preferred host tree species are in the genus *Fraxinus* (ash).

Gypsy Moth

The gypsy moth (GM) *(Lymantria dispar*) is native to Europe and first arrived in the United States in Massachusetts in 1869. This moth is a significant pest because its caterpillars have voracious appetites for more than 300 species of trees and shrubs. GM caterpillars defoliate trees, which makes them vulnerable to diseases and other pests that can eventually kill the tree.

Close-up of male (darker brown) and female (whitish color) European gypsy moths
Photograph courtesy of APHIS (2011b)

Male GMs are brown with a darker brown pattern on their wings and have a 1/2-inch wingspan. Females are slightly larger with a 2-inch wingspan and are nearly white with dark, saw-toothed patterns on their wings. Although they have wings, the female GM cannot fly.

The GMs prefer approximately 150 primary hosts but feed on more than 300 species of trees and shrubs. Some trees are found in these common genera: *Betula* (birch), *Juniperus* (cedar), *Larix* (larch), *Populus* (aspen, cottonwood, poplar), *Quercus* (oak), and *Salix* (willow).

Granulate Ambrosia Beetle

The granulate ambrosia beetle (*Xylosandrus crassiusculus*), formerly the Asian ambrosia beetle, was first found in the United States in 1974 on peach trees near Charleston, South Carolina. The native range of the granulate ambrosia beetle is probably tropical and subtropical Asia. The beetle is globally present in countries such as equatorial Africa, Asia, China, Guinea, Hawaii, India, Japan, New South Pacific, Southeast Indonesia, Sri Lanka, and the United States. In the United States, this species has spread along the lower Piedmont region and coastal plain to East Texas, Florida, Louisiana, and North Carolina. Populations were found in Oregon and Virginia in 1992, and in Indiana in 2002.

Adult granulate ambrosia beetle
Photograph courtesy of Paul M. Choate, University of Florida (Atkinson et al. 2011)

Adults are small and have a reddish-brown appearance with a downward facing head. Most individuals have a reddish head region and a dark-brown to black elytra (hard casings protecting the wings). Light-colored forms that appear almost yellow have also been trapped. A granulated (rough) region is located on the front portion of the head and long setae (hairs) can be observed on the back end of the wing covers. Females are 2–2.5mm and males are 1.5mm long. Larvae are C-shaped with a defined head capsule.

The granulate ambrosia beetle is considered an aggressive species and can attack trees that are not highly stressed. It is a potentially serious pest of ornamentals and fruit trees and is reported to be able to infest most trees and some shrubs (azalea, rhododendron) but not conifers. Known hosts in the United States include: *Acer* (maple); *Albizia* (albizia); *Carya* (hickory); *Cercis canadensis* (eastern redbud); *Cornus* (dogwood); *Diospyros* (persimmon); *Fagus* (beech); *Gleditsia* or *Robinia* (locust); *Juglans* (walnut); *Koelreuteria* (goldenrain tree); *Lagerstroemia* (crapemyrtle); *Liquidambar styraciflua* (sweetgum); *Liriodendron tulipifera* (tulip poplar); *Magnolia* (magnolia); *Populus* (aspen); *Prunus* (cherry); *Quercus* (oak); and *Ulmus parvifolia* (Chinese elm). *Carya illinoinensis* (pecan) and *Pyrus calleryana* (Bradford pear) are commonly attacked in Florida and in the southeastern United States.

Xm Ambrosia Beetle

The Xm ambrosia beetle (*Xylosandrus mutilatus*), is native to Asia and was first detected in the United States in 1999 in traps near Starkville, Mississippi. By 2002, the beetle spread throughout Missouri and quickly became well-established in Florida. The species also has been found in Alabama, northern Georgia, and Texas. In addition to its prevalence in the southeastern United States, the Xm ambrosia beetle is currently found in China, India, Indonesia, Japan, Korea, Malaya, Myanmar, Papua New Guinea, Sri Lanka, Taiwan, and Thailand.

Xm ambrosia beetle
Photograph courtesy of Michael C. Thomas, Florida Department of Agriculture and Consumer Services (Rabaglia et al 2003)

This species generally targets weakened and dead trees. Since the beetle attacks small diameter material, it may be commonly transported in nursery stock. Female adults are prone to dispersal by air currents and can travel 1–3 miles in pursuit of potential hosts. This active capability results in a broad host range and high probability of reproduction. The species is larger than any other species of *Xylosandrus* (greater than 3 millimeters) in the U.S. and is easily recognized by its steep declivity and dark brown to black elytra (hard casings protecting the wings). Larvae are white and c-shaped with an amber colored head capsule.

Known hosts in the U.S. include: *Acer* (maple); *Albizia* (silktree); *Benzoin* (northern spicebush); *Camellia* (camellia); *Carpinus laxiflora* (looseflower hornbeam); *Castanae* (sweet chestnut); *Cinnamomum camphora* (camphor tree); *Cornus* (dogwood); *Cryptomeria japonica* (Japanese cedar); *Fagus crenata* (Japanese beech); *Lindera erythrocarpa* (spicebush); *Machilus thurnbergii* (Japanese persea); *Ormosia hosiei* (ormosia); *Osmanthus fragrans* (sweet osmanthus); *Parabezion praecox*; *Platycarpa*; and *Sweitenia macrophylla* (mahogany).

Hemlock Woolly Adelgid

The hemlock woolly adelgid (HWA, *Adelges tsugae*) was first described in western North America in 1924 and first reported in the eastern United States in 1951 near Richmond, Virginia.

In their native range, populations of HWA cause little damage to the hemlock trees, as they feed on natural enemies and possible tree resistance has evolved with this insect. In eastern North America and in the absence of natural control elements, HWA attacks both *Tsuga canadensis* (eastern or Canadian hemlock) and *T. caroliniana* (Carolina hemlock), often damaging and killing them within a few years of becoming infested.

The HWA is now established from northeastern Georgia to southeastern Maine and as far west as eastern Kentucky and Tennessee.

Hemlock woolly adelgids on a branch

Photograph courtesy of USDA Forest Service (2011a)

Oak Wilt

Oak wilt was first identified in 1944 and is caused by the fungus *Ceratocystis fagacearum*. While considered an invasive and aggressive disease, its status as an exotic pest is debated since the fungus has not been reported in any other part of the world. This disease affects the oak genus and is most devastating to those in the red oak subgenus, such as *Quercus coccinea* (scarlet oak), *Q. imbricaria* (shingle oak), *Q. palustris* (pin oak), *Q. phellos* (willow oak), and *Q. rubra* (red oak). It also attacks trees in the white oak subgenus, although it is not as prevalent and spreads at a much slower pace in these trees.

Oak wilt symptoms on red and white oak leaves

Photograph courtesy of USDA Forest Service (2011a)

Just as with DED, oak wilt disease is caused by a fungus that clogs the vascular system of oaks and results in decline and death of the tree. The fungus is carried from tree to tree by several borers common to oaks, but the disease is more commonly spread through root grafts. Oak species within the same subgenus (red or white) will form root colonies with grafted roots that allow the disease to move readily from one tree to another.

Pine Shoot Beetle

The pine shoot beetle (*Tomicus piniperda L.*), a native of Europe, is an introduced pest of *Pinus* (pine) in the United States. It was first discovered in the United States at a Christmas tree farm near Cleveland, Ohio in 1992. Following the first detection in Ohio, the beetle has been detected in parts of 19 states (Connecticut, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, and Wisconsin).

The beetle attacks new shoots of pine trees, stunting the growth of the trees. The pine shoot beetle may also attack stressed pine trees by breeding under the bark at the base of the trees. The beetles can cause severe decline in the health of the trees and, in some cases, kill the trees when high populations exist.

Mined shoots on a Scotch pine

Photograph courtesy of USDA Forest Service

Adult pine shoot beetles range from 3 to 5 millimeters long, or about the size of a match head. They are brown or black and cylindrical. The legless larvae are about 5 millimeters long with a white body and brown head. Egg galleries are 10–25 centimeters long. From April to June, larvae feed and mature under the pine bark in separate feeding galleries that are 4–9 centimeters long. When mature, the larvae stop feeding, pupate, and then emerge as adults. From July through October, adults tunnel out through the bark and fly to new or 1-year-old pine shoots to begin maturation feeding. The beetles enter the shoot 15 centimeters or less from the shoot tip and move upwards by hollowing out the center of the shoot for a distance of 2.5–10 centimeters. Affected shoots droop, turn yellow, and eventually fall off during the summer and fall.

