The City of Rochester

Strategic Plan for the Emerald Ash Borer Infestation

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ACKNOWLEDGEMENTS

Mayor
Ardell F. Brede

City Council
Mark Bilderback
Nick Campion
Mark Hickey
Ed Hruska
Sandra Means
Randy Staver
Michael Wojcik

Parks Board Commissioners
Linnea Archer
Mike Quinn
Larry Mortensen
Dr. Paul Scanlon
John Sipple
Richard Dale
Vern Yetzer

City Staff
Paul Widman, Director of Park and Recreation
Mine Nigbur, Park and Forestry Division Head
Jeff Haberman, City Forester

Consultant

Rainbow TreeCare

Rainbow Treecare
11571 K-Tel Drive
Minnetonka MN, 55343
Phone: 952-922-3810

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Executive Summary

Emerald ash borer management plan: The City of Rochester (City) contracted with Rainbow Treecare to prepare this *Strategic Plan for the Emerald Ash Borer Infestation* (Strategic Plan). This Strategic Plan includes up-to-date information on the EAB infestation and the experience of cities EAB has already attacked (Section 1); descriptions of the City's urban forest and management goals (Section 2); and the strategies, policies, and resources needed to prepare for and manage the EAB infestation (Section 3 and 4). It includes an extensive cost-benefit analysis that examined 4 primary scenarios (Section 5). Attachment 2 provides 20 charts that illustrate the findings, and Attachment 1 lists the sources of information used to generate the analysis. Section 6 lists definitions for terms used in this Strategic Plan.

The Strategic Plan will help the City reduce and distribute the costs associated with certain and widespread tree death over an extended time period, and lessen the social and economic impacts on the quality of life in the City. While the estimated costs of a response to an EAB infestation are staggering, a well-developed plan can mitigate and justify such costs, demonstrate leadership rather than reaction or inaction, and reduce liabilities.

Green infrastructure: An estimated 83,000 trees of all kinds grace the City of Rochester. They clean the air, help to manage storm water, stabilize soils, and provide habitat. They provide air conditioning in the summer and buffer winter's harsh winds. They increase property values and enhance commercial sales; calm traffic; and reduce noise, crime, and even health care costs.

Ash trees constitute an estimated 15% of all the trees in the City; a total of approximately 12,400 trees. Looking only at trees on City property and easements, about 14% of these trees are ash, a total of about 5,800 citywide. Unfortunately, the emerald ash borer will be lethal to virtually all of these trees unless they are protected from this invasive species with treatments.

Because of their significant benefits, this Strategic Plan views trees as "green" infrastructure that is no less important to the City as its "grey" infrastructure (e.g. sewers, roadways, telecommunications, etc.). The complete loss of the ash trees in the City to EAB would have a significant effect on home values, quality of life, and the environment.

Failed strategies from the past: The experiences of other cities and states that have already been devastated by EAB offer valuable lessons. One such lesson is from the Wisconsin Department of Natural Resources, "It will hit you like a freight train."[1] In the years soon after EAB was discovered in North America, most communities attempted to eliminate EAB through a single strategy—eliminating the food supply. It did not work, and recent research indicates the strategy is counterproductive because the beetles can fly up to 12 miles per year and the infestation can expand close to a mile in a year.

Integrated pest management: The good news is that recent scientific advances have resulted in an integrated pest management approach that includes detection techniques, pest control measures, and the protection of high value, healthy trees. This coordinated strategy preserves about four times as

[1] All citations and references are included in the main body of this plan, not the Executive Summary.

much of the tree canopy and tree value over twenty years as the outdated approach yet it costs half as much and it helps protect untreated private ash trees that are nearby. This Strategic Plan is based on this new research, especially an analysis known as the SLAM study. The SLAM analysis concluded that, "The rate at which ash tree mortality advances is related to EAB density. Therefore, an over-riding theme within the SLAM approach is to reduce … the growth of EAB populations." The SLAM study argues for an integrated pest management strategy that includes efforts to reduce pest populations by means of pesticide treatments and other strategies to preserve valuable ash tree resources.

Herd immunity, also known as community immunity, is the public health phenomenon where protection from a disease for a critical percentage of the population allows protection for untreated individuals in the population. This principal occurs with a range of microscopic 'bugs,' but the same concept applies to a larger bug—the emerald ash borer. By treating a certain amount of the population of ash trees, there is a net benefit within the communities.

Strategic plan for the infestation: The Strategic Plan calls for *sanitizing* (removal of infested ash), *suppressing* (EAB populations), *slowing* (the spread of the infestation), and *saving* (structurally sound ash). It includes 7 strategies and the best practices and action steps to implement them:

- Detect and suppress the infestation
- Preserve structurally sound ash trees
- Improve species diversity
- Postpone and decrease peak ash mortality
- Minimize public costs
- Manage tree debris
- Enlist private ash tree owners

The following summarizes the Plan's specific Action Steps:

1. **Conduct EAB delimiting survey:** The City should conduct delimiting surveys to determine the ongoing extent of the infestation.

2. **Implement pest detection, suppression, and sanitation program:** The infestation is probably already well established in many parts of the City but not yet fully detected. The City should design and implement a program to use strategically located, low-quality trees as trap trees (including lethal trap trees) to help delineate the extent of the infestation and to help slow its spread by attracting the beetles to the trap trees instead of the structurally sound trees. Infested trees must be removed (or treated as trap trees) to ensure that developing EAB progeny are not allowed to emerge. Trees with canopy loss that exceeds 30% should be removed as soon as possible because dead ash trees generally deteriorate rapidly and many will become hazardous especially along streets, in yards, and along overhead power lines.

3. **Preserve structurally sound ash trees:** The City should protect all of the medium and high-priority ash trees. The City should also consider treating structurally sound, low-quality trees when any of the following conditions exist:

- They are located where the loss of the benefits they provide could be significant (e.g. a residential or very public area with a small or thin canopy).
- They are needed for pest suppression (e.g. close to the wave front of the infestation).
- The avoidance of the much higher removal and replacement costs is needed to flatten costs during the peak years of the infestation (Years 4-9).

4. **Expand tree diversity and tree canopy:** The City should plant a sufficient number of trees to replace all ash trees lost to EAB.

5. **Manage the record and evaluate:** The City should keep accurate and complete records of the implementation of this Plan, evaluate the results, and modify its implementation as needed.

6. **Flatten the peaks:** Past experience in places where no actions were taken, approximately 80% of the untreated ash trees were dead by the seventh year of the infestation, and most of those deaths occurred in years 5, 6, and 7. If the City took no pest suppression actions, it would be faced with the task of removing and replacing about 2,000 trees over that 3-year period, an amount that would probably overwhelm City crews and budgets. To better reduce these extreme periods and extend removals and replacements over more years, the Ash Tree Preservation (ATP) Plan B proposed herein assumes the City will treat selected trees for staged removal (described in more detail below).

7. **Manage tree debris:** As with tree removals, the peak years of the infestation will generate what some who have already been through the main wave of the infestation as a "wall of wood." ATP Plan B assumes the City will treat selected trees for staged removal in order to even out the debris stream over 20 years instead of 4, which will be valuable especially for the debris that are utilized as an industrial fuel.

8. **Provide educational materials for the public:** The City should use all tools available to communicate the goals and best practices in this Strategic Plan, and to encourage the owners of private ash trees to manage their trees consistent with them.

9. **Enlist private tree owners:** If private tree owners are willing to implement some of these Action Steps for private trees and public trees that abut their property, the City should consider subsidizing their efforts. Only high and medium-quality trees located where their loss would have a significant effect on public land should be eligible for public subsidy.

Pesticide safety: While there are valid concerns regarding the overuse of pesticides in our environment, those concerns should be aimed at reducing pesticide use where fewer benefits result. The environmental consequences of losing thousands of ash trees are vastly greater than the minimal risk associated with inoculating structurally sound ash trees to protect them from certain death. Dr. Deborah McCullough, a professor of entomology and forestry at Michigan State University, has stated, "There is no reason for a landscape ash tree to die from emerald ash borer anymore."

Cost-benefit analysis: As a part of this Strategic Plan, an extensive, 20-year, cost-benefit analysis of ash trees on City property and easements was prepared including the following, 20-year study scenarios:

- **Base Case:** The Base Case scenario assumes all ash trees are removed and replaced as they succumb to EAB. It serves as a theoretical, no-action scenario for comparison with the other action scenarios.

- **The Ash Tree Preservation (ATP) Plan A:** This scenario assumes the same tree removal and replacement policy for low-quality trees, but preserves medium and high-priority ash trees using pesticide treatments.

- **ATP Plan B:** ATP Plan B is identical to ATP Plan A except that some low-quality, but structurally sound trees are treated over a 6-year period (2 treatments for each tree, Years 4-9) in order to reduce and spread peak costs, removals, replacements, and tree debris; and preserve tree benefits for an additional 9+ years. This is called treating for *staged removal*.

- **ATP Plan B1:** When the deaths begin in Year 10 of the trees that were treated for staged removal, the City can decide whether to replace them at that time or continue their treatments. These structurally sound trees will have had at least nine more years to grow and provide their intended benefits. ATP Plan B1 is identical to ATP Plan B except that it presumes the continued treatment of these trees.

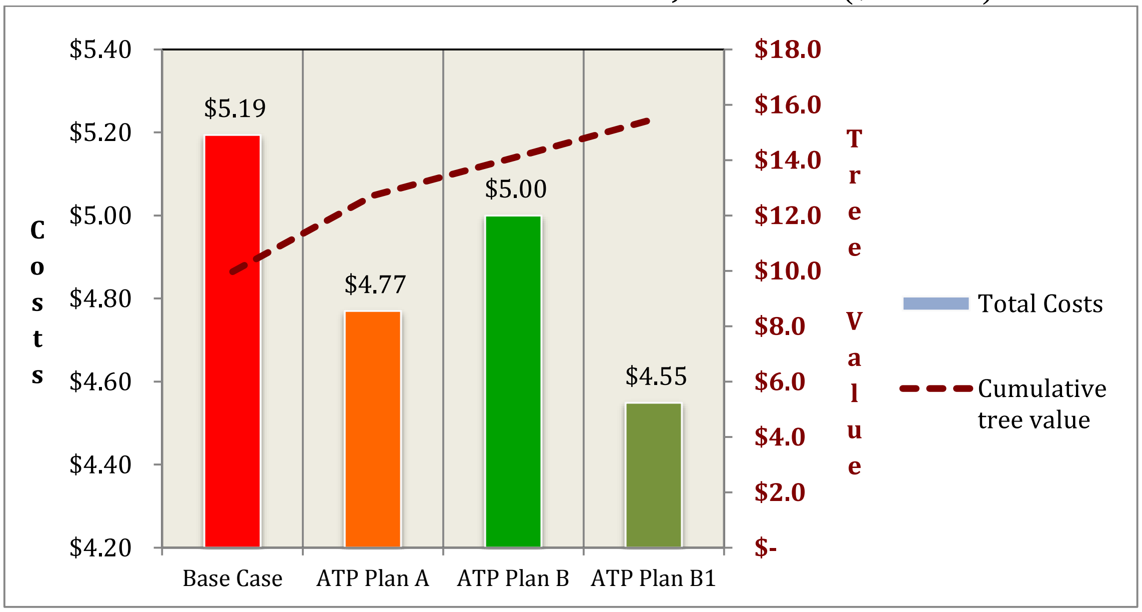
All of these scenarios assume the removal of the ash trees in woodland areas that may become hazards along trails, roadways, and adjacent private property. Using 20 pie, bar, and line charts, Attachment 2 graphically illustrates the cost-benefit comparisons of the scenarios.

Key findings: The following summarizes the key findings ("Takeaways") of the cost-benefit analysis:

- **Ash as a percent of all City trees:** Ash constitutes 15% of all City trees. This percentage will shrink to about 3% by Year 20 under the ATP Plan A and B scenarios (Chart 2 in Attachment 2).

- **Total costs:** The ATP Plan A scenario provides long-term treatments for close to 1,200 trees (9% of the public and private ash trees in the City, 20% of all of the trees in the City). By year 10, the ATP Plan A is 11% less expensive than the Base Case. Continued treatment, removal, and replacement costs over the next decade shrink this cost advantage for the ATP Plan A to 7% by Year 20. ATP Plan B is also less expensive than the Base Case, especially over the first 10 years (25% less); however, this is accomplished by flattening the costs during the peak period and moving them to the second decade of the infestation. By Year 20, the ATP Plan B is 5% higher than the ATP Plan A but still slightly lower than the Base Case (2% lower). After the main wave of the infestation has passed, the City may decide to continue the treatment of the staged removal trees, which is the ATP Plan B1 scenario. By Year 20, the ATP Plan B1 has 12% lower costs than the Base Case, reduces tree removals, replacements and debris management by 41% during the peak years (Year 4-8), and increases cumulative tree value by 55%.

Total Costs and Cumulative Tree Value, Years 1-20 ($ millions)



- **Peak period costs:** All scenarios have large increases in annual costs during the peak of the infestation (Years 4-9). The ATP Plan B is designed to flatten the peak and delay these costs by treating 1,100 low-quality (but survivable) trees. Costs by Year 10 for Plan B are 26% lower then the Base Case and 15% lower than the ATP Plan A. When staged removal trees start dying in Year 11, the City can decide whether to replace them or continue their treatments. If the latter course were chosen (ATP Plan B1), costs would remain relatively stable with a total of $4.55 million, about $645,000 below the Base Case.

