
Image from the City's web site

Emerald Ash Borer Management Plan

City of Albert Lea

May 2022


Image from: *Minnesota State Agency Report: Emerald Ash Borer in Minnesota, 2019*

Save the best, replace the rest

Rainbow TreeCare

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Introduction

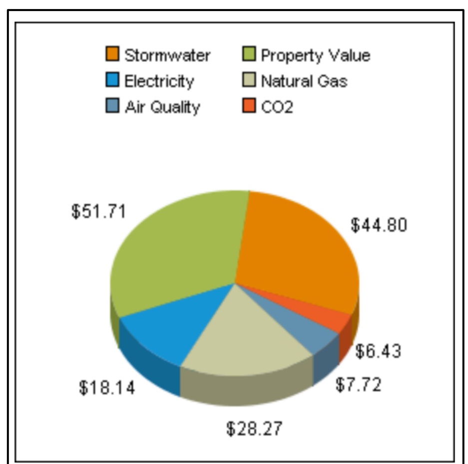
Project description: In anticipation of the imminent threat of the Emerald Ash Borer (EAB) infestation, the City of Albert Lea (City) contracted with Rainbow Treecare to prepare this *Emerald Ash Borer Management Plan* (EAB Plan) to help the City manage the infestation. The EAB Plan describes best practices for managing the infestation based on the most recent scientific findings. The EAB Plan also illustrates the cost advantages of using the full complement of integrated pest management strategies. The slogan, *Save the best, replace the rest*, summarizes its core strategy for the environment and for the City's budget. While the estimated costs of this EAB infestation will be relatively large in any case, a well-developed plan can minimize and justify such costs, demonstrate leadership rather than reaction or inaction, and reduce liabilities for the City.

EAB grant: The Minnesota Department of Natural Resourced awarded the City a $100,000 grant to help it manage the infestation. As a part of the grant agreement, the City pledged $40,000 in matching funds and is committed to completing all of the required actions by the end of July 2023, including the removal and replacement of approximately 250 undesirable ash trees. This EAB Plan incorporates those requirements.

Additional information: Attachment A includes definitions of terms used herein and Attachment B provides detailed information regarding the assumptions and data sources that serve as the basis for the cost-benefit analysis component of the EAB Plan.

Green Infrastructure

Albert Lea's urban forest: A 2007 survey completed by the Minnesota Department of Natural Resources estimated approximately 12,000 community sh trees growing in maintained areas of the city. These trees clean the air, help to manage stormwater, 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. According to the US Forest Service's National Tree Benefit Calculator, the City's average-sized, healthy ash tree (16-inch diameter) provides $157 worth of benefits each year.[1]



Breakdown of your tree's benefits

The City identified, geo-located, measured, and evaluated nearly 1,100 ash trees growing on City property including about 800 that are healthy, properly located, and have at least a 12-inch diameter by now. Unfortunately, the emerald ash borer will be lethal to virtually all of these trees

[1] http://www.treebenefits.com/calculator/ReturnValues.cfm?climatezone=Midwest

unless they are protected from this invasive species with treatments. Because of their significant benefits, this EAB Plan views trees as "green" infrastructure that is no less important to the City as its "grey" infrastructure (e.g. sewers, roadways, telecommunications, etc.).

Tree benefits: When these quantifiable benefits of trees are weighed against their purchase, planting, pruning, protection, and removal costs, the benefits outweigh the costs by a margin of about 3 to 1. For example, studies show that:

- The net cooling effect of an average, healthy tree is equivalent to 10 room-size air conditioners that operate 20 hours a day.[2]
- One acre of urban forest absorbs 6 tons of carbon dioxide and emits 4 tons of oxygen annually.[3]
- 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. An average mature tree will intercept over 1,800 gallons of stormwater annually.
- Street trees even help extend the life of expensive asphalt by 40-60% by reducing daily heating and cooling of roads.[4]
- Tree roots have a profound effect on the soil environment. They will direct 40-73% of assimilated carbon below ground.[5]

As experts have underscored, healthy urban trees mean healthier city residents. An analysis by the World Health Organization confirmed that air pollution is now the world's single largest environmental health risk.[6] An analysis 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."[7] The Forest Service 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.[8]

The below diagram is from a study published in 2013 in the *Journal of Environmental Science and Technology,* which measured the impact of boulevard trees on indoor air quality. Researchers found

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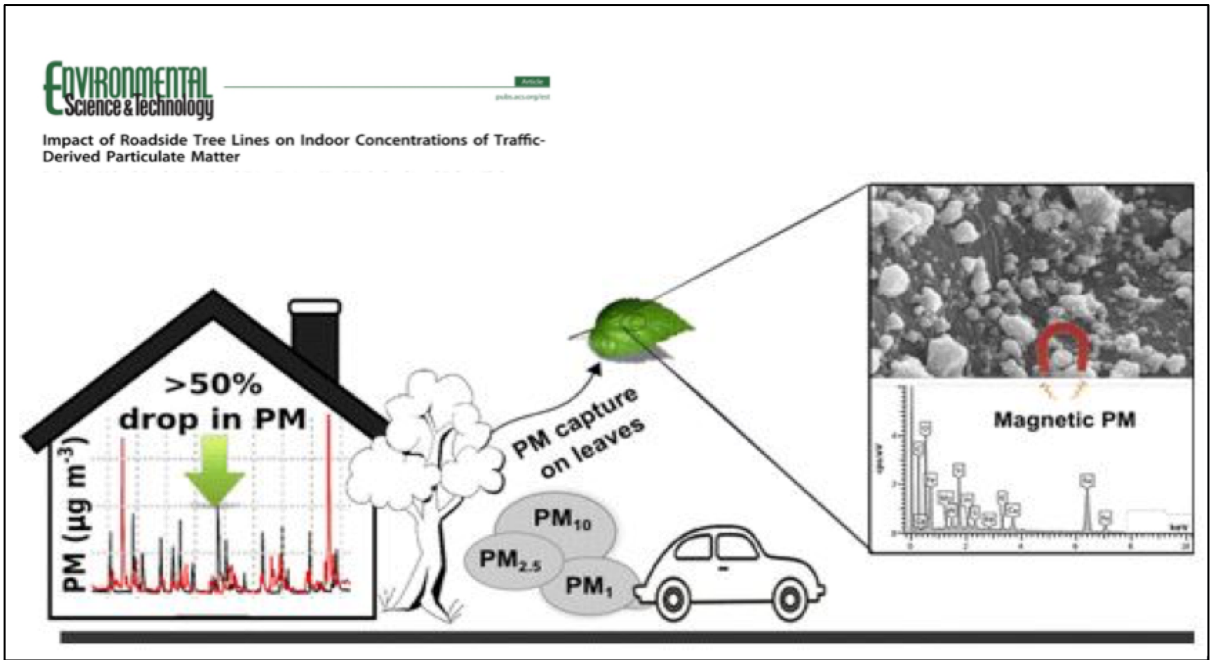
[2] http://www.arborday.org/trees/benefits.cfm
[3] Ibid.
[4] Source: "City to Consider Special Funding for Trees," City of Madison Wisconsin, 7/31/14, http://www.cityofmadison.com/news/city-to-consider-special-funding-for-trees
[5] Source: http://www.dailycamera.com/guest-opinions/ci_26131781/silent-environmental-devastation
[6] "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
[7] "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
[8] 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/.

a greater than 50% drop in traffic-derived indoor particulate matter when trees separated streets and homes.[9]



While the above studies quantify how trees benefit human health, another study demonstrates how tree deaths from the EAB infestation are associated with human deaths. An 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. Their 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 respiratory disease."[10]

The value of mature trees: A key word in the above information refers to *mature* trees. Contrary to past assumptions, a recent study showed that the older the tree, the more quickly it grows. "Trees with trunks three feet in diameter generated three times as much biomass as trees that were only half as wide. … If we want to use forests as a weapon against climate change, then we must allow them to grow old…."[11]

