

*Summary Report*  
*Calculated Public Tree Values and*  
*Benefits for The City of Ann Arbor*

The City of Ann Arbor, Michigan

July, 2009



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## ***Acknowledgements***

*This project was made possible by:*

**City of Ann Arbor Systems Planning Department**

While the specific reports and recommendations are unique to this study, the basis for its structure and written content comes from the entire series of *Municipal Forest Resource Analysis* reports prepared and published by the USDA Forest Service, Pacific Southwest Research Station, Center for Urban Forest Research, and credit should be given to those authors. The *Municipal Forest Resource Analysis* reports are companions to the regional *Tree Guides* and i-Tree's Streets application developed by the USDA Forest Service, Pacific Southwest Research Station, Center for Urban Forest Research.

## Executive Summary

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The City of Ann Arbor has a valuable resource in their public trees and is taking a proactive stance to ensure that these benefits are available for the community for years to come. Through Ann Arbor's staffing decisions and commitment to understanding the complexity of its urban forest, the City is creating a positive identity for their municipality and is fostering pride within their community. If left unattended, the benefits afforded by Ann Arbor's public trees will not be fully achieved, and priority maintenance concerns may create unwelcome liability issues in the future. Furthermore, numerous planting sites remain vacant, diminishing the possible magnitude of benefits to Ann Arbor and its citizens provided through public trees.

### Resource Structure

Ann Arbor's tree inventory includes 47,359 publicly managed trees, 8,853 available planting sites, and 843 stumps for a total of 57,055 sites. In order to gain an understanding of the benefits these trees provide the community and the management needs involved, an analysis of Ann Arbor's public tree resource must be performed. Species richness, relative age distribution, condition, and canopy coverage can be used to characterize Ann Arbor's resource as follows:

- There are over 187 distinct species of trees growing throughout the City of Ann Arbor: The predominant public tree species are Norway maple (*Acer platanoides*, 13.23%); sugar maple (*Acer saccharum*, 11.32%); thornless honeylocust (*Gleditsia triacanthos inermis*, 7.63%); red maple (*Acer rubrum*, 6.91%), and apple/crabapple (*Malus* spp., 6.33%).
- The relative age distribution of Ann Arbor's public trees is made up of 14.28% young (<6-inch DBH), 40.14% established trees (6- to 12-inch DBH), 36.51% maturing trees (12- to 24-inch DBH), and 8.97% mature trees (>24-inch DBH). Many of Ann Arbor's top performing species, in terms of benefits provided, dominate the mature size classes and will require a suitable replacement in size and structure in order to maintain their net benefits provided. Some of these species include white oak (*Quercus alba*), American elm (*Ulmus americana*), and silver maple (*Acer saccharinum*). Maintaining the flow of benefits provided by the City's urban forest will require a commitment to increase the amount of trees planted annually.



**Photograph 1:** Trees are a valuable city asset that provides monetary benefits that increase through time.

- The majority of public trees in Ann Arbor are in fair condition (54.1%), with 33.7% of inventoried trees classified as good and very good. Trees in poor or critical condition make up 11.0% of the inventory, while trees that are dead or dying make up 1.1% of the population. There is a need to maintain existing trees to increase their useful lifespan and maintain a flow of benefits, and to remove dead and dying trees as soon as possible.
- In Ann Arbor, the estimated canopy cover of inventoried trees in maintained areas is 780 acres, or about 4.5% of the City's total land area. .

### **Resource Function and Value**

The cumulative value provided by Ann Arbor's public trees is averaged to be \$97 per tree annually, for a gross total of about \$4.6 million annually. The City's public trees conserve and reduce energy, reduce carbon dioxide levels, improve air quality, mitigate stormwater runoff, and provide other benefits associated with aesthetics, increased property values, and quality of life. Ann Arbor's public trees are providing the community substantial benefits such as:

- Public trees reduce energy and natural gas use in Ann Arbor from shading and climate effects equal to 3,408 MWh and 1,260,313 therms, for a total savings valued at approximately \$2,252,055, with a citywide average of \$47.55 per public tree.
- Public trees in Ann Arbor reduce atmospheric CO<sub>2</sub> by a net of 7,851 tons per year, valued at \$52,450 for an average net benefit per tree of \$1.11.
- The net air quality improvement from the removal and avoidance of air pollutants is valued at \$395,569 per year, with an average net benefit per tree of \$8.35.
- Ann Arbor's public trees intercept 65.0 million gallons of stormwater annually. The total value of this benefit to the City is \$519,895 per year, for an average value of \$10.98 per inventoried tree.
- The estimated total annual benefit associated with increased property values, aesthetics, and other less tangible improvements is \$1,368,302 per year, for an average of \$28.89 per inventoried tree.
- When the City's annual tree-related expenditures are considered, approximately \$1,709,766 per year, the net annual benefit (benefits minus costs) to the City is \$2,878,470. The average net benefit for an individual public tree in Ann Arbor is \$60.78 per year. The City of Ann Arbor receives \$2.68 in benefits for every \$1 spent on its municipal forestry program.

### **Resource Management**

Ann Arbor's public tree resource is rich in the benefits it provides the community. However, maintaining this resource requires constant attention and commitment to achieve sustainability. Urban stressors, such as compacted soils, pollution, limited growing space, and insufficient nutrients, lead to an increased need for an aggressive management program. To maximize the benefits of Ann Arbor's resource and ensure sustainability, the following management practices should be implemented:

- Sustain the existing public tree resource through comprehensive tree maintenance, including new tree establishment and cyclical pruning. Develop a replacement plan for the City's most mature trees (and top benefit producers) to replace them with trees of similar stature gradually before they must be removed.
- Adjust tree planting in the City to expand the extent of the resource, and maintain the flow of benefits over time. Focus on large-stature trees where growing conditions permit and good-performing species to maximize benefits.
- Reduce dependence on Norway maple and sugar maple through careful species selection to achieve greater diversity and guard against catastrophic losses. Currently, maples (*Acer* spp.) make up approximately 38% of Ann Arbor's inventoried public trees.
- Strengthen the City's network of partners and urban forest managers to work together towards the common goal of an improved, more functional, and sustainable public tree resource.

## ***Introduction***

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The public trees growing on the rights-of-way and parks in the City of Ann Arbor constitute a valuable community resource. They provide tangible and intangible benefits for diverse services such as: pollution control, energy reduction, stormwater management, property values, wildlife habitat, education, and aesthetics.

Previously, the services and benefits trees provide in the urban and suburban setting were considered to be unquantifiable. However, by using extensive scientific studies and practical research, these benefits can now be confidently calculated using tree inventory information. The results of applying a proven, defensible model and method that determines tree benefit values for the City of Ann Arbor's current tree inventory data are summarized in this report using i-Tree's Streets application. Since Ann Arbor has conducted a complete tree inventory, an accurate insight can be drawn in regards to the overall health of the City's public trees and the benefits they provide the community.

The science behind this model and type of analysis is sound and has been published in peer-reviewed journals. The challenge now is to apply the science to enhance the quality of life in the City of Ann Arbor by improving the condition and extent of the urban forest.

## ***i-Tree Streets Benefit Model Overview***

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The method used to determine the overall and net values and benefits is the i-Tree's Streets application, which is a component of i-Tree version 3.0, a suite of free software tools recently released by the U.S. Forest Service that can be used to assess and manage community forests. With these tools, cities and urban forest managers can accurately quantify the benefits of urban forests, understand and balance the costs of managing an urban forest, and become better prepared for severe weather emergencies.

Specifically, i-Tree Streets is a tool that quantifies the benefits of public trees and compares them directly with the costs of urban forestry programs to produce accurate net benefit values. It is a statistically valid, financially sound, and defensible cost-benefit analysis tool for urban forestry that may be used with existing inventories or with a sampling of streets in a community. I-Tree's Streets application is formerly known as STRATUM (Street Tree Resource and Analysis Tool for Urban Forest Managers).

Appendix A lists additional sources for further information.



**Photograph 2.** A Davey Resource Group Inventory Arborist collects data for analysis using i-Tree Streets.

## ***i-Tree Streets Benefit Categories***

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Inventory data from the City of Ann Arbor inventory project was entered into the i-Tree Streets model by Davey Resource Group to assess and quantify the beneficial functions of the public tree resource and to place a dollar value on the annual environmental benefits they provide. Data collection began in February, 2009 and was concluded in May, 2009. A functional analysis was performed to determine and quantify these benefits:

- **Energy Consumption Savings**—The energy savings that trees provide can be attributed to shading, the cooling effect of transpiration, and wind reduction. These key factors reduce the amount of radiant energy absorbed in buildings and other hardscapes, cooling the air around buildings in the summer and helping retain heat during cold winter months. The energy savings is realized by lower cooling and heating costs for any type of building.
- **Carbon Sequestration**—Carbon dioxide (CO<sub>2</sub>) is used during a tree's photosynthesis process to produce the natural building blocks necessary for tree growth. This process takes carbon dioxide from the atmosphere and holds it as woody and foliar biomass. This is referred to as carbon sequestration.
- **Air Quality Improvements**—The air quality of Ann Arbor's urban environment greatly benefits from the presence of street and other public trees. Trees absorb gaseous pollutants in the form of ozone (O<sub>3</sub>) and nitrogen dioxide (NO<sub>2</sub>). Reduction in ozone can also be attributed to the tree shading effect on hardscape surfaces and the transpiration process. Trees intercept volatile organic compounds (VOCs), sulfuric dioxide (SO<sub>2</sub>), and small particulate matter (PM10), such as dust, ash, dirt, pollen, and smoke, from the air. Trees also emit biogenic volatile organic compounds (BVOCs), an air pollutant that contributes to the formation of ozone, a process which the i-Tree Streets model takes into account.
- **Stormwater Mitigation**—The City of Ann Arbor's public tree population reduces the volume of stormwater runoff in its neighborhoods and ultimately city-wide. This function and benefit is especially important in developed settings with increased quantities of impervious surfaces (roads, driveways, homes, parking areas) and in areas in close proximity to surface waters. A tree's surface area, especially the leaf surfaces, intercepts and stores rainfall. The root systems of trees increase soil infiltration, thereby decreasing runoff. Trees also reduce stormwater runoff by intercepting raindrops before they hit the ground, reducing soil compaction rates and improving soil absorptive properties. In addition, trees intercept suburban contaminants such as oils, solvents, pesticides, and fertilizers which are often part of stormwater runoff, reducing pollutant discharges into the City's vital waterways.



**Photograph 3.** Using the i-Tree Streets analysis software application, Ann Arbor's public tree resource returns an estimated \$4.6 million in benefits annually back to the community, for a net benefit of \$2,878,470 per year.

- **Aesthetics and Other Public Values**—It may seem difficult to place a dollar value on the benefit Ann Arbor’s public trees provide to the overall ambiance of the City and the well-being of neighborhood residents and visitors. However, trees provide beauty to the landscape, privacy to homeowners, and refuge for urban wildlife, and this can be quantified in terms of estimated property value increases.

Because Ann Arbor’s tree inventory does not include natural areas, forest preserves, or other non-manicured portions of the City, a large part of public trees are not represented in the report. As a result, the full extent and benefits of Ann Arbor’s public trees may be underestimated.

## ***Ann Arbor’s Municipal Tree Resource***

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### ***Public Tree Numbers***

Ann Arbor’s public tree population is dominated by broadleaf-deciduous trees (89.77% of the total). Broadleaf-deciduous trees usually have larger canopies than coniferous public trees, and because most of the benefits provided by trees are related to leaf surface area, broadleaf trees usually provide the highest level of benefit. There are 4,846 (10.23%) evergreen and coniferous trees rounding out the population (Appendix B).

### ***Species Richness and Composition***

Ann Arbor’s inventoried public tree population includes a mix of more than 187 species (Appendix C). This richness is to be commended, as a variety of species types can decrease the impact of species-specific pests and diseases by limiting the number of trees that are susceptible. This, in turn, reduces the time and money spent on mitigating problems resulting from any such episodes. Additionally, a wide variety of tree species may help to limit the impacts from a number of physical events, such as strong storms, wind, ice, flooding, drought, etc.

However, four of the top six occurring species are from the genus *Acer* (maple). Those four maple species include: Norway maple (13.2%); sugar maple (11.3%); red maple (6.9%); and silver maple (4.6%). Overall, 38% of the trees occurring in Ann Arbor are from the maple genus. Davey Resource Group recommends that no single species represents more than 10% of the total population and no single genus represents more than 20% of the total population. Both Norway maple and sugar maple exceed this population management guideline for species, while maples collectively exceed the guideline set for genera representation.



**Photograph 4.** American elms (*Ulmus americana*), with their majestic form, were once the most recognized tree in midwestern communities prior to Dutch elm disease. Today, they represent 1.5 % of all inventoried public trees in Ann Arbor.

Maintaining a healthy population with an appropriately balanced species composition will help deter a loss of benefits from species-specific pests and diseases. American elm, one of Ann Arbor's most productive species in terms of benefits, were once planted throughout Ann Arbor and the Midwest. In the 1950s and the 1960s, elm trees throughout the Midwest began dying from Dutch elm disease (*Ophiostoma ulmi*), a microfungi disease that is spread by elm bark beetles. Today, American elms provide Ann Arbor with over \$100,000 in annual benefits. Considering that Ann Arbor may have lost over 90% of their American elm population throughout the 1950s and 1960s from Dutch elm disease, that loss in benefits annually may equate to over one million dollars today.