P. sylvestris (Scots pine) is preferred, but other pine species, including *P. banksiana* (jack pine), *nigra* (Austrian pine),*P. resinosa* (red pine), and *P. strobus* (eastern white pine), have been infested in the Great Lakes region.

Sirex Woodwasp

Sirex woodwasp (*Sirex noctillio*) has been the most common species of exotic woodwasp detected at United States ports-of-entry associated with solid wood-packing materials. Recent detections of sirex woodwasp outside of port areas in the United States have raised concerns because this insect has the potential to cause significant mortality of pines. Awareness of the symptoms and signs of a sirex woodwasp infestation increases the chance of early detection, thus increasing the rapid response needed to contain and manage this exotic forest pest.

Close-up of female Sirex Woodwasp

Photograph courtesy of USDA (2005)

Woodwasps (or horntails) are large robust insects, usually 1.0 to 1.5 inches long. Adults have a spear-shaped plate (cornus) at the tail end; in addition, females have a long ovipositor under this plate. Larvae are creamy white, legless, and have a distinctive dark spine at the rear of the abdomen. More than a dozen species of native horntails occur in North America.

Sirex woodwasps can attack living pines, while native woodwasps attack only dead and dying trees. At low populations, sirex woodwasp selects suppressed, stressed, and injured trees for egg laying. Foliage of infested trees initially wilts, and then changes color from dark green to light green, to yellow, and finally to red, during the three to six months following attack. Infested trees may have resin beads or dribbles at the egg laying sites, but this is more common at the mid-bole level. Larval galleries are tightly packed with very fine sawdust. As adults emerge, they chew round exit holes that vary from 1/8 to 3/8 inch in diameter.

Southern Pine Beetle

The southern pine beetle (SPB, *Dendroctonus frontalis*) is the most destructive insect pest of pine in the southern United States. It attacks and kills all species of southern yellow pines including *P. strobus* (eastern white pine). Trees are killed when beetles construct winding, S-shaped egg galleries underneath the bark. These galleries effectively girdle the tree and destroy the conductive tissues that transport food throughout the tree. Furthermore, the beetles carry blue staining fungi on their bodies that clog the water conductive tissues (wood), which transport water within the tree. Signs of attack on the outside of the tree are pitch tubes and boring dust, known as frass, caused by beetles entering the tree.

Adult southern pine beetles
Photograph courtesy of Forest Encyclopedia Network (2012)

Adult SPBs reach an ultimate length of only 1/8 inch, similar in size to a grain of rice. They are short-legged, cylindrical, and brown to black in color. Eggs are small, oval-shaped, shiny, opaque, and pearly white.

Sudden Oak Death

The causal agent of sudden oak death (SOD, also known as *Phytophthora* canker disease), *Phytophthora ramorum*, was first identified in 1993 in Germany and the Netherlands on ornamental rhododendrons. In 2000, the disease was found in California. Since its discovery in North America, SOD has been confirmed in forests in California and Oregon and in nurseries in British Columbia, California, Oregon, and Washington. SOD has been potentially introduced into other states through exposed nursery stock. Through ongoing surveys, APHIS continues to define the extent of the pathogen's distribution in the United States and limit its artificial spread beyond infected areas through quarantine and a public education program.

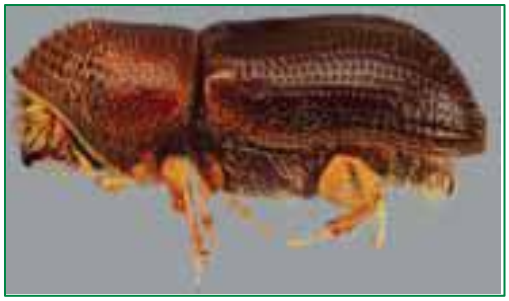
Drooping tanoak shoot
Photograph courtesy of Indiana Department of Natural Resources (2012)

Identification and symptoms of SOD may include large cankers on the trunk or main stem accompanied by browning of leaves. Tree death may occur within several months to several years after initial infection. Infected trees may also be infested with ambrosia beetles (*Monarthrum dentiger* and *M. scutellarer*), bark beetles (*Pseudopityophthorus pubipennis*), and sapwood rotting fungus (*Hypoxylon thouarsianum*). These organisms may contribute to the death of the tree. Infection on foliar hosts is indicated by dark grey to brown lesions with indistinct edges. These lesions can occur anywhere on the leaf blade, in vascular tissue, or on the petiole. Petiole lesions are often accompanied by stem lesions. Some hosts with leaf lesions defoliate and eventually show twig dieback.

This pathogen is devastating to *Quercus* (oaks) but also affects several other plant species.

Thousand Cankers Disease

A complex disease referred to as Thousand Cankers disease (TCD) was first observed in Colorado in 2008 and is now thought to have existed in Colorado as early as 2003. TCD is considered to be native to the United States and is attributed to numerous cankers developing in association with insect galleries.



Walnut twig beetle, side view
Photograph courtesy of USDA Forest Service (2011b)

TCD results from the combined activity of the *Geosmithia morbida* fungus and the walnut twig beetle (WTB, *Pityophthorus juglandis*). The WTB has expanded both its geographical and host range over the past two decades, and coupled with the *Geosmithia morbida* fungus, *Juglans* (walnut) mortality has manifested in Arizona, California, Colorado, Idaho, New Mexico, Oregon, Utah, and Washington. In July 2010, TCD was reported in Knoxville, Tennessee. The infestation is believed to be at least 10 years old and was previously attributed to drought stress. This is the first report east of the 100th meridian, raising concerns that large native populations of *J. nigra* (black walnut) in the eastern United States may suffer severe decline and mortality.

CITY OF COLUMBIA, MISSOURI

PUBLIC WORKS DEPARTMENT

Right of Way Tree Planting Permit Application

Date: ____/ ____/____ **Permit No:** _____

Owner:

Owner: _____

Address: _____

Phone: _____

Email: _____

Contractor:

Contractor: _____

Address: _____

Phone: _____

Email: _____

Plan Engineer: _____

Plan Approval Date: _____

Work Location:

_____

Type of Work:

☐ **Tree Planting**

Description of Work:

_____

_____

FOR OFFICE USE ONLY:

Calendar Days for Permit: _____

CITY OF COLUMBIA, MISSOURI

PUBLIC WORKS DEPARTMENT

(1) Any person who shall do any work for which a permit is required hereunder shall conduct such work in accordance with standard plans and specifications on file in the office of the Director of Public Works and the office of the city clerk, which shall be marked "Official Copy of Plans and Specifications for Improvements Under Division 2, Article II, Chapter 24 of the Code of Ordinances of Columbia, Missouri." (City of Columbia Code of Ordinances, Chapter 24, Section 41)

(2) No person shall construct, reconstruct, repair, alter or grade any sidewalk, curb, curb cut, driveway or street on the public streets or rights-of-way without first obtaining a permit from the Director of Public Works. (City of Columbia Code of Ordinances, Chapter 24, Section 41)

(3) The Director of Public Works is authorized to issue a stop work order whenever he believes a violation of this Article is occurring. A stop work order shall be in writing and shall be given to the owner of the property involved or to the owner's agent or to the person engaged in the activity suspected of violating this Article. It shall be unlawful for any person to engage in any activity in violation of a stop work order. (City of Columbia Code of Ordinances, Chapter 24, Section 90)

(4) Failure to follow all guidelines set forth by the City of Columbia and the Manual of Uniform Traffic Control Devices (MUTCD) will be subject to Chapter 24, Section 20 of the City of Columbia Code of Ordinances, which states "Any person violating any of the provisions of this article shall be deemed guilty of a Misdemeanor." (City of Columbia Code of Ordinances, Chapter 24, Section 20)

(5) Traffic control plans for any project in the downtown area, collector and arterial street or any other locations as determined appropriate by the Director of Public Works shall be prepared by a Professional Land Surveyor or Professional Engineer licensed in the State of Missouri.