- **Costs per DBH:** Every dollar invested in the ATP Plan B preserves about 3 times as much of the DBH as the Base Case by Year 10.

- **Tree value:** If tree costs were the only factor, no one would plant a tree. The ATP Plan A and B preserve 17% and 32% respectively higher tree values by Year 10 than the Base Case. ATP Plan B1 preserves 55% more tree value than the Base Case by Year 20.

- **Costs per tree value:** Every dollar invested in the ATP Plan B and B1 preserves about twice as much of the cumulative tree value as the Base Case by Year 10, which equals nearly $2 million. The analysis compared the degree to which the ATP Plan scenarios exceeded the tree benefits in the Base Case by Year 20. Six tree benefits were included: Increase in property values, intercepted storm water, energy conservation (electricity and natural gas), CO_2 reduction, and avoided health care costs. When averaged together, the tree benefit exceedances for the ATP Plan A, Plan B, and B1 are approximately 29%, 44%, and 58% respectively by Year 20.

- **Seasonal labor costs:** Seasonal labor costs in the peak year, Year 6, average about 20% lower than the Base Case for the ATP Plan A and 39% lower for Plan B.

- **Return on Investment:** Assuming 2% annual inflation and 5% discount factor, the ATP Plan B approach provides a positive return (i.e. additional dollars on top of the original investment) of a dollar in Year 4 for every dollar invested, and a return as high as $4 in Year 7 for every dollar invested. Returns remain highly positive in Year 15 and Year 20.

- **Individual tree:** More than 2 trees can be protected over a 20-year period for the cost of removing and replacing one tree. Every dollar spent removing and replacing a tree could preserve more than 5 times the tree value by protecting it instead.

Strategic Plan for the Emerald Ash Borer Infestation

1. Introduction

1.1. Purpose of the *Strategic Plan for the Emerald Ash Borer Infestation*

The City of Rochester has developed an *Urban Forest Management Plan* . In the plan's first paragraph, it states that the City "is a place of healing for people from all over the world.… The value of trees cannot be underestimated in the health and speedy recovery of hospital patients. … Today, scientists who have studied patient recovery, mental health, and the complete healing process, agree that a room with a view—a view of a tree—is of paramount importance. Toward that end, the City of Rochester should stand committed to further greening of the city."

The City contracted with Rainbow Treecare to prepare this report, the *City of Rochester Strategic Plan for the Emerald Ash Borer Infestation* (Strategic Plan). It is a direct response to the City's commitment to "further greening of the city" by supplementing the *Urban Forest Management Plan* with specific analysis and guidance regarding the emerald ash borer (EAB)[2] infestation, which has already been detected on the City's southern edge. This information will help buffer the infestation's impact on both public and private properties throughout the City.

This Strategic Plan includes up-to-date information on the EAB infestation and the experience of cities it has already attacked (Section 1); descriptions of the City's urban forest and management goals (Section 2); and the strategies, policies, and resources needed to prepare for and manage the EAB infestation (Section 3 and 4). It includes an extensive cost-benefit analysis that examined 3 primary scenarios (Section 5). Attachment 2 provides 20 charts that illustrate the findings, and Attachment 1 lists the sources of information used to generate the analysis. Section 6 lists definitions for terms used in this Strategic Plan.

The Strategic Plan will help the City reduce and distribute the costs associated with certain and widespread tree death over an extended time period, and lessen the social and economic impacts on the quality of life in the City. By taking a proactive approach toward EAB planning and preparation, the City can better position itself to roll with the ecological and financial punches that EAB will undoubtedly throw. While the estimated costs of a response to an EAB infestation are staggering, a well-developed plan can mitigate and justify such costs, demonstrate leadership rather than inaction, and reduce liabilities.

An estimated 83,000 trees of all kinds grace the City of Rochester. They clean the air, help to manage storm water, stabilize soils, and provide habitat. They provide air conditioning in the summer, buffer winter's harsh winds, and delight with their

[2] Consistent with common usage, the acronym, *EAB*, is used herein to refer to both the emerald ash borer *beetle* and occasionally, the EAB *infestation*.

splendor every fall. They increase property values and enhance commercial sales, calm traffic, and reduce noise and crime.

Ash trees constitute an estimated 15% of all the trees in the City; a total of approximately 12,400 trees.[3] Looking only at trees on City property and easements, about 14% of these trees are ash, a total of about 5,800 citywide; but their concentrations vary widely among the 18 urban forest districts from 63% to zero (Chart 1 in Attachment 2). Unfortunately, the emerald ash borer will be lethal to virtually all of these trees unless they are protected from this invasive species with pesticides. To implement the City's goal of "further greening the city" while EAB destroys thousands of trees, the City will have to plant and maintain even more thousands of trees to maintain and expand the City's tree cover.

EAB is not the only major challenge the future holds. According to the *Chicago Climate Action Plan*, the regional effects of climate change will bring increased frequency and severity of droughts, floods, and storms. The average day-to-day summer heat index values (the combination of the effects of temperature and humidity) are expected to increase over the coming decades to 94 and as high as 105 degrees F.[4]

These predicted threats from climate change will place great strains on the urban forest making it even more susceptible to the EAB infestation. No city within the U.S. has successfully maintained or increased the percentage of tree canopy cover once the pest begins to decimate it.

The City Forester, through the Park and Recreation Department's Forestry Division, will be responsible for implementing the provisions of this Strategic Plan.

1.2. The Value of Trees

Managing this infestation will cost the City millions of dollars. Even greater than these management costs are the losses of the benefits these trees provide. The City's *Urban Forest Management Plan* provides valuable information about the value of the City's urban forest. It is worthwhile to expand on that information somewhat for this report.

While the aesthetic value of trees is easily grasped, scientific studies have also quantified their benefits to the environment, the economy, and to human health. When the quantifiable benefits of trees are weighed against the costs (e.g. purchase, planting, pruning, and removal), the benefits outweigh the costs by a margin of about three to one. For example, an average mature ash will provide about $170 in benefits annually.[5] The net cooling effect of a young, healthy tree is equivalent to 10 room-size air conditioners operating 20 hours a day.[6] One acre of urban forest absorbs 6

[3] These population estimates do not include ash trees in woodland areas.
[4] Source: http://www.chicagoclimateaction.org
[5] National Tree Benefits Calculator, http://www.treebenefits.com/calculator/
[6] http://www.arborday.org/trees/benefits.cfm

tons of carbon dioxide and emits 4 tons of oxygen annually.[7] In one study, stands of trees reduced particulates by 9-13%, and the amount of dust reaching the ground was 27-42% less under a stand of trees than in an open area. Tree roots have a profound effect on the soil environment. They will direct 40-73% of assimilated carbon below ground,[8] and an average tree will intercept over 1,800 gallons of storm water annually.

Storm water interception by trees reduces the peak-flow and flooding during intense storms, thereby reducing the amounts of pollutants that are washed into our rivers and lakes. Street trees even help extend the life of expensive asphalt by 40-60% by reducing daily heating and cooling of roads.[9]

As regards human health, a recent analysis by the World Health Organization confirmed that air pollution is now the world's single largest environmental health risk.[10] In one study, stands of trees reduced particulates by 9-13%, and the amount of dust reaching the ground was 27-42% less under a stand of trees than in an open area. Another recent analysis (this one prepared by U.S. Forest Service scientists and collaborators) provides the first broad-scale estimate of how trees reduce air pollution, protect our health, and reduce health care costs. The article describing the analysis quoted Michael T. Rains, Director of the Forest Service's Northern Research Station and the Forest Products Laboratory: "With more than 80 percent of Americans living in urban area, this research underscores how truly essential urban forests are to people across the nation."[11] The study estimated that in 2010, trees in the urban areas of Minnesota removed 4,600 tons of pollutants from the air and that this resulted in $26.7 million in reduced health care costs.[12]

The above paragraph covers studies that quantify how trees benefit human health. Another study demonstrates how tree deaths from the EAB infestation are associated with human deaths. The analysis by U.S. Forest Service scientists concluded that, "Poor air quality and stress are risk factors for [lower respiratory disease and cardiovascular disease], and trees can improve air quality and reduce stress. Results showed that the spread of EAB across 15 states was associated with an additional 15,000 deaths from cardiovascular disease and an additional 6,000 deaths from lower

[7] Ibid.
[8] Source: http://www.dailycamera.com/guest-opinions/ci_26131781/silent-environmental-devastation
[9] Source: "City to Consider Special Funding for Trees," City of Madison Wisconsin, 7/31/14, http://www.cityofmadison.com/news/city-to-consider-special-funding-for-trees
[10] "7 million premature deaths annually linked to air pollution," World Health Organization press release, 3/25/14, www.who.int/mediacentre/news/releases/2014/air-pollution/en
[11] "Tree and forest effects on air quality and human health in the United States," Nowak, David, et al., *Environmental Pollution*, 7/25/14, http://www.nrs.fs.fed.us/pubs/46102
[12] The health impacts and their monetary values are based on the changes in NO_2, O_3, $PM_{2.5}$ and SO_2 concentrations using information from the U.S. EPA Environmental Benefits Mapping and Analysis Program model (http://www.epa.gov/air/benmap/).

respiratory disease."[13] The City's *Urban Forest Management Plan* includes additional descriptions of the benefits of trees.

Because of their significant benefits, this Strategic Plan views trees as "green" infrastructure that is no less important to the City as its "grey" infrastructure (e.g. sewers, roadways, telecommunications, etc.). The complete loss of the ash trees in the City to EAB would have a significant effect on home values, quality of life, and the environment.

1.3. The Emerald Ash Borer Infestation

The EAB problem is very complex. The City's physical and financial conditions will help define the most effective investment levels and timing regarding the following variables:

- Appropriate actions to reduce overall pest pressure and replace infested trees;
- Targeting for treatments those trees closest to the expected infestation wave front;
- Appropriate frequency of treatments and treatment doses;
- Best practices for wood and debris handling issues; and
- The question of City subsidy for managing certain private trees.

In the years soon after EAB was discovered in North America, most communities attempted to eliminate EAB through a single strategy—eliminating the food supply. It did not work, and recent research indicates the strategy is counterproductive because the beetles can fly up to 12 miles per year and the infestation can expand close to a mile in a year.[14, 15, 16]

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[13] "Exploring Connections Between Trees and Human Health," *Science Findings*, Pacific Northwest Research Station, U.S. Forest Service, Jan./Feb. 2014, http://www.fs.fed.us/pnw/sciencef/scifi158.pdf

[14] At the Emerald Ash Borer Symposium held March 5 and 6, 2014 in Roseville, Minnesota, Dr. Daniel Herms, Professor and Chairperson of Entomology, Ohio State University, stated that it is a myth that preemptive removal of ash trees will slow the spread of the infestation. He argued that the removal of infested trees is effective but not the removal of healthy trees because the beetles will simply fly further to find host trees. He said that this would only spread the infestation faster. "We can't cut our way out of this." Another presenter at the conference, Dr. John Bell, agreed and commented, "Don't burn down the village to save it."

[15] "Flight distances of 0.3 km (0.2 miles) to 19.3 km (12 miles) per year have been reported, with a maximum dispersal of 1.37 km (0.9 miles) per year in an intensive quarantine zone." Source: "Economic Analysis of Emerald Ash Borer (Coleoptera: Buprestidae) Management Options," A. R. Vannatta, R. H. Hauer, and N. M. Schuettpelz, *Journal of Economic Entomology*, 105(1): 196-206. 2012. Published By: Entomological Society of America, Feb. 2012, http://www.extendonondaga.org/wp-content/uploads/2013/02/Economics-Impacts1.pdf

[16] "A relative economic analysis was used to compare a control option (do-nothing approach, only removing ash trees as they die) to three distinct management options: 1) preemptive removal of all ash trees over a 5 yr. period, 2) preemptive removal of all ash trees and replacement with comparable non-ash trees, or 3) treating the entire population of ash trees with insecticides to minimize mortality. For each valuation and management option, an annual analysis was performed for both the remaining ash tree population and those lost to emerald ash borer. Retention of ash trees using insecticide treatments typically retained greater urban forest value, followed by doing nothing (control), which was better than preemptive removal and replacement. Preemptive removal without tree replacement, which was the least expensive management option, also provided the lowest net urban forest value over the 20-yr simulation." Source: Ibid.

Another strategy was to replace ash trees with different species as fast as possible. However, a 2005 study of the urban forest in Minneapolis by the US Forest Service stated, "There is a delay of 30 years until the annual benefit of a replacement tree equals that of the ash tree removed because of EAB."[17] The good news is that university scientists have developed and refined treatment protocols that can manage the infestation more effectively and at much lower cost when compared to past strategies that relied on preemptive removals or annual treatments for high-value trees.[18] This plan is based on this new research, especially an analysis known as the SLAM study. This analysis, described in more detail below, argues for an integrated pest management strategy that includes efforts to reduce pest populations by means of pesticide treatments and other strategies to preserve valuable ash tree resources.

1.3.1. Extent of the Infestation: The emerald ash borer, *Agrilus Planipennis,* is an invasive beetle from Asia that was discovered in the United States during the summer of 2002 near Detroit, Michigan. It is the most destructive and economically costly forest insect ever to invade the U.S. By 2011, it was approximately 4 times as destructive nationally as the next two most costly pests, the Gypsy moth and the Hemlock adelgid.[19] The adult beetles ingest ash leaves but cause minimal damage. However, the larvae (during the beetle's immature stage) feed on the inner bark of ash trees and disrupt the tree's ability to transport water and nutrients. EAB may take years to build populations large enough to infest an entire tree, and low densities of EAB have little effect on the health of a tree. However, once an ash tree is infested, it has almost zero chance of survival unless it is treated in time.