The loss of elm trees throughout the Midwest in the 1950s and 1960s was catastrophic in terms of benefits lost for cities. In many cities and towns, ash (*Fraxinus* spp.) trees were planted as a replacement for elms. In 2002, Ann Arbor had an estimated 10,000 public ash trees planted across the City. In the summer of 2002, an invasive species known as *Agrilus planipennis* (emerald ash borer) was introduced in Detroit, Michigan, and began destroying ash trees throughout the greater Detroit area. According to the recent 2009 tree inventory, Ann Arbor has approximately 234 public ash trees, in which 129 are dead or in critical condition. Of these 234 ash trees, 187 are in the 6- to 12-inch diameter class or below.

The recent and significant loss of ash trees greatly reduced the annual benefits provided by Ann Arbor's urban forest. Many of the ash trees that were destroyed from emerald ash borer were mature trees, which provide the greatest amount of benefits for a community. In order to restore those benefits lost from the destruction of emerald ash borer, Ann Arbor needs to replant a variety of species types, many of which are capable of developing large spreading canopies similar to ash trees.

## Species Importance

i-Tree Streets calculates the importance of any one species in a public tree inventory by assigning each species an Importance Value (IV). Importance values enable urban forest managers to indicate which trees have the greatest functional capacity within a community. Importance Values can be taken a step further to forecast the loss of benefits should a catastrophic event eliminate a single species.

The top five inventoried public trees in Ann Arbor have the following Importance Values: Norway maple, 12.3; sugar maple, 14.8; honeylocust, 9.4; red maple, 4.8 and apple/crabapple, 3.3. Ann Arbor relies heaviest on the functional capacity of sugar maple and Norway maple, which has a higher IV than any other species due to their maturity, greater size, broader leaf area, and prevalence among the City's public trees. In fact, Norway maple, sugar maple, red maple and silver maple constitutes about 50% of inventoried tree canopy in the City. Meanwhile, honeylocust, which has the third highest IV at 9.4, only represents 7.6% of the population. Appendix D provides IVs for the 14 most prevalent species.



**Photograph 5.** Maples (*Acer* spp.) make up over 50% of the inventoried tree canopy in Ann Arbor and make up three of the five species with the greatest importance values.

## ***Stocking Level***

Inventory results indicate that 57,055 trees, stumps, and planting spaces were collected. There were 8,853 vacant planting sites along Ann Arbor's inventoried streets that need to be planted in order to reach a stocking level of 100%. Currently, Ann Arbor's stocking level is 84%, assuming no new planting sites in parks and public properties. Planting sites were not recorded in parks and public properties. Of the 8,853 available planting sites, 2,902 (32.8%) can be utilized for small-stature trees, 2,672 (30.2%) for medium-stature trees, and 3,279 (37.0%) for large-stature trees. Appendix E summarizes stocking level for the current inventory data.

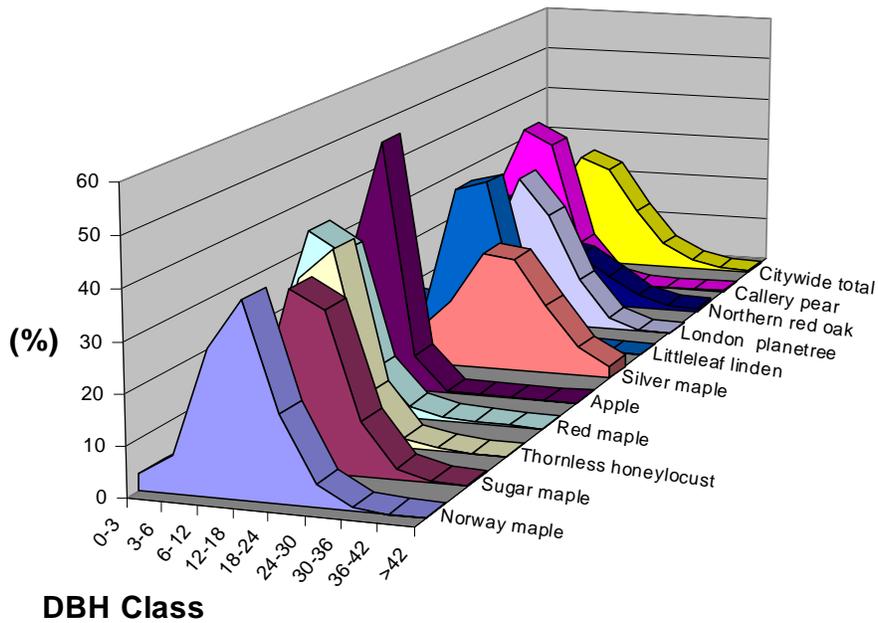
Calculating trees per capita is another important measure of tree stocking. Assuming that Ann Arbor has a human population of 114,000, and no other trees exist beyond the ones included in this study, then public trees per capita for the City is 0.42, about 1 tree for every 2.4 people.

## ***Relative Age Distribution***

The distribution of ages within a tree population influences present and future costs as well as the flow of benefits. An uneven-aged population allows managers to allocate annual maintenance costs uniformly over many years and assures continuity in overall tree canopy cover.

Ann Arbor urban forest is well established and maturing with a relatively even age distribution, having 14.28% of inventoried public trees considered young (<6-inch DBH), 40.14% established trees (6- to 12-inch DBH), 36.51% maturing trees (12- to 24-inch DBH), and 8.97% mature trees (>24-inch DBH). An ideal public tree population has an imbalanced age distribution, with higher percentages of young trees than mature trees to minimize fluctuations in functional benefits over time. As trees mature and begin to decline, a tree population skewed towards young trees will ensure that a flow of benefits continues to exist.

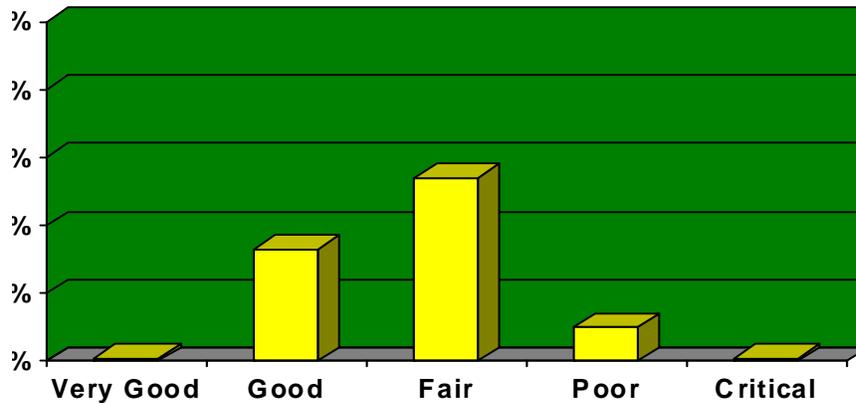
Relative age should also be considered between species (Figure 1). Sugar maple, which has the highest Importance Value (14.8) of any public tree in Ann Arbor, is represented in the population as 82% mature (>24-inch DBH) or maturing (12- to 24-inch DBH), with 15% established (6- to 12-inch DBH) and 3% young (<6-inch DBH). If young trees of similar size and structure are not planted to improve the age distribution of this species, the return of valuable benefits may be disrupted for future generations. Appendix F displays the relative age distribution for the ten most inventoried public trees in Ann Arbor.



*Figure 1. Relative Age Distribution of Ann Arbor's Top Ten Public Trees*

### **Tree Condition**

Tree condition indicates both how well trees are managed and how well they perform given site-specific conditions. The majority of Ann Arbor's public trees (54%) are in fair condition (Figure 2). When trees are performing at their peak, as are the 33% of trees classified as good, and the 1% classified as very good, the benefits they provide will be maximized. Trees in poor condition account for 17%, while 1% of the tree population is in critical condition. One percent of Ann Arbor's public trees are dead or dying (Appendix G). The goal for dead and dying trees should be zero.



*Figure 2. Condition Rating of Inventoried Public Trees*

## **Canopy Cover**

Leaf surface area directly correlates with the benefits of public trees. The greater the leaf surface area exhibited by a tree, the greater the benefits a particular tree is likely to provide the community. In other words, trees with large leaves and spreading canopies tend to produce the most benefits.

In Ann Arbor, the estimated public tree canopy covers approximately 780 acres of the total land area of 17,280 acres (27 square miles), or 4.5% of the City (Appendix H). Ann Arbor should always strive to improve the stocking level by planting additional trees. Planting the right species in the right place will increase canopy cover, leading to greater benefits in the community.

## **Replacement Value**

Ann Arbor's inventoried public tree resource is an asset valued at \$131.3 million (Appendix I). This value is determined by considering the cost of replacing Ann Arbor's inventory of 47,359 public trees with trees of a similar stature. Typically, the larger the tree is in size, the more benefits that tree is providing Ann Arbor and, therefore, will have a larger replacement cost. Appendix I demonstrates that the only chinkapin oak (*Quercus muhlenbergii*) inventoried was in the 36- to 42-diameter class and has an estimated replacement cost of \$24.5 thousand dollars. Likewise, the only chestnut oak (*Quercus montana*) inventoried was in the 12- to 18-diameter class, and has a replacement cost of about \$2.9 thousand dollars. The species of trees with the greatest replacement cost are Norway maple and sugar maple with replacement values of \$18.6 and \$15.5 million dollars, respectively.

## ***Costs of Managing Ann Arbor's Municipal Trees***

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Investing in Ann Arbor's public trees is well worth the cost. The City's trees provide numerous economical, environmental, psychological, and social benefits to the community. In the 2008 fiscal year, Ann Arbor's total related expenditures for public trees were approximately \$1,709,801, which is only 0.6% of the City's total municipal budget of \$298,968,534 (Appendix J).

### ***Tree Planting and Establishment***

Ensuring that the benefits of Ann Arbor's public trees are available for future generations requires quality nursery stock, proper planting techniques, and adequate follow-up care. In 2008, the City of Ann Arbor allocated approximately \$380,414 toward planting new trees. Of Ann Arbor's total expenditures for tree services, approximately 22% of costs can be attributed to tree planting. According to recent inventory data, Ann Arbor has an estimated 8,853 vacant planting spaces to be filled. Considering that Davey Resource Group conservatively estimates the cost of purchasing and planting a new tree at \$210 per tree, Ann Arbor could expect to spend \$1,859,130.00 to reach a stocking level of 100% in the inventoried area. However, this ballpark figure is only intended to highlight the attention needed to achieve stocking goals in the City, as regional and internal variances are not accounted for.



**Photograph 6.** Planting new trees improves the age structure of urban forests and ensures that the flow of benefits is uninterrupted.

### ***Maintenance***

In 2008, planting, pruning, pest management, removals, irrigation, and litter clean-up accounted for \$1,373,391, or 80% of Ann Arbor's total public tree related expenditures. Removals accounted for approximately 34% of total expenditures, while pruning accounted for 19%. Approximately 5% of total expenditures are attributed to litter clean-up, irrigation, and pest management.

### ***Administration***

Approximately \$228,644 or 13% of total expenditures for managing public trees in 2008 can be attributed to administration costs. These costs often include forestry personnel salaries, clerical staff, summer help, supplies, training, inspection, and other administration fees.

### ***Additional Tree Related Expenditures***

Other miscellaneous costs in maintaining public trees in 2008 made up approximately \$1,709,801 or 6% of Ann Arbor's total tree expenditures.

## ***Benefits of Ann Arbor's Municipal Trees***

Public trees provide a host of benefits to the City of Ann Arbor. Public trees conserve energy, reduce carbon dioxide levels, improve air quality, and mitigate stormwater runoff. In addition, trees provide numerous economical, psychological, and social benefits. However, the intent of this study is to determine whether the benefits of public trees outweigh the costs of maintaining them.

This study uses tree inventory data collected in Ann Arbor and i-Tree's Streets application to assess and quantify the beneficial functions of the City's public tree resource and to place a dollar value on the annual benefits they provide. Table 2 presents total annual benefits per species for the 14 most prevalent public trees in Ann Arbor.