(6) Contractor is responsible for the installation and maintenance of all necessary erosion and sediment control on site until which time the project is completed and is determined to be stable and non-erosive.

(7) Prior to excavation the contractor must contact 1-800-DIG-RITE for utility locations.

A Right of Way user shall indemnify and hold the City of Columbia and its officers and employees harmless against any and all claims, lawsuits, judgments, costs, liens, losses, expenses, fees (including reasonable attorney fees and cost of defense), proceedings, actions demands, causes of action, liability and suits of any kind and nature, including personal bodily injury (including death), property damage or others harm for which recovery of damages is sought, to the extent that it is found by a court of competent jurisdiction to be caused by the negligence of the Right of Way user, any agent, officer, director, or their respective officers, agents, employees, directors or representatives, while installing, repairing or maintaining Facilities in a public Right of Way.

Attach all applicable information required per the City of Columbia checklist for short term street closures for construction projects and repairs. Please note that Downtown projects must comply with the City of Columbia's checklist for Downtown construction projects and repairs.

Certification: I certify that I have read and understand the provisions of this permit as it pertains to construction, restoration, and liability to the City of Columbia. I also certify that the traffic control utilized during this project meets the most current edition of the MUTCD.

Signature: Approved: Director of Public Works/City Arborist

_____ by: _____

Date: ____/ ____/____ Date: ____/ ____/____

** Signature indicates acceptance of permit requirements and conditions of both the City of Columbia and MUTC

APPENDIX D
RISK ASSESSMENT TABLE AND INFORMATION

RISK ASSESSMENT TABLE

Tree Risk Zones Categories for Public Trees and Suggested Minimum Guidelines for Inspection Methods and Schedules

Risk Zone Category	Examples	Timing of Inspections	Suggested Inspection Method(s)
Very High	1. Emergency access routes 2. Medical and emergency facilities and shelters, handicap access areas 3. Police, fire, and other public safety facilities 4. School playgrounds 5. Individual trees or neighborhoods with very high-risk tree characteristics such as: • Standing dead trees, or those with poor condition class ratings • Severely storm-damaged trees • Trees visually obstructing traffic signs, stop lights, or security lights • Tree roots causing severe sidewalk buckling	Annual	Walk-by; Individual Tree Inspections
High	1. Main thoroughfares 2. High-use parks, playgrounds, and picnic areas 3. Parking lots adjacent to high-use public areas 4. Bus stops along high-use roads 5. Paved, high-use trails 6. Individual trees or neighborhoods with very high-risk tree characteristics such as: • Over-mature trees • Severely storm-damaged trees • High density of large diameter, mature, or “problem” tree species • Root injury caused by sidewalk or road construction	1–2 years	Walk-by; Individual Tree Inspections
Moderate	1. Secondary roadways 2. Neighborhoods with a moderate density of large diameter, mature, or “problem” tree species 3. Moderate use parks, playgrounds, and picnic areas 4. Undeveloped trails 5. Parking lots adjacent to moderate-use areas	3–5 years	Walk-by; Individual Tree Inspections
Low	1. Low-use roads and public areas with dispersed recreation 2. Open areas, woods, riparian corridors 3. Neighborhoods with a low density of large diameter, mature, or “problem” tree species	5–7 years	Walk-by; Individual Tree Inspections or Drive-by; Windshield Surveys

Tree Emergency Plan Worksheet

For: Urban and Community Foresters, Community Leaders, Public Works and Parks Departments, Planners, Councils, and other Public Officials

1. Early Warning System/Weather Forecasting Service — Use an early warning procedure to enhance mitigation: communicate with the National Weather Service, a consulting meteorological firm, a designated television weather channel, or the local police department. With a procedure in place, you should have at least three hours of lead time before most tree damaging weather strikes.

Staff Lead: _____
Contact Name: _____
Address: _____
Phone: _____
Mobile: _____
FAX: _____
Email: _____ **Web Site** _____
Description of services provided:

2. Local Emergency Manager – Lead contact for a community and responsible for emergency planning and response activities.

Name: _____ **Phone:** _____
Mobile: _____

Role(s):

3. Public Relations Coordinator — This is the individual responsible for primary public relations, media contacts, citizen information and communications about the natural disaster. (Must have full knowledge of damage, community issues and capabilities, and be able to make decisions.)

Name: _____ **Phone:** _____
Mobile: _____

Alternate(s):
Name: _____ **Phone:** _____
Mobile: _____
Name: _____ **Phone:** _____
Mobile: _____

4. Disaster Planning and Response Team Members: Your team should include: mayor, selected department heads including specialists in public relations and purchasing, public works specialists (streets, wood utilization and disposal, fleet manager), utilities, parks department, other local government heads, meteorologist, local emergency managers. Include creative people on your team that can think beyond barriers that may be up. Get media involved in planning so they understand what your cleanup priorities are after a storm. Someone involved with public tree management should be part of the community emergency management team. It is critical to include individuals who can make fiscal and administrative decisions because this team will most likely serve in the storm operations command center.

Name:	Role/Responsibility:
1.	**Mayor**
2.	**Fire Chief**
3.	**Director of Public Works**
4.	**Utility Representative**
5.	**Public Relations Representative**
6.	**City Council**
7.	**County Emergency Management**
8.	**Police Chief**
9.	**Director of Parks**
10.	
11.	
12.	
13.	
14.	
15.	
16.	
17.	
18.	
19.	
20.	

5. Available Disaster Response Staff and Crews: Identify and list all municipal staff and crews available for disaster response work. Consider forestry and parks departments, public works, engineering, streets and sanitation, etc. Where possible, establish teams that can be responsible for specific disaster response activities (primary route clearing, assistance to utility crews, manage debris staging sites, distribute equipment, etc.)

Staff Name:	Role/Responsibility:
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	
13.	
14.	
15.	
16.	
17.	
18.	
19.	
20.	
21.	

6. Emergency Call Out Procedure — phone contact tree for staff.

Name: ________________________ **Will Contact — Name:** ________________________
Phone: ________________________
Mobile: ________________________

Name: ________________________
Phone: ________________________
Mobile: ________________________

Name: ________________________
Phone: ________________________
Mobile: ________________________

Name: ________________________ **Will Contact — Name:** ________________________
Phone: ________________________
Mobile: ________________________

Name: ________________________
Phone: ________________________
Mobile: ________________________

Name: ________________________
Phone: ________________________
Mobile: ________________________

Name: ________________________ **Will Contact — Name:** ________________________
Phone: ________________________
Mobile: ________________________

Name: ________________________
Phone: ________________________
Mobile: ________________________

Name: ________________________
Phone: ________________________
Mobile: ________________________

Name: ________________________ **Will Contact — Name:** ________________________
Phone: ________________________
Mobile: ________________________

Name: ________________________
Phone: ________________________
Mobile: ________________________

Name: ________________________
Phone: ________________________
Mobile: ________________________

7. Primary transportation and evacuation corridors and routes for emergency vehicles. Identify and map for reference. Have map available and accessible, and review and update annually.

8. Critical power transmission corridor restoration sites (medical treatment centers). Identify and map for reference. Have map available and accessible, and review and update annually.

9. Identify who is responsible for decision making and priority response setting for multiple life threatening situations.

Name:_____ Phone:
Pager:_____ Mobile:_____

10. Tree Damage Clean-up Priorities — List areas that need attention after life threatening situations are abated. Share this information with key staff the will be answering phone calls from residents, businesses, etc. Create a work order form for use when receiving calls.

1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

11. Procedure for Debris Staging and Removal — Identify several areas for staging and processing debris. Establish a contract or agreement securing each site. Choose a processing site that is large, flat, well-drained and accessible to roads that can support truck weights of at least 9 tons per axle. Identify ways to protect significant trees or cultural resources during processing. Potential sites include undeveloped park, industrial, cemetery, fairgrounds, agency and state land. Large parking lots (even paved lots) work well. Remember to consider noise implications near residential areas. Identify multiple sites. Annually reconfirm access and availability to these sites. Make sure the site is large enough for safety considerations (flying debris from tub grinders), if possible, identify sites that can be secured (fencing).

