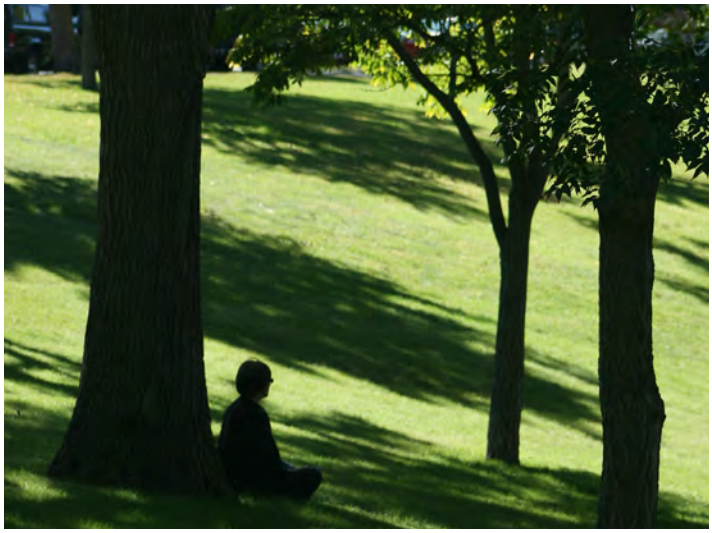

Health Impacts of Saint Paul's Emerald Ash Borer Management Plan

July 2015

This assessment connects the health of a city's urban forest with the health of its citizens.

Minnesota Pollution Control Agency

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This HIA is dedicated to Saint Paul's Standing Nation.

The connections to the Standing Nation, or Trees is one we honor and are aware of from birth to death.

The trees give us shelter, wood for warmth, food for hunger, and beauty for our spirits. Many birds and animals shelter and feed from the trees. The Standing Nation records the passing of time in their rings of life. From the rings we can look back on hundreds of years and understand the way things were here on this land during those times.

We choose the tree as the center of our most sacred ceremony it represents our past, future, and present. The trees are a great part of our religion and healing medicine.

We honor the tree in our Sun Dance and show respect for all living things that take nourishment from the sacred tree.

This tree is the center of our belief and holds all the wisdom that was given to the people.

Mitakuye Oyasin Waynonaha (Waynonaha, 2008)

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Foreword

As the Commissioner of the MPCA, the health of the environment is foremost on my mind. With my background in public health, I'm reminded daily of the impacts that our environmental choices have on human health. Our mission is "to protect and improve our environment and enhance human health," and we're always looking for opportunities to inform our work in new ways. I'm pleased that the agency had the opportunity to conduct this Health Impact Assessment (HIA) on Saint Paul's Emerald Ash Borer Management Plan and learn more about HIA, an emerging tool to better inform policy and program decisions.

In recent years, our understanding of the role that our urban forests play in the health of our environment and our human population has increased. We also recognize that there are some populations that remain disproportionately affected by pollution. What's promising is we now have a better understanding of the multifaceted benefits of the urban forest. We know that community trees can improve air quality, better manage stormwater, provide shade and windbreaks to conserve energy, and even reduce crime and enhance well-being. Planting trees in neighborhoods facing health equity issues is one way to address environmental justice and provide numerous long-term benefits; trees make neighborhoods better and our lives healthier.

I am grateful for support from The Pew Charitable Trusts, the Robert Wood Johnson Foundation, and Blue Cross and Blue Shield of Minnesota Foundation for this project. Thanks also to our numerous HIA partners for joining this effort. It's encouraging to see that health impact assessments can assist in better understanding a broad range of projected impacts, and to see policy options through a new lens. The MPCA will continue to look for ways to integrate these practices into our work.

In the words of Robert Louis Stevenson, *"It is not so much for its beauty that the forest makes a claim upon men's hearts, as for that subtle something, that quality of air, that emanation from old trees, that so wonderfully changes and renews a weary spirit."* We have intuitively known that trees benefit us; thanks to this HIA, we have evidence that trees benefit our health.

John Linc Stine
Commissioner
Minnesota Pollution Control Agency

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Introduction

In 2014, the Minnesota Pollution Control Agency (MPCA) conducted a Health Impact Assessment (HIA) to examine the projected health impacts of Saint Paul's Emerald Ash Borer Management Plan (EAB Plan). Urban forests are in decline nationally, and EAB poses an immediate threat to 20% of Saint Paul's neighborhood trees. The EAB crisis, along with increasing recognition of the health benefits that trees provide, prompted the genesis of this HIA. With 18% of youth diagnosed with asthma, an aging stormwater infrastructure, concerns about pesticide safety, increasing heating and cooling needs, and in many cases reduced access to green spaces, Saint Paul trees are an increasingly important resource and an increasingly threatened one.

The assessment was focused on five key areas linked to health outcomes – air quality, stormwater management, insecticide use, green space and urban heat island – and connects the health of a city's urban forest with the health of its citizens.

The purpose of this report is to project the human health impact of the wide-spread loss of ash trees in Saint Paul due to Emerald Ash Borer, and to further explore the nexus of public health and urban forestry.

Saint Paul leaders, forestry staff and residents are credited with a timely response to the EAB infestation by implementing the Saint Paul Emerald Ash Borer Management Program. These efforts have likely contributed to a slower-than-expected rate of advancement of Emerald Ash Borer across the city and in nearby areas to date. Nevertheless, the spread of Emerald Ash Borer is expected to continue at a faster rate in the near future.

Recommendations included in this report should be viewed as a list of potential activities (many of which are currently underway) that would serve to promote the health of the city's urban forest, and in turn, the health of its citizens in Saint Paul. Other urban settings that will experience similar wide-spread tree loss can utilize these recommendations in their planning and response; stakeholders similarly can operationalize this information for future partnership planning.

Value of ash trees

According to Saint Paul's tree inventory, approximately 1 in 5 city trees is an ash tree. Urban trees contribute significant benefits to Saint Paul, and according to iTree calculations based on the city's tree inventory, **ash trees alone contribute over $2.5 million worth of services each year**, including $138,847 of air quality services, $922,044 of stormwater mitigation, and $691,126 of aesthetic and other benefits. If the EAB infestation mirrors results from elsewhere, all of these trees will eventually become infested and this means that 20% of Saint Paul's trees will die. These benefits are expected to be lost due to EAB. If the city does not act to increase support for forestry activities, these benefits may never be replaced.

