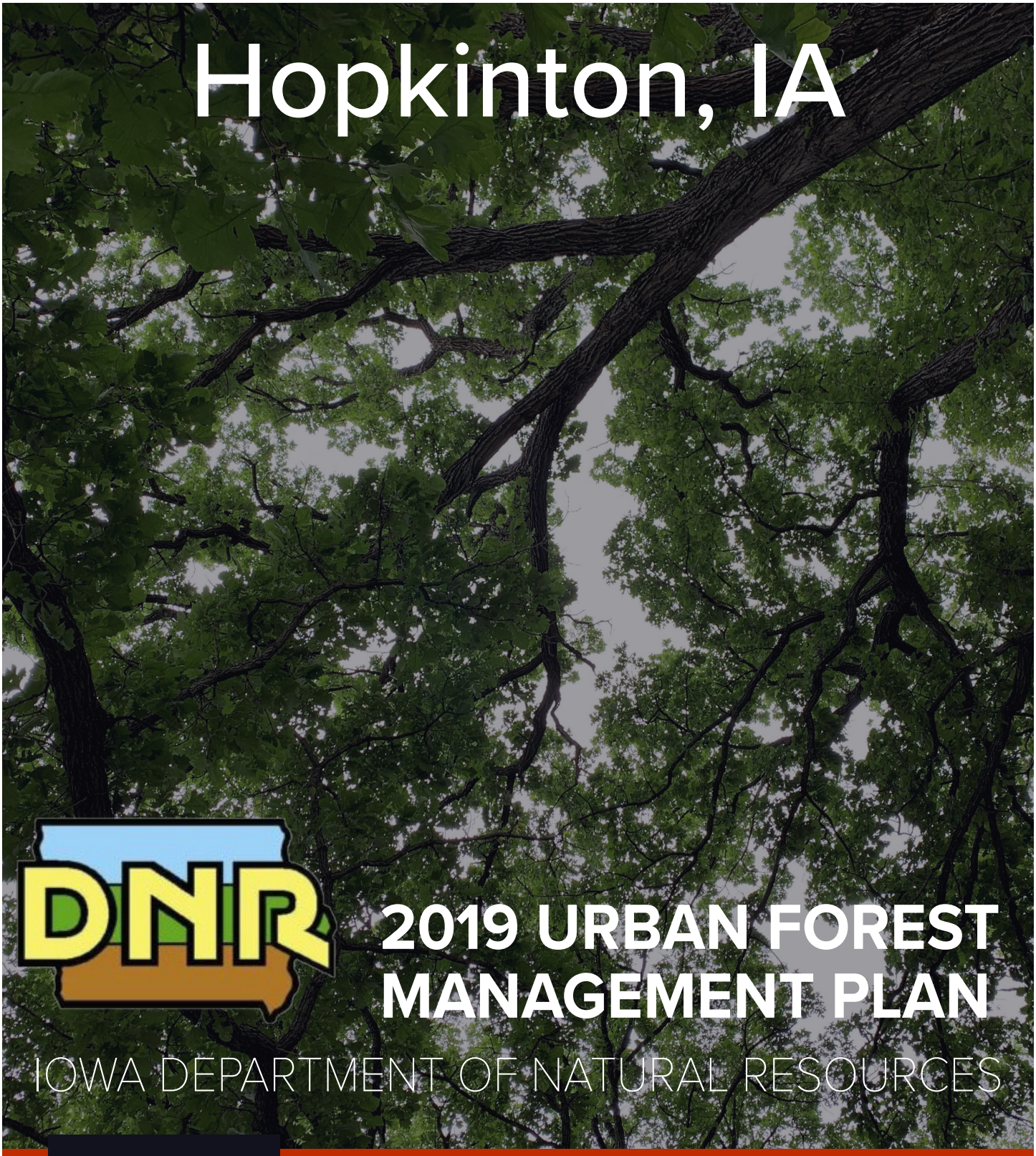

Hopkinton, IA

2019 URBAN FOREST MANAGEMENT PLAN

IOWA DEPARTMENT OF NATURAL RESOURCES

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Executive Summary

Overview

This plan was developed to assist the City of Hopkinton in managing its urban forest, including budgeting and future planning. Trees bring numerous benefits to a community, and sound management helps leaders take advantage of these benefits. Management is especially important now considering the serious threats posed by forest pests like the emerald ash borer (EAB). EAB is an invasive insect imported from Eastern Asia on wood shipping crates that kills all species of ash trees except mountain ash. There is a strong possibility that 14% of Hopkinton's city-owned trees will die once EAB becomes established in the community, unless local leaders begin preventative treatment. With proper planning and management, the costs of removing dead and dying trees can be extended over years, mitigating public safety issues.

Inventory and Results

In 2019, JEO conducted a tree inventory using Global Positioning System (GPS) data collectors. The inventory was a complete inventory of street and park trees. Below are some key findings of the 471 trees inventoried.

- Hopkinton's trees provide $74,680 of benefits annually, an average of $159 per tree
- There are over 36 species of trees
- The top three genera are: Maple 38%, Ash 14%, and Oak 11%
- 12% of trees need some type of management
- 12 trees should be removed

Recommendations

We detail our core recommendations in the Recommendations Section. In the Emerald Ash Borer Plan, we include management recommendations. Below are some key recommendations.

- Out of the 12 trees needing removal, 6 trees are over 24 inches in diameter at 4.5 ft and must be addressed immediately. *City ownership of the trees recommended for removal should be verified prior to any removal*
- All ash trees should be carefully examined for signs and symptoms that could be related to an EAB infestation.
- All trees should be pruned on a routine schedule: one third of the city every other year.
- Plant a diverse mix of trees that do not include: ash, maple, cottonwood, poplar, box elder, Chinese elm, evergreen, willow or black walnut.
- Check ash trees yearly with a visual survey.
- With the current estimated budget it could take 38 years to remove ash. We suggest that city officials request a budget increase to $3,5000 annually and apply for grants to plant replacement trees.

Introduction

This plan was developed to assist Hopkinton with managing, budgeting, and future planning of their urban forest. Across the state, forestry budgets continue to decrease as a higher percentage of the budgets are devoted to tree removal. With the anticipated arrival of Emerald Ash Borer (EAB), an invasive pest that kills native ash trees, it is time to prepare for the increased costs of tree removal, treatment, and replacement planting. With proper planning and management of the current canopy in Hopkinton, these costs can be spread out over the years and public safety issues from dead and dying ash trees can be mitigated.

Trees are an important part of Hopkinton's infrastructure and one of the city's greatest assets. The benefits of trees are immense. Trees improve air quality, intercept stormwater runoff, conserve energy, lower traffic speeds, increase property values, reduce crime, improve mental health, and create a desirable place to live, to name just a few. Good urban forestry management will maintain these important benefits for the people of Hopkinton and future generations.

Urban forestry management sets goals and develops management strategies to achieve them. To develop management strategies, a comprehensive public tree inventory must be conducted. The inventory informs maintenance, removal schedules, tree planting, and budgeting. Aligning management actions with the tree inventory results will help meet Hopkinton's urban forestry goals.

Inventory

In 2019, JEO conducted a tree inventory that included 100% of the city-owned trees on both streets and parks. The team collected tree data using a handheld Global Positioning System (GPS) receiver. The data collector gives Geographic Information Systems (GIS) coordinates with an accuracy of 3 meters, which can be used in Arc GIS as an active GIS data layer. Because the inventory is a digital document the data can be updated with new information and become a working document.

The data collectors' programming was written to be compatible with a state-of-the-art software suite called i-Tree. i-Tree was developed by the USDA Forest Service to quantify the structure of community trees and the environmental services that trees provide. The i-Tree suite is a public domain which can be accessed for free.

To quantify the urban forest structure and benefits, specific data is collected for each tree. This data includes: location, land use, species, diameter at 4.5 ft, recommended maintenance, priority of that maintenance, leaf health, and wood condition. Additionally, for all ash trees, the team notes signs and symptoms associated with EAB including canopy dieback, epicormic shoots, bark splitting, D-shaped borer exit holes, and wood pecker damage.

Inventory Results

JEO entered the data collected for the 471 city trees into the USDA Forest service program Street Tree Resource Analysis Tool for Urban forestry Management as part of the i-Tree suite. Below are results from the i-Tree STREETS analysis. Fin

Annual Benefits

Annual Energy Benefits

Trees conserve energy by shading buildings and blocking winds. Hopkinton's trees reduce energy-related costs by approximately $19,951 annually (Appendix A, Table 1). These savings are both in electricity (96 MWh) and in natural gas (12,926 Therms).

Annual Stormwater Benefits

Hopkinton's trees intercept about 1,011,742 gallons of rainfall or snow melt per year (Appendix A, Table 2). This interception provides $27,418 in benefit to the city.

Annual Air Quality Benefits

Air quality is a persistent public health issue in Iowa. The urban forest improves air quality by removing pollutants, lowering air temperature, and reducing energy consumption, which in turn reduces emissions from power plants, and lessens emissions of volatile organic matter (ozone). In Hopkinton, it is estimated that trees remove 1,171 lbs of air pollution (ozone (O_3), particulate matter less than 10 microns (PM10), carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2)) per year with a net value of $3,259 (Appendix A, Table 3).

Annual Carbon Benefits

Carbon sequestration and storage reduce the amount of carbon in the atmosphere, mitigating climate change. In Hopkinton, trees sequester about 208,115 lbs of carbon per year with an associated value of $1,561 (Appendix A, Table 5). In addition, the trees store 3,699,944 lbs of carbon, with a yearly benefit of $27,750 (Appendix A, Table 4).

Annual Aesthetics Benefits

The social benefits of trees are hard to capture. The i-Tree analysis does have a calculation for this area that includes aesthetic value, property values, lowered rates of mental illness and crime, city livability and much more. Hopkinton receives $21,425 in annual social benefits from trees (Appendix A, Table 6).

Financial Summary of all Benefits

According to the USDA Forest Service i-Tree STREETS analysis, Hopkinton's trees provide $74,680 of benefits annually. Benefits of individual trees vary based on size, species, health and location, but on average each of the 471 trees in Hopkinton provide approximately $159 annually (Appendix A, Table 7).