Site 1 – Location: _____

Contact Name/Role:

Phone: Mobile:

Site 2 – Location: _____

Contact Name/Role:

Phone: Mobile:

Site 3 – Location: _____

Contact Name/Role:

Phone: Mobile:

12. Debris and Brush Removal from Private Property — Identify how you will address this issue. A major storm makes it difficult for private property owners to remove brush and debris. Make a decision at the municipal level allowing for debris collection. Determine if your city has adequate equipment and staff available to accomplish this often enormous task. It is critical that you provide guidelines for residents. Specify the types, amounts and piling arrangement of the materials that you will accept. Cities can also assist private homeowners who must contract with private companies for trimming and removal by preparing a list of companies that are licensed, professionally trained and insured.

Person Responsible: _____
Phone: _____ **Mobile:**_____

Minor Storm Policy:

Major Storm Policy:

Listing of available tree care companies:

13. Identify Wood Utilization Options – Develop a list of companies and resources that can process the wood material generated from storm damage. When possible, establish a contract for utilization services.

Wood Utilization Contract: **Company/Organization:**

Phone: Mobile:
Utilization Service Contract: Yes / No
Description of Service:

Wood Utilization Contract: **Company/Organization:**

Phone: Mobile:
Utilization Service Contract: Yes / No
Description of Service:

14. Equipment Listing (available in-house) — Develop a list of public works and parks department equipment and vehicles available for tree clean up work. Keep it current. Include wood chippers, aerial bucket trucks, refuse packers, loaders, supervisory vehicles, chain saws, barricade and lighting equipment, hand saws and pole pruners on the list.

Person Responsible: _____
Phone:_____ **Mobile:**_____

Equipment Available	Quantity	Department/Contact
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

15. Additional Equipment and Assistance Sources — In an emergency, your city administrator may authorize the lease or rental of additional equipment for storm clean-up work. Make a list of potential vendors and keep it current. For certain equipment and assistance needs, it is critical to establish an emergency contract. Guaranteed access to large tub grinders and multiple additional tree trimming crews would be services to guarantee via an emergency contract. The city administrator may also authorize tree contractors to supplement city crews. Assemble a list of licensed and insured potential tree service contractors. Your neighbor cities may be unaffected by a storm that strikes your city. Establish a system to contact neighbor cities that could send staff and equipment to assist you in cleaning up your city.

Person Responsible: _____
Phone:_____ **Mobile:**_____

Equipment Available	Quantity	Department/Contact
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Emergency Contract:

Organization: Contact Name:
Phone: Mobile:

Emergency Contract:

Organization: Contact Name:
Phone: Mobile:

Emergency Contract:

Organization: Contact Name:
Phone: Mobile:

16. Staff, Crew Organization and Equipment Needs – In an emergency, staff members may need to lead crews from other departments or of private contractors. Determine staff who can function in this manner.

Name	Crew#	Equipment Needed

17. Individual(s) Responsible for Record Keeping — This person does documentation and cost accounting during and after disasters. Note – define a specific accounting code for each storm event. If you define a specific code for each storm event, it will allow for effective accounting.

Name: Phone:
Mobile:

Name: Phone:
Mobile:

Storm Accounting Code:

18. Individual(s) Responsible for Damage Assessment and Damage Survey Reports — This person is familiar with FEMA and Division of Emergency Management procedures and prepares the reports needed for public assistance.

Name: Phone:
Mobile:

Name: Phone:
Mobile:

19. Disaster Budget (identify potential activities to anticipate costs)

Personnel Regular Time:

Overtime:

Equipment Owned:

Equipment Contracted:

Contracted Work:

Operational Supplies:

Disposal/Recycling:

Administrative Costs (Overhead):

20. Funding Information from Past Storms — review costs from past storms to anticipate costs for future storms and establish funding needs.

Storm: _____ **Date**: _____

Activity	**Cost**
Personnel Regular Time	
Overtime	
Equipment Owned	
Equipment Contracted	
Contracted Work	
Operational Supplies	
Disposal/Recycling	
Administrative Costs (Overhead)	
TOTAL	

Storm: **Date**: _____ _____

Activity	**Cost**
Personnel Regular Time	
Overtime	
Equipment Owned	
Equipment Contracted	
Contracted Work	
Operational Supplies	
Disposal/Recycling	
Administrative Costs (Overhead)	
TOTAL	

21. Individual(s) and/or Organization(s) responsible for community regreening efforts: Develop a list of contacts for use in efforts to regreen the community after storm events.

Name/Organization: Phone:
Mobile:

Organization Role:

Name/Organization: Phone:
Mobile:

Organization Role:

Name/Organization: Phone:
Mobile:

Organization Role:

Name/Organization: Phone:
Mobile:

Organization Role:

22. Listing of community and neighborhood groups that promote and support community regreening efforts

Group:	Representative:	Phone: Mobile:
Group:	Representative:	Phone: Mobile:
Group:	Representative:	Phone: Mobile:
Group:	Representative:	Phone: Mobile:
Group:	Representative:	Phone: Mobile:
Group:	Representative:	Phone: Mobile:

23. Community urban forestry comprehensive management plan —

Comprehensive forest management is your best defense against storms. Well planted and cared for trees stand up to weather better than neglected trees. Develop or modify a forest management plan to include information related to disaster preparedness. Identify critical activities such as hazard tree removal, tree pruning cycles, annual tree care needs, etc.

Name: Completed:

24. Community tree risk management plan — A tree risk management plan will provide the community with a systematic approach to accurately identify moderate to high risk trees, an initiate the timely removal or corrective treatment of hazardous trees. Communities that carry out tree risk management strategies will likely see reductions in damage after storms. Go to: http://www.na.fs.fed.us/spfo/pubs/uf/utrmm/index.htm

Name: Completed:

25. Storm Damage Assessment – If a storm is significant enough to receive a formal disaster declaration, state and/or federal funding may be available. To assist communities in the process of applying for reimbursement for storm associated costs, it is important to be able to quickly develop an estimate of damage. Consider using the Storm Damage Assessment Protocol as a tool prior to a storm. This protocol allows a community to provide an assessment of damage in a simple, credible and efficient manner. Go to: http://www.umass.edu/urbantree/icestorm/

Name: Completed:

26. Contacts for additional assistance in natural disaster planning, response and recovery:

Name	Phone
Area or District Forester	
University Extension Agent	
Consulting Foresters	
City Foresters of Neighboring Cities:	
Other	

(Worksheet Prepared by: Lisa Burban (USDA Forest Service), Jim Hermann (Minneapolis Park and Recreation Board), and Katie Himanga (Heartwood Forestry) – Updated May, 2006. Worksheet available on-line at: http://www.na.fs.fed.us/urban/ucfdisasters/tree_emerg_plan/treeemerplanwksheet.htm)

APPENDIX E
UTC METHODOLOGY AND ACCURACY ASSESSMENT

Davey Resource Group Classification Methodology

DRG utilized an object-based image analysis (OBIA) semi-automated feature extraction method to process and analyze current high-resolution color infrared (CIR) aerial imagery and remotely-sensed data to identify tree canopy cover and land cover classifications. The use of imagery analysis is cost-effective and provides a highly accurate approach to assessing your community's existing tree canopy coverage. This supports responsible tree management, facilitates community forestry goal-setting, and improves urban resource planning for healthier and more sustainable urban environments.

Advanced image analysis methods were used to classify, or separate, the land cover layers from the overall imagery. The semi-automated extraction process was completed using Feature Analyst, an extension of ArcGIS®. Feature Analyst uses an object-oriented approach to cluster together objects with similar spectral (i.e., color) and spatial/contextual (e.g., texture, size, shape, pattern, and spatial association) characteristics. The land cover results of the extraction process was post-processed and clipped to each project boundary prior to the manual editing process in order to create smaller, manageable, and more efficient file sizes. Secondary source data, high-resolution aerial imagery provided by each UTC city, and custom ArcGIS® tools were used to aid in the final manual editing, quality checking, and quality assurance processes (QA/QC). The manual QA/QC process was implemented to identify, define, and correct any misclassifications or omission errors in the final land cover layer.