Implications of current and alternative EAB Plans

The HIA compared the results for the current EAB Plan with an alternative plan that would provide increased funds both for EAB activities as well as a re-investment in the urban forest as a whole. The

current EAB Plan states a goal of a 1:1 replacement rate, but may not achieve that goal due to both funding shortfalls and less than 100% survival rates of newly planted trees. This will result in fewer total trees in Saint Paul's urban forest. It will also shift the distribution of tree size by greatly reducing the number of 13 to 15 inch DBH (diameter at breast height) trees in the city. The current EAB Plan will preserve 5000 ash trees, and this means that the benefits provided by these trees will be retained for at least the next 10 years. But while positive contributions of these ash trees will be preserved, these 5000 trees will each receive multiple treatments of Emamectin benzoate, a chemical that is believed to be safe but has yet to undergo rigorous testing to identify its short and long term impact both to the environment and to people. At the conclusion of this 10 year period, it is difficult to predict what may happen to these 5000 trees as they will have reached an age when they begin to structurally fail and become increasingly susceptible to storm damage.

The alternative plan will provide sufficient funding and resources to replace not only all ash trees but also to replace all other trees that are removed due to a variety of reasons such as other diseases/pests, public works projects, redevelopment, old age, or storm damage. Existing levels of benefits provided by urban trees may fluctuate for an interim period due to changes in canopy cover (as a result of new, small trees replacing older, larger trees) but each year as trees grow, the benefits will correspondingly increase until the canopy cover is equal to, or eventually greater than, existing canopy cover.

The alternative plan would provide $550,000 towards a one-time purchase of heavy equipment (three large trucks used for tree planting, trimming and maintenance) along with funds to support additional staffing and programming, focused on activities to keep up with tree loss (planting and maintenance of trees as well as community engagement to build awareness and citizen capacity to care for neighborhood trees.)

Under the alternative plan, sufficient funding and staffing resources will replace trees at a minimum 2:1 ratio (every tree lost will be replaced by at least 2 trees), enough to reverse the trend of gradual loss (approximately 0.3% each year) that is reflected across the nation's urban forests overall. This means not only planting enough new trees but also working to ensure that these new trees as well as existing trees receive adequate water and ongoing care, in order to ensure the longevity of forest health and the many benefits that mature trees provide.

Key recommendations

A comprehensive list of recommendations can be found in the full HIA report, but several key recommendations are listed here:

1. City of Saint Paul should identify neighborhoods with lower canopy cover and higher rates of vulnerable populations, and target these neighborhoods for new tree planting and increased assistance.
2. The City of Saint Paul Mayor's Office should declare the stability of the urban forest a city priority.
3. Saint Paul Forestry should develop and implement a five-year community forestry master plan with measurable goals.
4. Saint Paul Forestry and Saint Paul Chamber of Commerce should work together to provide incentives to businesses and property management companies to reduce heating and cooling costs.
5. Saint Paul Planning and Economic Development should incorporate urban forestry approaches into plans for climate resilience and/or disaster preparedness as a temperature buffering and flood management strategy.

While there are costs associated with planting and maintaining urban forests, neighborhood trees provide numerous benefits. As our understanding of and ability to measure these benefits increases, budget decisions should reflect a consideration of the full contribution of trees, and what may be lost if their numbers continue to diminish.

Section 1: Background

Introduction & purpose

During 2014, the Minnesota Pollution Control Agency (MPCA) conducted a Health Impact Assessment (HIA) of Saint Paul's Emerald Ash Borer Management Plan (EAB Plan). The emerald ash borer (EAB) is an invasive species that is native to Asia. It has a track record of near-100% tree mortality in areas of infestation (DeSantis, 2013) (Ghandi & Herms, 2010), and was first identified in Saint Paul in May 2009. The city's original EAB Management Plan was issued in June 2009 outline the plan to address the EAB infestation. Each year, the plan is revised based on EAB activity (amount of pest pressure, location of infestations) and emerging national best practices. This HIA will help to inform not only the next update of the plan but also future urban forestry activities in Saint Paul and beyond by analyzing a projected major tree loss and its impact on human health. The HIA will also be relevant to future significant projected losses to the urban forest, including a 32% chance that another highly destructive borer species will invade the U.S. in the next 10 years (Aukema, 2011).

The purpose of this HIA is to illuminate the human health impacts of Saint Paul's EAB Plan and to develop health-supporting recommendations for future urban forestry program decisions. Ash trees comprise approximately 20% of the city's trees, so the city is likely to lose about 1 in 5 of trees in the coming years because of EAB infestation. It was determined in the HIA screening step that this HIA could provide an important additional lens of human health to the already existing forest health perspective. An objective of this HIA is to assist forestry staff and decision-makers in making program and funding decisions for the city's management of EAB. **More broadly, this assessment connects the health of a city's urban forest with the health of its citizens.**

Methods

What is a health impact assessment (HIA)?

HIA is a method that uses data, scientific research, evidence, and stakeholder input to determine how a proposed policy or project would impact health. HIA is a systematic process that uses an array of data sources and analytic methods and considers input from stakeholders to determine the potential effects of a proposed policy, plan, program, or project on the health of a population and the distribution of those effects within the population. HIA provides recommendations on monitoring and managing those effects. (National Research Council, 2011) An HIA can provide recommendations to increase positive health outcomes and minimize adverse health outcomes. HIA brings potential public health impacts and considerations to the decision-making process for plans, projects, and policies that fall outside the traditional public health arenas, such as transportation and land use. (Centers for Disease Control and Prevention, 2014) Typically, an HIA involves six steps, as shown in Figure 1. A description of these steps for this HIA is further discussed below.

Step 1: Screening

Screening was conducted as a part of the original grant proposal process to the Health Impact Project. The MPCA applicant team met with members of Saint Paul's Forestry Department and discussed a mutual concern about EAB and the projected loss of urban trees. The group recognized the value an HIA would bring to the decision-making process by adding a health lens to the ongoing conversation about

environmental, operational, and aesthetic impacts of EAB and related tree loss. In addition, the group recognized that areas with lower percentage of tree canopy cover might align with populations facing health equity and/or environmental justice issues. It was determined that an HIA would provide valuable information to decisions informing the current EAB Plan.

Figure 1: The Steps of HIA

Source: (Health Impact Project, 2014)

Step 2: Scoping

Part of the scoping step occurred during the grant proposal development process to the Health Impact Project for support of this HIA. During this step, the City of Saint Paul was defined as the area of study. Stakeholders also contributed to scoping by identifying the health pathways, affected or vulnerable populations, research questions, research methods, and existing data sources to include in this HIA. In the context of HIA, health pathways are common pathways through which policies and projects may affect human health (UCLA Health Impact Assessment Clearinghouse, 2014). The initial set of prioritized health pathways included: 1) air quality, 2) stormwater, 3) urban heat island effect, 4) mental health, 5) physical health, and 6) pesticide use. During the assessment phase, these health pathways were further refined for clarity and to better reflect the role of trees and their effect on human health. During the process of mapping these pathways, it was determined that mental health and physical health were health *outcomes*, so these were collapsed into a new pathway called green space. Pesticide experts noted that "pesticide" also includes fungicide and herbicide, and recommended the use of "insecticide" for this pathway. The final health pathways that are presented in this HIA are: 1) air quality, 2) stormwater management, 3) insecticide use, 4) green space and 5) urban heat island effect.

