TREE MANAGEMENT PLAN

Columbia City, Indiana

December 2017

Prepared for:
City of Columbia City
Tree Board
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Columbia City, Indiana 46725

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ACKNOWLEDGMENTS

Columbia City's vision to promote and preserve the urban forest and improve the management of public trees was a fundamental inspiration for this project. This vision will ensure canopy continuity, which will reduce stormwater runoff and improve aesthetic value, air quality, and public health.

Columbia City is thankful for the grant funding it received from the Indiana Department of Natural Resources, Division of Forestry, Community and Urban Forestry program (IDNR CUF) in cooperation with the U.S. Forest Service (USFS) through its Community and Urban Forestry (CUF) Grant Program. The IDNR CUF grant program is designed to encourage communities to create and support long-term and sustained urban and community forestry programs throughout Indiana.

The city also recognizes the support of its Mayor, Clerk Treasurer, Common Council, and Park Board:

Ryan Daniel, Mayor
Rosie Coyle, Clerk Treasurer
Walter Crowder, Council Member
Nicole Penrod, Council Member
Jennifer Romano, Council Member
Tad Varga, Council Member

Daniel Weigold, Council Member
Keith Nickolson, Board President
Larry Walter, Board Vice President
Roger Ferrell, Board Secretary
Kim Varga, Board Member
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EXECUTIVE SUMMARY

This plan was developed for the Columbia City by Davey Resource Group with a focus on addressing short-term and long-term maintenance needs for inventoried public trees. Davey Resource Group completed a phased tree inventory in 2007 and 2010. Since 2010, with assistance from Davey Resource Group, the city has maintained the tree inventory each year. The 2017 maintained inventory has provided an understanding of the needs of the existing urban forest and has enabled Davey Resource Group to project a recommended maintenance schedule for tree care. Analysis of inventory data and information about the city's existing program and vision for the urban forest were utilized to develop this *Tree Management Plan*. Also included in this plan are economic, environmental, and social benefits provided by the trees in Columbia City.

State of the Existing Urban Forest

The 2017 inventory included trees, stumps, and planting sites along public street rights-of-way (ROW). A total of 4,633 sites were recorded in the inventory: 2,272 trees, 57 stumps, and 2,304 planting sites. Analysis of the tree inventory data found the following:

- Two species, *Acer saccharinum* (silver maple) and *A. saccharum* (sugar maple), comprise a large percentage of the street ROW (19% and 12%) and threaten biodiversity.
- On the street ROW, *Acer* (maple) was found in abundance (43%), which is a concern for the city's biodiversity.
- The diameter size class distribution of the inventoried tree population trends towards the ideal, with a greater number of young trees than established, maturing, or mature trees.
- The overall condition of the inventoried tree population is rated Fair.
- Approximately 22% of the inventoried trees had poor structure, cavity, or decay.
- EAB currently poses a threat to 2% of the street tree population.
- Looper complex [(*Erannis tiliaria*) and (*Phigalia titea*)], Asian longhorned beetle (ALB or *Anoplophora glabripennis*), and forest tent caterpillar (*Malacosoma disstria*) pose the biggest potential threats to the health of the inventoried population.
- The current street ROW tree stocking level is 49%.
- Columbia City's trees have an estimated replacement value of $2,531,252.
- Trees provide approximately $284,850 in the following annual benefits:
  - *Aesthetic and other benefits*: valued at $93,190 per year.
  - *Air quality*: 4,907 pounds of pollutants removed valued at $13,703 per year.
  - *Carbon sequestered and avoided*: 817 tons valued at $12,251 per year.
  - *Energy*: 393 megawatt-hours (MWh) and 53,521 therms valued at $49,319 per year.
  - *Stormwater peak flow reductions:* 4,294,733 gallons valued at $116,387 per year.

Tree Maintenance and Planting Needs

Trees provide many environmental and economic benefits that justify the time and money invested in planting and maintenance. Recommended maintenance needs include: Tree Removal (4%); Stump Removal (1%); Priority Pruning (8%); Routine Pruning (29%); Young Tree Train (8%); and Plant Tree (50%). Maintenance should be prioritized by addressing trees with the highest risk first. The inventory noted many Priority 1 and Priority 2 trees (5% and 19% of trees assessed, respectively); these trees should be removed or pruned immediately to promote public safety. Priority 3 trees should be addressed after all elevated risk tree maintenance has been completed. Trees should be planted to mitigate removals and create canopy.

Columbia City's urban forest will benefit greatly from a three-year young tree training cycle and a five-year routine pruning 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. Based on inventory data, at least 125 young trees should be structurally pruned each year during the young tree training cycle, and approximately 265 trees should be cleaned each year during the routine pruning cycle.

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). Davey Resource Group recommends planting at least 52 trees of a variety of species each year to offset these losses, increase canopy, and maximize benefits.

Citywide 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. However, the planting of *Acer* (maple) should be limited until the species distribution normalizes. Due to the impending threat from emerald ash borer (EAB, *Agrilus planipennis*), all *Fraxinus* spp. (ash) trees should be temporarily removed from the planting list.

Urban Forest Program Needs

Adequate funding will be needed for the city to implement an effective management program that will provide short-term and long-term public benefits, ensure that priority maintenance is performed expediently, and establish proactive maintenance cycles. The estimated total cost for the first year of this five-year program is $99,023. This total will decrease to approximately $45,118 per year by Year 6 of the program. High-priority removal and pruning is costly; since most of this work is scheduled during the first year of the program, the budget is higher for that year. After high-priority work has been completed, the urban forestry program will mostly involve proactive maintenance, which is generally less costly. Budgets for later years are thus projected to be lower.

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*® or similar software is crucial for making informed management decisions and projecting accurate maintenance budgets.

Columbia City has many opportunities to improve its urban forest. 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.

FY 2017 $99,023

- 40 Priority 1 Removals
- 52 Stump Removals
- 39 Prioirty 1 Prunes
- YTT Cycle: 1/3 of Public Trees Trained
- 51 Trees Recommended for Planting and Follow-Up Care
- Newly Found Priority Tree Work (Removal or Pruning): Costs TBD

FY 2018 $97,977

- 28 Priority 1 Removals
- 12 Priority 2 Removals
- 66 Stump Removals
- 79 Prioirty 2 Prunes
- YTT Cycle: 1/3 of Public Trees Trained
- Newly Found Priority Tree Work (Removal or Pruning): Costs TBD

FY 2019 $94,918

- 40 Priority 2 Removals
- 56 Stump Removals
- 105 Prioirty 2 Prunes
- YTT Cycle: 1/3 of Public Trees Trained
- Newly Found Priority Tree Work (Removal or Pruning): Costs TBD

FY 2020 $66,361

- 40 Priority 2 Removals
- 40 Stump Removals
- 73 Prioirty 2 Prunes
- YTT Cycle: 1/3 of Public Trees Trained
- Newly Found Priority Tree Work (Removal or Pruning): Costs TBD

FY2021 $52,003

- 4 Priority 2 Removals
- 38 Priority 3 Removals
- 42 Stump Removals
- 77 Prioirty 2 Prunes
- YTT Cycle: 1/3 of Public Trees Trained
- Newly Found Priority Tree Work (Removal or Pruning): Costs TBD

FY2022 $45,118

- RP Cycle: 1/5 of Public Trees Cleaned
- YTT Cycle: 1/3 of Public Trees Trained
- Newly Found Priority Tree Work (Removal or Pruning): Costs TBD

FY2023 $45,118

- RP Cycle: 1/5 of Public Trees Cleaned
- YTT Cycle: 1/3 of Public Trees Trained
- Newly Found Priority Tree Work (Removal or Pruning): Costs TBD

FY2024 $45,118

- RP Cycle: 1/5 of Public Trees Cleaned
- YTT Cycle: 1/3 of Public Trees Trained
- Newly Found Priority Tree Work (Removal or Pruning): Costs TBD

FY2025 $45,118

- RP Cycle: 1/5 of Public Trees Cleaned
- YTT Cycle: 1/3 of Public Trees Trained
- Newly Found Priority Tree Work (Removal or Pruning): Costs TBD

FY2026 $45,118

- RP Cycle: 1/5 of Public Trees Cleaned
- YTT Cycle: 1/3 of Public Trees Trained
- Newly Found Priority Tree Work (Removal or Pruning): Costs TBD
- Newly Found Priority Tree Work (Removal or Pruning): Costs TBD

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INTRODUCTION

The City of Columbia City is home to more than 8,750 full-time residents who enjoy the beauty and benefits of their urban forest. The city's forestry program manages and maintains trees on public property, including trees, stumps, and planting sites in parks, public facilities, and along the street rights-of-way (ROW). For more than 10 years, Columbia City's Tree Board has committed to developing a strong urban forest. The Tree Board's mission is to be responsible for the study, investigation, development, annual update, and administration of a written plan for the care, preservation, pruning, planting, re-planting, removal, or disposition of trees and shrubs in parks, along streets, and in other public areas.

Funding for Columbia City's urban forestry program comes from the municipal fund and the Community and Urban Forestry (CUF) Grant Program from Indiana Department of Natural Resources, Division of Forestry, Community and Urban Forestry program (IDNR CUF). Columbia City conducted a phased inventory of street trees in 2007 and 2010 and then beginning in 2013 has cyclically kept updating to present day (November 2017). The city has a tree ordinance, maintains a budget of more than $2 per capita for tree-related expenses, celebrates Arbor Day, and has been a Tree City USA community for 23 years. Past urban forestry projects have demonstrated a desire to improve the environment through higher levels of tree care and have earned the city multiple Tree City USA Growth Awards.

Approach to Tree Management

The best approach to managing an urban forest is to develop an organized, proactive program using tools (such as a tree inventory, urban tree canopy assessment, and a tree management plan) to set goals and measure progress. These tools can be utilized to establish tree care priorities, build 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.

From 2013 to 2017, Columbia City has worked with Davey Resource Group to update the tree inventory and develop a management plan. An original inventory occurred in 2007 and 2010 (2 phases). This plan considers the diversity, distribution, and general condition of the inventoried trees, but also provides a prioritized system for managing public trees. This plan finds comparisons between data from 2010 to 2017 to create discussion points and make recommendations. The following tasks were completed:

- Recovered the 2010 inventory.
- Updated inventory of trees, stumps, and planting sites along the street ROW.
- Analysis of tree inventory data.
- Development of a plan that prioritizes the recommended tree maintenance.
- Assessment of urban tree canopy.
- Development of prioritized planting plan.

This plan is divided into three sections:

- *Section 1: Tree Inventory Analysis* summarizes the tree inventory data and presents trends, results, and observations.
- *Section 2: Benefits of the Urban Forest* summarizes the economic, environmental, and social benefits that trees provide to the community. This section presents statistics of an i-Tree Streets benefits analysis conducted for Columbia City.
- *Section 3: Tree Management Program* utilizes the inventory data to develop a prioritized maintenance schedule and projected budget for the recommended tree maintenance over a five-year period.
- *Section 4: Community Urban Forest Canopy Assessment* discusses total community tree canopy and benefits provided, compares canopy levels to similar communities in the region, and discusses the importance of measuring tree canopy and establishing canopy goals.
- *Section 5: Community Urban Forest Planting Plan* utilizes inventory data and urban tree canopy data to provide a prioritized planting strategy.

SECTION 1: TREE INVENTORY ANALYSIS

From 2012 to 2017, Davey Resource Group arborists assessed and inventoried trees, stumps, and planting sites along the street ROW. A total of 4,633 sites were maintained and updated during the inventory: 2,272 trees, 57 stumps, and 2,304 planting sites.

Table 1 provides a detailed breakdown of the number and type of sites in the 2017 and 2010 inventories.

The 2010 inventory was conducted in two phases. One phase was completed in 2007 and the second phase was completed in 2010. The foundation of the 2017 inventory is based on the completed 2010 inventory. The 2017 inventoried sites have been updated and new sites have been added.

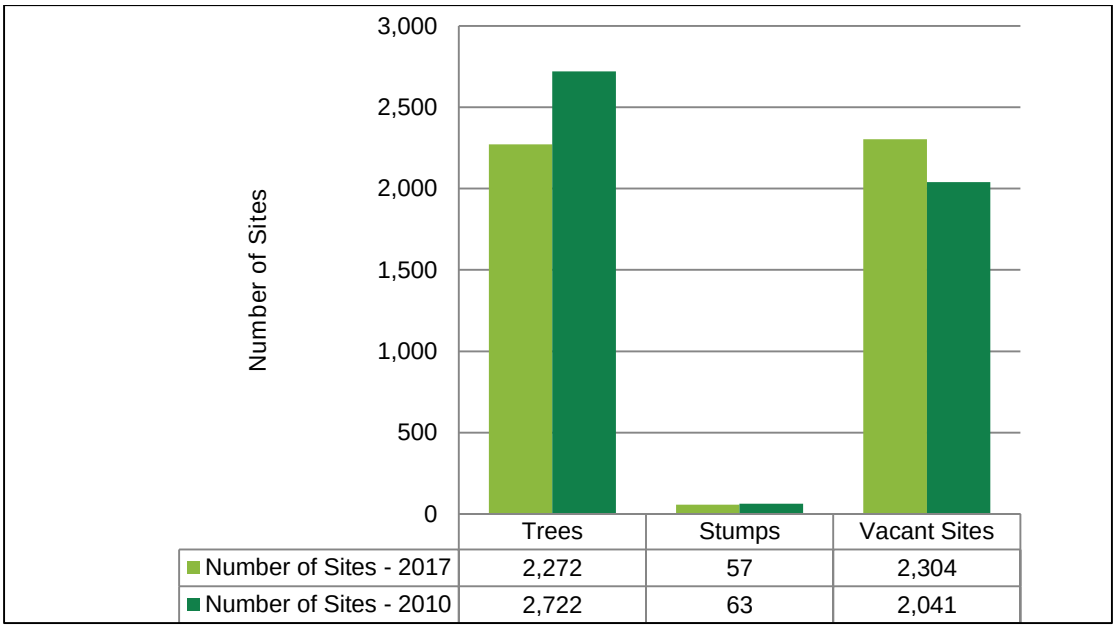


Figure 1. Sites collected during the 2017 and 2010 inventories.

Assessment of Tree Inventory Data

Photograph 1. Davey Resource Group inventoried trees, stumps, and planting sites along street ROWs and trees and stumps in community parks to collect information about trees that could be used to assess the state of the urban forest.

Data analysis and professional judgment are used to make generalizations about the state of the inventoried tree population. Recognizing trends in the data can help guide short-term and long-term management planning. See Appendix A for more information on data collection and site location methods. In this plan, the following criteria and indicators of the inventoried tree population were assessed:

- *Species Diversity*, the variety of species in a specific population affects the 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.
- *Diameter Size Class Distribution Data*, the statistical distribution of a given tree population's trunk-size class, is used to indicate the relative age of a tree population. The diameter size class distribution affects the valuation of tree-related benefits as well as the projection of maintenance needs and costs, planting goals, and canopy continuity.
- *Condition*, the general health of a tree population, indicates how well trees are performing given their site-specific conditions. General health affects both short-term and long-term maintenance needs and costs as well as canopy continuity.
- *Stocking Level* is the proportion of existing street trees compared to the total number of potential street trees (number of inventoried trees plus the number of potential planting spaces); stocking level can help determine tree planting needs and budgets.
- *Other Observations* include inventory data analysis that provides insight into past maintenance practices and growing conditions; such observations may affect future management decisions.
- *Further Inspection* indicates whether a particular tree requires additional inspection, such as a Level III risk inspection in accordance with ANSI A300, Part 9 (ANSI 2011), or periodic inspection due to particular conditions that may cause the tree to be a safety risk and, therefore, hazardous.

Species Diversity

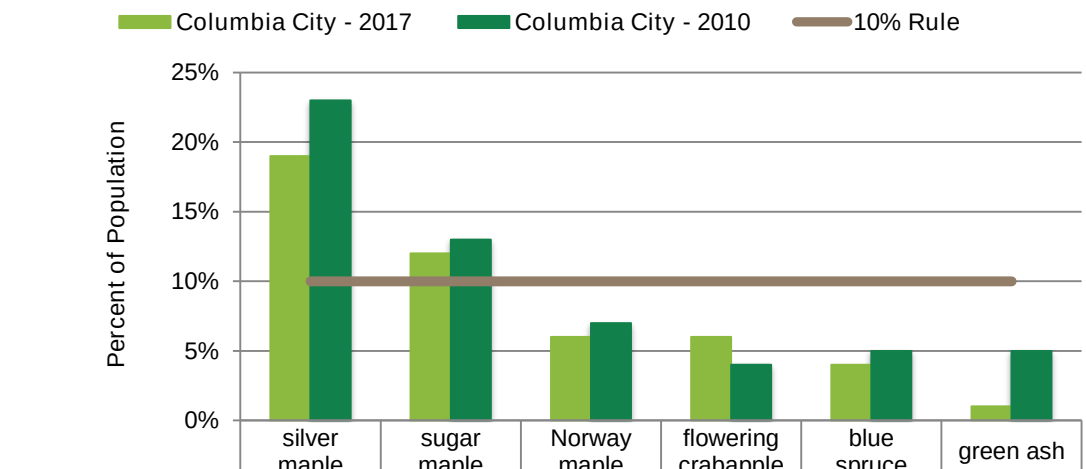
Species diversity affects maintenance costs, planting goals, canopy continuity, and the forestry program's ability to respond to threats from invasive pests or diseases. Low species diversity (large number of trees of the same species) can lead to severe losses in the event of species-specific epidemics such as the devastating results of Dutch elm disease (*Ophiostoma novo-ulmi*) throughout New England and the Midwest. Due to the spread of Dutch elm disease in the 1930s, combined with the disease's prevalence today, massive numbers of *Ulmus americana* (American elm), a popular street tree in Midwestern cities and towns, have perished (Karnosky 1979). Several Midwestern communities were stripped of most of their mature shade trees, creating a drastic void in canopy cover. Many of these communities have replanted to replace the lost elm trees. Ash and maple trees were popular replacements for American elm in the wake of Dutch elm disease. Unfortunately, some of the replacement species for American elm trees are now overabundant, which is a biodiversity concern. Emerald ash borer (EAB, *Agrilus planipennis*) and Asian longhorned beetle (ALB, *Anoplophora glabripennis*) are non-native insect pests that attack some of the most prevalent urban shade trees and certain agricultural trees throughout the country.

The composition of a 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%.

Findings

Analysis of Columbia City's 2017 tree inventory data indicated that the street tree population had 47 genera and 103 species represented. In 2010, the street trees contained 7 fewer species and 2 fewer genera than the 2017 inventoried population.

Figure 2 uses the 10% Rule to compare the percentages of the most common species identified during the 2017 inventory and 2010 inventory. *Acer saccharinum* (silver maple) and *A. saccharum* (sugar maple) far exceed the recommended 10% maximum for a single species in a population, comprising 19% and 12% of the inventoried tree population, respectively. Percentages of silver maple and sugar maple were slightly higher in the 2010 inventory.

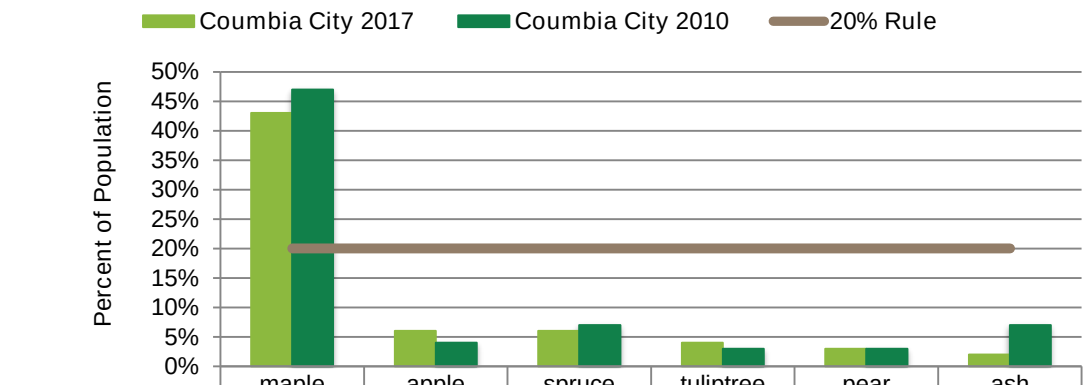


	silver maple	sugar maple	Norway maple	flowering crabapple	blue spruce	green ash
Columbia City - 2017	19%	12%	6%	6%	4%	1%
Columbia City - 2010	23%	13%	7%	4%	5%	5%
10% Rule	10%	10%	10%	10%	10%	10%

Figure 2. Most abundant species of the inventoried populations compared to the 10% Rule.

Figure 3 uses the 20% Rule to compare the percentages of the most common genera identified during the 2017 inventory and 2010 inventory. *Acer* (maple) far exceeds the recommended 20% maximum for a single genus in a population, comprising 43% of the inventoried tree population. The percentage of maple was slightly higher in the 2010 inventory.

Fraxinus (ash) represents 2% (50 trees) of the 2017 inventoried population and in 2010 represented 7% (188 trees).



	maple	apple	spruce	tuliptree	pear	ash
Coumbia City 2017	43%	6%	6%	4%	3%	2%
Coumbia City 2010	47%	4%	7%	3%	3%	7%
20% Rule	20%	20%	20%	20%	20%	20%

Figure 3. Most abundant genera of the inventoried population compared to the 20% Rule.

Discussion/Recommendations

Species diversity has improved with the introduction of seven new species to the street tree population. Columbia City should continue to diversify the population. Multi-year trial and error projects with new species to examine the performance possibility in Columbia City's environment will benefit the effort of enhancing species diversity. Multiple Indiana communities, such as Bloomington, Valparaiso, Evansville, and Indianapolis, have had much success with similar multi-year trial and error projects. See Appendix B for a recommended tree species list for planting.

Acer (maple) dominates the streets. This is a biodiversity concern because its abundance in the landscape makes it a limiting species. Diversity of tree species is an important objective that will ensure Columbia City's urban forest is sustainable and resilient to future invasive pest infestations.

Considering the large quantity of *Acer* (maple) in the city's population, along with its susceptibility to Asian longhorned beetle, the planting of *Acer* (maple) should be limited to minimize the potential for loss in the event that Asian longhorned beetle threatens Columbia City's urban tree population.

The city has stopped the planting of *Fraxinus* (ash) and should continue to do so until emerald ash borer resilient variations of *Fraxinus* are available in nursery's and approved by IDNR CUF.

Diameter Size Class Distribution

Analyzing diameter size class distribution provides an estimate of the relative age of a tree population and offers insight into maintenance practices and needs.

The inventoried trees were categorized into the following diameter size classes: young trees (0–8 inches DBH), established (9–17 inches DBH), maturing (18–24 inches DBH), and mature trees (greater than 24 inches DBH). These categories were chosen so that the population could be analyzed according to Richards' ideal distribution (1983). Richards proposed an ideal diameter size class distribution for street trees based on observations of well-adapted trees in Syracuse, New York. Richards' ideal distribution suggests that the largest percentage of a tree population (approximately 40% of the population) should be young (less than 8 inches DBH), while a smaller percentage (approximately 10%) should be mature (greater than 24 inches DBH). 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.