Classification Workflow

1. Prepare imagery for feature extraction (resampling, rectification, etc.), if needed.
2. Gather training set data for all desired land cover classes (canopy, impervious, grass, bare soil, shadows). Water samples are not always needed since hydrologic data are available for most areas. Training data for impervious features were not collected because the city maintained a completed impervious layer.
3. Extract canopy layer only; this decreases the amount of shadow removal from large tree canopy shadows. Fill small holes and smooth to remove rigid edges.
4. Edit and finalize canopy layer at 1:2000 scale. A point file is created to digitize-in small individual trees that will be missed during the extraction. These points are buffered to represent the tree canopy. This process is done to speed up editing time and improve accuracy by including smaller individual trees.
5. Extract remaining land cover classes using the canopy layer as a mask; this keeps canopy shadows that occur within groups of canopy while decreasing the amount of shadow along edges.
6. Edit the impervious layer to reflect actual impervious features, such as roads, buildings, parking lots, etc. to update features.

7. Using canopy and actual impervious surfaces as a mask; input the bare soils training data and extract them from the imagery. Quickly edit the layer to remove or add any features. DRG tries to delete dry vegetation areas that are associated with lawns, grass/meadows, and agricultural fields.
8. Assemble any hydrological datasets, if provided. Add or remove any water features to create the hydrology class. Perform a feature extraction if no water feature datasets exist.
9. Use geoprocessing tools to clean, repair, and clip all edited land cover layers to remove any self-intersections or topology errors that sometimes occur during editing.
10. Input canopy, impervious, bare soil, and hydrology layers into DRG's Five-Class Land Cover Model to complete the classification. This model generates the pervious (grass/low-lying vegetation) class by taking all other areas not previously classified and combining them.
11. Thoroughly inspect final land cover dataset for any classification errors and correct as needed.
12. Perform accuracy assessment. Repeat Step 11, if needed.

Automated Feature Extraction Files

The automated feature extraction (AFE) files allow other users to run the extraction process by replicating the methodology. Since Feature Analyst does not contain all geoprocessing operations that DRG utilizes, the AFE only accounts for part of the extraction process. Using Feature Analyst, DRG created the training set data, ran the extraction, and then smoothed the features to alleviate the blocky appearance. To complete the actual extraction process, DRG uses additional geoprocessing tools within ArcGIS®. From the AFE file results, the following steps are taken to prepare the extracted data for manual editing.

1. DRG fills all holes in the canopy that are less than 30 square meters. This eliminates small gaps that were created during the extraction process while still allowing for natural canopy gaps.
2. DRG deletes all features that are less than 9 square meters for canopy (50 square meters for impervious surfaces). This process reduces the amount of small features that could result in incorrect classifications and also helps computer performance.
3. The Repair Geometry, Dissolve, and Multipart to Singlepart (in that order) geoprocessing tools are run to complete the extraction process.
4. The Multipart to Singlepart shapefile is given to GIS personnel for manual editing to add, remove, or reshape features.

Accuracy Assessment Protocol

Determining the accuracy of spatial data is of high importance to DRG and our clients. To achieve to best possible result, DRG manually edits and conducts thorough QA/QC checks on all urban tree canopy and land cover layers. A QA/QC process will be completed using ArcGIS® to identify, clean, and correct any misclassification or topology errors in the final land cover dataset. The initial land cover layer extractions will be edited at a 1:2000 quality control scale in the urban areas and at a 1:2500 scale for rural areas utilizing the most current high-resolution aerial imagery to aid in the quality control process.

Table 1. Land Cover Classification Code Values

Land Cover Classification	Code Value
Tree Canopy	1
Impervious	2
Pervious (Grass/Vegetation)	3
Bare Soil	4
Open Water	5

To test for accuracy, random plot locations are generated throughout the city area of interest and verified to ensure that the data meet the client standards. Each point will be compared with the most current NAIP high-resolution imagery (reference image) to determine the accuracy of the final land cover layer. Points will be classified as either correct or incorrect and recorded in a classification matrix. Accuracy will be assessed using four metrics: overall accuracy, kappa, quantity disagreement, and allocation disagreement. These metrics are calculated using a custom Excel® spreadsheet.

Land Cover Accuracy

The following describes DRG's accuracy assessment techniques and outlines procedural steps used to conduct the assessment.

1. *Random Point Generation*—Using ArcGIS, 1,000 random assessment points are generated.
2. *Point Determination*—Each point is carefully assessed by the GIS analyst for likeness with the aerial photography. To record findings, two new fields, CODE and TRUTH, are added to the accuracy assessment point shapefile. CODE is a numeric value (1–5) assigned to each land cover class (Table 1) and TRUTH is the actual land cover class as identified according to the reference image. If CODE and TRUTH are the same, then the point is counted as a correct classification. Likewise, if the CODE and TRUTH are not the same, then the point is classified as incorrect. In most cases, distinguishing if a point is correct or incorrect is straightforward. Points will rarely be misclassified by an egregious classification or editing error. Often incorrect points occur where one feature stops and the other begins.

3. *Classification Matrix*—During the accuracy assessment, if a point is considered incorrect, it is given the correct classification in the TRUTH column. Points are first assessed on the NAIP imagery for their correctness using a "blind" assessment—meaning that the analyst does not know the actual classification (the GIS analyst is strictly going off the NAIP imagery to determine cover class). Any incorrect classifications found during the "blind" assessment are scrutinized further using sub-meter imagery provided by the client to determine if the point was incorrectly classified due to the fuzziness of the NAIP imagery or an actual misclassification. After all random points are assessed and recorded; a classification (or confusion) matrix is created. The classification matrix for this project is presented in Table 2. The table allows for assessment of user's/producer's accuracy, overall accuracy, omission/commission errors, kappa statistics, allocation/quantity disagreement, and confidence intervals (Figure 1 and Table 3).

Table 2. Classification Matrix

	Classes	Tree Canopy	Impervious Surfaces	Grass & Low-Lying Vegetation	Bare Soils	Open Water	Row Total	Producer's Accuracy	Errors of Omission
Reference Data	Tree Canopy	345	1	12	0	0	358	96.37%	3.63%
	Impervious	1	262	6	0	0	269	97.40%	2.60%
	Grass/Vegetation	3	1	317	0	0	321	98.75%	1.25%
	Bare Soils	0	0	4	36	0	40	90.00%	10.00%
	Water	0	0	0	0	12	12	100.00%	0.00%
	Column Total	349	264	339	36	12	1000		
	User's Accuracy	98.85%	99.24%	93.51%	100.00%	94.74%		Overall Accuracy	97.20%
	Errors of Commission	1.15%	0.76%	6.49%	0.00%	5.26%		Kappa Coefficient	0.9596

4. Following are descriptions of each statistic as well as the results from some of the accuracy assessment tests.

   Overall Accuracy – Percentage of correctly classified pixels; for example, the sum of the diagonals divided by the total points ((345+262+317+36+12+)/1000 = 97.20%).

   User's Accuracy – Probability that a pixel classified on the map actually represents that category on the ground (correct land cover classifications divided by the column total [345/349 = 98.85%]).

   Producer's Accuracy – Probability of a reference pixel being correctly classified (correct land cover classifications divided by the row total [345/358 = 96.37%]).

   Kappa Coefficient – A statistical metric used to assess the accuracy of classification data. It has been generally accepted as a better determinant of accuracy partly because it accounts for random chance agreement. A value of 0.80 or greater is regarded as "very good" agreement between the land cover classification and reference image.

   Errors of Commission – A pixel reports the presence of a feature (such as trees) that, in reality, is absent (no trees are actually present). This is termed as a false positive. In the matrix below, we can determine that 1.15% of the area classified as canopy is most likely not canopy.

Errors of Omission – A pixel reports the absence of a feature (such as trees) when, in reality, they are actually there. In the matrix below, we can conclude that 3.63% of all canopy classified is actually classified as another land cover type.

Allocation Disagreement – The amount of difference between the reference image and the classified land cover map that is due to less than optimal match in the spatial allocation (or position) of the classes.

Quantity Disagreement – The amount of difference between the reference image and the classified land cover map that is due to less than perfect match in the proportions (or area) of the classes.

Confidence Intervals – A confidence interval is a type of interval estimate of a population parameter and is used to indicate the reliability of an estimate. Confidence intervals consist of a range of values (interval) that act as good estimates of the unknown population parameter based on the observed probability of successes and failures. Since all assessments have innate error, defining a lower and upper bound estimate is essential.

