July 2020

TREE MANAGEMENT PLAN

City of Big Rapids, Michigan

Prepared for:

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Table of Contents

TABLES

FIGURES

APPENDICES

ACKNOWLEDGMENTS

This project supports the City of Big Rapids' vision to promote and enhance community well-being through public tree conservation and improved forestry management practices. This *Tree Management Plan* offers expertise in preserving and expanding urban canopy so the environmental, economic, and social benefits it provides continue for generations.

Big Rapids is grateful for the grant funding it received from the Michigan Department of Natural Resources (DNR) Urban and Community Forestry (UCF) which has established the Community Forestry Grants program in cooperation with the U.S. Forest Service (USFS). Michigan DNR's UCF Grant Program is designed to encourage communities to implement and support sustainable urban forestry programs throughout the United States.

The City of Big Rapids recognizes the support of its Mayor Thomas Hogenson, and its City Manager Mark Gifford.

Recommended Maintenance Types

TREE MANAGEMENT PLAN EXECUTIVE SUMMARY

The City of Big Rapids' *Tree Management Plan*, written by Davey Resource Group, Inc. "DRG", assesses the composition of the inventoried tree resource, estimates the value of its benefits, and addresses its maintenance needs. DRG completed a tree inventory for Big Rapids in May 2020 and analyzed the data collected to understand the structure of the city's public tree resource. DRG also provided a five-year tree resource maintenance schedule with priority ratings of recommended tree maintenance activities along with their estimated costs.

The functions of Big Rapids' inventoried tree resource provide annual benefits with an estimated total value of $437,737. The city uses about 25% of the General Funds appropriated to Park Facilities for urban forestry activities, which was approximately $118,875 in its Fiscal Year (FY) 2020 budget. The estimated return on investment of Big Rapids' urban forestry program is 268%, making implementing proactive tree maintenance a sound long-term investment that can improve community well-being and reduce management costs over time.

High priority tree removal and pruning is costly, accounting for the larger budget in the Year 1 of the five-year schedule, as shown in Figure 1. After high priority work has been completed, budgets are expected to decrease and stabilize as tree management transitions from reactive to proactive maintenance. This also reduces the number of new elevated risk trees over time by preventing deteriorating conditions of trees with initially minor defects.

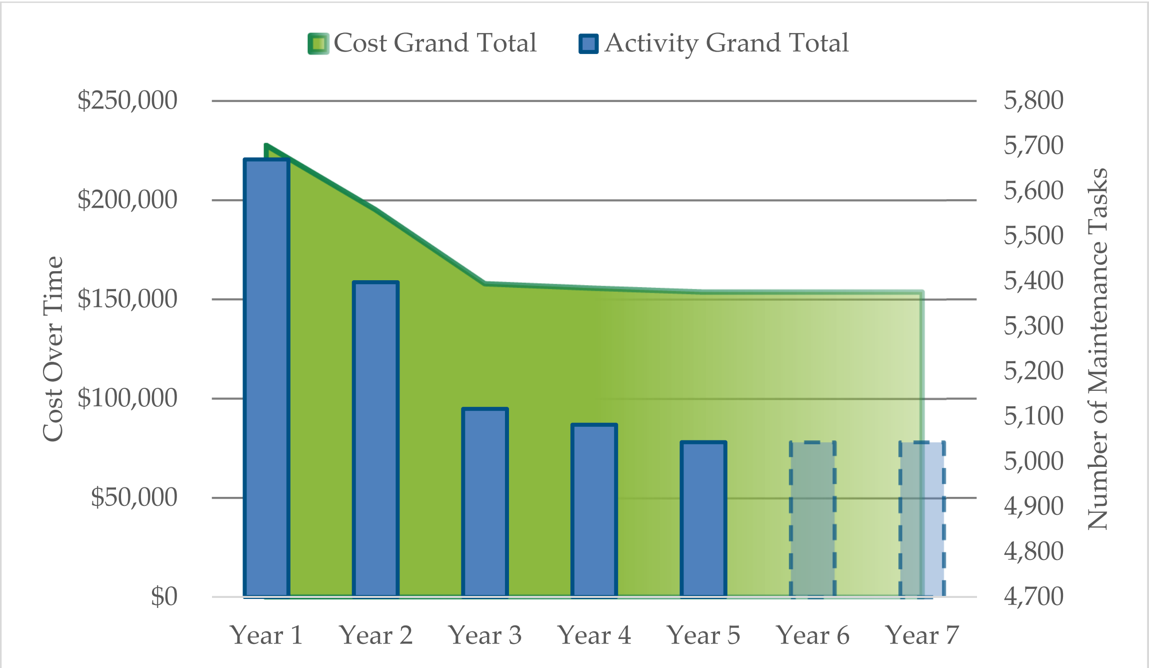


Figure 1. Five-year tree resource maintenance schedule budget totals.

Five-year Tree Resource Maintenance Schedule

Tree Removal

Trees designated for removal have defects that cannot be cost-effectively or practically corrected. Most of the trees in this category have a large percentage of dead crown.

Total = 344 trees
High Priority = 185 trees
Moderate Priority = 130 trees
Low Priority = 29 trees
Stumps = 399

Priority Pruning

Priority pruning removes defects such as Dead and Dying Parts or Broken and/or Hanging Branches. Pruning the defected branch(es) can lower risk associated with the tree while promoting healthy growth.

Total = 696 trees
High Priority = 319 trees
Moderate Priority = 377 trees

Routine Pruning Cycle

Over time, routine pruning of Low and Moderate Risk trees can minimize reactive maintenance, limit instances of elevated risk, and provide the basis for a robust risk management program.

Total = 2,510 trees
Number in cycle each year = at least 502 trees

Young Tree Training Cycle

Younger trees can have branch structures that lead to potential problems as the tree ages, requiring training to ensure healthy growth. Training is completed from the ground with a pole pruner or pruning shear.

Total = 916 trees
Number in cycle each year = at least 305 trees

Tree Planting

Planting new trees in areas that have poor canopy continuity is important, as is planting trees where there is sparse canopy, to ensure that tree benefits are distributed evenly across the city.

Total replacement plantings = 399 trees
Total new plantings = 141 trees

Routine Tree Inspection

Routine inspections are essential to uncovering potential problems with trees and should be performed by a qualified arborist who is trained in the art and science of planting, caring for, and maintaining individual trees.

Total = 3,825 existing trees
Number in drive-by assessment cycle each year = near 3,060 trees
Number in walk-by assessment cycle each year = near 765 trees

INTRODUCTION

The City of Big Rapids is home to 10,395 residents benefitting from public trees in their community. Big Rapids' annual urban forestry budgets draw from the city's Park Facilities General Fund. The Parks and Recreation Board is responsible for managing trees growing on public land, while the Department of Public Works is responsible for the care of all trees in the street right-of-way (ROW) and throughout public parks. Big Rapids has a tree ordinance, spends more than $2 per capita on tree maintenance, and annually celebrates Arbor Day, qualifying it as a Tree City USA for 41 years.

RECOMMENDED APPROACH TO TREE MANAGEMENT

An effective approach to tree resource management follows a proactive and systematic program that sets clear and realistic goals, prescribes future action, and periodically measures progress. A robust urban forestry program establishes tree maintenance priorities and utilizes modern tools, such as a tree inventory accompanied by TreeKeeper® or other asset management software.

In May 2020, the City of Big Rapids began working with DRG to develop this management plan by inventorying all public trees in the ROW and in parks. Consisting of three sections, this plan considers the distribution, size, and condition of the inventoried tree population, estimates the value of benefits it provides to the surrounding community, and recommends a prioritized maintenance plan and budget for managing the city's public tree resource.

- *Section 1: Structure and Composition of the Public Tree Resource* summarizes the inventory data with trends representing the current state of the tree resource.
- *Section 2: Functions and Benefits of the Public Tree Resource* summarizes the estimated value of benefits provided to the community by public trees' various functions.
- *Section 3: Recommended Management of the Public Tree Resource* details a prioritized five-year tree resource maintenance schedule and provides an estimated budget for the recommended activities.

Section 1:

Structure and Composition

of the Public Tree Resource

SECTION 1: STRUCTURE AND COMPOSITION OF THE PUBLIC TREE RESOURCE

In May 2020, DRG arborists collected site data on trees and stumps in the ROW and trees and stumps in parks for an inventory contracted by the City of Big Rapids. Of the total 3,825 sites inventoried, 85% were collected in the ROW and the remaining 15% were collected in parks. Figure 2 breaks down the total sites inventoried by type for each location. See Appendix A for details about DRG's methodology for collecting site data.

The City of Big Rapids designated a total of nine public park areas for DRG to collect site data for the tree inventory. These include Big Rapids City Hall, the Big Rapids Department of Public Safety, Clay Cliffs Natural Area, the Community Garden site at the Big Rapids Community Library, Hemlock Park, Mecosta County Courthouse, Mecosta County Jail, Northend Riverside Park, and River Street Park.

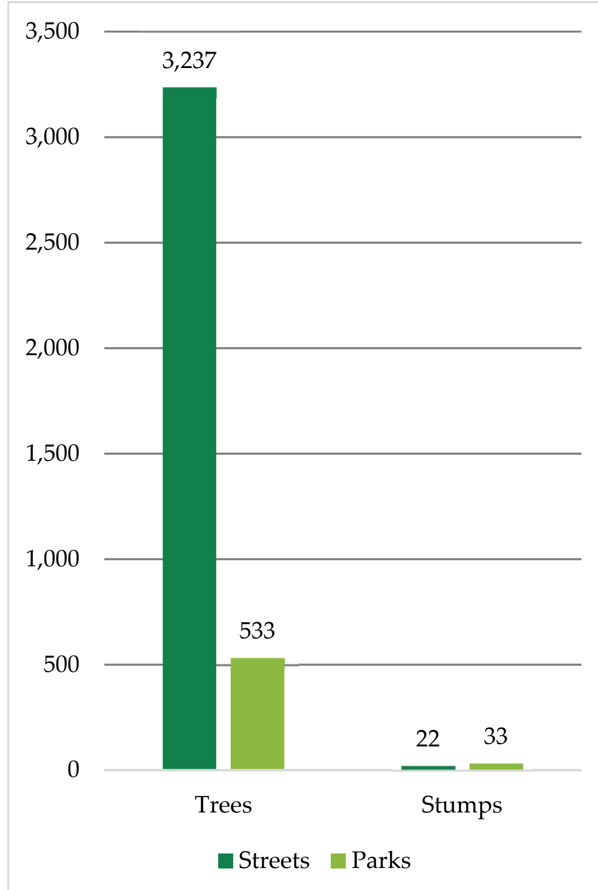


Figure 2. Number of inventoried sites by location and type.

SPECIES, GENUS, AND FAMILY DISTRIBUTION

The 10-20-30 Rule is a common standard for tree population distribution, in which a single species should comprise no more than 10% of the tree population, a single genus no more than 20%, and a single family no more than 30% (Santamour 1990).

Figure 3 shows Big Rapids' distribution of the most abundant tree species in the ROW compared to the recommended 10% threshold. Sugar maple (*Acer saccharum*, 24%) is the most abundant species in the ROW population followed by Norway maple (*A. platanoides*, 17%), which are both well above the threshold. Silver maple (*A. saccharinum*) and Callery pear (*Pyrus calleryana*) are both 10% of the ROW population, meaning any additional plantings of either species will exceed the threshold.

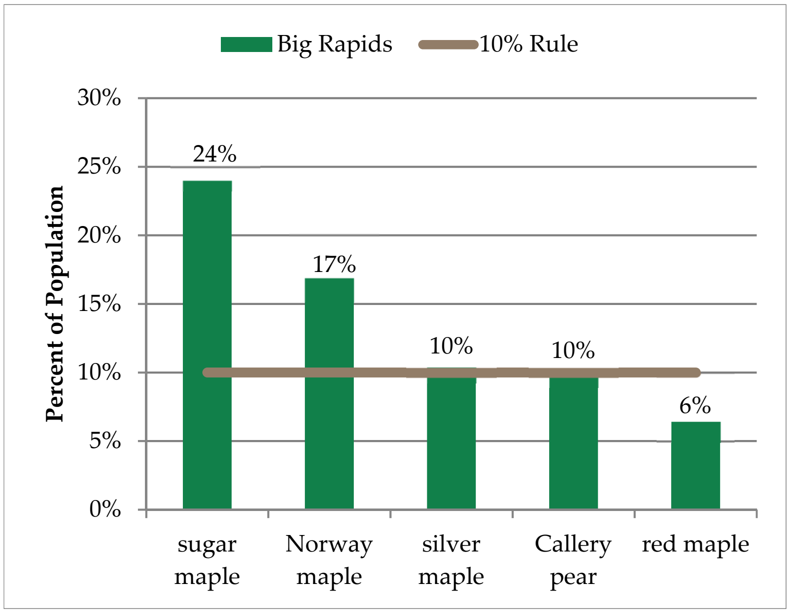


Figure 3. Species distribution of trees in the ROW.

RESILIENCE THROUGH DIVERSITY

The Dutch elm disease epidemic of the 1930s provides a key historical lesson on the importance of diversity (Karnosky 1979). The disease killed millions of American elm trees, leaving behind enormous gaps in the urban canopy of many Midwestern and Northeastern communities. In the aftermath, ash trees became popular replacements and were heavily planted along city streets. History repeated itself in 2002 with the introduction of the emerald ash borer into America. This invasive beetle devastated ash tree populations across the Midwest. Other invasive pests spreading across the country threaten urban forests, so it's vital that we learn from history and plant a wider variety of tree genera to develop a resilient public tree resource.

Ash trees in an urban forest killed by emerald ash borer.

USDA Forest Service (2017)

Figure 4 shows the city's distribution of the most abundant tree species in parks compared to the recommended 10% threshold. This population, while much smaller than the ROW population, has a species distribution with noteworthy differences. The only species at the threshold is black cherry (*Prunus serotina*, 10%); however, Norway maple (8%), boxelder (*Acer negundo*, 6%), eastern white pine (*Pinus strobus*, 6%), and thornless honeylocust (*Gleditsia thriacanthos inermis*, 5%) are all approaching the threshold and should be limited in future plantings. Planting sugar maple (5%) is advised against because while it is below the species threshold, both the genus and family it belongs to are above their respective thresholds.