Forest Structure

Species Distribution

Hopkinton has over 36 different tree species along city streets and parks (Appendix A, Figure 1). The distribution of trees by genera is as follows:

Maple	178	38%
Ash	68	14%
Oak	51	11%
Apple	37	8%
Spruce	25	5%
Linden/Basswood	23	5%
Walnut	21	4%
Hackberry	17	4%
Cedar	9	2%
Elm	7	1%
Locust	5	1%
Callery Pear	5	1%
Pine	4	1%
Pear	4	1%
Birch	3	<1%
Catalpa	2	<1%
Sycamore	1	<1%
Willow	1	<1%
Chokecherry	1	<1%
Other Evergreen	9	2%

Age Class

Most of Hopkinton's trees (40%) are between 6 and 18 inches in diameter at 4.5 ft (Appendix A, Figure 2). To prepare for natural mortality and to maintain canopy cover, most trees should be in the smallest size category (a downward slope), indicating youth. Hopkinton's size curve is on the smaller side, indicating a younger than average stand.

Condition: Wood and Foliage

Both wood condition and leaf condition are good indicators of the urban forest's overall health. The foliage condition results for Hopkinton indicate that 77% of the trees are in good health, with only 2% of the foliage in poor health, dead, or dying (Appendix A, Figure 3 & Appendix B, Figure 3). Similarly, 72% of Hopkinton's trees are in good health for wood condition (Appendix A, Figure 4 & Appendix B, Figure 3). Five percent of the tree population's wood condition is in poor health, dead, or dying. This 5% is an estimate of trees that need management follow up.

Management Needs

The following outlines the specific management needs of the street and park trees by number of trees and percent of canopy (Appendix B, Figure 3).

Crown Cleaning	20	4%
Crown Raising	12	3%
Tree Removal	12	3%
Tree Staking	11	2%
Crown Reduction	3	1%

Land Use and Location

The majority of Hopkinton's city and park trees are in planting strips in single family residential neighborhoods (Appendix A, Figure 6 & Appendix A, Figure7). The following describes the land use and locations for the street and park trees.

Land Use	
Single family residential	71%
Industrial/Large commercial	28%
Small commercial	1%
Park/vacant/other	<1%
Multifamily residential	0%

Recommendations

Risk Management

Hazardous trees can be a significant threat to both people and property. Trees that are dead, dying, or have large issues such as trunk cracks longer than 18 inches should be removed. Broken branches and branches that interfere with motorists' vision of pedestrians, vehicles, traffic signs and signals should be removed.

Hazardous trees

Hopkinton has 12 trees that need immediate removal. These trees can be seen on the Location of Trees with Recommended Maintenance Map (Appendix B, Figure 4). We recommend starting with the large-diameter, critical concern trees first. There are 6 trees over 24 inches in diameter at 4.5 ft that should be addressed immediately. Please refer to the Proposed Work Schedule and Budget at the end of this section. After all the critical concern trees are addressed, there should be follow up on the trees marked as needing maintenance. There are a total of 56 trees with maintenance needs.

Poor tree species

After removing the critical concern trees, ash trees in poor health should be assessed for removal (Appendix B, Figure 3 & Appendix B, Figure 4). There are a total of 68 ash trees which may develop signs and symptoms that have been associated with EAB. In addition, there are no trees that are in poor health. *City ownership of the trees recommended for removal should be verified prior to any removal*

Pruning Cycle

Proper pruning can extend the life and good health of trees, as well as reduce public safety issues. In the Management Needs section of the Findings there are four main maintenance issues to be addressed: routine pruning, crown cleaning, crown raising, and crown reduction. Crown cleaning removes dead, diseased, and damaged limbs. Crown raising removes lower branches that are two inches in diameter or larger to provide clearance for pedestrians or vehicles. Crown reduction removes individual limbs from structures or utility wires. We recommend that all trees be pruned on a routine schedule every five to seven years. Please refer to the Proposed Work Schedule and Budget for further information.

Planting

Most of the planting over the next five years will replace the trees that are removed. We recommend planting 1.2 trees for every tree removed, since survival rates will not be 100%. It is not essential that the new trees be planted in the same location of the trees being removed. However, maintaining the same number of trees helps ensure continuation of the benefits of the existing forest in Hopkinton.

It is important to plant a diverse mix of species in the urban forest to maintain canopy health, since most insects and diseases target a genus (ash) or species (green ash) of trees. Current diversity recommendations advise that a genus (i.e. maple, oak) not make up more than 20% of the urban forest and a single species (i.e. silver maple, sugar maple, white oak, bur oak) not make up more than 10% of the total urban forest. Presently, the forest is heavily planted with maple (38%) (Appendix A, Figure 1). Maples should not be planted until this percentage can be lowered. Also, ash trees have not been recommended since 2002, due to the threat of EAB. Other species to avoid because they are public nuisances include: cottonwood, poplar, box elder, Chinese elm, evergreen, willow or black walnut. While the city currently has no existing City Code in reference to tree species planting restrictions, we encourage the city to work with the Iowa Department of Natural Resources to develop a plan moving forward.

Continual Monitoring

Due to the threat of EAB, it is important to continuously check the health of ash trees. We recommend that ash trees be checked with a visual survey every year for tree decline and for the following signs and symptoms: canopy dieback, epicormic shoots, bark splitting, D-shaped borer exit holes, and wood pecker damage.

Emerald Ash Borer Plan

Ash Tree Removal

Tree removal will be prioritized by first removing dead, dying, hazardous trees (Appendix B, Figure 4). Next will be all ash in poor condition that display EAB signs and symptoms (Appendix B, Figure 2 & Appendix B, Figure 3). *City ownership of the tree recommended for removal should be verified prior to any removal*

Treatment of Ash Trees

Chemical treatment can be an effective tool for communities to spread removal costs out over several years while allowing trees to continue providing benefits. However, treatment is not recommended if

EAB is more than 15 miles away from the community. For more information on the cost of treatment strategies visit http://extension.entm.purdue.edu/treecomputer/

EAB Quarantines

EAB is an extremely destructive plant pest and it is responsible for the death and decline of millions of ash trees. Ash in both forested and urban settings constitute a significant portion of the canopy cover in the United States. Current tools to detect, control, suppress and eradicate this pest are not as robust as the USDA would desire. In order to stay ahead of this hard to detect beetle, the USDA is attempting to contain the beetle before it spreads beyond its known positions by regulating articles.

A regulated article under the USDA's quarantine includes any of the following items:

- emerald ash borer
- firewood of all hardwood species (for example ash, oak, maple and hickory)
- nursery stock and green lumber of ash
- any other ash material, whether living, dead, cut or fallen, including logs, stumps, roots, branches, as well as composted and not composted chips of the genus ash (Mountain ash is not included)

In addition, any other article, product, or means of conveyance not listed above may be designated as a regulated article if a USDA inspector determines that it presents a risk of spreading EAB once a quarantine is in effect for your county.

Wood Disposal

A very important aspect of planning is determining how wood infested with EAB will be handled, keeping in mind that quarantines will restrict its movement. Consider who will cut and haul the dead and dying trees? Is there an accessible, secured site big enough to store and sort the hundreds of trees and the associated brush and chips? How will wood be disposed of or utilized? Do you have equipment capable of handling the amount and size of ash trees your tree inventory has identified? Once your county is under quarantine for EAB, contact USDA-APHIS-PPQ at 515-251-4083 or visit the website http://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/regulatory.shtml. Wood waste can be normally disposed of if your county is not part of a quarantine.

Canopy Replacement

As budget permits, all removed trees will be replaced. All trees will meet the restrictions outlined by the Iowa Department of Natural Resources. While the city currently has no existing City Code in reference to tree species restrictions, we encourage the city to work with the Iowa Department of Natural Resources to develop a plan moving forward. We encourage the new plantings to be a diverse mix and not include ash, maple, cottonwood, poplar, box elder, Chinese elm, evergreen, willow or black walnut.

Postponed Work

While finances, staffing, and equipment are focused on the management of ash, usual services may be delayed. Tree removal requests on genera other than ash will be prioritized by hazardous or emergency situations only.

Monitoring
It is recommended that ash trees be checked with a visual survey every year for tree death and for EAB signs and symptoms including canopy dieback, epicormic shoots, bark splitting, D-shaped borer exit holes, and wood pecker damage.

Private Ash Trees
It is strongly recommended that private property owners start removing ash trees on their property upon arrival of EAB if preventative treatments are not being used. While there is no existing City Code in reference to private tree care and removal, we encourage the city to work with the Iowa Department of Natural Resources to develop a plan moving forward

Proposed Work Schedule and Budget

Budget Allowance of $1,256/Year – (Based off $2/Capita Calculation Due to no City Reporting)

YEAR 1	**ESTIMATED COSTS**
Remove 1 tree recommended for immediate removal	$700
Plant 3 trees in open locations	$450
Visual Survey of EAB Signs/Symptoms	
YEAR 2	
Remove 1 tree recommended for immediate removal	$700
Plant 3 trees in open locations	$450
Visual Survey of EAB Signs/Symptoms	
YEAR 3	
Remove 1 tree recommended for immediate removal	$700
Plant 3 trees in open locations	$450
Visual Survey of EAB Signs/Symptoms	
YEAR 4	
Remove 1 tree recommended for immediate removal	$700
Plant 3 trees in open locations	$450
Visual Survey of EAB Signs/Symptoms	
YEAR 5	
Remove 1 tree recommended for immediate removal	$700
Plant 3 trees in open locations	$450
Visual Survey of EAB Signs/Symptoms	

YEAR 6

Remove 1 tree recommended for immediate removal	$700
Plant 3 trees in open locations	$450
Visual Survey of EAB Signs/Symptoms	

Estimated costs based on average costs of $700/tree for removal, $150/tree for planting and maintenance, and $15/tree for pruning.

**To remove all ash trees within 6 years alone, the budget would need to be $8,000 a year. If the budget were increased to $3,500 a year all ash could be removed in 13.5 years.