The current evidence from Michigan and Ohio shows that, depending on pest pressure, EAB takes 5-10 years to infest and kill the majority of the ash trees in a city. Cities infested with this devastating pest have lost tens of millions of ash trees and endured billions of dollars of losses. To date, 25 states, including Minnesota, and two Canadian Providences, have discovered EAB and enforced quarantines.

1.3.2. Life Cycle of the Beetle and the EAB Death Curve: Recent research shows that the EAB beetle can have a 1-2-year life cycle. Adults begin emerging in mid-to-late May with peak emergence in late June. Females usually begin laying eggs about 2 weeks after emergence. Eggs hatch in 1-2 weeks, and the tiny larvae bore through the bark and into the cambium—the area between the bark and wood where nutrient levels are high. The larvae feed under the bark for several weeks, usually from late July or early August through October.

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[17] McPherson, E.G., Simpson, J.R., Peper, P.J., Maco, S., Gardner, S., Cozad, S., et al., 2005. "City of Minneapolis, Minnesota Municipal Tree Resource Analysis," Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station. http://www.treesearch.fs.fed.us/pubs/45984

[18] For more information, refer to "Coalition for Urban Ash Tree Conservation," http://www.emeraldashborer.info/files/conserve_ash.pdf

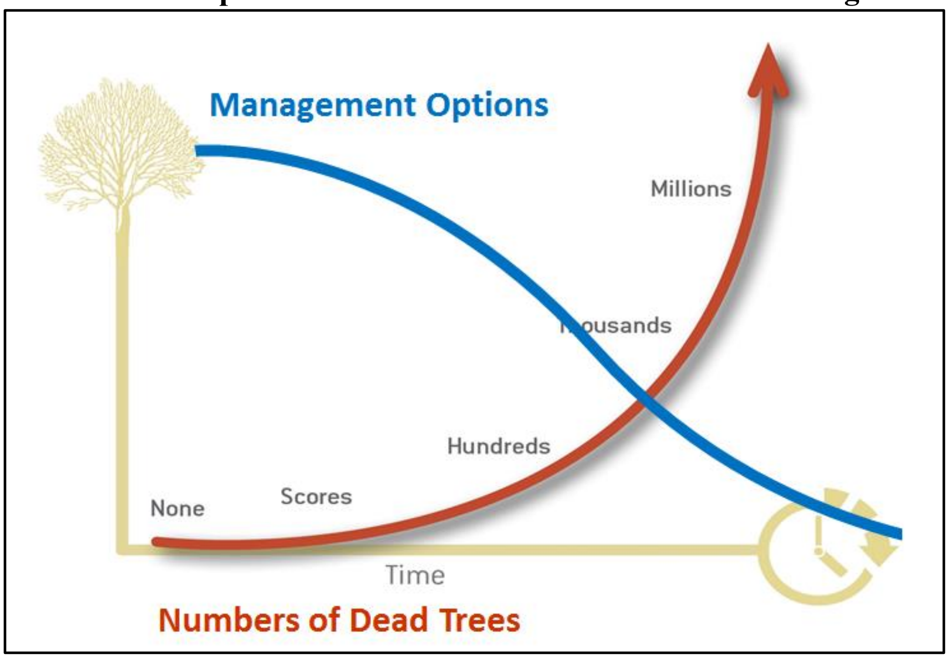
[19] Aukema JE, Leung B, Kovacs K, Chivers C, Britton KO, et al. (2011), "Economic Impacts of Non-Native Forest Insects in the Continental United States," *PLoS ONE*, 6(9): e24587. doi:10.1371/journal.pone.0024587, http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0024587

Most EAB larvae hibernate in a small chamber in the outer bark or in the outer inch of wood. Pupation occurs in spring, and the new generation of adults will emerge in May or early June, to begin the cycle again.[20]

Cities that have been decimated by EAB have observed the EAB "death curve" where the rates at which infested trees die occur in two phases. EAB populations grow by a factor of 40 (or more) each year because the beetle has few natural predators and its host tree has limited natural defenses. However, healthy trees can tolerate an infestation for probably 3-4 years before they reach a tipping point that leads quickly to death. This results in a linear phase of the death curve where tree deaths are limited to about 1-5% a year. During the second phase of the death curve (the exponential phase), pest pressure builds, and tree deaths begin to parallel the exponential growth rate of beetle populations. Annual tree deaths can exceed 20%, and thousands of dead trees quickly overwhelm city crews, equipment needs, debris yards, and budgets. Most local governments that manage urban forests are woefully unprepared.

The time to act is now—before the infestation exponentially increases in population, and tree deaths escalate as seen in other cities. As the pest population increases and a greater number of trees die, the number of management options goes down (refer to Figure 1).

Figure 1: The Relationship between the EAB "Death Curve" and Management Options[21]



[20] Source: http://www.emeraldashborer.info/faq.cfm#sthash.Bw4elMK7.dpbs. See more at: http://www.emeraldashborer.info/faq.cfm#sthash.Bw4elMK7.dpuf
[21] Source: Rainbow Treecare

1.4. Experience of Other Cities—"It will hit you like a freight train"

The experiences of other cities and states that have already been devastated by this invasive species offer valuable lessons. For example, consider this warning from the Wisconsin Department of Natural Resources, "It will hit you like a freight train."[22] Westland, Michigan, one of the first communities hit by EAB, provides a specific example of the effects of the infestation. The removal of the 3,000 municipal ash trees killed by EAB "led to 33% increase in outdoor water consumption, which subsequently caused the regional water authority to levy a 10% surcharge on the city."[23]

With EAB still sweeping through Illinois, Scott Schirmer (Plant and Pesticide Specialist Supervisor and Emerald Ash Borer Program Manager at the Illinois Department of Agriculture's Bureau of Environmental Programs) reflected about the state's early experience: "We promoted local partnerships … for a long time as a way to deflect overall cost and hopefully spread benefits, but it never really panned out here. One of our major issues was the individuality of each municipality and arborist, as some were anti-pesticide and some were jumping on board. However, looking back, I truly believe that's because the pesticides were still in their infancy and not 'tried and true' on a large scale at the time. Those communities that 'had faith' in the treatments are having great success today, whereas those that did not have lost large amounts of canopy. Communities on the leading edge have bought in a bit more, and are also benefitting from early, proactive treatment."

Chicago is an example of an Illinois city that "had faith" in treatments. According to a press release from Mayor Rahm Emanuel, Chicago is using emamectin benzoate to inoculate its high-priority ash trees. "The City of Chicago is committed to the health of the more than 500,000 parkway trees that not only beautify our neighborhoods, but offer countless environmental benefits."[24]

The City of Milwaukee began treating 33,000 of its larger ash trees in 2009 with emamectin benzoate as part of a plan to stage ash trees for their eventual removal while they transitioned to alternative species. However, residents have been so supportive of ash tree preservation that the city is considering altering the program to long-term preservation and to begin protecting smaller ash trees as well.[25]

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[22] Source: "Lessons Shared: Learning How Communities are Responding to EAB, Wisconsin Department of Natural Resources, Feb. 2013, http://dnr.wi.gov/topic/urbanforests/documents/eabtoolbox/eab-lessonsshared.pdf

[23] Source: McCullough, Deborah G.; Mercader, Rodrigo J.; "Evaluation of potential strategies to SLow Ash Mortality (SLAM) caused by emerald ash borer (Agrilus *Plan*ipennis): SLAM in an urban forest," *International Journal of Pest Management*, Vol. 58, No. 1, January–March 2012, 9–23.

[24] Chicago Office of Mayor Press Release, "City of Chicago begins second year of emerald ash borer inoculations: City to Treat 35,000 Ash Trees in 2014," Source: http://www.cityofchicago.org/content/dam/city/depts/mayor/Press%20Room/Press%20Releases/2014/May/5.19.14AshBorer.pdf

[25] Source: "Managing EAB Risk with Ash Injections," *Milwaukee Forestry*, Randy Krouse, Urban Forestry District Manager, City of Milwaukee, Wisconsin, http://milwaukeetrees.milwaukee.gov/pdf/Milwaukee_ManagEAB.pdf

The experience of the City of Madison Wisconsin is telling as regards effects on the city budget, as reported in the *Wisconsin State Journal*. The newspaper quoted Mark Clear, a City Alderman, as stating, "One of the things really looming is the cost of the emerald ash borer. It's one of the fastest growing areas of the budget, and it's almost completely out of our control. I don't think anyone wants to see the urban forest decimated." The article went on to report that the city was removing approximately 8,500 ash trees and treating about 12,500 more. "The overall forestry budget is jumping from $3.6 million in 2013 to a projected $5.9 million in 2015." To fund the increased costs, the city is considering levying a fee on property owners based on street frontage (which is even more regressive than property taxes).[26]

One final example: Six counties in Ohio expect to spend $1 million to clear 8,000 dead ash trees from the banks of a river because the dead trees were creating flooding problems.[27]

1.5. The SLAM Study and Herd Immunity

This Strategic Plan relies heavily on the scientific results from what is called the SLAM study and the study's website of the same name ("SLAM Steps in Implementing a Strategy to SL.ow A.sh M.ortality").[28] As such, it is important to summarize the study before describing the components of the Strategic Plan.

The SLAM study addressed the life cycle of the EAB beetle, pest pressure, the natural ability of healthy trees to tolerate an infestation, the limited effectiveness of the strategy of sanitation and pre-emptive removals to reduce the food source, the effectiveness of chemical treatments, the importance of early detection, and the relative costs of a variety of scenarios.

The SLAM website provides a succinct summary of the effort: "*The rate at which ash tree mortality advances is related to EAB density.[29] Therefore, an over-riding theme within the SLAM approach is to reduce … the growth of EAB populations* [emphasis added]. ... A do-nothing or a regulation-only approach means that EAB populations will build and advance unchecked. Under that scenario, extensive local tree mortality is likely to occur much sooner than under a SLAM management scenario. ... The goal of this management strategy is to slow the local invasion process and allow land managers time to be proactive rather than simply reacting to overwhelming numbers

[26] Source: "Madison council members recommend special fee to pay for city's forestry program," *Wisconsin State Journal*, 7/31/14, http://host.madison.com/wsj/news/local/govt-and-politics/madison-council-members-recommend-special-fee-to-pay-for-city/article_a66b8eb6-e485-5dd3-9b86-05743186d8a8.html

[27] Source: http://www.toledonewsnow.com/story/29364829/ash-trees-along-the-blanchard-river-to-be-removed

[28] "Evaluation of potential strategies to SLow Ash Mortality (SLAM) caused by emerald ash borer (Agrilus *Plan*ipennis): SLAM in an urban forest," *International Journal of Pest Management*, Vol. 58, No. 1, January–March 2012, 9–23; op. cit.

[29] From the SLAM study: "A low-density of A. planipennis [the EAB beetle] larvae generally has little effect on the overall health of the tree, in part because ash trees are highly sectorial (Tanis et al. forthcoming 2012) and relatively efficient at vertical translocation of nutrients and water. As larval densities build, however, more tissue is damaged, translocation is disrupted, canopies thin, branches die and eventually the tree succumbs."

of dead, often hazardous trees. ... Continued research and methods development will yield more options for EAB management and increase the effectiveness of existing technologies. Slowing the movement of EAB and the advance of ash mortality buys time for research and technology development."[30]

The SLAM study included over 200 computer simulations based on field-derived data and included a best-case scenario that was most effective at preserving ash trees at the lowest cost. This best-case scenario predicted that random treatment of 20% of the population of ash trees annually should protect 99% of the trees after 10 years. For comparison purposes, the study included a base case scenario that assumed no treatments. The costs of ash removal and replacement were "approximately fourfold higher than in any of the scenarios that included insecticide treatment. The dramatic difference in cumulative costs incurred, however, means that 20% of the ash trees could be treated for many years before treatment costs would approach removal and replacement costs."[31]

Herd immunity (also known as community immunity) is the public health phenomenon where protection from a disease for a critical percentage of the population allows protection for untreated individuals in the population. This principal occurs with a range of microscopic 'bugs,' but the same concept applies to a larger bug—the emerald ash borer. By treating a certain amount of the population of ash trees, there is a net benefit within the communities.

2. The Rochester Urban Forest Goals

The *Urban Forest Management Plan* reports that the City has "more than 100 parks, over 33,154 boulevard trees, and 61,144 potential planting spots." It is appropriate to repeat the goals of the City's *Urban Forest Management Plan* here because they are pertinent to the objectives of this Strategic Plan:

1. Increase street-tree stocking levels to a 70% level in residential areas of each management unit.
2. Facilitate tree planting on private and public properties to help the city reach an overall tree canopy cover of 40%.
3. Increase species diversity in Rochester through the use of a variety of proven, well-adapted, but relatively uncommon species.
4. Facilitate tree maintenance to minimize risk and potential damage and increase tree health.
5. Develop a tree preservation and tree protection ordinance encompassing the entire city.
6. Continually update the city's street-tree inventory by inventorying at least two forest management sectors … annually.

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[30] "Evaluation of potential strategies to SLow Ash Mortality (SLAM) caused by emerald ash borer (Agrilus *Plani*pennis): SLAM in an urban forest," *International Journal of Pest Management*, Vol. 58, No. 1, January–March 2012, 9–23; op. cit.
[31] Ibid.