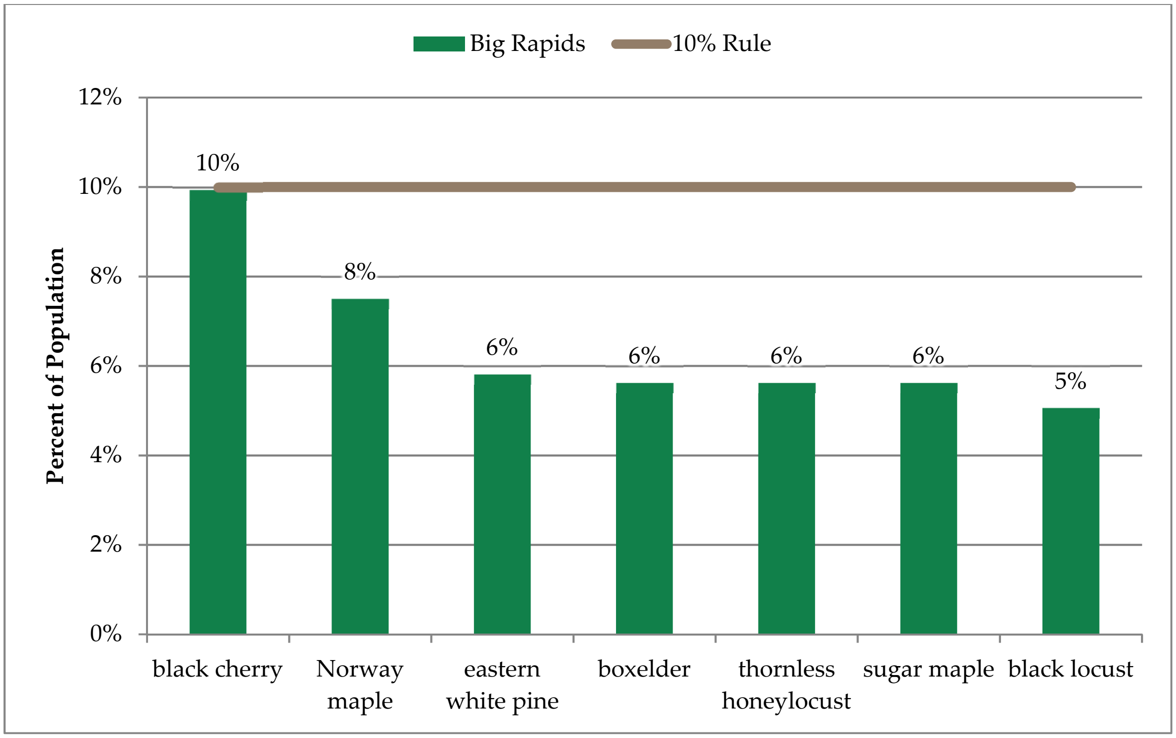


Figure 4. Species distribution of trees in parks.

Figure 5 shows Big Rapids' distribution of the most abundant tree genera in the ROW compared to the recommended 20% threshold. Maple (*Acer*, 61%) is three times greater than the recommended threshold and is the majority of trees in the ROW population, which is why planting red maple should be avoided despite it only being 6% of the ROW population, along with any other maple species. The other top five genera in the ROW population are elm (*Ulmus*, 3%), spruce (*Picea*, 3%), and linden (*Tilia*, 3%). All three of these genera are at low enough proportions that continuing to plant them is worthwhile; however, planting trees with even lower proportions of the population is even more worthwhile.

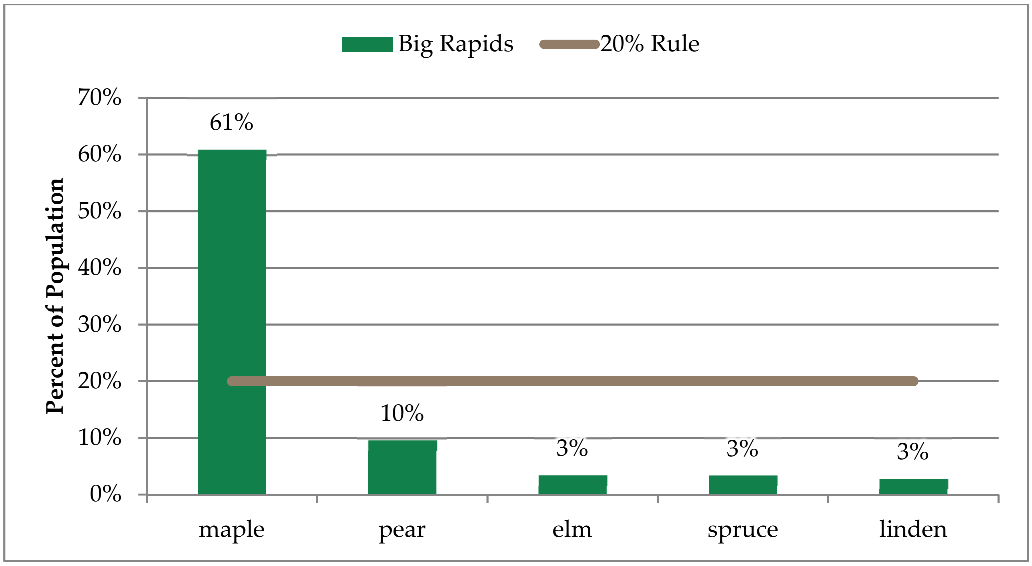


Figure 5. Genus distribution of trees in the ROW.

Figure 6 shows the city's distribution of the most abundant tree genera in parks compared to the recommended 20% threshold. While not as great a proportion of the parks population as the ROW population, maple (28%) still exceeds the threshold in parks. Cherry (*Prunus*, 12%) is approaching the threshold in parks, because of more of the native black cherry (*Prunus serotina*) growing in these natural areas. For this reason, it is important not to overplant flowering cherry species in parks. The other top five genera in the parks population are pine (*Pinus*, 7%), honeylocust (*Gleditsia*, 5%), and locust (*Robinia*, 5%). All three of these genera are at low enough proportions that continuing to plant them is worthwhile; however, planting trees with even lower proportions of the population is even more worthwhile. Except for maple, the most prevalent genera in the parks population are completely different from those in the ROW population, meaning Big Rapids' parks add complexity to the city's overall genus distribution.

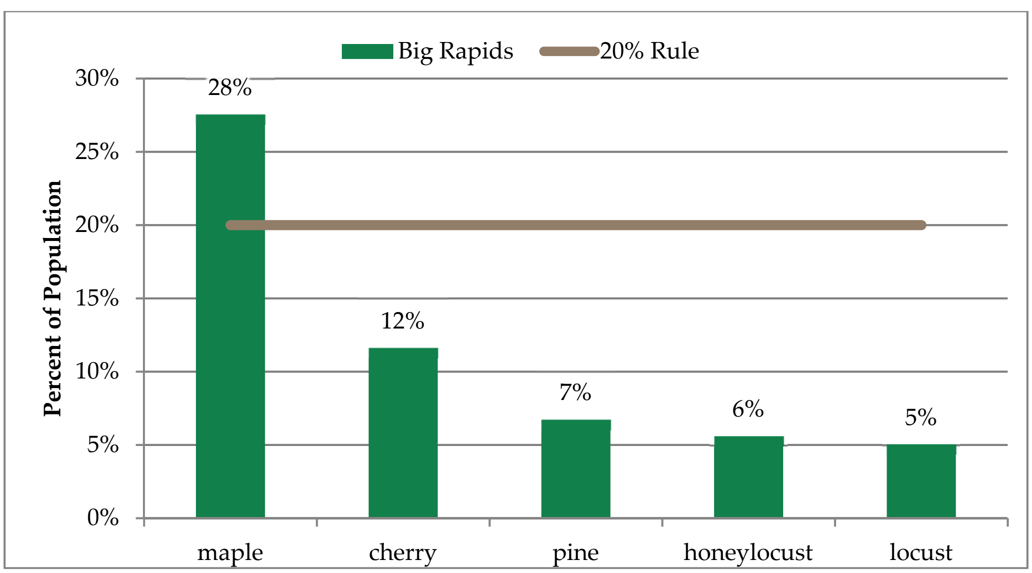


Figure 6. Genus distribution of trees in parks.

Figure 7 shows Big Rapids' distribution of the most abundant tree families in the ROW compared to the recommended 30% threshold. Because maple are so abundant and are in Sapindaceae (61%), most trees in the ROW belong to this family, which is two times greater than the threshold. While Rosaceae (14%) is only about halfway to the threshold, many popular ornamental tree species belong to this family, and planting plans should be careful not to overplant genera such as serviceberry (*Amelanchier*), hawthorn (*Crataegus*), apple (*Malus*), and cherry (*Prunus*). The other top five families in the ROW population are *Pinaceae* (5%) and *Ulmaceae* (4%). All three of these families are at low enough proportions that continuing to plant them is worthwhile; however, planting trees with even lower proportions of the population is even more worthwhile.

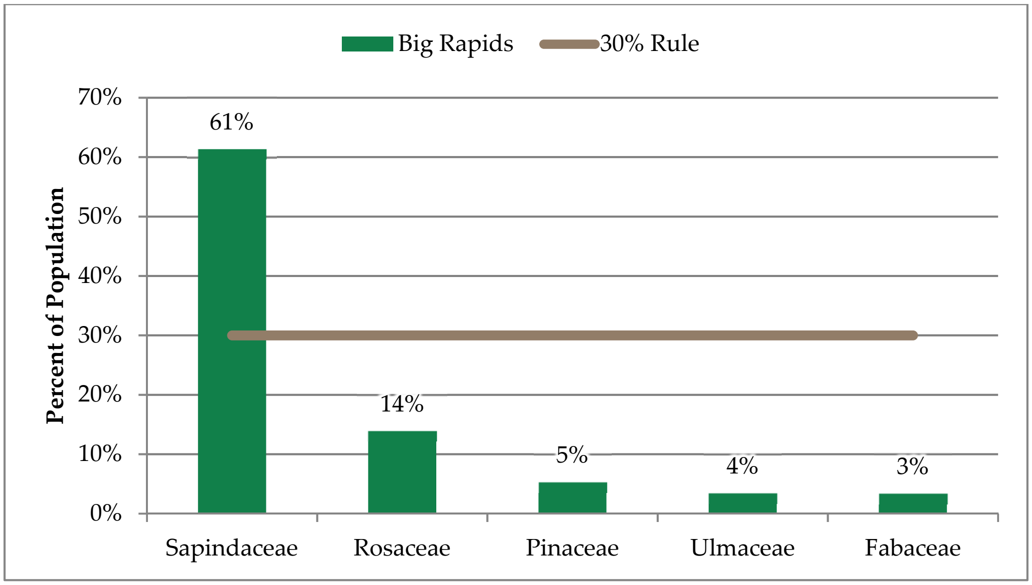


Figure 7. Family distribution of trees in the ROW.

Figure 8 shows the city's distribution of the most abundant tree families in parks compared to the recommended 30% threshold. The parks population is like the ROW population in that the large proportion of maple trees influences the family distribution; however, *Sapindaceae* (29%) is almost at the threshold rather than exceeding it. Still, maple plantings should be avoided along with species in *Rosaceae* (19%), which is a greater proportion of the parks population than the ROW population, and is closer to reaching the threshold. *Pinaceae* and *Fabaceae* plantings should be limited because they are already a significant proportion of the parks population, yet do not need to be completely avoided. *Ulmaceae* is a low enough proportion that planting them is worthwhile until they are closer to the threshold.

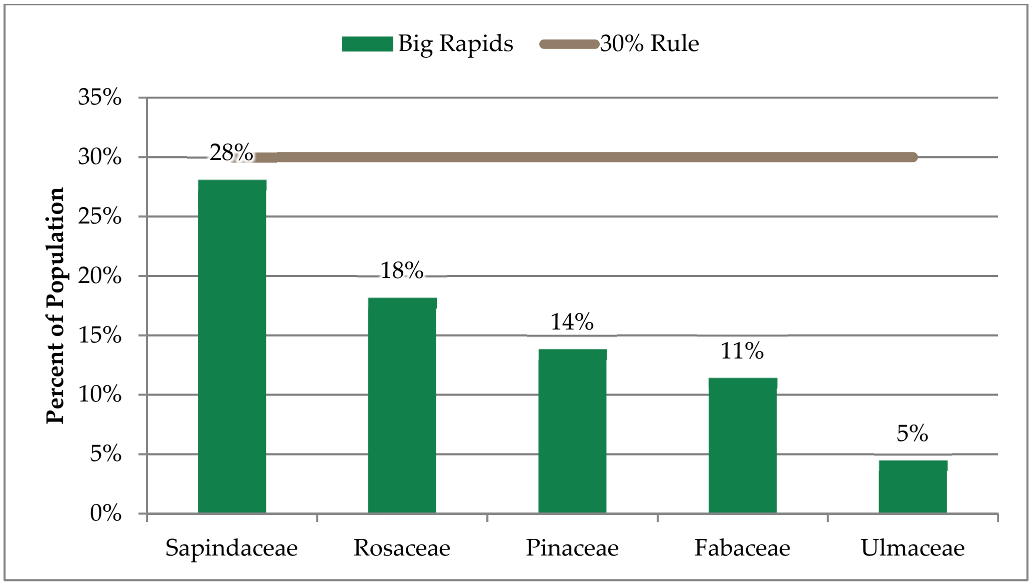


Figure 8. Family distribution of trees in parks.

Species, Genus, and Family Distribution Recommendations

Maple is a host of Asian longhorned beetle (ALB, *Anoplophora glabripennis*), so having a large maple population makes the city's tree resource more susceptible to infestation with more widespread damages. Some pests such as emerald ash borer (EAB, *Agrilus planipennis*) target a single genus as a host, and some pests also target a single family as a host. This illustrates how species distribution alone does not completely represent a tree population, and why planting different species may not increase diversity if the same genus or family is being planted.

Another consideration is the invasiveness of a species, which is why planting black locust (*Robinia pseudoacacia*, 5%) is advised against despite being below the 10% species threshold, because it is listed as an invasive species by the MI DNR (Michigan Department of Natural Resources 2020). Pear (*Pyrus*, 10%) is also below the threshold, but should still be avoided because it is non-native, and has both a growth habit and spread pattern, suggesting it is in the early stages of invasion (Culley & Hardiman 2007).

PEST SUSCEPTIBILITY

Early diagnosis of disease and infestation is essential to ensuring the health and continuity of Big Rapids' public tree resource. See Appendix B for additional information about the pests listed below and websites where additional information can be found.

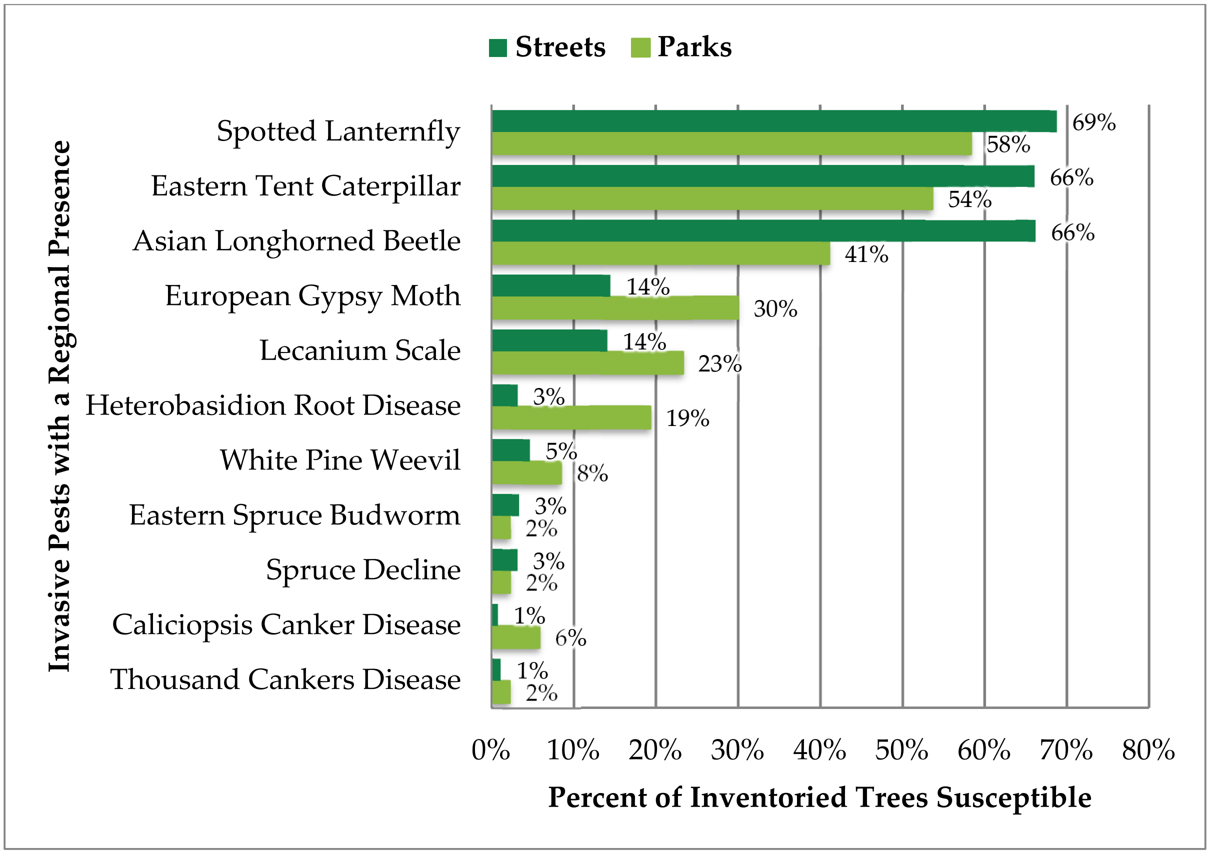


Figure 9. Tree resource susceptibility to invasive pests that have a regional presence.