Proposed Work Schedule with Increased Budget

Budget Allowance of $3,500/Year – (Budget Increase Suggested to Best Manage City Trees)

YEAR 1	**ESTIMATED COSTS**
Remove 4 trees recommended for immediate removal	$2,800
Plant 4 trees in open locations	$600
Visual Survey of EAB Signs/Symptoms	

YEAR 2

Remove 1 tree recommended for immediate removal	$700
Plant 3 trees in open locations	$450
Prune 1/3 of City Owned Trees	$2,355
Visual Survey of EAB Signs/Symptoms	

YEAR 3

Remove 4 trees recommended for immediate removal	$2,800
Plant 4 trees in open locations	$600
Visual Survey of EAB Signs/Symptoms	

YEAR 4

Remove 1 tree recommended for immediate removal	$700
Plant 3 trees in open locations	$450
Prune 1/3 of City Owned Trees	$2,355
Visual Survey of EAB Signs/Symptoms	

YEAR 5

Remove 2 trees recommended for immediate removal	$1,400
Remove 2 ash trees (prioritize largest diameter)	$1,400
Plant 4 trees in open locations	$600
Visual Survey of EAB Signs/Symptoms	

YEAR 6

Remove 1 ash tree (prioritize largest diameter)	$700
Plant 3 trees in open locations	$450
Prune 1/3 of City Owned Trees	$2,355
Visual Survey of EAB Signs/Symptoms	

Purposed Budget Increase

EAB could potentially kill all ash trees in Hopkinton within four years of its arrival. To remove all ash trees within six years, the budget would need to be increased to $8,000 a year. If the budget were increased to $3,500 per year all ash could be removed within 13.5 years. Additionally, we recommend that Hopkinton apply for grants to fund replacement trees. Utility Company grants are usually between $500 and $10,000 for community-based, tree-planting projects that include parks, gateways, cemeteries, nature trails, libraries, nursing homes, and schools.

Another option considered by many communities is treating selected trees, either to maintain those trees in the landscape or to delay their removal – to spread out the costs and number of trees needing removal all at once. Trunk injection is administered every two years for the life of the tree. If treatment is discontinued, the tree dies. For instance, in this treatment scenario, the average ash diameter is 20 inches and at $15 per inch, about 4 trees could be treated per year (every other year treatment). Eight trees would be selected for treatment, and Hopkinton would still need to find $42,000 for removal of the remaining ash. Alternatively, if there are 10 treatable trees, it would cost approximately $3,000 a year for treatment and leave $500 for removal under the proposed budget increase. These are alternatives to straight removal of ash trees. However, whether the treatment option is selected, there will be an increased cost of dealing with ash trees if EAB is found in Hopkinton. We suggest considering an increased budget to plan for this.

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Appendix A: i-Tree Data

Table 1: Annual Energy Benefits

Annual Energy Benefits of Public Trees

4/24/2020

Species	Total Electricity (MWh)	Electricity ($)	Total Natural Gas (Therms)	Natural Gas ($)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Sugar maple	27.7	2,106	3,737.9	3,663	5,769	(N/A)	19.3	28.9	63.40
Green ash	13.8	1,045	1,847.5	1,811	2,855	(N/A)	11.0	14.3	54.91
Apple	0.8	58	131.7	129	187	(N/A)	7.9	0.9	5.05
Norway maple	7.5	568	1,051.4	1,030	1,598	(N/A)	7.9	8.0	43.20
Northern red oak	4.9	371	627.4	615	986	(N/A)	6.4	4.9	32.88
Silver maple	8.4	634	1,096.0	1,074	1,708	(N/A)	5.7	8.6	63.28
Red maple	3.1	238	413.0	405	643	(N/A)	4.9	3.2	27.96
Black walnut	4.7	360	632.3	620	979	(N/A)	4.5	4.9	46.63
Northern hackberry	2.6	198	371.3	364	562	(N/A)	3.6	2.8	33.07
Bur oak	5.1	386	670.2	657	1,043	(N/A)	3.6	5.2	61.33
American basswood	1.0	77	153.6	150	227	(N/A)	2.8	1.1	17.50
Blue spruce	1.5	113	197.9	194	307	(N/A)	2.5	1.5	25.62
Littleleaf linden	1.1	84	150.5	147	231	(N/A)	2.1	1.2	23.14
Norway spruce	1.6	122	206.3	202	324	(N/A)	2.1	1.6	32.42
White ash	2.1	163	254.6	249	412	(N/A)	1.9	2.1	45.78
Northern white cedar	0.4	27	54.0	53	80	(N/A)	1.5	0.4	11.40
Conifer Evergreen Mediu	0.4	31	66.0	65	96	(N/A)	1.5	0.5	13.68
Ash	1.1	85	147.2	144	230	(N/A)	1.5	1.2	32.79
Siberian elm	2.2	171	306.0	300	470	(N/A)	1.3	2.4	78.41
Honeylocust	1.7	130	226.9	222	352	(N/A)	1.1	1.8	70.48
Callery pear	0.3	25	52.3	51	76	(N/A)	1.1	0.4	15.18
Pear	0.1	9	21.0	21	30	(N/A)	0.8	0.1	7.47
River birch	0.4	29	52.5	51	80	(N/A)	0.6	0.4	26.74
Swamp white oak	0.2	16	34.5	34	50	(N/A)	0.6	0.3	16.68
Conifer Evergreen Large	0.2	13	23.7	23	36	(N/A)	0.4	0.2	18.04
Catalpa	0.7	51	86.0	84	135	(N/A)	0.4	0.7	67.63
Eastern white pine	0.3	24	39.2	38	62	(N/A)	0.4	0.3	31.15
Red pine	0.1	9	19.0	19	27	(N/A)	0.4	0.1	13.58
Black spruce	0.3	20	34.7	34	54	(N/A)	0.4	0.3	27.08
Eastern red cedar	0.2	17	32.9	32	49	(N/A)	0.4	0.2	24.57
Common chokecherry	0.1	6	12.8	13	18	(N/A)	0.2	0.1	18.19
American sycamore	0.3	25	46.9	46	71	(N/A)	0.2	0.4	70.91
Northern pin oak	0.3	20	39.6	39	59	(N/A)	0.2	0.3	58.69
Spruce	0.1	10	14.6	14	24	(N/A)	0.2	0.1	24.14
Willow	0.3	24	47.4	46	71	(N/A)	0.2	0.4	70.84
American elm	0.2	19	27.5	27	46	(N/A)	0.2	0.2	45.87
Total	96.0	7,283	12,926.2	12,668	19,951	(N/A)	100.0	100.0	42.36

Table 2: Annual Stormwater Benefits

Annual Stormwater Benefits of Public Trees

4/24/2020

Species	Total rainfall interception (Gal)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Sugar maple	352,177	9,002	(N/A)	19.5	32.8	98.92
Green ash	134,749	3,652	(N/A)	11.0	13.3	70.22
Apple	2,479	67	(N/A)	7.9	0.2	1.82
Norway maple	57,074	1,547	(N/A)	7.9	5.6	41.80
Northern red oak	32,962	893	(N/A)	6.4	3.3	29.78
Silver maple	104,974	2,845	(N/A)	5.7	10.4	105.36
Red maple	20,707	561	(N/A)	4.9	2.0	24.40
Black walnut	43,135	1,169	(N/A)	4.5	4.3	55.66
Northern hackberry	13,668	370	(N/A)	3.6	1.4	21.79
Bur oak	75,395	2,043	(N/A)	3.6	7.5	120.19
American basswood	8,776	238	(N/A)	2.8	0.9	18.29
Blue spruce	21,852	592	(N/A)	2.5	2.2	49.35
Littleleaf linden	6,636	180	(N/A)	2.1	0.7	17.98
Norway spruce	33,577	910	(N/A)	2.1	3.3	90.99
White ash	15,990	433	(N/A)	1.9	1.6	48.15
Northern white cedar	6,264	170	(N/A)	1.5	0.6	24.25
Conifer Evergreen Medium	4,789	130	(N/A)	1.5	0.5	18.54
Ash	6,548	177	(N/A)	1.5	0.6	25.35
Siberian elm	24,988	677	(N/A)	1.3	2.5	112.86
Honeylocust	19,865	538	(N/A)	1.1	2.0	107.67
Callery pear	1,660	45	(N/A)	1.1	0.2	9.00
Pear	409	11	(N/A)	0.8	0.0	2.77
River birch	2,158	58	(N/A)	0.6	0.2	19.49
Swamp white oak	1,184	32	(N/A)	0.6	0.1	10.70
Conifer Evergreen Large	3,182	86	(N/A)	0.4	0.3	43.12
Catalpa	8,704	236	(N/A)	0.4	0.9	117.95
Eastern white pine	6,143	166	(N/A)	0.4	0.6	83.24
Red pine	1,191	32	(N/A)	0.4	0.1	16.14
Black spruce	3,857	105	(N/A)	0.4	0.4	52.26
Eastern red cedar	3,269	89	(N/A)	0.4	0.3	44.30
Common chokecherry	264	7	(N/A)	0.2	0.0	7.17
American sycamore	3,943	107	(N/A)	0.2	0.4	106.85
Northern pin oak	2,479	67	(N/A)	0.2	0.2	67.19
Spruce	1,539	42	(N/A)	0.2	0.2	41.70
Willow	3,764	102	(N/A)	0.2	0.4	102.01
American elm	1,391	38	(N/A)	0.2	0.1	37.69
Citywide total	1,011,742	27,418	(N/A)	100.0	100.0	58.21