**Table 1. i-Tree Streets Analysis Results for Total Annual Benefits per Species in the City of Ann Arbor**

<b>Species</b>	<b>Energy</b>	<b>CO<sub>2</sub></b>	<b>Air Quality</b>	<b>Stormwater</b>	<b>Aesthetic/Other</b>	<b>Total (\$)</b>
Norway maple	\$325,780.34	\$9,322.87	\$57,892.64	\$62,040.71	\$185,782.33	\$640,818.90
sugar maple	\$345,761.63	\$8,186.39	\$58,543.27	\$87,285.21	\$186,026.58	\$685,803.08
thornless honeylocust	\$242,619.64	\$4,808.36	\$41,682.75	\$47,354.79	\$144,399.23	\$480,864.77
red maple	\$84,291.92	\$1,642.05	\$13,406.09	\$19,621.02	\$94,890.72	\$213,851.80
apple	\$63,366.55	\$1,110.12	\$10,139.23	\$9,491.55	\$28,416.94	\$112,524.39
silver maple	\$196,181.74	\$4,544.52	\$37,250.27	\$56,778.58	\$63,175.49	\$357,930.62
littleleaf linden	\$77,430.56	\$1,635.13	\$12,571.05	\$14,732.65	\$42,139.84	\$148,509.23
London planetree	\$106,510.35	\$2,296.21	\$17,599.66	\$23,424.81	\$49,622.11	\$199,453.14
Northern red oak	\$56,600.12	\$1,360.20	\$9,654.41	\$13,284.21	\$29,498.66	\$110,397.60
Callery pear	\$23,336.95	\$778.45	\$4,566.20	\$5,465.40	\$43,900.86	\$78,047.86
Colorado spruce	\$22,679.95	\$436.18	\$4,139.20	\$6,602.32	\$14,780.87	\$48,638.53
Austrian pine	\$31,819.39	\$615.59	\$5,955.41	\$9,087.45	\$14,453.32	\$61,931.17
black walnut	\$73,719.62	\$1,509.06	\$14,175.50	\$19,714.56	\$47,056.01	\$156,174.74
American elm	\$53,758.18	\$1,455.57	\$10,447.62	\$14,026.01	\$40,179.40	\$119,866.77
Siberian elm	\$42,108.88	\$1,111.71	\$8,113.07	\$10,812.93	\$30,654.24	\$92,800.83
Japanese zelkova	\$31,808.65	\$641.18	\$5,180.54	\$5,695.90	\$26,340.60	\$69,666.88
Eastern white pine	\$11,031.67	\$208.90	\$2,003.78	\$3,258.31	\$7,648.90	\$24,151.57
swamp white oak	\$6,960.90	\$159.58	\$1,054.12	\$1,414.80	\$11,985.52	\$21,574.93
white oak	\$46,475.00	\$1,589.46	\$9,216.58	\$14,231.32	\$26,646.93	\$98,159.29
other public trees	\$409,813.10	\$9,038.83	\$71,977.14	\$95,572.41	\$280,703.01	\$867,104.48
Citywide total	\$2,252,055.17	\$52,450.38	\$395,568.52	\$519,894.93	\$1,368,301.56	\$4,588,270.56

## **Electricity and Natural Gas Results**

Ann Arbor's inventoried public trees provide a savings of 3,408.5 MWh (\$477,534) and 1,260,313.0 therms (\$1,774,521) in shading and climate effects (Appendix K). The average savings per inventoried tree in the City is \$47.55, while Ann Arbor saves a total of \$2,252,055 per year. Sugar maple produces the largest electricity and natural gas savings at \$685,803, about 15% of all energy savings from public trees.

## **Avoided and Sequestered Carbon Dioxide**

Ann Arbor's public tree resource reduces a net 7,851 tons of CO<sub>2</sub> per year valued at \$52,450, with the average savings per inventoried tree at \$1.11. Norway maples account for 17.8% of these savings while constituting 13.2% of the total tree inventory. On the other hand, white oaks make up only 1.1% of the total population while generating more benefits per tree (\$3.12/tree) than Norway maples (\$1.49/tree). Ann Arbor may want to consider planting more oaks where applicable to take advantage of these benefits, while at the same time increasing species and genera diversity.

Because carbon benefits directly correlate with woody biomass and leaf surface area, higher densities of large trees tend to offset the most CO<sub>2</sub>. Planting new trees and maintaining existing ones is the best approach to sustaining these benefits. Appendix L presents benefits associated with carbon sequestration for species.

## **Deposition and Interception**

Each year, Ann Arbor's inventoried public trees provide a savings of \$416,828 by intercepting or avoiding O<sub>3</sub>, NO<sub>2</sub>, PM<sub>10</sub>, and SO<sub>2</sub>. Norway maple, sugar maple, honeylocust, and silver maple contribute the most benefits towards air quality due to their representation in the public tree population and maturity. The combined savings of these three species makes up 49% of the total tree population savings, which amounts to \$303,020 annually.

## **Avoided Pollutants**

Trees indirectly reduce pollutant emissions such as NO<sub>2</sub>, PM<sub>10</sub>, VOCs, and SO<sub>2</sub> by lowering dependence on energy consumption. Sugar maple and Norway maple trees have the greatest impact on reducing energy needs, returning a combined savings of \$60,574.

## **BVOC Emissions**

Trees emit BVOCs that negatively affect air quality. Larger trees such as sugar maples, honeylocusts, and London planetrees tend to have higher BVOC emissions. In Ann Arbor, BVOC emissions offset total air quality benefits by \$21,259.

## **Net Air Quality Improvement**

Ann Arbor experiences a net air quality improvement of \$395,569 per year, averaging \$8.35 per tree. Sugar maples may be high BVOC emitters, but they provide the high number of benefits with a savings of \$58.543 per year. White oak and black walnut (*Juglans nigra*) produce the most air quality benefits per tree with an average savings of \$18.07 and \$17.25, respectively. Together, white oak and black walnut only make up about 3% of the total number of trees, which accounts for 6% of the annual air quality benefits. Appendix M illustrates annual and net benefit values for species on matters of air quality improvement.

## **Stormwater Runoff Reductions**

Public trees in Ann Arbor intercept 65 million gallons of stormwater annually, for a savings of \$519,895 (Appendix N). The average benefit per inventoried public tree is valued at \$10.98. White oak, silver maple, and black oak intercept the greatest amounts of stormwater per tree. Sugar maple, Norway maple, and silver maple intercept the greatest amount of rainfall per year, with a yearly stormwater interception of 10.1 million, 7.8 million, and 7.1 million gallons, respectively.

## **Aesthetic, Property Value, Social, Economic, and Other Benefits**

Aesthetic and other related benefits in Ann Arbor provide an estimate of \$1,368,302 annually to the City, for an average of \$28.89 per inventoried tree. While Norway maples represent 13.2% of the inventoried population with average benefits of \$29.66 per tree annually, American elms (1.5%) return the second most benefits at \$57.24 per tree (Appendix O). Siberian elms (*Ulmus pumila*) return the most benefits per tree, with an average savings of \$58.39. This does not suggest that Ann Arbor should begin to plant Siberian elms for aesthetic benefits, but the majority of the Siberian elms in Ann Arbor are reaching maturity, which influences the amount of aesthetic benefits a tree provides.

## **Net Benefits and Benefit-Cost Ratio (BCR)**

Ann Arbor receives substantial benefits from its public trees. However, the City must also consider the cost of maintaining this resource. Applying a benefit-cost ratio (BCR) is a useful way to evaluate the public investment in public trees. A BCR is an indicator used to summarize the overall value compared to the costs of a given project. Specifically in this analysis, BCR is the ratio of the cumulative benefits provided by the City's public trees, expressed in monetary terms, compared to the costs associated with their management, also expressed in monetary terms.

It is important to recognize that the i-Tree Streets analysis conducted for Ann Arbor only accounts for the public trees in manicured and maintained areas throughout the City. Ann Arbor has a significant amount of natural and non-manicured areas, whose benefit are not accounted for within this study. If Ann Arbor were to do an inventory and study of its natural areas, the City would most likely see the value of its net benefits increase.

Not all of the benefits attributed to public trees are easily quantified; therefore, some intangible benefits are not included in this study. For example, benefits linked with human needs, such as increased public safety, are difficult to measure. Furthermore, variances within species and between sites often occur to make estimates less precise.

Ann Arbor's public trees provide significant benefits to the community and environment alike. Energy benefits are the largest quantifiable benefits (49%) to the City annually, with aesthetic and other intangible benefits second at 30%. Stormwater runoff savings account for 11% of annual benefits. Air quality improvement and carbon dioxide reduction annual benefits each account for 9% and 1%, respectively. As determined throughout this analysis, larger-growing trees, such as white oak, sugar maple, and Norway maple, consistently supply the most benefits.

The sum of estimated benefits for the City of Ann Arbor (Table 4) is \$4,588,271 annually at an average of an estimated \$97 per inventoried public tree and \$40 per capita. When Ann Arbor’s annual expenditures are considered (\$1,709,901), the net annual benefit (benefits minus costs) returned by public trees to the City is \$886,831. The average net annual benefit for an individual public tree in Ann Arbor is \$60.78, nearly \$25 per capita. Based on an inventory count of 47,359 public trees, Ann Arbor receives \$2.68 in benefits for every \$1 that is spent on its municipal forestry program (Appendix P).

**Table 2. i-Tree Streets Analysis Results for Annual Benefits, Net Benefits, and Cost for Public Trees**

	Total (\$)	\$/Tree	\$/Capita
Total Benefits	4,588,271	96.88	40.25
Total Costs	1,709,901	36.10	15.00
Net Benefits	2,878,470	60.78	25.25
Benefit Cost Ratio	2.68		

## ***Management Implications***

When cared for properly, Ann Arbor’s public trees are worth the investment. Citizens of Ann Arbor can take comfort in knowing that the benefits produced by maintaining their urban forest outweigh the costs. Based on this study, every \$1 spent on public tree management returns an average net value of \$2.68 in benefits back to the community each year. That is a yearly rate of return of 168%. Unfortunately, public trees can become a burden to any municipality if neglected. As trees grow larger and mature, those that are not adequately maintained become increasingly more costly to manage and may create liability issues. Meanwhile, valuable benefits that are not fully achieved lessen opportunities to encourage a safe, healthy, and more enjoyable environment in which to live.

Implementing a comprehensive tree management program, including new tree establishment and cyclical pruning, is the first step to ensure that benefits produced by the City’s public trees surpass the cost of managing them. Currently, 54% of Ann Arbor’s inventoried public trees are considered to be in fair condition. Trees in good and excellent condition account for 34% of the population, with 11 % of public trees recorded as poor or critical and 1% inventoried as dead or dying. While these figures indicate a strong commitment to public tree management, Ann Arbor should strive to eliminate all dead and dying trees, replace poor performers, and maintain strong-performing and large-growing species that provide the most benefits. Replacing overutilized species, such as maples (38%), should be considered to improve overall species diversity and reduce the impact of species-specific pests or disease. White oak, American elm, and London planetree combine to represent about 6% of the population yet account for 9% of all benefits. Planting large-growing and underutilized trees like these three species will result in a more sustainable flow of benefits for future generations.

The City of Ann Arbor is on the right path to a sustainable urban forest. The results of this analysis can be used to improve the City's public tree management strategy, promoting a valuable asset with invaluable qualities. By strengthening its network with partners and urban forest managers, Ann Arbor will help to develop the relationships and resources it needs to achieve its urban forestry goals.

## ***Conclusion***

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Ann Arbor's urban forest is a valuable resource. The public trees inventoried in this study return an annual gross benefit of \$4,588,271 to the City each year at an average of \$97 per tree and \$40 per capita. Citizens of Ann Arbor see a return on their investment of a \$2.68 for every \$1 spent on management. As a result, this i-Tree Streets analysis suggests that there is justification for more attention and funding for urban forestry planning, design, management, and maintenance in the City of Ann Arbor. Planning for a greener and healthier city can begin by including urban forestry in all project discussions and considering creative ways to ensure the private and public tree canopy is kept healthy, well-maintained, safe, and is also enhanced by well-planned planting projects.



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***Appendix A***  
***Further Information***

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## Further Information

[www.itreetools.org](http://www.itreetools.org)

*New York City, New York Municipal Tree Resource Analysis*

McPherson, E.G., Simpson, J. R., Peper, S. E., Gardner,  
S. L., Cozad, S. K., Xiao, Q (2007).

*Northeast Community Tree Guide*

*Benefits, Costs, and Strategic Planning*

McPherson, E.G., Simpson, J. R., Peper, P. J., Gardner, S. L.,  
Vargas, S.E., Xiao, Q (2007).