Figure 9 shows the proportion of inventoried trees susceptible to some of the known pests in and around Michigan. It is important to remember that this figure only represents data collected during the inventory. Many more trees throughout the Big Rapids area, particularly those on private property, may be susceptible to hosting these invasive pests. The inventoried tree resource is most threatened by spotted lanternfly (SLF, *Lycorma delicatula*), ALB, and eastern tent caterpillar (ETC, *Malacosoma americanum*). Two-thirds of the ROW population or more is susceptible to each of these three pests, and more than half of the parks population is susceptible to SLF and ETC, because maple are a host to all three of these pests. ETC is a native species with fluctuating population levels from year to year and outbreaks only once every several years; however, SLF and ALB are aggressive invasive pests that could cause massive losses to Big Rapids if either were found in Michigan.

Currently, SLF has been found in Pennsylvania and ALB has been found in New York, Massachusetts, and Ohio. ALB is a wood-boring beetle that can cause tree mortality, and unlike EAB, it has hosts in several genera besides ash (*Fraxinus*). The potential losses from ALB are great, and while quarantine efforts are ongoing, it is important to be prepared in case it spreads to

Michigan. While SLF also has several hosts, it does not cause tree mortality as directly as ALB because it feeds on tree sap rather than boring into wood. Sap has more sugar than can be readily digested by SLF, so its excrement is referred to as "honeydew" because it still has sugar content, attracting other insects to the infested tree as well as providing growth substrate to sooty molds. Sap-sucking and pest attraction cause stress that makes it difficult for a tree to withstand other environmental stress over time, which can lead to worsening condition or death.

Pest Susceptibility Recommendations

The overabundance of maple in Big Rapids' tree resource is a management concern because it risks elevated losses in the event of an invasive pest outbreak. This abundance is not only more trees to lose but is also more habitat for the pests they are hosts to, making it easier for them to spread. While other species and genera besides maple are susceptible to pests that have a regional presence, they are a small proportion of the city's tree resource. Increasing species and genus diversity is a critical goal that will help Big Rapids' tree resource become resilient in the event of future pest invasions. Limiting planting trees in *Rosaceae* to prevent it from approaching the 30% threshold is good for the tree resource's overall structure, but efforts to improve the species and genus distributions are a better use of short-term resources until more research is done on family diversity as a mechanism for improving system resilience.

CONDITION

Several factors affecting condition 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 by an arborist as Good, Fair, Poor, or Dead. The general health of the Big Rapids' tree resource was characterized by the most prevalent condition assigned during the inventory.

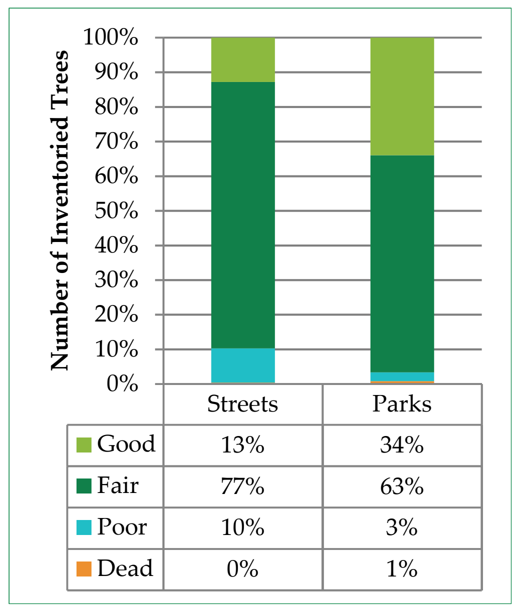


Figure 10. Condition of inventoried trees.

Figure 10 shows most of the inventoried trees were rated in Fair condition, 77% in the ROW population, and 63% in the parks population. 34% of the park population was rated in Good condition and only 3% rated in Poor condition, compared to 13% of the ROW population rated in Good condition and 10% rated in Poor condition. This data represent the generally better condition of trees in parks, which may be explained by its much smaller population. Big Rapids has a generally low percentage of trees rated in Poor condition and almost no Dead trees, so the overall health of the city's tree resource seems to be improving and approaching Good condition rather than declining.

Condition Recommendations

The structural pruning, or training, of younger trees and the routine pruning of older trees is important for correcting defects that would otherwise deteriorate over time, which can prevent Poor condition trees from developing and maintain trees in Fair and Good condition. Pruning should follow *ANSI A300 (Part 1)* guidelines (American National Standards Institute, 2017). Poor condition ratings among mature trees were generally due to visible signs of stress and decline, such as dead limbs and cavity decay, which is further discussed in the Defect Observation section. Maintenance recommendations for these trees are generally higher priority, which will be discussed further in Section 3.

The health of most trees in Poor condition is unlikely to improve, even with intensive maintenance interventions, and removal is recommended as the most cost-effective management option. Since the overall condition of Big Rapids' tree resource is Fair, after addressing trees that are Dead or in Poor condition, the city will transition from the reactive maintenance of those trees to proactive maintenance maintaining trees in Fair and Good condition. Over the long term, proactive maintenance can improve the overall condition of the tree resource.

RELATIVE AGE DISTRIBUTION

Analysis of a tree population's relative age distribution is performed by assigning age classes to the size classes, offering insight into the maintenance needs of the city's tree resource. The inventoried trees are grouped into the following relative age classes: young trees 0–8 inches diameter at breast height (DBH), established trees 9–17 inches DBH, maturing trees 18–24 inches DBH, and mature trees greater than 24 inches DBH.

These size classes were chosen so that the public tree resource can be compared to the ideal relative age distribution, which holds that the largest proportion of the tree population (approximately 40%) should be young trees, while a smallest proportion (approximately 10%) should be mature trees (Richards 1983). Since tree species have different lifespans and mature at different diameters, actual tree age cannot be determined from diameter size class alone, yet size classifications can be extrapolated into relative age classes.

Figure 11 compares the relative age distribution of Big Rapids' tree resource to Richards' ideal distribution. The city's ROW population is close to the ideal, but maturing trees fall short by 2% while young trees fall short by 4%. It is possible that the relative age distribution will approach closer to the ideal over time, as mature trees are routinely replaced with young trees when they reach the end of their healthy lifespan, additional trees are planted in new locations, and maturing trees are proactively cared for so they reach maturity. The proportion of mature trees is 6% higher than the ideal, which provide the most benefits because of their size, and are important to maintain until it is no longer cost-effective.

The city's parks population is further from the ideal distribution than the ROW population, with maturing trees falling short by 12% and mature trees falling short by 3%. The relative age distribution will approach the ideal over time as young and established trees grow and fill the gaps in the older relative age classes. This emphasizes the importance of maintaining trees in parks so they remain healthy and reach older age classes.

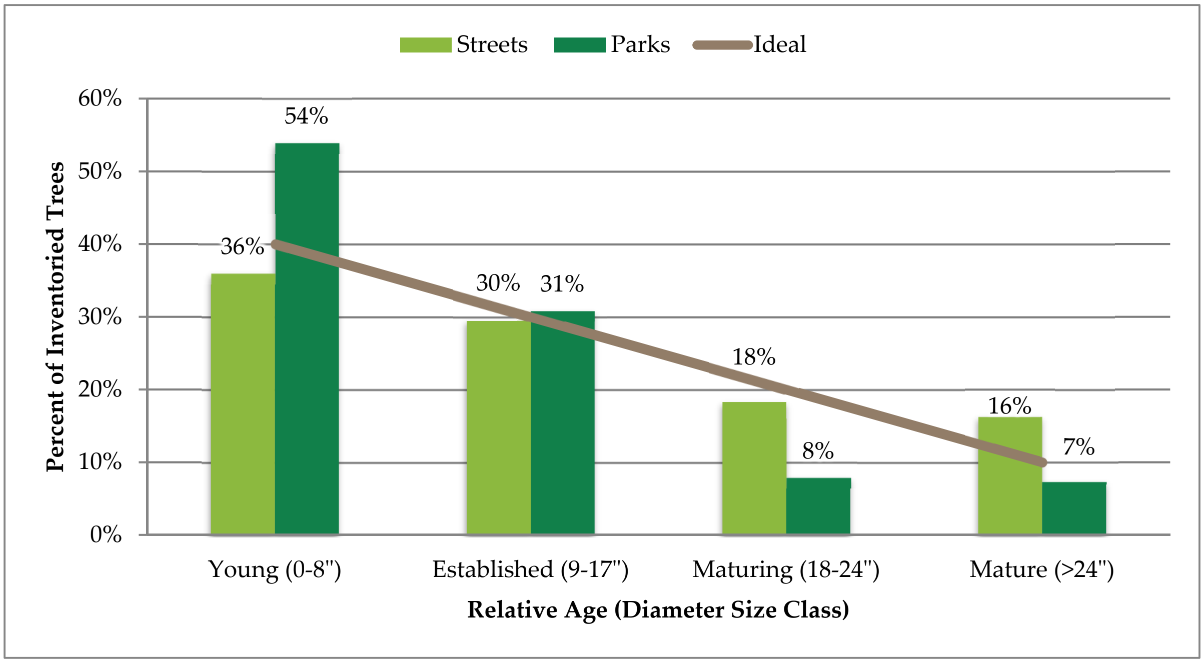


Figure 11. Relative age distribution of the inventoried tree resource.

Relative Age Recommendations

Figure 12 cross analyzes the condition of ROW trees with the relative age distribution, providing insight into the population's stability. 73% of both young and mature trees are rated in Fair condition; however, 23% of young trees are rated in Good condition while 24% of mature trees are rated in Poor condition or Dead. Similarly, 81% of both established and maturing trees are rated in Fair condition; however, 12% of established trees are rated in Good condition while 14% of maturing trees are rated in Poor condition or Dead. The maintenance recommendations for mature and maturing trees rated in Poor condition or Dead are a high priority because management of these trees is a crucial step for transitioning from reactive to proactive maintenance, since these trees will continue to deteriorate over time until they fail, potentially requiring emergency maintenance.

Aside from the mature and maturing trees rated in Poor condition or Dead, most of the ROW population is rated in Fair condition with many young and established trees rated in Good condition. For this reason, it is important to implement a Young Tree Training Cycle and a Routine Pruning Cycle, so these trees remain in Fair or Good condition as they age and grow.

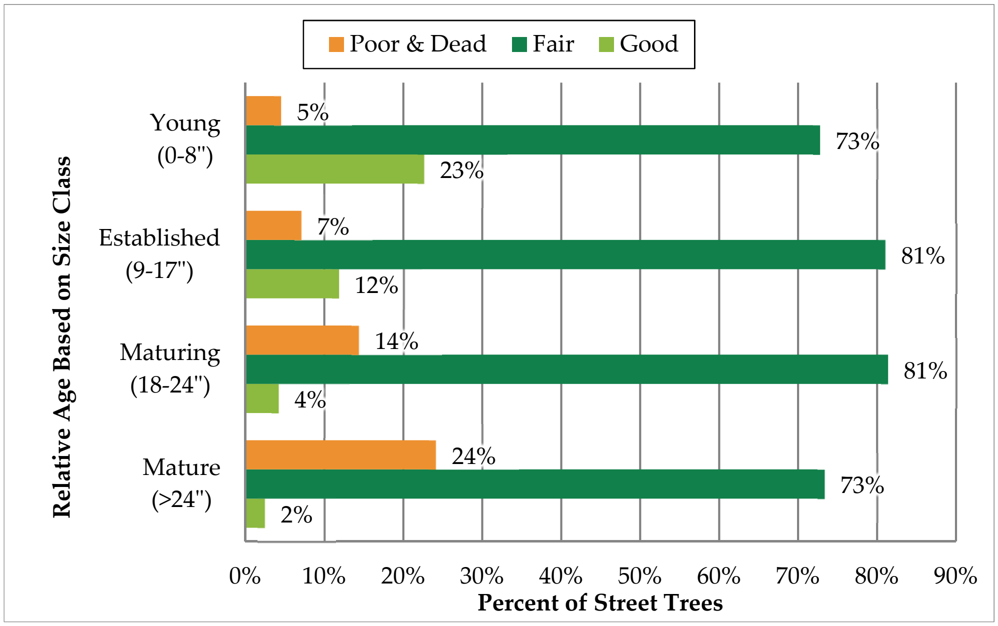


Figure 12. Condition of trees in the ROW by relative age class.

Figure 13 cross analyzes the condition of the parks population with the relative age distribution, showing each age class having less than 5% of trees rated in Poor condition or Dead. 44% of young trees and 31% of established trees are rated in Good condition, while only 5% of maturing and 8% of mature trees are rated in Good condition. This emphasizes the need for proactive maintenance, so younger trees remain in Good condition as they grow and mature. The maintenance recommendations for the small proportion of mature and maturing trees rated in Poor condition or Dead are still a high priority but having fewer high priority trees to manage means that the Routine Pruning Cycle can start sooner. This will improve the likelihood that more trees in parks can be maintained in Good condition as they age.