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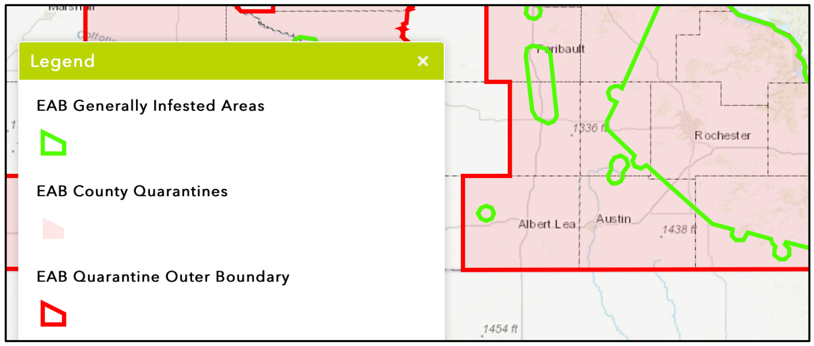
[9] "Independently, the two approaches identify >50% reductions in measured [particulate matter] (PM) levels inside those houses screened by the temporary tree line. Electron microscopy analyses show that leaf-captured PM is concentrated in agglomerations around leaf hairs and within the leaf microtopography. … The efficacy of roadside trees for mitigation of PM health hazard might be seriously underestimated in some current atmospheric models." Source: http://pubs.acs.org/doi/abs/10.1021/es404363m

[10] "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

[11] Wohlleben, Peter, *The Hidden Life of Trees: What They Feel, How They Communicate*; Greystone Books, 2015, pp. 97-98.

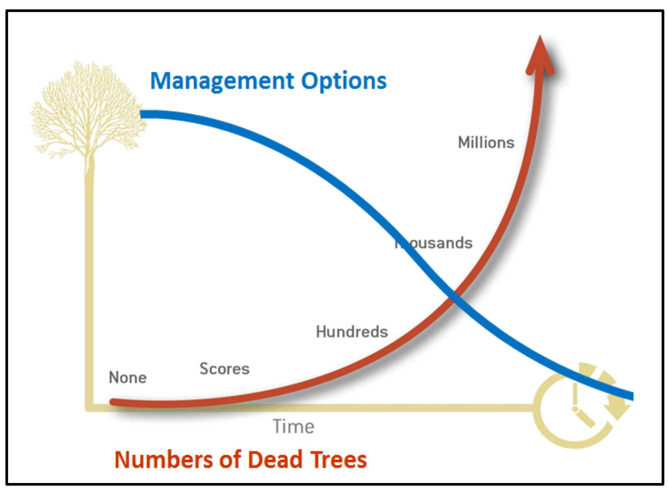
Proximity of the infestation



As of May 2022, 5 Canadian provinces and all but 15 states[12] have detected the EAB infestation and enforced quarantines, including Freeborn County. The image on the right shows the current, nearby locations where EAB infestations have been detected; namely, less than 7 miles to the northwest and about 25 miles to the northeast. While still some distance away, these are *known* infestations. Since it is likely that the infestation has already arrived, just not yet detected, this EAB Plan assumes action is needed immediately. The complete loss of the City's ash trees would have a significant effect on home values, quality of life, human health, and the environment. The time to act is now.

Failed EAB 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."



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 dead trees quickly overwhelm city crews, equipment needs, debris yards, and budgets. As the pest population increases and a greater number of trees die, the number of management options goes down (refer

[12] Source: US Dept. of Agriculture, http://www.emeraldashborer.info/about-eab.php

to above chart). The infestation makes ash trees desiccated and brittle to the point they can become a hazard to people and property. This makes removals more risky and expensive (removals require bucket trucks because the trees are not safe to climb) and it also increases a cities liability.

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 research indicates the strategy was counterproductive because the beetles can fly up to 12 miles per year and the infestation can expand close to a mile in a year.[13]

Integrated Pest Management and *Herd Immunity*

The good news is that 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.[14] The so-called SLAM (SL.ow A.sh M.ortality) study included over 200 computer simulations based on field-derived data and a best-case scenario that was most effective at preserving ash trees at the lowest cost.[15, 16] This best-case scenario predicted that random treatment of 20% the population of ash trees annually should protect 99% of the trees after 10 years. This coordinated strategy preserves 3-4 times as much of the tree canopy and tree value over 20 years as the outdated approach, yet it costs much less and it helps protect untreated private ash trees that are nearby. This EAB Plan is based on this research. 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.[17] This principal occurs with a range of microscopic 'bugs,' but the same concept applies to a larger bug—the EAB beetle. By treating a certain amount of the population of ash trees (i.e., at least 20%), there is a net benefit within the communities.

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[13] The Minnesota Environmental Quality Board produced the *2019 Minnesota Emerald Ash Borer Report*, which includes an extensive amount of information about the infestation: https://www.eqb.state.mn.us/EAB

[14] This management plan is based on the research in the *Model Emerald Ash Borer Management Plan*, 2015, by Jeffery Hafner and Michael Orange, http://www.mnstac.org/uploads/2/0/9/3/20933948/mnstac_model_eab_management_plan.pdf.

[15] 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.

[16] Dr. McCullough reviewed the guidelines in the *Model Emerald Ash Borer Management Plan* in May 2022 and stated that she has not come across "any studies that would affect the guidelines."

[17] The COVID pandemic has highlighted the importance of herd immunity.

City Policy

Albert Lea has a long and impressive of record of urban-forest-related accomplishments. For over 20 years, it has been a member of Tree City USA. With the leadership from a group of City staff known as the Green Committee and the strong support from the City's elected officials, the City achieved Step 3 in 2017 in the state's GreenStep Cities program. This is testament to a very high degree of commitment in a wide variety of environmental concerns including enhancing the urban forest. The City commissioned the preparation of a climate action plan, the *Albert Lea Climate Action Plan*.[18] It incorporates a high-level assessment of climate vulnerabilities including the following policies that address urban forest issues (emphasis added):

- Increase Tree Cover and Diversity, achieve a city-wide Tree Canopy coverage increase of 10% by 2030.

- Protect and sustain green spaces, urban tree canopy, and wildland ecosystems, enhancing their resilience to climate change impacts.

- Replanting tree loss, and Ash tree replacement for EAB management, at 150% or more of replacement with improved diversity.

- Create a tree preservation ordinance with reasonable exceptions that support the CAP tree canopy coverage and heat island mitigation goals. Ordinance should reflect projected climate changes and impacts on tree species.

- Develop a performance-based ordinance requiring tree planting within parking lots. Ordinance should establish a specific goal of percentage of pavement to be shaded by trees. Explore partnering with local business to create a pilot project to illustrate new ordinance requirements and benefits.

- Develop a policy that requires all housing and commercial development projects receiving City funding, PUD approval, and/or Conditional Use Permitting to implement commercial scale heat island mitigation strategies including cool surfaces, solar-friendly landscape shading strategies, impervious surface reduction, and breeze capture.

[18] *City of Albert Lea Climate Action Plan,* https://cityofalbertlea.org/wp-content/uploads/Albert-Lea-Climate-Action-Plan-web.pdf.

Action Steps

The EAB Management Plan includes the following specific Action Steps:

1. **ACTION STEP: Implement pest detection, suppression, and sanitation program:** The City should design a program to use strategically located, low-quality trees as *trap trees*[19] to help delineate the extent of the infestation after it is first detected and to help slow its spread by attracting the beetles to the trap trees instead of the structurally sound trees.[20]

   When cities first decide to address the infestation, city foresters are often unsure how to prioritize their efforts—remove heavily infested trees (sanitation), protect the most valuable trees even if they are already infested, or save as many valuable, healthy trees as possible. Typically, forestry budgets are inadequate for the tasks ahead, especially during the early years of the infestation when comprehensive action is most cost effective.