During initial meetings, the advisory committee also developed the following goals for the HIA project:

1. Inform the future of the current EAB Plan and build capacity to advance recommendations emerging from this HIA
2. Identify influence of trees on human health
3. Advance the dialogue of how urban trees impact human health, and the importance of including human health impact as a factor in urban tree-related decisions
4. Forge lasting relationships among partners/stakeholders that will go beyond this HIA
5. Build capacity for HIA among project partners

Step 3: Assessment

Baseline health data was assembled from Saint Paul-Ramsey County Public Health and Minnesota Department of Health in order to characterize important causes of illness and conditions that influence the health of Saint Paul residents, given that the EAB Plan may affect some of these conditions. Saint Paul Forestry Unit provided data from its 2011 tree canopy assessment and digital, map-based tree

inventory (data collected from 2009-2014 and ongoing). A variety of data sources were utilized to inform the assessment, including 1) literature review of dozens of sources (see Works cited), 2) interviews with n=9 subject matter experts, and 3) internet searches of emerald ash borer, urban heat island effect, Emamectin benzoate, imidacloprid, green space, stormwater management, and air quality.

Step 4: Recommendations

Recommendations were developed based on assessment findings, evidence, best practices, and local needs in order to inform future actions that the City of Saint Paul and others can take to optimize the human health benefits of the city's urban forest, particularly in light of the significant tree loss projected in the coming years as a result of the emerald ash borer. Recommendations were developed with the assistance of subject matter experts and vetted by the HIA advisory committee.

Step 5: Reporting

A variety of reporting opportunities and tools were identified for this HIA. These are outlined in the dissemination plan in Appendix 3.

Step 6: Monitoring/evaluation

In keeping with HIA practices, a process evaluation for the EAB HIA project was done is attached in Appendix 4. An impact evaluation will be ongoing to assess the impact of this HIA project on the partners and stakeholders, on the decision and decision-making process, on the issue of urban forestry on a local, regional, and state level, on health determinants and on health and environmental outcomes. These impacts will be tracked through an ongoing monitoring plan, attached in Appendix 5.

Stakeholder engagement

After receiving funding to conduct the HIA, extensive outreach was conducted to identify stakeholders to participate. In early 2014, numerous community groups were invited to participate in this HIA and related training, including racial justice organizations, cultural advocacy groups, environmental advocacy groups, Saint Paul city departments, and relevant state agencies. Participating stakeholders are listed in the acknowledgements section of this HIA. Stakeholders identified the five health pathways included in this HIA, and created health pathway diagrams (located in the assessment section) linking aspects of the current EAB Plan, i.e. change in the number of trees, to changes in health outcomes.

Stakeholder groups engaged

An analysis of relevant populations was conducted to identify the various individuals or sectors that are impacted by Saint Paul's urban forest and to prioritize those to engage in this HIA process. Affected or interested populations identified included:

- Cultural and ethnically focused nonprofit organizations
- Advocacy organizations focused on health and/or the environment
- Elementary and secondary education (facilities)
- Higher education (research, campus facilities)
- Utility companies (power lines and trees)
- Tree service companies
- Media
- Watershed districts and management organizations

- Firewood suppliers
- Healthcare plan providers
- Local hospitals and clinics
- Landscape/nursery professionals
- Elected officials
- Public agencies at federal/state/local level focused on planning, housing, parks and recreation, agriculture, natural resources, environment, commerce
- Pollinator advocates

Individuals from these stakeholder categories were invited to participate in the EAB HIA project on the advisory committee and/or as a subject matter expert to ensure a diverse representation of perspectives and interests.

Methods of engagement

The primary mechanisms used to engage stakeholders were:

- **Advisory committee –** an advisory committee consisting of 13 local stakeholders, HIA and content area experts, state and city employees was developed to 1) serve as an ongoing source of technical expertise to conduct this HIA, 2) ensure the input of a diverse group of stakeholders in this HIA, and 3) assist in disseminating HIA information to their broader constituencies. The advisory committee met five times over the 14 months of the project (November 2013-December 2014) to provide feedback and input to the HIA project. The advisory committee also provided review of the report and its findings and recommendations.
- **Introductory workshop on HIA –** a 2-day workshop was held in January 2014 to provide training on HIA and the EAB HIA in particular. This workshop was attended by 33 individuals representing city departments, Saint Paul community members, state agencies, and nonprofit organizations.
- **Subject matter experts –** a total of nine subject matter experts were accessed. Subject matter experts served as resources for local data, background information, reality checks/ground truthing, ongoing technical expertise via email and connections to additional resources for information.
- **Presentation –** approximately 50 people attended a workshop session on the EAB HIA at the 2014 Minnesota Shade Tree Short Course, an annual 2-day conference attended by over 1,000 individuals in the forestry sector.