Confidence Intervals

Class	Acreage	Percentage	Lower Bound	Upper Bound
Tree Canopy	14,917.7	35.6%	35.3%	35.8%
Impervious Surfaces	9,452.5	22.5%	22.3%	22.7%
Grass & Low-Lying Vegetation	15,145.7	36.1%	35.9%	36.4%
Bare Soils	1,794.4	4.3%	4.2%	4.4%
Open Water	617.0	1.5%	1.4%	1.5%
Total	41,927.3	100.00%		

Statistical Metrics Summary	
Overall Accuracy =	97.20%
Kappa Coefficient =	0.9595
Allocation Disagreement =	1%
Quantity Disagreement =	2%

Accuracy Assessment

Class	User's Accuracy	Lower Bound	Upper Bound	Producer's Accuracy	Lower Bound	Upper Bound
Tree Canopy	98.9%	98.3%	99.4%	96.4%	95.4%	97.4%
Impervious Surfaces	99.2%	98.7%	99.8%	97.4%	96.4%	98.4%
Grass & Low-Lying Vegetation	93.5%	92.2%	94.8%	98.8%	98.1%	99.4%
Bare Soils	100.0%	100.0%	100.0%	90.0%	85.3%	94.7%
Open Water	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

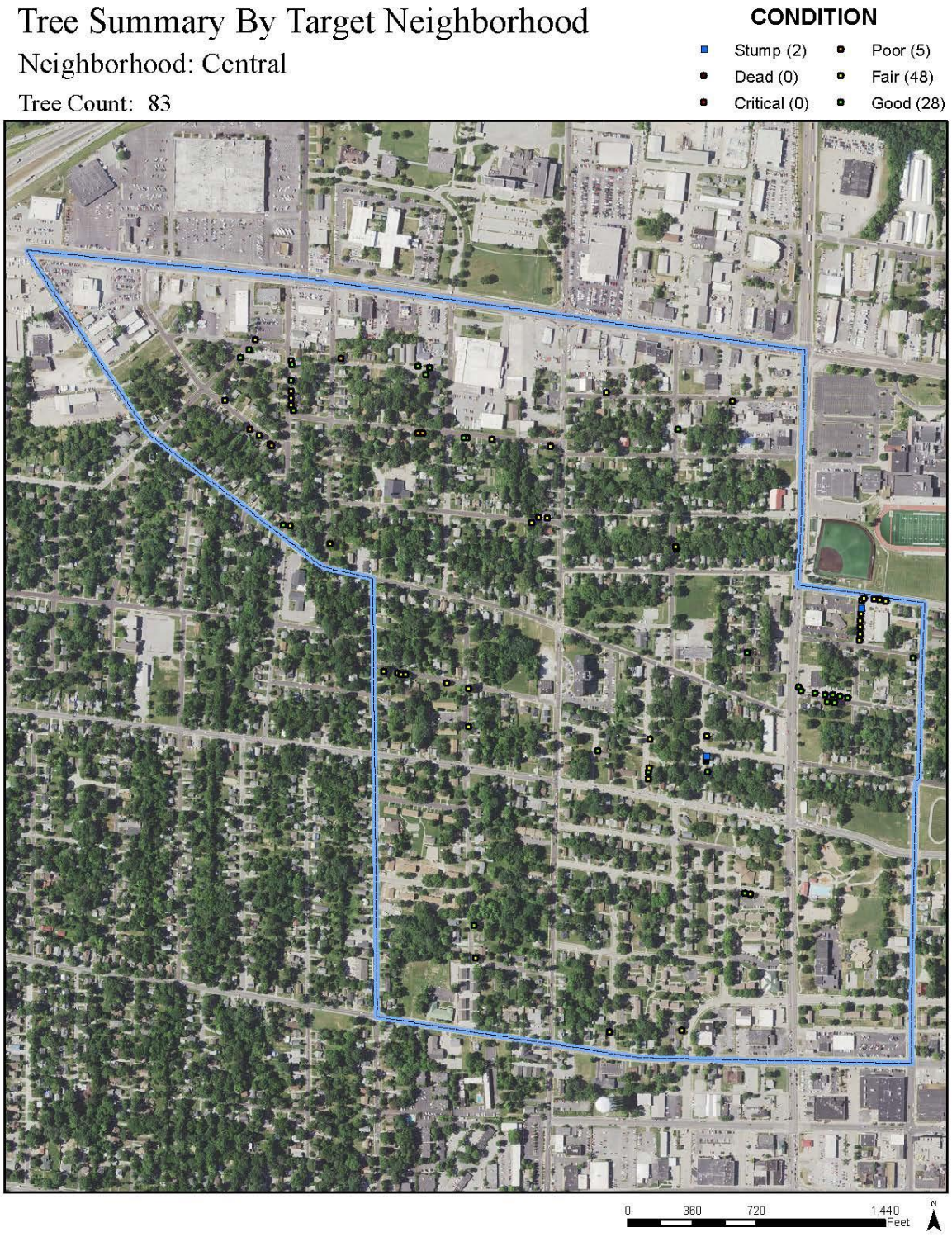
APPENDIX F
LEAF LITTER METHODOLOGY

Leaf Litter Study Analysis

1. A 20-foot buffer was created around street segments.
2. Urban Tree Canopy data within 20 feet of street segments were clipped out for analysis.
3. Street segments buffer within 10 feet of 'Residential' and 'Condo' land use types where there is a high likelihood of the existence of high tree canopy was identified.
4. Street segments buffer within 10 feet of 'Agricultural', 'Utilities', Telecom', and 'Commercial' land use types where there is a high likelihood of the existence of low tree canopy was identified.
5. Street segments buffer within 10 feet of 'Exempt' and 'Not Applicable' land use types where there is a high likelihood of the existence of medium tree canopy was identified.
6. Scores were assigned to each canopy zone defined by its proximity to specific land use types—'3' was assigned to High Canopy; '2' was assigned to Medium Canopy; and '1' was assigned to Low Canopy.
7. Tree Canopy percent within each Road segment buffer was computed.
8. Scores were assigned to each canopy zone defined by the percentage of tree canopy—'3' was assigned to (50%-100%) High Canopy; '2' was assigned to (5%-50%) Medium Canopy; and '1' was assigned to (0%-5%) Low Canopy.
9. A composite score was calculated based on an aggregation of land use and canopy percent scores.
10. Scores were assigned to each street segment based on the composite scores—'3' was assigned to (50%-100%) High Canopy; '2' was assigned to (5%-50%) Medium Canopy; and '1' was assigned to (0%-5%) Low Canopy.
11. Tree canopy length (Miles) and Area (Acres) for each canopy class were calculated.

Tree Canopy Zones	Linear Street (Miles)	Canopy Area (Acres)	Number of Street Segments	Percentage of Street Segments
High	452.62	398.16	2600	29.29
Medium	157.60	118.17	3656	41.20
Low	46.98	21.97	2618	29.50