   An analysis using data from the City of Burnsville provides important guidance.[21] The report classifies 3 degrees of infestation for ash trees. The *first level* is for trees with the lowest intensity of the infestation, the *second level* is a moderate degree, and a *third level* classifies trees that are infested beyond hope, doomed to die, and, thus, not eligible for treatments. The authors conclude the following (emphasis added):

   > Note that it is crucial to initially treat trees in the second infestation level followed by trees in the first infestation level because this prevents trees from transitioning into [the third infestation level] where they may have more impact on susceptible trees. Furthermore, although the third infestation level poses the highest threat to susceptible trees in the first [level], they will transition to dead trees and will no longer spread the infestation. Therefore, treating lightly infested clusters are given priority to removing highly-infested trees.
   >
   > Another core result is that once the actual number of trees in each infestation level is detected, the optimal decision is to treat second-level-infested trees, followed by first- and third-level infested trees. This prevents mid-level-infested trees from becoming highly infested in the following period. Results indicate that if budget is not sufficient, then decision makers may need to let

[19] 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. Attachment B includes more information on this and other terms.

[20] For more information, refer to "Evaluation of potential strategies to SLow Ash Mortality (SLAM) caused by emerald ash borer (Agrilus *Plan*ipennis): SLAM in an urban forest" as cited above.

[21] "A Multi-Stage Stochastic Programming Approach to the Optimal Surveillance and Control of Emerald Ash Borer in Cities," Eyyüb Y. Kıbış, İ. Esra Büyüktahtakın, Robert G. Haight, Najmaddin Akhundov, Kathleen Knight, Charlie Flower (downloaded 2/12/22, https://icerm.brown.edu/video_archive/?play=1965)

some highly infested trees die in favor of treating low- and mid-level-infested trees.

2. **ACTION STEP: Preserve high-quality ash trees and minimize public costs:** Figure 1 summarizes the results of the City's inventory of ash trees located on City property. It lists the number and average size[22] of City-owned ash trees. Tree size is shown as *diameter at breast height* (DBH), which can serve as a surrogate for tree canopy.

Figure 1: Albert Lea Public Ash Tree Inventory

Tree Inventory Classification [1]				
Inventory Classification	**Tree Count**	**DBH Estimate**	**Total DBH**	**Ave. DBH**
Good	110	>12"	1,771	16.1
Good	84	<12"	660	7.9
Good	5	Would be >12" now	53	13.0
Subtotal	**194**		**2,431**	**12.5**
Fair	687	>12"	11,652	17.0
Fair	172	<12"	1,579	9.2
Fair	12	Would be >12" now	126	13.0
Subtotal	**859**		**13,231**	**15.4**
Poor	17	all	314	18.5
Watch	12	>12"	228	19.0
Other	10	>12"	182	18.2
Other	2	<12"	21	10.5
Subtotal	**41**		**745**	**18.2**
Grand total [2]	**1,094**		**16,407**	**15.0**
EAB Plan Classification	**Tree Count**	**Share of Total Trees**	**Total DBH**	**Ave. DBH**
High quality	826	76%	13,830	16.7
Low quality [3]	268	24%	2,682	10.0
Notes:				
(1) Tree size meaurements in the City's inventory were grouped into 46 circumference range categories instead of the typical DBH measurements for each tree. This analysis assumed the midpoints of the 46 circumference categories to estimate DBH. Also, 170 trees had not been measured for 5 or more years. Given the large margin for error in the DBH estimation, it did not make sense to attempt greater accuracy by "growing" the estimated DBH for these trees to their likely current size.				
(2) Excludes 7 trees with no DBH data				
(3) Includes the 7 trees with no DBH data. Assumes they have the average DBH for all trees.				

This EAB Plan uses 2 tree categories to determine the appropriate strategy. *High-quality* ash trees are the estimated 830 City-owned ash trees that are assumed to be a) healthy (i.e.,

[22] The City's tree inventory included multiple ranges of tree sizes rather than a measured diameter. The table used the average of the range to estimate a diameter at breast height.

classified as in good or fair condition), b) at least 12" in diameter by now, and c) located within clear view from public lands and rights-of-way. This includes boulevards, front yards of public facilities, and the mowed areas of public parks and open spaces. The other approximately 270 ash trees are classed as *low-quality*.

As a part of this EAB Plan, an extensive, cost-benefit analysis of ash trees on City property and easements was prepared for a 20-year study period. The analysis assumes the City will contract out implementation of the following components of the plan:

- Removal and stump grinding of the approximately 270 low-quality trees that are unhealthy, damaged, or poorly located by the end of April 2023 (per the grant agreement).
- Replacement tree purchase and planting by October 15, 2022 (per the grant agreement).
- Pesticide treatments for healthy, properly located trees (i.e., *high-quality* trees).
- Update City's tree inventory with current tree size and condition for treated City-owned trees.
- Management of tree debris, including tree debris from private tree removals if the City decides to offer that service.

There may be ash trees in woodland areas that may become hazards along trails, roadways, and adjacent private property. However, since the City's inventory did not include these trees, they are not included in this analysis. The analysis includes the following 2 scenarios, both of which assume the removal of all low-quality trees by August 1, 2023:

- **Base Case:** The Base Case scenario assumes all of the estimated 1,100 ash trees are removed and replaced as they succumb to EAB by Year 10 consistent with the *EAB death curve*. It serves as a theoretical, response-only scenario for comparison with the other action scenarios.

- **EAB Plan:** This scenario assumes the same tree removal and replacement policy for low-quality trees, but preserves the high-quality ash trees using systemic pesticide treatments (emamectin benzoate).[23]

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 more 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 12, virtually all of the

[23] If the budget does not permit protection of all high-quality trees, refer to the section above that described the study of the trees in Burnsville to prioritize treatments.

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 10 years would preserve 97% of the trees.

Figure 2: Cost-Benefit Analysis Assumptions

Assumptions		EAB Plan
Tree data:		
	Number of ash trees	1,094
	DBH of high-quality trees	16.7
	DBH of low-quality trees	10.0
	Average DBH, all ash trees	15.0
	New tree DBH	2.5
Cost data:		
	Removal cost per DBH	$ 40
	New tree cost (per grant agreement)	$ 250
	Treatment cost per DBH	$ 7
Actions:		
	Replacement tree percentage	100%
	High-quality trees to be treated	826
	Low-quality trees to be removed	268
	Treatment frequency during aggressive-treatment period	33%
	Treatment frequency during maintenance-treatment period	20%

Figure 2 lists the assumptions used to develop the cost-benefit analysis and Figure 3 shows the results of the analysis at 10-year and 20-year milestones. Attachment 2 includes a detailed list of the assumptions and data sources for the analysis. It should be noted that although the model produces estimates to the exact dollar amounts, it is not that accurate. As stated above, the model uses the very rough estimates of tree size based on the averages of the City's 46 size categories in its inventory. By the third study year (2026), all of the low-quality trees will have been removed and replaced and the City will have an accurate inventory of the size and treatment history of every high-quality tree. At that time, this analysis could be updated to predict future and total costs and benefits more accurately.

The 2 tables in Figure 3 compare the results at the end of the first 10 years and the end of the 20-year study period. It lists the main components of the costs for the Base Case and the EAB Plan and the cumulative tree value at the end of those 2 periods. The tree value calculation measures the annual benefit per the US Forest Service's National Tree Benefit Calculator of the living trees, both existing and the new replacement trees. The analysis "grows" the trees and totals the cumulative tree value over the 2 periods. The potential costs for the management of tree debris are addressed in a separate section at the end of this analysis.