Baseline community profile

Impacted community/Scope of study: the City of Saint Paul

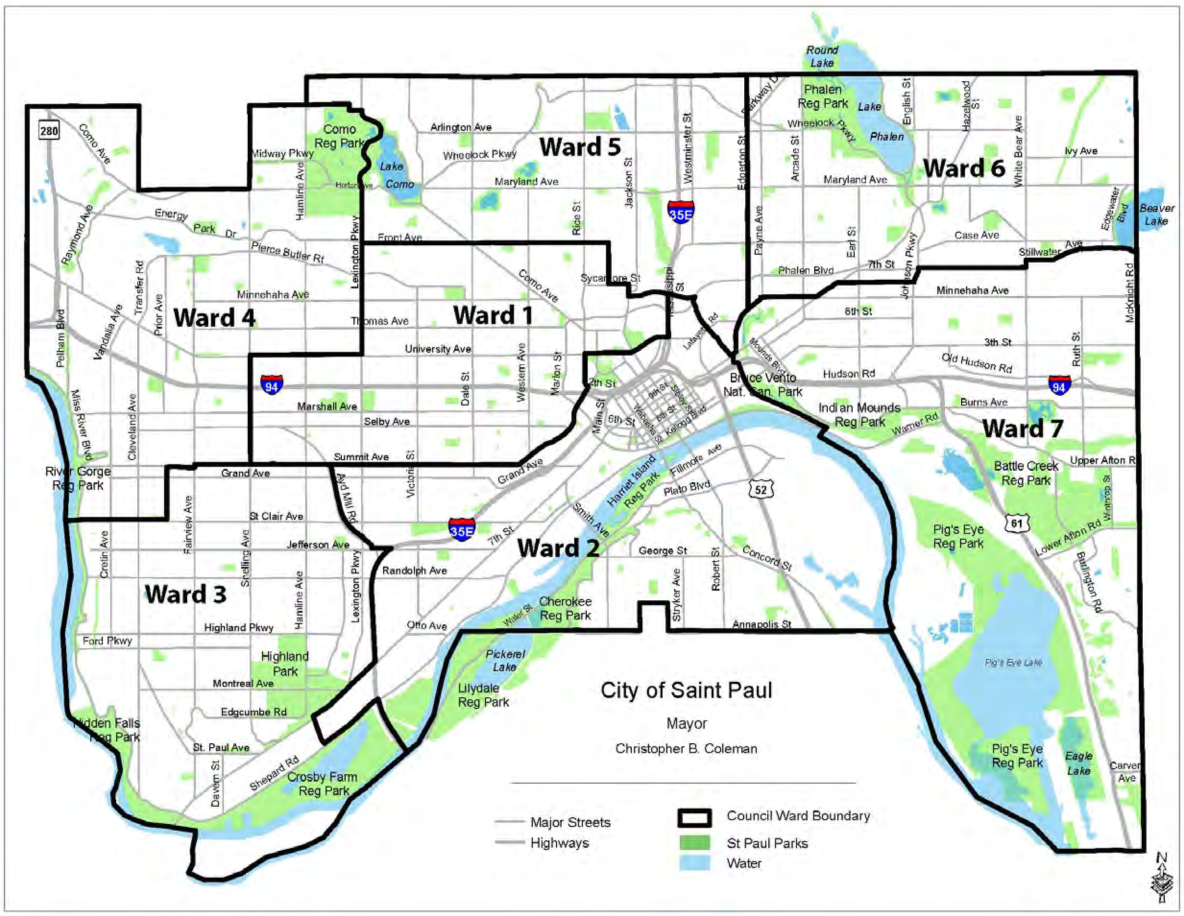
The geographic boundaries of this HIA are the city limits of Saint Paul, though it is important to acknowledge that EAB does not recognize geo-political distinctions. The HIA is also limited to the city's actively managed public trees, which are the boulevard trees and trees in manicured (as opposed to wild growth) areas of city parks. While ash trees located on private property are also susceptible to EAB infestation, these fall outside the scope of this HIA because the current EAB Plan does not address them. Further, the city's jurisdiction of privately owned trees is limited to condemning them if they are determined to be diseased or pose a public hazard. Considerations regarding insecticide treatment of privately owned ash trees for EAB are further discussed in Appendix 2.

According to census data (Table 1), the population of Saint Paul in 2013 was 294,873. Saint Paul is a young city with about 25% of its population under age 18, and only 9% over 65. Saint Paul is becoming

more ethnically diverse, with approximately 15% Asian, 15% African-American, and 10% Hispanic residents; a majority (60%) of residents are white. (Census.gov, 2014) During the 2012-2013 school year, there were 37,840 students enrolled in the city's public schools. Of those, 31.4% were Asian, 29.6% were Black, and 23.7% were Caucasian. These students represented over 100 languages and dialects. Nearly three-quarters of them were eligible for free or reduced-price lunch (Saint Paul Public Schools, 2013). In addition, 11% of SPPS students have asthma or respiratory conditions, 1.5% have diabetes and 6 % have been diagnosed with Attention Deficit Hyperactivity Disorder or Attention Deficit Disorder (Yackley, 2014).

The City of Saint Paul together with Ramsey County share joint responsibility for public health concerns for city residents. About 60% of Ramsey County residents live in Saint Paul.

Figure 2: Saint Paul Neighborhoods



Source: (City of Saint Paul)

Table 1: Saint Paul sociodemographic profile

Indicator	Saint Paul	Ramsey County	Minnesota
Population			
Total (count)	294,873	526,714	5,420,380
White (%)	60.1	70.9	85.3
African American (%)	15.7	11.6	5.2
Hispanic/Latino (%)	9.6	7.3	4.7
Asian (%)	15.0	13.2	4.0
Age Distribution			
Under 5 years old (%)	7.8	7.0	6.7
Under 18 years old (%)	25.1	23.3	24.2
Over 65 years old (%)	9.0	12.7	12.9
Income			
Median household income ($)	$46,305	53,152	$59,126
Living below poverty line (%)	22.8	16.8	11.2

Source: (Census.gov, 2014)