Table 3: Annual Air Quality Benefits

Annual Air Quality Benefits of Public Trees

4/24/2020

Species	Deposition (lb) O_3	NO_2	PM_{10}	SO_2	Total Depos ($)	Avoided (lb) NO_2	PM_{10}	VOC	SO_2	Total Avoided ($)	BVOC Emissions (lb)	BVOC Emissions ($)	Total (lb)	Total ($)	Standard Error	% of Total Trees	Avg $ tree
Sugar maple	48.6	7.9	22.8	2.1	251	131.8	19.2	18.3	125.7	822	-36.3	-136	338.1	937	(N/A)	19.3	10.30
Green ash	15.0	2.4	7.5	0.7	81	65.4	9.5	9.1	62.4	408	0.0	0	172.0	489	(N/A)	11.0	9.41
Apple	0.3	0.0	0.2	0.0	2	3.9	0.5	0.5	3.4	23	0.0	0	8.9	25	(N/A)	7.9	0.68
Norway maple	10.2	1.8	5.2	0.5	55	36.0	5.2	5.0	34.0	224	-2.5	-9	95.2	270	(N/A)	7.9	7.29
Northern red oak	5.9	1.0	3.1	0.3	32	23.0	3.4	3.2	22.2	144	-8.1	-31	53.8	146	(N/A)	6.4	4.86
Silver maple	16.6	2.8	8.4	0.7	90	39.4	5.8	5.5	37.8	247	-9.2	-34	107.8	302	(N/A)	5.7	11.19
Red maple	4.0	0.7	2.0	0.2	22	14.8	2.2	2.1	14.2	93	-1.5	-5	38.7	109	(N/A)	4.9	4.74
Black walnut	4.5	0.7	2.3	0.2	24	22.5	3.3	3.1	21.5	140	0.0	0	58.0	165	(N/A)	4.5	7.84
Northern hackberry	1.0	0.2	0.7	0.0	6	12.6	1.8	1.7	11.9	78	0.0	0	30.0	84	(N/A)	3.6	4.96
Bur oak	15.3	2.4	6.7	0.7	80	24.0	3.5	3.4	23.0	150	0.0	0	79.0	230	(N/A)	3.6	13.52
American basswood	1.0	0.2	0.5	0.0	5	5.0	0.7	0.7	4.6	31	-0.9	-3	11.8	33	(N/A)	2.8	2.52
Blue spruce	3.1	0.6	2.5	0.4	20	7.1	1.0	1.0	6.8	44	-8.2	-31	14.3	34	(N/A)	2.5	2.81
Littleleaf linden	0.7	0.1	0.4	0.0	4	5.3	0.8	0.7	5.0	33	-0.4	-2	12.7	35	(N/A)	2.1	3.54
Norway spruce	4.0	0.8	3.2	0.5	26	7.5	1.1	1.1	7.3	47	-18.7	-70	6.8	3	(N/A)	2.1	0.35
White ash	1.3	0.2	0.8	0.1	7	9.9	1.5	1.4	9.7	62	0.0	0	24.8	70	(N/A)	1.9	7.75
Northern white cedar	0.7	0.1	0.6	0.1	4	1.7	0.2	0.2	1.6	11	-3.3	-12	2.0	3	(N/A)	1.5	0.38
Conifer Evergreen Medium	0.4	0.1	0.4	0.1	3	2.0	0.3	0.3	1.8	12	-1.5	-6	4.0	10	(N/A)	1.5	1.42
Ash	0.9	0.2	0.5	0.0	5	5.3	0.8	0.7	5.1	33	-0.3	-1	13.4	38	(N/A)	1.5	5.37
Siberian elm	4.3	0.7	2.1	0.2	23	10.7	1.6	1.5	10.2	67	0.0	0	31.3	90	(N/A)	1.3	14.98
Honeylocust	3.9	0.6	1.8	0.2	21	8.1	1.2	1.1	7.8	51	-3.0	-11	21.6	60	(N/A)	1.1	11.97
Callery pear	0.1	0.0	0.1	0.0	1	1.6	0.2	0.2	1.5	10	-0.1	0	3.8	11	(N/A)	1.1	2.11
Pear	0.1	0.0	0.0	0.0	0	0.6	0.1	0.1	0.6	4	0.0	0	1.4	4	(N/A)	0.8	1.02
River birch	0.3	0.0	0.2	0.0	2	1.8	0.3	0.3	1.7	11	-0.1	0	4.5	13	(N/A)	0.6	4.20
Swamp white oak	0.1	0.0	0.1	0.0	1	1.1	0.2	0.1	1.0	7	0.0	0	2.5	7	(N/A)	0.6	2.36
Conifer Evergreen Large	0.4	0.1	0.3	0.0	2	0.8	0.1	0.1	0.8	5	-1.4	-5	1.1	2	(N/A)	0.4	1.00
Catalpa	1.3	0.2	0.6	0.1	7	3.2	0.5	0.4	3.0	20	0.0	0	9.2	26	(N/A)	0.4	13.23
Eastern white pine	0.7	0.1	0.6	0.1	5	1.5	0.2	0.2	1.4	9	-3.4	-13	1.5	1	(N/A)	0.4	0.62
Red pine	0.1	0.0	0.1	0.0	1	0.6	0.1	0.1	0.5	3	-0.3	-1	1.1	3	(N/A)	0.4	1.48
Black spruce	0.5	0.1	0.4	0.1	4	1.2	0.2	0.2	1.2	8	-1.4	-5	2.5	6	(N/A)	0.4	2.99
Eastern red cedar	0.7	0.1	0.5	0.1	4	1.1	0.2	0.1	1.0	7	-1.8	-7	2.0	4	(N/A)	0.4	2.19
Common chokecherry	0.0	0.0	0.0	0.0	0	0.4	0.1	0.1	0.3	2	0.0	0	0.9	3	(N/A)	0.2	2.55
American sycamore	0.5	0.1	0.2	0.0	3	1.6	0.2	0.2	1.5	10	0.0	0	4.4	12	(N/A)	0.2	12.48
Northern pin oak	0.5	0.1	0.2	0.0	3	1.3	0.2	0.2	1.2	8	-0.1	0	3.6	10	(N/A)	0.2	10.16
Spruce	0.2	0.0	0.1	0.0	1	0.6	0.1	0.1	0.6	4	-0.5	-2	1.2	3	(N/A)	0.2	2.82
Willow	0.9	0.1	0.4	0.0	5	1.6	0.2	0.2	1.5	10	-0.2	-1	4.7	14	(N/A)	0.2	13.58
American elm	0.1	0.0	0.1	0.0	0	1.1	0.2	0.2	1.1	7	0.0	0	2.7	8	(N/A)	0.2	7.68
Citywide total	146.2	24.8	75.7	7.3	801	456.0	66.5	63.5	434.8	2,846	-103.4	-388	1,171.4	3,259	(N/A)	100.0	6.92

Table 4: Annual Carbon Stored

Stored CO2 Benefits of Public Trees

4/24/2020

Species	Total Stored CO2 (lbs)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Sugar maple	1,353,340	10,150	(N/A)	19.3	36.6	111.54
Green ash	487,395	3,655	(N/A)	11.0	13.2	70.30
Apple	7,441	56	(N/A)	7.9	0.2	1.51
Norway maple	168,011	1,260	(N/A)	7.9	4.5	34.06
Northern red oak	105,318	790	(N/A)	6.4	2.8	26.33
Silver maple	381,790	2,863	(N/A)	5.7	10.3	106.05
Red maple	46,886	352	(N/A)	4.9	1.3	15.29
Black walnut	145,576	1,092	(N/A)	4.5	3.9	51.99
Northern hackberry	12,792	96	(N/A)	3.6	0.3	5.64
Bur oak	535,250	4,014	(N/A)	3.6	14.5	236.14
American basswoo	37,214	279	(N/A)	2.8	1.0	21.47
Blue spruce	21,601	162	(N/A)	2.5	0.6	13.50
Littleleaf linden	17,119	128	(N/A)	2.1	0.5	12.84
Norway spruce	47,648	357	(N/A)	2.1	1.3	35.74
White ash	37,344	280	(N/A)	1.9	1.0	31.12
Northern white ced	7,938	60	(N/A)	1.5	0.2	8.50
Conifer Evergreen I	1,748	13	(N/A)	1.5	0.0	1.87
Ash	16,034	120	(N/A)	1.5	0.4	17.18
Siberian elm	103,402	776	(N/A)	1.3	2.8	129.25
Honeylocust	50,220	377	(N/A)	1.1	1.4	75.33
Callery pear	2,857	21	(N/A)	1.1	0.1	4.29
Pear	1,277	10	(N/A)	0.8	0.0	2.39
River birch	4,943	37	(N/A)	0.6	0.1	12.36
Swamp white oak	2,218	17	(N/A)	0.6	0.1	5.55
Conifer Evergreen I	3,381	25	(N/A)	0.4	0.1	12.68
Catalpa	42,930	322	(N/A)	0.4	1.2	160.99
Eastern white pine	8,661	65	(N/A)	0.4	0.2	32.48
Red pine	513	4	(N/A)	0.4	0.0	1.93
Black spruce	3,779	28	(N/A)	0.4	0.1	14.17
Eastern red cedar	2,204	17	(N/A)	0.4	0.1	8.27
Common chokeche	908	7	(N/A)	0.2	0.0	6.81
American sycamor	15,773	118	(N/A)	0.2	0.4	118.30
Northern pin oak	7,945	60	(N/A)	0.2	0.2	59.59
Spruce	1,170	9	(N/A)	0.2	0.0	8.78
Willow	14,280	107	(N/A)	0.2	0.4	107.10
American elm	3,037	23	(N/A)	0.2	0.1	22.78
Citywide total	3,699,944	27,750	(N/A)	100.0	100.0	58.92