Figure 3: Conclusions of the Cost-Benefit Analysis

First 10 Years		Base Case	EAB Plan
City costs:			
	Removal costs	$ 783,148	$ 107,279
	New tree costs	$ 333,670	$ 81,740
	Treatment costs		$ 398,599
	Total costs	$ 1,116,818	$ 587,618
	Cost savings (over Base Case)		-47%
Cumulative tree value:			
	Cumulative tree value	$ 6,502,207	$ 9,814,356
	Additional tree value (over Base Case)		51%
All 20 Years		**Base Case**	**EAB Plan**
City costs:			
	Removal costs	$ 783,148	$ 122,632
	New tree costs	$ 333,670	$ 88,391
	Treatment costs		$ 656,303
	Total costs	$ 1,116,818	$ 867,326
	Cost savings over Base Case		-22%
Cumulative tree value:			
	Cumulative tree value	$ 17,749,279	$ 33,903,854
	Additional tree value (over Base Case)		91%

The following provides the "takeaways" from the analysis (it also references the charts in Figure 4):

- **Totals costs:** Compared to the Base Case, the EAB Plan costs about half as much and results in $530,000 in savings by Year 10. Since Base Case costs come to an end after Year 10 but treatment costs continue for the EAB Plan (including limited removal and replacement costs), the comparative savings are smaller by Year 20: Costs are 22% lower and the savings are $250,000 (Charts 1 &2).

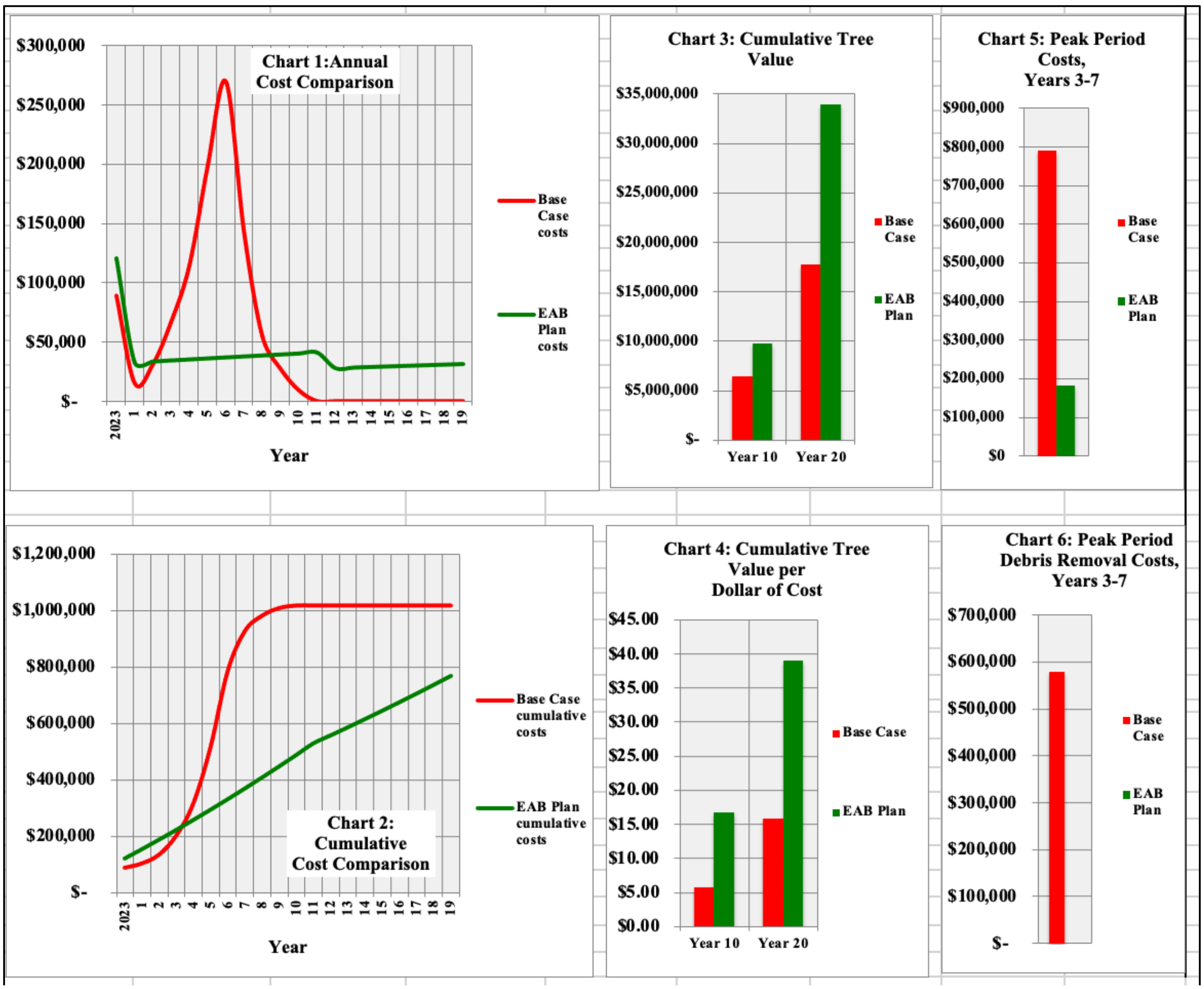
- **DBH per dollar invested:** Compared to the Base Case, every dollar invested in the EAB Plan preserves nearly 3 times as much cumulative tree value by Year 10 and 2.5 times by Year 20 (Charts 3 & 4). Eventually, treatment costs may exceed Base Case costs sometime after Year 30. However, compared to the Base Case, the EAB Plan will always preserve significantly more tree value well beyond the 20-year study period.

- **Peak period advantages:** The EAB Plan cuts costs and reduces the severe liabilities and the removal and debris-management costs especially during the peak years of the infestation (Years 3-7). Compared to the Base Case, the EAB Plan reduces peak-period costs by $610,000, a -77% reduction, and eliminates peak-period debris removal and debris management for City trees (Charts 5 & 6).

- **SLAM treatment protocol:** By Year 12, 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 to preserve 97% of the trees. The analysis also compared the costs differential if the *aggressive* treatment protocol (treatments every 3 years for high-quality trees) was maintained for the entire 20-year study period instead of moving to the *maintenance* treatment protocol recommended by the SLAM analysis (treatments every 5 years since no untreated ash trees would still be around to support a reinfestation). Total costs would increase by $160,000 over that 10-year period, a 19% increase.

Figure 4 provides graphs that compare the 2 scenarios. Clearly, the more high-quality trees that are treated, the greater the cost savings and tree value preservation compared to the Base Case.

Figure 4: Cost-Benefit Analysis Charts



3. **ACTION STEP: Flatten the peaks for removals and debris management:** Past experience in places where no actions were taken, approximately 80% of the untreated ash trees were dead by the eighth year of the infestation, and most of those deaths occurred in years 3-7.

This overwhelmed city crews and budgets. 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." The EAB Plan is extremely effective here. The EAB Plan assumes all removals of low-quality trees by the end of June 2023 (per the grant agreement). When compared to the Base Scenario, the EAB Plan cuts peak-period costs by $610,000, a -77% reduction (Figures 3 & 4).

Figure 5 includes the annual budget to implement the EAB Plan. It does not include any costs associated with implementing Action Steps 1, 5, and 6 since these steps can be completed by City staff.