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***Appendix B***  
***Population Summary for the City of Ann Arbor***

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<b>Population Summary of Public Trees</b>
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7/22/2009

Species	DBH Class (in)									Total Standard Error
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	
<b>Total</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0 (±NaN)</b>
<b>Palm Evergreen Small (PES)</b>										
pes OTHER	0	0	0	0	0	0	0	0	0	0
<b>Total</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0 (±NaN)</b>
<b>Grand Total</b>	<b>6,763</b>	<b>6,860</b>	<b>12,193</b>	<b>10,984</b>	<b>6,308</b>	<b>2,710</b>	<b>1,018</b>	<b>333</b>	<b>190</b>	<b>47,359 (±0)</b>

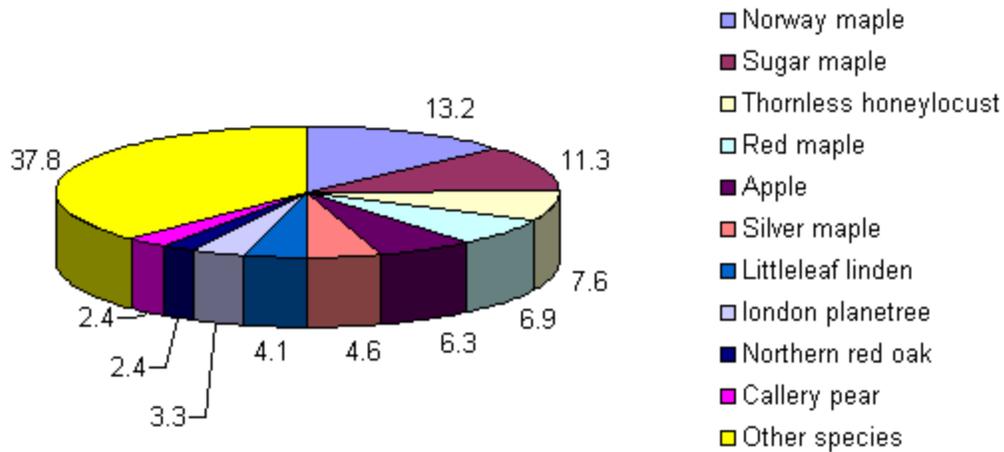
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***Appendix C***  
***Species Distribution***

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**Species Distribution of Public Trees (%)**

7/22/2009



Species	Percent
Norway maple	13.2
Sugar maple	11.3
Thornless honeylocust	7.6
Red maple	6.9
Apple	6.3
Silver maple	4.6
Littleleaf linden	4.1
london planetree	3.3
Northern red oak	2.4
Callery pear	2.4
Other species	37.8
Total	100.0

# Complete Population of Public Trees

7/22/2009

Species	DBH Class (in)									Total Standard Error
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	
<b>Broadleaf Deciduous Large (BDL)</b>										
Norway maple	215	463	1,782	2,405	1,079	274	42	3	1	6,264
Sugar maple	180	241	588	1,909	1,715	584	121	17	4	5,359
Thornless honeylocust	177	376	1,183	1,407	381	71	17	0	0	3,612
Silver maple	57	66	169	308	550	535	320	134	55	2,194
london planetree	93	104	252	508	385	163	34	2	0	1,541
Northern red oak	218	247	262	143	128	77	31	11	8	1,125
Black walnut	16	27	135	186	227	142	60	20	9	822
American elm	62	41	160	138	117	80	64	29	11	702
Siberian elm	12	46	116	107	98	84	38	17	7	525
Japanese zelkova	69	62	176	157	55	4	1	0	0	524
Swamp white oak	270	190	39	10	3	2	1	1	0	516
White oak	11	6	24	82	168	101	68	26	24	510
American basswood	1	16	36	104	151	108	24	10	1	451
Shagbark hickory	15	26	126	114	67	21	5	0	0	374
Bur oak	44	41	59	33	51	45	28	17	40	358
Northern hackberry	227	62	15	5	9	0	1	0	0	319
Tulip tree	115	36	38	40	42	23	2	0	0	296
Black locust	10	16	56	71	68	23	9	1	1	255
Eastern cottonwood	3	6	34	51	78	43	30	3	6	254
Black cherry	4	14	77	71	49	18	7	4	1	245
Ginkgo	136	38	24	13	5	5	1	0	0	222
Freeman maple	18	69	83	45	3	0	0	0	0	218
Pin oak	25	17	90	52	18	6	5	1	2	216
English oak	14	32	90	47	13	1	0	0	0	197
Sweetgum	56	56	46	6	2	0	0	0	0	166
American sycamore	1	3	16	45	36	39	12	2	1	155
River birch	91	18	19	2	1	0	0	0	0	131
Kentucky coffeetree	38	6	51	18	3	5	1	1	0	123
Ash	3	18	51	27	8	1	0	0	0	108
Horsechestnut	9	21	27	17	14	11	2	0	0	101
White ash	22	38	31	4	0	2	0	0	0	97
Black oak	12	1	13	13	20	18	12	2	2	93
Amur maple	28	32	21	6	1	0	0	0	0	88
Shingle oak	49	26	10	1	0	0	0	0	0	86
Pignut hickory	0	2	8	21	28	14	5	0	0	78
Tree of heaven	5	7	18	10	13	5	2	1	0	61
Honeylocust	5	3	15	17	11	3	2	2	0	58
Hardy rubber tree	41	3	0	0	0	0	0	0	0	44
Hybrid elm	27	8	5	1	1	0	0	0	0	42
Dawn redwood	20	4	11	0	2	2	0	0	0	39
Bitternut hickory	4	4	4	2	12	6	2	0	0	34
Mockernut hickory	0	2	16	4	5	3	0	0	0	30
Green ash	11	5	6	6	0	0	0	0	0	28
Silver linden	11	7	6	3	0	0	0	0	0	27
Elm	0	5	13	7	1	0	0	0	0	26
Sycamore maple	0	0	7	11	1	0	0	0	0	19
Paper birch	5	3	6	5	0	0	0	0	0	19
Sawtooth oak	8	10	1	0	0	0	0	0	0	19
Smoothleaf elm	1	5	6	5	1	1	0	0	0	19
American beech	9	2	2	2	0	0	1	0	0	16
Turkish hazelnut	9	0	2	0	0	0	0	0	0	11
English walnut	0	0	5	5	0	0	1	0	0	11
Bigtooth aspen	0	0	2	2	5	1	0	0	0	10
Baldcypress	6	2	1	0	0	0	0	0	0	9
Three-flower maple	0	5	3	0	0	0	0	0	0	8
European beech	2	0	3	2	0	0	0	0	0	7
Oak	2	2	0	1	1	1	0	0	0	7
Shumard oak	0	0	7	0	0	0	0	0	0	7

# Complete Population of Public Trees

7/22/2009

Species	DBH Class (in)									Total Standard Error
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	
Yellow buckeye	4	0	1	1	0	0	0	0	0	6
White poplar	0	0	0	0	6	0	0	0	0	6
Quaking aspen	0	0	3	2	1	0	0	0	0	6
Butternut	1	2	2	0	0	0	0	0	0	5
Black maple	0	0	1	3	0	0	0	0	0	4
Ohio buckeye	4	0	0	0	0	0	0	0	0	4
Western sugar maple	2	0	0	0	0	0	0	0	0	2
European larch	0	1	0	0	1	0	0	0	0	2
Scarlet oak	0	1	0	0	0	1	0	0	0	2
Caucasian linden	2	0	0	0	0	0	0	0	0	2
Blue ash	1	0	0	0	0	0	0	0	0	1
Chestnut oak	0	0	0	1	0	0	0	0	0	1
Northern pin oak	0	1	0	0	0	0	0	0	0	1
Chinkapin oak	0	0	0	0	0	0	0	1	0	1
Willow oak	1	0	0	0	0	0	0	0	0	1
<b>Total</b>	<b>2,482</b>	<b>2,545</b>	<b>6,053</b>	<b>8,256</b>	<b>5,634</b>	<b>2,523</b>	<b>949</b>	<b>305</b>	<b>173</b>	<b>28,920 (±NaN)</b>

**Broadleaf Deciduous Medium (BDM)**

Red maple	514	1,223	1,094	322	77	24	13	5	1	3,273
Littleleaf linden	175	160	666	707	197	47	7	0	0	1,959
Boxelder	13	28	69	74	38	9	1	1	2	235
Northern catalpa	23	10	14	24	64	53	20	8	2	218
Japanese snowbell	16	5	74	87	23	0	0	0	0	205
Hedge maple	60	83	30	6	0	0	0	0	0	179
White mulberry	21	31	58	29	19	4	5	3	1	171
European hornbeam	76	23	15	5	0	0	0	0	0	119
American hornbeam	59	8	6	1	0	0	0	0	0	74
Yellowwood	62	3	4	2	0	2	0	0	0	73
Amur corktree	8	5	41	16	2	0	0	0	0	72
Unknown	23	3	18	12	2	0	1	0	0	59
Amur maackia	56	0	0	0	0	0	0	0	0	56
Katsura tree	35	5	4	2	0	0	0	0	0	46
Weeping willow	2	3	4	3	5	3	11	6	8	45
Black willow	0	0	5	6	15	8	3	3	1	41
Black tupelo	18	11	7	0	0	0	0	0	0	36
Slippery elm	0	2	8	13	7	1	1	0	1	33
Maple	13	5	1	0	0	0	0	0	0	19
Common alder	16	1	1	0	0	0	0	0	0	18
Eastern hophornbeam	7	1	7	2	0	0	0	0	0	17
Red horsechestnut	12	2	1	0	0	0	0	0	0	15
Corkscrew willow	1	8	2	1	0	0	0	0	0	12
Osage-orange	0	0	4	1	2	2	0	0	0	9
Sassafras	0	2	5	2	0	0	0	0	0	9
Gray birch	2	1	3	1	1	0	0	0	0	8
Sweet cherry	0	0	4	2	0	0	0	0	0	6
Willow	3	0	0	0	0	0	0	0	0	3
Chinese chestnut	0	0	1	1	0	0	0	0	0	2
Red mulberry	0	0	0	0	0	1	1	0	0	2
Royal paulownia	0	0	1	1	0	0	0	0	0	2
European white birch	1	0	0	0	0	0	0	0	0	1
Common persimmon	0	0	0	0	1	0	0	0	0	1
American larch	0	0	0	1	0	0	0	0	0	1
<b>Total</b>	<b>1,216</b>	<b>1,623</b>	<b>2,147</b>	<b>1,321</b>	<b>453</b>	<b>154</b>	<b>63</b>	<b>26</b>	<b>16</b>	<b>7,019 (±NaN)</b>

**Broadleaf Deciduous Small (BDS)**

Apple	375	834	1,563	218	7	0	0	0	0	2,997
Callery pear	223	403	364	104	19	0	0	0	1	1,114
Eastern redbud	254	107	74	6	0	0	0	0	0	441
Plum	246	70	66	11	2	1	0	0	0	396
Serviceberry	260	90	5	0	0	0	0	0	0	355



# Complete Population of Public Trees

7/22/2009

Species	DBH Class (in)									Total Standard Error
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	
<b>Conifer Evergreen Large (CEL)</b>										
Colorado spruce	148	201	407	217	17	2	0	0	0	992
Austrian pine	35	63	457	364	44	2	0	0	0	965
Eastern white pine	93	119	207	77	20	4	0	0	0	520
Norway spruce	52	70	138	115	68	21	6	2	0	472
White spruce	88	132	146	44	3	1	0	0	0	414
Scotch pine	5	25	133	104	20	0	0	0	0	287
Douglas fir	27	30	80	35	9	1	0	0	0	182
White fir	35	14	17	18	4	0	0	0	0	88
Balsam fir	48	10	6	2	0	0	0	0	0	66
Red pine	1	6	20	24	2	0	0	0	0	53
Spruce	1	6	3	0	0	1	0	0	0	11
Leyland cypress	4	0	1	3	0	0	0	0	0	8
Japanese white pine	2	4	0	0	0	0	0	0	0	6
Ponderosa pine	0	0	0	2	1	0	0	0	0	3
Pine	1	0	0	0	0	0	0	0	0	1
Japanese black pine	0	1	0	0	0	0	0	0	0	1
<b>Total</b>	<b>540</b>	<b>681</b>	<b>1,615</b>	<b>1,005</b>	<b>188</b>	<b>32</b>	<b>6</b>	<b>2</b>	<b>0</b>	<b>4,069 (±NaN)</b>
<b>Conifer Evergreen Medium (CEM)</b>										
Northern white cedar	288	64	48	12	2	0	0	0	0	414
Eastern red cedar	43	44	54	19	1	0	0	0	0	161
Eastern hemlock	75	21	7	1	0	0	0	0	0	104
Juniper spp.	29	6	9	0	0	0	0	0	0	44
Jack pine	4	1	13	4	0	0	0	0	0	22
Serbian spruce	8	1	1	0	0	0	0	0	0	10
Nootka falsecypress	2	0	0	0	0	0	0	0	0	2
<b>Total</b>	<b>449</b>	<b>137</b>	<b>132</b>	<b>36</b>	<b>3</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>757 (±NaN)</b>
<b>Conifer Evergreen Small (CES)</b>										
Mugo pine	9	0	1	0	0	0	0	0	0	10
Yew	3	5	0	0	0	0	0	0	0	8
Hinoki falsecypress	0	0	1	0	0	0	0	0	0	1
<b>Total</b>	<b>12</b>	<b>5</b>	<b>2</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>19 (±NaN)</b>
<b>Palm Evergreen Large (PEL)</b>										
<b>Total</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0 (±NaN)</b>
<b>Palm Evergreen Medium (PEM)</b>										
<b>Total</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0 (±NaN)</b>
<b>Palm Evergreen Small (PES)</b>										
<b>Total</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0 (±NaN)</b>
<b>Grand Total</b>	<b>6,763</b>	<b>6,860</b>	<b>12,193</b>	<b>10,984</b>	<b>6,308</b>	<b>2,710</b>	<b>1,018</b>	<b>333</b>	<b>190</b>	<b>47,359 (±0)</b>

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***Appendix D***  
***Importance Value for Most Abundant Trees***

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## Importance Values for Most Abundant Public Trees