7. Facilitate public education concerning the relevance and importance of urban forestry.

8. Encourage solicitation of donations, grants, and other funds to increase outside funding to sustain Rochester's urban forest.

The policies in this Strategic Plan address most of these goals (refer to Section 3).[32]

The *Urban Forest Management Plan* also lists the City ordinances pertinent to the management of the EAB infestation. Section 47. Shade Tree Disease and Insect Control of the City's zoning code includes Subsection 47.01. Nuisance Declared, which states the following: "The prevention, control and abatement of Dutch Elm disease and Oak Wilt disease and the Emerald Ash Borer insect is necessary for the protection, preservation and conservation of public and private lands and the investment and benefit therein, and to protect and promote the general welfare of the public and this community."[33] The code provides sufficient authority for the City to implement this Strategic Plan. However, the City's ordinances have room for improvements to make them more protective of public and private trees.

3. Strategic Plan for the Emerald Ash Borer Infestation

Table 1 lists the number and average DBH of ash trees by category on City property and identifies the action for each of these tree categories. It references the 20-year study scenarios that are defined above in Section 1.6. The Base Case scenario assumes all ash trees are removed and replaced as they succumb to EAB.[34] It serves as a theoretical, no-action scenario for comparison with the other two action scenarios. The Ash Tree Preservation (ATP) Plan A assumes the same tree removal and replacement policy for low-quality trees, but preserves medium and high-priority ash trees using pesticide treatments. ATP Plan B is identical to ATP Plan A except that some low-quality, but structurally sound trees are treated over a 6-year period (2 treatments for each tree, Years 4-9) in order to reduce and spread peak costs, removals, replacements, and tree debris; and preserve tree benefits for an additional 9+ years.

Taken together, the medium and high-priority ash trees equal 20% of the inventoried City ash trees. As part of the pest suppression strategies in the ATP Plan A and B, a limited number of low-quality trees will be girdled for about a year prior to removal so they can serve as *trap trees* (refer to definitions in Section 6).

Since this analysis focuses on inventoried trees, tree estimates do not include woodland trees. Woodlands are City-owned wooded areas that are not mowed or subject to regular maintenance. It is assumed the woodland ash will die in place and the surrounding trees will fill in the gaps in the canopy cover. However, ash trees located along woodland trails and

[32] The exceptions include the private tree planting aspect of goal 2, goal 5, and goal 8.
[33] The complete ordinance can be found online at:
http://www.rochestermn.gov/departments/attorney/ordinances/Ch47ShadeTreeDiseaseControl.asp
[34] The assumption is that a tree is either preemptively removed or removed after it displays 30% or more canopy loss due to being infested. For simplicity, tree replacement is assumed to occur in the same area as the removed tree and to occur within the same Study Year. However, limited resources may actually delay the replacement of all ash trees in a timely manner, especially during the peak years of the infestation (Years 4-8).

roads and adjacent private property may become hazard trees that need to be chipped in place. The table includes a City staff estimate of the number of these ash trees and the analysis assumes they are removed during the early years for all of the scenarios in order to front-load costs so that they do not add to the already burdensome peak years (discussed in more detail below).

Table 1: Current Conditions of the Urban Forest and Action by Scenario

Tree Populations	Ash Trees				Action by Scenario		
	Number	**Percent of Total Ash Trees**	**Average DBH**	**Total DBH**	**Base Case**	**ATP Plan A**	**ATP Plan B and B1[1]**
Inventoried City trees:							
High-priority ash trees	383	3%	17.2	6,574	Remove and replace	Treat	
Medium-priority ash trees	782	6%	16.8	13,171			
Subtotal (20%, excluding hazard trees)	1,165	9%	16.9	19,745			
Low-quality trees	4,662	37%	16.8	78,473		Remove and replace and girdle some	
Low-quality trees treated for staged removal							1,100
Total City trees	**5,827**	**47%**	**16.9**	**98,218**			
Estimated private trees [3]	6,659	53%	16.9	112,249	Public education		
Estimated total trees	**12,486**	**100%**	**16.9**	**210,467**			
Potential hazard ash trees along woodland trails and roads [2]	2,500		16.8	42,085	Chip in place		

1 ATP Plan B is identical to ATP Plan A except that some structurally sound, low-quality trees are treated over a 6-year period (2 treatments each) in order to reduce and spread peak costs, removals, replacements, and tree debris; and preserve tree benefits for an additional 9+ years. This is called treating for staged removal. ATP Plan B1 is a variation on ATP Plan B that assumes the City will continue to treat the trees that were treated for staged removal.

2 Trees that may cause a hazard along woodland paths and roads and adjacent private property will be preemptively processed (chipped or cut into small pieces) on site. These tree counts are not included in the other population figures or charts.

3 The statewide urban tree survey conducted by the Minnesota Department of Natural Resources found that 7% of the State's urban trees were ash trees owned by municipalities and 8% were ash trees located on private property. These findings were used to estimate the number of ash trees on private property and the total number of trees. Tree estimates are based on survey results of ash trees located within 66 feet of the roadway's edge in residential and commercial areas. They do not include woodland trees. The figures include public and private ash trees. Source: "Rapid Assessment of Ash and Elm Resources in Minnesota Communities," 1/5/07, Minnesota Department of Natural Resources. Downloaded: http://files.dnr.state.mn.us/assistance/backyard/treecare/forest_health/ash_elmRapidAssessment/rapidassessment_AshElm.pdf

In order to maximize the benefits of the City's urban forest, the goals and policies in the *Urban Forest Management Plan* are designed to make the City healthier, more diverse, and more complete. This Strategic Plan shares those same goals.

This Strategic plan calls for *sanitizing* (removal of infested ash), *suppressing* (EAB populations), *saving* (structurally sound ash), and *slowing* (the spread of the infestation). It includes 7 strategies and the best practices and action steps to implement them. Section 5 summarizes the analysis of the cost advantages of using the full complement of these integrated pest management strategies.

1. Detect and suppress the infestation

2. Preserve structurally sound ash trees
3. Improve species diversity
4. Postpone and decrease peak ash mortality
5. Manage tree debris
6. Minimize public costs
7. Enlist private ash tree owners

3.1. Strategy 1—Detect and Suppress the Infestation

The SLAM study emphasizes the importance of early detection and actions to confine the infestation within the lessened pest pressure stage, which is the flat part of the death curve (refer to Section 1.5). This will reduce the vulnerability of the area to an overwhelming ash mortality event (i.e. the "freight train" analogy). This strategy helps to implement Goal 4 of the *Urban Forest Management Plan* because it helps to "minimize risk and potential damage, and increase tree health."

Since appropriate control strategies vary according to the intensity of the infestation, it is important to detect the presence of the infestation as soon as possible and, once detected, periodically estimate the extent and the density of the EAB population. At this writing, EAB has been detected on the southwestern edge of the City and all of Olmsted County is under the Minnesota Department of Agriculture quarantine. As such, it is crucial for the City to initiate this Strategic Plan immediately.

As mentioned above, a failed strategy of the past included the preemptive removal of ash trees hoping that the reduction of the food supply would slow the infestation.[35] For ash trees in woodland areas and in low-priority areas such as backyards, a policy of "benign neglect" allows the EAB to kill the trees so the natural forest canopy can grow into the gaps. This can also reduce the current overabundance of ash in the urban forest. The problem with the "benign neglect" approach is that it allows EAB populations to increase exponentially wherever ash trees are left untreated. This increases overall pest pressure and hastens its spread.

This Strategic Plan incorporates important strategies intended to reduce the overall intensity of the infestation, i.e. the pest pressure, and preserve the trees worth saving. To put it another way, the strategy is to *sanitize, suppress, slow, and save*.

Best Practices:

- **EAB survey:** As soon as possible, forest managers should conduct delimiting surveys organized in a grid pattern and focusing on the wave front in the southwest quadrant of the City. Surveys should include visual inspections as well as some amount of destructive sampling (cutting and peeling of ash trees) to confirm the presence or absence of EAB. A key indicator is woodpecker damage.

[35] From the SLAM study: "Simply felling or removing ash trees to reduce the amount of ash phloem available for larvae, however, has the least effect on A. planipennis population growth and, if used exclusively, could increase spread rates."

- **Removal of infested trees:** Infested trees must be removed (or treated as trap trees) to ensure that developing EAB progeny are not allowed to emerge. Trees with canopy loss that exceeds 30% should be removed as soon as possible because dead ash trees generally deteriorate rapidly and many will become hazardous especially along streets, in yards, and along overhead power lines. This can entail chipping, grinding, debarking, burning, or other methods.[36] Removing a few key infested trees, especially if they are large and heavily infested, could remove a locally significant number of EAB adults.[37] Since trees that have been dead for more than one year are unlikely to harbor EAB, their removal will not result in any reduction in the number of EAB. Canopy loss is a trailing indicator of infestation. Losses above about 30% imply that EAB has so damaged the vascular system of the tree that it will not be able to take up the pesticide that might have saved it if applied earlier.

- **Priorities for removal:** The City should focus on areas where people walk, especially near schools. Auto-oriented places such as strip malls, parking lots, and industrial areas can be a lower priority. Once an ash tree dies, it does not maintain its structural integrity compared to other tree species like oaks or the American elms that were killed from Dutch elm disease. Ash trees "explode" when they are dropped if they have been dead for a while, so it's best to remove them before they die rather than after they've had a chance to desiccate and become brittle and relatively fragile. It's also significantly more expensive (and dangerous) to remove a dead ash tree than a dying tree.

- **"Totem pole management:"** Communities already devastated by EAB warn that the number of dead trees quickly overwhelmed their resources. To reduce the chance of falling dead limbs causing damage, they recommend the trees be topped and the limbs removed during the peak years. Removal of the standing dead pole and stump can occur later.

- **Delayed tree replacement:** The costs of replacement trees are comparable to the costs of tree and stump removal. During the peak years of the infestation, the strain on City resources may result in the postponement of tree replacements.

- **Trap trees and population sinks:** Table 1 lists the numbers of low-quality ash trees, most of which should be removed and replaced during the course of the infestation. Rather than preemptively removing these low-value trees, many

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[36] Ash materials generated from tree removal should be disposed according to guidelines established by USDA Animal and Plant Health Inspection Service (APHIS) (http://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/quarantine.shtml) and Minnesota Department of Agriculture. A properly managed community marshaling yard can enhance the disposal process.

[37] "EAB infested trees can produce ca. 90-100 adult EAB per square meter (8-10 EAB per square ft.) of bark surface area. A single 20-inch diameter ash tree has the potential to produce approximately 3,600-4,000 beetles before it succumbs." ("SLAM: SLow Ash Borer Mortality Pilot Project").

can be girdled[38] to serve several vital roles before they die. Girdling stresses a tree and usually kills it within a year. Recent studies have shown that EAB beetles are attracted to stressed ash trees, especially those in sunny locations such as along roads and trails, and tend to lay more eggs on stressed trees than on healthy trees. Girdled trees organized in a grid pattern are very effective for detection and assessment. This best practice also has a second important purpose, to function as beetle population "sinks" that concentrate and eliminate adult beetles before they can disperse and reproduce.

Girdled trees can serve a third important purpose as "trap-trees," a technique with a long history of use in forest pest management. The key to managing the infestation is reducing pest pressure; or put more bluntly—killing the beetles, not the trees. The following are important considerations listed in the SLAM study to accomplish this:

- If trees are girdled and remain standing for more than one year, they will serve as beetle magnets. Since girdled trees must be removed before the next generation of adults can emerge, a large component of future adults can be eliminated.

- If tree cutting and removal is not a viable option (for example in woodland areas), then creating *lethal* trap trees should be considered. As the infestation builds, it may be economically preferable to invest in reducing pest pressure near high-priority trees. Lethal trap trees can be used by treating trap trees a few weeks before girdling. However, the effectiveness of girdled trees to function as traps or sinks appears to diminish as EAB densities build in an area.[39]

- Clustering three or four girdled trees creates a more powerful attraction for EAB adults than isolated single girdled trees in areas with low-density populations.

- There is evidence to suggest that at very low EAB population levels, the location of sink trees can influence how beetles disperse. Sink trees will pull some beetles towards them as EAB adults respond to the presence of artificially stressed trees. Placing clusters of sink trees inside the core of an outbreak versus outside the outer edges could pull dispersing beetles away from the edges and potentially reduce spread rates.

- Although all native ash trees will attract EAB adults, some species are more attractive than others. If different ash species are present, select by

[38] Refer to the Definitions for a description of tree girdling.
[39] For more detail, refer to McCullough, Deborah G.; Siegert, Nathan W.; *Using Girdled Trap Trees Effectively for Emerald Ash Borer Detection, Delimitation and Survey*, Dept. of Entomology and Dept. of Forestry, Michigan State University, July 2007. http://www.emeraldashborer.info/files/handoutforpdf.pdf

priority, from most to least preferred: (1) green ash, (2) black ash, (3) white ash, and (4) blue ash.

- **Timing for girdling trees:** Dates for girdling trap trees or setting traps and debarking trees or retrieving traps should be based on accumulated degree days for the local area since adults predictably fly at the same number of degree days each year. Girdled trees should be felled and debarked or destroyed in the fall, winter or early spring following their establishment to ensure that larvae die before completing development.