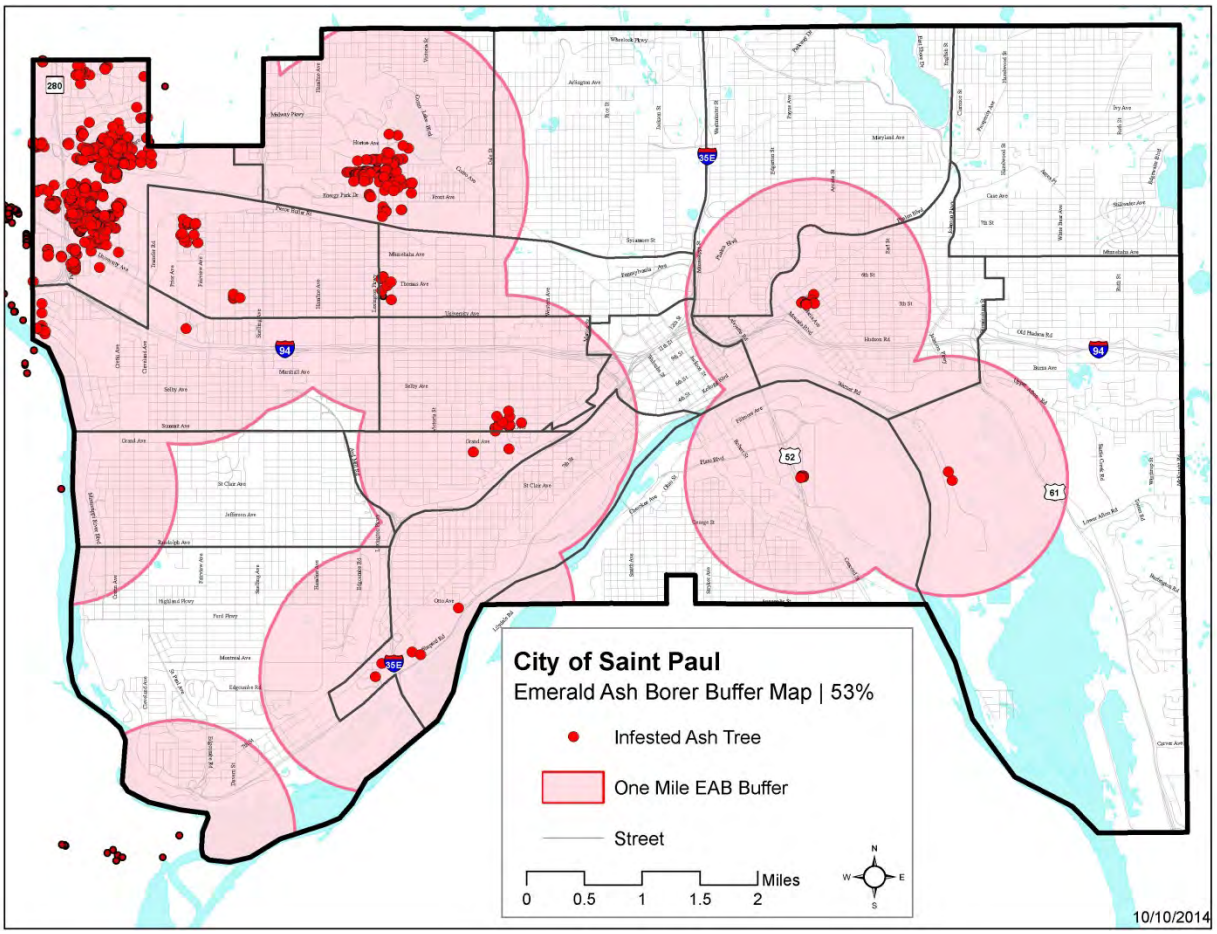
Baseline EAB information in Saint Paul

EAB and Saint Paul's urban forest (please refer to Appendix 1 for a primer on EAB)

Emerald Ash Borer is a non-native beetle that was first identified in North America in 2002 (USDA Forest Service, Michigan State University, Purdue University and Ohio State University, 2014). In its larval stage EAB feeds on the inside of ash trees. Over time, EAB consumes so much of the nutrient-transporting layers of the tree that the tree becomes compromised and eventually dies. There are no known natural predators of EAB in North America, so the only way to avoid infestation is to treat an ash tree with insecticide, which comes with environmental and economic impacts. The U.S. Forest Service encourages municipalities to develop EAB Management Plans, which should incorporate a variety of approaches with the goal of managing pest pressure to allow removal of ash trees to occur at a pace that does not exceed local capacity.

Saint Paul is considered "ground zero" for EAB in metropolitan Minnesota, so it is looked to as a model for other cities and towns in the immediate metropolitan area, in greater Minnesota, and elsewhere. EAB was discovered in 2009 in the St. Anthony Park neighborhood near Minnesota State Highway 280, a north-south transportation corridor that is within sight of the Saint Paul/Minneapolis border. Since then, the infestation has spread to other areas of the city. In summer 2014, crews determined that approximately 60% of ash trees in Saint Paul are now within infested zones (an infested zone is a one-mile radius of a confirmed EAB infestation).

Figure 3: City of Saint Paul EAB infested zones



Source: City of Saint Paul Forestry

City forestry staff project that in 2015-2016, removal of dead or dying ash trees will consume a substantial portion of forestry resources, deferring other needs for an undetermined period of time. As the current EAB Plan states, "The goal of the EAB Management Program from the beginning has been to replant a new tree for every ash tree lost. So far, the City has been able to keep that commitment. However, if EAB spreads rapidly and funding does not keep pace, the concern is replanting could fall far behind the number of trees removed." (Saint Paul Forestry Unit, 2013) While such a scenario may not seem harmful in the short run, it could have serious implications for the future. It takes 25 to 30 years for a tree to attain a functional mature size (Johnson, 2014). A 5-year delay in replacing a mature tree means adding five years onto this 25 to 30 year timeframe. If even 100 trees fall into this category, it would result in delaying many years of those tree benefits in the future.

Urban trees can be measured in two ways: 1) tree canopy cover and 2) tree inventory. Tree canopy cover is a calculated percentage based on land mapping technology. It reflects the percentage of the land that is covered by all trees in the city, both publicly and privately owned. This measurement gives a sense of the volume of canopy that exists and therefore the amount of leaf surface that is available to provide benefits. A large tree may span a 30' diameter, but a newly planted tree may span only a few feet. Similarly, trees planted close to one another will have overlapping canopies, while trees that are evenly spaced (as is the case on most boulevards) generally do not. A tree inventory, on the other hand, provides a count of the city's publicly owned trees along with their species, size, and other distinguishing characteristics gathered at the time of the inventory. Tree inventories are most useful when examining

the composition of a city's urban forest: how many trees of a certain species are among the population, or how many trees of a certain size are among the population. Tree inventories serve as a planning tool for urban foresters because an inventory allows them to manage what they have and identify areas of immediate or future vulnerability.

A complete tree canopy study was done in 2011 and is available on the city's Forestry website (City of Saint Paul, 2011). The study found that the average tree canopy cover in the city is 32.5% with a potential of 66%. It includes a forecast that 30,545 additional trees would be required to increase the total cover to 40%, and notes that the greatest potential for increased canopy is on residential, single family parcels.

In addition, Saint Paul's Forestry Unit reports that the city's tree inventory is 97% complete as of December 2014 and results are also available on the city's forestry website (Saint Paul Forestry, 2014). Ash trees now comprise approximately 18% of the city's tree inventory (Jorgensen, 2014). EAB infestations elsewhere have caused near-100% ash mortality. If this occurs in Saint Paul, we can anticipate that all ash trees, or about 1 out of 5 of the city's trees, will eventually become infested and need to be removed.

In addition to tree canopy assessments and tree inventories, urban forests can also be evaluated economically using iTree software (U.S. Forest Service). The U.S. Forest Service developed iTree to quantify and assign monetary value for the numerous benefits of urban trees. (Of relevance to this HIA, work is now in progress to develop a version of iTree to specifically measure the health impact of urban trees.) Table 2 below shows the calculated value of Saint Paul's urban forest using iTree, including a breakout of the contributions of ash trees. According to the above iTree estimations, **Saint Paul's urban forest provides $10,155,755 worth of annual benefits each year, with 25% of this or $2,546,202 provided by ash trees alone**.