Figure 5: EAB Plan Budget

Annual Budget for City Trees										
Study Year	Tree Removals [1]	Replacement Tree Costs [2]	Treatment Costs	Total Removal, Replacement, and Treatment Costs	Sources of Funds			Potential Chipping Costs for City Trees		Total City Costs [5]
					State Grant	City Matching Funds	Other City Funds	Low Cost [3]	High Cost [4]	
2022	$ 53,640	$ 81,740		$ 135,380	$ 95,380	$ 40,000		$ 1,766	$ 7,319	$ 44,542
2023	$ 53,640		$ 31,947	$ 85,587	$ 4,620		$ 80,967	$ 1,766	$ 7,319	$ 85,509
2024	$ -	$ -	$ 32,806	$ 32,806			$ 32,806			$ 32,806
2025	$ -	$ -	$ 33,689	$ 33,689			$ 33,689			$ 33,689
2026	$ -	$ -	$ 34,562	$ 34,562			$ 34,562			$ 34,562
2027	$ -	$ -	$ 35,426	$ 35,426			$ 35,426			$ 35,426
2028	$ -	$ -	$ 36,281	$ 36,281			$ 36,281			$ 36,281
2029	$ -	$ -	$ 37,126	$ 37,126			$ 37,126			$ 37,126
2030	$ -	$ -	$ 37,961	$ 37,961			$ 37,961			$ 37,961
2031	$ -	$ -	$ 38,787	$ 38,787			$ 38,787			$ 38,787
2032	$ -	$ -	$ 39,604	$ 39,604			$ 39,604			$ 39,604
2033	$ -	$ -	$ 40,410	$ 40,410			$ 40,410			$ 40,410
2034	$ -	$ -	$ 41,208	$ 41,208			$ 41,208			$ 41,208
2035	$ 1,741	$ 831	$ 25,452	$ 28,024			$ 28,024			$ 28,024
2036	$ 1,793	$ 831	$ 25,923	$ 28,548			$ 28,548			$ 28,548
2037	$ 1,845	$ 831	$ 26,389	$ 29,065			$ 29,065			$ 29,065
2038	$ 1,895	$ 831	$ 26,849	$ 29,576			$ 29,576			$ 29,576
2039	$ 1,946	$ 831	$ 27,304	$ 30,081			$ 30,081			$ 30,081
2040	$ 1,995	$ 831	$ 27,752	$ 30,579			$ 30,579			$ 30,579
2041	$ 2,044	$ 831	$ 28,195	$ 31,071			$ 31,071			$ 31,071
2042	$ 2,093	$ 831	$ 28,632	$ 31,556			$ 31,556			$ 31,556
Totals	**$ 122,632**	**$ 88,391**	**$ 656,303**	**$ 867,326**	**$ 100,000**	**$ 40,000**	**$ 727,326**	**$ 3,531**	**$ 14,638**	**$ 776,410**
Annual average over study period	$ 5,840	$ 4,209	$ 31,253	$ 41,301				$ 168	$ 697	$ 36,972

Notes:

1	Per the state grant agreement, removals must be completed by end of April 2023. Assumes removal costs split over both study years.
2	Per the state grant agreement, replacement tree planting for low-quality trees must be completed by October 15, 2022.
3	Low cost estimate assumes local company bids low cost range ($3 per cu. yd.) and high production rate (15 tons per day).
4	High cost estimate assumes distant company bids high cost range ($4 per cu. yd.) and low production rate (6 tons per day). Includes higher transportation costs plus per-diem expenses.
5	Estimates of total costs assume the average of debris management and excludes $100,000 state grant funds.

4. **ACTION STEP: Expand tree diversity and minimize tree canopy loss:** The EAB grant agreement requires the City to replace every tree that was removed using grant funds. It also has clear replanting requirements regarding the appropriate species and how to limit

their numbers to increase tree diversity. This EAB Plan assumes a one-to-one replacement for all City ash trees that are removed.[24]

The EAB infestation will have a profound effect on private ash trees as well. If the City is to implement the policies described above in the City's Climate Action Plan, for example, the 10% increase in tree canopy cover, it will have to supplement its efforts to protect and expand the tree canopy on City property by encouraging expansion on private property too. There are several ways the City can minimize tree loss and maximize the diversity and extent of its urban forest:

- **City as example:** Of course, the most important is to serve as a good example. Public promotion of the City's implementation of this EAB Plan can inspire the owners of private ash trees to also *save the best and replace the rest*.

- **Discounted services for private ash trees:** Since the City is probably the largest single owner of ash trees, it has the greatest leverage to obtain economical tree services from commercial providers. The City could encourage the companies it hires to help manage City trees to extend the same or close service rates to private tree owners.

- **City subsidies:** The $100,000 in state funds the City received could free up City funds to subsidize private actions that enhance the urban forest. The City could design a subsidy program that targets neighborhoods that are likely to be most impacted by public and private ash tree losses. Studies have documented that low-income people and racial minorities disproportionately live in neighborhoods that have less tree cover than higher-income neighborhoods and thus are at greater health risk during heat waves. Over 45% of the households in the City are low income. Residents in higher-density and lower-income neighborhoods are generally more reliant on the environmental, economic, and human health benefits provided by trees than residents of high-income neighborhoods.[25, 26, 27] More than 35% of the $157 in annual tree benefits from an average-sized ash tree in Albert Lea are advantageous primarily to the general public, as opposed to the individual property owner (i.e., stormwater management, air quality improvement, and greenhouse gas mitigation). As such, a

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[24] It should be noted that a policy in the City's Climate Action Plan calls for a 150% replacement ratio (refer to the above listing of selected policy statements from the plan).

[25] "Environmentalists face challenges trying to plant in less-green neighborhoods," Annie Gowen and Ted Mellnik, Washington Post, 4/26/13. http://www.washingtonpost.com/local/environmentalists-face-challenges-trying-to-plant-in-less-green-neighborhoods/2013/04/25/21294968-ad27-11e2-a198-99893f10d6dd_story.html

[26] "The Inequality of Urban Tree Cover: Minorities are significantly more likely to live in heat-prone neighborhoods that will be particularly at risk with climate change," Mily Badger, *The Atlantic*, 5/15/13. http://www.citylab.com/housing/2013/05/inequality-urban-tree-cover/5604/

[27] "The Racial/Ethnic Distribution of Heat Risk-Related Land Cover in Relation to Residential Segregation," Bill M. Jesdale, Rachel Morello-Frosch and Lara Cushing, *National Institute of Environmental Health Sciences*, 5/14/13, http://dx.doi.org/10.1289/ehp.1205919

public subsidy in that range may be appropriate, provided the investment in the private tree is consistent with the City's finally adopted EAB Management Plan.

- **Model Landscape Ordinance:** Mother Nature ignores property lines. The report, *Model Landscape Ordinance for a Municipal Zoning Code,*[28] details how a city's zoning code, development review process, and stormwater management ordinance could be improved to protect healthy mature trees and living soils on sites, and enhance the urban forest with new plantings. Very importantly, it addresses the issue of developments that impact off-site mature trees, a matter that few zoning codes address, including Albert Lea's.[29] The City's Climate Action Plan refers to these kinds of changes where it calls for a "tree preservation ordinance," a "performance-based ordinance requiring tree planting within parking lots," and a policy that requires "all housing and commercial development projects receiving City funding, PUD approval, and/or Conditional Use Permitting to implement commercial scale heat island mitigation strategies including cool surfaces, solar-friendly landscape shading strategies."

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

6. **ACTION STEP: Provide educational materials for the public and enlist private tree owners:** The EAB grant agreement requires the City to inform the public about the infestation and the City's efforts to manage it.

   In an effort to raise public awareness and encourage action from private residents, the City should develop communication strategies to educate residents and business owners about the problems posed by EAB, and the best practices to manage their trees. Communication strategies include the following:

- **City website information:**
  - A description of the EAB infestation and how ash trees are affected
  - How to identify an ash tree
  - The best practices of *save the best and replace the rest*
  - Treatment options
  - How and why to hire a qualified arborist
  - Information and links to the Minnesota Department of Agriculture EAB quarantine regulations and the EAB location map

[28] Source: https://greenstep.pca.state.mn.us/media/8

[29] The Minnesota Department of Natural Resources, the Minnesota Pollution Control Agency, the Minnesota Tree Trust, and the University of Minnesota have developed comprehensive guides of best management practices for the protection of trees and soils in developments (MnDNR BMPs for developments, Minnesota Stormwater Manual, *City Trees: Sustainability Guidelines & Best Practices*, and "SULIS: Sustainable Urban Landscape Information Series" (http://www.extension.umn.edu/garden/landscaping/).