3.2. Strategy 2—Preserve Structurally Sound Ash Trees

This Strategic Plan recommends reliance on trunk injection of emamectin benzoate (average of 5 ml active ingredient per DBH) to preserve structurally sound ash trees, including trees with a minimal degree of infestation and no more than 30% canopy loss from EAB. Treatments will eliminate the infestation. Section 4 includes information regarding pesticide safety. As with the first strategy, this one also helps to implement Goal 4 of the *Urban Forest Management Plan* because it helps to "minimize risk and potential damage, and increase tree health."

Strategic Plan Best Practices:

- **Insecticide treatments:** Insecticide treatments should be used for the following public trees:

  - **Aggressive treatment protocol—Years 1 to 13:** Treat 100% of medium and high-priority trees beginning with those closest to the infestation wave front (including trees with less than 30% canopy loss from EAB). Since trees can tolerate three or more years of low-to-moderate infestation, treat approximately 1/3 of the trees each year to even out demands on crews, equipment, and budgets. While emamectin benzoate products are labeled to effectively treat EAB for two years, research indicates treatments may be effective for three years.[40] Field research and the SLAM study confirm that treatments using emamectin benzoate will keep trees completely free of pests for the first two years after the injection, and that it takes three to four years after the start of an infestation for trees to decline to the degree they show more than 30% canopy loss and require removal.

  - **Maintenance treatment protocol—Year 13 and beyond:** Inspect 100% of medium and high-priority trees in Year 13. Treat (and track) those trees that show 30% or greater canopy decline thereafter. Implement SLAM Study practices by randomly selecting 20% of medium and high-priority

[40] A recent study examined the percentage of canopy decline in treated ash trees located in the midst of an EAB infestation ("Systemic Insecticide Technology for Tree Care," by Dan Herms, Department of Entomology, Ohio State University, Ohio Agricultural Research and Development Center, Wooster, Ohio). The study found that trees treated with emamectin benzoate in 2006 (0.8 g active ingredient / DBH) had only 5% canopy decline three years later in 2009.

trees for treatment in Year 13. Thereafter, treat 20% of randomly selected trees that had not been treated during the prior five years.

- **Maximize preservation and "herd immunity:"** From both an economic and an environmental perspective, the more structurally sound trees the City can protect from this invasive species the better, even if it is only a temporary period of protection (refer to the next bullet point). Compared to the outdated strategy of just removing and replacing the trees, an integrated pest management approach that includes protecting structurally sound trees with pesticide treatments preserves about four times as much of the tree canopy and tree value over twenty years, and it costs half as much. Treatments not only preserve public trees and dollars, they also help protect untreated private ash trees that are nearby via what is known as "herd immunity."

  The City should look carefully at every ash tree. If a tree is classified as "low-quality" because of serious structural problems and warrants removal regardless of EAB, it should be removed. If it is because of factors that are manageable (e.g. drought stress, insect pests, etc.), it can be treated to extend the period during which the tree can continue to provide the benefits that were expected when the City made the initial investment to plant it. Low-quality trees can also serve a pest suppression role as a "staged removal" tree at least during the peak years of the infestation (refer to the next bullet point).

  As the percentage of treated trees increases, so do the "herd immunity" benefits discussed in Section 1.5 because treated trees kill the larvae within them and their leaves kill all EAB beetles that feed on them. It's an appropriate public role to have the public trees serve as pest suppression trees to help protect private trees, plus it saves public funds and preserves public tree benefits.

  The best approach to an EAB infestation is to fight it like a human health epidemic. While it is not necessary for 100% of the host population to be inoculated to control an epidemic, better results are achieved by inoculating a critical percentage of *all* hosts susceptible to the epidemic. That critical percentage is likely to be in the range of 20% of all ash trees in an area.[41]

  Incorporating treatments to protect trees from attack maintains a greater level of public safety by keeping trees in good condition. It also buys time (refer to Section 1.5). Scientists developed many of the integrated pest management strategies described herein since the first cities came under attack. Over time, new strategies may be found to protect trees longer and for less money, and new predators may limit or eliminate EAB. From an economic standpoint, removal and replacement costs are trending higher (especially due to the higher skill demands for removals), and treatment costs are trending lower as

[41] Based on personal communication with Deborah G. McCullough, Ph.D., 1/17/14.

competition and scientific findings drive pesticide prices lower and because lower skilled labor can complete the work.

- **Treating for staged removal:** For urban forests where large numbers of ash trees are likely to need removal during the peak period of the infestation, forest managers may wish to treat trees so that they can survive long enough to be removed after the main wave of the infestation has passed. Continued inspection can determine when canopy loss approaches 30%, so that they can be treated again to postpone removal, or girdled to serve as trap trees and then removed the following spring.

3.3. Strategy 3—Improve Species Diversity

Strategy 3 involves a balancing act. Expanding the City's tree canopy helps to implement goals 2 and 3 from the *Urban Forest Management Plan* because it facilitates "tree planting on private and public properties to help the city reach an overall tree canopy cover of 40%" (Goal 2).

Goal 3 in the City's plan calls for increased "species diversity." In order to reduce the risk of catastrophic loss due to diseases and pests like EAB, the traditional tree diversity guideline known as the "10-20-30 rule" suggests an urban tree population should include no more than 10% of any one species, 20% of any one genus, or 30% of any family. Since the various species of ash comprise a genus, ideally, ash trees should not exceed about 20% of the total tree population in an area according to this guideline. However, the EAB infestation's ability to wipe out all species of ash trees highlights the limitations of this guideline.

Tree diversity also means age diversity. Cities with a large percentage of ash that decide to replace them over a short period of time will create a less diverse population age-wise than if they protected their structurally sound ash trees either for staged removal or, ideally, for the rest of their useful lives.

The estimates in Table 1 (and Chart 2 in Attachment 2) show that ash trees constitute about 15% of the current urban forest (excluding woodland trees). If the ATP Plan A or B were implemented, that percentage would shrink to about 3%. Focusing on City-owned trees, there are several urban forest districts that have ash populations that are close to or exceed the arboriculture diversity limit of 20% (Districts 1, 7, 8, and 12). The inevitable loss of virtually all untreated ash trees will eliminate the overabundance in these districts and allow replacement trees to diversify forest and urban tree resources.

Best Practices:

- **Tree replacement:** This Strategic Plan establishes a City policy of replacing ash trees lost to EAB with at least a one-to-one ratio from a diversified list of eligible trees.

- **Stocking goal versus "no-net-loss:"** The first goal in the *Urban Forest Management Plan* calls for increasing street-tree stocking levels of City trees to 70% in residential areas of each urban forest district. The above strategy of a one-to-one replacement for ash trees lost to EAB will not meet this goal and alleviate the lack of trees in certain districts. As stated above, no city has been able to expand its canopy after dealing with the devastation from this infestation. This Strategic Plan estimates that the City is facing new expenses that approach $5 million over the next 10 years just to keep the current number of City trees constant. Expanding the City's inventory is not a reasonable expectation. As such, this Strategic Plan incorporates a "no-net-loss" goal as regards tree populations.

3.4. Strategy 4—Postpone and Decrease Peak Ash Mortality

When EAB swept through cities, thousands of trees began to die all at once, this overwhelmed city resources and created major safety and liability issues. Cities can operate more efficiently if they can better predict the future costs and labor demands, adopt strategies that reduce the high peak period of the EAB death curve, and spread costs over a longer period. A critical purpose of this management plan is to accomplish just those objectives through the implementation of these 7 Strategies.

3.5. Strategy 5—Minimize Public Costs

Section 5 includes detailed cost estimations for the Base Case and several variations of the ATP Plan. In all cases, the ATP Plans have lower costs and protect more of the tree value.

Goal 8 in the City's *Urban Forest Management Plan* deals with securing the necessary resources to implement that plan. The best practices described herein are consistent with this goal because of the savings they will produce.

Strategic Plan Best Practices:

- **Record keeping:** Proper record keeping over the course of the infestation will produce a trove of data that will be invaluable to the forest managers. It is an essential tool in the battle against the EAB infestation as well as future infestations and diseases. A wide variety of software programs exist for urban forest management, complete with standardized reports and the ability to customize them for EAB data recordation and evaluation.[42] The data needed to evaluate the EAB management program include the following:
  - **High and medium-priority ash tree on public property:** Data should include geographic location, setting (e.g. boulevard, public yard or park,

[42] Davey Tree Co. has "TreeKeeper" software (c. $2,000 per year): http://www.davey.com/services/urban-forestry/urban-forestry-management-software/tree-keeper.aspx

etc.), condition, size, management protocol (treatment in this case), treatment data (pesticide, treatment method, date of treatment, and dosage), inspection history, date of removal.

- **Ash trees in low-priority public areas and low-quality ash trees:** Same as above.

- **Detection and trap trees:** Data should include geographic location, setting (e.g. boulevard, public yard or park, etc.), management protocol (e.g. girdling and removal).

- **Costs:** All program costs must be logged and tracked.

- **Public outreach history:** Records should include the program description, activity descriptions, and costs.

- **Program evaluation:** Careful record keeping will provide the data with which forest managers can compare the results on the ground with the predictions in the Strategic Plan. For example, if the 3-year treatment protocol results in higher-than-predicted canopy cover loss, the protocol should be changed to either every 2 years or the dosage per DBH increased. Similarly, some trees could serve as experiments in saving money by lengthening treatment periods or lowering dosages. A practice of early investments in detection and lowering pest pressure (e.g. through detection and trap trees) should be weighed against investing in treatments for additional trees.

3.6. Strategy 6—Manage Tree Debris

All strategies to use or dispose of the wood generated from this Strategic Plan must conform to current Minnesota Department of Agriculture (MDA) specifications.

Strategic Plan Best Practices:

- **Disposal:** As the site allows, the City should continue the current relationship with City brush dump, to lease City land for the operation of a tree-waste recycling site for the disposal of trees, tree roots, and non-demolition generated wood waste. The site should be continue to be open to the public for disposal purposes during the hours of 8:00 a.m. to 5:00 p.m. Monday through Friday, and from 8:00 a.m. to 12:00 noon on Saturday.

  The City has also adopted a storm response plan, which outlines 8 secondary temporary wood disposal sites throughout the City. As tree-waste volume exceeds the capacity of the City brush dump site, or in an effort to maximize transportation efficiency, these secondary sites will be utilized as part of this Strategic Plan.

- **Wood Utilization:** A partnership with St. Paul District Energy allows for wood waste generated through tree removal to be hauled away and utilized for the purpose of energy production at the downtown St. Paul facility. City staff should look for opportunities to utilize wood waste at the energy plant in the City in cooperation with the recently expanded boundaries of the Destination Medical Center. Tree debris volumes will follow the EAB death curve with a huge peak during Years 4-8. The ATP Plan B flattens this peak and delays the production of wood waste into Years 14-17. This will ease handling and help stabilize the value of the debris.

3.7. Strategy 7—Enlist Private Tree Owners

Most of the ash trees in the City are on private property. Private owners can benefit from the information in this plan and the City's best practices strategies for public trees will serve as an example for the private sector. As mentioned above, treatments of public trees will also help protect private trees. Much has been learned from the cities that have battled the infestation since its discovery in 2002. Nonetheless, not all cities and property owners implement the best practices described herein.

Strategic Plan Best Practices:

- **Education and communication:** The City should use all tools available to communicate the goals and best practices in this Strategic Plan, and to encourage the owners of private ash trees to manage their trees consistent with them. Educational and communication tools include the City's website, newsletters, utility billings, and press releases. Community meetings are an excellent way to collaborate with those property owners and neighborhood and community groups most interested in preserving their ash trees.

- **Public subsidy for private trees:** In order to help suppress citywide pest pressure and to preserve high-value private trees, the City may decide to subsidize certain strategies on private property, for example treatments for high and medium-quality trees. Only trees located where their loss would have a significant effect on public land should be eligible for public subsidy. Budgetary constraints will determine the percent of the treatment costs to be subsidized. Subsidies for treatments should be contingent upon the property owner complying with the best practices described herein and should end after the thirteenth year when the peak of the infestation should have already occurred and the wave front of the infestation will have moved on.

3.8. Action Steps: The previous subsections described the Strategies and associated best practices. This subsection condenses the above analysis into concise action steps (Action Steps) necessary to implement the Strategies:

1. **Conduct EAB delimiting survey:** The City should conduct delimiting surveys as described above to determine the ongoing extent of the infestation. For

budgetary purposes, this Action Step 1 may require 0.5 full-time-equivalent (FTE) employee for one year; however, the budget does not include these costs at this time.

2. **Implement pest detection, suppression, and sanitation program:** The infestation is probably already well established in many parts of the City but not yet fully detected. The City should design and implement a program to use strategically located, low-quality trees as trap trees (including lethal trap trees) to help delineate the extent of the infestation and to help slow its spread by attracting the beetles to the trap trees instead of the medium and high-priority trees. Trees with canopy loss that exceeds 30% should be removed as soon as possible because dead ash trees generally deteriorate rapidly and many will become hazardous especially along streets, in yards, and along overhead power lines.

3. **Preserve the structurally sound ash trees:** The City should protect all of the medium and high-priority ash trees according to the treatment protocols described above. The City should also consider treating structurally sound, low-quality trees when any of the following conditions exist:
    - They are located where the loss of the benefits they provide could be significant (e.g. a residential or very public area with a small or thin canopy).
    - They are needed for pest suppression (e.g. close to the wave front of the infestation).
    - The avoidance of the much higher removal and replacement costs is needed to flatten costs during the peak years of the infestation (Years 4-9).