7/22/2009

Species	Number of Trees	% of Total Trees	Leaf Area (ft <sup>2</sup> )	% of Total Leaf Area	Canopy Cover (ft <sup>2</sup> )	% of Total Canopy Cover	Importance Value
Norway maple	6,264	13.2	10,017,557	10.0	4,675,644	13.8	12.3
Sugar maple	5,359	11.3	18,602,595	18.6	4,949,958	14.6	14.8
Thornless honeylocust	3,612	7.6	9,211,874	9.2	3,806,498	11.2	9.4
Red maple	3,273	6.9	4,250,216	4.3	1,088,467	3.2	4.8
Apple	2,997	6.3	1,497,000	1.5	743,141	2.2	3.3
Silver maple	2,194	4.6	11,578,338	11.6	3,297,696	9.7	8.6
Littleleaf linden	1,959	4.1	2,746,073	2.7	1,041,714	3.1	3.3
London planetree	1,541	3.3	4,317,425	4.3	1,669,826	4.9	4.2
Northern red oak	1,125	2.4	2,398,558	2.4	908,982	2.7	2.5
Callery pear	1,114	2.4	922,011	0.9	357,053	1.1	1.4
Colorado spruce	992	2.1	882,881	0.9	333,261	1.0	1.3
Austrian pine	965	2.0	1,189,355	1.2	471,310	1.4	1.5
Black walnut	822	1.7	4,203,422	4.2	1,232,722	3.6	3.2
American elm	702	1.5	3,096,986	3.1	959,545	2.8	2.5
Siberian elm	525	1.1	2,382,492	2.4	741,609	2.2	1.9
Japanese zelkova	524	1.1	1,127,609	1.1	388,763	1.1	1.1
Eastern white pine	520	1.1	437,487	0.4	163,600	0.5	0.7
Swamp white oak	516	1.1	275,493	0.3	93,721	0.3	0.5
White oak	510	1.1	2,711,611	2.7	945,577	2.8	2.2
Other trees	11,845	25.0	18,061,628	18.1	6,102,993	18.0	20.4
<b>Total</b>	<b>47,359</b>	<b>100.0</b>	<b>99,910,612</b>	<b>100.0</b>	<b>33,972,079</b>	<b>100.0</b>	<b>100.0</b>

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***Appendix E***  
***Summary of Stocking Level***

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## Summary of Available Planting Sites for Public Trees

7/23/2009

Zone	No. of Unplanted Sites	No. of Planted Sites	Total No. of Sites	Stocking (%)	No. of Unplanted Sites			
					Small	Medium	Large	Undefined
Undefined	8,853	47,359	56,212	84	2,902	2,672	3,279	0
Citywide total	8,853	47,359	56,212	84	2,902	2,672	3,279	0

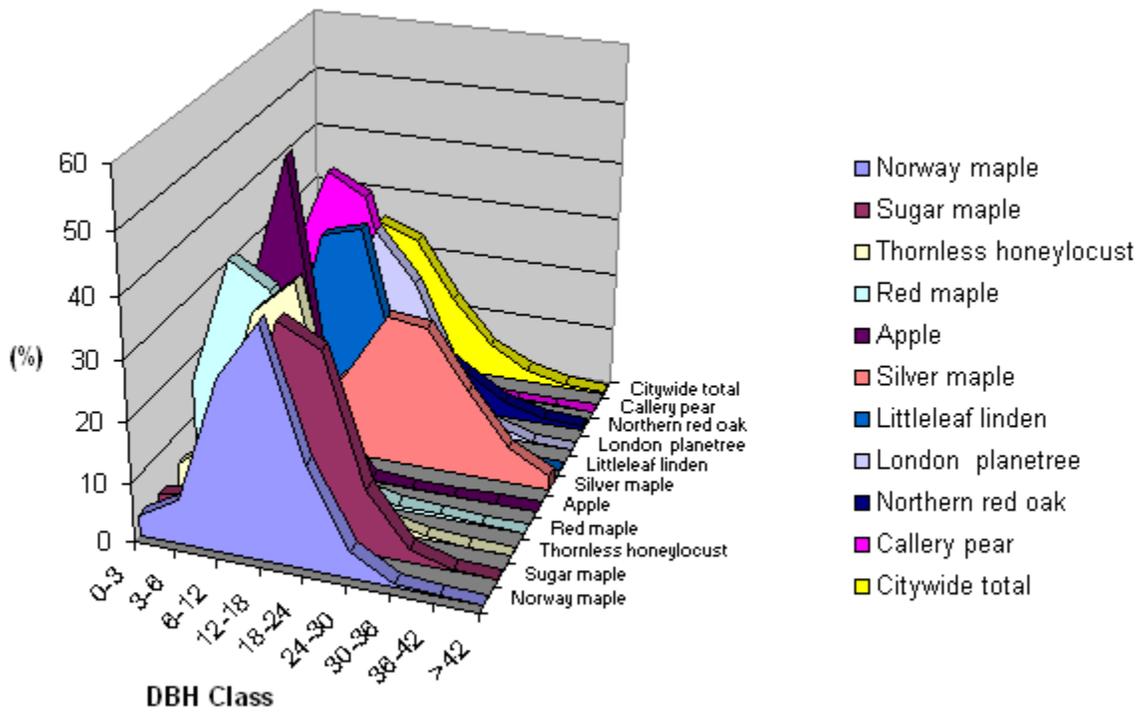
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***Appendix F***  
***Relative Age Distribution***

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**Relative Age Distribution of Top 10 Public Tree Species (%)**

7/22/2009



Species	DBH class (in)								
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42
Norway maple	3.43	7.39	28.45	38.39	17.23	4.37	0.67	0.05	0.02
Sugar maple	3.36	4.50	10.97	35.62	32.00	10.90	2.26	0.32	0.07
Thornless honeylocust	4.90	10.41	32.75	38.95	10.55	1.97	0.47	0.00	0.00
Red maple	15.70	37.37	33.42	9.84	2.35	0.73	0.40	0.15	0.03
Apple	12.51	27.83	52.15	7.27	0.23	0.00	0.00	0.00	0.00
Silver maple	2.60	3.01	7.70	14.04	25.07	24.38	14.59	6.11	2.51
Littleleaf linden	8.93	8.17	34.00	36.09	10.06	2.40	0.36	0.00	0.00
London planetree	6.04	6.75	16.35	32.97	24.98	10.58	2.21	0.13	0.00
Northern red oak	19.38	21.96	23.29	12.71	11.38	6.84	2.76	0.98	0.71
Callery pear	20.02	36.18	32.68	9.34	1.71	0.00	0.00	0.00	0.09
Citywide total	14.28	14.49	25.75	23.19	13.32	5.72	2.15	0.70	0.40

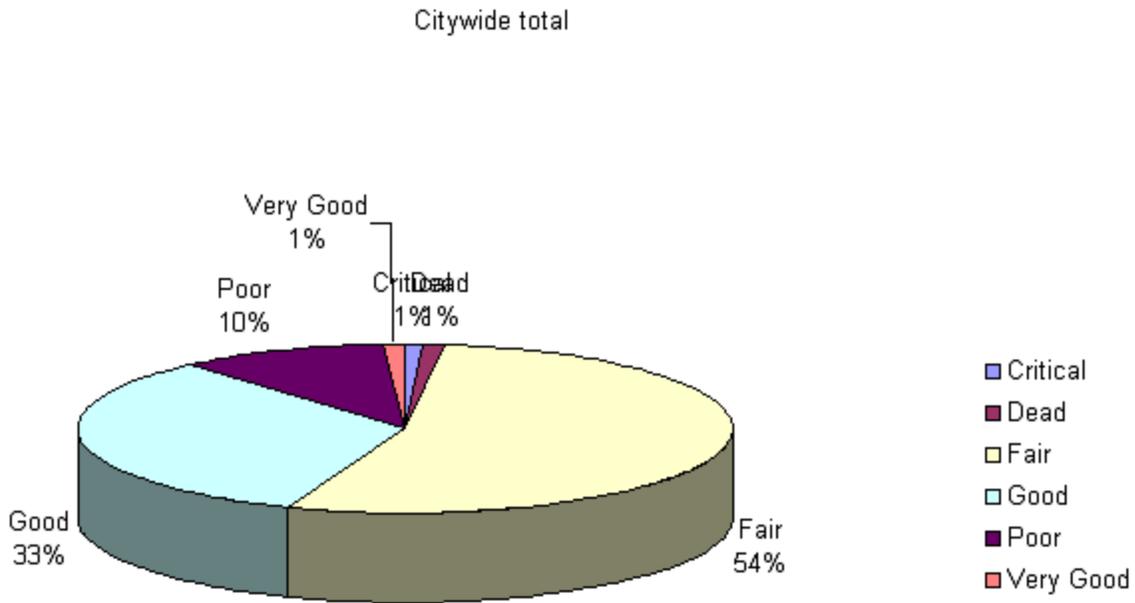
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***Appendix G***  
***Structural (Woody) Condition of Trees***

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**Structural (Woody) Condition of Public Trees by Species (%)**

7/23/2009



Species	Critical	Dead	Fair	Good	Poor	Very Good
Norway maple	0.4	0.2	61.3	27.3	10.6	0.2
Sugar maple	0.7	0.2	55.3	29.0	14.6	0.2
Thornless honeylocust	0.1	0.0	41.5	53.0	3.9	1.5
Red maple	0.5	0.5	47.9	40.1	9.7	1.3
Apple	0.8	0.9	53.0	34.4	10.1	0.8
Silver maple	0.6	0.1	60.8	17.2	21.1	0.2
Littleleaf linden	0.3	0.1	56.4	33.4	9.1	0.8
London planetree	0.2	0.2	32.3	59.6	4.4	3.4
Northern red oak	1.4	0.7	52.4	33.4	11.3	0.8
Callery pear	0.1	0.0	66.8	25.1	6.8	1.2
Colorado spruce	0.2	0.6	44.3	46.4	3.6	4.9
Austrian pine	1.9	2.4	61.7	25.5	8.2	0.4
Black walnut	0.5	0.4	62.8	27.3	8.4	0.7
American elm	1.7	7.4	63.8	19.9	7.1	0.0
Siberian elm	0.6	0.4	64.2	5.1	29.5	0.2
Japanese zelkova	0.8	0.0	65.6	30.2	3.2	0.2
Eastern white pine	0.4	0.8	48.5	45.2	4.4	0.8
Swamp white oak	1.9	0.6	58.3	26.9	9.9	2.3
White oak	0.8	0.8	66.1	20.0	12.2	0.2
Citywide total	0.7	1.1	54.1	32.6	10.3	1.1

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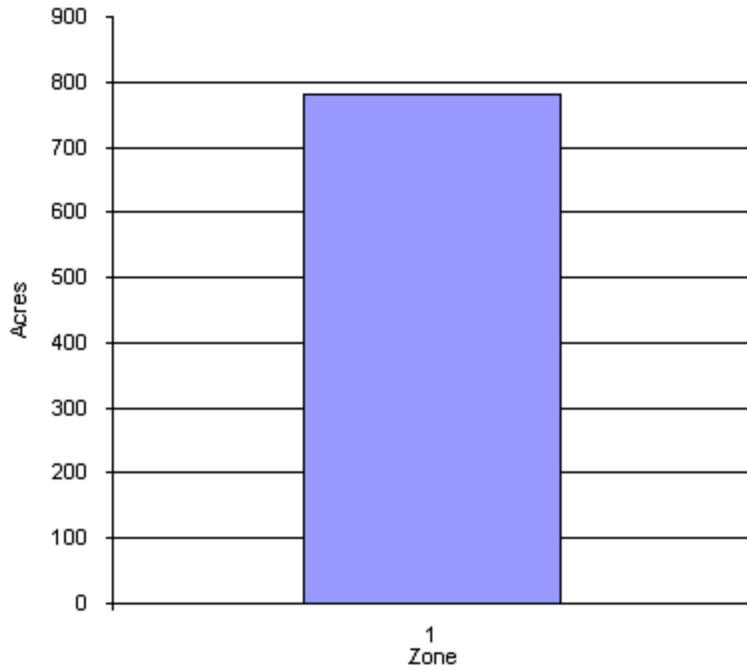
***Appendix H***  
***Canopy Cover***

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**Canopy Cover of Public Trees (Acres)**

7/22/2009

Canopy Cover



Zone	Acres	% of Total Canopy Cover
1	780	100.0
Citywide total	780	100.0

	Total Land Area	Total Street and Sidewalk Area	Total Canopy Cover	Canopy Cover as % of Total Land Area	Canopy Cover as % of Total Streets and Sidewalks
Citywide total	17,280	2,182	780	4.51	35.75

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***Appendix I***  
***Replacement Value (by Species and Zone)***

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# Replacement Value for Public Trees by Species