  - Information on managing, transporting, and processing EAB-infested wood
  - A list of City-licensed contractors
- **Printed information:**
  - Flyers mailed directly to homeowners with the above information
  - Articles in local newspapers
  - Leaflets or statements in mailed utility bills
  - City staff who are already in the neighborhoods (e.g., city inspectors and forestry and parks and recreation staff who maintain city trees and property) could be trained to spot ash trees and drop door hangers or leaflets with the above information
  - Tree companies licensed by the City could be encouraged to leaflet properties with ash trees
- **Broadcast media:**
  - Forestry staff could appear on local radio and TV programs
  - Posts on City-owned social media pages
  - Sharing EAB content from other entities (Minnesota Department of Agriculture, University of Minnesota) on City's social media pages
- **In person actions:** Schedule community events and information sessions, including "piggybacking" on other community meetings

The City should initiate these strategies as soon as possible. Raising awareness <u>before</u> the City is heavily infested will increase the likelihood of private ash trees being treated or proactively removed, which will slow the community spread of EAB. Since no single communication medium will reach all residents, repeated communications of all types will be necessary to encourage residents to take the most appropriate action. The City should be persistent with its messaging and be prepared to make funds available for the creation and distribution of EAB informational material.

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 pesticide recommended herein, emamectin benzoate, is *not* a neonicotinoid. It is a systemic insecticide injected directly into the trunks of the trees, which minimizes its non-target effects. 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."

Considerations Regarding City Management of Private Ash Tree Debris

Introduction: The City is considering managing debris from ash trees located on non-City property. City staff questioned whether the City would have enough space for storing and chipping this private tree debris on City property, what is the best way to manage the debris, and how much will it cost? The following makes reasonable assumptions and calculations to assess the space requirements, some of the potential costs, and other impacts were the City to take on this responsibility. The calculations are based on the EAB Plan cost-benefit analysis and the assumption that the City will contract out the chipping of the debris. The analysis does not account for the possible need for additional City staff resources and out-of-pocket costs to control access to a debris-handling operation on City property, and to manage debris piles and mulch that are beyond the scope of a City contract with a private tree company that will do the chipping.

Likely debris stream: Using the Minnesota Department of Natural Resources (DNR) "Rapid Assessment" data, the cost-benefit analysis estimated the current sizes and condition of all ash trees in the City and made a reasonable assumption that private owners would manage 40% of their trees via treatments to preserve healthy trees, or removals by themselves or tree removal companies. The following summarizes the "Takeaways" from the analysis (also refer to Figure 6). It accounts for the total number of trees to be removed as they succumb to the infestation over the next 10 years consistent with what is known as the *EAB Death Curve*.[30]

Amounts and costs: Private ash tree removals will total almost 6,500 trees, weigh over 6,000 tons, and have a volume of about 25,000 cu. yd.

Figure 6: Private Ash Tree Debris Management Scenarios

Cost Scenarios	Low-Cost Scenario	High-Cost Scenario	Totals
Private tree debris management:			
Total private trees			10,824
Total private trees to be removed over the 10-year period			6,494
Total green weight of trees to be removed (tons)			6,250
Volume of debris piles (cu. yds.)			25,001
Through-put capacity of a wood chipper (tons per 8-hour day)	6	15	
Total days to chip the debris stream over 10 years	417	1,042	
Cost for chipping ($3-4 per cu. yd.)	$ 75,004	$ 100,005	
Annual equipment transportation to the City sites ($1,500-2,000)	$ 15,000	$ 20,000	
Per-diem lodging for a 2-person crew ($200 per night)		$ 166,675	
Total costs	**$ 90,004**	**$ 286,680**	
Total City costs*	**$ 93,535**	**$ 301,319**	**$ 964,752**

[30] 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.

The following assumptions were built into the cost benefit model in order to develop very rough estimates of the likely costs and time it would take to chip the private debris. They are based on discussions with a private tree company located in the Twin Cities that is capable of handling large debris streams:

- Through-put capacity of a wood chipper: 6-15 tons per 8-hour day
- Cost for chipping: $3-4 per cu. Yd. for whole tree debris (mix of logs and brush)
- Cost for equipment transportation to the City sites: $1,500-2,000 each year
- Per-diem for a 2-person crew (assuming travel from the Twin Cities and lodging): $200 per night

The analysis includes 2 costs scenarios:

- **Low-cost scenario:** This scenario assumed a local company could bring the needed equipment on site at the rate of $1,500 each year, and do the chipping at the high through-put rate (15 tons per day) and the low cost ($3 per cu. yd.).

- **High-cost scenario:** Assumes only a company from the Twin Cities would perform the work. The cost to bring the needed equipment on site is at the higher rate of $2,000 each year, and the through-put rate is at the low end (6 tons per day) and at the high-cost rate ($4 per cu. yd.) Per-diem costs for the 2-person crew were added.

Figure 6 shows that the total for the low-cost scenario is about $90,000 and $287,000 for the high-cost scenario. If the average of the low and high-cost chipping estimates were added to the cost estimate for the EAB Plan, total costs would be close to $1 million over the 20-year study period.

The great range of cost estimates reflects the large uncertainties in this part of the analysis. There are no accurate assessments of the size and number of private ash trees and chipping cost estimates are highly dependent on the availability of the needed equipment, the distance from the company's location to the City's sites, and whether the company would have to pay per-diem costs. Costs could be significantly reduced if a local company could bring a high-capacity chipper or a tub grinder with a throughput capacity of 30 tons per hour or more. The City will need to go through a request for proposal process to determine the best method of chipping the private debris stream.

Peak-year management: The analysis focused on managing the private tree debris during the peak year, Year 6, assuming that if it was manageable, other years would also be manageable. Figure 7 shows that the debris stream during the peak year would involve about 1,700 trees, weigh over 1,700 tones, and have a volume of about 7,000 cubic yards. At the low-production rate, 6 tons per day, the debris from the peak year would take over 290 days to chip. At the high-production rate, it would take 117 work days to chip. According to the Minnesota Department of Agriculture (MDA), chipping should occur over the 7-month period from the beginning of October through the end of April in order to destroy the beetle larvae before they emerge in the spring (refer to discussion below). That period only includes 150 weekdays. Figure 7 shows that a crew would need to have a production rate of about 12 tons per day to be able to chip the debris stream on weekdays only or to avoid paying overtime premiums.

Figure 7: Peak-Year Private Ash Tree Debris Management

Peak-Year (Year 6) Debris Management, Private Trees		Amount
Percent of debris for chipping (tons)		100%
Number of trees		1,753
Weight of debris (tons)		1,750
Volume of debris (cu. yds.)		7,000
Length of peak year's debris pile (ft.)		3,008
Debris pile length, assumes 2 wood-chipping areas (ft.)		752
Footprint of theoretical wood-chipping site (sq. ft.)		79,198
Footprint of theoretical wood-chipping site (acres)		1.8
Wood-chipper reduction ratio: debris :: mulch after chipping		3
Days to chip peak-year debris (assumes an 8-hour work day):		
	Low-production rate, 6 tons per day	292
	High-production rate, 15 tons per day	117
	Weekdays during 7-month period for chipping	150
	Production rate need to complete weekday chipping in the 7-month period (tons per day)	12

Spacial evaluation: In order to evaluate whether the City had adequate management space, it was assumed debris piles would be 20 ft. wide, 6 ft. high,[31] and have the half-ellipsoid shape shown in Figure 8.

Figure 8: Half-Ellipsoid Shape of Debris Piles

Shape code 6: Half-ellipsoid—The pile is elongated, rounded side-to-side, with well-rounded ends (fig. 4). This shape is typical of windrowed slash. (Observe and record height [*h*], total length [*l*], and width at the widest section [*w*].)