Findings

Figure 4 compares Columbia City's diameter size class distribution of the 2017 and 2010 inventoried tree populations to the ideal proposed by Richards (1983). Columbia City's distribution trends towards the ideal of 40% in both years. There were more young trees (smaller diameter) than older trees (larger diameter).

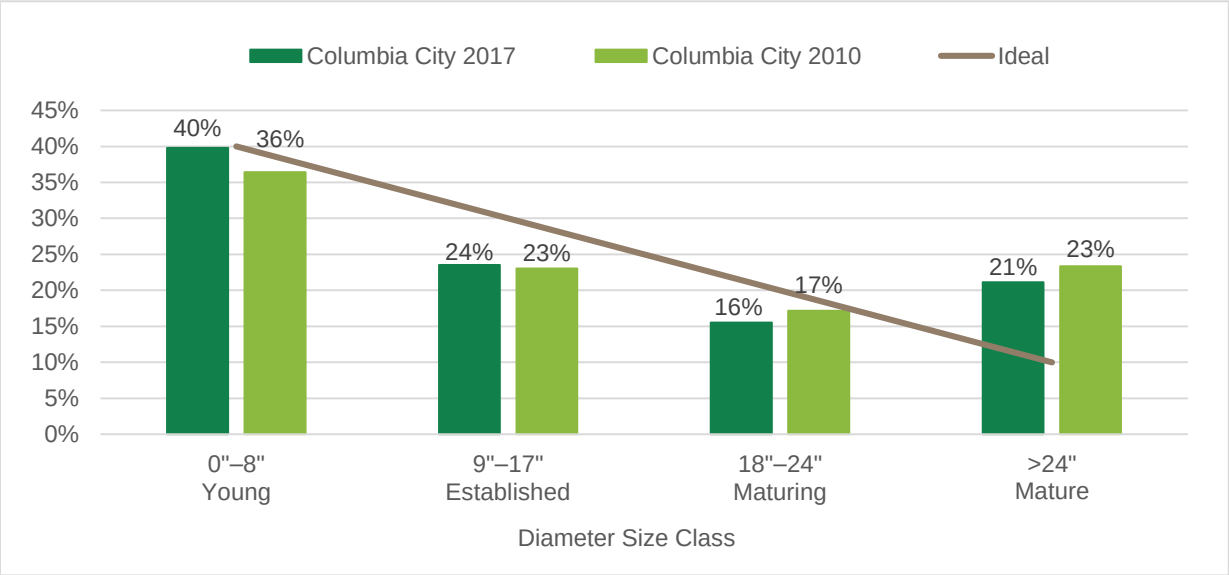


Figure 4. Comparison of diameter size class distribution for inventoried trees to the ideal distribution.

Discussion/Recommendations

One of Columbia City's objectives is to have an uneven-aged distribution of trees. Davey Resource Group recommends that Columbia City continue to support and build upon the existing planting and maintenance programs to ensure that young, healthy trees are in place to fill in gaps in tree canopy and replace older declining trees. The city must seek alternative funding sources to have the budget capacity to allow for annual tree plantings. As of 2012, the city has planted 30 trees bi-annually with funding from the IDNR CUF grant program. Prior to 2012 tree planting was irregular. In addition to tree planting, the city will need to continue promoting 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.

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.

Condition

Davey Resource Group assessed the condition of individual trees based on methods defined by the International Society of Arboriculture (ISA). Several factors were considered for each tree, including: root characteristics, branch structure, trunk, canopy, foliage condition, and the presence of pests. The condition of each inventoried tree was rated Excellent, Very Good, Good, Fair, Poor, Critical, or Dead.

In this plan, the general health of the inventoried tree population was characterized by the most prevalent condition assigned during the inventory.

Comparing the condition of the inventoried tree population with relative tree age (or size class distribution) can provide insight into the stability of the population. Since tree species have different lifespans and mature at different diameters, heights, and crown spreads, actual tree age cannot be determined from diameter size class alone. However, general classifications of size can be extrapolated into relative age classes. The following categories are used to describe the relative age of a tree: young (0–8 inches DBH), established (9–17 inches DBH), maturing (18–24 inches DBH), and mature (greater than 24 inches DBH).

Figures 5 and 6 illustrate the general health and distribution of young, established, mature, and maturing trees relative to their condition in 2017. Figures 5 and 7 illustrate the general health and distribution of young, established, mature, and maturing trees relative to their condition in 2010.

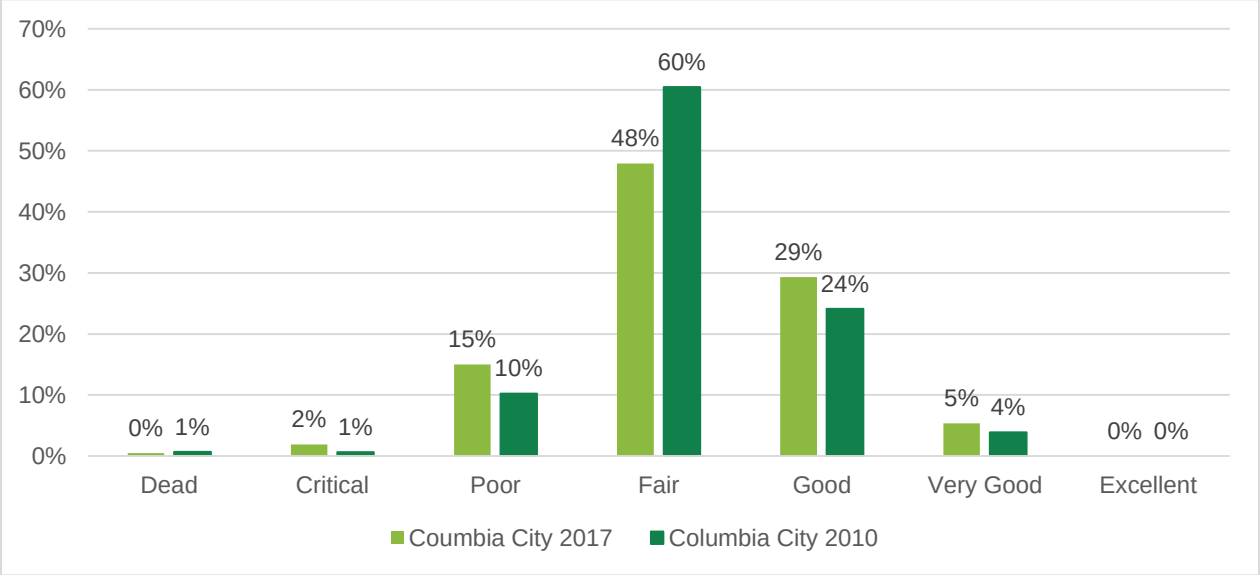


Figure 5. Conditions of inventoried trees.

Findings

Most of the inventoried trees in 2017 were recorded to be in Fair condition (Figure 4). Based on these data, the general health of the overall inventoried tree population is rated Fair. The general health of inventoried trees in 2010 was also rated Fair. When comparing the 2017 inventory to the 2010 inventory there are greater percentages of trees in Good (7%) and Poor (6%) conditions in 2017 than in 2010. Implementing a routine pruning program in 2012, experiencing an epic drought in 2012, and battling the threat of emerald ash borer since 2010 are all factors that can be attributed to these conditional changes.

Figure 6 (2017 inventory) illustrates that most of the young trees were rated to be in Good or Very Good condition and most of the established, maturing, and mature trees were rated to be in Fair condition. Figure 7 (2010 inventory) illustrates that most of the young, established, maturing, and mature trees were rated to be in Fair condition. In comparing the two figures, the most notable observation is the young population of 2017 were rated to be in Good and Very Good condition and the young population of 2010 were rated to be in Fair condition. These tree condition changes can be attributed to changes to city planting policy and maintenance practices established since 2010.

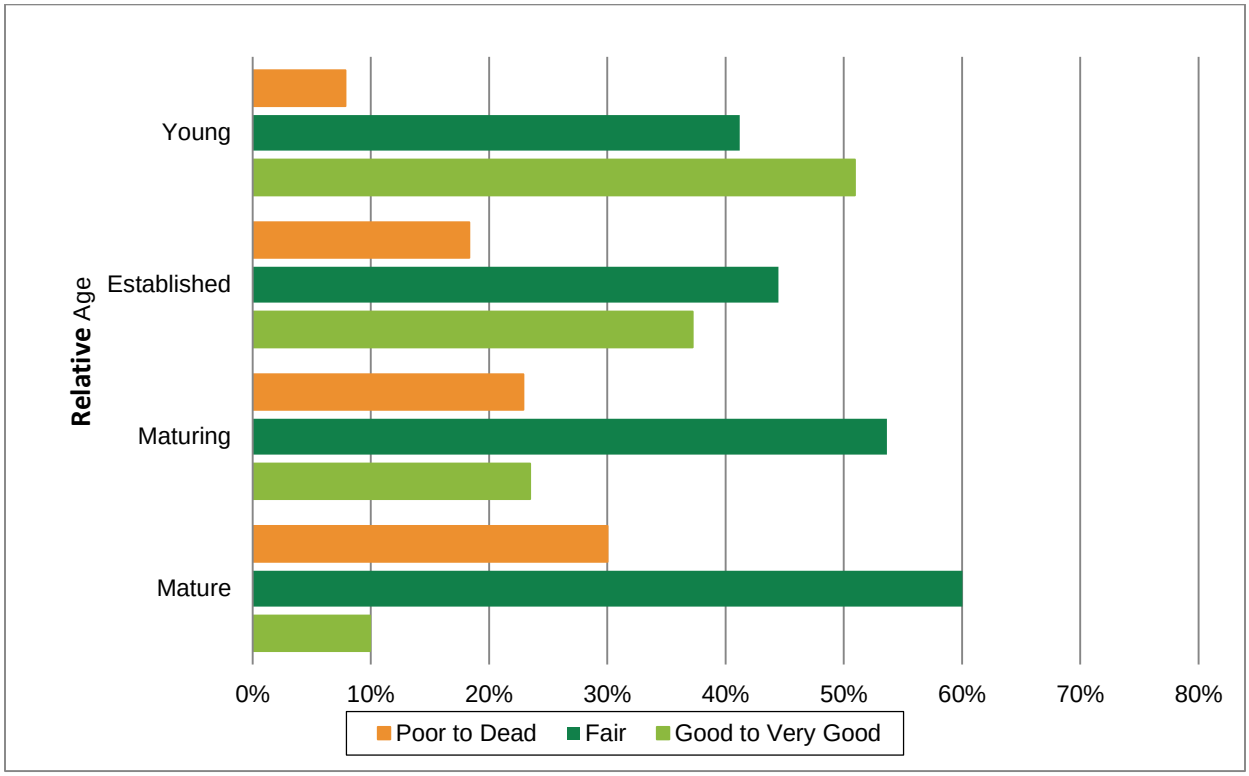


Figure 6. Tree condition by relative age during the 2017 inventory.

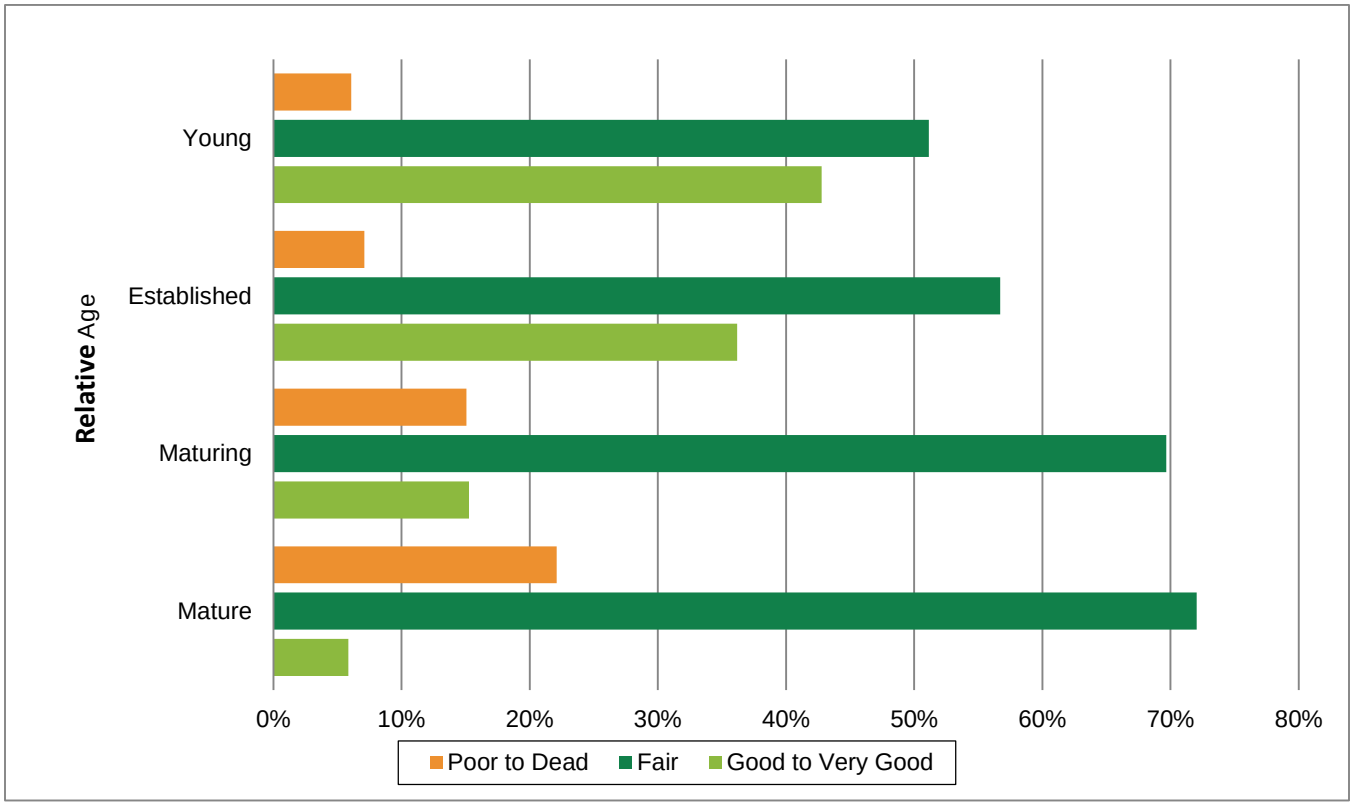


Figure 7. Tree condition by relative age during the 2010 inventory.

Discussion/Recommendations

Even though the condition of Columbia City's inventoried tree population is typical (rated Fair), data analysis has provided the following insight into maintenance needs and historical maintenance practices:

- The dissimilar trend in condition from 2010 to 2017 reveals that growing conditions have been challenging and modifications in tree management practices has been beneficial.
- 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.
- Poor condition ratings 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 possibly intensive plant health care to improve their vigor.
- Younger trees rated in Fair or Poor condition may benefit from improvements in structure that may improve their health over time. 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. 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 urban forest.

Replacement Value

Replacement value describes the historical investment in trees over time. Replacement value on a species level gives urban forest managers a look into the landscape value of their species populations. Values will reflect species population, stature, and condition.

Findings

Columbia City's street trees are an important municipal asset valued at $2,531,252. Over time, this value should increase as trees mature and more are planted, provided the trees are properly maintained. The average replacement value is approximately $1,114 per tree. Silver maple is shown to have the highest replacement value of all inventoried species at $803,823, or 32% of Columbia City's historical investment.

Discussion/Recommendations

A healthy, well-placed tree will become more valuable over time as it grows from a young tree to a mature tree. Davey Resource Group recommends that the city focus on tree care practices that will improve upon species diversity, size distribution, and health of the urban forest. Focusing on these things can promote higher valued investments.

Street ROW Stocking Level

Stocking is a traditional forestry term used to measure the density and distribution of trees. For an urban/community forest such as Columbia City, stocking level is used to estimate the total number of sites along the street ROW that could contain trees.

Stocking level is the ratio of street ROW spaces occupied by trees to the total street ROW spaces suitable for trees. For example, a street ROW tree inventory of 1,000 total sites with 750 existing trees and 250 planting sites would have a stocking level of 75%.

For an urban area, Davey Resource Group recommends that the street ROW stocking level be at least 90% so that no more than 10% of the potential planting sites along the street ROW are vacant.

Findings

The 2017 inventory reports 2,304 vacant planting sites and 57 stumps. Of the inventoried vacant planting sites, 46% (1,067) were potential planting sites for large-size trees (8-foot-wide and greater growing space size); 19% (431) were potential sites for medium-size trees (6- to 7-foot-wide growing space sizes); and 35% (806) were potential sites for small-size trees (4- to 5-foot-wide growing space sizes). Based on the data collected during this inventory, Columbia City's current street ROW tree stocking level is 49%.

Discussion/Recommendation

Fully stocking the street ROW with trees is an excellent goal. Inadequate tree planting and maintenance budgets, along with tree mortality, will result in lower stocking levels. Nevertheless, working to attain a fully stocked street ROW is important to promote canopy continuity and environmental sustainability. The city should consider improving its street ROW population's stocking level of 49% and work towards achieving the ideal of 90% or better. Generally, this entails a planned program of planting, care, and maintenance for the city's street trees.

Columbia City estimates that it plants about 30 trees per year. With a current total of 2,361 vacant planting sites and stumps along the street ROW, it would take approximately 64 years for the city to reach the recommended stocking level of 90%. If budgets allow, Davey Resource Group recommends that Columbia City increase the number of trees planted to 190 to achieve 90% stocking level in 10 years. If possible, exceed this recommendation to better prepare for impending threats and to increase the benefits provided by the urban forest.

Calculations of trees per capita are important in determining the density of a city's urban forest. The more residents and greater housing density a city possesses, the greater the need for trees to provide benefits.

Columbia City's ratio of street trees per capita is 0.26, which falls slightly below the mean ratio of 0.39 reported for the average community with a population of 5,000–9,999 (Hauer and Petterson 2016). According to the citywide study, there is 1 tree for every 3.9 residents. Columbia City's potential is 1 tree for every 1.9 residents.

Other Observations

Observations were recorded during the inventory to further describe a tree's health, structure, or location when more detail was needed.

Findings

Poor structure and cavity or decay were most frequently observed and recorded (11% and 11% of inventoried trees, respectively). Of these 494 trees, 101 were recommended for removal.

Signs of stress was recorded for 88 trees (4%); smaller than normal leaves for the species, early fall color foliage, necrotic foliage, and construction damage were observed. Of these 88 trees, 20 were recommended for removal.

Table 1. Observations Recorded During the 2017 Street Tree Inventory

Observation	Number of Trees	Percent
Poor Structure	253	11%
Cavity or Decay	241	11%
Signs of Stress	88	4%
Improperly Pruned	43	2%
Pest Problem	36	2%
Poor Root System	32	1%
Grate or Guard	29	1%
Remove Hardware	28	1%
Serious Decline	22	1%
Poor Location	18	1%
Mechanical Damage	17	1%
Improperly Installed	12	1%
Improperly Mulched	7	0%
Nutrient Deficiency	7	0%
Storm Damage	1	0%
None	1,438	63%
Total	2,272	100%

Discussion/Recommendations

Trees noted as having poor structure, cavity or decay, or signs of stress may require removal. Of the 582 trees, 121 trees (21%) were recommended for removal.

Generally, Davey Resource Group recommends routine tree inspections followed by prescribed maintenance to reduce reactive maintenance, minimize instances of elevated risk, and provide the basis for a more defensible management program. The inventory can assist with recording the need for shorter inspection interval by using the inventory data field Further Inspection needed (Yes/No). Davey Resource Group recommends trees with Further Inspection 'Yes' be reassessed annually. A portion of the 461 trees, not recommended for removal and observed as having poor structure, cavity or decay, or signs of stress may need to be assessed annually.

Further Inspection

This data field indicates whether a particular tree requires further inspection, such as a Level III risk inspection 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. If a tree was noted for further inspection, city staff should investigate as soon as possible to determine corrective actions.

Findings

Davey Resource Group recommended 50 trees for further inspection.

Discussion/Recommendations

An ISA Certified Arborist should perform additional inspections of the 50 trees. If it is determined that these trees exceed the threshold for acceptable risk, the defective part(s) of the tree should be corrected or removed, or the entire tree may need to be removed.

Potential Threats from Pests

Insects and diseases pose serious threats to tree health. Awareness and early diagnosis are essential to ensuring the health and continuity of street trees. Appendix C provides information about some of the current potential threats to Columbia City's trees and includes websites where more detailed information can be found.

Many pests target a single species or an entire genus. The inventory data were analyzed to provide a general estimate of the percentage of trees susceptible to some of the known pests in Indiana (see Figure 8). It is important to note that the figure only presents data collected from the inventory. Many more trees throughout Columbia City, including those on public and private property, may be susceptible to these invasive pests.

Findings

Looper complex [(*Erannis tiliaria*) and (*Phigalia titea*)], Asian longhorned beetle (ALB or *Anoplophora glabripennis*), and forest tent caterpillar (*Malacosoma disstria*) are known threats to a large percentage of the inventoried street trees. Large populations of these pests were not detected in Columbia City, but if they were, the city could see severe losses or degradation to health in its tree population.

- Looper complex, linden looper (*Erannis tiliaria*), and spiny looper (*Phigalia titea*) feed on many species and cause widespread defoliation. These insects may not directly kill trees, but they can severely damage tree health. These insects threaten 60% of the street tree population. The potential loss equates to approximately $1.9 million in replacement value.

- ALB is an insect that bores into and kills a wide range of hardwood species. ALB poses a threat to 45% of the street tree population, which represents a potential loss of approximately $1.6 million in replacement value.
- Forest tent caterpillar feeds on many species and causes widespread defoliation. These insects may not directly kill trees, but they can severely damage tree health. Forest tent caterpillar threatens 25% of the street tree population. The potential loss equates to approximately $767,000 in replacement value.

A large population of emerald ash borer (EAB, *Agrilus planipennis*) was detected in Columbia City. EAB is an insect that bores into and kills most *Fraxinus* species. There were 50 ash trees inventoried along Columbia City's street ROW. Many showed signs and symptoms. EAB poses a threat to 2% of the street tree population, which represents a potential loss of $26,000 in replacement value. The city preemptively removed the majority of the ash tree population between 2010 and 2012 and has transitioned to reactively removing dead and critical ash trees for the last few years.