7/22/2009

Species	DBH Class (in)									Total	Standard Error	% of Total
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42			
Norway maple	28,317	175,134	2,140,131	7,422,467	6,064,135	2,280,653	473,495	37,006	20,675	18,642,012	(±0)	14.1969263572%
Sugar maple	27,554	81,038	501,225	3,991,064	6,550,981	3,332,378	948,721	83,764	27,715	15,544,439	(±0)	11.8379530837%
Thornless honeylocust	20,762	158,307	1,807,130	5,986,591	3,111,186	962,318	310,222	0	0	12,356,516	(±0)	9.41017286029%
Red maple	43,998	564,984	1,972,118	1,556,619	680,889	338,983	278,347	149,733	30,901	5,616,571	(±0)	4.27733082256%
Apple	44,180	345,373	2,120,358	741,481	36,849	0	0	0	0	3,288,241	(±0)	2.50417790484%
Silver maple	9,831	20,780	142,752	560,715	1,851,321	2,852,152	2,376,973	1,399,162	627,056	9,840,742	(±0)	7.49427149908%
Littleleaf linden	19,810	68,659	1,018,923	2,962,180	1,584,073	467,737	112,825	0	0	6,234,208	(±0)	4.74769547956%
London planetree	10,185	45,506	419,180	2,430,813	3,624,979	2,385,461	797,689	49,192	0	9,763,006	(±0)	7.43507063204%
Northern red oak	14,033	109,061	522,635	811,442	1,311,135	1,154,669	643,377	288,994	254,467	5,109,812	(±0)	3.89140547248%
Callery pear	38,736	141,777	314,097	185,562	11,948	0	0	0	13,858	705,978	(±0)	0.53764142450%
Colorado spruce	19,634	87,459	597,210	823,445	132,656	22,379	0	0	0	1,682,784	(±0)	1.28153375975%
Austrian pine	7,504	17,244	243,231	415,547	96,198	1,958	0	0	0	781,681	(±0)	0.59529322158%
Black walnut	2,017	10,530	160,541	569,750	1,370,928	1,407,365	852,600	334,593	170,570	4,878,894	(±0)	3.71554821887%
American elm	10,691	13,168	113,947	273,173	458,350	535,387	643,890	383,658	161,672	2,593,935	(±0)	1.97542570751%
Siberian elm	1,739	9,663	43,769	81,385	144,910	208,356	146,301	78,424	49,281	763,827	(±0)	0.58169689110%
Japanese zelkova	6,547	33,662	323,131	734,338	476,840	31,034	3,562	0	0	1,609,113	(±0)	1.22542912500%
Eastern white pine	12,797	54,137	293,767	324,929	161,569	49,421	0	0	0	896,619	(±0)	0.68282550398%
Swamp white oak	25,573	83,340	65,435	41,819	15,486	12,756	18,585	0	0	262,994	(±0)	0.20028475888%
White oak	883	2,727	47,119	385,620	1,570,956	1,471,144	1,459,618	731,437	689,061	6,358,564	(±0)	4.84239963059%
Norway spruce	3,564	32,604	222,382	527,384	659,439	340,173	142,922	0	0	1,928,468	(±0)	1.46863540535%
American basswood	149	6,451	52,029	395,953	1,015,614	1,270,332	408,299	168,074	27,493	3,344,394	(±0)	2.54694131650%
Eastern redbud	43,897	36,673	49,896	8,411	0	0	0	0	0	138,877	(±0)	0.10576264275%
White spruce	8,574	59,210	240,709	207,104	15,486	2,126	0	0	0	533,208	(±0)	0.40606752451%
Northern white cedar	33,718	33,162	76,505	37,504	7,743	0	0	0	0	188,632	(±0)	0.14365380592%
Plum	39,201	22,276	53,506	18,048	3,983	6,490	0	0	0	143,503	(±0)	0.10928513917%
Shagbark hickory	1,939	9,576	153,178	385,665	449,485	170,006	39,650	0	0	1,209,499	(±0)	0.92110039110%
Bur oak	4,353	15,378	100,367	150,681	445,863	662,274	510,104	364,844	1,081,375	3,335,239	(±0)	2.53996992162%
Serviceberry	28,761	38,322	7,995	0	0	0	0	0	0	75,078	(±0)	0.05717621851%
Northern hackberry	32,057	24,294	17,604	16,079	50,459	0	16,962	0	0	157,455	(±0)	0.11991079722%
Tulip tree	11,589	16,284	60,688	152,804	312,366	306,785	23,621	0	0	884,137	(±0)	0.67331953288%
Scotch pine	956	8,440	116,070	226,564	87,953	0	0	0	0	439,983	(±0)	0.33507138638%
Hawthorn	10,097	42,583	63,848	11,664	0	0	0	0	0	128,191	(±0)	0.09762485478%
Black locust	1,457	5,542	47,862	161,264	359,099	113,070	113,928	18,503	20,675	841,400	(±0)	0.64077313327%
Eastern cottonwood	467	1,629	15,453	59,488	171,719	159,973	155,081	24,211	41,067	629,089	(±0)	0.47908597540%
Black cherry	396	3,659	59,804	126,862	158,979	83,282	70,183	29,989	0	533,155	(±0)	0.40602676421%

Species	DBH Class (in)									Total	Standard Error	% of Total
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42			
Boxelder	1,966	4,995	35,883	88,488	57,750	7,571	0	0	13,858	210,510	(±0)	0.160315225939
Ginkgo	11,858	19,378	42,041	72,729	54,269	95,488	21,374	0	0	317,136	(±0)	0.241516751850
Freeman maple	3,427	26,443	74,738	111,793	15,267	0	0	0	0	231,668	(±0)	0.176427869958
Northern catalpa	3,413	3,419	9,555	36,271	165,285	240,113	123,125	62,047	13,858	657,086	(±0)	0.500407166010
Pin oak	3,646	4,434	84,151	124,759	90,940	25,958	55,293	17,580	27,715	434,476	(±0)	0.330877588327
Japanese snowbell	1,484	2,399	122,994	433,033	217,798	0	0	0	0	777,708	(±0)	0.592267793374
English oak	1,349	13,041	162,851	211,086	98,077	12,756	0	0	0	499,161	(±0)	0.380138588571
Douglas fir	4,292	12,285	88,748	113,595	52,766	0	0	0	0	271,686	(±0)	0.206903896540
Hedge maple	6,630	41,251	47,847	30,535	0	0	0	0	0	126,262	(±0)	0.096155697800
White mulberry	3,478	6,744	23,180	25,578	26,984	13,424	9,736	12,632	0	121,756	(±0)	0.092724123477
Sweetgum	4,942	27,461	97,960	32,283	24,602	0	0	0	0	187,247	(±0)	0.142599341789
Eastern red cedar	5,928	17,827	63,945	61,108	5,863	0	0	0	0	154,671	(±0)	0.117790923790
American sycamore	134	1,416	21,993	143,261	219,368	421,808	191,773	26,212	20,675	1,046,643	(±0)	0.797076582354
Japanese tree lilac	14,086	17,704	11,239	0	0	0	0	0	0	43,029	(±0)	0.032768995240
River birch	12,349	7,975	27,419	8,621	8,306	0	0	0	0	64,669	(±0)	0.049249229797
Kentucky coffeetree	3,586	3,580	107,484	109,835	36,903	69,229	20,880	27,643	0	379,140	(±0)	0.288735911754
European hornbeam	7,304	11,193	10,086	21,573	0	0	0	0	0	50,157	(±0)	0.038197054877
Ash	287	3,365	25,266	33,117	18,586	3,786	0	0	0	84,408	(±0)	0.064281155994
Eastern hemlock	11,452	9,145	9,592	3,043	0	0	0	0	0	33,232	(±0)	0.025307733177
Horsechestnut	1,611	7,158	24,559	28,211	37,504	51,916	9,404	0	0	160,364	(±0)	0.122125719110
White ash	1,693	4,701	3,256	701	0	1,082	0	0	0	11,432	(±0)	0.008706234204
Black oak	1,345	523	16,858	40,316	103,088	126,703	147,226	37,006	49,965	523,030	(±0)	0.398316712520
White fir	2,669	7,556	33,550	101,328	42,502	0	0	0	0	187,605	(±0)	0.142871427790
Amur maple	3,014	8,868	11,820	6,085	5,863	0	0	0	0	35,650	(±0)	0.027149769999
Japanese maple	5,316	7,916	24,600	3,983	0	0	0	0	0	41,814	(±0)	0.031843780420
Shingle oak	4,467	10,182	16,359	5,642	0	0	0	0	0	36,650	(±0)	0.027910800608
Pignut hickory	0	739	9,592	64,658	162,694	162,789	82,099	0	0	482,571	(±0)	0.367504408830
American hornbeam	5,789	4,219	8,856	3,983	0	0	0	0	0	22,847	(±0)	0.017399223600
Yellowwood	9,301	893	3,972	3,043	0	0	0	0	0	17,209	(±0)	0.013105543520
Washington hawthorn	1,883	18,813	16,568	0	0	0	0	0	0	37,263	(±0)	0.028377830590
Amur corktree	655	2,215	62,857	76,068	13,748	0	0	0	0	155,544	(±0)	0.118455318940
Balsam fir	10,241	3,508	3,662	3,294	0	0	0	0	0	20,705	(±0)	0.015767980358
Goldenrain tree	4,773	4,219	3,567	23,233	7,743	0	0	0	0	43,535	(±0)	0.033154337980
Tree of heaven	773	1,901	8,798	8,138	22,253	11,467	9,736	6,316	0	69,383	(±0)	0.052838750184
Unknown	1,213	775	17,143	31,169	10,130	0	12,468	0	0	72,899	(±0)	0.055516254410
Honeylocust	599	1,346	20,449	60,009	83,335	33,569	16,290	21,550	0	237,147	(±0)	0.180600798220
Flowering dogwood	5,680	3,926	3,256	0	0	0	0	0	0	12,862	(±0)	0.009795166660
Amur maackia	7,217	0	0	0	0	0	0	0	0	7,217	(±0)	0.005496091979
Common buckthorn	2,130	5,315	12,739	0	0	0	0	0	0	20,185	(±0)	0.015371790740
Paradise apple	724	6,678	15,712	6,308	0	0	0	0	0	29,421	(±0)	0.022405843580

Species	DBH Class (in)									Total	Standard Error	% of Total
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42			
Red pine	170	2,626	24,627	85,184	16,440	0	0	0	0	129,048	(±0)	0.098276910929
Striped maple	5,648	369	0	0	0	0	0	0	0	6,017	(±0)	0.00458248604
Katsura tree	2,366	2,259	9,394	11,897	0	0	0	0	0	25,916	(±0)	0.01973654734
White fringetree	8,711	321	0	0	0	0	0	0	0	9,032	(±0)	0.006878174410
Weeping willow	181	1,698	8,571	10,761	38,350	42,970	137,954	66,804	105,580	412,868	(±0)	0.31442157417
Hardy rubber tree	4,686	1,035	0	0	0	0	0	0	0	5,721	(±0)	0.00435692917
Juniper spp.	3,642	2,217	14,339	0	0	0	0	0	0	20,198	(±0)	0.015381936500
Miyabei maple	7,319	1,229	0	0	0	0	0	0	0	8,547	(±0)	0.00650915442
Hybrid elm	4,506	3,365	3,751	0	0	0	0	0	0	11,622	(±0)	0.00885104320
Black willow	0	0	3,397	6,308	23,897	27,040	18,807	42,399	13,858	135,705	(±0)	0.10334716142
Dawn redwood	1,929	2,510	24,082	0	24,602	40,582	0	0	0	93,704	(±0)	0.071361163279
Black tupelo	1,971	3,766	10,332	0	0	0	0	0	0	16,068	(±0)	0.012236992460
Bitternut hickory	538	1,786	6,104	3,043	71,820	42,502	27,988	0	0	153,780	(±0)	0.11711215810
Slippery elm	0	739	9,107	41,077	45,926	9,623	0	0	20,675	127,147	(±0)	0.09682932462
Kousa dogwood	1,612	4,798	0	0	0	0	0	0	0	6,411	(±0)	0.00488200959
Paperbark maple	4,301	2,003	0	0	0	0	0	0	0	6,304	(±0)	0.00480103732
Mockernut hickory	0	886	22,993	19,666	50,651	42,970	0	0	0	137,166	(±0)	0.10445942396
Green ash	986	493	2,519	10,142	0	0	0	0	0	14,140	(±0)	0.01076856602
Chinese magnolia; Sauce	1,827	2,298	7,146	9,953	0	0	0	0	0	21,224	(±0)	0.016163143420
Persian parrotia	4,315	641	0	0	0	0	0	0	0	4,956	(±0)	0.003774034150
Silver linden	1,244	4,150	10,701	13,608	0	0	0	0	0	29,702	(±0)	0.02261960908
Elm	0	935	6,440	8,586	2,323	0	0	0	0	18,285	(±0)	0.01392470486
Tatarian maple	3,099	0	0	0	0	0	0	0	0	3,099	(±0)	0.00236040148
Pagoda dogwood	1,789	321	0	0	0	0	0	0	0	2,109	(±0)	0.00160626447
Common smoketree	2,703	1,736	0	0	0	0	0	0	0	4,440	(±0)	0.00338103068
Jack pine	928	321	11,395	9,287	0	0	0	0	0	21,931	(±0)	0.016701310610
Maple	1,020	1,078	678	0	0	0	0	0	0	2,776	(±0)	0.00211377406
Sycamore maple	0	0	4,651	15,721	5,863	0	0	0	0	26,234	(±0)	0.019978750650
Paper birch	888	962	6,157	13,142	0	0	0	0	0	21,148	(±0)	0.01610553364
Sawtooth oak	631	3,522	2,091	0	0	0	0	0	0	6,243	(±0)	0.00475472374
Smoothleaf elm	164	1,549	7,219	13,142	3,983	6,490	0	0	0	32,546	(±0)	0.02478565131
Common alder	1,673	0	1,633	0	0	0	0	0	0	3,305	(±0)	0.00251708292
Star magnolia	1,585	2,022	0	0	0	0	0	0	0	3,608	(±0)	0.002747425990
Eastern hophornbeam	736	593	9,471	7,966	0	0	0	0	0	18,765	(±0)	0.01429051423
American beech	1,128	952	3,188	7,025	0	0	16,290	0	0	28,583	(±0)	0.021767813190
Red horsechestnut	1,670	893	1,163	0	0	0	0	0	0	3,725	(±0)	0.00283697534
Magnolia	1,611	321	4,954	0	0	0	0	0	0	6,886	(±0)	0.00524399588
common lilac	1,379	1,282	0	0	0	0	0	0	0	2,661	(±0)	0.00202660049
Sargent cherry	1,502	0	0	0	0	0	0	0	0	1,502	(±0)	0.00114354788
Common pear	232	454	2,548	10,513	0	0	0	0	0	13,747	(±0)	0.01046946602