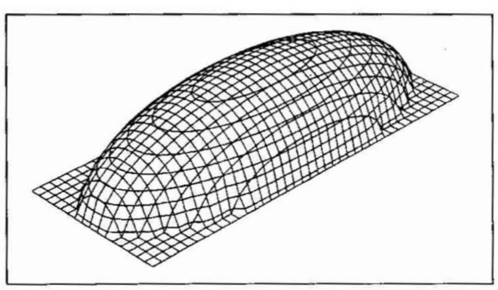


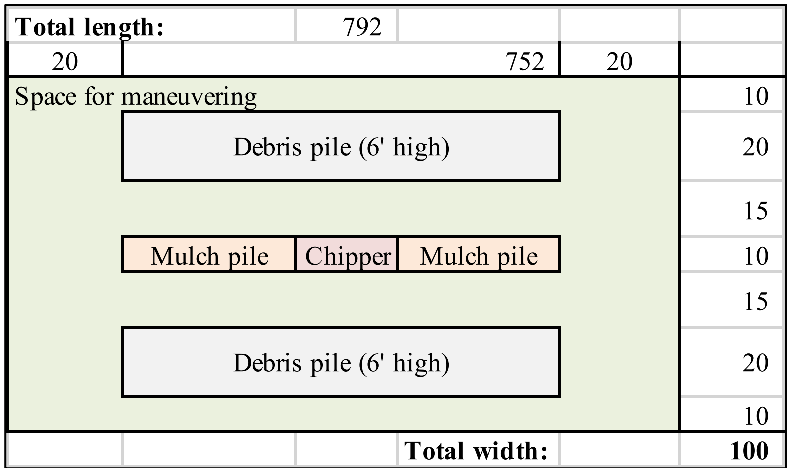
Figure 4—The half-ellipsoid shape represents a long, symmetric, tapering pile with well-rounded ends

Figure 9 shows a conceptual layout of a 79,000 sq. ft. wood chipping site (about 2 acres). The City expects to begin operation of a composting facility at its wastewater treatment facility (17424 780th Ave.) in 2026 or 2027, which would be well-timed to compost excess mulch. City staff also identified

[31] It was assumed that a skid steer or similar smaller equipment could stack the debris to that height and that higher piles may not be acceptable from both an aesthetic viewpoint and safety since the City might decide to make the site accessible by the public.

2 other potential wood-chipping sites: Transfer Station, 2506 Richway Dr., which already has composting on site, and the Madsen Pit site located on the corner of South Broadway and W. 9th Street. All 3 sites are sufficiently large to accommodate one or more of the conceptual wood-chipping footprints.

Figure 9: Conceptual Wood-Chipping Site (drawing not to scale)



EAB periods: According to recommendations from the MDA, tree removals should only occur when the beetle larvae are feeding beneath the bark, which includes the 7 months from the beginning of October through the end of April (*EAB Dormant Period*). In order to destroy the larvae, tree debris should be chipped so that individual chips are no larger than 1 inch in 2 dimensions. This means that the length can be longer than 1 inch. During the other 5 months (*EAB Active Period*), infested trees should not be removed unless they are hazardous or for other necessary reasons. The MDA states why: [32]

> "By postponing pruning until the fall, you can help reduce the risk of EAB spreading. If the tree is left intact during the EAB Active Period, it can provide habitat for EAB adults to lay eggs. But since the adults won't emerge until the following year, if this tree or branch is cut and properly disposed of during the EAB Dormant Period, any EAB that may exist in the ash material will be destroyed when the wood is destroyed.
>
> "Material moved during the EAB Active Period may release adults at any time during transportation into a previously un-infested area."

The City might choose to open and staff its public wood chipping site(s) on Saturdays (or by appointment for tree companies it has licensed) only during this EAB dormancy period. The City's RFP should require all chipping to be completed by April 30 of each year.

[32] Source: https://www.mda.state.mn.us/best-management-practices-eab

Wood chips and mulch: Wood chips are shredded, chipped, or ground-up pieces of wood. It sometimes includes bark, branches, and leaves. Wood mulch refers to the way wood chips are used. When spread on the soil surface as a protective top-dressing, it is called wood mulch. Wood chippers have varying reduction ratios. A 3-to-1 ratio would reduce the volume of the debris by 33%. Figure 7 shows that the total mulch volume would equal over 8,000 cu. yd. and total about 2,300 cu. yd. during the peak year. The City could also allow, and encourage, public use of the *mulch. The City could spread excess mulch in the wooded areas of its parks.*

Open burning: The City has an open burn permit from the Minnesota DNR and is considering using it to dispose of tree debris. It is appropriate to examine the consequences associated with this management method. First of all, in 1980, Minnesota adopted a waste management hierarchy (refer to adjacent image).[33] Organic recycling (using the wood mulch) is preferred over burning (incineration). Secondly, open burning results in significant air pollutants. The cost benefit analysis examined the greenhouse gases and criteria pollutants associated with open burning.

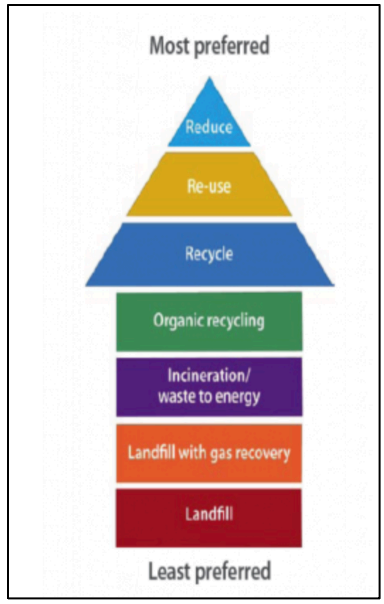


Figure 10 points out that open burning of 50% of the entire debris stream (private trees and City trees per the EAB Plan)[34] would result in greenhouse gas emissions equal to the annual emissions from over 600 cars, and the criteria pollutant emissions from over 150,000 campfires. The relationships among the calculations are linear; thus, a change in the assumed percentage of tree debris that the City would burn will be directly related to the resulting emissions calculations. For example, a 10% increase in the burn assumption will increase the emissions and the comparisons by 10%.

Open burning would run counter to one of the key objectives in the City's Climate Action Plan; namely to avoid "potentially harmful atmospheric emissions."[35] An analysis by the Minnesota Pollution Control Agency stated the following:

> "Saving the best ash trees with insecticide preserves their natural life and benefits and delays their eventual entry into the waste management system. The 1980 state law bans the open burning of [municipal solid waste]. Logically, the open burning of waste ash wood should be considered the worst management option."[36, 37]

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[33] Source: https://www.pca.state.mn.us/waste/managing-waste-planning-and-research

[34] Again, the relationships among the calculations are linear; thus, a change in the assumed percentage for burning private trees will be directly related to the resulting calculations. For example, a 10% decrease in the percentage of trees burned will also decrease the associated emissions.

[35] *City of Albert Lea Climate Action Plan*, op. cit.

[36] Source: *Burning the "Wall of Wood:" Estimate of Potential Emissions from Open Burning of Waste Ash Wood*

[37] When the City of Winona decided to burn a large portion of its ash debris, the fire burned for weeks and then smoldered for many more weeks even over the winter.

Figure 10: Open Burning Considerations

Assumptions		Base Case	EAB Plan	Private Trees
Open burning considerations: [1]				
	Estimated portion of debris to be openly burned, City and private trees	50%	50%	50%
	Total dry weight (81% of green weight, US tons)	391	69	2,531
	Biogenic greenhouse gases (tons) [2]	798	140	5,174
	Fine particulate matter (lbs.)	9,200	1,600	59,700
	Carbon monoxide (lbs.)	58,200	10,200	377,200
	Sulphur dioxide (lbs.)	160	30	1,010
	Volatile organic compounds (lbs.)	7,400	1,300	47,800
	Nitrogen oxides (lbs.)	1,000	200	6,600
Greenhouse gas comparison to annual emissions of average car (number of cars) [3]		90	20	610
Comparison to typical campfire (number of campfires) [4]		24,000	4,200	155,800
Notes:				
1	The Minnesota Department of Natural Resources controls open burning permits. The agency's approval process could require applicants to provide evidence that no other viable alternatives are economically feasible. Conversion factor is from the MPCA report: *Burning the "Wall of Wood:" Estimate of Potential Emissions from Open Burning of Waste Ash Wood*, J. Michael Orange, 8/9/19			
2	Biogenic GHG results from the combustion or decomposition of biologically-based materials; wood, in this case. Anthropogenic GHG results from the combustion of fossil fuels.			
3	The figure lists the number of cars that would emit an equivalent amount of GHG emissions in a year. A typical passenger vehicle emits about 4.6 metric tonnes of carbon dioxide per year (4.17 US tons). Source: EPA, https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle			
4	The Minnesota Pollution Control Agency estimated the amount of wood burned in a typical campfire (32.5 lbs.). The above figures show the number of typical campfires that would emit criteria pollutants equal to those from the number of trees burned.			
5	The relationships among the calculations are linear; thus, a change in the assumed percentage of tree debris that that the City would burn will be directly related to the resulting emissions calculations. For example, a 10% increase in the burn assumption will increase the emissions and comparisons by 10%.			