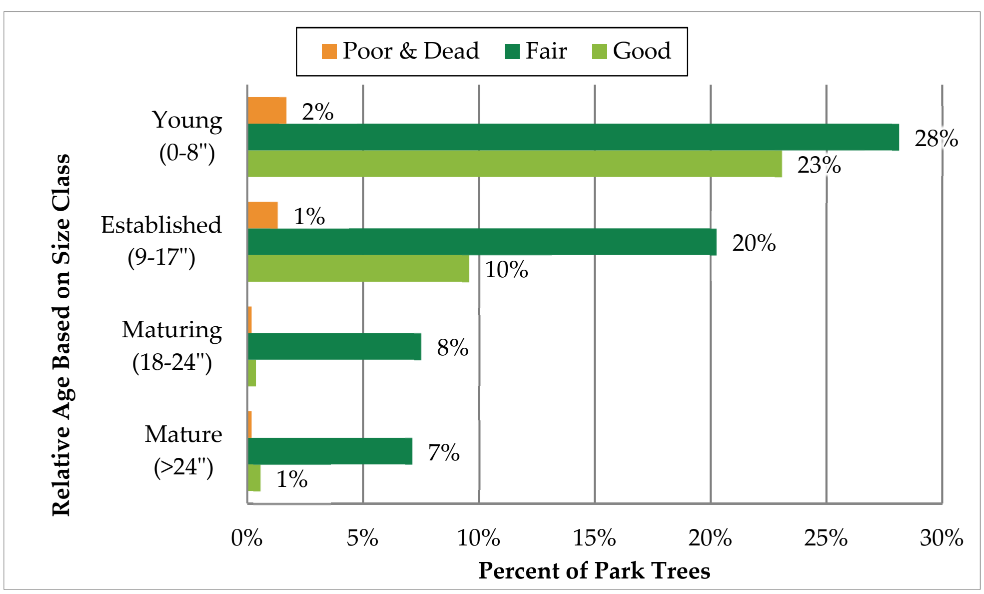


Figure 13. Condition of trees in parks by relative age class.

DEFECT OBSERVATIONS

For each tree inventoried, DRG assessed conditions indicating the presence of structural defects and recorded the most significant defect. When considering the defect recorded for each tree, there are two important qualifiers to keep in mind. First, the categories are broadly inclusive. For example, the "Signs of Stress" category can include trees with smaller diameter dead limbs as well as trees observed with large-diameter dead limbs. Therefore, inferences on overall tree condition or risk rating cannot be derived solely from recording the presence or absence of a defect during the inventory and should be a factor in the outcome of an assessed condition rating. Second, an inventoried tree may have multiple defects; the 2020 Big Rapids inventory recorded only the most significant defect observed for each tree. These two qualifiers are important to keep in mind when considering urban forest management planning and the prioritization of maintenance or monitoring activities. Defect recordings were limited to the following categories:

- Cavity Decay
- Grate Guard
- Improperly Installed
- Improperly Mulched
- Improperly Pruned
- Mechanical Damage
- Pest Problem
- Poor Location
- Poor Root System
- Poor Structure
- Serious Decline
- Signs of Stress
- None

Table 1. Tree defect categories recorded during the inventory.

Defects	Street Trees	Percent of Street Trees	Park Trees	Percent of Park Trees
Cavity Decay	319	10%	6	1%
Grate Guard	25	1%	0	0%
Improperly Installed	3	0%	0	0%
Improperly Mulched	8	0%	0	0%
Improperly Pruned	12	0%	0	0%
Mechanical Damage	60	2%	8	2%
Pest Problem	6	0%	0	0%
Poor Location	27	1%	10	2%
Poor Root System	87	3%	0	0%
Poor Structure	1,422	44%	162	30%
Serious Decline	96	3%	12	2%
Signs of Stress	758	23%	150	28%
None	414	13%	185	35%
Total	**3,237**	**100%**	**533**	**100%**

The most frequently recorded defect category was Poor Structure, which includes almost half of the ROW population and slightly less than a third of the parks population. Signs of Stress was the only defect category with similar proportions, which includes about a quarter of both the ROW population and the parks population. While about a third of inventoried park trees did not have any observed defects, only 13% of ROW trees did not. 10% of ROW trees had observed Cavity Decay, while only 1% of inventoried park trees did. All other defect observations were less than 5% of their respective population.

Defect Observation Recommendations

The large proportion of trees in both the ROW population and the parks population with recorded Poor Structure, Signs of Stress, and Cavity Decay emphasizes the importance of a routine pruning cycle, which can address these defects before they deteriorate enough to reduce a tree's condition or become a hazard. These particular defect observations, factored in with condition rating and size class, affect the level of priority determined for the maintenance schedule in Section 3.

INFRASTRUCTURE CONFLICTS

In an urban setting, space is limited both above and below ground. Trees in this environment may conflict with infrastructure, such as buildings, sidewalks, utility wires, and pipes, which could pose risks to people and property. Existing or possible conflicts between trees and infrastructure recorded during the inventory include:

- *Overhead Utilities*—The presence of overhead utility lines above a site was noted; it is important to consider these data when planning pruning activities and selecting tree species for planting.

Table 2. Tree conflicts with overhead infrastructure recorded during the inventory.

Overhead Utilities	Street Trees	Percent of Street Trees	Park Trees	Percent of Park Trees
Present and Conflicting	294	9%	0	0%
Present and Not Conflicting	410	13%	35	7%
Not Present	2,533	78%	498	93%
Total	**3,237**	**100%**	**533**	**100%**

Table 2 shows 294 ROW trees with overhead utilities conflicting with their canopy. Of those trees, 18 (6%) are medium-growing species and 276 (94%) are large-growing species. There are 410 ROW trees with overhead utilities that are not conflicting with their canopy. Of those trees, 56 (13%) are small-growing species, 52 (13%) are medium-growing species, and 302 (74%) are large-growing species.

There are 0 parks trees with overhead utilities conflicting with their canopy, although there are 35 parks trees with overhead utilities that are not conflicting with their canopy. Of those trees, 2 (6%) are small-growing species, 1 (3%) is a medium-growing species, and 32 (91%) are large-growing species.

Infrastructure Recommendations

Planting only small-growing species within 20 feet of overhead utilities, medium-growing species within 20–40 feet, and large-growing trees outside 40 feet will help improve future tree conditions, minimize future utility line conflicts, and reduce the costs of maintaining trees under utility lines.

Section 2:

Functions and Benefits

of the Public Tree Resource

SECTION 2: FUNCTIONS AND BENEFITS OF THE PUBLIC TREE RESOURCE

Trees occupy a vital role in the urban environment by providing of a wide array of economic, environmental, social, and health benefits far exceeding the investments in planting, maintaining, and removing them. Trees sequester and store carbon, reduce stormwater runoff, reduce energy use, reduce air pollution, and increase property value. Using advanced analytics, such as the i-Tree software suite, understanding the importance of trees in a community continues to expand by providing tools to estimate monetary values of the various benefits provided by trees.

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 a 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).

TREE BENEFIT ANALYSIS

TreeKeeper® calculates the ecosystem benefits of individual trees, groups of trees, or an entire urban forest using inventory data. TreeKeeper® ecosystem benefits value is based on the science of i-Tree Streets. i-Tree Streets, a component of i-Tree Tools, analyzes an inventoried tree population's structure to estimate the benefits of that tree population. See Appendix C for details about DRG's tree benefit methodology. These quantified benefits 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.
- *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 kilowatt-hours ([kWh]).
- *Carbon Sequestered and Avoided:* Presents annual reductions in atmospheric CO_2 due to sequestration by trees and reduced emissions from power plants due to reductions in energy use measured pounds. 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 [NO2], 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 calculated.

ANNUAL RETURN ON INVESTMENT FROM THE PUBLIC TREE RESOURCE

TreeKeeper® estimated the value of functional benefits provided by the City of Big Rapids' public tree resource using unit prices of carbon dioxide (CO_2) in pounds (lbs.), avoided runoff in gallons, reduced energy use in kilowatt-hours (kWh) and therms, air pollutants removed in lbs., and increased property value from leaf surface area (LSA). As shown in Figures 14 and 15, the estimated value of annual benefits provided by the ROW population is $395,123, and the estimated value of annual benefits provided by the parks population is $42,614, bringing the total value of Big Rapids' annual benefits from its public tree resource to $437,737. The city uses about 25% of the General Funds appropriated to Park Facilities for urban forestry activities, which was approximately $118,875 in its FY2020 budget. The estimated return on investment of Big Rapids' urban forestry program is 2%, with continued investment benefitting the city's community, economy, and environment.

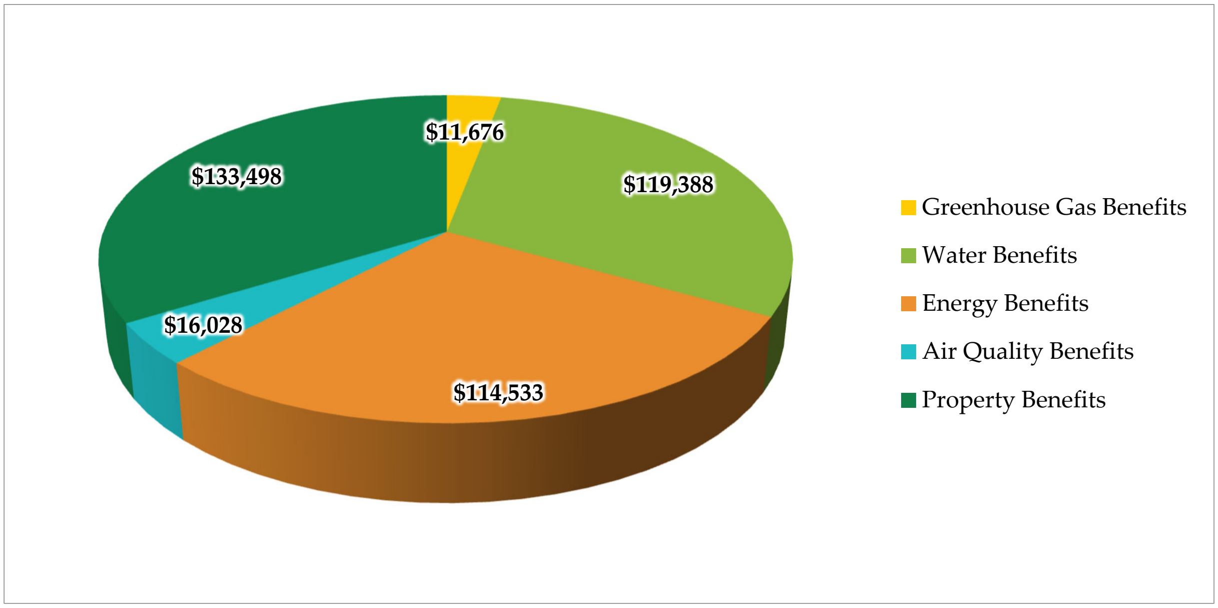


Figure 14. Estimated annual value of functional benefits from trees in the ROW.

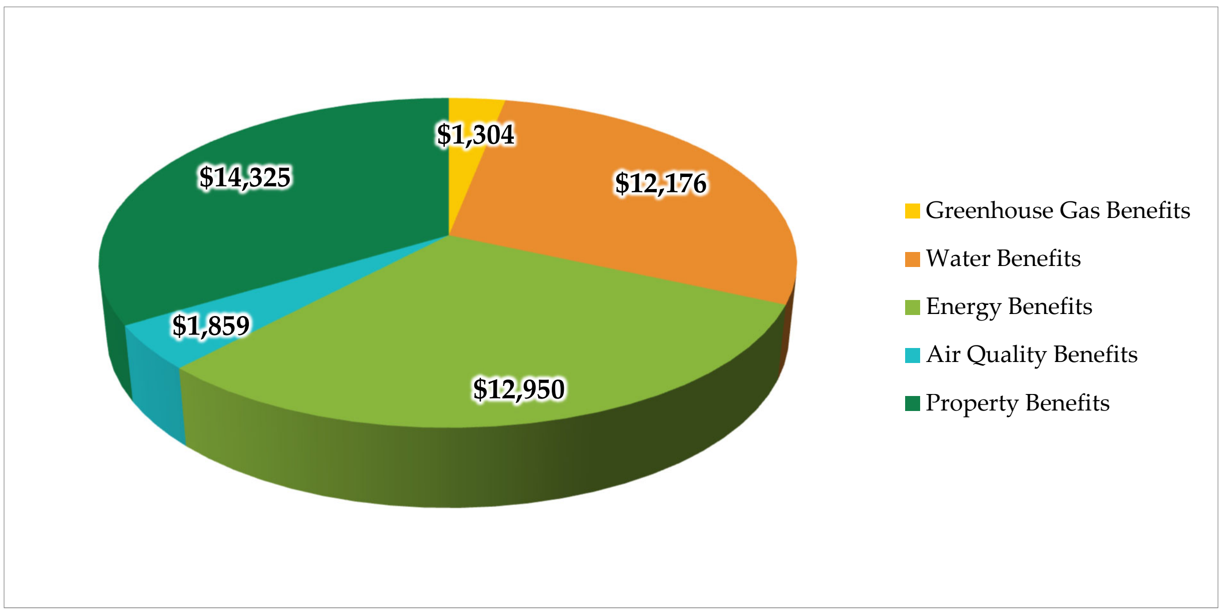


Figure 15. Estimated annual value of functional benefits from trees in parks.

Quantifying monetary values of the many benefits provided by the public tree resource makes the possibility of significant losses from new invasive pests more tangible, because another outbreak the magnitude of Dutch elm disease or emerald ash borer would have costs greater than clean-up. It is critical to promote a diverse species distribution with future plantings so susceptibility to potential threats is minimized, and to plant large-sized tree species wherever growth space allows. It is important to remember that trees provide most of their benefits after they have matured, and that they are an investment of time along with money, so tree care to preserve their health is essential. See Appendix D for a tree species list recommended by DRG.

SEQUESTERING AND STORING CARBON

Trees are carbon sinks, which are the opposite of carbon sources. While heavy amounts of carbon are emitted from cars and smokestacks, carbon is absorbed into trees during photosynthesis and stored in their tissue as they grow. CO_2 impacts people, infrastructure, and the environment by being the primary greenhouse gas driving climate change. The i-Tree Streets model estimates both the total carbon sequestered and the total carbon stored each year based on simulated growth rates for each species. The 710,121 lbs. of CO_2 avoided annually and the 914,080 lbs. sequestered annually by the ROW population, along with the 84,466 lbs. of CO_2 avoided annually and 96,641 lbs. sequestered annually by the parks population, has an estimated total value of $12,980.

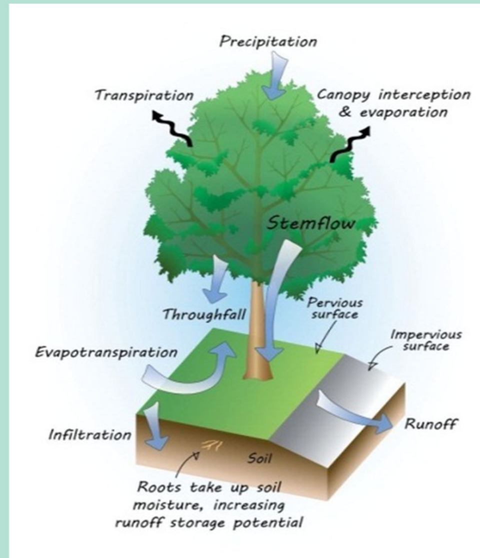
CONTROLLING STORMWATER

Trees intercept rainfall with their leaves and branches, helping lower stormwater management costs by avoiding runoff. Avoiding stormwater runoff reduces the risk of flooding and combined sewer overflow, both of which impact people, infrastructure, and the environment. The 4,405,473 gals. of runoff avoided annually with the city's ROW trees and the 449,306 gals. avoided annually with its parks trees has a total estimated value of $131,564.