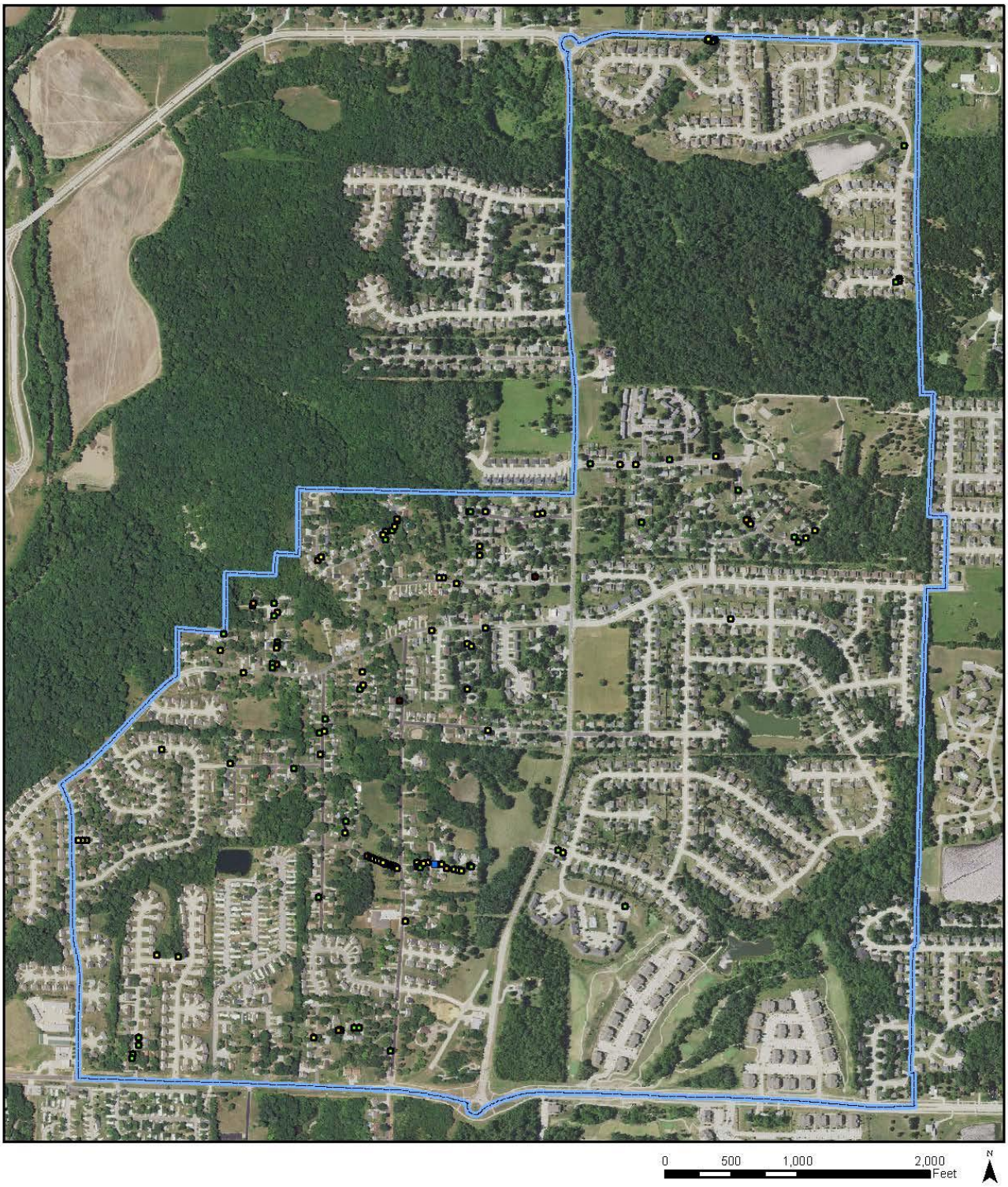
APPENDIX G
TARGET NEIGHBORHOOD INVENTORY MAPS



Tree Summary By Target Neighborhood

Neighborhood: East

Tree Count: 141



Tree Summary By Target Neighborhood

Neighborhood: North

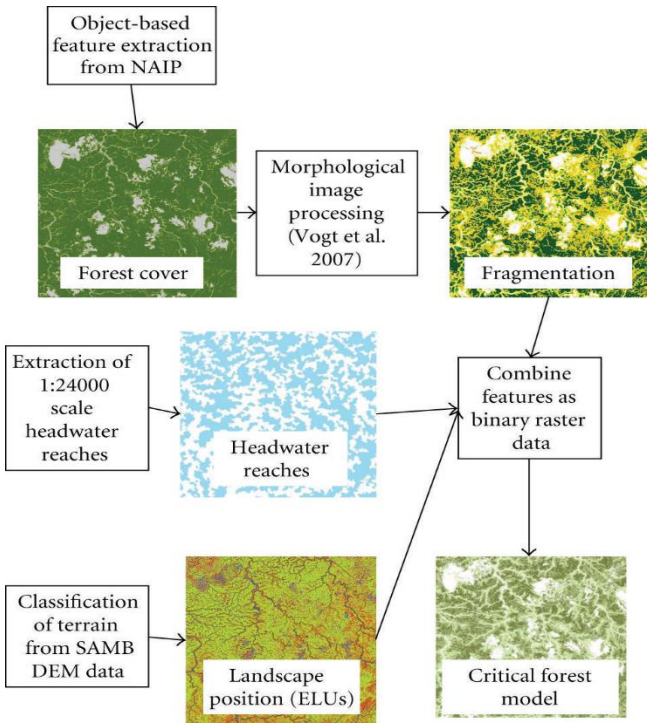
Tree Count: 149

APPENDIX H
CRITICAL FOREST METHODOLOGY

Critical Forest Modeling

This assessment included include land cover data, forest fragmentation metrics, and localized catchment basins. Creating small catchments was crucial in selecting forested areas that fell into headwater catchments. These catchments are important mainly because what activities occur, such as runoff and pollution, greatly affects streams and water supplies downstream. Using this data, headwater catchments and their landscape positions will be determined in order to identify the most crucial areas for protecting and preserving tree canopy.

This modeling effort follows the work of Maxwell et al. 2012 as they sought to find important forested areas that greatly impact water quality. While this model was created on a landscape scale, the fundamental aspects of the model carry over to urban applications. Characteristics of the model seek to apply environmental data based from current forest conditions and position within a watershed (or catchment, in this case).



Identification of Critical Forest

Using a hydrological corrected 10m DEM from the National Hydrological Dataset (NHD), ArcHydro tools within the ArcGIS platform were utilized to derive raster datasets for flow direction, flow accumulation, and stream networks. Streams were segmented into pieces to effectively delineate small catchments basins for the extents of the project area. Due to hydrological processing of catchments, some exceedingly small catchments were adjoined to larger adjacent catchments for the purposes of this analysis. Through drainage line processing, a drainage network is created for all segmented streams within the study area.

Headwater catchments were selected using the drainage network by locating the most upstream catchment area. In general, any pollution accumulation downstream will begin in these headwater catchments; therefore, it is crucial to identify these focused areas within the project area. Using the focal catchments, forest fragmentation data were clipped for each catchment. Critical forest was identified by selecting edge, perforated, and core forest communities within each of these focal catchments.

APPENDIX I
PRIORITIZED PLANTING PLAN METHODOLOGY

Prioritized Planting – Planting Location

The planting location polygons were created by taking all grass/open space and bare ground areas and combining them into one dataset. Non-feasible planting areas such as agricultural fields, recreational fields, major utility corridors, airports, etc. were removed from consideration. The remaining planting space was consolidated into a single feature and then exploded back out to multipart features, creating separate, distinct polygons for each location. Using zonal statistics, the priority grid raster was used to calculate an average value for each planting location polygon. The averages were binned into five (5) classes with the higher numbers indicating higher priority for planting. These classes ranged from Very Low to Very High.

How Sites Were Prioritized

To identify and prioritize planting potential, DRG assessed a number of environmental features, including proximity to hardscape, urban heat island, proximity to floodplains, canopy fragmentation, slope, soil permeability, and soil erosion factor (K-factor). Each factor was assessed using data from various sources and analyzed using separate grid maps. Values between zero and four (with zero having the lowest priority) were assigned to each grid assessed. The grids were overlain and the values were averaged to determine the priority levels at an area on the map. A priority ranging from Very Low to Very High was assigned to areas on the map based on the calculated average of all grid maps.

Once the process of identifying priority was completed, the development of planting strategies was the next task. All potential planting sites were not treated equal as some sites were considered to be more suitable than others. Through prioritization, sites were ranked based on a number of factors pertaining to stormwater reduction and a relative urban heat island index.

Priority Ranking Variables

Dataset	Source	Weight
Proximity to Hardscape	Urban Tree Canopy Assessment	0.30
Urban Heat Island	Urban Tree Canopy Assessment	0.25
Proximity to Floodplain	National Hydrologic Data/FEMA	0.15
Canopy Fragmentation	Urban Tree Canopy Assessment	0.10
Slope	National Elevation Data	0.10
Soil Permeability	Natural Resource Conservation Service	0.05
Soil Erosion (K-factor)	Natural Resource Conservation Service	0.05

APPENDIX J
TREE CANOPY HEALTH METHODOLOGY

Tree Canopy Health Index

Following the mapping and analysis of tree canopy cover, additional models were completed to evaluate the condition of the tree canopy. Broad-band based vegetation indices, based on sensors with broad wavelength region bands, are the most frequently used indicators for monitoring ecosystem dynamics and vegetation health. Many vegetation indices have been developed and applied in vegetation studies since the first vegetation index was introduced. Vegetation indices were created to evaluate cover, chlorophyll content, leaf area, phenology, and absorbed photosynthetically active radiation. Since live green vegetation and tree canopy absorb solar radiation in the photosynthetically active radiation (PAR) spectral region, they scatter solar radiation in the near-infrared spectral region. When the two spectral regions are assessed in ratio-based indices, they contrast with cover that absorbs or reflects light similarly in both regions.