Table 5: Annual Carbon Sequestered

Annual CO_2 Benefits of Public Trees

4/24/2020

Species	Sequestered (lb)	Sequestered ($)	Decomposition Release (lb)	Maintenance Release (lb)	Total Released ($)	Avoided (lb)	Avoided ($)	Net Total (lb)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Sugar maple	66,162	496	-6,497	-305	-51	46,544	349	105,904	794	(N/A)	19.3	30.2	8.73
Green ash	32,019	240	-2,339	-137	-19	23,087	173	52,629	395	(N/A)	11.0	15.0	7.59
Apple	1,286	10	-36	-18	0	1,274	10	2,506	19	(N/A)	7.9	0.7	0.51
Norway maple	12,461	93	-808	-73	-7	12,551	94	24,130	181	(N/A)	7.9	6.9	4.89
Northern red oak	7,460	56	-506	-54	-4	8,210	62	15,111	113	(N/A)	6.4	4.3	3.78
Silver maple	31,212	234	-1,833	-87	-14	14,019	105	43,312	325	(N/A)	5.7	12.4	12.03
Red maple	6,177	46	-225	-30	-2	5,267	40	11,189	84	(N/A)	4.9	3.2	3.65
Black walnut	10,855	81	-699	-47	-6	7,947	60	18,057	135	(N/A)	4.5	5.2	6.45
Northern hackberry	1,832	14	-62	-23	-1	4,382	33	6,130	46	(N/A)	3.6	1.8	2.70
Bur oak	6,474	49	-2,569	-62	-20	8,528	64	12,371	93	(N/A)	3.6	3.5	5.46
American basswood	2,501	19	-179	-14	-1	1,701	13	4,009	30	(N/A)	2.8	1.1	2.31
Blue spruce	1,348	10	-104	-27	-1	2,508	19	3,725	28	(N/A)	2.5	1.1	2.33
Littleleaf linden	2,942	22	-83	-13	-1	1,856	14	4,701	35	(N/A)	2.1	1.3	3.53
Norway spruce	1,490	11	-229	-31	-2	2,697	20	3,927	29	(N/A)	2.1	1.1	2.94
White ash	4,522	34	-179	-18	-1	3,592	27	7,917	59	(N/A)	1.9	2.3	6.60
Northern white cedar	399	3	-38	-8	0	594	4	947	7	(N/A)	1.5	0.3	1.02
Conifer Evergreen Medi	244	2	-8	-8	0	686	5	913	7	(N/A)	1.5	0.3	0.98
Ash	1,959	15	-78	-10	-1	1,885	14	3,755	28	(N/A)	1.5	1.1	4.02
Siberian elm	4,466	33	-496	-24	-4	3,770	28	7,715	58	(N/A)	1.3	2.2	9.64
Honeylocust	6,330	47	-241	-14	-2	2,875	22	8,950	67	(N/A)	1.1	2.6	13.43
Callery pear	735	6	-16	-4	0	545	4	1,260	9	(N/A)	1.1	0.4	1.89
Pear	198	1	-6	-3	0	204	2	394	3	(N/A)	0.8	0.1	0.74
River birch	706	5	-24	-4	0	635	5	1,313	10	(N/A)	0.6	0.4	3.28
Swamp white oak	453	3	-11	-3	0	359	3	799	6	(N/A)	0.6	0.2	2.00
Conifer Evergreen Large	205	2	-16	-3	0	284	2	470	4	(N/A)	0.4	0.1	1.76
Catalpa	1,357	10	-206	-7	-2	1,127	8	2,272	17	(N/A)	0.4	0.6	8.52
Eastern white pine	116	1	-42	-7	0	527	4	594	4	(N/A)	0.4	0.2	2.23
Red pine	105	1	-2	-2	0	189	1	289	2	(N/A)	0.4	0.1	1.08
Black spruce	238	2	-18	-5	0	445	3	660	5	(N/A)	0.4	0.2	2.48
Eastern red cedar	86	1	-11	-4	0	374	3	445	3	(N/A)	0.4	0.1	1.67
Common chokecherry	114	1	-4	-1	0	124	1	232	2	(N/A)	0.2	0.1	1.74
American sycamore	857	6	-76	-4	-1	552	4	1,330	10	(N/A)	0.2	0.4	9.97
Northern pin oak	470	4	-38	-3	0	440	3	869	7	(N/A)	0.2	0.2	6.52
Spruce	116	1	-6	-2	0	216	2	324	2	(N/A)	0.2	0.1	2.43
Willow	0	0	-69	-4	-1	539	4	466	3	(N/A)	0.2	0.1	3.49
American elm	222	2	-15	-2	0	418	3	623	5	(N/A)	0.2	0.2	4.67
Citywide total	208,115	1,561	-17,768	-1,058	-141	160,952	1,207	350,241	2,627	(N/A)	100.0	100.0	5.58

Table 6: Annual Social and Aesthetic Benefits

Annual Aesthetic/Other Benefits of Public Trees

4/24/2020

Species	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Sugar maple	6,685	(N/A)	19.3	31.2	75.46
Green ash	2,787	(N/A)	11.0	13.0	53.60
Apple	63	(N/A)	7.9	0.3	1.71
Norway maple	1,248	(N/A)	7.9	5.8	33.74
Northern red oak	642	(N/A)	6.4	3.0	21.39
Silver maple	2,534	(N/A)	5.7	11.8	93.86
Red maple	873	(N/A)	4.9	4.1	37.97
Black walnut	1,002	(N/A)	4.5	4.7	47.70
Northern hackberry	462	(N/A)	3.6	2.2	27.19
Bur oak	453	(N/A)	3.6	2.1	26.67
American basswood	208	(N/A)	2.8	1.0	15.98
Blue spruce	258	(N/A)	2.5	1.2	21.52
Littleleaf linden	363	(N/A)	2.1	1.7	36.30
Norway spruce	270	(N/A)	2.1	1.3	26.99
White ash	588	(N/A)	1.9	2.7	65.36
Northern white cedar	76	(N/A)	1.5	0.4	10.83
Conifer Evergreen Medium	139	(N/A)	1.5	0.6	19.83
Ash	209	(N/A)	1.5	1.0	29.80
Siberian elm	295	(N/A)	1.3	1.4	49.12
Honeylocust	1,556	(N/A)	1.1	7.3	311.18
Callery pear	91	(N/A)	1.1	0.4	18.22
Pear	11	(N/A)	0.8	0.0	2.64
River birch	78	(N/A)	0.6	0.4	26.09
Swamp white oak	55	(N/A)	0.6	0.3	18.39
Conifer Evergreen Large	54	(N/A)	0.4	0.3	26.96
Catalpa	104	(N/A)	0.4	0.5	52.10
Eastern white pine	32	(N/A)	0.4	0.2	16.16
Red pine	31	(N/A)	0.4	0.1	15.42
Black spruce	45	(N/A)	0.4	0.2	22.60
Eastern red cedar	27	(N/A)	0.4	0.1	13.68
Common chokecherry	6	(N/A)	0.2	0.0	6.40
American sycamore	66	(N/A)	0.2	0.3	65.59
Northern pin oak	43	(N/A)	0.2	0.2	43.05
Spruce	32	(N/A)	0.2	0.2	32.32
Willow	0	(N/A)	0.2	0.0	0.00
American elm	37	(N/A)	0.2	0.2	36.79
Citywide total	21,425	(N/A)	100.0	100.0	45.49

Table 7: Summary of Benefits in Dollars

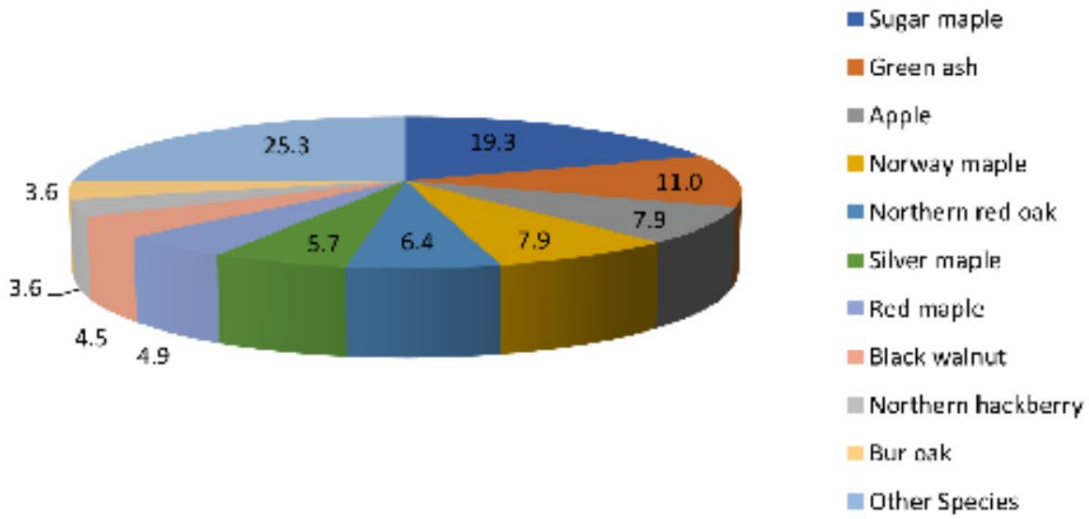
Annual Benefits of Public Trees by Species ($/tree)

4/24/2020

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error
Sugar maple	63.40	8.73	10.30	98.92	73.46	254.81	(N/A)
Green ash	54.91	7.59	9.41	70.22	53.60	195.72	(N/A)
Apple	5.05	0.51	0.68	1.82	1.71	9.77	(N/A)
Norway maple	43.20	4.89	7.29	41.80	33.74	130.93	(N/A)
Northern red oak	32.88	3.78	4.86	29.78	21.39	92.69	(N/A)
Silver maple	63.28	12.03	11.19	105.36	93.86	285.72	(N/A)
Red maple	27.96	3.65	4.74	24.40	37.97	98.72	(N/A)
Black walnut	46.63	6.45	7.84	55.66	47.70	164.29	(N/A)
Northern hackberry	33.07	2.70	4.96	21.79	27.19	89.72	(N/A)
Bur oak	61.33	5.46	13.52	120.19	26.67	227.17	(N/A)
American basswood	17.50	2.31	2.52	18.29	15.98	56.61	(N/A)
Blue spruce	25.62	2.33	2.81	49.35	21.52	101.63	(N/A)
Littleleaf linden	23.14	3.53	3.54	17.98	36.30	84.49	(N/A)
Norway spruce	32.42	2.94	0.35	90.99	26.99	153.70	(N/A)
White ash	45.78	6.60	7.75	48.15	65.36	173.64	(N/A)
Northern white ceda	11.40	1.02	0.38	24.25	10.83	47.88	(N/A)
Conifer Evergreen M	13.68	0.98	1.42	18.54	19.83	54.45	(N/A)
Ash	32.79	4.02	5.37	25.35	29.80	97.34	(N/A)
Siberian elm	78.41	9.64	14.98	112.86	49.12	265.01	(N/A)
Honeylocust	70.48	13.43	11.97	107.67	311.18	514.72	(N/A)
Callery pear	15.18	1.89	2.11	9.00	18.22	46.40	(N/A)
Pear	7.47	0.74	1.02	2.77	2.64	14.63	(N/A)
River birch	26.74	3.28	4.20	19.49	26.09	79.81	(N/A)
Swamp white oak	16.68	2.00	2.36	10.70	18.39	50.13	(N/A)
Conifer Evergreen L	18.04	1.76	1.00	43.12	26.96	90.88	(N/A)
Catalpa	67.63	8.52	13.23	117.95	52.10	259.42	(N/A)
Eastern white pine	31.15	2.23	0.62	83.24	16.16	133.41	(N/A)
Red pine	13.58	1.08	1.48	16.14	15.42	47.70	(N/A)
Black spruce	27.08	2.48	2.99	52.26	22.60	107.41	(N/A)
Eastern red cedar	24.57	1.67	2.19	44.30	13.68	86.40	(N/A)
Common chokecher	18.19	1.74	2.55	7.17	6.40	36.05	(N/A)
American sycamore	70.91	9.97	12.48	106.85	65.59	265.81	(N/A)
Northern pin oak	58.69	6.52	10.16	67.19	43.05	185.60	(N/A)
Spruce	24.14	2.43	2.82	41.70	32.32	103.40	(N/A)
Willow	70.84	3.49	13.58	102.01	0.00	189.93	(N/A)
American elm	45.87	4.67	7.68	37.69	36.79	132.71	(N/A)
Citywide Total	42.36	5.58	6.92	58.21	45.49	158.56	(N/A)