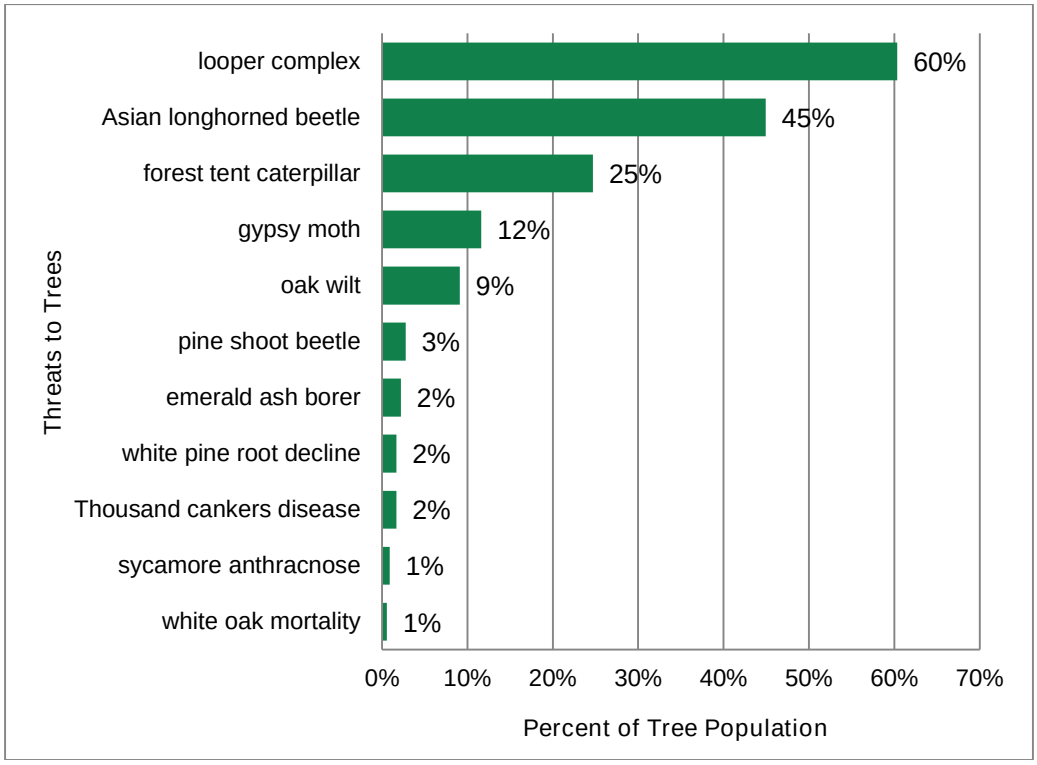


Figure 8. Potential impact of insect and disease threats noted during the 2017 inventory.

Discussion/Recommendations

Columbia City should be aware of the signs and symptoms of potential infestations and should be prepared to act if a significant threat is observed in its tree population or a nearby community. An integrated pest management plan should be established. The plan should focus on identifying and monitoring threats, understanding the economic threshold, selecting the correct treatment, properly timing management strategies, recordkeeping, and evaluating results. Davey Resource Group recommends the city continue to reactively remove the remaining ash tree population.

SECTION 2: BENEFITS OF THE URBAN FOREST

The urban forest plays an important role in supporting and improving the quality of life in urban areas. Trees' shade and beauty contributes to a community's quality of life and softens the often-hard appearance of urban landscapes and streetscapes. When properly maintained, trees provide communities abundant environmental, economic, and social benefits that far exceed the time and money invested in planting, pruning, protection, and removal.

Environmental Benefits

- Trees decrease energy consumption and moderate local climates by providing shade and acting as windbreaks.
- Trees act as mini-reservoirs, helping to slow and reduce the amount of stormwater runoff that reaches storm drains, rivers, and lakes. One hundred mature tree crowns intercept roughly 100,000 gallons of rainfall per year (U.S. Forest Service 2003a).
- Trees help reduce noise levels, cleanse atmospheric pollutants, produce oxygen, and absorb carbon dioxide.
- Trees can reduce street-level air pollution by up to 60% (Coder 1996). Lovasi (2008) suggested that children who live on tree-lined streets have lower rates of asthma.
- Trees stabilize soil and provide habitat for wildlife.

Economic Benefits

- Trees in a yard or neighborhood increase residential property values by an average of 7%.
- Commercial property rental rates are 7% higher when trees are on the property (Wolf 2007).
- Trees moderate temperatures in the summer and winter, saving on heating and cooling expenses (North Carolina State University 2012, Heisler 1986).
- On average, consumers will pay about 11% more for goods in landscaped areas, with this figure being as high as 50% for convenience goods (Wolf 1998b, Wolf 1999, and Wolf 2003).
- Consumers also feel that the quality of products is better in business districts surrounded by trees than those considered barren (Wolf 1998b).
- The quality of landscaping along the routes leading to business districts had a positive influence on consumers' perceptions of the area (Wolf 2000).

Social Benefits

- Tree-lined streets are safer; traffic speeds and the amount of stress drivers feel are reduced, which likely reduces road rage/aggressive driving (Wolf 1998a, Kuo and Sullivan 2001a).
- Chicago apartment buildings with medium amounts of greenery had 42% fewer crimes than those without any trees (Kuo and Sullivan 2001b).
- Chicago apartment buildings with high levels of greenery had 52% fewer crimes than those without any trees (Kuo and Sullivan 2001a).
- Employees who see trees from their desks experience 23% less sick time and report greater job satisfaction than those who do not (Wolf 1998a).
- Hospital patients recovering from surgery who had a view of a grove of trees through their windows required fewer pain relievers, experienced fewer complications, and left the hospital sooner than similar patients who had a view of a brick wall (Ulrich 1984, 1986).
- When surrounded by trees, physical signs of personal stress, such as muscle tension and pulse rate, were measurably reduced within three to four minutes (Ulrich 1991).

The trees growing along the public streets constitute a valuable community resource. They provide numerous tangible and intangible benefits such as pollution control, energy reduction, stormwater management, property value increases, wildlife habitat, education, and aesthetics.

The services and benefits of trees in the urban and suburban setting were once considered to be unquantifiable. However, by using extensive scientific studies and practical research, these benefits can now be confidently calculated using tree inventory information. The results of applying a proven, defensible model and method that determines tree benefit values for Columbia City's tree inventory data are summarized in this report using the i-Tree Streets application. The results of Columbia City's tree inventory provide insight into the overall health of the city's public trees and the management activities needed to maintain and increase the benefits of trees into the future.

Tree Benefit Analysis

i-Tree Streets

In order to identify the dollar value provided and returned to the community, the city's street tree inventory data were formatted for use in the i-Tree Streets benefit-cost assessment tool.

i-Tree Streets, a component of i-Tree Tools, analyzes an inventoried tree population's structure to estimate the costs and benefits of that tree population. The assessment tool creates an annual benefit report that demonstrates the value street trees provide to a community:

These quantified benefits and the reports generated are described below.

- **Aesthetic/Other Benefits:** Shows the tangible and intangible benefits of trees reflected by increases in property values (in dollars).
- **Stormwater:** Presents reductions in annual stormwater runoff due to rainfall interception by trees measured in gallons.
- **Carbon Stored:** Tallies all of the carbon dioxide (CO_2) stored in the urban forest over the life of its trees as a result of sequestration. Carbon stored is measured in pounds and has been translated to tons for this report.
- **Energy:** Presents the contribution of the urban forest towards conserving energy in terms of reduced natural gas use in the winter (measured in therms [thm]) and reduced electricity use for air conditioning in the summer (measured in Megawatt-hours ([MWh]).
- **Carbon Sequestered:** Presents annual reductions in atmospheric CO_2 due to sequestration by trees and reduced emissions from power plants due to reductions in energy use. This is measured in pounds and has been translated to tons for this report. The model accounts for CO_2 released as trees die and decompose and CO_2 released during the care and maintenance of trees.
- **Air Quality:** Quantifies the air pollutants (ozone [O_3], nitrogen dioxide [NO_2], sulfur dioxide [SO_2], 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 organic compounds [VOCs], SO_2) due to reduced electricity use in pounds. The potential negative effects of trees on air quality due to biogenic volatile organic compounds (BVOC) emissions is also reported.

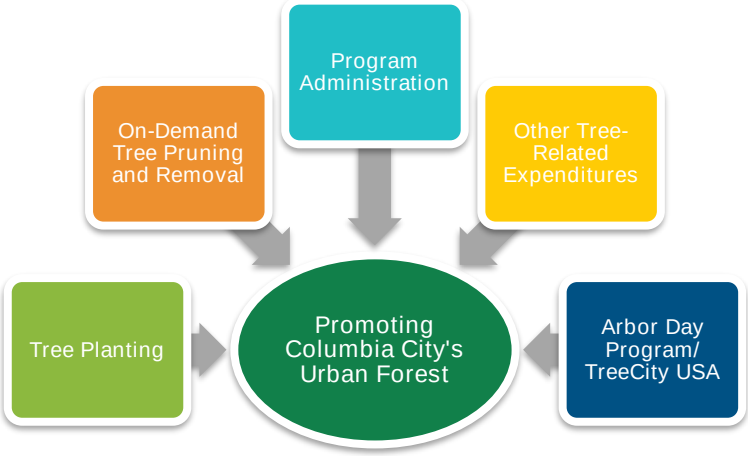
- **Importance Value (IV):** IVs are calculated for species that comprise more than 1% of the population. The Streets IV is the mean of three relative values (percentage of total trees, percentage of total leaf area, and percentage of canopy cover) and can range from 0 to 100, with an IV of 100 suggesting total reliance on one species. IVs offer valuable information about a community's reliance on certain species to provide functional benefits. For example, a species might represent 10% of a population but have an IV of 25% due to its substantial benefits, indicating that the loss of those trees would be more significant than just their population percentage would suggest.

i-Tree Tools

i-Tree Tools software was developed by the U.S. Department of Agriculture, Forest Service (USDA FS) with the help of several industry partners, including The Davey Tree Expert Company. Learn more at www.itreetools.org.

i-Tree Streets Inputs

In addition to tree inventory data, i-Tree Streets requires cost-specific information to manage a community's tree management program—including administrative costs and costs for tree pruning, removal, and planting. Regional data, including energy prices, property values, and stormwater costs are required inputs to generate the environmental and economic benefits trees provide. If community program costs or local economic data are not available, i-Tree Streets uses default economic inputs from a reference city selected by USDA FS for the climate zone in which the community is located. Any default value can be adjusted for local conditions.



Columbia City's Inputs

Local data were available at the time of this plan and were used to the greatest extent possible with i-Tree Streets to calculate the benefits Columbia City's trees provide its citizens. i-Tree Streets methods Davey Resource Group used for Columbia City are further described in Appendix D.

Annual Benefits

The i-Tree Streets model estimated that the inventoried street trees provide a total annual benefit of $284,850. Essentially, $284,850 was saved to cool buildings, manage stormwater, and clean the air. In addition, community aesthetics were improved and property values increased because of the presence of trees. On average, one of Columbia City's trees provides an annual benefit of $125.37.

i-Tree Tools

A common example of a natural BVOC is the gas emitted from pine trees, which creates the distinct smell of a pine forest.

The assessment found that stormwater management benefits trees provide were the greatest value to the community. The city's street trees alone intercept over 4.3 million gallons of rainfall per year which equates to a savings of $116,387 in stormwater management costs. Approximately 41% of the total annual benefits were due to stormwater management. In addition to stormwater management, trees also play a major role in aesthetics and other tangible and intangible benefits, measured in home resale value. Property value increases comprise 33% of the annual benefits street trees provide. Energy conservation, air quality improvement, and reductions in CO_2 are important but account for lesser amounts of work performed by community trees. Energy reductions accounted for 17% of the annual benefits, air quality improvement accounted for 5% of the annual benefits, while CO_2 reductions accounted for 4% of the annual benefits.

Figure 9 summarizes the annual benefits and results for the street tree population. Table 3 presents results for individual tree species from the i-Tree Streets analysis.

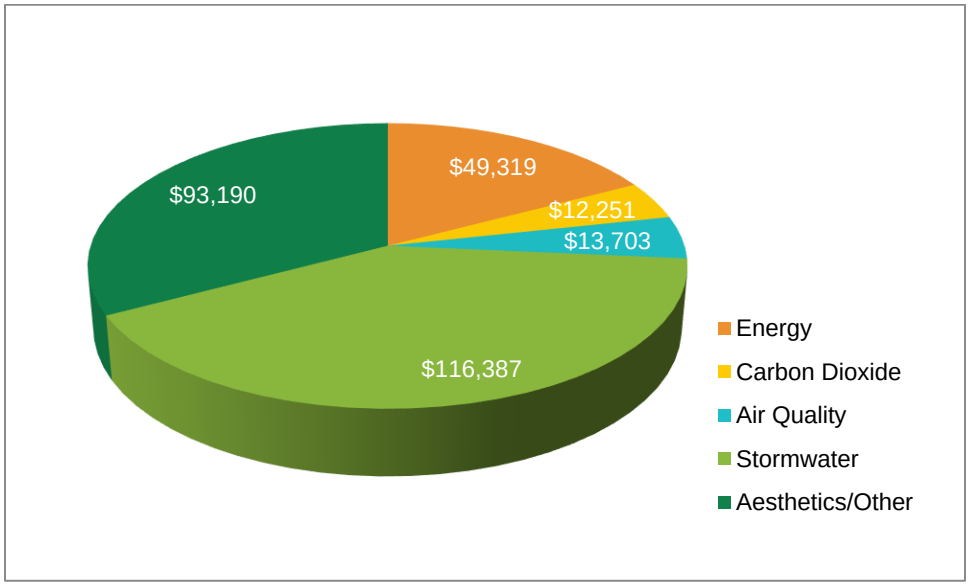


Figure 9. Breakdown of total annual benefits provided to Columbia City.

Net Benefits and Benefit-Cost Ratio

According to the benefits presented in this chapter, trees make good sense, but are the collective benefits worth the costs of management? In other words, are trees a good investment for Columbia City? To answer that question, we must compare the benefit public trees provide to the cost of their management.

The sum of environmental and economic benefits provided to Columbia City is $284,850 annually at an average of $125 per public tree and $32 per capita (Table 2). Compared to the median values of eight benchmark communities used in the Sample Urban Statewide Inventory (SUSI) in Table 2, Columbia City's gross benefit per tree is more than the benchmark of $84, and Columbia City's gross benefit per capita is more than the benchmark of $15.

Applying a benefit-cost ratio (BCR) is another useful way to evaluate the investment in public trees. A BCR is an indicator used to summarize the overall value compared to the costs of a given project. Specifically, in this analysis, BCR is the ratio of the cumulative benefits provided by the city's public trees, expressed in monetary terms, compared to the costs associated with their management, also expressed in monetary terms. When Columbia City's annual expenditures of $157,619 are considered, the net annual benefit (benefits minus costs) returned by public trees to the city is $127,231. Columbia City receives $1.81 in benefits for every $1 spent on its municipal forestry program (Table 2).

Table 2. Columbia City's Annual Benefits Compared to Other Indiana Communities' Annual Benefits

	SUSI Benchmark (Median Values)	Columbia City, Indiana
Annual Gross Benefit	$107,515	$284,850
Gross Benefit per Tree	$84.24	$125.37
Gross Benefit per Capita	$15.16	$32.37
Annual Costs	$44,350	$157,619
Cost per Tree	$36.43	$69.37
Cost per Capita	$6.56	$17.91
Annual Net Benefit	$107,412	$127,231
Net Benefit per Tree	$47.81	$56.00
Net Benefit per Capita	$8.48	$14.46
Benefit-Cost Ratio	$1.17	$1.81

Table 3. Benefit Data for Common Street Trees by Species

Most Common Trees Collected During Inventory		Number Trees on the ROW	Percent of Total Trees	Canopy Cover	Benefit Provide By Street Trees					Importance Value (IV)
					Aesthetic/ Other	Stormwater	Energy	Carbon Sequestered	Air Quality	
Common Name	Botanical Name		(%)	(ft^2)	Average/$/Tree					0–100 (higher IV = more important species)
silver maple	Acer saccharinum	433	19	770,600	90.10	117.05	39.24	12.68	11.74	33
sugar maple	Acer saccharum	282	12	370,590	55.40	78.12	32.99	7.26	8.73	18
Norway maple	Acer platanoides	144	6	104,022	25.98	37.83	21.64	4.10	6.31	5
apple	Malus species	132	6	31,322	4.71	5.69	7.43	1.38	2.02	3
blue spruce	Picea pungens	98	4	32,184	21.68	32.18	10.94	1.70	1.72	3
tuliptree	Liriodendron tulipifera	92	4	68,848	35.87	40.17	21.95	5.00	5.96	4
red maple	Acer rubrum	70	3	45,914	20.69	30.98	17.97	2.85	5.30	2
callery pear	Pyrus calleryana	68	3	21,048	17.58	12.79	10.34	2.21	2.72	2
thornless honeylocust	Gleditsia triacanthos inermis	65	3	65,194	110.30	47.56	25.51	6.38	6.84	3
northern white cedar	Thuja occidentalis	60	3	11,217	12.34	14.12	5.92	0.89	1.12	1
eastern redbud	Cercis canadensis	57	3	11,658	4.15	5.00	6.22	1.19	1.71	1
plum	Prunus species	45	2	8,706	3.68	4.46	6.07	1.12	1.62	1
black walnut	Juglans nigra	38	2	45,309	48.49	68.81	31.48	7.40	8.96	2
eastern white pine	Pinus strobus	38	2	8,383	15.10	22.54	7.05	1.11	0.95	1
juniper	Juniperus species	35	2	3,690	14.21	8.65	3.23	0.46	0.32	1
black maple	Acer nigrum	34	1	41,468	58.61	63.11	32.14	6.90	9.96	2
Norway spruce	Picea abies	31	1	11,029	19.17	42.24	11.27	1.69	1.00	1
littleleaf linden	Tilia cordata	28	1	9,908	28.88	19.23	12.66	3.30	3.34	1
white ash	Fraxinus americana	28	1	18,279	43.88	32.12	21.56	4.69	5.54	1
other street trees	~33 genera and ~87 species	494	22	269,514	24.87	29.70	15.15	3.24	4.10	16
Total	~47 genera and ~103 species	2,272	100	1,948,885	41.02	51.23	21.71	5.39	6.03	100

Stormwater Benefits

Trees intercept rainfall, which helps lower costs to manage stormwater runoff. The inventoried trees in Columbia City intercept 4,294,733 gallons of rainfall annually (Table 4). On average, the estimated annual savings for the city in stormwater runoff management is $116,387.

Of all species inventoried, silver maple contributed most of the annual stormwater benefits. The population of silver maple (19% of ROW) intercepted approximately 1.9 million gallons of rainfall. On a per-tree basis, large trees with leafy canopies provided the most value. Norway maple and flowering crabapple comprised 6% and 6% of the ROW population, respectively. Silver maple (large-statured tree) absorbed 67 times more gallons of rainfall than flowering crabapple (small-statured tree) and Norway maple (medium-statured tree) absorbed 7 times more gallons of rainfall than flowering crabapple. Large-statured trees with big canopies offered the greatest benefits.

Table 4. Stormwater Benefits Provided by ROW Trees

Most Common Trees Collected During Inventory		Number of Trees on the ROW	Percent of Total Trees	Total Rainfall Interception
Common Name	Botanical Name		(%)	(gal.)
silver maple	Acer saccharinum	433	19	1,870,284
sugar maple	Acer saccharum	282	12	812,944
Norway maple	Acer platanoides	144	6	201,015
apple	Malus species	132	6	27,722
blue spruce	Picea pungens	98	4	116,385
tulip tree	Liriodendron tulipifera	92	4	136,384
red maple	Acer rubrum	70	3	80,022
callery pear	Pyrus calleryana	68	3	32,101
thornless honeylocust	Gleditsia triacanthos inermis	65	3	114,070
northern white cedar	Thuja occidentalis	60	3	31,270
eastern redbud	Cercis canadensis	57	3	10,513
plum	Prunus species	45	2	7,404
black walnut	Juglans nigra	38	2	96,488
eastern white pine	Pinus strobus	38	2	31,608
juniper	Juniperus species	35	2	11,178
black maple	Acer nigrum	34	1	79,181
Norway spruce	Picea abies	31	1	48,320
littleleaf linden	Tilia cordata	28	1	19,867
white ash	Fraxinus americana	28	1	33,191
other street trees	~33 genera and ~87 species	494	22	534,787
Total	~47 genera and ~103 species	2,272	100	4,294,733

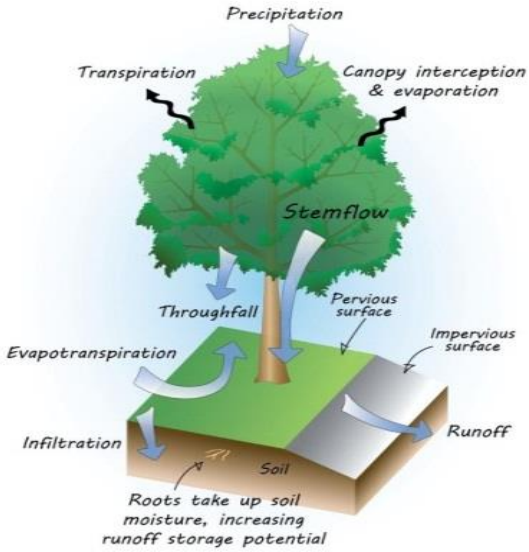
Aesthetic/Other Benefits

The total annual benefit associated with property value increases and other tangible and intangible benefits of street trees was $93,190. The average benefit per tree equaled $41.02 per year.

Energy Benefits

Public trees conserve energy by shading structures and surfaces, which reduces electricity use for air conditioning in the summer. Trees divert wind in the winter to reduce natural gas use. Based on the inventoried trees, the annual electric and natural gas savings are equivalent to 393 MWh of electricity and 53,521 therms of natural gas. When converted into dollars and cents using Columbia City's economic data, this accounts for an annual savings of $49,319 in energy consumption.

Silver maple contributed $16,989 (34%) the annual energy benefits of the urban forest, but its contribution was mostly due to its dominance on the streets. Other tree species, specifically northern catalpa and three hickory species, contributed more to reduce energy usage on a per-tree basis. The annual value these trees provide exceeds $40 per tree, although their individual populations comprise less than 1% of the population. These large leafy canopies are valuable because they provide shade, which reduces energy usage. Smaller canopy trees inventoried, such as flowering crabapple and blue spruce, were found to have smaller reductions in energy usage on a per-tree basis.



- *Trees reduce stormwater runoff by capturing and storing rainfall in their canopy and releasing water into the atmosphere.*
- *Tree roots and leaf litter create soil conditions that promote the infiltration of rainwater into the soil.*
- *Trees help slow down and temporarily store runoff and reduce pollutants by absorbing nutrients and other pollutants from soils and water through their roots.*
- *Trees transform pollutants into less harmful substances.*

Acer saccharinum (silver maple)	Malus spp. (flowering crabapple)	Picea pungens (blue spruce)	Catalpa speciosa (northern catalpa)
19% of ROW	**6% of ROW**	4% of ROW	**< 1% of ROW**
136 MWh Electricity	8 MWh Electricity	9 MWh Electricity	**8 MWh** Electricity
17,881 thm Natural Gas	1,218 thm Natural Gas	**1,125 thm** Natural **Gas**	1,111 thm Natural Gas
$39.24 Average $/tree	$7.43 Average $/tree	**$10.94 Average $/**tree	**$46.54 Average $/tree**

Carbon Storage and Carbon Sequestration

Trees store some of the carbon dioxide (CO_2) they absorb. This prevents CO_2 from reaching the upper atmosphere, where it can react with other compounds and form harmful gases like ozone, which adversely affects air quality. These trees also sequester some of the CO_2 during growth (Nowak et al. 2013).