Reuse and waste-to energy: Near the top of the state's waste management hierarchy is reuse. However, opportunities may be limited in the Albert Lea area. As for waste-to-energy possibilities, the closest large energy plants that accept wood chips are the University of Minnesota Steam Plant, District Energy in downtown St. Paul, and the Koda Energy plant in Shakopee, all 90-100 miles away. It is unlikely that the cost to truck chips to these facilities will be less expensive than chipping, grinding, and distributing the mulch within the City and surrounding areas.

Other considerations: While the cost-benefit analysis estimated the size of the private ash tree debris stream, it did not describe in detail the logistical and staffing challenges the City might have to address. Presumably, private tree companies will have access to City dump sites, and, thus, could save a lot of their own debris-management costs. Should these savings be redirected to the City perhaps via an annual dumping fee for those companies licensed by the City? If the focus is on ash tree management, how would the City prevent tree companies from dumping debris from any tree they removed or trimmed—and from anywhere they operated?

Since most of the tree debris would likely come from the local area, the above issues may not pose major concerns for the City. However, liability should be a major concern. To minimize the possibility of trash dumping at debris-handling sites, and bodily injuries or vehicle damage due to unstable debris piles, the City should secure the perimeter of the debris management area, include security cameras and signage that notifies users of their usage, and restrict hours when the site is open to the public to times when it could be controlled by attendants or other on-site staff people. It may be wise to require users sign liability waivers upon entry. The City's legal department should be consulted to minimize liability concerns.

The City might also decide to restrict access to the sites to residents only. This would reduce all the estimates herein by a large percentage and reduce the dumping of very thick trunks and branches.

Attachment A

Definitions

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

- **City ash tree classifications:**

    - **High-quality trees:** City-owned ash trees that are healthy (Condition *good* and *fair*), at least 12" in diameter, and located within clear view from public lands and rights-of-way. This includes boulevards, front yards of public facilities, and the mowed areas of public parks and open spaces.

    - **Low-quality trees:** City-owned ash trees that are not healthy (Condition *poor* or other descriptions). 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 trap tree and can be treated once or twice for *staged removal* after the peak years to shrink and stretch out removal requirements.

    - **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.

- **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.

- **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 an 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%.

- **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 12, 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.

- **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.

- **Woodlands:** City-owned areas where trees dominate and where development, mowed areas, and trails are absent or minimal. Topography and forest density make 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.

- **EAB Dormant Period:** This is the 7-month period from the beginning of October through the end of April when tree removals should occur because the beetle larvae are feeding beneath the bark. Any beetles that may exist in the ash material will be destroyed when the wood is destroyed.

- **EAB Active Period:** This is the 5-month period from the beginning of May through the end of September when tree removals should not occur because material moved during this period may release adult beetles at any time during transportation and storage into a previously un-infested area.

Attachment B

Components and Data Sources for the Cost-Benefit Analysis

The cost-benefit analysis includes 15 spreadsheets that generate the data that are summarized in the tables and charts in the EAB Plan. The following describes the components and methods of the analysis:

- **20-year study period.**
- **Physical characteristics of the 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.[38]
- **Mortality rates:**
  - EAB death curve: Predicts tree mortality due to EAB for untreated trees.[39]
  - Treated trees: Predicts tree mortality due to EAB for treated trees.[40]
  - Replacement trees: Predicts mortality for replacement trees.[41]
- **Costs:**
  - Tree and trunk removal costs based on tree size at time of death.[42]
  - Replacement trees:
    - ✓ Cost of tree and planting.[43]
    - ✓ Additional costs related to the higher maintenance costs of new trees versus mature trees.[44]
  - Treatments for surviving trees: Labor, materials, and overhead based on tree size.[45]

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[38] 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.

[39] 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

[40] 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.

[41] 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/

[42] Averages for tree and stump removal costs are based on data from Milwaukee, Hamilton, Ontario, and four cities in Minnesota's Twin Cities: Wayzata, Columbia Heights, Burnsville, and Inver Grove Heights.

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

[44] 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.

[45] 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.

  - Cost escalators during the peak of the infestation.[46]
- **Benefit analysis:** The primary source is the National Tree Benefit Calculator.[47]
  - Overall economic value.
  - Property value increase.
  - Blended benefit factor that accounts for different economic benefit rates by land use.[48]
  - Stormwater 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.[49]
  - Air pollution reduction and associated reduction in health care costs.[50, 51]

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[46] 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).

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

[48] 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 within the Twin Cities metropolitan area. Sources: 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

[49] 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.

[50] 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

[51] The 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.

Debris management:

Assumptions and Estimates	Amount	Explanations, Assumptions, and Sources
Total private trees (less City trees)	10,824	The source of the tree estimates is the MN DNR *Rapid Assessment of Ash and Elm Resources in Minnesota Communities*, 2007, https://files.dnr.state.mn.us/assistance/backyard/treecare/forest_health/ash_elmRapidAssessment/rapidassessment_AshElm.pdf. The term "high-quality tree" includes healthy trees with >12" DBH. Assuming a growth rate of 1/2" per year, healthy ash trees will have an additional 7" of DBH since the 2007 survey. Thus, "Pole Class" trees will have a DBH range of 12-19" and be classified as high-quality trees along with the "Sawtimber Class."
High-quality trees, 2007 (Healthy, >12")	5,545	
High-quality trees, 2022 (Healthy, >12")	9,624	
Assumed DBH of all trees in 2022 (same as for City trees)	15.0	
Assumed debris-stream rate for private trees	60%	The relationships among the calculations are linear; thus, a change in the assumed percentage of private tree debris that that City will assume responsibility for will be directly (or inversely) related to the resulting calculations. For example, a 10% increase in the debris-stream assumption will increase the total DBH of private tree removals by 10% and all the subsequent calculations.
Total trees to be removed over the 10-year period	6,494	
Total weight of trees to be removed (tons)	6,250	Conversion factor is from the MPCA report: *Emerald Ash Borer Emissions and Cost-Benefit Calculator*, https://greenstep.pca.state.mn.us/media/451
"Standard debris pile" assumptions:		Debris pile size estimates from *Guidelines for Estimating Volume, Biomass, and Smoke Production for Piled Slash*, Colin C. Hardy, Feb. 1996, US Dept. of Agriculture, https://www.fs.fed.us/pnw/pubs/pnw_gtr364.pdf. To find the debris pile length for a known volume (V) of debris (with volume in cu. ft.): length = (V*6)/(pi*h*w). Conversion of tons of green wood debris to volume: 1 ton equal 4 cubic yards (27 cu. ft.). Source: *Debris Estimating Field Guide*, Sept. 2010, Federal Emergency Management Agency, https://www.fema.gov/sites/default/files/2020-07/fema_329_debris-estimating_field-guide_9-1-2010.pdf
Length of a half-ellipsoid pile	40	
Width of the pile	20	
Height of the pile	6	
Volume (cu. ft.)	2,513	
Green weight (tons)	23	
Footprint (sq. ft.)	800	