Species Distribution of Public Trees

4/24/2020

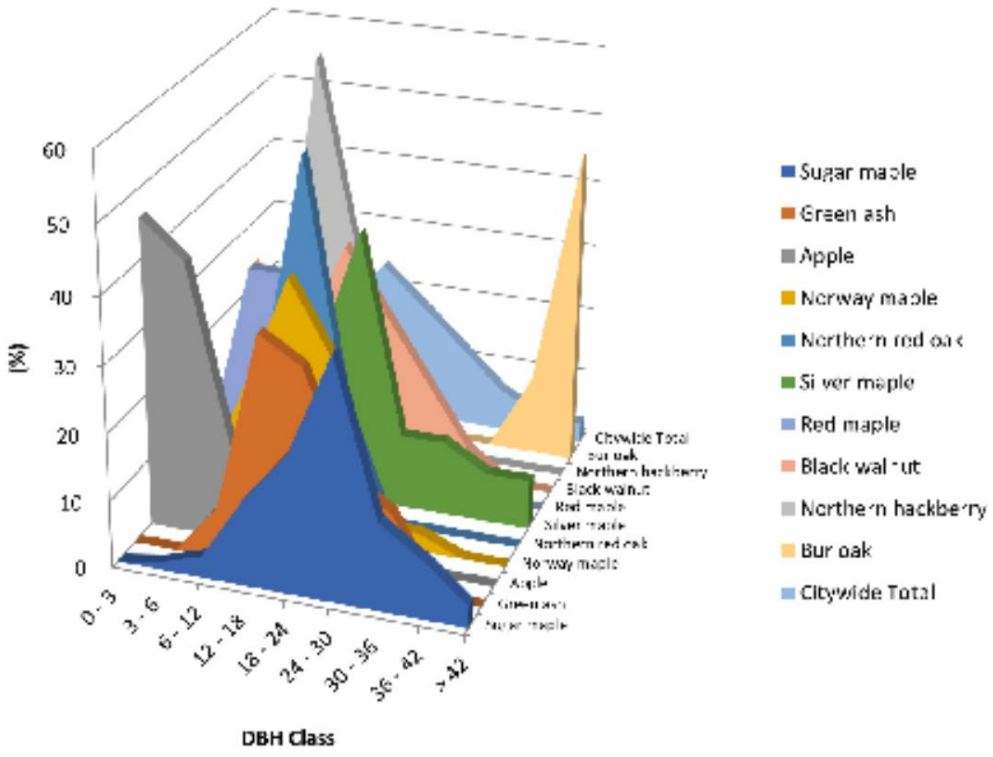


Species	Percent
Sugar maple	19.3
Green ash	11.0
Apple	7.9
Norway maple	7.9
Northern red oak	6.4
Silver maple	5.7
Red maple	4.9
Black walnut	4.5
Northern hackberry	3.6
Bur oak	3.6
Other Species	25.3
Total	100.0

Figure 1: Species Distribution

Relative Age Distribution of Top 10 Public Tree Species for All Zones (%)

4/24/2020



	DBH class (in)								
Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	> 42
Sugar maple	0.00	1.10	3.30	13.19	20.88	36.26	13.19	8.79	3.30
Green ash	0.00	0.00	7.69	34.62	30.77	15.38	11.54	0.00	0.00
Apple	45.95	40.54	13.51	0.00	0.00	0.00	0.00	0.00	0.00
Norway maple	2.70	5.41	21.62	37.84	27.03	2.70	2.70	0.00	0.00
Northern red oak	0.00	10.00	20.00	53.33	16.67	0.00	0.00	0.00	0.00
Silver maple	0.00	0.00	0.00	22.22	40.74	11.11	11.11	7.41	7.41
Red maple	4.35	30.43	30.43	26.09	8.70	0.00	0.00	0.00	0.00
Black walnut	0.00	4.76	19.05	33.33	23.81	14.29	4.76	0.00	0.00
Northern hackberry	0.00	11.76	58.82	29.41	0.00	0.00	0.00	0.00	0.00
Bur oak	23.53	11.76	0.00	0.00	5.88	0.00	0.00	11.76	47.06
Citywide Total	5.94	11.68	15.92	23.78	18.05	12.31	6.37	2.97	2.97

Figure 2: Relative Age Class

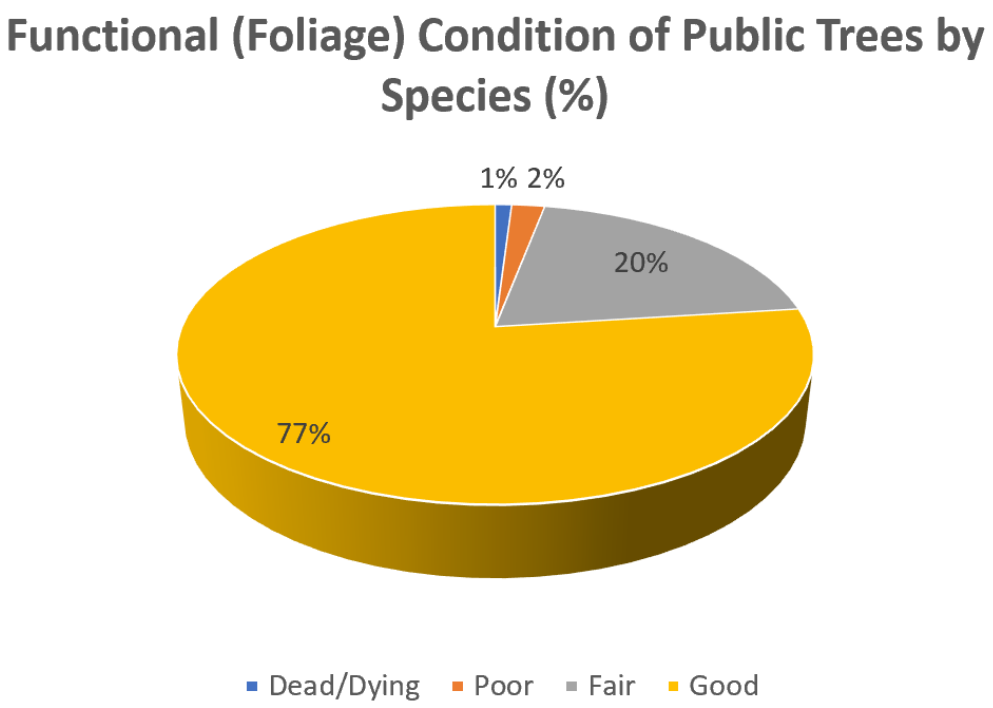


Figure 3: Foliage Condition

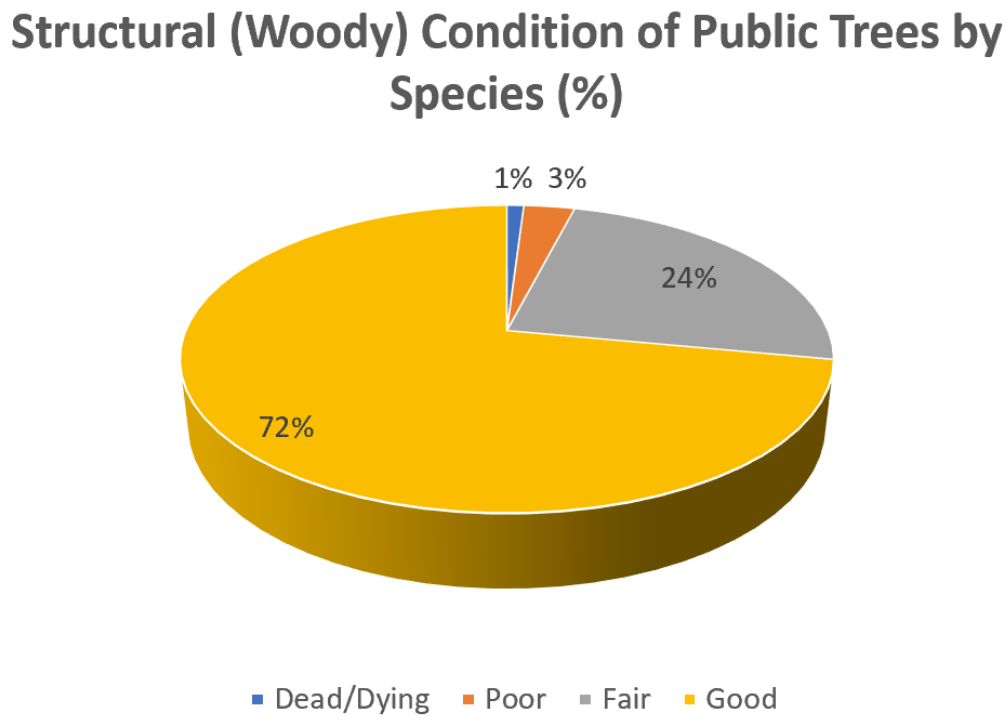
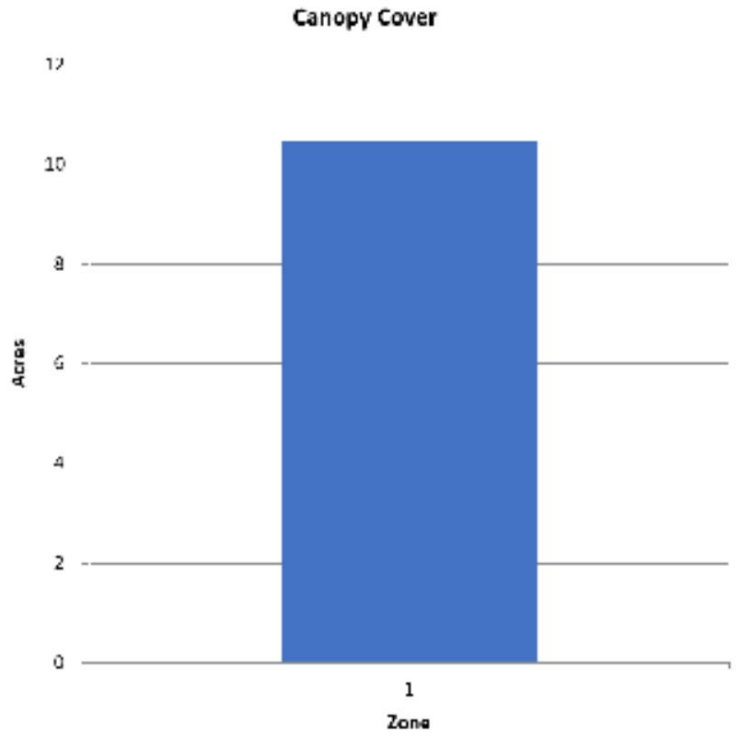