IMPROVING AIR QUALITY

Compared to rural landscapes, urban landscapes are characterized by high emissions in a relatively small area, such as sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), and particulate matter (PM_{10}). The 5,011 lbs. of airborne pollutants annually removed by Big Rapids' ROW population and the 590 lbs. annually removed by its parks population has a total estimated value of $17,887.

CANOPY FUNCTIONS



Trees provide many functions and benefits all at once simply by existing, such as:

- Catching rainfall in the canopy so it drips to the ground with less of an impact or flows down their trunk into the soil.
- Helping stormwater soak into the ground by slowing runoff.
- Helping stormwater move through the soil by creating more pore space with their roots.
- Cooling the surrounding landscape by casting shade with their canopy and releasing water from their leaves.
- Catching airborne pollutants on their leaves and holding them until they wash off in the rain.

ENERGY REDUCTION AND PROPERTY VALUE

The public tree resource reduces energy use in buildings, with ROW trees annually saving 544,414 kWh and 74,706 therms while parks trees annually save 60,656 kWh and 8,516 therms, having a total estimated value of $127,483. The parcels occupied by those buildings also have higher property values from trees, which increases with square footage of the total LSA grown in a single year. The ROW population has estimated annual LSA growth of 551,832 ft^2 and the parks population has estimated annual LSA growth of 59,216 ft^2, which has a total estimated value of $147,822.

Section 3:

Recommended Management

of the Public Tree Resource

SECTION 3: RECOMMENDED MANAGEMENT OF THE PUBLIC TREE RESOURCE

During the inventory, a condition rating and recommended maintenance activity were assigned to each tree. DRG factored both of these into assigning a priority rating to each tree, which are the basis for prioritizing maintenance activities. The proposed five-year tree resource maintenance schedule takes a proactive approach to tree resource management.

High Priority
- All High Priority tree removals and pruning should be completed as soon as possible, because these trees have significant defects that will become severe over time.

Moderate Priority
- Moderate Priority tree removals and pruning should only start after most High Priority tree maintenance has been completed, and be performed concurrently.

Low Priority
- Low Priority tree maintenance should be performed after all High and Moderate Priority maintenance has been completed.

Stump Removal
- Stump removals should be performed either when a tree is removed or before a planting season begins, so planting sites become vacant for replacement trees.

Routine Inspection
- Routine Inspection from a drive-by perspective is important for detecting major defects before they worsen, and a walk-by perspective is important for updating inventory data.

Young Tree Training
- Young Tree Training Cycles improve tree structure so defects do not worsen and become more costly to correct as they grow, and should begin as soon as possible.

Routine Pruning
- Routine Pruning Cycles correct defects before they worsen, which is crucial for maintaining the overall condition of the inventoried tree resource over the long-term.

Replace Trees
- Removed trees should be replaced so there is no net loss of the tree resource, which should enter the Young Tree Training Cycle immediately.

Tree Planting
- Planting new trees is important for increasing population size and urban canopy, but can wait until higher priority maintenance is complete or at least in progress.

PRIORITIZATION OF RECOMMENDED MAINTENANCE

The following sections briefly summarize the recommended maintenance identified during the inventory, and gives priority ratings based on condition rating, defect observation, size, and best management practices. Even though large short-term expenditures may be required, it is important to secure the funding needed to complete high priority tree maintenance as soon as possible, which promotes public safety and reduces long-term costs.

HIGH PRIORITY RECOMMENDED MAINTENANCE

Although tree removal is usually considered a last resort and may sometimes cause a negative public reaction, there are circumstances where it is necessary. Trees fail from natural causes such as diseases, insects, and weather conditions, as well as from physical injury due to vehicles, vandalism, and root disturbances. DRG recommends that trees be removed when corrective pruning will not adequately mitigate risk or when correcting problems would be cost-prohibitive. Pruning defected branch(es) maintains tree condition by preventing defects from deteriorating until correcting them becomes cost-prohibitive, thereby decreasing the number of trees that need to be removed and reducing management costs over time.

High Priority Removal Recommendations

DRG recommends high priority removals to be completed as soon as possible. Performing maintenance activities for the largest diameter trees (greater than 20 inches) first is important because their failure is more likely to cause damage than smaller diameter trees (less than 20 inches). Shown in Figure 16, the inventory identified a total of 170 high priority removals in the ROW, comprising 53% of ROW trees with a removal recommendation. These trees are either Dead or are rated in Poor condition with Cavity Decay. The diameter size classes range between 1–5 inches DBH and greater than 35 inches DBH, with most trees greater than 20 inches DBH. Ideally, after removing all high-priority ROW trees greater than 20 inches DBH in Year 1 of the proposed five-year tree resource maintenance schedule, all high-priority removals smaller than 20 inches DBH should be completed in Year 2.

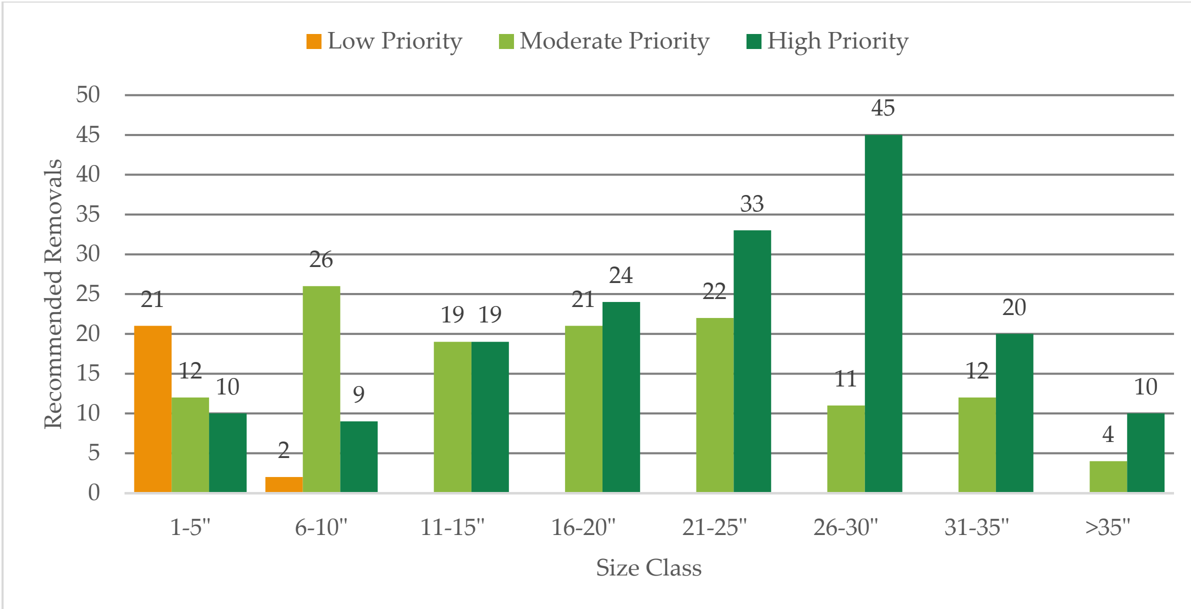


Figure 16. Recommended removals in ROW by size class and priority rating.

Shown in Figure 17, the inventory identified a total of 15 high priority removals in parks, comprising 63% of parks trees with a removal recommendation. These trees are either Dead or rated in Poor condition with Serious Decline. The diameter size classes range between 1–5 inches DBH and 26–30 inches DBH, with most trees 10 inches DBH or less. Ideally, after removing high-priority parks trees larger than 10 inches DBH in Year 1 of the proposed five-year tree resource maintenance schedule, all smaller high-priority removals in parks should be completed in Year 2.

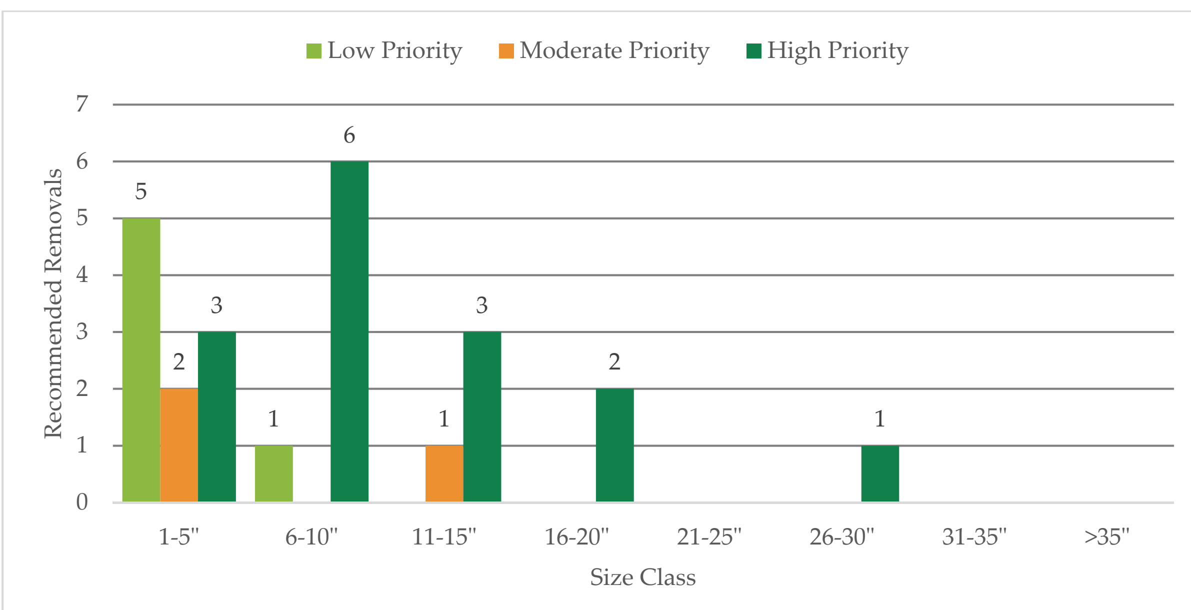


Figure 17. Recommended removals in parks by size class and priority rating.

High Priority Pruning Recommendations

DRG recommends high priority pruning to be completed as soon as possible, ideally in Year 1 of the proposed five-year tree resource maintenance schedule. These trees are either rated in Poor condition, rated in Fair condition with Serious Decline, were observed with Cavity Decay, or were observed with Poor Structure. Performing maintenance activities for the largest diameter trees (greater than 20 inches) first is important because their failure is more likely to cause damage than smaller diameter trees (less than 20 inches). Shown in Figure 18, the inventory identified a total of 313 high priority trees in the ROW, comprising 49% of all ROW trees with a pruning recommendation. The diameter size classes range between 6–10 inches DBH and greater than 35 inches DBH, with most trees larger than 15 inches DBH. Ideally, after pruning all high priority ROW trees greater than 20 inches DBH in Year 1 of the five-year tree resource maintenance schedule, all high priority trees in the ROW less than 20 inches DBH should be pruned in Year 2.

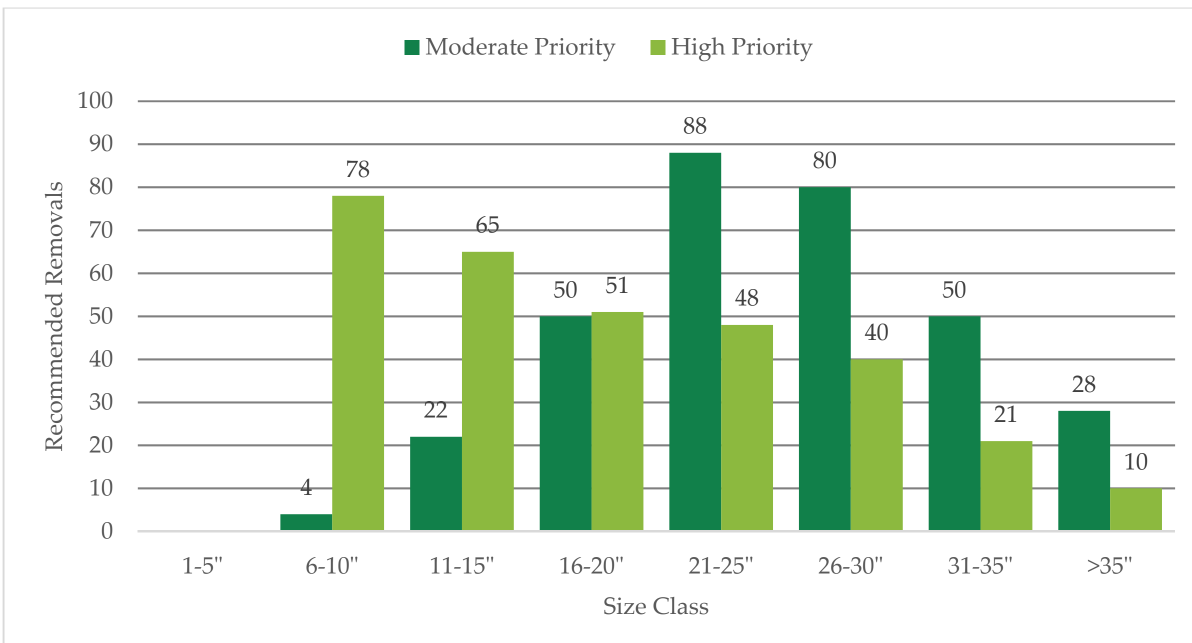


Figure 18. Recommended pruning in ROW by size class and priority rating.

Shown in Figure 19, the inventory identified a total of 6 high priority trees in parks, comprising 10% of all parks trees with a pruning recommendation. The diameter size classes range between 11–15 inches DBH and 31–35 inches DBH, with most trees larger than 20 inches DBH. Ideally, after pruning all high priority parks trees greater than 20 inches DBH in Year 1 of the five-year tree resource maintenance schedule, all high priority trees in parks less than 20 inches DBH should be pruned in Year 2.

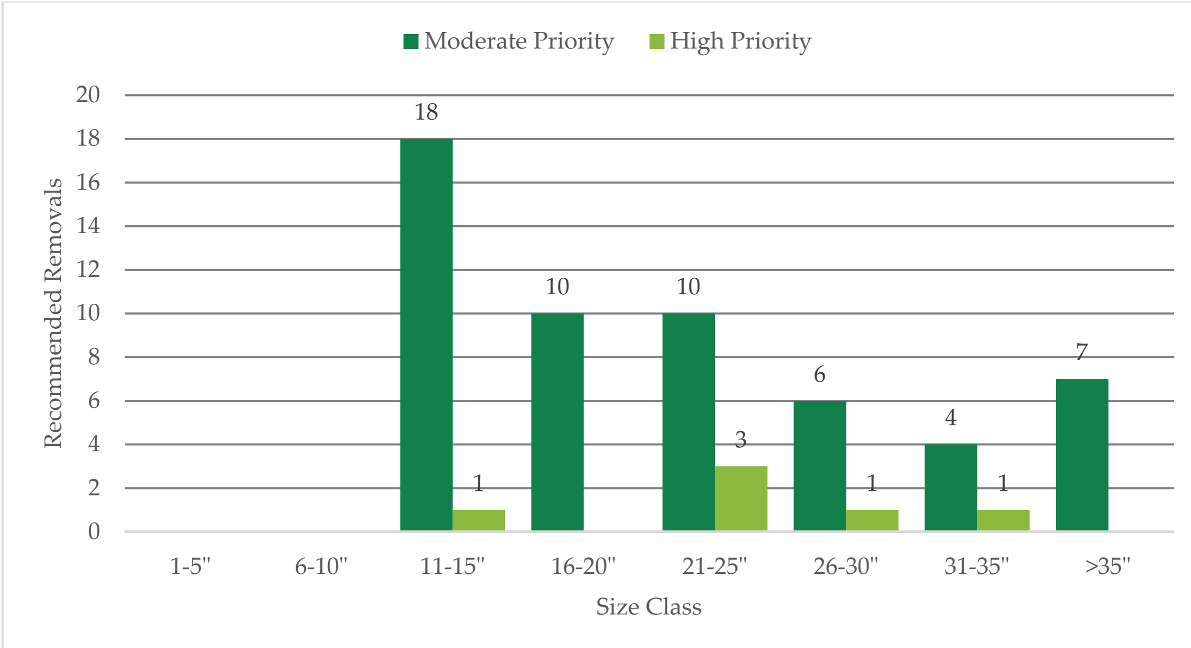


Figure 19. Recommended pruning in parks by size class and priority rating.