Normalized Difference Vegetation Index

The Normalized Difference Vegetation Index (NDVI) is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum and is adapted to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not. NDVI is a ratio (using red and near-infrared bands) ranging from -1 to 1 with vegetation being a positive value – normally greater than 0.3. Increasing positive values indicates healthier vegetation communities. Generally, healthy vegetation will absorb most of the visible light that falls on it, and reflects a large portion of the near-infrared light; thus, healthy vegetation will be more pronounced than dead or dying vegetation because of the amount of chlorophyll within the leaves to absorb visible light.

Determining Tree Canopy Health

To assess canopy health and to identify areas with dead or dying trees, DRG utilized NDVI to extract ratio values from the 2016 NAIP imagery using the red and near-infrared bands. The NDVI values were normalized on a scale from 0–1 to highlight canopy communities and the overall condition of the trees. Results of this analysis include a breakdown of tree canopy health into six classes: Very Good, Good, Fair, Poor, Critical, and Shadow/Unclassified for pixels that were affected by shadowing. The number of acres for each canopy health class were tabulated below. The results of this analysis can be used by Columbia to further inspect the poor condition canopy to find out the real cause of poor health (i.e. drought, disease, fire, dying trees, etc.).

APPENDIX K
i-TREE METHODOLOGY

How Tree Canopy Benefits Are Calculated

Air Quality

The i-Tree Canopy v6.1 Model was used to quantify the value of ecosystem services for air quality. i-Tree Canopy was designed to give users the ability to estimate tree canopy and other land cover types within any selected geography. The model uses the estimated canopy percentage and reports air pollutant removal rates and monetary values for carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and particulate matter (PM) (Hirabayashi 2014).

Within the i-Tree Canopy application, the U.S. EPA's BenMAP Model estimates the incidence of adverse health effects and monetary values resulting from changes in air pollutants (Hirabayashi 2014; US EPA 2012). Different pollutant removal values were used for urban and rural areas. In i-Tree Canopy, the air pollutant amount annually removed by trees and the associated monetary value can be calculated with tree cover in areas of interest using BenMAP multipliers for each county in the United States.

To calculate ecosystem services for the study area, canopy percentage metrics from UTC land cover data performed during the assessment were transferred to i-Tree Canopy. Those canopy percentages were matched by placing random points within the i-Tree Canopy application. Benefit values were reported for each of the five listed air pollutants.

Carbon Storage and Sequestration

The i-Tree Canopy v6.1 Model was used to quantify the value of ecosystem services for carbon storage and sequestration. i-Tree Canopy was designed to give users the ability to estimate tree canopy and other land cover types within any selected geography. The model uses the estimated canopy percentage and reports carbon storage and sequestration rates and monetary values. Methods on deriving storage and sequestration can be found in Nowak et al. 2013.

To calculate ecosystem services for the study area, canopy percentage metrics from UTC land cover data performed during the assessment were transferred to i-Tree Canopy. Those canopy percentages were matched by placing random points within the i-Tree Canopy application. Benefit values were reported for carbon storage and sequestration.

Stormwater

The i-Tree Hydro v5.0 Model was used to quantify the value of ecosystem services for stormwater runoff. i-Tree Hydro was designed for users interested in analysis of vegetation and impervious cover effects on urban hydrology. This most recent version (v5.0) allows users to report hydrologic data on the city level rather than just a watershed scale giving users more flexibility. For more information about the model, please consult the i-Tree Hydro v5.0 manual (http://www.itreetools.org).

To calculate ecosystem services for the study area, land cover percentages derived for the project area and all municipalities that were included in the project area were used as inputs into the model. Precipitation data from 2005-2012 was modeled within the i-Tree Hydro to best represent the average conditions over an eight-year time period. Model simulations were run under a Base Case as well as an Alternate Case. The Alterative Case set tree canopy equal to 0% and assumed that impervious and vegetation cover would increase based on the removal of tree canopy. Impervious surface was increased 1.8% based on a percentage of the amount of impervious surface under tree canopy and the rest was added to the vegetation cover class. This process was completed to assess the runoff reduction volume associated with tree canopy since i-Tree Hydro does not directly report the volume of runoff reduced by tree canopy. The volume (in cubic meters) was converted to gallons to retrieve the overall volume of runoff avoided by having the current tree canopy.

Through model simulation, it was determined that tree canopy decreases the runoff volume in the project area by 336,306,674 gallons per year using precipitation data from 2005-2012. This equates to approximately 22,545 gallons per acre of tree canopy (336,306,674 gals/14,917 acres).

To place a monetary value on storm water reduction, the cost to treat a gallon of storm/waste water was given by the project partners. This value was $0.002 per gallon. Tree canopy was estimated to contribute roughly $672,613 to avoided runoff annually to the project area.

Energy Saving (Cooling)

Trees have a profound effect on building energy and has been studies using various methods. The process of estimating energy (electricity) savings starts with determining the number of 1-unit structures by vintage (age) class within each census block group. Vintage refers to construction type for a building (i.e. average floor area, floor types, insulation (R-value), and number of stories) and was broken into three categories: pre-1950, 1950-80, and post-1980.

Census data obtained from the most recent American Community Survey (Table B25024 – UNITS IN STRUCTURE and Table B25034 - YEAR STRUCTURE BUILT) was used to determine the number of 1-unit structures. The data was based on 5-year estimates. Since the number of 1-unit structures differed at the block group level, the number of 1-unit structures was determined by vintage and block group by multiplying the percentage of units in each vintage by the total number of 1-unit structures in each block group (McPherson et al. 2013). For each block group, total energy savings were tallied for each block group using a function of percent UTC, vintage class, and energy saving coefficients (McPherson and Simpson 2003, McPherson et al. 2013).

To provide energy savings for neighborhoods, census tracts were assigned based on their spatial positioning related to the block group data. While the boundaries do not overlay perfectly, it does provide a rough estimate for these boundaries. Census tracts were calculated without assigning a block group because these data nested within each census tract. The kWh saved were summarized.

The monetary value for energy savings was valued by summing all estimated kWh saved for each vintage class and multiplied by the average residential electricity cost priced at $0.1099 per kWh.

Property Value

Many benefits of tree canopy are difficult to quantify. When accounting for wildlife habitat, well-being, shading, and beautification, these services are challenging to translate into economic terms. In order to provide some estimation of these additional services, property value based on the median value of home prices for Columbia was calculated and reported. During a search it was found the median list price of homes in Kingsley was $155,575 in 2016. Limitations to this approach include determining actual value of individual trees on a property and extrapolation of residential trees to other land use categories (McPherson et al. 2013).

In a study completed in 1988, it was found that single-family residences in Athens, Georgia had a 0.88% increase in the average home sale price for every large front-yard tree on the property (Anderson and Cordell 1988). Using this study, sales price increase was utilized as an indicator of additional tree benefits. Because home sale can vary widely, the 0.88% was used as a multiplier to determine the value of a large front yard tree on various types of land use classes. This value was converted into annual benefits by dividing the total added value by the estimated leaf surface area of a 30-year-old shade tree $1,627/5,382ft2) which yields a base value of $0.30/ft^2.

Using methodology from McPherson et al. 2013 to convert into units of UTC, the base value of tree canopy was determined to be $0.22 ft^2 UTC. Since this value was derived using residential land use designations, transfer functions were used to adapt and apply the base value to other land use categories. To be conservative in the estimation of tree benefits, the land use reduction factors calculated property value at 50% impact for single-family residential parcels, 20% for commercial parcels, and 10% for all other land uses. The price per unit of UTC values were multiplied by the amount of square feet of tree canopy within each municipality and the project area as a whole.

Land Use Reduction Transfer Function Values

Land Use Category	Impact	Price per unit of UTC
Residential	40%	$0.088
Commercial	20%	$0.044
All Other	10%	$0.011

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