Figure 4: Wood Condition

Canopy Cover of Public Trees (Acres)

4/24/2020



Zone	Acres	% of Total Canopy Cover
1	10	100.0
Citywide total	10	100.0

	Total Land Area	Total Street and Sidewalk Area	Total Canopy Cover	Canopy Cover as % of Total Land Area	Canopy Cover as % of Total Streets and Sidewalks
Citywide Total	0	0	10	0.00	0.00

Figure 5: Canopy Cover in Acres

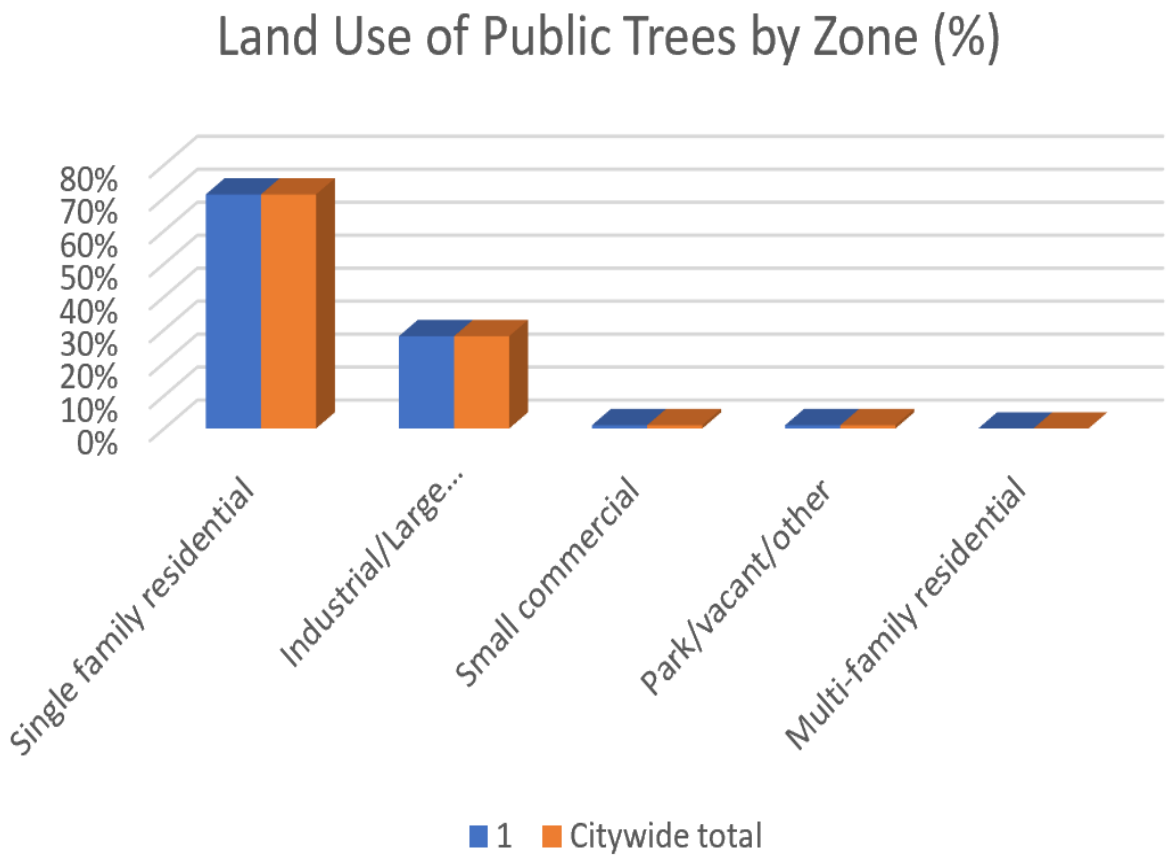


Figure 6: Land Use of city/park trees

Appendix B: ArcGIS Mapping