Table 2: Value of Saint Paul's urban forest, highlighting contributions of ash trees

	Current Total Benefits (all trees)	Benefits generated by ash tree population**	% Total benefits generated by ash trees
District Land Area (does not include water surface area)	33,267 acres	33,267 acres	
Number of Street Trees	112,075	19,977	18%
Street Tree Canopy Area*	1,588 acres	394 acres	25%
Percentage of City Land Cover	4.8%	1.2%	
Annual Energy Reductions			
Electricity	16,762 MWh	4,100 MWh	24%
Natural Gas	2.24 million Therms	534,321 Therms	24%
Annual Economic Value	$2,811,427	$678,654	24%
Carbon Reductions			
Stored in Street Trees	358.3 million pounds	104.6 million pounds	29%
Sequestered Annually	31.2 million pounds	8.5 million pounds	27%
Avoided Annually	28.1 million pounds	6.9 million pounds	24%
Annual Economic Value	$3,131,852	$900,329	26%
Annual Removal of Air Pollutants			
Ozone	16,382 pounds	3,247 pounds	20%
Nitrogen dioxide	2,758 pounds	519 pounds	19%
Particulate matter (PM_{10})	8,745 pounds	1,738 pounds	20%
Sulfur dioxide	747 pounds	146 pounds	20%
Annual Air Pollutants Avoided			
Nitrogen dioxide	79,566 pounds	19,334 pounds	24%
Particulate matter (PM_{10})	11,621 pounds	2,833 pounds	24%
VOC's	11,088 pounds	2,705 pounds	24%
Sulfur dioxide	76,000 pounds	18,586 pounds	24%
Annual Economic Value	$562,257	$138,847	25%
Stormwater Mitigation			
Runoff reductions	124.68 million gallons	34 million gallons	27%
Annual Economic Value	$3,379,154	$922,044	27%
Aesthetic/Other Benefits			
Annual Economic Value	$2,958,287	$691,126	23%
Total Net Annual Benefit	**$10,155,755**	**$2,546,202**	**25%**

*Tree canopy as calculated by iTree. Does not include all right of way canopy cover as measured by the 2011 canopy assessment

**Figures represent the number of ash trees and associated benefits that could be affected by the emerald ash borer.

***Approximately 97% of street tree inventory data collected – December 2014

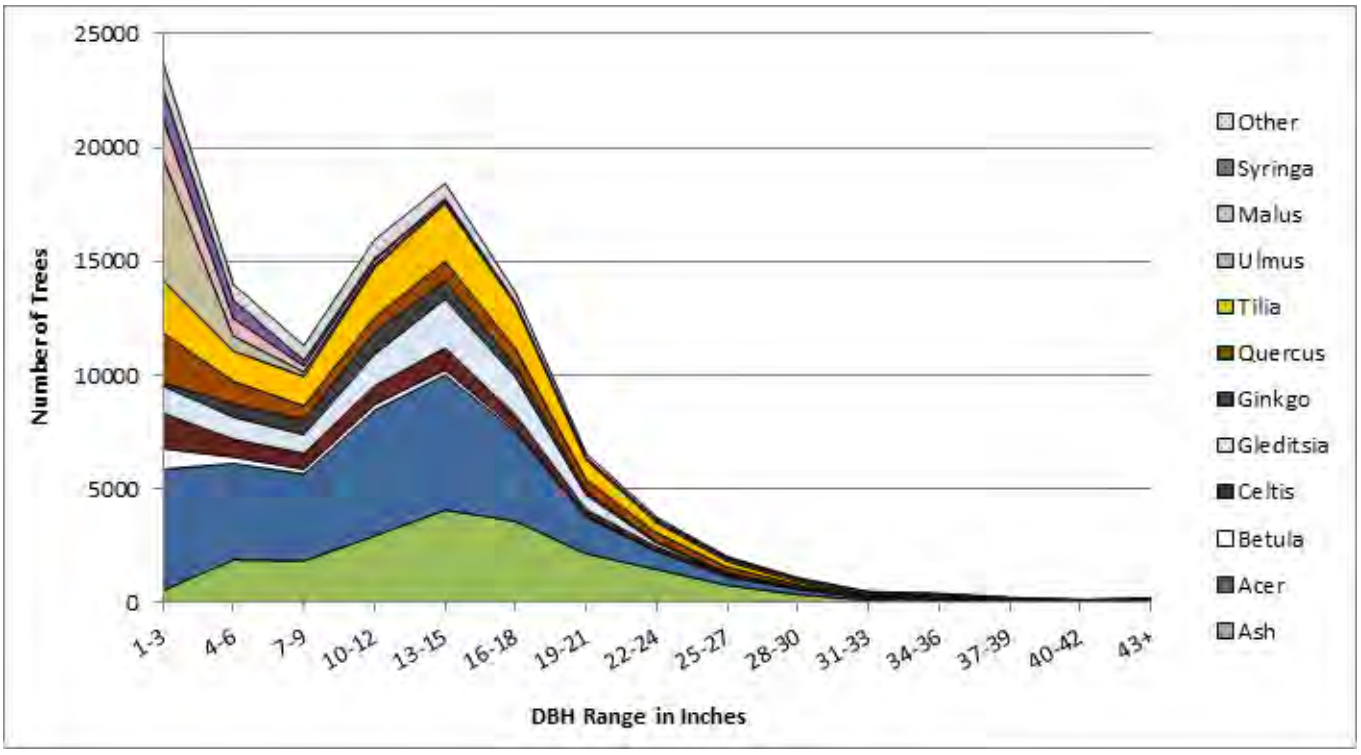
Source: City of Saint Paul iTree assessment results-street trees – City of Saint Paul Forestry

Calculations for columns 1 (current total benefits from all trees) and 2 (benefits generated by ash trees) were generated using iTree software based on real numbers of trees in the city's inventory. Column 3 is a calculation based on the first to columns and shows that although ash trees comprise only 18% of the city's inventory, they contribute 25% of the benefits. Implications of EAB are serious in terms of potential loss of all ash trees, but based on this chart, if the city loses all ash trees it will lose approximately 20% of its trees *but 25% of its tree benefits.* This assessment underscores the disproportionate contribution of ash as a single species to the total economic and environmental contributions to the community, i.e., 18% of the population contributes 25% of the benefits. In this perspective, EAB threatens the contributions of an environmental "over-achiever."

City foresters believe that the ash tree contributions are higher than average because there is an overrepresentation of ash trees among larger sized trees in the city, and larger trees contribute more. In fact, large, healthy trees can remove more than 70 times more pollution than small trees. (Get Educated - Benefits of Trees, 2012)

A recent study linked increased rates of cardiovascular death to loss of ash trees due to Emerald Ash Borer. There was an increase in mortality related to cardiovascular and lower-respiratory-tract illness in counties infested with the emerald ash borer. The magnitude of this effect was greater as infestation progressed and in counties with above-average median household income. Across the 15 states in the study area, the borer was associated with an additional 6113 deaths related to illness of the lower respiratory system, and 15,080 cardiovascular-related deaths (Donovan G. , 2013).