The i-Tree Streets calculation takes into account the carbon emissions that are *not* released from power stations due to the heating and cooling effect of trees (i.e., conserved energy in buildings and homes). It also calculates emissions released during tree care and maintenance, such as driving to the site and operating equipment. The net carbon benefit is approximately $12,251 per year.

The city's street trees store 7,360 tons of carbon (measured in CO_2 equivalents). This amount reflects the amount of carbon they have amassed during their lifetimes. Through sequestration and avoidance, 817 tons of CO_2 are removed each year. Black locust, silver maple, and American basswood provided the most carbon benefits, with each tree sequestering an annual average of more than $10 worth of carbon.

Air Quality Improvements

The inventoried tree population annually removes 1,140 pounds of air pollutants (including ozone, nitrogen dioxide, sulfur dioxide, and particulate matter) through deposition. The population also avoids 4,182 pounds of air pollutants annually.

The i-Tree Streets calculation takes into account the biogenic volatile organic compounds (BVOC's) that are released from trees. The net total value of these benefits is estimated to be $1,556. The inventoried trees removed or avoided more pollutants than they emitted, resulting in a positive economic value equal to $13,703 annually.

The trees that provided the most benefits based on an annual per-tree average value were northern catalpa and black locust ($15.32 and $12.87), respectively. The individual populations of these two species represent less than 1% of the street tree population. Using the annual per-tree values in Table 4 (species representing 1% or more of the street trees population), silver maple and black maple had the most beneficial impact on air quality based on their annual per-tree average values. These two species populations, among ten other large-statured species populations, provide the most air quality benefits based on the annual per-tree average value.

Importance Value (IV)

Understanding the importance of a tree species to the community is based on its presence on the ROW, but also its ability to provide environmental and economic benefits to the community. The IV calculated by the street computer model takes into account the total number of trees of a species, its percentage in the population, and its total leaf area and canopy cover. The IV can range from 0 to 100, with an IV of 100 suggesting total reliance on one species. If IV values are greater or less than the percentage of a species on the ROW, it indicates that the loss of that species may be more important or less important than its population percentage implies.

The i-Tree Streets assessment found that silver maple has the greatest IV in the ROW population at 33, even though it comprises only 19% of the ROW. This indicates that the loss of the silver maple population would be more economically detrimental than its percentage of the population leads us to believe. The second highest IV was for sugar maple (18), followed by Norway maple (5) and tuliptree (4). The abundance of tuliptree (4%) is the same as its IV. Tuliptree is a large growing species; the size and canopy of broadleaf species by nature provide more environmental benefits to the community, which are factors of assigning IV. The IV for flowering crabapple (3) is less than its percentage of the population, indicating that if flowering crabapple was lost, its economic impact would not be as significant. The same is true for Norway maple as its IV is 5 and its population is 6% of the street ROW.

Discussion/Recommendations

The i-Tree Streets analysis found that public trees provide environmental and economic benefits to the community by virtue of their mere presence on the streets. Currently, the stormwater management benefits provided by public trees were rated as having the greatest value to the community. The stormwater management provided by trees is an important nature-based solution to sustainable urban drainage systems and the community's economic growth. In addition to stormwater management, trees stimulate economic growth through increased property values, provide shade and windbreaks to reduce energy usage, and store and sequester CO_2. Even though these environmental benefits were not found to be as great as the stormwater management benefits, they are noteworthy.

i-Tree Streets analysis found that the silver maple is Columbia City's most influential street tree. If this species was lost to an invasive species or disease or other threats, its loss would be felt more than the community may realize.

To increase the benefits the urban forest provides, the city should plant young, large-statured tree species that manage the most stormwater, absorb the most CO_2, and remove the most air pollutants. Leafy, large-stature trees consistently created the most environmental and economic benefits. The following list of tree species is used for improving environmental benefits (iTree Species 2017):

<u>Pollutant Removal</u>

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

<u>Carbon Storage</u>

- *Quercus shumardii* (shumard oak)
- *Platanus occidentalis* (American sycamore)
- *Zelkova serrata* (Japanese zelkova)
- *Ulmus americana* (American elm)
- *Betula alleghaniensis* (yellow birch)

Stormwater Reduction

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

Energy Reduction

- *Liriodendron tulipifera* (tuliptree)
- *Ulmus americana* (American elm)
- *Tilia americana* (American linden)
- *Betula alleghaniensis* (yellow birch)
- *Platanus occidentalis* (American sycamore)

SECTION 3: TREE MANAGEMENT PROGRAM

This tree management program was developed to uphold Columbia City's comprehensive vision for preserving its urban forest. This ten-year program is based on the tree inventory data; the program was designed to reduce risk through prioritized tree removal and pruning, and to improve tree health and structure through proactive pruning cycles. Tree planting to mitigate removals and increase canopy cover and public outreach are important parts of the program as well.

While implementing a tree care program is an ongoing process, tree work must always be prioritized to reduce public safety risks. Davey Resource Group recommends completing the work identified during the inventory based on the assigned priority. However, it is also essential to routinely monitor the tree population to identify other high-risk trees so that they may be systematically addressed. While regular pruning cycles and tree planting is important, priority work (especially for Priority 1 and 2 trees) must sometimes take precedence to ensure that risk is expediently managed.

Priority and Proactive Maintenance

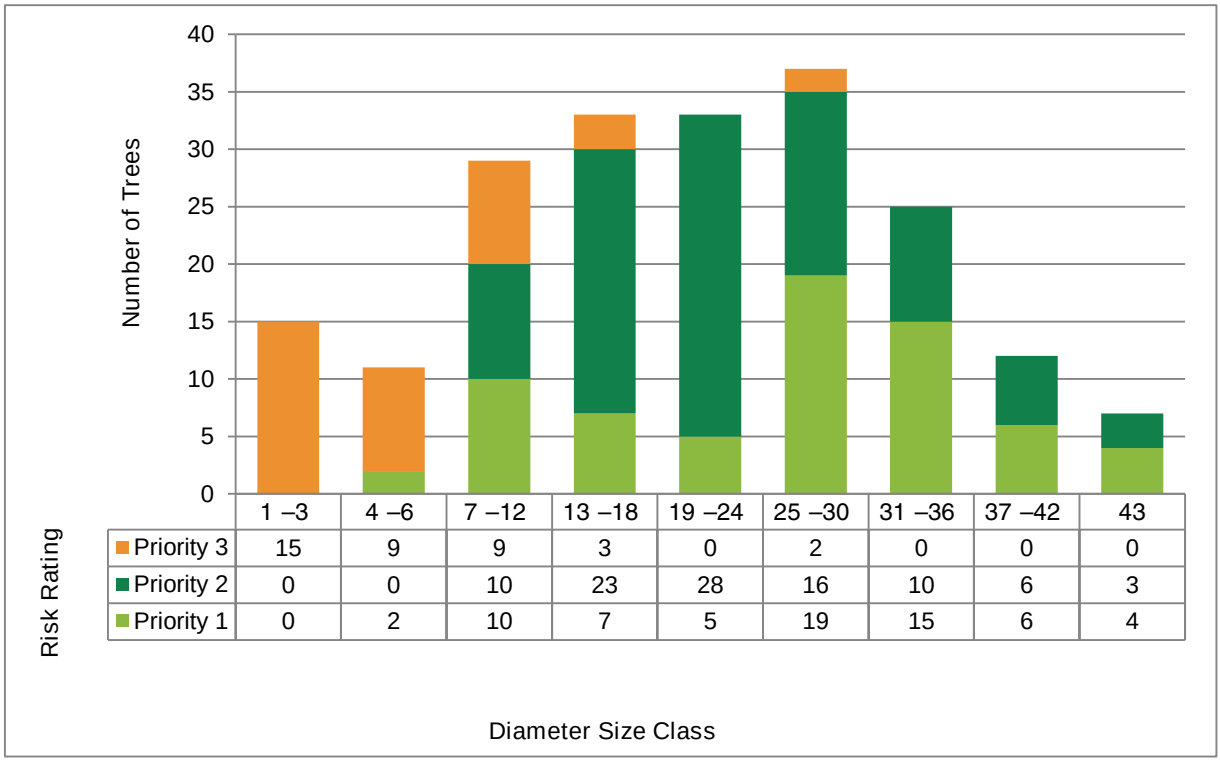
In this plan, the recommended tree maintenance work was divided into either priority or proactive maintenance. Priority maintenance includes all tree and stump removals and Priority 1 and 2 Prunes. Proactive tree maintenance includes routinely pruning young and more mature trees. Tree planting, inspections, and community outreach are also considered proactive maintenance. Further explanation about priority and proactive maintenance can be found in Appendix E.

Tree and Stump Removal

Although tree removal is usually considered a last resort and may sometimes create a reaction from the community, there are circumstances in which removal is necessary. Trees fail from natural causes, such as diseases, insects, and weather conditions, and from physical injury due to vehicles, vandalism, and root disturbances. Davey Resource Group recommends that trees be removed when corrective pruning will not adequately eliminate the hazard or when correcting problems would be cost-prohibitive. Trees that cause obstructions or interfere with power lines or other infrastructure should be removed when their defects cannot be corrected through pruning or other maintenance practices. Diseased and nuisance trees also warrant removal.

Even though large short-term expenditures may be required, it is important to secure the funding needed to complete priority tree removals. Expedient removal reduces risk and promotes public safety.

Figure 10 presents tree removals by priority and diameter size class. The following sections briefly summarize the recommended removals identified during the inventory.



	1 –3	4 –6	7 –12	13 –18	19 –24	25 –30	31 –36	37 –42	43
Priority 3	15	9	9	3	0	2	0	0	0
Priority 2	0	0	10	23	28	16	10	6	3
Priority 1	0	2	10	7	5	19	15	6	4

Figure 10. Tree removals by risk rating and diameter size class.

Findings

The inventory identified 68 Priority 1 trees, 96 Priority 2 trees, and 38 Priority 3 trees that are recommended for removal.

The diameter size classes for Priority 1 trees ranged mostly between 13–18 inches diameter at breast height (DBH) and 31–36 inches DBH. These trees should be removed immediately based on their assessed risk.

Most Priority 2 trees were smaller than 25 inches DBH. These trees should be removed as soon as possible after all Priority 1 removals have been completed.

Priority 3 removals pose little threat; these trees are generally small, dead, invasive, or poorly-formed trees that should to be removed. Eliminating these trees will reduce breeding site locations for insects and diseases and will increase the aesthetic value of the area. Healthy trees growing in poor locations or undesirable species are also included in this category. All Priority 3 trees should be removed when convenient and after all Priority 1 and 2 removals have been completed.

The inventory identified 12 ash trees recommended for removal (less than 1% of the population).

The inventory identified 57 stumps recommended for removal. All of these stumps were larger than 2 inches in diameter yet smaller than 46 inches in diameter. Stump removals should occur when convenient.

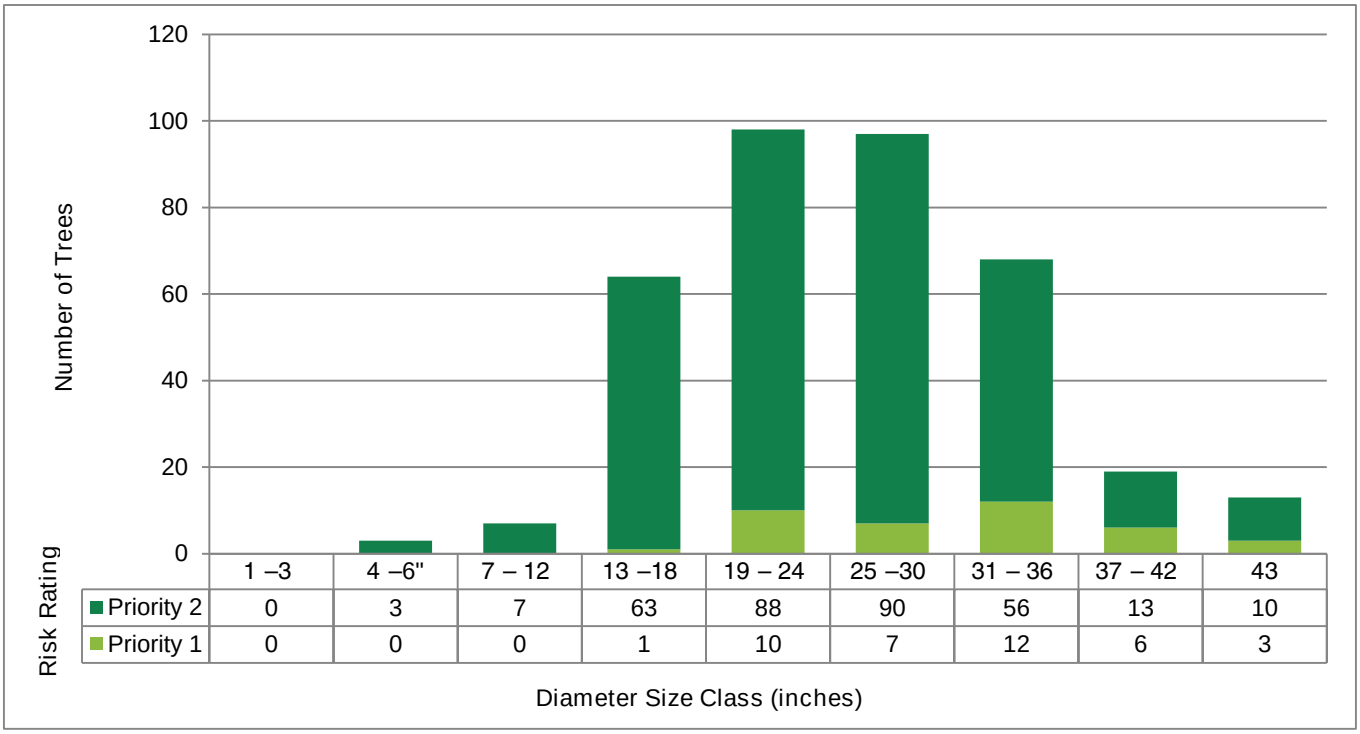
Discussion/Recommendations

Trees noted as needing further inspection (50 trees) should be inspected on a regular basis. Corrective action should be taken when warranted. If their condition worsens, tree removal may be required. Proactive tree maintenance that actively mitigates elevated-risk situations will promote public safety.

Tree Pruning

Priority 1 and 2 pruning generally requires cleaning the canopy of both small and large trees to remove hazardous defects such as dead and/or broken branches that may be present even when the rest of the tree is sound. In these cases, pruning the branch or branches can correct the problem and reduce risk associated with the tree.

Figure 11 presents the number of Priority 1 and 2 trees recommended for pruning by size class. The following sections briefly summarize the recommended pruning maintenance identified during the inventory.



Risk Rating	1 –3	4 –6"	7 – 12	13 –18	19 – 24	25 –30	31 – 36	37 – 42	43
Priority 2	0	3	7	63	88	90	56	13	10
Priority 1	0	0	0	1	10	7	12	6	3

Figure 11. Priority 1 and 2 pruning by diameter size class.

Findings

The inventory identified 39 Priority 1 trees and 330 Priority 2 trees recommended for pruning.

Priority 1 trees ranged in diameter size classes from 13–18 inches DBH to greater than 43 inches DBH. This pruning should be performed immediately based on assessed risk.

Priority 2 trees ranged in diameter size classes from 4–6 inches DBH to greater than or equal to 43 inches DBH. This pruning should be performed as soon as possible based on assigned risk and may be performed concurrently with other Priority 1 pruning.

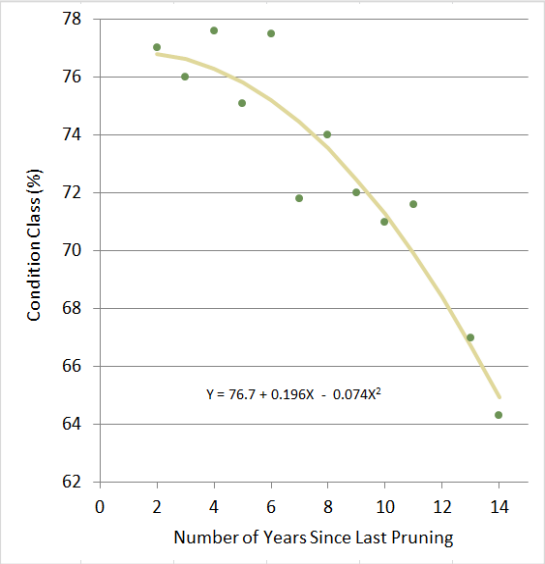


Figure 12. Relationship between average tree condition class and the number of years since the most recent pruning (adapted from Miller and Sylvester 1981).

Pruning Cycles

The goals of pruning cycles are to visit, assess, and prune trees on a regular schedule to improve health and reduce risk. In the ten-year program, Davey Resource Group recommends that pruning cycles begin after all Priority 1 and 2 trees are corrected through pruning. However, due to the long-term benefits of pruning cycles, Davey Resource Group recommends that the cycles be implemented as soon as possible. To ensure that all trees receive the type of pruning they need to mature with better structure and fewer hazards, two pruning cycles are recommended: the young tree training cycle (YTT Cycle) and the routine pruning cycle (RP Cycle). The cycles differ in the type of pruning, the general age of the target tree and length.

The recommended number of trees in the pruning cycles will need to be modified to reflect changes in the tree population as trees are planted, mature, and die. Newly planted trees will enter the YTT Cycle once they become established. As young trees reach maturity, they will be shifted from the YTT Cycle into the RP Cycle. When a tree reaches the end of its useful life, it should be removed and eliminated from the RP Cycle.

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. Miller and Sylvester suggested that a pruning cycle of five years is optimal for urban trees.

For many communities, a proactive tree management program is considered unfeasible. An on-demand response to urgent situations is the norm. Research has shown that a proactive program that includes a routine pruning cycle will improve the overall health of a tree population (Miller and Sylvester 1981). Proactive tree maintenance has many advantages over on-demand maintenance, the most significant of which is reduced risk. In a proactive program, trees are regularly assessed and pruned, which helps detect and eliminate most defects before they escalate to a hazardous situation with an unacceptable level of risk. Other advantages of a proactive program include: increased environmental and economic benefits from trees, more predictable budgets and projectable workloads, and reduced long-term tree maintenance costs.

Young Tree Training Cycle

Trees included in the YTT Cycle are generally less than 8 inches DBH. These younger trees sometimes have branch structures that can lead to potential problems as the tree ages. Potential structural problems include 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, increasing risk and creating potential liability.

YTT pruning is performed to improve tree form or structure; the recommended length of a YTT Cycle is three years because young trees tend to grow at faster rates (on average) than more mature trees.

The YTT Cycle differs from the RP Cycle in that these trees generally can be pruned from the ground with a pole pruner or pruning shear. The objective is to increase structural integrity by pruning for one dominant leader. YTT Pruning is species-specific, since many trees such as *Betula nigra* (river birch) may naturally have more than one leader. For such trees, YTT pruning is performed to develop a strong structural architecture of branches so that future growth will lead to a healthy, structurally sound tree.

Recommendations

The inventory found that 16% of trees on the street ROW needed training pruning. In 2016 Columbia City began training young trees. Davey Resource Group recommends that Columbia City continue to train young trees and implement a three-year YTT Cycle as soon as possible. The YTT Cycle will include existing young trees. During the inventory, 357 trees smaller than 12 inches DBH were inventoried and recommended young tree training. The benefit of beginning the YTT Cycle is substantial, Davey Resource Group recommends that an average of 125 trees be structurally pruned each year over 3 years, beginning in Year One of the management program.

If trees are planted, they will need to enter the YTT Cycle after establishment, typically a few years after planting.

In future years, the number of trees in the YTT Cycle will be based on tree planting efforts and growth rates of young trees. The city should strive to prune approximately one-third of its young trees each year.

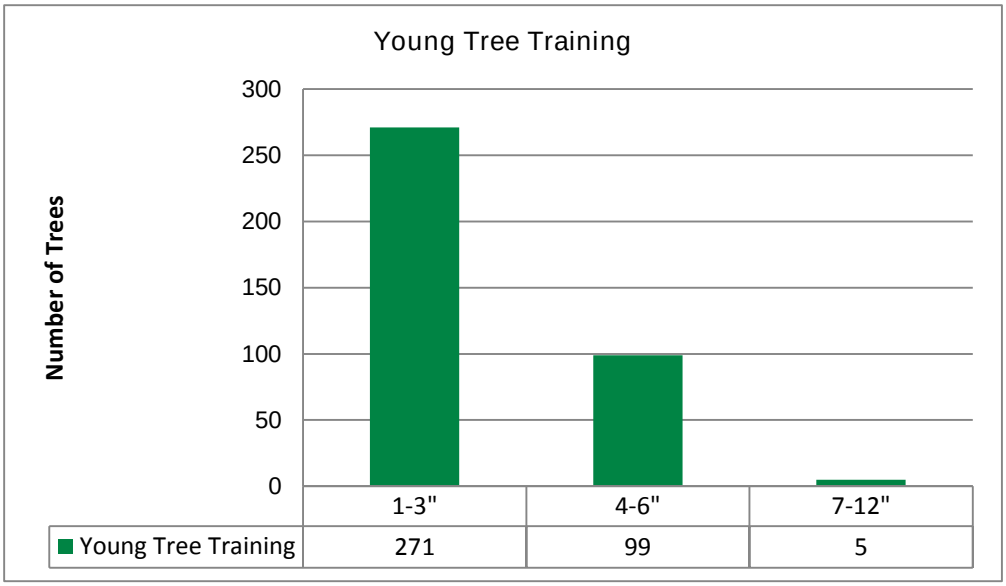


Figure 13. Trees recommended for the YTT Cycle by diameter size class.