    The cost-benefit analysis accounts for the implementation of this Action Step.

4. **Expand tree diversity and tree canopy:** The City should plant a sufficient number of trees to replace all ash trees lost to EAB. The cost-benefit analysis accounts for the implementation of this Action Step.

5. **Manage the record and evaluate:** The City should keep accurate and complete records of the implementation of this Strategic Plan, evaluate the results, and modify its implementation as needed.

6. **Flatten the peaks:** By Year 7, approximately 80% of the untreated ash trees will be dead, and most of those deaths will have occurred in Years 5, 6, and 7 (18%, 26%, and 20% respectively). The City will be faced with the task of removing and replacing about 2,000 trees over that 3-year period, an amount that would probably overwhelm City crews and budgets. To better reduce these extreme periods and extend removals and replacements over more years, ATP Plan B assumes the City will treat selected trees for staged removal.

7. **Manage tree debris:** Section 3.5 fully describes the actions necessary to manage tree debris in a safe and efficient manner. As with tree removals, the peak years of the infestation will generate what some who have already been through the main wave of the infestation refer to as a "wall of wood." ATP Plan B assumes the City will treat selected trees for staged removal in order to even out the debris stream over 20 years instead of 4, which will be valuable especially for the debris that are utilized as industrial fuels. The cost-benefit analysis does not account for the associated costs or potential revenues from debris management.

8. **Provide educational materials for the public:** The City should use all tools available to communicate the goals and best practices in this Strategic Plan, and to encourage the owners of private ash trees to manage their trees consistent with them. The cost-benefit analysis does not allocate funds for this purpose since the City should be able to implement it using existing resources.

9. **Enlist private tree owners:** If private tree owners are willing to implement some of these Action Steps for private trees and public trees that abut their property, the City should consider subsidizing their efforts. Only high and medium-quality trees located where their loss would have a significant effect on public land should be eligible for public subsidy.

4. Pesticide Safety

There are increasing and well-warranted concerns regarding the overreliance on pesticides. Neonicotinoids and their effects on pollinators, such as bees, and soil-applied products that have the potential to reach storm water or ground water have all been highly publicized.

The pesticide recommended herein, emamectin benzoate (EB), is *not* a neonicotinoid. It is a systemic insecticide injected directly into the trunks of the trees, which minimizes its non-target effects. Ash trees are wind pollinated; they are not a substantial nectar source for bees, and they flower early in the growing season and only for a limited number of days. According to research conducted at Purdue University, "It is highly unlikely that bees would be exposed to systemic insecticides applied to ash."[43] EB has a low toxicity rating for mammals, a low bioaccumulation potential within ecosystems, and is immobile in soil. This means that the insecticide will not build up levels within an ecosystem and will be minimally harmful to people and animals that might encounter tree debris.[44]

[43] "Frequently Asked Questions Regarding Potential Side Effects of Systemic Insecticides Used To Control Emerald Ash Borer," http://extension.entm.purdue.edu/eab/PDF/potentialSideEffectsofEABInsecticidesFAQ.pdf

[44] "Emamectin benzoate is derived from a naturally occurring soil bacterium and has been registered for more than 10 years as a foliar spray to control pests in vegetable and cotton fields and parasitic sea lice in salmon aquaculture. Similar products are used in veterinary medicine as wormers for dogs, horses, and other animals." "Insecticide concentrations that have been measured in treated trees are far below the levels known to be toxic to birds.... In Michigan and Ohio, where EAB has been established for several years, many ash trees have been treated with systemic insecticides. There have been no reported cases of woodpecker poisoning caused by insecticides applied for control of EAB." (Hahn, Herms, McCullough, 2011)

While there are valid concerns regarding the overuse of pesticides in our environment, those concerns should be aimed at reducing pesticide use where fewer benefits result. The known environmental consequences of losing thousands of ash trees are vastly greater than the minimal risk associated with inoculating ash trees to protect them from certain death. Marla Spivak, the Distinguished McKnight Professor in Entomology at the University of Minnesota, and an internationally recognized expert on bees, has said that the benefits of trunk-injected emamectin benzoate for ash trees outweigh the minimal potential harm to bees.[45] Dr. Deborah McCullough, a professor of entomology and forestry at Michigan State University, has stated, "There is no reason for a landscape ash tree to die from emerald ash borer anymore."[46]

5. Cost-Benefit Analysis of the Strategic Plan

As a part of this Strategic Plan, an extensive, 20-year, cost-benefit analysis[47] was prepared to compare various scenarios. The Base Case represents the theoretical, no-action scenario for comparison to the other scenarios. It assumes the removal and replacement of all trees that are either preemptively removed or removed because they succumbed to EAB (greater than 30% canopy loss). The scenario includes no treatments. The Ash Tree Preservation (ATP) Plan A scenario assumes the use of a pesticide treatment protocol to preserve all high and medium-priority ash trees. It also includes strategies for the detection and reduction of pest populations, and the model can analyze subsidy programs for private trees and the costs of public education programs if the City decides to add them. The analysis includes an ATP Plan B and a variation of that scenario called ATP Plan B1:

- **ATP Plan B:** ATP Plan B addresses the concern that the City may not be able to fully implement the Action Steps during the peak years of the infestation (Years 4-9). In addition to preserving the medium and high-priority trees, this alternative scenario assumes 1,100 structurally sound, low-quality trees are treated twice over the 6-year peak infestation period to delay the need for their removal until after the infestation wave has passed. This is the staging for removal option described above in Section 3.2. This scenario predicts their deaths from Year 10-20 according to the EAB death curve.

- **ATP Plan B1:** When the deaths begin in Year 10 of the trees that were treated for staged removal, the City can decide whether to replace them at that time or continue their treatments. These structurally sound trees will have had at least nine more years to grow and provide their intended benefits. ATP Plan B1 calculates the costs and benefits of a future decision to continue the preservation of these 1,100 trees.

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[45] At the Minnesota Shade Tree Short Course held in Arden Hills, Minnesota, March 18 and 19, Dr. Marla Spivak, the Distinguished McKnight Professor in Entomology at the University of Minnesota and an internationally recognized expert on bees, said that the benefits of trunk-injected emamectin benzoate outweigh potential harm to bees.
[46] "Emerald ash borer treatments costing less, working better," *Minneapolis StarTribune*, 8/8/13: http://www.startribune.com/local/south/218936301.html
[47] Attachment 1 provides a complete listing of these data sources used in the spreadsheets that generated the charts and tables included in the report and in Attachment 2, Charts. All associated spreadsheets are available upon request.

The analysis consists of 15 interconnected spreadsheets that produce the 20 charts that comprise Attachment 2. Trees are categorized into 3 main groups: a) high-priority trees, b) medium-priority trees, and c) low-quality trees. Average tree size (DBH) is estimated for each group and the analysis accounts for the differing growth rates for each group over the 20-year study period for both DBH and cross-sectional trunk area. Cost and benefit analyses for the 3 tree categories and for the scenarios described above include the following (Attachment 1 includes the data sources used to generate the calculations):

- Tree and trunk removal
- Operational costs for treatments (labor, materials, and overhead)
- Tree replacement costs (costs of tree and planting, and additional costs related to the higher maintenance costs and mortality rates of new trees versus mature trees)
- Tree benefits (overall economic value, property value increase, stormwater interception, conservation of electricity and natural gas, carbon sequestration and avoidance, and reduced health care costs)
- Tree deaths in accordance with the EAB death curve
- Return on investment analysis that accounts both for inflation and the time-value of money.

Attachment 2 is the heart of the analysis. Using 20 pie, bar, and line charts, it graphically illustrates the cost-benefit comparison of the 4 scenarios. The following summarizes each of these charts:

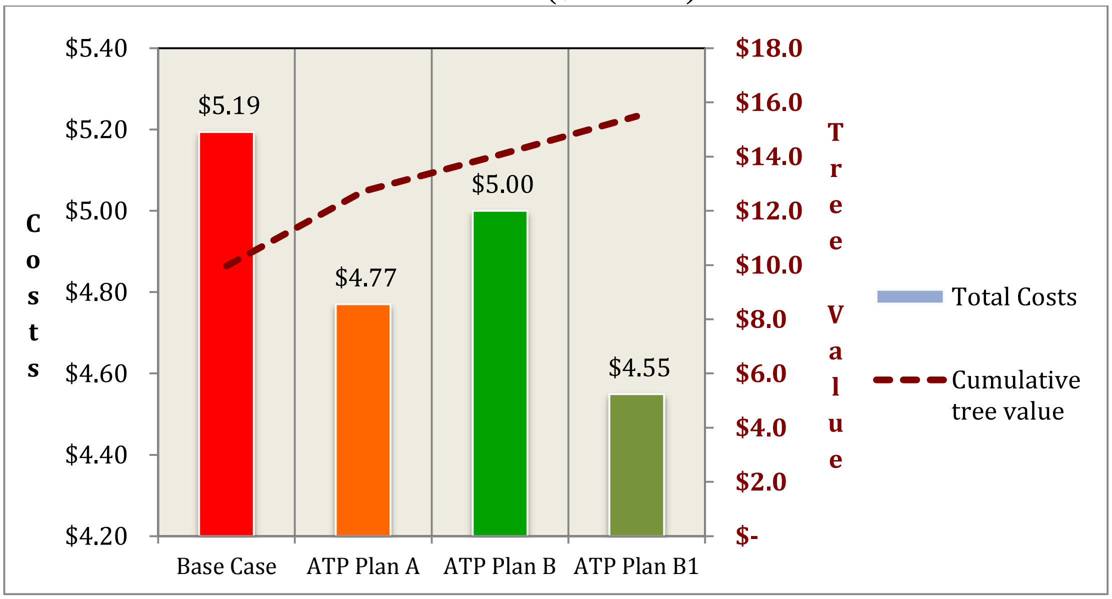
- **Charts 1 and 2:** The pie chart in Chart 1 shows that ash trees comprise about 15% of the current urban forest (not including woodlands), with about 7% of the ash trees on City property and 8% on non-City property (referred to as "private" for the analysis). The chart also breaks out the 4 categories for City ash trees. The bar chart, Chart 2, again shows the current percentage of ash at 15% of all trees and adds the prediction that this percentage will shrink to about 3% by Year 20 under the ATP Plan A and B scenarios. Of course, under the Base Case scenario, the infestation will destroy virtually all ash in the City.

- **Charts 3 and 4, Cost Comparisons, Year 1-20:** These two charts summarize cost comparisons. Chart 3 is stacked-bar chart that provides a side-by-side look at the primary cost components and the cumulative tree value of Base Case and the 3 ATP Plan alternatives over the 20-year study period. Because of its value in visualizing the comparative costs and benefits of the scenarios, a simplified version of the data in Chart 3 is included below as Figure 2.

  The ATP Plan A scenario provides long-term treatments for close to 1,200 trees (9% of the public and private ash trees in the City). Because it's less expensive to treat a tree rather than remove and replace it, the Base Case costs more. By year 10, the ATP Plan A is 13% less expensive. Continued treatment, removal, and replacement costs over the next decade shrink this cost advantage for the ATP Plan A to 8% by Year 20. ATP Plan B is also less expensive than the Base Case, especially over the first 10 years (26% less); however, this is accomplished by flattening the costs during the peak period and moving them to the second decade of the infestation. By Year 20, the ATP

Plan B is 5% higher than the ATP Plan A but still lower than the Base Case (4% lower).

Figure 2: Comparison of Total Costs and Cumulative Tree Value, Years 1-20
($ millions)



If tree costs were the only factor, no one would plant a tree. Chart 3/Figure 2 also compares the overall cumulative tree value of the above-described scenarios (note that the dashed purple line refers to the vertical axis on the right for cumulative tree value). The up-sloping line illustrates the advantages of the ATP Plan A, B, and B1 which preserve 28%, 41%, and 55% respectively higher tree values by Year 20 than the Base Case.

Turning to Chart 4, the high cost of removals and replacements drive the red line for the Base Case to the top of this chart at about $5 million over the 20-year study period. The lowest line on the chart, dotted red, reflects Base Case costs if trees were not replaced. The consequences of that option are best illustrated in the next Chart, Chart 5, where DBH goes to virtually zero by Year 10 (dashed red line).

Since relatively few trees are treated in the ATP Plan A scenario (20% of City trees), the cumulative cost savings compared to the Base Case do not appear very large (as stated above, 13% less by Year 10 and 8% less by Year 20). The chart also shows the costs for the ATP Plan A if the labor costs for treatments are excluded. These costs are relatively small, so the dashed black line is indistinguishable from the solid orange line representing the ATP Plan A.

Both the Base Case and the ATP Plan A show large increases in annual costs during the peak of the infestation (Years 4-9). The ATP Plan B (green line) is designed to flatten the peak and delay these costs by treating 1,100 low-quality (but structurally sound) trees. Costs by Year 10 for Plan B are 26% lower then the Base Case and 15%

lower than the ATP Plan A. The chart shows how these costs are paid after the main infestation wave has passed. This results in ATP Plan B costs in Year 20 being only slightly lower than the Base Case (4% less) and slightly higher than the ATP Plan A (5% higher). The rise in the green line for the ATP Plan B reflects the cost of removing and replacing the trees that were treated for staged removal.