Species	DBH Class (in)									Total	Standard Error	% of Total
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42			
Corkscrew willow	232	2,698	849	2,103	0	0	0	0	0	5,882	(±0)	0.00447932460
Turkish hazelnut	1,165	0	3,567	0	0	0	0	0	0	4,732	(±0)	0.00360350686
English walnut	0	0	8,610	19,914	0	0	19,023	0	0	47,547	(±0)	0.03620979544
Spruce	70	1,379	2,309	0	0	6,527	0	0	0	10,285	(±0)	0.00783251250
Serbian spruce	1,468	523	1,163	0	0	0	0	0	0	3,154	(±0)	0.00240198388
Mugo pine	1,707	0	759	0	0	0	0	0	0	2,466	(±0)	0.00187804740
Bigtooth aspen	0	0	1,295	2,325	14,894	3,356	0	0	0	21,871	(±0)	0.01665563556
American filbert	1,051	641	0	0	0	0	0	0	0	1,692	(±0)	0.00128885372
Osage-orange	0	0	4,898	4,453	8,683	14,323	0	0	0	32,357	(±0)	0.02464160628
Sassafras	0	739	0	3,550	0	0	0	0	0	4,289	(±0)	0.00326616296
Baldcypress	569	593	2,091	0	0	0	0	0	0	3,253	(±0)	0.00247736973
Three-flower maple	0	2,617	3,972	0	0	0	0	0	0	6,590	(±0)	0.00501828141
Gray birch	328	321	1,840	2,103	3,983	0	0	0	0	8,574	(±0)	0.00652942155
Leyland cypress	232	0	849	7,184	0	0	0	0	0	8,266	(±0)	0.00629469179
Yew	359	2,092	0	0	0	0	0	0	0	2,451	(±0)	0.00186678827
Trident maple	784	0	1,647	0	0	0	0	0	0	2,431	(±0)	0.00185171419
European beech	218	0	4,898	10,761	0	0	0	0	0	15,877	(±0)	0.01209148914
Goldenchain tree	492	1,229	0	0	0	0	0	0	0	1,720	(±0)	0.00131003220
Oak	123	488	0	2,323	4,517	7,441	0	0	0	14,892	(±0)	0.01134112593
Shumard oak	0	0	10,701	0	0	0	0	0	0	10,701	(±0)	0.00814933643
Yellow buckeye	860	0	1,203	2,103	0	0	0	0	0	4,166	(±0)	0.00317267568
Japanese white pine	170	1,576	0	0	0	0	0	0	0	1,746	(±0)	0.00132932478
White poplar	0	0	0	0	10,513	0	0	0	0	10,513	(±0)	0.00800654240
Quaking aspen	0	0	1,072	2,325	2,979	0	0	0	0	6,376	(±0)	0.00485565766
Sweet cherry	0	0	3,972	3,043	0	0	0	0	0	7,015	(±0)	0.00534237076
Peach	819	0	0	0	0	0	0	0	0	819	(±0)	0.00062389466
Viburnum	983	0	0	0	0	0	0	0	0	983	(±0)	0.00074867360
American smoketree	478	0	0	0	0	0	0	0	0	478	(±0)	0.00036393855
Russian olive	0	0	1,699	2,103	0	0	0	0	0	3,801	(±0)	0.00289487713
Butternut	134	369	2,325	0	0	0	0	0	0	2,829	(±0)	0.00215461856
European mountain ash	0	0	2,548	0	0	0	0	0	0	2,548	(±0)	0.00194035298
Black maple	0	0	849	4,205	0	0	0	0	0	5,055	(±0)	0.00384940129
Ohio buckeye	860	0	0	0	0	0	0	0	0	860	(±0)	0.00065508940
Pussy willow	0	641	849	0	0	0	0	0	0	1,490	(±0)	0.00113497323
Ponderosa pine	0	0	0	8,489	6,803	0	0	0	0	15,292	(±0)	0.01164571542
Willow	492	0	0	0	0	0	0	0	0	492	(±0)	0.00037433680
Tamarix	0	641	0	2,103	0	0	0	0	0	2,744	(±0)	0.00208949738
Western sugar maple	328	0	0	0	0	0	0	0	0	328	(±0)	0.00024955786
Pawpaw	164	0	0	0	0	0	0	0	0	164	(±0)	0.00012477893
Chinese chestnut	0	0	849	2,979	0	0	0	0	0	3,828	(±0)	0.00291530467

Species	DBH Class (in)									Total	Standard Error	% of Total
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42			
Nootka falsecypress	269	0	0	0	0	0	0	0	0	269	(±0)	0.00020481454
European filbert	0	641	0	0	0	0	0	0	0	641	(±0)	0.00048818890
European larch	0	523	0	0	5,863	0	0	0	0	6,386	(±0)	0.00486350338
Sweetbay magnolia	396	0	0	0	0	0	0	0	0	396	(±0)	0.00030154908
Red mulberry	0	0	0	0	0	3,356	4,813	0	0	8,169	(±0)	0.00622130803
Royal paulownia	0	0	849	2,103	0	0	0	0	0	2,952	(±0)	0.00224809281
Pin cherry	164	454	0	0	0	0	0	0	0	618	(±0)	0.00047057940
Scarlet oak	0	0	0	0	0	12,756	0	0	0	12,756	(±0)	0.00971476377
American mountain ash	0	0	849	0	0	0	0	0	0	849	(±0)	0.00064678432
Caucasian linden	298	0	0	0	0	0	0	0	0	298	(±0)	0.00022676757
Tag alder	164	0	0	0	0	0	0	0	0	164	(±0)	0.00012477893
Allegheny serviceberry	0	0	0	2,103	0	0	0	0	0	2,103	(±0)	0.00160130848
Devils-walkingstick	0	321	0	0	0	0	0	0	0	321	(±0)	0.00024409445
European white birch	274	0	0	0	0	0	0	0	0	274	(±0)	0.00020846334
Hinoki falsecypress	0	0	536	0	0	0	0	0	0	536	(±0)	0.00040815329
gray dogwood	232	0	0	0	0	0	0	0	0	232	(±0)	0.00017677015
Cornelian cherry	128	0	0	0	0	0	0	0	0	128	(±0)	9.75371937619
Cockspur hawthorn	0	369	0	0	0	0	0	0	0	369	(±0)	0.00028138055
Common persimmon	0	0	0	0	5,642	0	0	0	0	5,642	(±0)	0.00429688417
Blue ash	134	0	0	0	0	0	0	0	0	134	(±0)	0.00010240727
Carolina silverbell	232	0	0	0	0	0	0	0	0	232	(±0)	0.00017677015
Witch hazel	149	0	0	0	0	0	0	0	0	149	(±0)	0.00011338378
Holly	149	0	0	0	0	0	0	0	0	149	(±0)	0.00011338378
American larch	0	0	0	4,453	0	0	0	0	0	4,453	(±0)	0.00339104126
Pine	96	0	0	0	0	0	0	0	0	96	(±0)	7.27877111370
Japanese black pine	0	0	0	0	0	0	0	0	0	0	(±0)	0
Cherry plum	0	385	0	0	0	0	0	0	0	385	(±0)	0.00029297849
Chestnut oak	0	0	0	2,979	0	0	0	0	0	2,979	(±0)	0.00226852034
Northern pin oak	0	0	0	0	0	0	0	0	0	0	(±0)	0
Chinkapin oak	0	0	0	0	0	0	0	24,596	0	24,596	(±0)	0.01873140292
Willow oak	105	0	0	0	0	0	0	0	0	105	(±0)	8.00356137410
Bristly locust	0	0	0	0	0	0	0	0	0	0	(±0)	0
Yellowhorn	164	0	0	0	0	0	0	0	0	164	(±0)	0.00012477893
Citywide total	834,396	2,789,508	15,855,444	35,302,015	34,922,927	22,166,257	11,471,231	4,486,369	3,482,048	131,310,194	(±0)	100

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***Appendix J***  
***Annual Management Costs***

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## Annual Management Costs of Public Trees

7/22/2009

Expenditures	Total (\$)	\$/Tree	\$/Capita
Purchasing Trees and Planting	380,414	8.03	3.34
Contract Pruning	329,260	6.95	2.89
Pest Management	303	0.01	0.00
Irrigation	1,012	0.02	0.01
Removal	585,544	12.36	5.14
Administration	210,726	4.45	1.85
Inspection/Service	17,918	0.38	0.16
Infrastructure Repairs	0	0.00	0.00
Litter Clean-up	76,858	1.62	0.67
Liability/Claim	0	0.00	0.00
Other Cost	107,766	2.28	0.95
Total Expenditures	1,709,801	36.10	15.00

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***Appendix K***  
***Annual Benefits Energy (by Species and Zone)***

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## Annual Energy Benefits of Public Trees By Species

7/22/2009

Species	Total Electricity (MWh)	Electricity (\$)	Total Natural Gas (Therms)	Natural Gas (\$)	Total (\$)	Standard Error	% of Total Trees	% of Total \$	Avg. \$/tree
Norway maple	489.5	68,581	182,670.3	257,200	325,780	(N/A)	13.2	14.5	52.01
Sugar maple	511.4	71,648	194,683.3	274,114	345,762	(N/A)	11.3	15.4	64.52
Thornless honeylocust	376.7	52,774	134,833.8	189,846	242,620	(N/A)	7.6	10.8	67.17
Red maple	115.1	16,128	48,411.6	68,163	84,292	(N/A)	6.9	3.7	25.75
Apple	77.4	10,850	37,298.4	52,516	63,367	(N/A)	6.3	2.8	21.14
Silver maple	303.0	42,448	109,185.6	153,733	196,182	(N/A)	4.6	8.7	89.42
Littleleaf linden	117.7	16,494	43,278.5	60,936	77,431	(N/A)	4.1	3.4	39.53
London planetree	164.8	23,085	59,250.7	83,425	106,510	(N/A)	3.3	4.7	69.12
Northern red oak	86.2	12,070	31,626.2	44,530	56,600	(N/A)	2.4	2.5	50.31
Callery pear	36.2	5,073	12,971.2	18,263	23,337	(N/A)	2.4	1.0	20.95
Colorado spruce	36.5	5,108	12,480.0	17,572	22,680	(N/A)	2.1	1.0	22.86
Austrian pine	52.3	7,326	17,395.9	24,493	31,819	(N/A)	2.0	1.4	32.97
Black walnut	115.6	16,202	40,850.4	57,517	73,720	(N/A)	1.7	3.3	89.68
American elm	87.3	12,237	29,489.2	41,521	53,758	(N/A)	1.5	2.4	76.58
Siberian elm	68.0	9,526	23,141.6	32,583	42,109	(N/A)	1.1	1.9	80.21
Japanese zelkova	47.4	6,646	17,871.5	25,163	31,809	(N/A)	1.1	1.4	60.70
Eastern white pine	17.4	2,434	6,106.6	8,598	11,032	(N/A)	1.1	0.5	21.21
Swamp white oak	9.4	1,312	4,011.8	5,649	6,961	(N/A)	1.1	0.3	13.49
White oak	79.3	11,108	25,118.3	35,367	46,475	(N/A)	1.1	2.1	91.13
Other street trees	617.3	86,483	229,638.0	323,330	409,813	(N/A)	25.0	18.2	34.60
Citywide total	3,408.5	477,534	1,260,313.0	1,774,521	2,252,055	(N/A)	100.0	100.0	47.55

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***Appendix L***  
***Annual Benefits Carbon Dioxide (by Species and Zone)***