MODERATE PRIORITY RECOMMENDED MAINTENANCE

Moderate Priority Removal Recommendations

Shown in Figure 16, the inventory identified a total of 127 moderate priority removals in the ROW, comprising 40% of all ROW trees with a removal recommendation. These trees are rated in Poor condition with any defect other than Cavity Decay. The diameter size classes range between 1–5 inches DBH and greater than 35 inches DBH, with most trees less than 11 inches DBH. In Year 2 of the five-year tree resource maintenance schedule, moderate priority removals in the ROW above 20 inches DBH should coincide with high priority removals less than 20 inches DBH. Ideally, after removing all moderate priority ROW trees greater than 20 inches DBH, all moderate priority removals less than 20 inches DBH should be completed in Year 3.

Shown in Figure 17, the inventory identified a total of 3 moderate priority removals in parks, comprising 13% of all parks trees with a removal recommendation. These trees are rated in Poor condition with any defect other than Serious Decline or Cavity Decay. The diameter size classes range between 1-5 inches DBH and 11-15 inches DBH, with most trees less than 6 inches DBH. Ideally, after removing all moderate priority ROW trees greater than 20 inches DBH, all moderate priority removals in parks should be completed in Year 3.

Moderate Priority Pruning Recommendations

Shown in Figure 18, the inventory identified a total of 322 moderate priority trees in the ROW, comprising 51% of all ROW trees with a pruning recommendation. These trees are rated in Fair condition with any defects other than Serious Decline, Cavity Decay, or Poor Structure or were observed with Signs of Stress. The diameter size classes range between 6–10 inches DBH and greater than 35 inches DBH, with most trees above 20 inches DBH. Performing maintenance activities for the largest diameter trees (greater than 20 inches) first is important because their failure is more likely to cause damage than smaller diameter trees (less than 20 inches). Moderate priority pruning in the ROW should be performed alongside high priority pruning, ideally completing both in Year 1 and Year 2 of the five-year tree resource maintenance schedule.

Shown in Figure 19, the inventory identified a total of 55 moderate priority trees in parks, comprising 90% of all parks trees with a pruning recommendation. These trees are rated in Fair condition with any defects other than Serious Decline, Cavity Decay, or Poor Structure or were observed with Signs of Stress. The diameter size classes range between 6–10 inches DBH and greater than 35 inches DBH, with most trees above 15 inches DBH. Performing maintenance activities for the largest diameter trees (greater than 20 inches) first is important because their failure is more likely to cause damage than smaller diameter trees (less than 20 inches). Moderate priority pruning in the ROW should be performed alongside high priority pruning, ideally completing both in Year 1 and Year 2 of the five-year tree resource maintenance schedule.

LOW PRIORITY RECOMMENDED MAINTENANCE

Low priority removals should only start after all high priority and moderate priority maintenance has been completed. Instead of being addressed separately, all low priority pruning is included in the Routine Pruning Cycle.

Low Priority Removal Recommendations

Shown in Figure 16, the inventory identified a total of 23 low priority removals in the ROW, comprising 7% of all row trees with a removal recommendation. Shown in Figure 17, the inventory also identified a total of 6 low priority removals in parks, comprising 25% of all parks trees with a removal recommendation. These trees are all rated in Fair or Good condition and are all below 11 inches DBH. Ideally, all low priority removals should be completed in Year 4 of the five-year tree resource maintenance schedule.

ROUTINE 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. Ideally, the arborist will be ISA Certified and also hold the ISA Tree Risk Assessment Qualification credential.

Routine Inspection Recommendations

All inventoried trees should be regularly inspected and attended to as needed. DRG recommends that Big Rapids annually inspect 3,825 trees, or 80% of the inventoried tree resource, via drive-by assessment in line with *ANSI A300 (Part 9)* to identify major defects or signs and symptoms of pests/disease. The City of Big Rapids has a large population of trees that are susceptible to pests and diseases, specifically maple, cherry, and pear trees.

Annually inspecting 765 trees, or 20% of the inventoried tree resource, via walk-by assessment is important for completely updating inventory data on a five-year cycle. Utilize asset management software such as TreeKeeper® to make updates and keep a log of work records. When trees require additional or new work they should be added to the maintenance schedule immediately and the budget should be updated to reflect this additional work.

ROUTINE PRUNING CYCLE

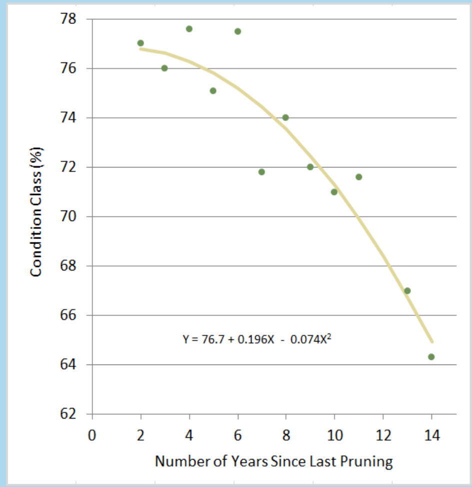
The Routine Pruning Cycle includes all trees that received a pruning maintenance recommendation and occurs after higher priority pruning is completed. Over time, routine pruning can minimize reactive maintenance, limit instances of elevated risk, and provide the basis for a proactive management program.

Based on Miller and Sylvester's research, DRG recommends a five-year Routine Pruning Cycle to maintain the condition of the inventoried tree resource. However, not all municipalities are able to remain proactive with a five-year cycle based on budgetary constraints, the size of the public tree resource, or both. In these cases, extending the length of the Routine Pruning Cycle is an option; however, it is in the municipality's best interest to implement a five-year cycle. Tree condition deteriorates significantly without regular pruning, because their once-minor defects have enough time to deteriorate, reducing tree health and potentially increasing risk (Miller and Sylvester 1981).

Routine Pruning Cycle Recommendations

As shown in Figure 20, Big Rapids has 2,510 trees recorded as Prune or Discretionary Prune, which is 66% of the inventoried tree resource that would benefit from routine pruning every five years. DRG recommends that the city implements a five-year cycle with 502 trees pruned each year, beginning in Year 3 of the five-year tree resource maintenance schedule. Figure 18 shows a distribution of all trees recommended for routine pruning by size class, most of which are smaller than 15 inches DBH.

PROACTIVE MAINTENANCE



Relationship between tree condition and years since previous pruning.

(adapted from Miller and Sylvester 1981)

Miller and Sylvester studied the pruning frequency of 40,000 street trees in Milwaukee, Wisconsin. Trees that had not been pruned for more than 10 years had an average condition rating 10% lower than trees that had been pruned in the previous several years. Their research suggests that a five-year pruning cycle is optimal for urban trees.

Routine inspection and pruning cycles help detect and correct most defects before they reach higher risk levels. DRG recommends two pruning cycles: a Young Tree Training Cycle and a Routine Pruning Cycle.

Newly planted trees will enter the Young Tree Training Cycle once they become established and will move into the Routine Pruning Cycle when they reach maturity. A tree should be eliminated from the Routine Pruning Cycle and removed when its condition warrants it or ages beyond its healthy lifespan.

Figure 20. Five-year Routine Pruning Cycle by size class.

YOUNG TREE TRAINING CYCLE

Trees included in the Young Tree Training Cycle are 6 inches DBH or less, which can be pruned from the ground with a pole saw, loppers, or shears. These younger trees often have branching structure that can lead to problems as they age. Potential structural problems include codominant leaders, multiple limbs attaching at the same point on the trunk, and crossing/interfering limbs. Trees growing in restricted areas can also have problems as they age when their scaffold branches are either growing too low or into conflict, such as trees with branches hanging over the road or sidewalk. If these defects are not corrected while a tree is small, they will become more difficult and costly to correct as the tree grows. The recommended length of this cycle is three years because young trees tend to grow at faster rates than mature trees do.

Young Tree Training Cycle Recommendations

DRG recommends that Big Rapids implement a three-year Young Tree Training Cycle beginning in Year 1 of the five-year tree resource maintenance schedule. As shown in Figure 21, 759 trees in the ROW and 157 trees in parks have a Train maintenance recommendation, amounting to a total of 305 trees each year of the cycle.

When trees are planted, they should enter the Young Tree Training Cycle within three years after planting. In future years, the number of trees in the Young Tree Training Cycle will be based on all new plantings and replacement plantings for removed trees. After trees have grown larger than 6 inches DBH or cannot be pruned from the ground, they should enter the Routine Pruning Cycle.

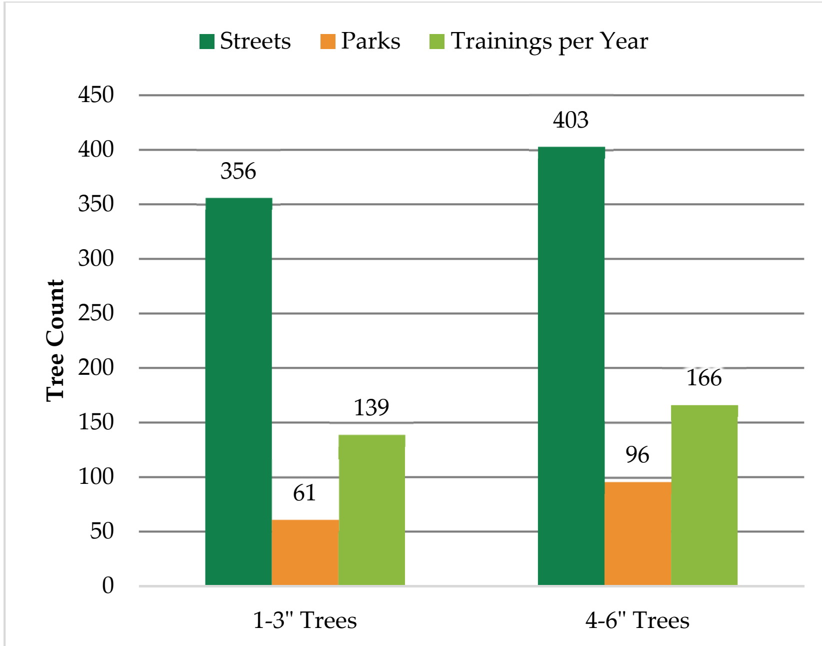


Figure 21. **Three-year Young Tree Training Cycle by size class.**

TREE PLANTING AND STUMP REMOVAL

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. 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 site to plant it in. 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 and hardscape as it grows taller, wider, and deeper. If the tree at maturity will reach overhead lines, or conflict with sidewalks and curbs, it is best to choose either a different species or a different location.

Tree Planting Recommendations

Over the course of the five-year tree resource maintenance schedule, a total of 320 trees in the ROW and 24 trees in parks are recommended for removal. Additionally, tree populations have a typical annual mortality rate ranging from 1–3% of the population. Given the inventoried population's overall condition rating of Fair, Big Rapids' tree resource is likely to be on the low end of this range. Using a 1% annual mortality rate of about 37 trees per year, the city should be prepared to remove an additional 185 trees over this five-year period. When accounting for scheduled removals and annual mortality, the city must plant 529 replacement trees over the next five years to have zero net loss of its tree population.

Big Rapids should also plant new trees in addition to replacement trees to increase its tree population and expand its urban canopy. DRG recommends planting 75 new trees each year, increasing the tree resource by 2% annually, in areas with sparse canopy and in areas with gaps in existing canopy. While Big Rapids as a whole receives value from the ecosystem services provided by the public tree resource, those benefits are usually unevenly distributed across the city based on where urban canopy is located.

Creating larger growing sites for trees in the ROW is among the most beneficial management practices to improve the survival rate of both newly planted and maturing trees. Increasing growth space can also reduce the amount of tree-related infrastructure conflicts, because trees can be planted further from hardscape and overhead utilities. Depending on the site, there are several methods available to create and/or increase growth space for newly planted trees:

- Install or enlarge tree wells/pits in existing sidewalks of sufficient width. Ideally, the minimum growing space of a small-sized tree is 32 square feet. On sidewalks with sufficient width and length, the city could install tree pits with enough space remaining for the sidewalk to still comply with American Disability Act (ADA) standards.
- Planting trees 4 feet behind a curb without a sidewalk, or 4 feet behind an existing sidewalk, can be a low-cost alternative to more construction intensive methods. This can result in less damage to the sidewalk and give tree roots room to grow into the open soil.
- Re-routing the sidewalk around an area to create designated large tree sites is a relatively cost-effective method to increase growing spaces. This method can also be applied to existing large tree sites, where tree roots have already come in conflict with the sidewalk.
- A landscape bump-out/curb extension is a vegetative area that protrudes into the parking lane of a street, to provide a growing space for plants or trees. These spaces can be used quite effectively by municipalities to beautify a streetscape, provide greater storm water retention, along with the added benefit of slowing car speeds at the bump-out location.

Stump Removal Recommendations

The inventory identified 55 stumps in all size classes; however, most are 15 inches diameter or smaller. The 344 trees recommended for removal and the 185 trees anticipated to be removed from natural mortality will leave behind an additional 584 stumps. Because these sites can be replanted once they become vacant, stump removals should occur as soon as possible after a tree removal, or at least before the next planting is planned.

A list of suggested tree species is provided in Appendix D. These tree species are specifically selected for the climate of Big Rapids. This list is not exhaustive but can be used as a guideline for species that meet community objectives and to enhance any existing list of approved species.

MAINTENANCE SCHEDULE AND BUDGET

Utilizing 2020 City of Big Rapids tree inventory data, an annual maintenance schedule was developed detailing the recommended tasks to complete each year. DRG made budget projections using industry knowledge and client feedback. A complete table of estimated costs for Big Rapids' five-year tree resource maintenance schedule follows.

This schedule provides a framework for completing the recommended inventoried tree maintenance over the next five years. Following this schedule can shift tree maintenance activities from being reactive maintenance to a more proactive tree care program.

To implement the tree resource maintenance schedule, Big Rapids' urban forestry budget should be $272,593 for Year 1 of implementation, which is the costliest year because of the high priority maintenance scheduled. Year 2 will be $32,450 less than Year 1, Year 3 will be $37,265 less than Year 2, Year 4 will be $2,250 less than Year 3, and Year 5 will be $1,950 less than Year 4. Budgets for following years will stabilize at near $153,678, because as of Year 4 all reactive maintenance will be complete, and proactive maintenance is routine and less costly.