Figure 4: Number and size of Saint Paul public trees by species



Source: Saint Paul Forestry

The illustration in Figure 4 above shows that the majority of trees in Saint Paul are 13-15 inches diameter at breast height (DBH). Ash trees, shown at the bottom of the graph, are no exception. What is unique about ash trees is that there are many more large ash trees in the city than any other species at any size above 13-15 DBH. This explains the differential between the ash trees that represent 18% of

total trees, while the benefits provided by ash trees represent 25% of total benefits. As the US Forest Service recognizes:

> *"Compared to a small-stature tree, a strategically located large-stature tree has a bigger impact on conserving energy, mitigating an urban heat island, and cooling a parking lot. They do more to reduce stormwater run off; extend the life of streets; improve local air, soil and water quality; reduce atmospheric carbon dioxide; provide wildlife habitat; increase property values; enhance the attractiveness of a community; and promote human health and well being. And when we use large stature trees, the bottom-line benefits are multiplied. When it comes to trees, size really does matter."* (Center for Urban Forest Research, 2004)

Results in Table 2 were calculated based on Saint Paul's current tree inventory, which is 97% complete. While this chart focuses on the *economic value* of ash trees to the city, which is distinct from the purpose of this HIA (to examine the *health impacts* of losing these trees), it nevertheless presents a clear picture: **city trees offer myriad, significant and ongoing contributions to the benefit of the city, its residents and its infrastructure**. Further, two of the HIA's health pathways, *air quality* and *stormwater mitigation*, are included in Table 2, while *aesthetic and other benefits* are relevant to an additional health pathway, green space. These numbers can offer an initial sense of what ash trees do, and what stands to be lost as a result of the EAB infestation.

Saint Paul's EAB Management Plan

EAB was first discovered in Saint Paul in May 2009 and the city's original EAB Plan was written and presented to city council in June 2009. The plan presented a multifaceted approach:

- promptly remove infested trees
- proactively remove low-quality ash trees
- replace infested and low-quality ash trees with new trees of diverse species
- immunize certain high-quality ash trees with insecticide to prevent infestation
- conduct ongoing monitoring to track new infestations

While there are no universally accepted best practices of EAB management, guidance for development of EAB management plans is provided by the Minnesota DNR, Minnesota Department of Agriculture, University of Minnesota, and U.S. Forest Service (Minnesota DNR, 2013) (U.S. Forest Service) (University of Minnesota , 2009) (Minnesota Department of Agriculture, 2014). Emphasis is placed on the need to tailor the EAB response to local needs, capacity and political considerations. Although the state places the responsibility for EAB plans at the local government level, EAB experts (Venette, 2014), (Johnson, 2014) (Holman, 2014) agree that urban foresters should:

- Use an integrated strategy instead of relying on a single approach to manage EAB
- Consider options to diversify urban trees/forests
- Attempt to maximize the economic benefits of urban trees
- Consider the short- and long-term costs of any EAB management strategy (EAB management can be as much about managing finances as it is about managing insects and trees.)

The purpose of Saint Paul's EAB Plan was not only to describe an initial management approach but also to convey the significant scope of the threat and identify the budgetary and operational impacts of EAB management on Forestry resources. That year, the state of Minnesota provided $722,000 which was bolstered by $250,000 from city funds to address the outbreak. City council reviewed the plan but did not act further to endorse or support full implementation of the plan. From 2010-2014, the Forestry

budget has received approximately $1 million of funds each year dedicated to addressing EAB. While this additional funding helps the Forestry unit conduct current EAB Plan activities, this funding is not enough to cover full implementation of the plan to effectively address the crisis. This means that some current EAB plan activities go undone, while other activities proceed but utilize non-EAB funds that are meant for general forestry activities. As EAB infestations increase and the amount of resources (staff, tools, and program dollars) required to manage EAB correspondingly increases, resources from other Forestry activities will continue to be re-allocated to EAB to address these immediate and time-sensitive needs. While this may seem like a feasible short term approach, it will have long term repercussions on the health of the city's urban forest and therefore on the health of the city's residents.

For example, urban forestry best practices prescribe regular pruning of trees every five to seven years. Prior to EAB the city was already on a 10-12 year pruning cycle due to limited staff and equipment. Now that the city must address EAB, the pruning schedule has been extended to more than 13 years. At first this may seem like a cost-effective choice, but the trade-off is sizable: trees with inadequate pruning become more susceptible to damage from wind storms, street maintenance, and diseases. Pruning is but one example, and even when such cost-adjusting measures are taken, Forestry staff does not foresee having adequate resources to remove the substantial number of dead, dying, or infested ash trees that is expected in the next few years, much less while continuing to maintain the overall health of the urban forest.

Since the first version was introduced in 2009, the EAB Management Plan has been updated annually but not fully implemented due to incomplete funding. The current EAB Plan has retained the original multifaceted approach, which is modified each year based on pest pressure and geographic spread of the infestation. The current EAB Plan, revised in 2013, called for:

- monitoring activities to ensure early identification of new infestation areas
- completing and maintaining the city's tree inventory to ensure high quality data tracking and preparedness for future EAB activities as well as other urban forestry management practices
- removing aging, declining and infested ash trees (ongoing structured removal)
- replacing trees from structured removal (reforestation)
- treating a few hundred "high quality" qualifying ash trees (with pesticide)

The alternative plan would provide funding to sufficiently address EAB needs while also building the resilience of Saint Paul's urban forest as a whole. The alternative plan would provide:

- A one-time capital investment of $550,000 to purchase three additional trucks
  - Tower truck, tandem truck, and clam truck
- $1 million per year for 10 years above current funding levels to fund:
  - an additional crew (1 crew leader plus 4 staff)
  - ongoing and timely maintenance of 4000 existing trees per year
  - regular watering and other care of new/replacement trees
  - in-house capacity to respond to forestry needs
- increase in EAB funds of 1% total right of way budget per year from 2015-2020 and decreasing 1.5% per year thereafter until 2024
- $500,000 per year for subsequent 10 years (years 11-20) to fund:
  - ongoing work of the additional crew to conduct maintenance of the new/replacement trees now that they have been established
  - greater ability to address other crises that may emerge (example: gypsy moth)

- timely pruning/maintenance of existing trees
- Contingency fund of $200,000 per year to address storm damage and tree removal
  - This fund would set aside monies to be used for tree removal in the event of severe storm damage to Saint Paul's urban forest. If the fund goes unused, monies will accumulate in a fund with a maximum of $750,000. This ensures that funds allocated for EAB management, planting, and ongoing urban forest work remains dedicated to those activities and not re-allocated to managing storm aftereffects.