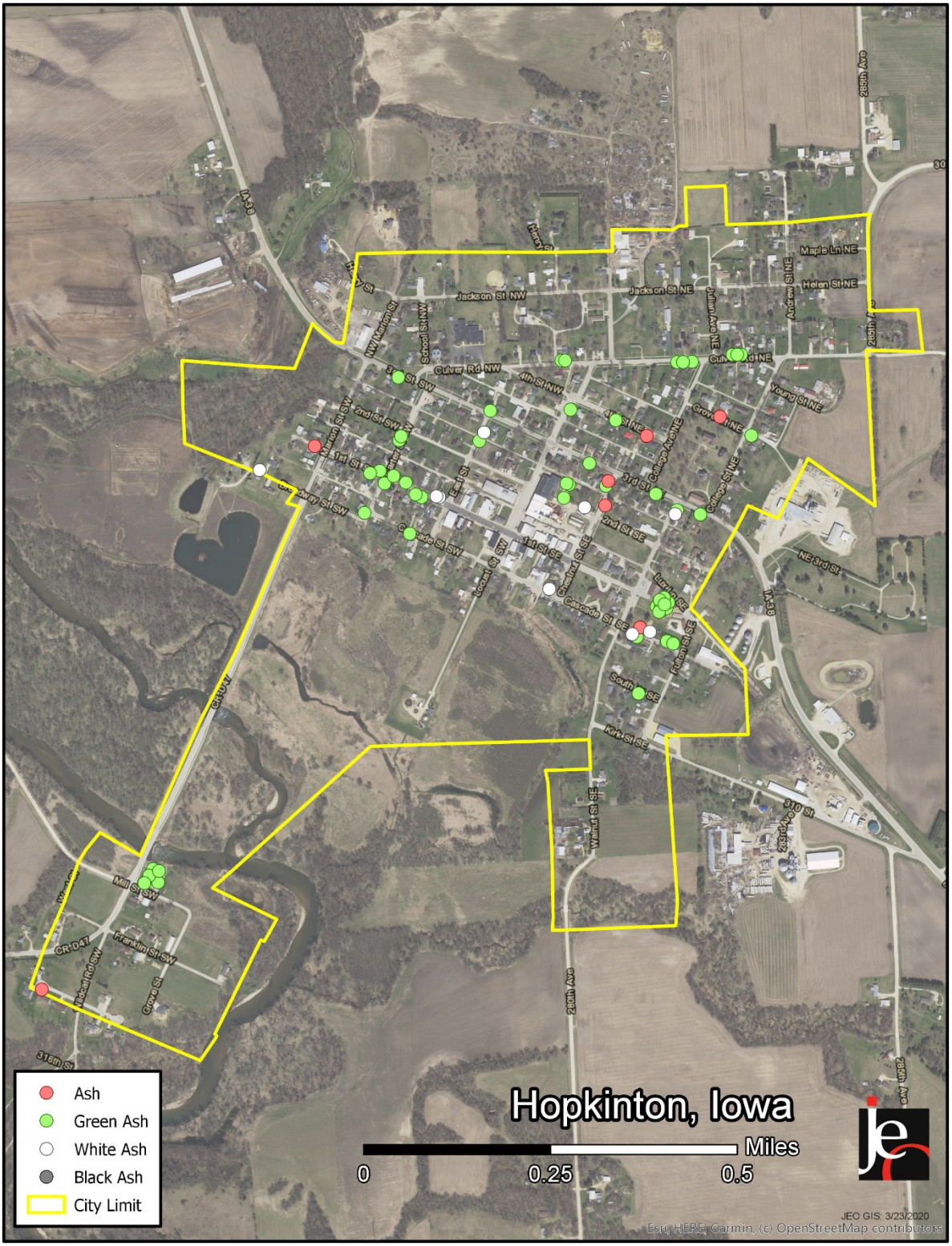


Figure 1: Location of Ash Trees

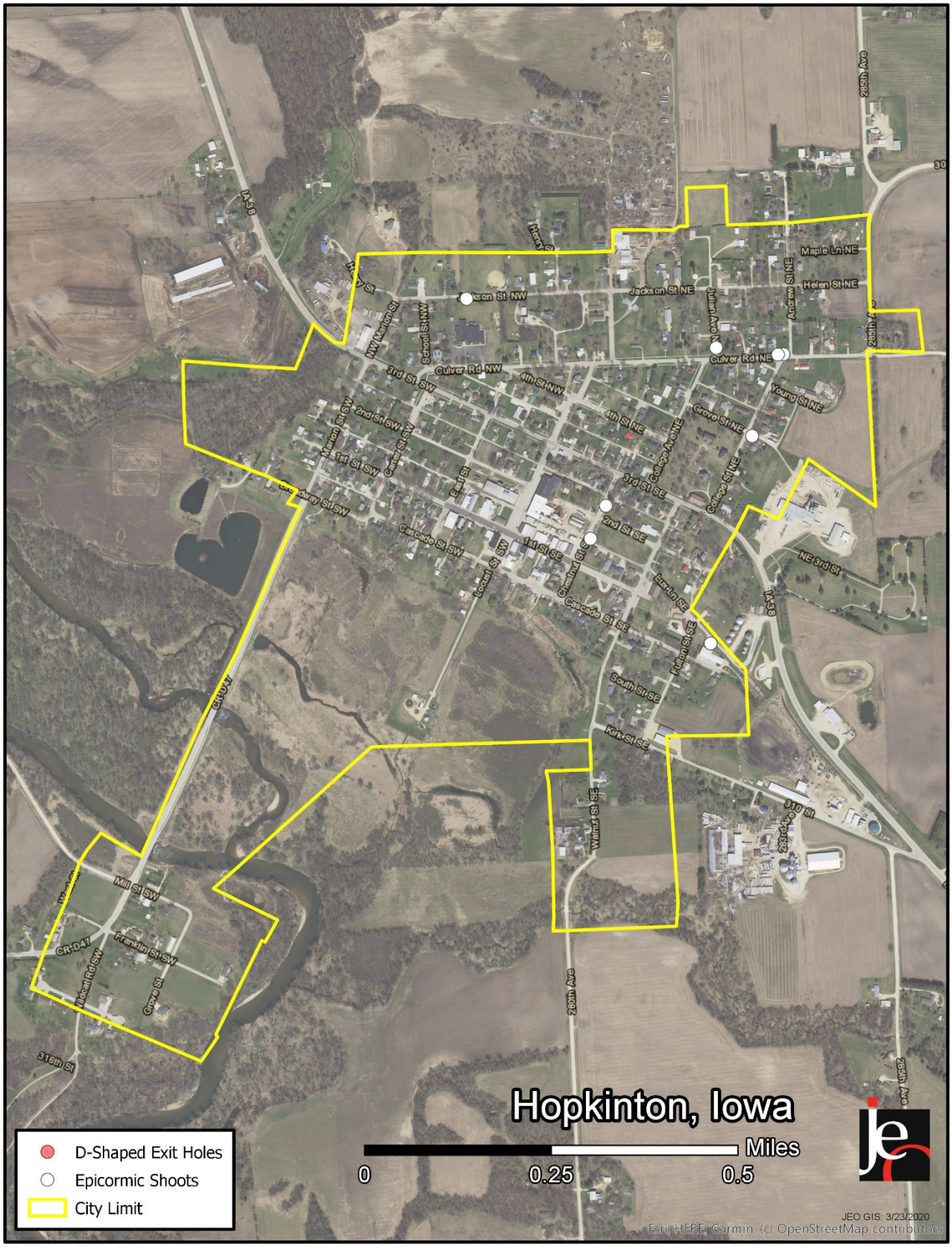


Figure 2: Location of EAB symptoms

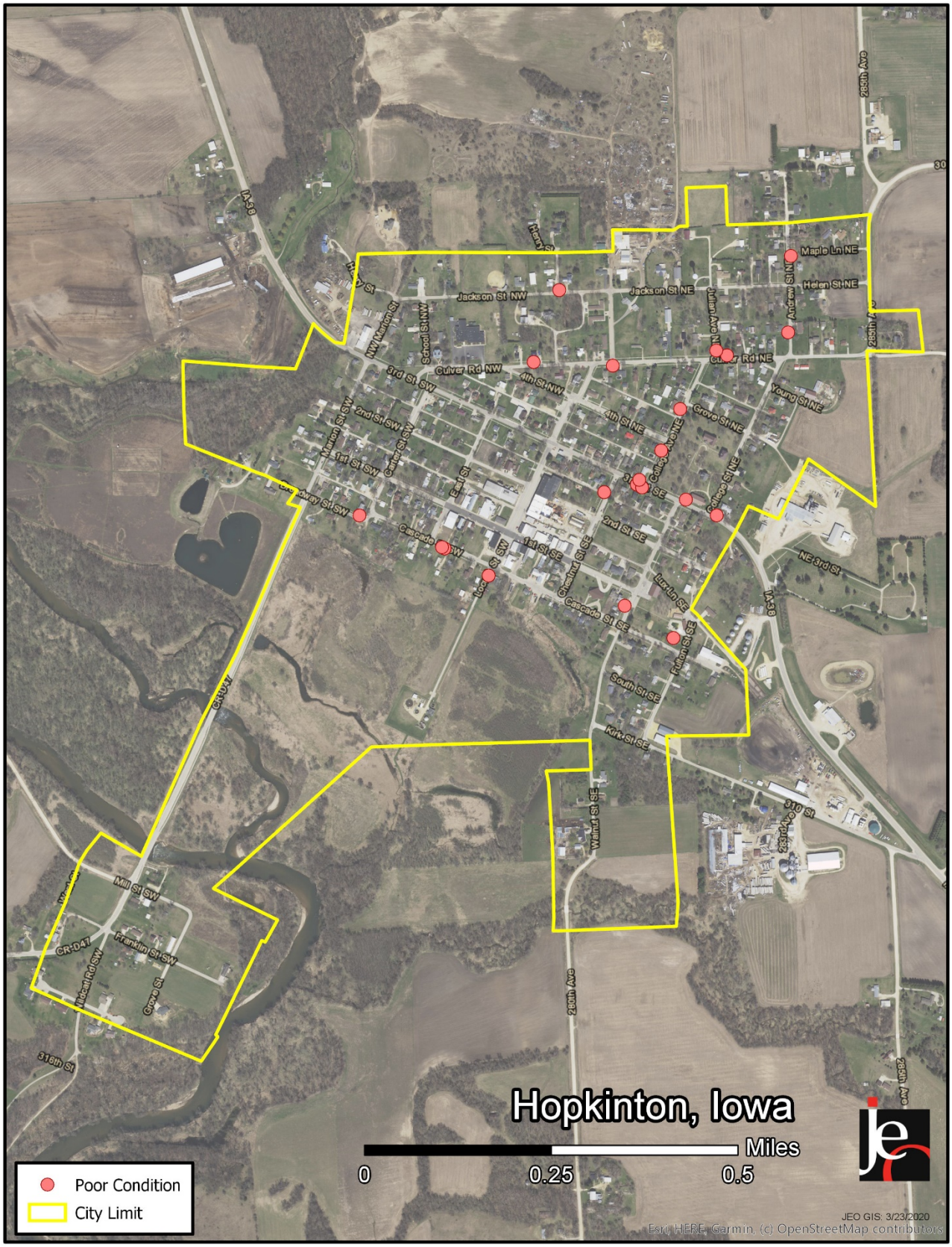


Figure 3: Location of Poor Condition Trees

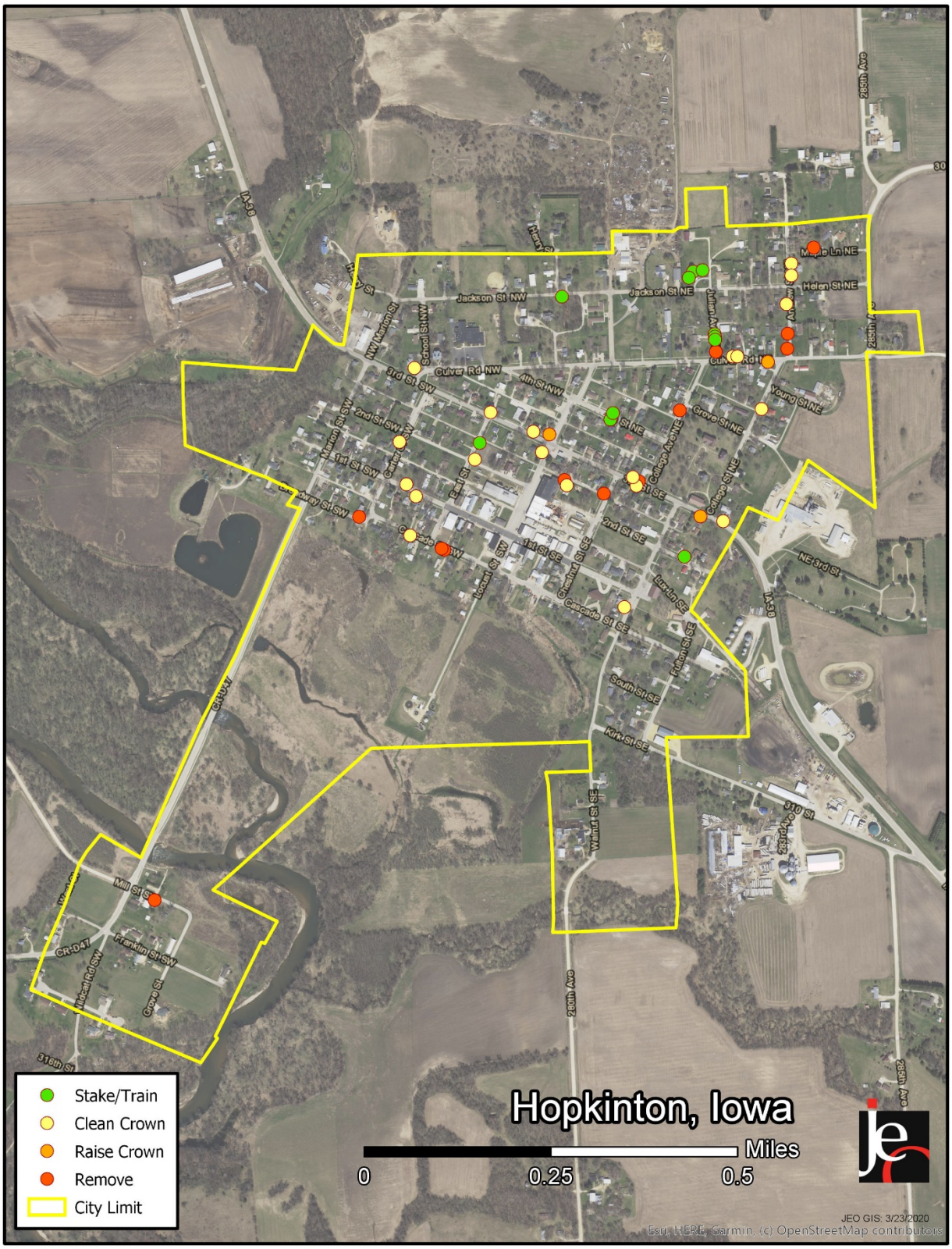


Figure 4: Location of Trees with Recommended Maintenance *City ownership of the trees recommended for removal should be verified prior to any removal*

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