Routine Pruning Cycle

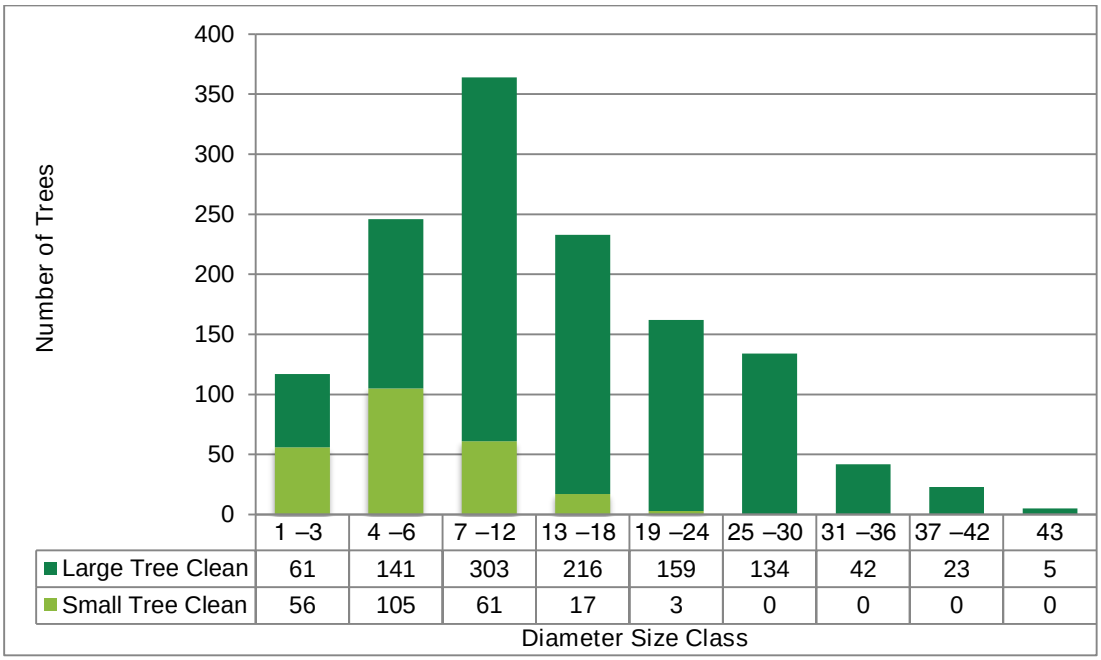
The RP Cycle includes established, maturing, and mature trees (mostly greater than 8 inches DBH) that need cleaning, crown raising, and reducing to remove deadwood and improve structure. Over time, routine pruning generally improves health and reduces risk as most problems can be corrected before they escalate into more costly priority tree work.

The length of the RP Cycle is based on the size of the tree population and what was assumed to be a reasonable number of trees for a program to prune per year. Generally, the RP Cycle recommended for a tree population is five years but may extend to seven years if the population is large.

Recommendations

Davey Resource Group recommends that Columbia City establish a five-year RP Cycle in which approximately one-fifth of the tree population is to be pruned each year. The 2017 tree inventory identified approximately 1,326 trees (including Large and Small Tree Clean) that should be pruned over a five-year RP Cycle. An average of 265 trees should be pruned each year over the course of the cycle. Davey Resource Group recommends that the RP Cycle begin in Year Six of this ten-year plan, after all Priority 1 and 2 trees are pruned.

Figure 14 shows that a variety of tree sizes will require pruning; however, most of the trees that require routine pruning were between 4 and 18 inches DBH.



	1 –3	4 –6	7 –12	13 –18	19 –24	25 –30	31 –36	37 –42	43
Large Tree Clean	61	141	303	216	159	134	42	23	5
Small Tree Clean	56	105	61	17	3	0	0	0	0

Figure 14. Trees recommended for the RP Cycle by diameter size class.

Tree Planting

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. Davey Resource Group recommends Columbia City achieve a no net loss of street tree population. This translates to the planting of 259 trees over the next 5 years (or approximately 52 trees per year for the next 5 years) to replace all trees and stumps recommended for removal in the 2017 inventory and account for at least a 1% mortality of the remaining population (approximately 21 additional trees to be planted). In Section 4, the Street Tree Planting Plan discusses in more detail how Columbia City might proceed with the planting of inventoried vacant sites to increase canopy cover and tree benefits. Appendix F includes important tree planting considerations.

Maintenance Schedule

Utilizing data from the 2017 Columbia City tree inventory, an annual maintenance schedule was developed that details the number and type of tasks recommended for completion each year. Davey Resource Group made budget projections using industry knowledge and public bid tabulations. Actual costs were not specified by Columbia City. A complete table of estimated costs for Columbia City's ten-year tree management program is presented in Table 5.

The schedule provides a framework for completing the inventory maintenance recommendations over the next ten years. Following this schedule can shift tree care activities from an on-demand system to a more proactive tree care program.

To implement the maintenance schedule, the city's tree maintenance budget should be no less than $99,023 for the first year of implementation, no less than $97,977 for the second year, no less than $94,918 for the third year, no less than $64,361 for the fourth year, no less than $52,003 for the fifth year, and no less than $45,118 for the final five years. Annual budget funds are needed to ensure that hazard trees are remediated and that critical YTT and RP Cycles can begin. This budget does not account for aging of the population and anticipates a no net loss or gain in tree population. With proper professional tree care, the safety, health, and beauty of the urban forest will improve.

Table 5. Estimated Costs for Ten-Year Urban Forestry Management Program

Estimated Costs for Each Activity			Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9		Year 10		Five-Year 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	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	
Priority 1 Removal	1-3"	$28	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	4-6"	$58	0	$0	2	$115	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$115
	7-12"	$138	0	$0	10	$1,375	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$1,375
	13-18"	$314	0	$0	7	$2,195	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$2,195
	19-24"	$605	0	$0	5	$3,025	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$3,025
	25-30"	$825	15	$12,375	4	$3,300	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$15,675
	31-36"	$1,045	15	$15,675	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$15,675
	37-42"	$1,485	6	$8,910	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$8,910
	43"+	$2,035	4	$8,140	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$8,140
Activity Total(s)			40	$45,100	28	$10,010	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$55,110
Priority 2 Removal	1-3"	$28	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	4-6"	$58	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	7-12"	$138	0	$0	0	$0	0	$0	6	$825	4	$550	0	$0	0	$0	0	$0	0	$0	0	$0	$1,375
	13-18"	$314	0	$0	0	$0	0	$0	23	$7,211	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$7,211
	19-24"	$605	0	$0	0	$0	17	$10,285	11	$6,655	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$16,940
	25-30"	$825	0	$0	0	$0	16	$13,200	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$13,200
	31-36"	$1,045	0	$0	3	$3,135	7	$7,315	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$10,450
	37-42"	$1,485	0	$0	6	$8,910	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$8,910
	43"+	$2,035	0	$0	3	$6,105	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$6,105
Activity Total(s)			0	$0	12	$18,150	40	$30,800	40	$14,691	4	$550	0	$0	0	$0	0	$0	0	$0	0	$0	$64,191
Priority 3 Removal	1-3"	$28	0	$0	0	$0	0	$0	0	$0	15	$413	0	$0	0	$0	0	$0	0	$0	0	$0	$413
	4-6"	$58	0	$0	0	$0	0	$0	0	$0	9	$518	0	$0	0	$0	0	$0	0	$0	0	$0	$518
	7-12"	$138	0	$0	0	$0	0	$0	0	$0	9	$1,238	0	$0	0	$0	0	$0	0	$0	0	$0	$1,238
	13-18"	$314	0	$0	0	$0	0	$0	0	$0	3	$941	0	$0	0	$0	0	$0	0	$0	0	$0	$941
	19-24"	$605	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	25-30"	$825	0	$0	0	$0	0	$0	0	$0	2	$1,650	0	$0	0	$0	0	$0	0	$0	0	$0	$1,650
	31-36"	$1,045	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	37-42"	$1,485	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	43"+	$2,035	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
Activity Total(s)			0	$0	0	$0	0	$0	0	$0	38	$4,758	0	$0	0	$0	0	$0	0	$0	0	$0	$4,758

Estimated Costs for Each Activity			Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9		Year 10		Five-Year 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	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	
Stump Removals	1-3"	$18	0	$0	2	$35	0	$0	0	$0	15	$263	0	$0	0	$0	0	$0	0	$0	0	$0	$298
	4-6"	$28	0	$0	5	$138	0	$0	0	$0	9	$248	0	$0	0	$0	0	$0	0	$0	0	$0	$385
	7-12"	$44	0	$0	9	$396	0	$0	6	$264	13	$572	0	$0	0	$0	0	$0	0	$0	0	$0	$1,232
	13-18"	$72	0	$0	24	$1,716	23	$1,645	23	$1,645	3	$215	0	$0	0	$0	0	$0	0	$0	0	$0	$5,220
	19-24"	$94	0	$0	10	$935	17	$1,590	11	$1,029	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$3,553
	25-30"	$110	20	$2,200	4	$440	16	$1,760	0	$0	2	$220	0	$0	0	$0	0	$0	0	$0	0	$0	$4,620
	31-36"	$138	20	$2,750	3	$413	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$3,163
	37-42"	$160	7	$1,117	6	$957	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$2,074
	43"+	$182	5	$908	3	$545	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$1,452
Activity Total(s)			52	$6,974	66	$5,574	56	$4,994	40	$2,937	42	$1,517	0	$0	0	$0	0	$0	0	$0	0	$0	$21,995
Priority 1 Prune	1-3"	$20	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	4-6"	$30	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	7-12"	$75	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	13-18"	$120	1	$120	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$120
	19-24"	$170	10	$1,700	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$1,700
	25-30"	$225	7	$1,575	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$1,575
	31-36"	$305	12	$3,660	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$3,660
	37-42"	$380	6	$2,280	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$2,280
	43"+	$590	3	$1,770	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$1,770
Activity Total(s)			39	$11,105	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$11,105
Priority 2 Prune	1-3"	$20	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
	4-6"	$30	0	$0	0	$0	0	$0	0	$0	3	$90	0	$0	0	$0	0	$0	0	$0	0	$0	$90
	7-12"	$75	0	$0	0	$0	0	$0	0	$0	7	$525	0	$0	0	$0	0	$0	0	$0	0	$0	$525
	13-18"	$120	0	$0	0	$0	0	$0	0	$0	63	$7,560	0	$0	0	$0	0	$0	0	$0	0	$0	$7,560
	19-24"	$170	0	$0	0	$0	15	$2,550	73	$12,410	4	$680	0	$0	0	$0	0	$0	0	$0	0	$0	$15,640
	25-30"	$225	0	$0	0	$0	90	$20,250	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$20,250
	31-36"	$305	0	$0	56	$17,080	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$17,080
	37-42"	$380	0	$0	13	$4,940	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$4,940
	43"+	$590	0	$0	10	$5,900	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$5,900
Activity Total(s)			0	$0	79	$27,920	105	$22,800	73	$12,410	77	$8,855	0	$0	0	$0	0	$0	0	$0	0	$0	$71,985

Estimated Costs for Each Activity			Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9		Year 10		Five-Year 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	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	# of Trees	Total Cost	
Routine Pruning (5-year cycle)	1-3"	$20	0	$0	0	$0	0	$0	0	$0	0	$0	23	$468	23	$468	23	$468	23	$468	23	$468	$0
	4-6"	$30	0	$0	0	$0	0	$0	0	$0	0	$0	49	$1,476	49	$1,476	49	$1,476	49	$1,476	49	$1,476	$0
	7-12"	$75	0	$0	0	$0	0	$0	0	$0	0	$0	73	$5,460	73	$5,460	73	$5,460	73	$5,460	73	$5,460	$0
	13-18"	$120	0	$0	0	$0	0	$0	0	$0	0	$0	47	$5,592	47	$5,592	47	$5,592	47	$5,592	47	$5,592	$0
	19-24"	$170	0	$0	0	$0	0	$0	0	$0	0	$0	32	$5,508	32	$5,508	32	$5,508	32	$5,508	32	$5,508	$0
	25-30"	$225	0	$0	0	$0	0	$0	0	$0	0	$0	27	$6,030	27	$6,030	27	$6,030	27	$6,030	27	$6,030	$0
	31-36"	$305	0	$0	0	$0	0	$0	0	$0	0	$0	8	$2,562	8	$2,562	8	$2,562	8	$2,562	8	$2,562	$0
	37-42"	$380	0	$0	0	$0	0	$0	0	$0	0	$0	5	$1,748	5	$1,748	5	$1,748	5	$1,748	5	$1,748	$0
	43"+	$590	0	$0	0	$0	0	$0	0	$0	0	$0	1	$590	1	$590	1	$590	1	$590	1	$590	$0
Activity Total(s)			0	$0	0	$0	0	$0	0	$0	0	$0	265	$29,434	265	$29,434	265	$29,434	265	$29,434	265	$29,434	$0
Young Tree Training Pruning (3-year cycle)	1-3"	$20	90	$1,807	90	$1,807	90	$1,807	90	$1,807	90	$1,807	90	$1,807	90	$1,807	90	$1,807	90	$1,807	90	$1,807	$9,033
	4-8"	$30	33	$990	33	$990	33	$990	33	$990	33	$990	33	$990	33	$990	33	$990	33	$990	33	$990	$4,950
	7-12"	$75	2	$125	2	$125	2	$125	2	$125	2	$125	2	$125	2	$125	2	$125	2	$125	2	$125	$625
Activity Total(s)			125	$2,922	125	$2,922	125	$2,922	125	$2,922	125	$2,922	125	$2,922	125	$2,922	125	$2,922	125	$2,922	125	$2,922	$14,608
Replacement Tree Planting	Purchasing	$170	51	$8,670	52	$8,840	52	$8,840	52	$8,840	52	$8,840	9	$1,530	9	$1,530	9	$1,530	9	$1,530	9	$1,530	$44,030
	Planting	$110	51	$5,610	52	$5,720	52	$5,720	52	$5,720	52	$5,720	9	$990	9	$990	9	$990	9	$990	9	$990	$28,490
Activity Total(s)			102	$14,280	104	$14,560	104	$14,560	104	$14,560	104	$14,560	18	$2,520	18	$2,520	18	$2,520	18	$2,520	18	$2,520	$72,520
Replacement Young Tree Maintenance	Mulching	$100	51	$5,100	52	$5,200	52	$5,200	52	$5,200	52	$5,200	9	$900	9	$900	9	$900	9	$900	9	$900	$25,900
	Watering	$100	51	$5,100	52	$5,200	52	$5,200	52	$5,200	52	$5,200	9	$900	9	$900	9	$900	9	$900	9	$900	$25,900
Activity Total(s)			102	$10,200	104	$10,400	104	$10,400	104	$10,400	104	$10,400	18	$1,800	18	$1,800	18	$1,800	18	$1,800	18	$1,800	$51,800
Annual Mortality (1%) Removals	Average Tree	$138	21	$2,898	21	$2,898	21	$2,898	21	$2,898	21	$2,898	21	$2,898	21	$2,898	21	$2,898	21	$2,898	21	$2,898	$14,490
Activity Total(s)			21	$2,898	21	$2,898	21	$2,898	21	$2,898	21	$2,898	21	$2,898	21	$2,898	21	$2,898	21	$2,898	21	$2,898	$14,490
Annual Mortality (1%) Stump Removals	Average Tree	$44	21	$924	21	$924	21	$924	21	$924	21	$924	21	$924	21	$924	21	$924	21	$924	21	$924	$4,620
Activity Total(s)			21	$924	21	$924	21	$924	21	$924	21	$924	21	$924	21	$924	21	$924	21	$924	21	$924	$4,620
Annual Mortality (1%) Planting	Average Tree	$220	21	$4,620	21	$4,620	21	$4,620	21	$4,620	21	$4,620	21	$4,620	21	$4,620	21	$4,620	21	$4,620	21	$4,620	$23,100
Activity Total(s)			21	$4,620	21	$4,620	21	$4,620	21	$4,620	21	$4,620	21	$4,620	21	$4,620	21	$4,620	21	$4,620	21	$4,620	$23,100
Activity Grand Total			523		581		597		549		557		489		489		489		489		489		
Cost Grand Total				$99,023		$97,977		$94,918		$66,361		$52,003		$45,118		$45,118		$45,118		$45,118		$45,118	$410,281

If routing efficiencies and/or contract specifications allow for the completion of more tree work, or if the schedule requires modification to meet budgetary or other needs, then the schedule should be modified accordingly. Unforeseen situations such as severe weather events may arise and change the maintenance needs of trees. Should conditions or maintenance needs change, budgets and equipment will need to be adjusted to meet the new demands.

Community Outreach

The data collected and analyzed to develop this plan contribute significant information about the tree population and can be utilized to guide the proactive management of that resource. These data can also be utilized to promote the value of the urban forest and the tree management program in the following ways:

- Tree inventory data can be used to justify necessary priority and proactive tree maintenance activities as well as tree planting and preservation initiatives.
- Species data can be used to guide tree species selection for planting projects with the goals of improving species diversity and limiting the introduction of invasive pests and diseases.
- Information in this plan can be used to advise citizens about threats to urban trees (such as looper complex, Asian longhorned beetle, and emerald ash borer).

There are various avenues for outreach. Maps can be created and posted on websites, in parks, or in business areas. Public service announcements can be developed. Articles can be written and programs about trees and the benefits they provide can be developed. Arbor Day and Earth Day celebrations can become community traditions. Signs can be hung from trees to highlight the contributions trees make to the community. Contests can even be created to increase awareness of the importance of trees. Trees provide oxygen we need to breathe, shade to cool our neighborhoods, and canopies to stand under when it rains.

Columbia City's data are instrumental in helping to provide tangible and meaningful outreach about the urban forest.

Inspections

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.

Trees along the street ROW should be regularly inspected and attended to as needed based on the inspection findings. When trees need additional or new work, they should be added to the maintenance schedule and budgeted as appropriate. In addition to locating potential new hazards, inspections are an opportunity to look for signs and symptoms of pests and diseases. Columbia City has a large population of trees that are susceptible to pests and diseases, such as maple, crabapple, and oak.

Inventory and Plan Updates

Davey Resource Group recommends that the inventory and management plan be updated so that the city can sustain its program and accurately project future program and budget needs:

- Conduct inspections of trees after all severe weather events. Record changes in tree condition, maintenance needs, and risk rating in the inventory database. Update the tree maintenance schedule and acquire the funds needed to promote public safety. Schedule and prioritize work based on risk.
- Perform routine inspections of public trees as needed. Windshield surveys (inspections performed from a vehicle) in line with *ANSI A300 (Part 9)* (ANSI 2011) will help city staff stay apprised of changing conditions. Update the tree maintenance schedule and the budget as needed so that identified tree work may be efficiently performed. Schedule and prioritize work based on risk.
- If the recommended work cannot be completed as suggested in this plan, modify maintenance schedules and budgets accordingly.
- Update the inventory database as work is performed. Add new tree work to the schedule when work is identified through inspections or a citizen call process.
- Re-inventory the street ROW, and update all data fields in five years or a portion (1/5 the population/area) every year.
- Revise the *Tree Management Plan* after five years when the re-inventory has been completed.

SECTION 4: URBAN TREE CANOPY ANALYSIS

The amount and distribution of urban tree canopy (UTC) determines the urban forest's capacity for providing environmental and social benefits to the community. A community's UTC is composed of all public and private trees within a community's urban forest, as viewed from above the trees. Recognizing the importance of UTC, Columbia City wanted valuable data that will support efforts to develop community goals, establish the importance of the community's tree resources among its other assets, and prioritize tree planting and other on-the-ground projects. Davey Resource Group conducted a UTC assessment which provides information for data-backed strategies and plans benefiting current and future community urban forestry tools and programming in Columbia City.

Process and Methods

Davey Resource Group's UTC assessment was created using a well-established and statistically rigorous process. First, a land cover extraction was completed using 2016 National Agriculture Imagery Program (NAIP) photography. A series of random plots was generated and manually inspected to ensure accuracy. As an added level of comparison, Davey Resource Group completed an i-Tree Canopy assessment, which closely reflected the results of the comprehensive land cover extraction. Next, the canopy data from the land cover extraction were analyzed using i-Tree models to generate an estimate of ecosystem benefits provided by the existing tree canopy. Finally, a realistic estimate of potential canopy was created by eliminating areas not suitable for tree planting (e.g., concrete surfaces, water, or sports fields). Methods and illustrated results of Davey Resource Group's UTC assessment are presented in Figure 15 and are also available in Appendix G.

Urban Tree Canopy

Based on the most recent aerial imagery, the estimated tree canopy in Columbia City is currently 26%. The total tree canopy percentage in Columbia City is above the median when compared to that of other Indiana northeast third class cities (Table 6). These various communities were part of a study conducted by the IDNR, Division of Forestry, Community and Urban Forestry Program in 2011 to understand the existing statewide UTC (Davey Resource Group 2011).

Table 6. Comparison of Urban Tree Canopy Across Various Northeast Indiana Communities

Community	Urban Tree Canopy
Albion, IN	24%
Auburn, IN	21%
Berne, IN	17%
Columbia City, IN	26%
Decatur, IN	19%
Howe, IN	16%
Huntertown, IN	15%
Kendallville, IN	19%
Rome City, IN	18%
Tri-Lakes, IN	27%

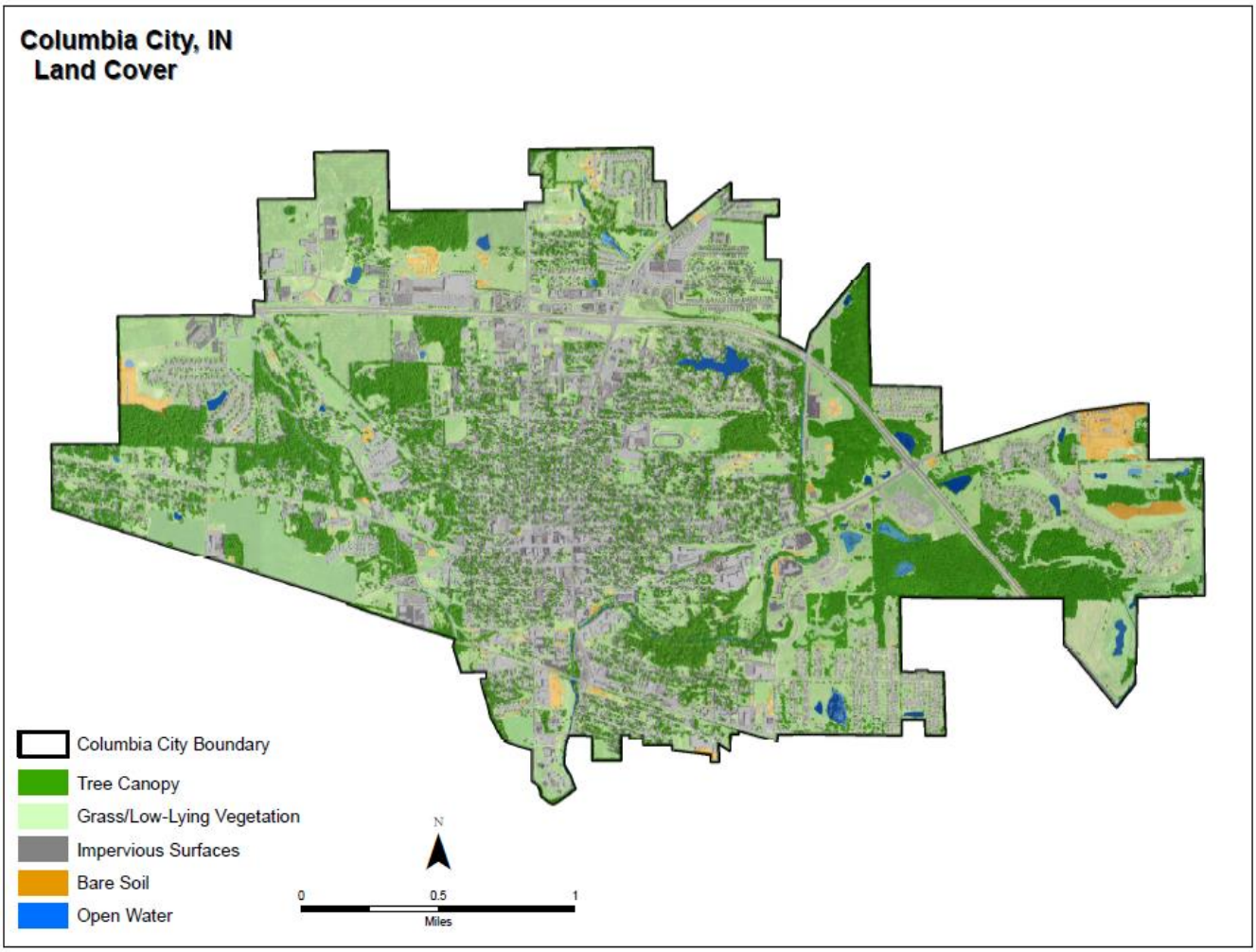


Figure 15. **Columbia City's** 5-class land cover distribution using 2016 NAIP imagery.