Adequate annual funding is needed to ensure that high priority trees are expediently managed and that the Young Tree Training Cycle and Routine Pruning Cycle can begin. If routing efficiencies and/or contract specifications allow more tree work to be completed each year, or if this maintenance schedule requires adjustment to meet budgetary or other needs, then it should be modified accordingly. Unforeseen situations such as severe weather events may arise and change the maintenance needs of the inventoried tree population. If maintenance needs change, then budgets, staffing, and equipment should be adjusted to meet the new demand.

Table 3. Estimated budget for proposed five-year tree resource maintenance schedule.

Activity Cost			Year 1		Year 2		Year 3		Year 4		Year 5		Five-Year Cost
Activity	Diameter	Cost/Tree	Count	Cost	Count	Cost	Count	Cost	Count	Cost	Count	Cost	
High Priority Removals	1-5"	$50	13	$650	-	-	-	-	-	-	-	-	$650
	6-10"	$50	15	$750	-	-	-	-	-	-	-	-	$750
	11-15"	$100	22	$2,200	-	-	-	-	-	-	-	-	$2,200
	16-20"	$150	26	$3,900	-	-	-	-	-	-	-	-	$3,900
	21-25"	$250	33	$8,250	-	-	-	-	-	-	-	-	$8,250
	26-30"	$250	46	$11,500	-	-	-	-	-	-	-	-	$11,500
	31-35"	$250	20	$5,000	-	-	-	-	-	-	-	-	$5,000
	>35"	$250	10	$2,500	-	-	-	-	-	-	-	-	$2,500
Activity Total(s)			**185**	**$34,750**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**$34,750**
Moderate Priority Removals	1-5"	$50	-	-	14	$700	-	-	-	-	-	-	$700
	6-10"	$50	-	-	26	$1,300	-	-	-	-	-	-	$1,300
	11-15"	$100	-	-	20	$2,000	-	-	-	-	-	-	$2,000
	16-20"	$150	-	-	21	$3,150	-	-	-	-	-	-	$3,150
	21-25"	$250	-	-	22	$5,500	-	-	-	-	-	-	$5,500
	26-30"	$250	-	-	11	$2,750	-	-	-	-	-	-	$2,750
	31-35"	$250	-	-	12	$3,000	-	-	-	-	-	-	$3,000
	>35"	$250	-	-	4	$1,000	-	-	-	-	-	-	$1,000
Activity Total(s)			**0**	**$0**	**130**	**$19,400**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**$19,400**
Low Priority Removals	1-5"	$50	-	-	-	-	26	$1,300	-	-	-	-	$1,300
	6-10"	$50	-	-	-	-	3	$150	-	-	-	-	$150
	11-15"	$100	-	-	-	-	-	-	-	-	-	-	$0
	16-20"	$150	-	-	-	-	-	-	-	-	-	-	$0
	21-25"	$250	-	-	-	-	-	-	-	-	-	-	$0
	26-30"	$250	-	-	-	-	-	-	-	-	-	-	$0
	31-35"	$250	-	-	-	-	-	-	-	-	-	-	$0
	>35"	$250	-	-	-	-	-	-	-	-	-	-	$0
Activity Total(s)			**0**	**$0**	**0**	**$0**	**29**	**$1,450**	**0**	**$0**	**0**	**$0**	**$1,450**

Activity Cost			Year 1		Year 2		Year 3		Year 4		Year 5		Five-Year Cost
Activity	Diameter	Cost/Tree	Count	Cost	Count	Cost	Count	Cost	Count	Cost	Count	Cost	
Stump Removals	1-5"	$50	13	$650	14	$700	26	$1,300	3	$150	-	-	$2,800
	6-10"	$50	15	$750	26	$1,300	3	$150	13	$650	-	-	$2,850
	11-15"	$50	22	$1,100	20	$1,000	-	-	18	$900	-	-	$3,000
	16-20"	$50	26	$1,300	21	$1,050	-	-	5	$250	-	-	$2,600
	21-25"	$75	33	$2,475	22	$1,650	9	$675	-	-	-	-	$4,800
	26-30"	$75	46	$3,450	11	$825	4	$300	-	-	-	-	$4,575
	31-35"	$100	20	$2,000	12	$1,200	2	$200	-	-	-	-	$3,400
	>35"	$125	10	$1,250	4	$500	1	$125	-	-	-	-	$1,875
Activity Total(s)			**185**	**$12,975**	**130**	**$8,225**	**45**	**$2,750**	**39**	**$1,950**	**0**	**$0**	**$25,900**
High and Moderate Priority Pruning	1-5"	$50	-	-	-	-	-	-	-	-	-	-	$0
	6-10"	$100	78	$7,800	4	$400	-	-	-	-	-	-	$8,200
	11-15"	$150	66	$9,900	40	$6,000	-	-	-	-	-	-	$15,900
	16-20"	$150	51	$7,650	60	$9,000	-	-	-	-	-	-	$16,650
	21-25"	$150	51	$7,650	98	$14,700	-	-	-	-	-	-	$22,350
	26-30"	$150	41	$6,150	86	$12,900	-	-	-	-	-	-	$19,050
	31-35"	$150	22	$3,300	54	$8,100	-	-	-	-	-	-	$11,400
	>35"	$150	10	$1,500	35	$5,250	-	-	-	-	-	-	$6,750
Activity Total(s)			**319**	**$43,950**	**377**	**$56,350**	**0**	**$0**	**0**	**$0**	**0**	**$0**	**$100,300**
Routine Inspection	Drive-by Assessment	$1	3,060	$3,060	3,060	$3,060	3,060	$3,060	3,060	$3,060	3,060	$3,060	$15,300
	Walk-by Assessment	$5	765	$765	765	$765	765	$765	765	$765	765	$765	$19,125
Activity Total(s)			**3,825**	**$6,885**	**3,825**	**$6,885**	**3,825**	**$6,885**	**3,825**	**$6,885**	**3,825**	**$6,885**	**$34,425**
Young Tree Training (3-year Cycle)	1-3"	$50	139	$6,950	139	$6,950	139	$6,950	139	$6,950	139	$6,950	$34,750
	4-6"	$100	166	$16,633	166	$16,633	166	$16,633	166	$16,633	166	$16,633	$83,167
Activity Total(s)			**305**	**$23,583**	**305**	**$23,583**	**305**	**$23,583**	**305**	**$23,583**	**305**	**$23,583**	**$117,917**

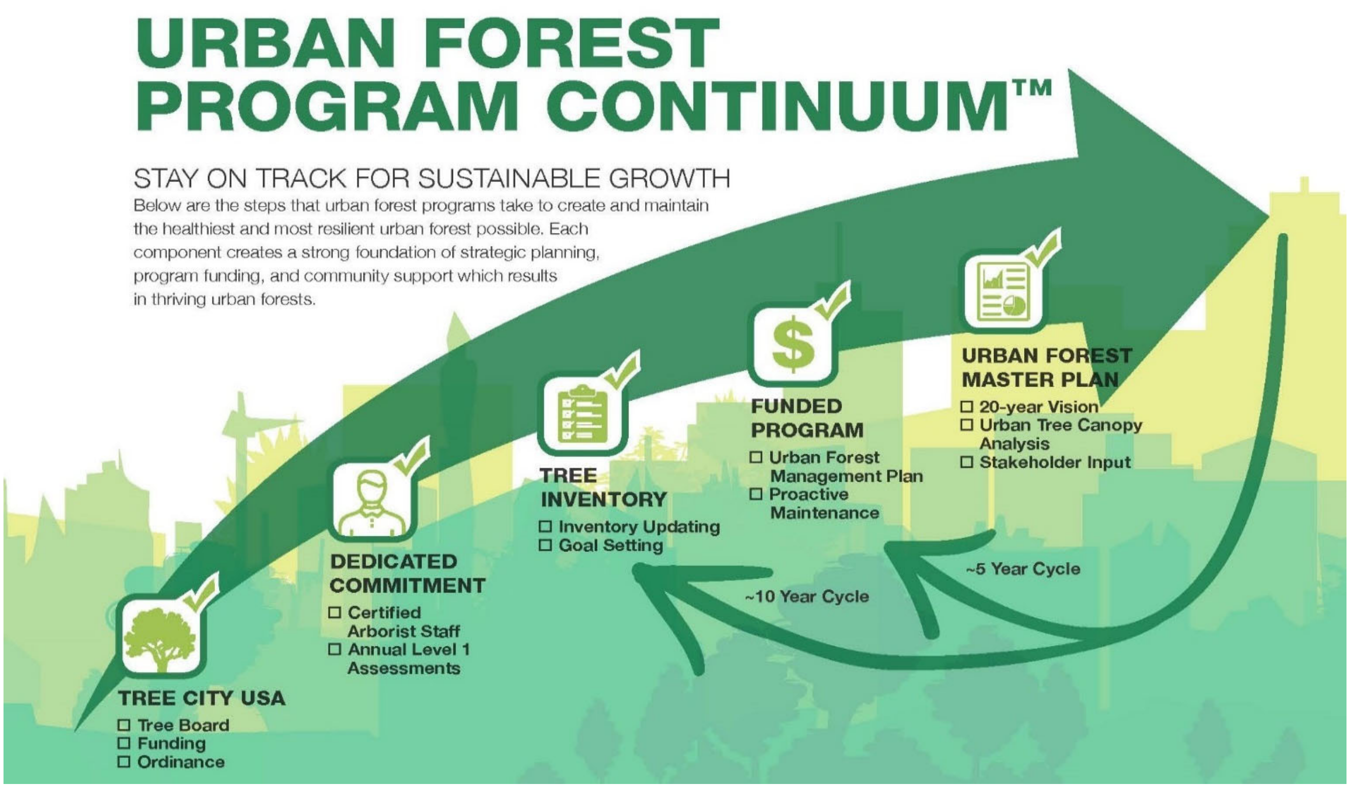
Activity Cost			Year 1		Year 2		Year 3		Year 4		Year 5		Five-Year Cost
Activity	Diameter	Cost/Tree	Count	Cost	Count	Cost	Count	Cost	Count	Cost	Count	Cost	
Routine Pruning (5-year Cycle)	1-5"	$50	-	-	-	-	14	$680	14	$680	14	$680	$2,040
	6-10"	$100	-	-	-	-	134	$13,360	134	$13,360	134	$13,360	$40,080
	11-15"	$150	-	-	-	-	114	$17,130	114	$17,130	114	$17,130	$51,390
	16-20"	$150	-	-	-	-	85	$12,810	85	$12,810	85	$12,810	$38,430
	21-25"	$150	-	-	-	-	73	$10,980	73	$10,980	73	$10,980	$32,940
	26-30"	$150	-	-	-	-	46	$6,900	46	$6,900	46	$6,900	$20,700
	31-35"	$150	-	-	-	-	23	$3,510	23	$3,510	23	$3,510	$10,530
	>35"	$150	-	-	-	-	13	$1,890	13	$1,890	13	$1,890	$5,670
Activity Total(s)			**0**	**$0**	**0**	**$0**	**502**	**$67,260**	**502**	**$67,260**	**502**	**$67,260**	**$201,780**
Replacement Tree Planting and Maintenance	Purchasing	$125	185	$23,125	130	$16,250	45	$3,625	39	$4,875	-	-	$49,875
	Planting	$125	185	$23,125	130	$16,250	45	$3,625	39	$4,875	-	-	$49,875
	Mulching	$100	185	$18,500	130	$13,000	45	$2,900	39	$3,900	-	-	$39,900
	Watering	$100	185	$18,500	130	$13,000	45	$2,900	39	$3,900	-	-	$39,900
Activity Total(s)			**740**	**$83,250**	**520**	**$58,500**	**180**	**$13,050**	**156**	**$17,550**	**0**	**$0**	**$179,550**
New Tree Planting and Maintenance	Purchasing	$125	0	$0	0	$0	30	$3,750	36	$4,500	75	$9,375	$17,625
	Planting	$125	0	$0	0	$0	30	$3,750	36	$4,500	75	$9,375	$17,625
	Mulching	$100	0	$0	0	$0	30	$3,000	36	$3,600	75	$7,500	$14,100
	Watering	$100	0	$0	0	$0	30	$3,000	36	$3,600	75	$7,500	$14,100
Activity Total(s)			**0**	**$0**	**0**	**$0**	**120**	**$13,500**	**144**	**$16,200**	**300**	**$33,750**	**$168,750**
Natural Mortality (1%)	Tree Removal	$100	37	$3,700	37	$3,700	37	$3,700	37	$3,700	37	$3,700	$18,500
	Stump Removal	$50	37	$1,850	37	$1,850	37	$1,850	37	$1,850	37	$1,850	$9,250
	Replacement Tree	$450	37	$16,650	37	$16,650	37	$16,650	37	$16,650	37	$16,650	$83,250
Activity Total(s)			**111**	**$22,200**	**111**	**$22,200**	**111**	**$22,200**	**111**	**$22,200**	**111**	**$22,200**	**$111,000**
Activity Grand Total			**5,670**		**5,398**		**5,117**		**5,082**		**5,043**		**26,312**
Cost Grand Total				**$227,593**		**$195,143**		**$157,878**		**$155,628**		**$152,678**	**$888,622**

CONCLUSION

When properly maintained, the valuable benefits trees provide over their lifetime far exceeds the time and money invested in planting, maintaining, and inevitably removing them. The 3,825 public trees inventoried provide annual benefits with a total estimated value of $437,737 and Big Rapids spends about $118,875 on urban forestry activities per year. The estimated return on investment of the City's urban forestry program is 268%, and successfully implementing the five-year tree resource maintenance schedule may increase Big Rapids' ROI over time, or at least maintain it.

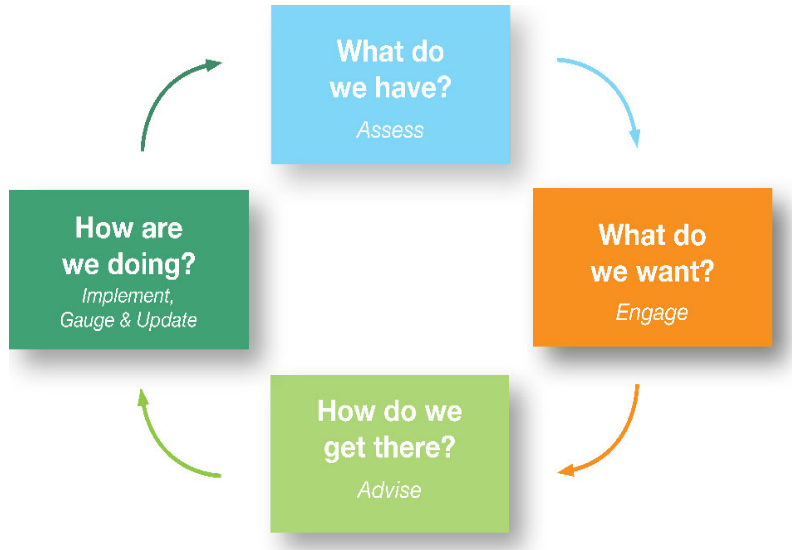
The proposed maintenance schedule is ambitious and is a challenge to complete in five years, but it becomes easier after all high priority tree maintenance is completed. This *Tree Management Plan* could potentially help the City advocate for an increased urban forestry budget to fund the recommended maintenance activities. Year 1 is the most difficult because of the higher cost, which represents the transition from reactive maintenance to proactive maintenance, yet this significant investment early on can reduce tree maintenance costs over time.