- **Alternative ATP Plan B1:** When staged removal begins in Year 10, the City can decide whether to replace these trees or continue their treatments. The dashed olive-colored line in Chart 4 represents the alternative, called ATP Plan B1, where the City chooses the latter course to preserve instead of replace the 1,100 trees. Since the cost of treating these trees would be about half that of replacing them, the total costs for the ATP Plan B1 alternative are $450,000 less than ATP Plan B and 12% lower than the Base Case.

- **Cost and Benefit Comparisons:** Tables 2 and 3 include the cost comparisons for these 4 scenarios and show the associated cumulative tree values, and Figure 1/Chart 3 illustrates this information graphically. Since ATP Plan B1 treats the most trees (about 40% of the City trees), it has the lowest removal and replacement cost and the highest treatment costs. By Year 20, ATP Plan B1 total costs are 15% lower and it preserves 50% more of the cumulative tree value compared to the Base Case. The "Takeaway" statement in Figure 1/Chart 3 references the advantages of ATP Plan B1 during the peak years of the infestation, which are addressed in more detail below regarding Table 5.

Table 2: Cost Estimations, Years 1-20 ($ millions)

Categories	Base Case	ATP Plan A	ATP Plan B	ATP Plan B1
Removals	$2.17	$1.78	$1.86	$1.35
Replacement trees	$2.26	$1.72	$1.71	$1.38
Treatments		$0.51	$0.67	$1.06
Girdling trap trees		$0.01	$0.01	$0.01
Hazard tree removal	$0.76	$0.76	$0.76	$0.76
Totals	**$5.19**	**$4.77**	**$5.00**	**$4.55**

Table 3 and Figure 2 also account for the benefits trees provide as measured by the U.S. Forest Service's Tree Benefit Calculator. All 3 of the ATP Plan scenarios cost less and preserve more of the cumulative tree value than the Base Case. ATP Plan B1 has the lowest cost and greatest amount of preservation compared to the Base Case at 12% less cost and 55% more preservation.

Table 3: Cost Comparisons, Years 1-20

Scenarios	Total Costs	Comparison to Base Case		Cumulative Tree Value	
		Amount	% Difference	Amount	Comparison to Base Case
Base Case	$5.19			$10.0	
ATP Plan A	$4.77	-$0.424	-8%	$12.7	28%
ATP Plan B	$5.00	-$0.194	-4%	$14.1	41%
ATP Plan B1	$4.55	-$0.645	-12%	$15.5	55%

- **Chart 5 Net DBH:** This chart introduces a new scenario, Theoretical (no EAB) to serve as a benchmark for conditions were there no infestation. All of the other scenarios show a reduction in net DBH during the first decade as small, newly planted trees replace existing low-quality ash trees. The lines start bending upwards by Year 10 as the replacement trees grow. The ATP Plan B is the best performer until Year 16 when the ATP Plan A provides slightly more DBH. The dip in the green line for the ATP Plan B reflects the removal of the trees that were treated for staged removal. As discussed above, the City can decide whether to replace these trees or continue their treatments. If the latter course were chosen, the dashed olive-colored line representing ATP Plan B1 shows how this alternative preserves the highest amount of tree canopy, exceeding 100,000 DBH by Year 20.

- **Chart 6 Cumulative Tree Value:** All of the lines are roughly equal until around Year 5 when EAB forces the replacement of trees in increasingly higher numbers, especially for the Base Case and ATP Plan A. The dashed olive-colored line for ATP Plan B1 shows this scenario as preserving the most tree value.

- **Chart 7 Cost per DBH:** This bar chart combines the relative costs of the 4 main scenarios with the resulting DBH of surviving urban forest. The higher cost and lower resulting DBH for the Base Case drives up the red bars relative to the ATP Plan bars. As the “Takeaway” box explains, every dollar invested in the ATP Plan B and B1 preserves about 3 times as much of the DBH as the Base Case by Year 10. The cost of removing and replacing the staged removal trees in ATP Plan B shrinks this cost advantage somewhat by Year 20 while the continued treatment of these trees in ATP Plan B1 yields the lowest cost-per-DBH amount.

- **Chart 8 Tree Value Per Dollar of Cost:** Like the previous chart, this chart combines the overall measure of the value of the trees and the costs to maintain tree value in the face of the infestation. As the “Takeaway” box explains, every dollar invested in the ATP Plan B and B1 preserves about twice as much of the cumulative tree value as the Base Case by Year 10, which equals nearly $2 million more in tree value. As with the prior bullet regarding cost per DBH, the cost of removing and replacing the staged removal trees in ATP Plan B shrinks this cost-per-tree-value advantage somewhat by Year 20 and the continued treatment of these trees in ATP Plan B1 yields the highest amount.

- **Charts 9-14:** These 6 charts compare the various tree benefits of the 4 scenarios. [48, 49] Table 4 provides a summary of the degree to which ATP Plan scenarios exceed the benefits in the Base Case by Year 20. When averaged together, the tree benefit exceedances for the ATP Plan A, Plan B, and B1 are approximately 29%, 44%, and 58% respectively by Year 20.

Table 4: Summary of Tree Benefit Comparisons to Base Case, Year 20

Benefits	ATP Plan A	ATP Plan B	ATP Plan B1
Increase in property value	21%	32%	44%
Cumulative intercepted stormwater	42%	64%	84%
Cumulative electricity conservation	26%	40%	53%
Cumulative natural gas conservation	30%	46%	60%
Cumulative CO_2 reduction	29%	44%	58%
Cumulative health care reduction	25%	38%	51%
Average of 6 benefits	**29%**	**44%**	**58%**

- **Chart 15 Return on Investment:** Assuming 2% annual inflation and 5% discount factor, the ATP Plan B1 alternative provides a positive return (i.e. additional dollars on top of the original investment) of a dollar in Year 4 for every dollar invested, and a return as high as $4 in Year 7 for every dollar invested. Returns remain highly positive in Year 15 and Year 20.

- **Chart 16 Annual Costs to City:** Chart 16 shows annual costs to the City in order to highlight peak-period expenses. Table 5 below lists these costs for the Base Case and ATP Plans A and B.[50] As mentioned above, Plan B reduces costs 26% by Year 10 compared to the Base Case and shifts costs to the second decade of the infestation. Compared to Plan A, Plan B costs are slightly higher (5%) by Year 20 but most can be avoided by longer-term treatments of the staged removal trees (this is the ATP Plan B1 alternative scenario).

- **Charts 17-19:** These charts examine operational concerns associated with peak demands on financial and labor resources. As mentioned above, cities can operate more efficiently if costs and labor demands are predictable and do not vary considerably from year to year. However, the infestation has an opposite effect since the EAB death curve kills trees slowly at first and then it builds quickly and only levels off after it kills most of the unprotected trees by Year 10. Chart 16 and Table 5 below show that costs of ATP Plan A and B during the peak of the infestation (Years 4-8) are 16% and 33% lower respectively than the Base Case. Charts 17 and 18 show that similar pattern of reduced and delayed costs for Plan B for tree debris and labor costs. To deal with the "wall of wood" concern mentioned above, ATP Plan A and B

[48] Source: Source: National Tree Benefit Calculator. Figures are for green ash in residential areas in the Midwest Climate Zone, which includes portions of 15 states. http://www.treebenefits.com/calculator/treeinfor.cfm?zip=55118&city=SAINT%20PAUL&state=MN&climatezone=Midwest

[49] Data have been adjusted with weighted averages to account for trees in non-residential land uses. All references for the calculations are listed in Attachment 1.

[50] ATP Plan B1 is not included because it is identical to ATP Plan B for the first 10 years.

reduce removals by about 2,200 trees. During the peak years, Plan A and B reduce peak period debris management by 20% and 40% respectively compared to the Base Case.

Charts 18 and 19 focus on the labor component during the peak of the infestation. Even if the City contracts out most of the labor to implement this plan, City responsibilities to secure and manage these contracts, oversee performance, complete complementary responsibilities, respond to citizen requests and complaints, etc. will also swell during peak periods. This is why it is important that the ATP Plan A and B will reduce these labor costs by 17% and 52% respectively during these peak periods compared to the Base Case (Table 5).

Chart 19 examines this issue on a seasonal basis for the peak year, Year 6, of the infestation. The up-and-down pattern shows that spring and fall labor costs almost double those in winter and there are almost no costs in summer. The ATP Plan A and B reduce these large swings and flatten the curves. A closer look at these labor costs on a seasonal basis in Year 6 reveals that Plan B reduces them by an average of about 39% compared to the Base Case.

Table 5: Operational Comparison of Scenarios ($ millions)

Scenarios	Total Costs		Labor Costs		Debris Management (DBH)	
	Peak Years 4-8	Year 10 Total	Peak Years 4-8	Year 10 Total	Peak Years 4-8	Year 10 Total
Base Case	$3,814,704	$5,148,329	$2,196,552	$3,075,927	95,170	111,853
Plan A	$3,202,980	$4,497,955	$1,821,612	$2,647,004	76,326	89,705
Plan B	$2,552,230	$3,819,803	$1,058,620	$1,773,072	56,700	68,368
Plan A Versus Base Case	-16%	-13%	-17%	-14%	-20%	-20%
Plan B Versus Base Case	-33%	-26%	-52%	-42%	-40%	-39%

- **Chart 20 Individual Tree Benefits and Costs:** All of the previous charts and tables provide an overview of the infestation. However, individuals, whether a trained arborist or a resident with an ash tree, will stand in front of a single tree and ponder the best strategy to deal with it. Chart 20 applies the ATP Plan's protection principles to an average sized tree with a DBH of 17 inches and compares the benefits (i.e. cumulative tree value) and costs to the Base Case assumptions with the tree being replaced in Year 6, the peak year of the infestation. To repeat the Takeaway statement, more than 2 trees can be protected over a 20-year period for the cost of removing and replacing one tree. Every dollar spent removing and replacing a tree could preserve more than 5 times the tree value by protecting it instead.

6. Definitions

The following describes the words and terms used in this Strategic Plan:

- **Ash tree classifications:**

  - **High-priority trees:** Ash trees located in high-priority areas having a condition rating of Good and a DBH of at least 6”, or a condition rating of Fair with no structural defects and a DBH of at least 8”.

  - **Medium-priority trees:** Ash trees located in high-priority areas having a condition rating of Fair, with minor structural defects and a DBH of at least 10”.

  - **Low-quality trees:** This category includes 2 subgroups. If a tree is classified as low quality because of serious structural problems and warrants removal regardless of EAB, it should be removed. If it is because of factors that are manageable (e.g. drought stress, insect pests, etc.), it can be treated to extend the period during which the tree can continue to provide the benefits that were expected when the tree owner made the initial investment to plant it. Low-quality trees can also serve a pest suppression role as a “staged removal” tree at least during the peak years of the infestation.

  - **Woodland hazard trees:** Ash trees that may cause a hazard along woodland paths and roads and adjacent private property as they succumb to the infestation. All cost-benefit scenarios assume they will be preemptively processed (chipped or cut into small pieces) on site.

- **Condition rating:** A system to rate the condition of trees from zero to four. A tree with a condition rating of four is the highest quality; zero is dead.

- **Cost-benefit analysis scenarios:** The analysis includes four scenarios for cost-benefit comparisons over a 20-year study period. The analysis also assumes that the woodland hazard trees defined above will be preemptively removed in the scenarios:[51]

  - **Base Case:** The Base Case represents the theoretical, no-action scenario for comparison with the other scenarios. It assumes the removal and replacement of all trees that are either preemptively removed or removed because they succumbed to EAB (greater than 30% canopy loss). The scenario includes no treatments.

  - **Ash Tree Preservation Plan A:** This scenario assumes the use of a pesticide treatment protocol to preserve all high and medium-priority ash trees. It also includes strategies for the detection and reduction of pest populations, and it can analyze subsidy programs for private trees and the costs of public education

[51] In order to present valid comparisons, all of the scenarios assume the same tree replacement ratios for tree deaths. They do not account for ash tree mortality from causes other than the EAB infestation. Therefore, ash trees not killed by EAB are assumed to survive to Year 20.

programs.

- **Ash Tree Preservation Plan B:** This scenario is identical to the Plan A scenario with one important exception: It assumes some low-quality trees are treated over a 6-year period (2 treatments each) and then removed as they succumb to EAB. This strategy is in response to, firstly, the over-riding theme within the SLAM analysis described above—"reduce EAB numbers and the growth of EAB populations." Secondly, it responds to the concern described above that the infestation will "hit you like a freight train." It is intended to reduce and spread peak costs, removals, replacements, and tree debris until after the main wave of the infestation has moved on; and to preserve tree benefits for an additional 9+ years.

- **Theoretical "No-EAB" Case:** In order to compare urban forest conditions that result from the scenarios, the analysis estimates what the DBH and forest benefits would be were there no infestation.

- **EAB "death curve:"** The analysis by Daniel Herms, "EAB-Induced Ash Mortality in the Upper Huron River Watershed, SE Michigan," OARDC, Ohio State University, described the expected rate of ash mortality in an area over a 10-year period from the assumed start of the EAB infestation. By year 10, the infestation will kill virtually all unprotected ash.

- **Diameter at breast height (DBH):** The diameter (inches) of the cross section of a trunk measured at 4½ feet above ground.

- **Estimated tree value:** Tree value estimates rely on the National Tree Benefit Calculator to quantify those benefits for the purpose of cost comparisons.

- **Geographic distinctions for ash trees:**

  - **High-priority areas:** Public and private areas used or within clear view from public lands and rights-of-way. This includes boulevards, front yards of public and private property, and the mowed areas of public parks and open spaces. The term also applies to areas where it is especially important to preserve the environmental, economic, and aesthetic contributions from high-priority ash trees; and those areas where pest suppression efforts are especially important.