Along with tree canopy, five other land cover classifications were generated by this assessment. Additional land covers that were assessed in Columbia City include impervious surfaces (e.g., streets, sidewalks, buildings), pervious surfaces (e.g., grass, shrubs), bare soil, and water. All land cover classifications were measured within the confines of the city's boundary (Table 7).

Table 7. Land Cover Results for Columbia City

Land Cover Classification	Assessment (%) 2016
Tree Canopy	26%
Impervious Surfaces	28%
Pervious Surfaces	42%
Bare Soils	2%
Open Water	2%

Paired with other GIS information, these data can be further segmented and examined to identify trends in the following:

- Tree canopy coverage by land use
- Tree canopy coverage by management zone

Tree Canopy Related to Land Use

Tree canopy levels tend to correlate with land use types. In a typical community, commercial areas and road rights-of-way tend to have much lower levels of tree canopy and higher levels of impervious surfaces than residential areas. Understanding this relationship across a community can help identify policy concerns or areas of need for new outreach and education programs that would appeal to specific landowners or property types. Table 8 presents current land coverage classes across land use in Columbia City. Figure 16 illustrates a general land use map of Columbia City, Indiana.

Table 8. Land Cover by Land Use in Columbia City, Indiana

	Land Cover Findings in Columbia City				
Land Use Type	Tree Canopy	Impervious	Pervious	Bare Soil	Water
Commercial	18%	38%	41%	2%	1%
Industrial	14%	29%	54%	2%	1%
Low Density Residential	35%	20%	39%	3%	2%
Medium Density Residential	25%	23%	50%	2%	1%
Parks or Recreation	44%	6%	46%	2%	3%
Public or Semi Public	21%	31%	44%	1%	2%

Findings

- The highest level of tree canopy is found in the park or recreation (44%) land use type, followed by low-density residential (35%) and medium-density residential (25%). Impervious coverage for these land uses is relatively low compared to the entire community.
- The tree canopy percentage within the public or semi-public land use type (21%) is relatively low and impervious coverage (31%) is among the highest of the land use types when compared to the rest of the community. The highest level of land cover is pervious (44%), which includes grass, shrubs, and athletic fields.
- Industrial and commercial land use types have the lowest amounts of tree canopy (14 and 18%, respectively) with the highest levels of impervious surfaces (29% and 38%, respectively) of all land use types. Pervious surfaces for industrial and commercial land use comprise 54% and 41% respectively.

Discussion/Recommendations

These results indicate that significant opportunities exist to optimize tree canopy within low density residential, industrial, medium density residential, and commercial land use types. Moreover, citywide, impervious surfaces are higher than, the city's tree canopy cover. This relationship is important, as impervious surfaces directly contribute to stormwater runoff and, therefore, impact water management needs. Additional tree cover can help mitigate stormwater runoff effects.

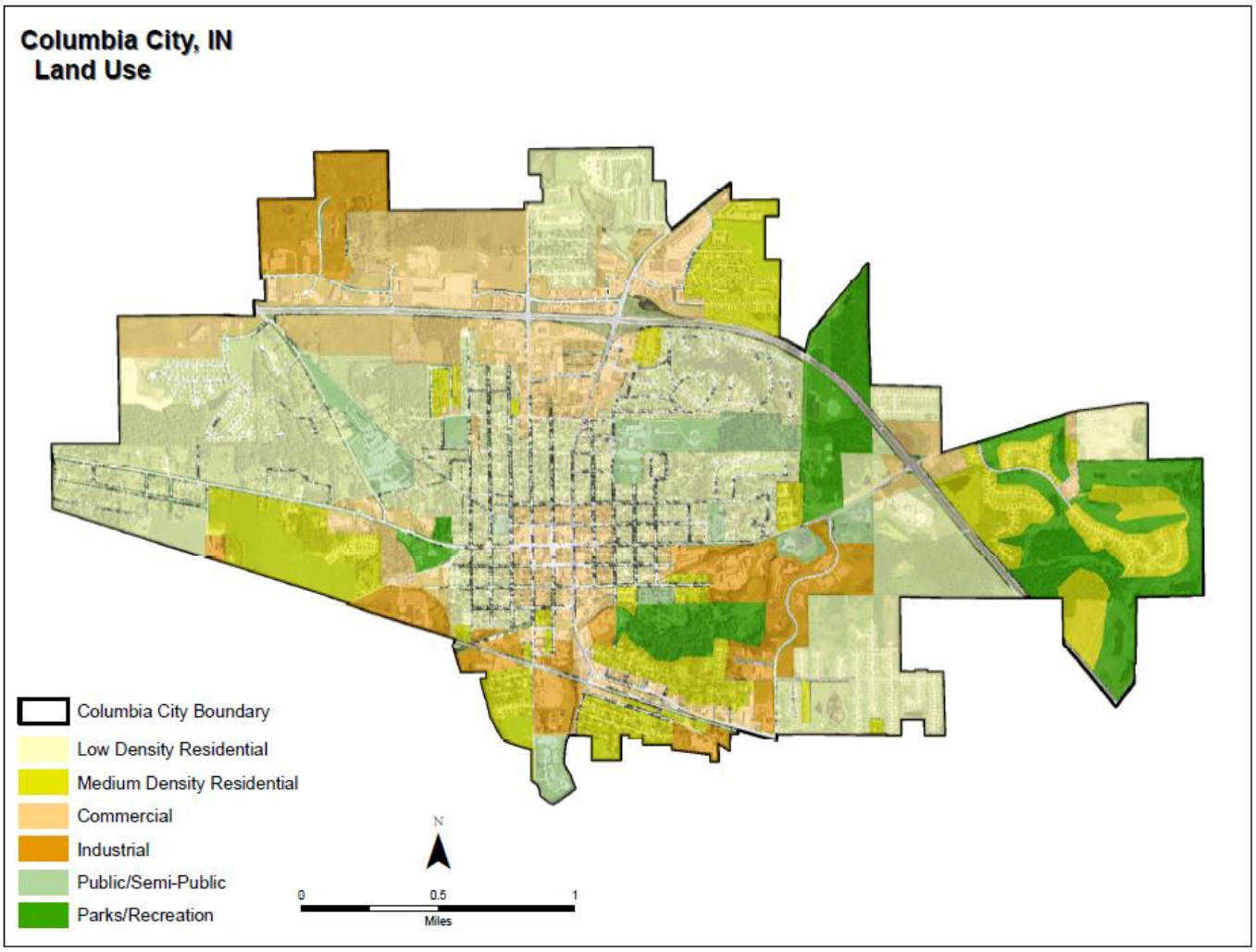


Figure 16. Land use in Columbia City, Indiana.

Management Zones Tree Canopy

Urban tree canopy results were further examined by management zones. Management zones are often used to understand tree canopy as they tend to reflect geographies that are well understood by community members and social institutions. Exploring canopy distribution at this level can help facilitate community outreach and education activities, and contribute to developing a deeper understanding of tree canopy at a meaningful community scale.

Current canopy coverage by Columbia City's 5 management zones are identified in Table 9. Figure 17 shows the location of management zones across the city.

Table 9. Land Cover by Management Zone in Columbia City, Indiana

Management Zone	Land Cover Findings in Columbia City				
	Tree Canopy	Impervious	Pervious	Bare Soil	Water
Northwest 1	27%	25%	45%	2%	1%
Northwest 2	15%	40%	43%	1%	1%
Northeast	29%	32%	36%	1%	2%
Southeast	28%	25%	41%	1%	2%
Southwest	23%	26%	49%	3%	1%

Findings

- Northeast, Southeast, and Northwest 1 have the highest levels of tree canopy at 29%, 28%, and 27%, respectively. These management zones contain large tracts of wooded areas mixed with residential areas and parks and open spaces.
- Conversely, Northwest 2 and Southwest have the lowest levels of tree canopy at 15% and 23%, respectively. These zones are primarily residential areas where dense development has not left much room for trees or other greenery.

Discussion/Recommendations

These results indicate that significant opportunities to preserve large tracts of tree canopy exist to optimize tree canopy citywide. This relationship is important, as tree canopy directly contributes to cleaner air and, therefore, less respiratory health problems within the community.

The results also indicate that where impervious surfaces are higher than the management zones tree canopy cover, additional tree canopy can help mitigate stormwater runoff effects. This relationship is important, as impervious surfaces directly contribute to stormwater runoff and, therefore, impact water management needs.

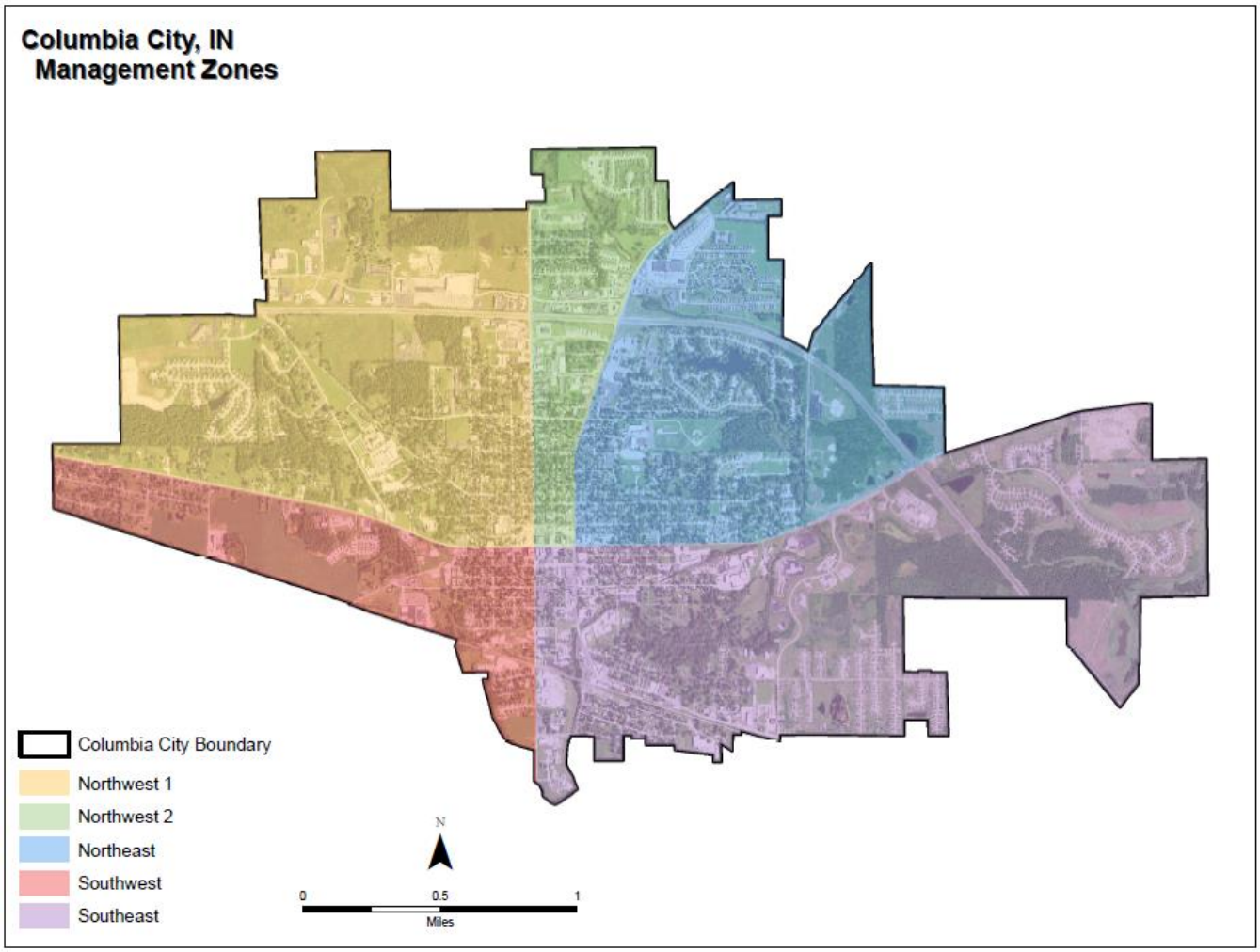


Figure 17. Street tree management zones in Columbia City, Indiana.

Ecosystem Benefits Analysis

Trees provide numerous benefits to Columbia City. Trees conserve energy, reduce carbon dioxide levels, improve air quality, and mitigate stormwater runoff. In addition, trees provide many economic, psychological, and social benefits that are less quantifiable.

On an annual basis, Columbia City's community tree canopy provides nearly $300,000 in quantifiable ecosystem benefits (Table 10). This includes removal of almost 51,000 pounds of air pollutants, interception of more than 17.6 million gallons of stormwater, and sequestration of almost 4,000 tons of carbon.

Aside from annual benefits, Columbia City's community urban forest stores approximately 116,600 tons of accumulated carbon, valued at over $4,000,000, as shown in Table 10.

Table 10. Estimated Ecosystem Benefits Provided by Columbia City's Community Urban Tree Canopy in 2016

Ecosystem Benefits	Annual Benefits	
	Quantity	Value
Air: CO (carbon monoxide) removed	766 lbs.	$510
Air: NO_2 (nitrogen dioxide) removed	5,620 lbs.	$978
Air: O_3 (ozone) removed	31,660 lbs.	$33,263
Air: SO_2 (sulfur dioxide) removed	4,840 lbs.	$311
Air: particulate matter (dust, soot, etc.) removed	7,740 lbs.	$24,157
Carbon sequestered	3,792 tons	$133,680
Stormwater: reduction in runoff	17,676,342 gals.	$106,058
Total annual benefits		$298,957
Current stored carbon*	116,635 tons	$4,112,001

* Current stored carbon is not an annual value but rather a measurement of the total contribution of storage over the life of the tree canopy.

i-Tree Canopy Analysis

The i-Tree Canopy tool allows users to easily interpret Google Earth aerial imagery for areas of interest and produce statistical estimates of tree cover and other cover types. Calculation of estimate uncertainty is provided as well. This tool provides a quick and inexpensive means for communities and forest managers to accurately estimate their tree canopy cover.

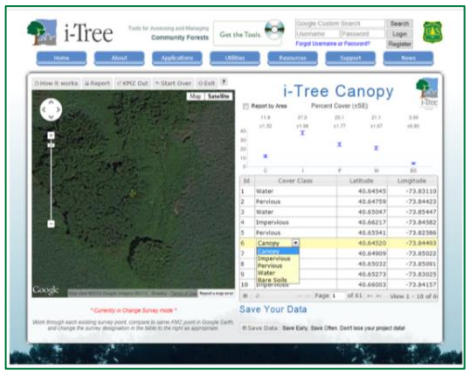


Figure 18. i-Tree Canopy.

This affordable i-Tree Canopy tool can be used by Columbia City in future land cover assessments to provide land cover analysis using new aerial images as they become available in Google® Maps. The random point locations derived from i-Tree Canopy can be re-imported in future works to produce a statistically valid estimate of land cover. The i-Tree Canopy data were provided on CD-ROM and futher instruction for assessing community tree canopy on a regular basis can be found in Appendix G.

Water Quality Improvement

Trees intercept rainwater by capturing water droplets on their leaves and bark. A tree's expansive root system also absorbs water from the surrounding soil, thereby increasing the soil's water retention capacity. These processes collectively result in reducing or slowing stormwater runoff. Without trees, cities would have to invest in significantly more stormwater infrastructure to address the additional water flow that would otherwise be captured by trees.

On an annual basis, Columbia City's trees capture over 17.7 million gallons of stormwater. That is enough water to fill approximately 27 Olympic-size swimming pools. This benefit provides $106,058 in annual value. In other words, if the community's trees did not exist, the city could incur an additional $106,058 in expenses each year to manage stormwater.

Air Quality Improvements

Not only do trees absorb carbon dioxide and produce oxygen, but they can also capture pollutants and particulate matter on the surfaces of their leaves. Trees go a long way in improving a city's air quality. Sulfur dioxide is a contributor to acid rain, while carbon monoxide and nitrogen dioxide are greenhouse gases that contribute to changes in global climate. Ozone and particulate matter, on the other hand, can exacerbate asthma and other respiratory illnesses. In fact, recent studies have shown a strong correlation between total tree canopy and reduced rates of pulmonary and cardiovascular disease.

Every year, Columbia City's tree canopy removes roughly 50,626 pounds of pollutants from the air, including 766 pounds of carbon monoxide (CO); 5,620 pounds of nitrogen dioxide (NO_2); 31,660 pounds of ozone (O_3); 4,840 pounds of sulfur dioxide (SO_2); and 7,740 pounds of dust, soot, and other particulate matter. The combined removal of pollutants results in an annual value of $59,219 in air quality improvements.

Carbon Reduction

Trees store a massive amount of carbon in their woody tissue. Carbon is an infamous greenhouse gas that directly influences climate change. Forests, both urban and rural, are an important carbon sink, helping to mitigate climate change. In total, Columbia City's community urban forest stores almost 116,635 tons of carbon, which equates to $44,112,001 in value (based on current carbon markets). Based on values provided by the Environmental Protection Agency, this benefit reflects the amount of carbon produced by burning 43.7 million gallons of gasoline. Each year, an additional 3,792 tons of carbon are sequestered for an annual value of $133,680. This storage helps offset the amount of carbon in the air.

Urban Tree Canopy Goal Setting

Many communities have set canopy coverage goals, standards, or policies. One of the most widespread uses of urban tree canopy assessments is to set a community's canopy coverage goals.

The amount of tree canopy drives the amount of benefits that an urban forest provides. Whether Columbia City wants to increase or maintain tree canopy, setting goals will help organize tree planting programs and inform tree preservation efforts. Establishing realistic and achievable tree canopy goals will help capitalize on the economic, environmental, and social benefits trees provide to the community.

Knowing the amount and distribution of tree canopy and knowing the amount and distribution of possible tree canopy has made canopy goal setting more practical and achievable for Columbia city. Columbia City's maximum potential for tree canopy is 59% citywide.

Could Columbia City have 59% urban tree canopy cover?

While land cover analysis sheds light on existing tree canopy distribution and value, communities are often interested in expanding tree canopy to optimize the ecosystem benefits provided by its trees. Therefore, it is common practice to calculate realistic potential planting areas based on the total of all land cover that is open ground—such as those covered in bare soil, shrubs, grass, and other low-lying vegetation.

While open ground generated in these analyses present possibilities to plant a tree, not all open spaces are candidates for tree plantings (e.g., sports and agricultural fields). Similarly, not all impervious areas may remain impervious forever. Trees can be added in certain locations (e.g., sidewalk cutouts, parking lot islands) to expand canopy in those areas. Some locations are clearly better suited to meeting community goals than others. Therefore, this study attempted to eliminate areas not suitable to planting. Table 11 presents preferred planting area estimates by geographical area.

Table 11. Potential Tree Canopy in Columbia City, Indiana

Geographical Area	Canopy	Impervious Percent	Pervious Percent	Preferred Plantable Percent	Maximum UTC
Commercial	18%	38%	41%	32%	50%
Industrial	14%	29%	54%	34%	48%
Low Density Residential	35%	20%	39%	39%	75%
Medium Density Residential	25%	23%	50%	34%	59%
Parks or Recreation	44%	6%	46%	7%	51%
Public or Semi-Public	21%	31%	44%	30%	51%
Northwest 1	27%	25%	45%	31%	58%
Northwest 2	15%	40%	43%	44%	59%
Northeast	29%	32%	36%	32%	61%
Southeast	28%	25%	41%	32%	60%
Southwest	23%	26%	49%	28%	51%
Citywide	26%	28%	42%	32%	59%

Findings

- Low density residential land use properties have the most preferred plantable space (412 acres or 39% of the 1,163 acres all total for low density residential land use).
- Industrial, medium density residential, and commercial each have more than 100 acres of preferred plantable space and could increase canopy cover with each land use by 34%, 34%, and 32%, respectively.
- All management zones with the exception of industrial have the possibility of more than 50% tree canopy cover.

Street Tree Planting Plan

The amount and distribution of urban tree canopy determines the urban forest's ability to return environmental and social benefits to the community. Recognizing the importance of urban tree canopy, Columbia City wanted to apply the urban tree canopy information in a planting strategy. Using the urban tree canopy assessment, Davey Resource Group has developed a prioritized planting map (Figure 19). On CD-ROM is a printable PDF of Figure 19 to allow for larger versions. Red (below 5% canopy over ROW) means there is a need for canopy over the street ROW, and Purple (above 20% canopy over ROW) means there is a lesser need for canopy over the street ROW compared to other street ROW citywide. The planting sites along Red, Orange, and Yellow streets may be the focus of any new tree planting programs, as they involve the least amount of tree canopy.