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**Ann Arbor**

**Annual CO Benefits of Public Trees by Species**

7/22/2009

Species	Sequestered (lb)	Sequestered (\$)	Decomposition Release (lb)	Maintenance Release (lb)	Total Released (\$)	Avoided (lb)	Avoided (\$)	Net Total (lb)	Total Standard (\$)	Standard Error	% of Total Trees	% of Total \$	Avg. \$/tree
Norway maple	1,685,927	5,631	-303,466	-65,582	-1,233	1,474,400	4,924	2,791,279	9,323	(N/A)	13.2	17.8	1.49
Sugar maple	1,267,463	4,233	-286,812	-69,974	-1,192	1,540,337	5,145	2,451,014	8,186	(N/A)	11.3	15.6	1.53
Thornless honeylocust	522,501	1,745	-183,791	-33,650	-726	1,134,570	3,789	1,439,630	4,808	(N/A)	7.6	9.2	1.33
Red maple	215,178	719	-52,102	-18,186	-235	346,742	1,158	491,632	1,642	(N/A)	6.9	3.1	0.50
Apple	154,160	515	-38,459	-16,600	-184	233,271	779	332,373	1,110	(N/A)	6.3	2.1	0.37
Silver maple	634,900	2,121	-148,307	-38,547	-624	912,590	3,048	1,360,636	4,545	(N/A)	4.6	8.7	2.07
Littleleaf linden	232,811	778	-80,214	-17,649	-327	354,612	1,184	489,560	1,635	(N/A)	4.1	3.1	0.83
London planetree	251,756	841	-42,163	-18,414	-202	496,308	1,658	687,487	2,296	(N/A)	3.3	4.4	1.49
Northern red oak	193,116	645	-35,854	-9,517	-152	259,501	867	407,246	1,360	(N/A)	2.4	2.6	1.21
Callery pear	129,170	431	-3,903	-1,272	-17	109,074	364	233,069	778	(N/A)	2.4	1.5	0.70
Colorado spruce	37,885	127	-10,671	-6,439	-57	109,819	367	130,594	436	(N/A)	2.1	0.8	0.44
Austrian pine	51,063	171	-15,963	-8,291	-81	157,499	526	184,309	616	(N/A)	2.0	1.2	0.64
Black walnut	191,362	639	-75,928	-11,947	-294	348,329	1,163	451,815	1,509	(N/A)	1.7	2.9	1.84
American elm	241,729	807	-59,794	-9,222	-231	263,088	879	435,800	1,456	(N/A)	1.5	2.8	2.07
Siberian elm	186,259	622	-51,032	-7,167	-194	204,788	684	332,848	1,112	(N/A)	1.1	2.1	2.12
Japanese zelkova	70,596	236	-17,218	-4,278	-72	142,872	477	191,971	641	(N/A)	1.1	1.2	1.22
Eastern white pine	18,060	60	-4,618	-3,214	-26	52,318	175	62,545	209	(N/A)	1.1	0.4	0.40
Swamp white oak	24,488	82	-3,436	-1,485	-16	28,213	94	47,780	160	(N/A)	1.1	0.3	0.31
White oak	309,315	1,033	-63,099	-9,148	-241	238,818	798	475,886	1,589	(N/A)	1.1	3.0	3.12
Other street trees	1,248,141	4,169	-318,317	-82,864	-1,340	1,859,276	6,210	2,706,236	9,039	(N/A)	25.0	17.2	0.76
Citywide total	7,665,878	25,604	-1,795,148	-433,447	-7,444	10,266,425	34,290	15,703,708	52,450	(N/A)	100.0	100.0	1.11

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***Appendix M***  
***Annual Benefits Air Quality (by Species and Zone)***

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# Annual Air Quality Benefits of Public Trees by Species

7/23/2009

Species	Deposition (lb)				Total Depos. (\$)	Avoided (lb)				Total Avoided (\$)	BVOC Emissions (lb)	BVOC Emissions (\$)	Total (lb)	Total Standard (\$) Error	% of Total Trees	Avg. \$/tree
	O <sub>3</sub>	NO <sub>2</sub>	PM <sub>10</sub>	SO <sub>2</sub>		NO <sub>2</sub>	PM <sub>10</sub>	VOC	SO <sub>2</sub>							
Norway maple	2,602.9	1,125.2	1,278.0	427.1	29,218	4,225.1	273.9	162.7	2,148.6	29,522	-367.1	-848	11,876.4	57,893 (N/A)	13.2	9.24
Sugar maple	2,755.6	1,191.3	1,353.0	452.2	30,933	4,453.3	289.0	172.1	2,244.9	31,052	-1,489.7	-3,441	11,421.5	58,543 (N/A)	11.3	10.92
Thornless honeylocust	1,941.3	786.6	921.9	297.8	21,219	3,192.8	206.5	122.1	1,653.0	22,406	-840.5	-1,942	8,281.6	41,683 (N/A)	7.6	11.54
Red maple	582.3	251.5	290.5	97.2	6,579	1,049.2	68.5	41.2	505.6	7,240	-178.7	-413	2,707.3	13,406 (N/A)	6.9	4.10
Apple	446.6	195.0	217.8	76.1	5,020	754.1	49.6	30.3	340.4	5,128	-3.6	-8	2,106.2	10,139 (N/A)	6.3	3.38
Silver maple	1,835.8	793.6	901.3	301.2	20,608	2,575.6	166.6	98.6	1,329.7	18,062	-614.3	-1,419	7,388.2	37,250 (N/A)	4.6	16.98
Littleleaf linden	559.9	235.3	269.8	86.0	6,191	1,009.5	65.4	38.8	516.7	7,065	-296.5	-685	2,484.9	12,571 (N/A)	4.1	6.42
London planetree	897.4	377.2	432.5	137.8	9,924	1,399.4	90.5	53.6	723.1	9,816	-926.5	-2,140	3,185.1	17,600 (N/A)	3.3	11.42
Northern red oak	486.3	210.0	242.6	81.2	5,494	738.3	47.8	28.4	378.1	5,168	-436.1	-1,007	1,776.5	9,654 (N/A)	2.4	8.58
Callery pear	214.6	93.7	104.6	36.6	2,412	307.0	19.9	11.7	158.9	2,154	0.0	0	947.0	4,566 (N/A)	2.4	4.10
Colorado spruce	253.1	121.0	160.4	68.5	3,288	303.2	19.6	11.5	160.0	2,138	-557.1	-1,287	540.2	4,139 (N/A)	2.1	4.17
Austrian pine	357.9	171.2	226.8	96.8	4,651	429.7	27.7	16.2	229.4	3,038	-750.5	-1,734	805.4	5,955 (N/A)	2.0	6.17
Black walnut	662.5	278.5	319.3	101.7	7,326	974.7	63.0	37.2	507.5	6,849	0.0	0	2,944.4	14,175 (N/A)	1.7	17.25
American elm	489.4	198.3	232.4	75.1	5,349	722.2	46.6	27.4	383.2	5,099	0.0	0	2,174.5	10,448 (N/A)	1.5	14.88
Siberian elm	378.2	153.3	179.6	58.0	4,134	564.1	36.4	21.4	298.3	3,979	0.0	0	1,689.3	8,113 (N/A)	1.1	15.45
Japanese zelkova	208.9	87.8	100.7	32.1	2,311	411.2	26.7	15.9	208.2	2,870	0.0	0	1,091.4	5,181 (N/A)	1.1	9.89
Eastern white pine	124.2	59.4	78.7	33.6	1,614	146.1	9.4	5.6	76.2	1,027	-276.0	-638	257.3	2,004 (N/A)	1.1	3.85
Swamp white oak	50.1	21.7	25.0	8.4	566	86.1	5.6	3.4	41.1	593	-45.6	-105	195.8	1,054 (N/A)	1.1	2.04
White oak	505.9	218.5	252.4	84.4	5,716	638.8	41.0	23.9	347.8	4,539	-449.1	-1,038	1,663.5	9,217 (N/A)	1.1	18.07
Other street trees	3,439.8	1,491.0	1,756.6	606.9	39,341	5,320.7	344.8	204.8	2,709.4	37,190	-1,971.5	-4,554	13,902.6	71,977 (N/A)	25.0	6.08
Citywide total	18,792.6	8,060.0	9,343.9	3,158.7	211,894	29,301.3	1,898.4	1,126.9	14,960.3	204,934	-9,203.0	-21,259	77,439.1	395,569 (N/A)	100.0	8.35

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***Appendix N***  
***Annual Benefits Stormwater (by Species and Zone)***

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## Annual Stormwater Benefits of Public Trees by Species

7/23/2009

Species	Total rainfall interception (Gal)	Total (\$)	Standard Error	% of Total Trees	% of Total \$	Avg. \$/tree
Norway maple	7,754,549	62,041	(N/A)	13.2	11.9	9.90
Sugar maple	10,909,893	87,285	(N/A)	11.3	16.8	16.29
Thornless honeylocust	5,918,937	47,355	(N/A)	7.6	9.1	13.11
Red maple	2,452,458	19,621	(N/A)	6.9	3.8	5.99
Apple	1,186,362	9,492	(N/A)	6.3	1.8	3.17
Silver maple	7,096,829	56,779	(N/A)	4.6	10.9	25.88
Littleleaf linden	1,841,453	14,733	(N/A)	4.1	2.8	7.52
London planetree	2,927,898	23,425	(N/A)	3.3	4.5	15.20
Northern red oak	1,660,411	13,284	(N/A)	2.4	2.6	11.81
Callery pear	683,127	5,465	(N/A)	2.4	1.1	4.91
Colorado spruce	825,233	6,602	(N/A)	2.1	1.3	6.66
Austrian pine	1,135,852	9,087	(N/A)	2.0	1.8	9.42
Black walnut	2,464,148	19,715	(N/A)	1.7	3.8	23.98
American elm	1,753,129	14,026	(N/A)	1.5	2.7	19.98
Siberian elm	1,351,522	10,813	(N/A)	1.1	2.1	20.60
Japanese zelkova	711,938	5,696	(N/A)	1.1	1.1	10.87
Eastern white pine	407,261	3,258	(N/A)	1.1	0.6	6.27
Swamp white oak	176,838	1,415	(N/A)	1.1	0.3	2.74
White oak	1,778,791	14,231	(N/A)	1.1	2.7	27.90
Other street trees	11,945,720	95,572	(N/A)	25.0	18.4	8.07
Citywide total	64,982,349	519,895	(N/A)	100.0	100.0	10.98

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***Appendix O***  
***Annual Benefits, Aesthetic, and Other Value (by Species and Zone)***

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<b>Annual Aesthetic/Other Benefits of Public Trees by Species</b>
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7/23/2009

Species	Total (\$)	Standard Error	% of Total Trees	% of Total \$	Avg. \$/tree
Norway maple	185,782	(N/A)	13.2	13.6	29.66
Sugar maple	186,027	(N/A)	11.3	13.6	34.71
Thornless honeylocust	144,399	(N/A)	7.6	10.6	39.98
Red maple	94,891	(N/A)	6.9	6.9	28.99
Apple	28,417	(N/A)	6.3	2.1	9.48
Silver maple	63,175	(N/A)	4.6	4.6	28.79
Littleleaf linden	42,140	(N/A)	4.1	3.1	21.51
London planetree	49,622	(N/A)	3.3	3.6	32.20
Northern red oak	29,499	(N/A)	2.4	2.2	26.22
Callery pear	43,901	(N/A)	2.4	3.2	39.41
Colorado spruce	14,781	(N/A)	2.1	1.1	14.90
Austrian pine	14,453	(N/A)	2.0	1.1	14.98
Black walnut	47,056	(N/A)	1.7	3.4	57.25
American elm	40,179	(N/A)	1.5	2.9	57.24
Siberian elm	30,654	(N/A)	1.1	2.2	58.39
Japanese zelkova	26,341	(N/A)	1.1	1.9	50.27
Eastern white pine	7,649	(N/A)	1.1	0.6	14.71
Swamp white oak	11,986	(N/A)	1.1	0.9	23.23
White oak	26,647	(N/A)	1.1	2.0	52.25
Other street trees	280,703	(N/A)	25.0	20.5	23.70
Citywide total	1,368,302	(N/A)	100.0	100.0	28.89

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***Appendix P***  
***Annual Benefits, Net Benefits, and Cost Summary***

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<b>Total Annual Benefits, Net Benefits, and Costs for Public Trees</b>
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7/23/2009

Benefits	Total (\$) Standard Error	\$/tree Standard Error	\$/capita Standard Error
Energy	2,252,055 (N/A)	47.55 (N/A)	19.75 (N/A)
CO2	52,450 (N/A)	1.11 (N/A)	0.46 (N/A)
Air Quality	395,569 (N/A)	8.35 (N/A)	3.47 (N/A)
Stormwater	519,895 (N/A)	10.98 (N/A)	4.56 (N/A)
Aesthetic/Other	1,368,302 (N/A)	28.89 (N/A)	12.00 (N/A)
<b>Total Benefits</b>	<b>4,588,271 (N/A)</b>	<b>96.88 (N/A)</b>	<b>40.25 (N/A)</b>
<b>Costs</b>			
Planting	380,414	8.03	3.34
Contract Pruning	329,260	6.95	2.89
Pest Management	303	0.01	0.00
Irrigation	1,012	0.02	0.01
Removal	585,544	12.36	5.14
Administration	210,726	4.45	1.85
Inspection/Service	17,918	0.38	0.16
Infrastructure Repairs	0	0.00	0.00
Litter Clean-up	76,858	1.62	0.67
Liability/Claims	0	0.00	0.00
Other Costs	107,766	2.28	0.95
<b>Total Costs</b>	<b>1,709,801</b>	<b>36.10</b>	<b>15.00</b>
<b>Net Benefits</b>	<b>2,878,470 (N/A)</b>	<b>60.78 (N/A)</b>	<b>25.25 (N/A)</b>
<b>Benefit-cost ratio</b>	<b>2.68 (N/A)</b>		