  - **Low-priority areas:** Public and private areas that are not considered high priority areas as regards the management of the EAB infestation.

  - **Woodlands:** Areas where trees dominate and where development, mowed areas, and trails are absent or minimal. Topography and forest density makes protecting ash trees in woodlands difficult and uneconomical. Woodland trees grow in close proximity to one another and compete for light. This competition reduces the canopy size of each tree, which makes the losses less significant to total canopy cover. Neighboring trees are positioned to quickly grow into the opened spaces created as ash trees die.

- **Legacy ash tree:** All public ash trees with a condition rating of 3 or 4 and a DBH greater than 10 inches located in a high-priority area.

- **Peak period:** During study Years 4-8, pest pressure and tree mortality for untreated trees, as described by the EAB "death curve," climb geometrically, peak, and quickly decline by Year 9 and 10 as EAB kills virtually all unprotected ash trees.

- **Pest pressure classifications:**

  - **Low pest pressure:** A condition in an area where beetle and larvae populations are relatively low such that the ash trees in an area easily tolerate beetle feeding levels and the associated tree phloem loss. There will be no symptoms of canopy loss.

  - **Moderate pest pressure:** A condition in and area where beetle and larvae populations are moderate such that the ash trees in the area are able to tolerate feeding levels and the associated phloem loss. The symptom of canopy loss will be less than 30%. If not treated with a pesticide, the pest pressure will likely grow to high levels and trees will begin the dying process. If treated before the past pressure is too high, the trees can fully recover, with the exception of the parts of the trees that suffered canopy loss.

  - **High pest pressure:** High pest pressure is a condition in an area where beetle and larvae populations are relatively high such that the ash trees in the area cannot long tolerate feeding levels and the associated phloem loss, which will approach 60%. The symptom of canopy loss will be approximately 50%.

- **Private trees:** Trees existing wholly or partially upon land not owned by the City and existing outside of City easements and right-of-ways.

- **Public right-of-way (boulevard area):** A strip of land granted for public transportation or public or private utility purpose, such as a street and its boulevard. Public Right-of-Way includes the median areas of streets.

- **Public trees:** Trees existing wholly or partially upon City-owned property such as parks, public buildings and facilities, and public rights-of-way.

- **Staged for removal:** A strategy of reducing peak-period strain on resources by treating lower-quality trees for a period of time (generally throughout the peak years of the infestation) and removing them after the main wave of the infestation has passed.

- **Study Year:** Study Years refer to the 20-year period addressed by this analysis for the purpose of estimating and comparing the costs and benefits of the scenarios. It is assumed that Year 1 designates the start of the EAB infestation as regards the EAB "death curve."

- **Treatment protocols:** There are two levels of treatment protocols based on the SLAM Study analysis. Both are intended to minimize costs and pesticide use:

  - **Aggressive treatment protocol (Years 1-12):** During the most intense phase of the infestation, treatments are administered to 100% of the high-priority trees over a three-year period (1/3 of the trees each year).

  - **Maintenance treatment protocol (Years 13-20):** By Year 11, virtually all of the untreated ash trees will be dead and the pest pressure will be nearly nonexistent. Consistent with the SLAM Study, only 20% of the trees will need treatment annually through Year 20. The SLAM study predicted that randomly treating only 20% of the ash trees in an area each year for ten years would preserve 97% of the trees.

- **Treatment for staged removal:** This strategy uses treatments to protect trees during the peak years of the infestation (Years 4-8). Its value is to reduce and spread peak costs, removals, replacements, and tree debris until after the main wave of the infestation has moved on; and to preserve tree benefits during these peak years and move those costs beyond the peak years; and to preserve tree benefits.

- **Trap trees and lethal trap trees:** This refers to the strategy of girdling low-quality ash trees to attract the beetles to that location so that their larvae can be killed when the tree is removed before the beetles emerge as adults. If the tree is treated with an insecticide before it is girdled, the tree will be lethal to both beetle larvae and every adult beetle that feeds on it. The use of multiple trap trees in an area can help to concentrate the infestation, reduce pest populations, and slow the spread of the infestation.

- **Tree diversity:** The tree diversity guideline known as the "10-20-30 Rule" is an arboriculture best practice designed to reduce the risk of catastrophic loss due to pests like EAB. The guideline recommends an urban forest be made up of no more than 10% of any one species, 20% of anyone genus, and 30% of anyone family. Some communities are further reducing these percentages to increase diversity to a maximum of 5% any one species, 10% genus, and 15% any family.

Attachment 1

Components and Data Sources for the Ash Tree Preservation Analysis

The Ash Tree Preservation Analysis includes 15 spreadsheets that generate the data that are summarized in 20 charts. The following describes the components and methods of the analysis:

- **20-year study period.**
- **Population categories for public and private trees:**
  - High-priority city trees
  - Low-quality city trees
  - Medium-priority trees
  - Woodlands hazard trees
  - Private trees
- **Tree population data sources:** Tree population estimates for the above categories are developed using city data, tree survey data for the 7-county metropolitan area from the Minnesota Department of Natural Resources (DNR), the DNR's statewide urban tree survey,[52] land use data from the Metropolitan Council,[53, 54] and tree inventories from a sampling of cities in the region.
- **Policies:** The ATP Analysis includes the following EAB management policies and activities:
  - Detection and pest-suppression activities (traps, trap trees, detection grids).
  - Treatments at 2 levels of intensity:
    - ✓ Aggressive treatment protocol: Treatments every 3 years on a rotational basis to even out annual costs.
    - ✓ Maintenance protocol: Treatments every 5 years on a rotational basis to even out annual costs. Protocol is based on the SLAM model.[55]
  - Replacement trees for trees that succumb to EAB or are removed.
  - Public outreach and subsidies of private trees.
- **Physical characteristics of the three main tree groups:** Since costs and tree benefits vary by tree size, the scenarios take into account the different average tree sizes (DBH and cross-sectional area) and growth rates for each of the groups of trees and for each of the 20 study years.[56]

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[52] The statewide urban tree survey conducted by the Minnesota Department of Natural Resources found that 7% of the State's urban trees were ash trees owned by municipalities and 8% were ash trees located on private property. These findings were used to estimate the number of ash trees on private property and the total number of trees. Tree estimates are based on survey results of ash trees located within 66 feet of the roadway's edge in residential and commercial areas. They do not include woodland trees. The figures include public and private ash trees. Source: "Rapid Assessment of Ash and Elm Resources in Minnesota Communities," 1/5/07, Minnesota Department of Natural Resources. Downloaded: http://files.dnr.state.mn.us/assistance/backyard/treecare/forest_health/ash_elmRapidAssessment/rapidassessment_AshElm.pdf

[53] Source: http://stats.metc.state.mn.us/stats/pdf/MetroStats_LandUse2010.pdf

[54] Source: http://stats.metc.state.mn.us/data_download/DD_Years.aspx?datasource=landuse&level=region

[55] Source: McCullough, Deborah G.; Mercader, Rodrigo J.; "Evaluation of potential strategies to SLow Ash Mortality (SLAM) caused by emerald ash borer (Agrilus *Plani*pennis): SLAM in an urban forest," *International Journal of Pest Management*, Vol. 58, No. 1, January–March 2012, 9–23.

[56] Growth rates for trees from: "Predicting Dimensional Relationships for Twin Cities Shade Trees," Lee E. Frelich, Department of Forest Resources, University of Minnesota, June 1992. http://www.forestry.umn.edu/prod/groups/cfans/@pub/@cfans/@forestry/documents/asset/cfans_asset_249769.pdf.

- **Mortality rates:**
  - EAB death curve: Predicts tree mortality due to EAB for untreated trees.[57]
  - Treated trees: Predicts tree mortality due to EAB for treated trees.[58]
  - Replacement trees: Predicts mortality for replacement trees.[59]
- **Costs:**
  - Tree and trunk removal costs based on tree size at time of death.[60]
  - Replacement trees:
    - ✓ Cost of tree and planting.[61]
    - ✓ Additional costs related to the higher maintenance costs of new trees versus mature trees.[62]
  - Treatments for surviving trees: Labor, materials, and overhead based on tree size.[63]
  - Cost escalators during the peak of the infestation.[64]
  - Return on investment analysis that accounts for both inflation and the time-value of money.[65]
- **Benefit analysis:** The primary source is the National Tree Benefit Calculator.[66]
  - Overall economic value.
  - Property value increase.
  - Blended benefit factor that accounts for different economic benefit rates by land use.[67]

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[57] Source of the EAB "death curve:" "EAB-Induced Ash Mortality in the Upper Huron River Watershed, SE Michigan," OARDC, Ohio State University. http://www.oardc.ohio-state.edu/hermslab/images/Herms_EAB_Management_12_Feb_2013.pdf

[58] Source for mortality rates for treated and untreated trees: McCullough, Deborah G.; Mercader, Rodrigo J.; "Evaluation of potential strategies to SLow Ash Mortality (SLAM) caused by emerald ash borer (Agrilus Planipennis): SLAM in an urban forest," *International Journal of Pest Management*, Vol. 58, No. 1, January–March 2012, 9–23.

[59] New trees have a higher mortality rate than mature trees. Plan assumes 5% of new trees will die in first year and 2% of the remaining trees over the next 5 years consistent with field studies. This will equal a 6.9% loss overall. Source: Purdue University EAB Cost Calculator, http://extension.entm.purdue.edu/treecomputer/

[60] Averages for tree and stump removal costs are from the City of Columbia Heights.

[61] Source of estimates for purchase and planting of replacement trees: Rainbow TreeCare. Costs account for labor and benefits, materials, and overhead.

[62] New trees require more per-tree maintenance costs for pruning, watering, etc. The annual additional maintenance costs are based on: "Value, Benefits, and Costs of Urban Trees," Brian Kane, Assistant Professor, University of Massachusetts, Amherst, Jeff Kirwan, Extension Forestry Specialist, Virginia Tech. http://pubs.ext.vt.edu/420/420-181/420-181_pdf.pdf.

[63] Assumed labor cost rate: Minnesota median hourly wage for pesticide handlers, sprayers, and applicators (source: http://www.bls.gov/oes/current/oes373012.htm#st) plus 25% in benefits. Materials costs are based on application rates and wholesale costs for Arborjet brand of emamectin benzoate.

[64] During the peak of the infestation, demand for many tree-related services for ash trees (as well for all other landscape-related services including pruning, removals, maintenance, debris management, etc.) will explode. For example, the pruning contract for the City of Fort Wayne Indiana increased 53% between the beginning and the peak of the infestation (personal communication with the City Arborist). This analysis assumes the EAB death curve is an appropriate surrogate for the expected increases. It is applied to the removal costs. Dr. John Ball agreed with the reasonableness of this assumption (personal communication) and said it is a conservative estimate. Due to the ability of tree nurseries to quickly restock with a variety of species to meet the increased demand for replacement trees, and the relative ease of planting a 2.5 caliper tree, the peak-period-escalator costs are not applied to replacement tree costs. It is also not applied to treatment costs due to the relative ease of existing businesses that offer treatments to expand and obtain additional active ingredients, and to the relative ease of new businesses to enter the market. This does not hold true for the more capital-intensive nature of the removal business and its higher training and wage costs (8% higher average wage in Minnesota).

[65] Assumes 2% annual inflation and a 5% discount rate over the 20-year budget period.

[66] Source: http://www.treebenefits.com/calculator

[67] The National Tree Benefit calculations are based on ash trees on single-family residential lots. In order to account for the reduced economic benefits attributable to ash trees on multi-family and non-residential lots, the benefits are reduced on a pro-rata basis per the share that each land use category represents overall. Sources:

- Storm water interception.
- Conservation of electricity and natural gas.
- Carbon sequestration and avoidance.
- Calculation of how surviving trees offset the energy consumption and carbon emissions of average Minnesota households.[68]
- Air pollution reduction and associated reduction in health care costs.[69, 70]

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http://stats.metc.state.mn.us/stats/pdf/MetroStats_LandUse2010.pdf; and http://stats.metc.state.mn.us/data_download/DD_Years.aspx?datasource=landuse&level=region

[68] Sources for the calculations for energy and carbon offsets for the average Minnesota household are as follows: Persons per household, 2008-2012, source: http://quickfacts.census.gov/qfd/states/27000.html. Average per-capita consumption in Minnesota of electricity (2011) was 4,212 kWh and 25.2 million Btu of natural gas. Source: US Department of Energy. http://apps1.eere.energy.gov/states/residential.cfm/state=MN#ng. Xcel Energy was the source for conversion factors for electricity and natural gas consumption to CO_2.

[69] A recent study estimated that in 2010, trees in the urban areas of Minnesota removed 4,600 tons of pollutants from the air and that this resulted in $26.7 million in reduced health care costs. Source: “Tree and forest effects on air quality and human health in the United States,” Nowak, David, et al., Environmental Pollution, 7/25/14, http://www.nrs.fs.fed.us/pubs/46102

[70] The ATP Analysis assumes human population is a surrogate for urban tree populations. Since the 2010 populations for the region and the state are 3.28 million and 5.38 million respectively, it assumes that 67% of the urban trees in the State are located in the Twin Cities region. Therefore, pollution reduction and reduced health costs for the region are 67% of the totals for the state, and 20% of these figures apply to the ash tree population.