As the urban forest grows, the benefits enjoyed by the City of Big Rapids and its residents will increase as well. Inventoried trees are only a fraction of the total trees in Big Rapids when including private property, which is why it is important to also incentivize private landowners to care for their trees and to plant new ones. The City's urban forestry program is well on its way to creating a sustainable and resilient public tree resource, and can stay on track by setting goals and updating inventory data to check progress.



EVALUATING AND UPDATING THIS PLAN

This *Tree Management Plan* provides maintenance priorities for the next five years, and it is important to update the tree inventory using TreeKeeper® as work is completed, so the software can provide updated species distribution and benefit estimates. This empowers Big Rapids to self-assess the City's progress over time and set goals to strive toward by following the adaptive management cycle. Below are some ways of implementing the steps of this cycle:



- Prepare planting plans well enough in advance to schedule and complete stump removal in the designated area, and to select species best suited to the available sites.
- Annually comparing the number of trees planted to the number of trees removed and the number of vacant planting sites remaining, then adjusting future planting plans accordingly.
- Annually comparing the species distribution of the inventoried tree resource with the previous year after completing planting plans to monitor recommended changes in abundance.
- Schedule and assign high-priority tree work so it can be completed as soon as possible instead of reactively addressing new lower priority work requests as they are received.
- Include data collection such as measuring DBH and assessing condition into standard procedure for tree work and routine inspections, so changes over time can be monitored.

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APPENDIX A
DATA COLLECTION AND SITE LOCATION METHODS

DATA COLLECTION METHODS

DRG collects tree inventory data using their proprietary GIS software, called Rover, loaded onto pen-based field computers. At each site, the following data fields were collected:

- Address
- Comments
- Condition
- Date of Inventory
- Maintenance Recommendation
- Multi-stem Tree
- Notes
- Relative Location
- Size*
- Species and Identification Confidence Level
- Utility Interference
- X and Y Coordinates

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

The knowledge, experience, and professional judgment of DRG's arborists ensure the high quality of inventory data.

SITE LOCATION METHODS

Equipment and Base Maps

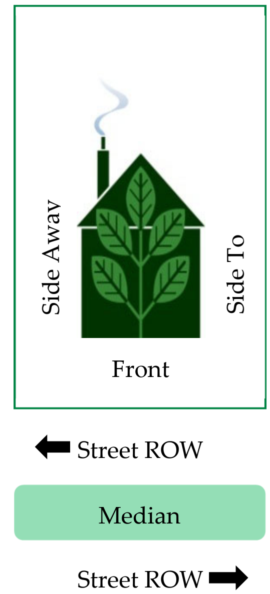
Inventory arborists use FZ-G1 Panasonic Toughpad® units with internal GPS receivers. Geographic information system (GIS) map layers are loaded onto these units to help locate sites during the inventory. This table lists these base map layers, along with each layer's source and format information.

Data Source	Data Year	Projection
Shapefile Big Rapids, MI Information Technology Department	2019-2020	NAD 1983 State Plane Michigan South, FT
Aerial Imagery Big Rapids, MI Information Technology Department	2014	NAD 1983 State Plane Michigan South, FT

STREET ROW SITE LOCATION

Individual street ROW sites were located using a methodology that identifies sites by *address number*, *street name*, *side*, and *on street*. This methodology was used to help ensure consistent assignment of location.

Address Number and Street Name



Where there was no GIS parcel addressing data available for sites located adjacent to a vacant lot, or adjacent to an occupied lot without a posted address number, the arborist used their best judgment to assign an address number based on nearby 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 were assigned an address number by the arborist in Rover using parcel and streets geographical data. Each segment was numbered with an assigned address that was interpolated from addresses facing that median and addressed on that same street as the median. If there were multiple medians between cross streets, each segment was assigned its own address. The *street name* assigned to a site was determined by street centerline information.

Side Value

Each site was assigned a *side value*, including *front*, *side*, *median*, or *rear* based on the site's location in relation to the lot's street frontage. The *front* is the side facing the address street. *Side* is either side of the lot that is between the front and rear. *Median* indicates a median or island surrounded by pavement. The *rear* is the side of the lot opposite of the address street.

PARK AND PUBLIC SPACE SITE LOCATION

Park and/or public space site locations were collected using the same methodology as street ROW sites, however nearly all of them have the "Assigned Address" field set to 'X' and have the "Park Name" data field filled.

Site Location Example

Corner Lot A

Address/Street Name: 205 Hoover St.
Side: Side
On Street: Taft St.

Address/Street Name: 205 Hoover St.
Side: Side
On Street: Taft St.

Address/Street Name: 205 Hoover St.
Side: Side
On Street: Taft St.

Address/Street Name: 205 Hoover St.
Side: Front
On Street: Hoover St.

Corner Lot B

Address/Street Name: 226 E Mac Arthur St.
Side: Side
On Street: Davis St.

Address/Street Name: 226 E Mac Arthur St.
Side: Front
On Street: E Mac Arthur St.

Address/Street Name: 226 E Mac Arthur St.
Side: Front
On Street: E Mac Arthur St.

APPENDIX B
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 cleanup costs. Keeping these pests and diseases out of the country is the number one priority of the USDA's Animal and Plant Inspection Service (APHIS).

Updated pest range maps can be found at: https://www.nrs.fs.fed.us/tools/afpe/maps/ and updated pest information can be found at: https://www.aphis.usda.gov/aphis/resources/pests-diseases/hungry-pests/Pest-Tracker

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, invasive 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

SPOTTED LANTERNFLY

The spotted lanternfly (SLF, *Lycorma delicatula*) is native to China and was first detected in Pennsylvania in September 2014. SLF feeds on a wide range of fruit, ornamental, and woody trees, with tree-of-heaven being one of its preferred hosts. SLF is a hitchhiker and can be spread long distances by people who move infested material or items containing egg masses.

Pinned spotted lanternfly.

Photograph courtesy of PA Dept of Agriculture

If allowed to spread in the United States, this pest could seriously impact the country's grape, orchard, and logging industries. Be sure to inspect for the pest. Egg masses, juveniles, and adults can be on trees and plants, as well as on bricks, stone, metal, and other smooth surfaces. Also thoroughly check vehicles, trailers, and even the clothes you are wearing to prevent accidently moving SLF.

Pinned spotted lanternfly nymph with wingspan open.

Photograph courtesy of USDA APHIS

Symptoms of SLF are plants oozing or weeping with a fermented odor, buildup of a sticky fluid called honeydew on the plant or on the ground underneath them, and sooty mold growing on plants. The following trees are susceptible to SLF: almonds, apples, apricots, cherries, maples, nectarines, oaks, peaches, pines, plums, poplars, sycamores, walnuts, and willows, as well as grape vines and hop plants.

EASTERN TENT CATERPILLAR

Eastern tent caterpiller (*Malacosoma americanum*) was first observed in the United States in 1646. In spring, caterpillars make nests in the forks and crotches of tree branches. Caterpillars do not feed within the nest; they leave the nest to feed up to 3 feet from nest, and return to rest and take shelter in wet weather. Large infestations may occur at 8- to 10-year intervals. Egg masses overwinter on twigs. Trees are rarely killed by eastern tent caterpillar, but health is compromised that year and aesthetic value is decreased.

Eastern tent caterpillar nest.

Photograph courtesy of Prairie Haven (2008)

Easter tent caterpiller have a wide range of hosts, including *Malus* (apple) and *Prunus* (cherry).

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).

EUROPEAN 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.

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

Photograph courtesy of USDA APHIS (2019)

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).

THOUSAND CANKERS DISEASE

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

Walnut twig beetle, side view.

Photograph courtesy of USDA Forest Service (2011)

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

The tree species preferred as hosts for TCD are walnut.

OAK WILT

Oak wilt symptoms on red and white oak leaves.

Photograph courtesy of USDA Forest Service (2011a)

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.

Just as with DED, oak wilt disease is caused by a fungus that clogs the vascular system of oak and results in decline and death of the tree. The fungus is carried from tree to tree by several borers common to oak, 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.

HEMLOCK WOOLY ADELGID

Hemlock woolly adelgids on a branch.

Photograph courtesy of Connecticut Agricultural Experiment Station, Bugwood.org (2011)

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

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

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

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 an emerald ash borer.

Photograph courtesy of USDA APHIS (2020)

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).

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APPENDIX C
i-TREE STREETS METHOLOGY

i-Tree Streets regionalizes the calculations of its output by incorporating detailed reference city project information for 16 climate zones across the United States. Big Rapids 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 Big Rapids to the results of Midwest Reference City Project to obtain an estimation of the annual benefits provided by Big Rapids' tree resource.

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. 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 make 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 science-based platform for decision-making.

A detailed description of how the default benefit prices are derived, refer to the *City of Minneapolis, Minnesota Municipal Tree Resource Analysis* (McPherson *et al.* 2005) and the *Midwest Community Tree Guide: Benefits, Costs, and Strategic Planning* (McPherson *et al.* 2009). i-Tree Streets' default values from the Midwest Climate Zone were used for air quality and stormwater benefit prices and local values were used for energy usage, aesthetics, and other benefits.

Benefit Prices Used by i-Tree Streets in the Analysis of Big Rapids' Tree Inventory

Benefits	Price	Unit	Source
Electricity	$0.00759	$/Kwh	Xcelenergy 2004
Natural Gas	$0.0098	$/Therm	Centerpoint Energy
CO_2	$0.0075	$/lb	US EPA 2003
PM_{10}	$2.84	$/lb	US EPA 2003
NO_2	$3.34	$/lb	US EPA 2003
O_3	$3.34	$/lb	US EPA 2003
SO_2	$2.06	$/lb	US EPA 2003
VOCs	$3.75	$/lb	Ottinger and others
Stormwater Interception	$0.0046	$/gallon	McPherson & Xiao
Aesthetic Value	$218,000	Average Midwest Housing Price	TreeKeeper®

Using these prices, the magnitude of the benefits provided by the public tree resource was calculated based on the science of i-Tree Streets using DRG's TreeKeeper® inventory management software. For a detailed description of how the magnitudes of benefit prices are calculated, refer to the *Midwest Community Tree Guide: Benefits, Costs, and Strategic Planning* (McPherson *et al.* 2009).

APPENDIX D
SUGGESTED TREE SPECIES
FOR USDA HARDINESS ZONE 4

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 community 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 soil and climate conditions throughout Zones 5 and 6 on the USDA Plant Hardiness Zone Map.

DECIDUOUS TREES

Large Trees (greater than 50 feet in height when mature)

Scientific Name	Common Name	Cultivar
Acer platanoides	Norway maple	'Cleveland' 'Emerald Queen' 'Summershade'
Acer rubrum	red maple	'Red Sunset'
Betula papyrifera	paper birch	
Catalpa speciosa	northern catalpa	
Celtis occidentalis	common hackberry	'Prairie Pride'
Fraxinus americana	white ash	'Autumn Applause' 'Autumn Purple'
Ginko biloba	ginko	'Autumn Gold'
Gleditsia triacanthos var. *inermis*	thornless honeylocust	'Shademaster' 'Skyline'
Gymnocladus dioicus	Kentucky coffeetree	
Juglans nigra	black walnut	'Laciniata'
Quercus macrocarpa	bur oak	
Quercus rubra	northern red oak	
Tilia americana	American linden	'Redmond'
Tilia cordata	Littleleaf linden	'Greenspire'
Ulmus americana	American elm	'Princeton' 'Valley Forge'

Medium Trees (26 to 50 feet in height when mature)

Scientific Name	Common Name	Cultivar
Aesculus glabra	Ohio buckeye	
Betula pendula	European white birch	
Fraxinus mandshurica	Manchurian ash	'Mancana'
Gleditsia triacanthos var. *inermis*	thornless honeylocust	'Imperial'
Ostrya virginiana	American hophornbeam	
Phellodendron amurense	Amur corktree	
Prunus cerasus	sour cherry	'Montmorency' 'Northstar'
Prunus maackii	Amur chokecherry	
Sorbus aucuparia	European mountainash	'Beissneri'
Sorbus decora	showy mountainash	

Small Trees (10 to 25 feet in height when mature)

Scientific Name	Common Name	Cultivar
Acer ginnala	amur maple	
Acer grandidentatum	bigtooth maple	
Acer tataricum	Tatarian maple	
Aesculus × carnea	red horsechestnut	'Briotii'
Crataegus ambigua	Russian hawthorn	
Crataegus crusgalli var. *inermis*	thornless cockspur hawthorn	'Crusader'
Crataegus viridis	green hawthorn	'Winter King'
Malus spp.	crabapple spp.	'Centennial' 'David' 'Harvest Gold' 'Madonna' 'Prairifire' 'Spring Snow'
Prunus cerasifera	cherry plum	'Newport'
Prunus nigra	Canada plum	'Princess Kay'
Prunus padus	European birdcherry	
Prunus virginiana	common chokecherry	'Canada Red'
Syringa reticulata	Japanese tree lilac	'Ivory Silk'

CONIFEROUS AND EVERGREEN TREES

Large Trees (greater than 50 feet in height when mature)

Scientific Name	Common Name	Cultivar
Abies concolor	white fir	'Violacea'
Larix deciduas	European larch	
Picea glauca	white spruce	
Picea pungens	Colorado spruce	
Picea pungens var. *glauca*	Colorado blue spruce	'Thompsenii'
Pinus nigra	Austrian pine	
Pinus ponderosa	ponderosa pine	
Pinus sylvestris	Scotch pine	
Pseudotsuga menziesii	Douglas-fir	
Tsuga canadensis	Canadian hemlock	

Medium Trees (26 to 50 feet in height when mature)

Scientific Name	Common Name	Cultivar
Juniperus scopulorum	Rocky mountain juniper	'Blue Heaven' 'Skyrocket'
Juniperus virginiana	eastern redcedar	
Picea glauca var. *densata*	Black Hills spruce	
Pinus flexilis	limber pine	'Glauca'

Small Trees (10 to 25 feet in height when mature)

Scientific Name	Common Name	Cultivar
Pinus aristata	bristlecone pine	
Pinus edulis	Piñon 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 DRG's experience. Tree availability will vary based on availability in the nursery trade.

SUGGESTED TREE SPECIES FOR USDA HARDINESS ZONE 5

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 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 frainetto	Hungarian oak	
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	
Quercus texana	Texas 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'
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	
Cladrastis kentukea	American yellowwood	'Rosea'
Eucommia ulmoides	hardy rubbertree	
Koelreuteria paniculata	goldenraintree	
Ostrya virginiana	eastern hophornbeam	
Parrotia persica	Persian parrotia	'Vanessa'
Phellodendron amurense	amur corktree	'Macho'
Prunus maackii	amur chokecherry	'Amber Beauty'
Prunus sargentii	Sargent cherry	
Quercus acutissima	sawtooth oak	
Quercus cerris	European turkey oak	
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	
*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 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	Douglasfir	
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	
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 DRG's experience. Tree availability will vary based on availability in the nursery trade.