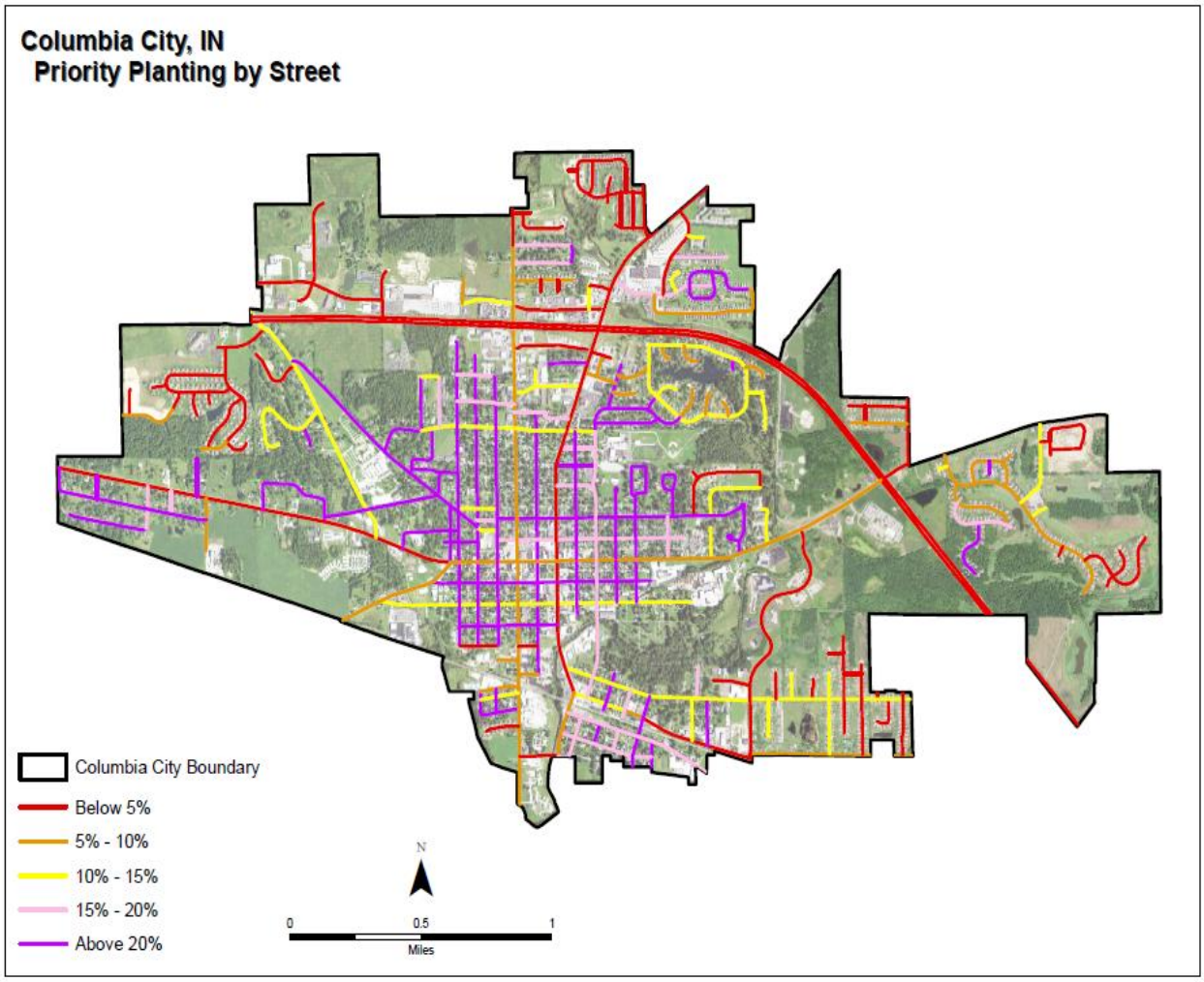


Figure 19. **Columbia City's prioritized planting plan.**

Next Steps

Because trees provide so many services to a community, Columbia City is encouraged to continue efforts to protect, enhance, and expand tree canopy across the community.

1. *Plant New Trees.* Columbia City can start by using the data in this report to plant trees in locations with a "High" planting priority. Every tree does not need to be planted by the city or even on city property. Many of the available opportunities for canopy expansion are on private lands. Additional strategies such as incentive and cost-share programs, grants, education and outreach, or policy changes can encourage residents and business owners to plant trees throughout the community.
2. *Preserve Existing Tree Canopy.* While tree planting will directly contribute to improving tree canopy, it is important to note that planting alone is insufficient. Older, mature trees contribute far more to the community's tree canopy than young ones. Caring for and preserving mature trees should be part of the community's strategy to maximize the benefits provided by trees, thereby preserving existing tree canopy.
3. *Ordinance Revision.* The city recognizes the importance of mature trees in the urban environment and tree-lined street ROW. Davey Resource Group recommends Columbia City review its tree ordinance to establish standards for protecting existing trees on public and private land. This will allow for a more effective and efficient implementation of the city's tree preservation initiative through enforcement measures outlined therein. In addition to mature tree protection, Davey Resource Group also recommends Columbia City review the tree ordinance to require installation of new trees on private property within commercial, industrial, and public land uses and along the street ROW when any property is developed or redeveloped.
4. *Outreach and Education.* While new policies, incentives, or other significant measures can be useful, they are not the only measures needed to retain trees. Public works projects should consider how new streets, sidewalks, or infrastructure improvements might affect existing trees. While not all trees can be saved, communities should prioritize tree retention rather than treating trees as infrastructure that can be removed and replaced. Furthermore, outreach and education campaigns can encourage citizens to care for and retain their existing trees. Many people do not fully understand how their trees contribute to both their property value and impact the community. Development of the permitting process by which trees are removed on both private and public lands will help establish a protocol that appropriately determines the need for removal throughout the community forest.
5. *Measure Canopy Changes on a Regular Basis.* As with any program or initiative, it is important to regularly track progress and re-evaluate efforts towards achieving community goals. From the ground, it can be difficult to assess whether community initiatives are having an impact on tree canopy. To track changes, tree canopy should be assessed every ten years. While a rigorous tree canopy analysis provides a lot of useful information, self-assessments can be performed using the i-Tree Canopy tool.

CONCLUSIONS

Every hour of every day, public trees in Columbia City are supporting and improving the quality of life. The city's street trees provide an annual benefit of $284,850 at a return of $1.81 in benefits for every $1 spent on its municipal forestry program. When properly maintained, trees provide numerous environmental, economic, and social benefits that far exceed the time and money invested in planting, pruning, protection, and removal.

Managing trees in urban areas is often complicated. Navigating the recommendations of experts, the needs of residents, the pressures of local economics and politics, concerns for public safety and liability, physical components of trees, forces of nature and severe weather events, and the expectation that these issues are resolved all at once is a considerable challenge.

The city must carefully consider these challenges to fully understand the needs of maintaining an urban forest. With the knowledge and wherewithal to address the needs of the city's trees, Columbia City is well positioned to thrive. If the management program is successfully implemented, the health and safety of Columbia City's trees and citizens will be maintained for years to come.

GLOSSARY

aboveground utilities (data field): Shows the presence or absence of overhead utilities at the tree site.

address number (data field): The address number was recorded based on the visual observation by the Davey Resource Group arborist at the time of the inventory of the actual address number posted on a building at the inventoried site. In instances where there was no posted address number on a building or sites were located by vacant lots with no GIS parcel addressing data available, the address number assigned was matched as closely as possible to opposite or adjacent addresses by the arborist(s) and an "X" was added to the number in the database to indicate that the address number was assigned.

Aesthetic/Other 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.

area (data fields): A collection of data fields collected during the inventory to aid in finding trees, including park section number.

Benefit-Cost Ratio (BCR): The i-Tree Streets (BCR) is the ratio of the cumulative benefits provided by the landscape trees, expressed in monetary terms, compared to the costs associated with their management, also expressed in monetary terms.

biogenic volatile organic compounds (BVOC): Gases emitted from trees, like pine trees, which create the distinct smell of a pine forest. When exposed to sunlight in the air, BVOCs react to form tropospheric ozone, a harmful gas that pollutes the air and damages vegetation.

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.

community forest: see **urban forest**.

condition (data field): 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**.

Energy Report: The i-Tree Streets Energy Report presents the contribution of the urban forest toward conserving energy in terms of reduced natural gas use in winter measured in therms (th) and reduced electricity use for air conditioning in summer measured in megawatt-hours (MWh).

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 (data field): 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.

global positioning system (GPS): GPS is a system of earth-orbiting satellites that make it possible for people with ground receivers to pinpoint their geographic location.

importance value (IV): A calculation in i-Tree Streets displayed in table form for all species that make up more than 1% of the population. The i-Tree Streets IV is the mean of three relative values (percentage of total trees, percentage of total leaf area, and percentage of canopy cover) and can range from 0 to 100, with an IV of 100 suggesting total reliance on one species. IVs offer valuable information about a community's reliance on certain species to provide functional benefits. For example, a species might represent 10% of a population, but have an IV of 25% because of its great size, indicating that the loss of those trees due to pests or disease would be more significant than their numbers suggest.

invasive, exotic tree: A tree species that is out of its original biological community. Its introduction into an area causes or is likely to cause economic or environmental harm, or harm to human health. An invasive, exotic tree has the ability to thrive and spread aggressively outside its natural range. An invasive species that colonizes a new area may gain an ecological edge since the insects, diseases, and foraging animals that naturally keep its growth in check in its native range are not present in its new habitat.

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.

Large Tree Routine Prune (Primary Maintenance Need): These trees require routine horticultural pruning to correct structural problems or growth patterns which would eventually obstruct traffic or interfere with utility wires or buildings. Trees in this category are large enough to require bucket truck access or manual climbing.

location (data fields): A collection of data fields collected during the inventory to aid in finding trees, including address number, street name, site number, side, and block side.

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.

mapping coordinate (data field): Helps to locate a tree; X and Y coordinates were generated for each tree using GPS.

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

Net Annual Benefits: Specific data field for i-Tree Streets. Citywide benefits and costs are calculated according to category and summed. Net benefits are calculated as benefits minus costs.

Nitrogen Dioxide (NO_2): Nitrogen dioxide is a compound typically created during the combustion processes and is a major contributor to smog formation and acid deposition.

None (Secondary Maintenance Need): Used to show that no secondary maintenance is recommended for the tree. Usually a vacant planting site or stump will have a secondary maintenance need of *none*.

notes (data field): Describes additional pertinent information.

observations (data field): When conditions with a specific tree warrant recognition, it was described in this data field. Observations include cavity decay, grate guard, improperly installed, improperly mulched, improperly pruned, mechanical damage, memorial tree, nutrient deficiency, pest problem, poor location, poor root system, poor structure, remove hardware, serious decline, and signs of stress.

ordinance: See **tree ordinance**.

overhead utilities (data field): The presence of overhead utility lines above a tree or planting site.

Ozone (O_3): A strong-smelling, pale blue, reactive toxic chemical gas with molecules of three oxygen atoms. It is a product of the photochemical process involving the Sun's energy. Ozone exists in the upper layer of the atmosphere as well as at the Earth's surface. Ozone at the Earth's surface can cause numerous adverse human health effects. It is a major component of smog.

Particulate Matter (PM_{10}): A major class of air pollutants consisting of tiny solid or liquid particles of soot, dust, smoke, fumes, and mists.

Plant Tree (Primary Maintenance Need): If collected during an inventory, this data field identifies planting sites as small, medium, or large (indicating the ultimate size that the tree will attain), depending on the growspace available and the presence of overhead wires.

Primary Maintenance Need (data field): The type of tree work needed to reduce immediate risk.

Priority 1 Removal (Primary Maintenance Need): Trees designated for removal have defects that cannot be cost-effectively or practically treated. The majority of the trees in this category have a large percentage of dead crown and pose an elevated level of risk for failure. Any hazards that could be seen as potential dangers to persons or property and seen as potential liabilities to the client would be in this category. Large dead and dying trees that are high liability risks are included in this category. These trees are the first ones that should be removed.

Priority 2 Removal (Primary Maintenance Need): Trees that should be removed but do not pose a liability as great as the first priority will be identified here. This category would need attention as soon as "Priority One" trees are removed.

Priority 3 Removal (Primary Maintenance Need): Trees that should be removed, but that pose minimal liability to persons or property, will be identified in this category.

Priority 1 Prune (Primary Maintenance Need): Trees that require priority one pruning are recommended for trimming to remove hazardous deadwood, hangers, or broken branches. These trees have broken or hanging limbs, hazardous deadwood, and dead, dying, or diseased limbs or leaders greater than four inches in diameter.

Priority 2 Prune (Primary Maintenance Need): These trees have dead, dying, diseased, or weakened branches between two and four inches in diameter and are potential safety hazards.

pruning: The selective removal of plant parts to meet specific goals and objectives.

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

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

side value (data field): Each site is assigned a side value to aid in locating the site. Side values include: *front*, *side to*, *side away*, *median* (includes islands), and *rear* based on the site's location in relation to the lot's street frontage. The *front* side is the side that faces the address street. *Side to* is the name of the street the arborist is walking towards as data are being collected. The *side from* is the name of the street the arborist is walking away from while collecting data. *Median* indicates a median or island. The *rear* is the side of the lot opposite the front.

site number (data field): All sites at an address are assigned a *site number*. Sites numbers are not unique; they are sequential to the side of the address only (the only unique number is the tree identification number assigned to each site). Site numbers are collected in the direction of vehicular traffic flow. The only exception is a one-way street. Site numbers along a one-way street are collected as if the street were actually a two-way street, so some site numbers will oppose traffic.

Small Tree Routine Prune (Primary Maintenance Need): These trees require routine horticultural pruning to correct structural problems or growth patterns which would eventually obstruct traffic or interfere with utility wires or buildings. These trees are small growing, mature trees that can be evaluated and pruned from the ground.

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

stem: A woody structure bearing buds and foliage, and giving rise to other stems.

stems (data field): Identifies the number of stems or trunks splitting less than 1 foot above ground level.

Stored Carbon Report: While the i-Tree Streets Carbon Dioxide Report quantifies annual CO_2 reductions, the i-Tree Streets Stored Carbon Report tallies all of the Carbon (C) stored in the urban forest over the life of the trees as a result of sequestration measured in pounds as the CO_2 equivalent.

Stormwater Report: A report generated by i-Tree Streets that presents the reductions in annual stormwater runoff due to rainfall interception by trees measured in gallons (gals.).

street name (data field): The name of a street right-of-way or road identified using posted signage or parcel information.

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.

Stump Removal (Primary Maintenance Need): Indicates a stump that should be removed.

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.

topping: Characterized by reducing tree size using internodal cuts without regard to tree health or structural integrity; this is not an acceptable pruning practice.

Training Prune (Primary Maintenance Need): 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.

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 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 (data field): 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 greenspaces, 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.

Volatile Organic Compounds (VOCs): Hydrocarbon compounds that exist in the ambient air and are by-products of energy used to heat and cool buildings. Volatile organic compounds contribute to the formation of smog and/or are toxic. Examples of VOCs are gasoline, alcohol, and solvents used in paints.

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APPENDIX A
DATA COLLECTION AND SITE LOCATION METHODS

Data Collection Methods

For the 2010 tree inventory, Davey Resource Group collected tree inventory data using a system that utilizes a customized ArcPad program loaded onto pen-based field computers equipped with geographic information system (GIS) and global positioning system (GPS) receivers. For the 2017 tree inventory, Davey Resource Group updated data fields using the 2010 spreadsheet. The knowledge and professional judgment of Davey Resource Group's arborists ensure the high quality of inventory data.

Data fields are defined in the glossary of the management plan. At each site, the following data fields were collected in 2010:

- Area
- Aboveground utilities
- Block side
- Clearance requirements
- Condition
- Grow space size
- Grow space type
- Further inspection
- Hardscape damage
- Location
- Primary maintenance needs
- Mapping coordinates
- Observations
- Species
- Stems
- Tree size*

At each site, the following data fields were updated in 2017:

- Aboveground utilities
- Clearance requirements
- Condition
- Further inspection
- Observations
- Species
- Stems
- Tree size*

* measured in inches in diameter at 4.5 feet above ground (or diameter at breast height [DBH])

Maintenance needs are based on *ANSI A300 (Part 1)* (ANSI 2008). Risk assessment and risk rating are based on *Urban Tree Risk Management* (Pokorny et al. 1992)

The 2010 data collected were provided in an ESRI® shapefile, Access™ database, and Microsoft Excel™ spreadsheet on a CD-ROM. The 2017 data is maintained in Google Sheets™.

Site Location Methods

Equipment and Base Maps

During the 2010 inventory arborists used CF-19 Panasonic Toughbook® unit(s) and Trimble® GPS Pathfinder® ProXH™ receiver(s).

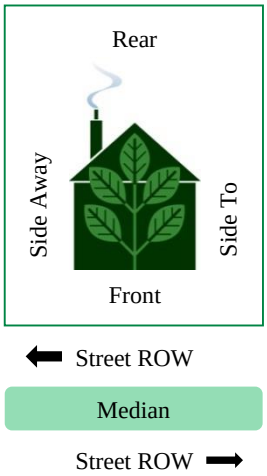
Base map layers were loaded onto these unit(s) to help locate sites during the inventory. Table 1 lists the base map layers, utilized along with source and format information for each layer.

Table 1. Base Map Layers Utilized for Inventory

Imagery/Data Source	Date	Projection
Vector: Whitley County Coordinator: Dan Weigold	2009-2010	NAD 1983 StatePlane Indiana East; Feet
Imagery: 4" Mike Smith	2008	NAD 1983 StatePlane Indiana East; Feet

Street ROW Site Location

Individual street ROW sites (trees, stumps, or planting sites) were located using a methodology that identifies sites by *address number*, *street name*, *side*, *site number*, or *block side*. This methodology was developed by Davey Resource Group to help ensure consistent assignment of location.



Side values for street ROW sites.

Address Number and Street Name

The *address number* was recorded based on visual observation by the arborist at the time of the inventory (the address number was posted on a building at the inventoried site). Where there was no posted address number on a building, or where the site was located by a vacant lot with no GIS parcel addressing data available, the arborist used his/her best judgment to assign an address number based on opposite or adjacent addresses. An "X" was then added to the number in the database to indicate that it was assigned (for example, "37X Choice Avenue").

Sites in medians or islands were assigned an address number using the address on the right side of the street in the direction of collection closest to the site. Each segment was numbered with an assigned address that was interpolated from addresses facing that median/island. If there were multiple median/islands between cross streets, each segment was assigned its own address.

The *street name* assigned to a site was determined by street ROW parcel information and posted street name signage.

Side Value and Site Number

Each site was assigned a *side value* and *site number*. Side values include: *front*, *side to*, *side away*, *median* (includes islands), or *rear* based on the site's location in relation to the lot's street frontage (Figure 1). The *front side* is the side that faces the address street. *Side to* is the name of the street the arborist walks towards as data are being collected. *Side from* is the name of the street the arborist walks away from while collecting data. *Median* indicates a median or island. The *rear* is the side of the lot opposite the front.

All sites at an address are assigned a *site number*. Site numbers are not unique; they are sequential to the side of the address only. The only unique number is the tree identification number assigned to each site. Site numbers are collected in the direction of vehicular traffic flow. The only exception is a one-way street. Site numbers along a one-way street are collected as if the street was a two-way street; therefore, some site numbers will oppose traffic.

A separate site number sequence is used for each side value of the address (*front*, *side to*, *side away*, *median*, or *rear*). For example, trees at the front of an address may have site numbers from 1 through 999; if trees are located on the *side to*, *side away*, *median*, or *rear* of that same address, each side will also be numbered consecutively beginning with the number 1.

Block Side

Block side information for a site includes the *on street*, *from street*, and *to street*.

- The *on street* is the street on which the site is located. The *on street* may not match the address street. A site may be physically located on a street that is different from its street address (i.e., a site located on a side street).
- The *from street* is the first cross street encountered when proceeding along the street in the direction of traffic flow.
- The *to street* is the second cross street encountered when moving in the direction of traffic flow.

Site Location Examples

The tree trimming crew in the truck traveling westbound on E. Mac Arthur Street is trying to locate an inventoried tree with the following location information:

Address/Street Name:	226 E. Mac Arthur Street
Side:	Side To
Site Number:	1
On Street:	Davis Street
From Street:	Taft Street
To Street:	E. Mac Arthur Street

The tree site circled in red signifies the crew's target site. Because the tree is located on the side of the lot, the on street is Davis Street, even though it is addressed as 226 East Mac Arthur Street. Moving with the flow of traffic, the from street is Taft Street, and the to street is East Mac Arthur Street.

Location information collected for
inventoried trees at Corner Lots A and B.

<u>Corner Lot A</u>

Address/Street Name:	205 Hoover St.
Side/Site Number:	Side To / 1
On Street:	Taft St.
From Street:	E Mac Arthur St.
To Street:	Hoover St.
Address/Street Name:	205 Hoover St.
Side/Site Number:	Side To / 2
On Street:	Taft St.
From Street:	E Mac Arthur St.
To Street:	Hoover St.
Address/Street Name:	205 Hoover St.
Side/Site Number:	Side To / 3
On Street:	Taft St.
From Street:	19th St.
To Street:	Hoover St.
Address/Street Name:	205 Hoover St.
Side/Site Number:	Front / 1
On Street:	Hoover St.
From Street:	Taft St.
To Street:	Davis St.

<u>Corner Lot B</u>

Address/Street Name:	226 E Mac Arthur St.
Side/Site Number:	Side To / 1
On Street:	Davis St.
From Street:	Hoover St.
To Street:	E Mac Arthur St.
Address/Street Name:	226 E Mac Arthur St.
Side/Site Number:	Front / 1
On Street:	E Mac Arthur St.
From Street:	Davis St.
To Street:	Taft St.
Address/Street Name:	226 E Mac Arthur St.
Side/Site Number:	Front / 2
On Street:	E Mac Arthur St.
From Street:	Davis St.
To Street:	Taft St.

APPENDIX B
RECOMMENDED SPECIES FOR FUTURE PLANTING

Proper landscaping and tree planting are critical components of the atmosphere, livability, and ecological quality of a community's urban forest. The tree species listed below have been evaluated for factors such as size, disease and pest resistance, seed or fruit set, and availability. The following list is offered to assist all relevant city personnel in selecting appropriate tree species. These trees have been selected because of their aesthetic and functional characteristics and their ability to thrive in the majority of soil and climate conditions throughout Zone 5 on the USDA Plant Hardiness Zone Map.

Deciduous Trees

Large Trees: Greater than 45 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Acer rubrum	red maple	Red Sunset®
Acer nigrum	black maple	
Acer saccharum	sugar maple	'Legacy'
Aesculus flava	yellow buckeye	
Betula nigra	river birch	Heritage®
Carpinus betulus	European hornbeam	'Franz Fontaine'
Castanea mollissima*	Chinese chestnut	
Celtis occidentalis	common hackberry	'Prairie Pride'
Cercidiphyllum japonicum	katsuratree	'Aureum'
Diospyros virginiana*	common persimmon	
Fagus grandifolia*	American beech	
Fagus sylvatica*	European beech	(numerous exist)
Ginkgo biloba	ginkgo	(male trees only)
Gleditsia triacanthos inermis	thornless honeylocust	'Shademaster'
Gymnocladus dioica	Kentucky coffeetree	Prairie Titan®
Juglans nigra*	black walnut	
Juglans regia*	English walnut	'Hansen'
Larix decidua*	European larch	
Liquidambar styraciflua	American sweetgum	Cherokee™
Liriodendron tulipifera	tuliptree	'Fastigiatum'
Maclura pomifera*	osage-orange	'White Shield','Witchita'
Magnolia acuminata*	cucumbertree magnolia	(numerous exist)
Magnolia macrophylla*	bigleaf magnolia	
Metasequoia glyptostroboides	dawn redwood	'Emerald Feathers'
Nyssa sylvatica	black tupelo	
Platanus × acerifolia	London planetree	'Yarwood'
Platanus occidentalis*	American sycamore	
Quercus alba	white oak	
Quercus bicolor	swamp white oak	
Quercus coccinea	scarlet oak	
Quercus ellipsoidalis	northern pin oak	

Large Trees: Greater than 45 Feet in Height at Maturity (continued)

Scientific Name	Common Name	Cultivar
Quercus imbricaria	shingle oak	
Quercus lyrata	overcup oak	
Quercus macrocarpa	bur oak	
Quercus montana	chestnut oak	
Quercus muehlenbergii	chinkapin oak	
Quercus phellos	willow oak	
Quercus robur	English oak	Heritage®
Quercus rubra	northern red oak	'Splendens'
Quercus shumardii	Shumard oak	
Styphnolobium japonicum	Japanese pagodatree	'Regent'
Taxodium distichum	common baldcypress	'Shawnee Brave'
Tilia americana	American linden	'Redmond'
Tilia cordata	littleleaf linden	'Greenspire'
Tilia tomentosa	silver linden	'Sterling'
Tilia × euchlora	Crimean linden	
Ulmus parvifolia	Chinese elm	Allée®
Zelkova serrata	Japanese zelkova	'Green Vase'

Medium Trees: 31 to 45 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Aesculus × carnea	red horsechestnut	
Asimina triloba*	pawpaw	
Cladrastis kentukea	American yellowwood	'Rosea'
Corylus colurna	Turkish filbert	
Eucommia ulmoides	hardy rubbertree	
Koelreuteria paniculata	goldenraintree	
Ostrya virginiana	eastern hophornbeam	
Parrotia persica	Persian parrotia	'Vanessa'
Prunus maackii	amur chokecherry	'Amber Beauty'
Prunus sargentii	sargent cherry	
Quercus acutissima	sawtooth oak	
Quercus cerris	European turkey oak	
Sassafras albidum*	sassafras	
Sorbus alnifolia	Korean mountainash	'Redbird'

Small Trees: 15 to 30 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Acer buergerianum	trident maple	Streetwise®
Acer campestre	hedge maple	Queen Elizabeth™
Acer cappadocicum	coliseum maple	'Aureum'
Acer ginnala	amur maple	Red Rhapsody™
Acer griseum	paperbark maple	
Acer pensylvanicum*	striped maple	
Acer truncatum	Shantung maple	
Acer triflorum	three-flower maple	
Aesculus pavia*	red buckeye	
Amelanchier arborea	downy serviceberry	(numerous exist)
Amelanchier laevis	Allegheny serviceberry	
Carpinus caroliniana	American hornbeam	
Cercis canadensis	eastern redbud	'Forest Pansy'
Chionanthus virginicus	white fringetree	
Cornus alternifolia	pagoda dogwood	
Cornus kousa	Kousa dogwood	(numerous exist)
Cornus mas*	corneliancherry dogwood	'Spring Sun'
Corylus avellana	European filbert	'Contorta'
Cotinus coggygria*	common smoketree	'Flame'
Cotinus obovata*	American smoketree	
Crataegus phaenopyrum	Washington hawthorn	Princeton Sentry™
Crataegus viridis	green hawthorn	'Winter King'
Franklinia alatamaha*	Franklinia	
Halesia tetraptera	Carolina silverbell	'Arnold Pink'
Magnolia × soulangiana*	saucer magnolia	'Alexandrina'
Magnolia stellata*	star magnolia	'Centennial'
Magnolia tripetala*	umbrella magnolia	
Magnolia virginiana*	sweetbay magnolia	Moonglow®
Malus spp.	flowering crabapple	(disease resistant only)
Oxydendrum arboreum	sourwood	'Mt. Charm'
Prunus subhirtella	Higan cherry	pendula
Prunus virginiana	common chokecherry	'Schubert'
Styrax japonicus	Japanese snowbell	'Emerald Pagoda'
Syringa reticulata	Japanese tree lilac	'Ivory Silk'

Note: * denotes species not recommended for use as street trees.

Coniferous and Evergreen Trees

Large Trees: Greater than 45 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Abies balsamea	balsam fir	
Abies concolor	white fir	'Violacea'
Chamaecyparis nootkatensis	Nootka falsecypress	'Pendula'
Cryptomeria japonica	Japanese cryptomeria	'Sekkan-sugi'
Ilex opaca	American holly	
Picea omorika	Serbian spruce	
Picea orientalis	Oriental spruce	
Pinus densiflora	Japanese red pine	
Pinus strobus	eastern white pine	
Pinus sylvestris	Scotch pine	
Psedotsuga menziesii	Douglas fir	
Thuja plicata	western arborvitae	(numerous exist)
Tsuga canadensis	eastern hemlock	

Medium Trees: 31 to 45 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Chamaecyparis thyoides	Atlantic whitecedar	(numerous exist)
Juniperus virginiana	eastern redcedar	
Pinus bungeana	lacebark pine	
Pinus flexilis	limber pine	
Pinus parviflora	Japanese white pine	
Thuja occidentalis	eastern arborvitae	(numerous exist)

Small Trees: 15 to 30 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Ilex × attenuata	Foster's holly	
Pinus aristata	bristlecone pine	
Pinus mugo mugo	mugo pine	

Dirr's Hardy Trees and Shrubs (Dirr 2013) and *Manual of Woody Landscape Plants (5th Edition)* (Dirr 1988) were consulted to compile this suggested species list. Cultivar selections are recommendations only and are based on Davey Resource Group's experience. Tree availability will vary based on availability in the nursery trade.

APPENDIX C
INVASIVE PESTS AND DISEASES

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 naturally enter the United States via wind, ocean currents, and other means, most invasive species enter the country with some help from human activities. Their introduction to the U.S. 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 that you can be prepared to combat their attack.

APHIS, Plant Health, Plant Pest Program Information
- www.aphis.usda.gov/plant_health/plant_pest_info

The University of Georgia, Center for Invasive Species and Ecosystem Health
- www.bugwood.org

USDA National Agricultural Library
- www.invasivespeciesinfo.gov/microbes

USDA Northeastern Areas Forest Service, Forest Health Protection
- www.na.fs.fed.us/fhp

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 Indiana, 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

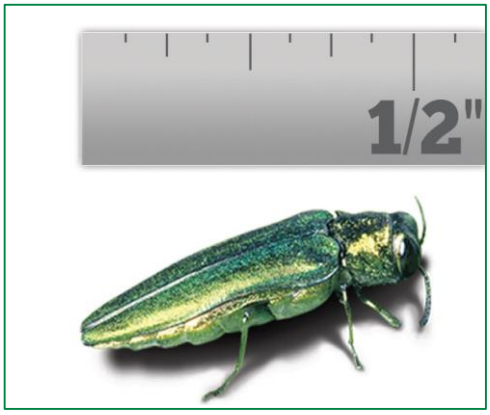
Photograph courtesy of Steven Katovich, USDA Forest Service, Bugwood.org (2011)

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).

Forest Tent Caterpillar

The forest tent caterpillar (FTC) (*Malacosoma disstria*) is a widely distributed insect that feeds on the foliage of broadleaved trees. FTC overwinters as larvae inside eggs on the twigs of the host tree. The larvae (about 2-3mm in size) emerge as the leaves unfold and feed on the buds and leaves of hosts for 5 to 6 weeks. Defoliation typically progresses inward and downward from the outer tree crown and is usually completed by mid-June. Rather than spinning a tent, the caterpillars form a silken mat on the truck or branches of the tree. Pupation takes place in July inside of the cocoon and the moths emerge late July and lay cylindrical egg masses. Regionwide outbreaks of the FTC occur in intervals and typically last two to three years.

Forest tent caterpillars on trunk of tree

Photo courtesy of James Solomon, USDA Forest Service, Bugwood.org (2017)

While these insects may not directly kill the tree, defoliation over an extended period of time may kill or reduce radial growth of the host. These pests also weaken the tree making it vulnerable to attack by other pests and diseases.

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 an appetite for more than 300 species of trees and shrubs. GM caterpillars defoliate trees, which makes the species vulnerable to diseases and other pests that can eventually kill the tree.

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).

Close-up of male (darker brown) and female (whitish color) European gypsy moths

Photograph courtesy of APHIS (2011b)

Loopers

Loopers pose a threat to tree populations due to defoliation caused by feeding during the larval stage of the insect. Loopers prefer trees such as maples, lindens, oaks, birch, elm, hickory, and other hardwoods. Moths of the loopers are wingless and will remain on the tree trunk for the male to mate. After mating, females will crawl up the tree to deposit eggs.

Linden looper (Erannis tiliaria)

Photo courtesy of Steven Katovich, USDA Forest Service, Bugwood.org (2017)

Spiny looper (Phigalia titea)

Photo courtesy of Steven Katovich, USDA Forest Service, Bugwood.org (2017)

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).

Mined shoots on a Scotch pine

Photograph courtesy of USDA Forest Service (1993)

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.

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), *P. nigra* (Austrian pine), *P. resinosa* (red pine), and *P. strobus* (eastern white pine), have been infested in the Great Lakes region.

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APPENDIX D
i-TREE STREETS METHODOLOGY

Columbia City's tree inventory data was formatted for use in i-Tree's street tree population assessment tool, Streets (Version 5.1.5). i-Tree Streets assesses tree population structure and the function of those trees, such as their role in reducing energy use, air pollution removal, reducing stormwater flows, carbon dioxide removal, and property value increases. In order to analyze the economic benefits of Columbia City's public trees, i-Tree Streets assigns a dollar value to the annual resource functionality and compares that to annual program expenditures. This analysis combines the results of the City's tree inventory with benefit-cost modeling data to produce information regarding resource structure, resource function, and resource value to make resource management recommendations. For a detailed accounting of how i-Tree Streets handles tree sampling, tree growth modeling, replacement value, and the calculations of annual benefits, refer to the *Minneapolis, Minnesota Municipal Forest Resource Analysis* (McPherson and others 2005) and the *Midwest Community Tree Guide* (McPherson and others 2006).

i-Tree Streets regionalizes the calculations of its output by incorporating detailed reference city project information for 16 climate zones across the United States. Columbia City falls within the Midwest Climate Zone. Sample inventory data from Minneapolis represent the basis for the Midwest Reference City Project for the Midwest Community Tree Guidelines. The basis for the benefit modeling in this study compares the inventory data from Columbia City to the results of Midwest Reference City Project to obtain an estimation of the annual benefits provided by Columbia City's resource.

Annual benefits for Columbia City's public trees were estimated for the fiscal year 2016. Growth rate modeling information was used to perform computer-simulated growth of the existing tree population for one year and account for the associated annual benefits. This "snapshot" analysis assumed that no trees were added to or removed from the existing population during the year 2014. Calculations of carbon dioxide (CO_2) released due to decompositions of wood from removed trees did consider average annual mortality. This approach directly connects benefits with tree-size variables such as diameter at breast height (DBH) and leaf-surface area. Many benefits of trees are related to processes that involve interactions between leaves and the atmosphere (e.g., interception, transpiration, photosynthesis). Therefore, benefits increase as tree canopy cover and leaf surface area increase.

For each of the modeled benefits, an annual resource unit was determined on a per-tree basis. Resource units are measured as megawatt-hours of electricity saved per tree; therms of natural gas conserved per tree, pounds of atmospheric CO_2 reduced per tree; pounds of nitrogen dioxide (NO_2), particulate matter (PM_{10}), and volatile organic compounds (VOCs) reduced per tree; cubic feet of stormwater runoff reduced per tree; and square feet of leaf area added per tree to increase property values.

Prices were assigned to each resource unit using economic indicators of society's willingness to pay for the environmental benefits trees provide. Estimates of benefits are initial approximations as some benefits are difficult to quantify (e.g., impacts on psychological health, crime, and violence). In addition, limited knowledge about the physical processes at work and their interactions makes estimates imprecise (e.g., fate of air pollutants trapped by trees and then washed to the ground by rainfall). Therefore, this method of quantification provides first-order approximations. It is meant to be a general accounting of the benefits produced by urban trees—an accounting with an accepted degree of uncertainty that can, nonetheless, provide a science-based platform for decision-making.

For a detailed description of how the default benefit prices are derived, refer to the *Minneapolis, Minnesota Municipal Forest Resource Analysis* (McPherson and others 2005) and the *Midwest Community Tree Guide* (McPherson and others 2006). i-Tree Streets' default values from the Midwest Climate Zone were used for all benefit prices.

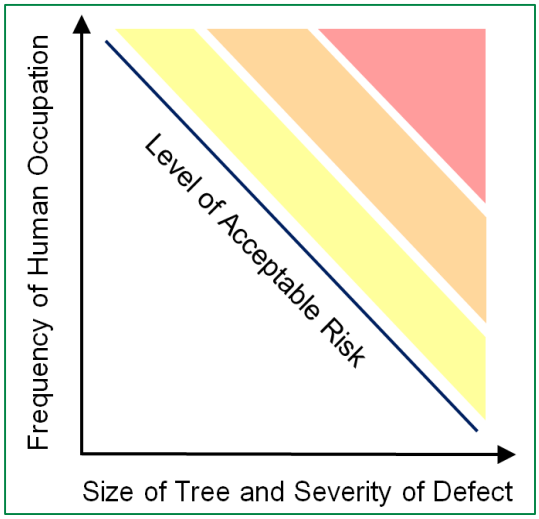
Columbia City's Benefit Prices Used in this Analysis

Benefits	Price	Unit	Source
Electricity	$0.1104	$/Kwh	NIPSCO
Natural Gas	$0.1113	$/Therm	NIPSCO
CO_2	$0.0075	$/lb	Streets default- Midwest
PM_{10}	$2.84	$/lb	Streets default- Midwest
NO_2	$3.34	$/lb	Streets default- Midwest
SO_2	$2.06	$/lb	Streets default- Midwest
VOC	$3.75	$/lb	Streets default- Midwest
Stormwater Interception	$0.0271	$/gallon	Streets default- Midwest
Average Home Resale Value	$198,000	$	Trulia

Using these prices, the magnitude of the benefits provided by the public tree resource was calculated using i-Tree Streets. For a detailed description of how the magnitudes of benefit prices are calculated, refer to the *Minneapolis, Minnesota Municipal Forest Resource Analysis* (McPherson and others 2005).

APPENDIX E
PRIORITY AND PROACTIVE MAINTENANCE

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 Priority 1 and Priority 2 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 urban forest, as every tree in the inventoried population is regularly visited, assessed, and maintained. Davey Resource Group recommends proactive tree maintenance that includes pruning cycles, inspections, and planned tree planting.

APPENDIX F
TREE PLANTING

Tree Planting

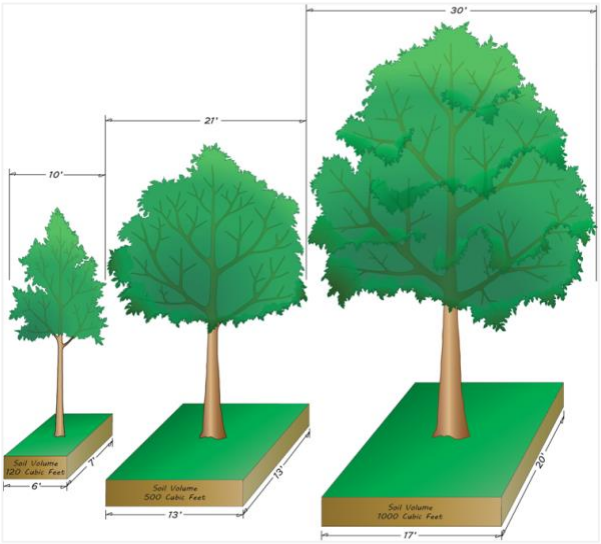
Planting trees is a valuable goal as long as tree species are carefully selected and correctly planted. When trees are planted, they are planted selectively and with purpose. Without proactive planning and follow-up tree care, a newly planted tree may become a future problem instead of a benefit to the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

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.

Inventoried Street ROW Planting Space

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.



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

Planting Site Evaluations

The development of streetscape design guidelines that involve tree installation will be a key aspect in the planting program. Some general tree placement standards are included in the table below.

General Tree Placement Standards

Clearance Distances	Tree Size		
	Small (feet)	Medium (feet)	Large (feet)
Overhead Wires	30	30–50	50
Side Structures	20	20–30	30
From Intersection	35	35	35
Visible Utilities	10	10	10
Other Trees/Planting Sites	20	30	40
Driveways/Alleys	10–15	10–15	10–15
Tree Lawn Width	4–5	6–8	8 or more
Fire Hydrant	15	15	15

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 City is located in USDA Hardiness Zone 5b, which is identified as a climatic region with average annual minimum temperatures between −15°F and −10°F. Tree species selected for planting in Columbia City 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.

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.

Newly Planted and 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 deep, and the growing area should be covered. Mulch should not touch the tree trunk or be piled up around the tree.

Lifelong 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 urban 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.

APPENDIX G
URBAN TREE CANOPY ASSESSMENT

Methodology and Accuracy Assessment

Davey Resource Group Classification Methodology

Davey Resource Group 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.

<u>Classification Workflow</u>

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. Davey Resource Group 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 Davey Resource Group'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 Davey Resource Group utilizes, the AFE only accounts for part of the extraction process. Using Feature Analyst, Davey Resource Group created the training set data, ran the extraction, and then smoothed the features to alleviate the blocky appearance. To complete the actual extraction process, Davey Resource Group 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) Davey Resource Group 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) Davey Resource Group 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 Davey Resource Group and our clients. To achieve to best possible result, Davey Resource Group manually edits and conducts thorough QA/QC checks on all urban tree canopy and land cover layers. A QA/QC process is 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 are 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.

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 Davey Resource Group's accuracy assessment techniques and outlines procedural steps used to conduct the assessment.

1. *Random Point Generation*—Using ArcGIS, 3,533 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 below. The table allows for assessment of user's/producer's accuracy, overall accuracy, omission/commission errors, kappa statistics, allocation/quantity disagreement, and confidence intervals.

Classification Matrix

Reference Data	Classes	Tree Canopy	Impervious Surfaces	Grass & Low-Lying Vegetation	Bare Soils	Open Water	Row Total	Producer's Accuracy	Errors of Omission
	Tree Canopy	739	3	57	1	7	807	91.57%	8.43%
	Impervious	1	747	27	1	7	778	95.37%	4.63%
	Grass/Vegetation	9	5	661	0	0	675	97.93%	2.07%
	Bare Soils	1	0	3	735	1	740	99.32%	0.68%
	Water	0	0	2	0	531	533	99.62%	0.38%
	Column Total	750	750	750	737	546	3533		
	User's Accuracy	98.53%	98.93%	88.13%	99.73%	97.25%		Overall Accuracy	96.46%
	Errors of Commission	1.47%	1.07%	11.87%	0.27%	2.75%		Kappa Coefficent	0.9516

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 ((739+747+661+735+531)/3533 = 96.46%).

   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 [739/750 = 98.53%]).

   Producer's Accuracy – Probability of a reference pixel being correctly classified (correct land cover classifications divided by the row total [739/807 = 91.57%]).

   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 1.47% 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 8.43% of all canopy classified is actually classified as another land cover class.

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.

Results of Accuracy Assessment Tests

Class	Acreage	Percentage	Lower Bound	Upper Bound
Tree Canopy	926.3	26.5%	25.7%	27.2%
Impervious Surfaces	970.6	27.8%	27.0%	28.5%
Grass & Low-Lying Vegetation	1,481.2	42.4%	41.5%	43.2%
Bare Soils	70.0	2.0%	1.8%	2.2%
Open Water	48.8	1.4%	1.2%	1.6%
Total	3,496.9	100.0%		

Statistical Metrics Summary	
Overall Accuracy =	96.46%
Kappa Coefficient =	0.9516
Allocation Disagreement =	1%
Quantity Disagreement =	2%

Class	User's Accuracy	Lower Bound	Upper Bound	Producer's Accuracy	Lower Bound	Upper Bound
Tree Canopy	98.5%	98.1%	99.0%	91.6%	90.6%	92.6%
Impervious Surfaces	98.9%	98.6%	99.3%	95.4%	94.6%	96.1%
Grass & Low-Lying Vegetation	88.1%	87.0%	89.3%	97.9%	97.4%	98.5%
Bare Soils	99.7%	99.5%	99.9%	99.3%	99.0%	99.6%
Open Water	97.3%	96.6%	98.0%	99.6%	99.4%	99.9%

Methodology

1. How Tree Canopy Benefits Are Calculated:

1.1 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.

1.2 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.

1.3 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 1.3% 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. To place a monetary value on storm water reduction, the cost to treat a gallon of storm/waste water was taken from Peper et al 2009. This value was $0.006 per gallon.

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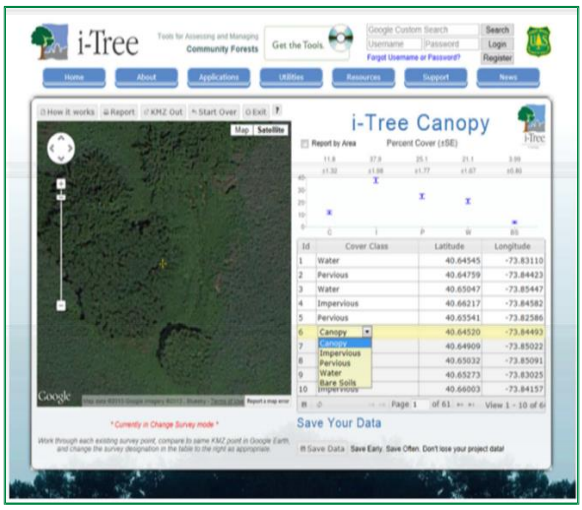
Future Use of i-Tree Canopy Tool

For future assessments, the i-Tree Canopy tool can be used to quickly measure land cover changes and progress towards canopy goals between more thorough and complete community tree canopy assessments. Though less precise and complete than a professional tree canopy assessment, canopy can be assessed through i-Tree using new aerial imagery as it becomes available in Google® Maps. Detailed instructions can be found at the i-Tree website (http://www.itreetools.org).



Screenshot of the i-Tree Canopy tool.

For comparison, i-Tree Canopy was used to estimate land cover percentage for the project area. Based on the underlying methodology, i-Tree Canopy results may be less precise than those generated by a comprehensive tree canopy assessment. While less sophisticated, i-Tree Canopy reports offer a statistically valid comparison for total tree canopy.

The benefit of the i-Tree Canopy tool is that it allows users to easily interpret Google® Earth aerial imagery for areas of interest and produce estimates of tree cover and other cover types. The tool also calculates levels of uncertainty for the land cover estimates provided. This tool provides a quick and inexpensive means for communities and forest managers to assess their tree canopy cover.