Table 3: Current EAB Plan vs. Alternative Plan

Plan	Total Funding/year (millions)	Activities	Ability to perform activities	Implications and other notes
Current EAB Plan	EAB $1M General Forestry Budget $3.7M Total $4.7M	Insecticide treatment of high quality ash trees	Plan is to treat and safeguard 5000 total trees from 2011-2024. Did not meet projected numbers for 2013 due to redirection of treatment crew to assist with storm damage.	Continued underfunding may reduce ability to treat 5000 trees per plan. Fewer trees will be protected and fewer benefits will be maintained.
		Remove infested ash trees	Infested trees will be removed	This is an immediate priority activity that will increase as more ash trees become infested. If budget is insufficient, dollars from elsewhere must be substituted to fulfill these needs.
		Structured removal of ash trees	Structured removal will be ongoing, contingent on availability of resources after infested trees are removed.	Eventually all right of way ash (except for ~5000 or however many are treated) will be removed
		Monitoring for new infestations	Forestry staff examine trees for signs and symptoms of infestation	Early detection is important so that infested trees can be removed and pest pressure can remain controlled.
		Ongoing management of urban forest (pruning, watering)	Greatly reduced. Pruning cycle should be every 5-7 years. Before EAB at every 10-12 years. Now at 13+ years.	Trees without regular pruning will be more susceptible to storm damage or structural failure.
		Reforestation	Replanting trees at less than 1:1 replacement ratio due to budget limitations.	Net loss in the number of trees and of tree canopy. Not all replanted trees able to survive due to limited ability to care for them.
		Contingency fund for storm cleanup	$0	Current storm cleanup plan is to redirect general forestry funds and crews away from general forestry activities and EAB management to address storm damage. Average annual storm cleanup costs are $221,000 plus implications of deferred maintenance.

Plan	Total Funding/year (millions)	Activities	Ability to perform activities	Implications and other notes
Alternative plan	· $1M current EAB Plan · $3.7M current general forestry budget · A one-time equipment investment of $550,000 · Increase in EAB funds of 1% per year of total right of way funds from 2015-2020, decreasing 1.5% per year from 2021-2024 · $1 million/year for 10 years to fund an extra crew (1 supervisor plus 4 members), boost planting efforts, address unmet needs and prepare urban forest for future · $500k for subsequent 10 years to ensure ongoing capacity	Insecticide treatment of high quality ash trees	Funds will be available to preserve the 5000 trees identified in the plan	Benefits provided by these trees will be maintained for the next 10 years.
		Remove infested ash trees	Crews are able to remove infested trees as they are identified.	These removals will take place in a timely fashion and will not take over resources otherwise directed to general forestry practices.
		Structured removal of ash trees	Structured removal takes place on pace	Crews aren't overburdened and pest pressure remains in control.
		Monitoring for new infestations	City foresters can continue monitoring for new infestations	Early detection is important so that infested trees can be removed and pest pressure can remain controlled.
		Ongoing management of urban forest	Pruning restored to 10 year cycle. Newly planted trees receive adequate water/trimming to boost establishment.	Saint Paul will have a well maintained urban forest that is resilient to future pests/storm damage
		Reforestation	Able to replant at least 2:1 ratio (two new trees for every tree removed)	Saint Paul will have a diverse and expanding urban forest that is resilient to future pests/storm damage
		Contingency fund for storm cleanup	$200,000 allocated for this fund with a roll over account established	Forestry will have sufficient funds to carry out storm cleanup activities without impacting general forestry budget or related activities.

Decision and decision alternative

This HIA analyzes the current EAB Plan and compares it with an alternative plan in order to highlight the projected human health impacts of Saint Paul's urban forest both now and into the future. A comparison of these plans can be found in Table 3. The alternative plan would provide adequate funding and staffing resources to fully implement the current EAB Plan and also ensure a thriving urban forest for years to come. This plan would allow the city's forestry department to:

- develop and implement an urban forest master plan
- boost reforestation efforts and ensure ongoing care of newly planted trees
- provide timely maintenance of established trees on a regular schedule
- nurture collaborations with other city departments and other entities (such as non-profits, state agencies, local businesses, etc.) to promote the health of Saint Paul's urban forest
- unify existing urban and community forestry efforts across the city
- engage the public with educational outreach and citizen volunteer opportunities
- address the current EAB threat at the scale that is required
- fortify both the urban forest itself and forestry staff capacity to address future diseases and pests

The above activities are considered best practices for urban forestry by the U.S. Forest Service.

Currently, the annual city budget for the Forestry unit is approximately $4.7 million. A 1% increase per year of current total right of way funds from 2015-2020 (and decreasing by 1.5% each year from 2021-2024) would add necessary capacity to implement the current EAB Plan. A one-time investment of half a million ($500,000) would be used toward the purchase of a tower truck, a tandem truck, and a clam truck. The remaining funds would provide additional staff for both EAB and regular forestry maintenance and funds to purchase new trees.

EAB and urban forestry experts participating on the HIA advisory committee suggested that this HIA examine impacts at baseline and at 10, 20, and 30 years into the future. This timeline is based on the prediction that all ash trees in Saint Paul will be infested with EAB by 2025 (Venette, 2014) (Jorgensen, 2014). All of these infested trees will (or should) be removed by 2035. Trees planted as ash replacements will begin to mature and provide substantial eco-benefits by 2045 (Johnson, 2014).

Decision-makers for Saint Paul's EAB Management Plan and comprehensive alternative include the City of Saint Paul's Department of Parks and Recreation (Forestry staff are a subdivision of Parks and Recreation and are responsible for writing and implementing the EAB Management Plan, along with overall management of the city's urban forest), City Council members and the Mayor's Office (responsible for city department budgets and operational oversight).

Projected impacts on Saint Paul's urban forest: EAB Plan vs. alternative plan

Given the level of Saint Paul's current activities, it is likely that all ash trees will become infested in the next 10 years. This is a concern because in other areas of infestation, ash mortality has followed what is known as the "death curve." (See Figure 5) This curve shows that in initial years of infestation and low pest pressure, tree mortality is low. But several years into the infestation, pest pressure builds and there is a steep increase in tree mortality over one or two seasons. This creates capacity problems for tree removal (as crews cannot keep up with the number of dead/dying trees), more costly tree removal (due to brittle wood on dead/dying ash trees creating hazardous situations for arborists and the public), and also presents a significant public hazard from standing dead ash trees and the imminent threat of total failure and/or breakage.

Figure 5: Ash tree death curve

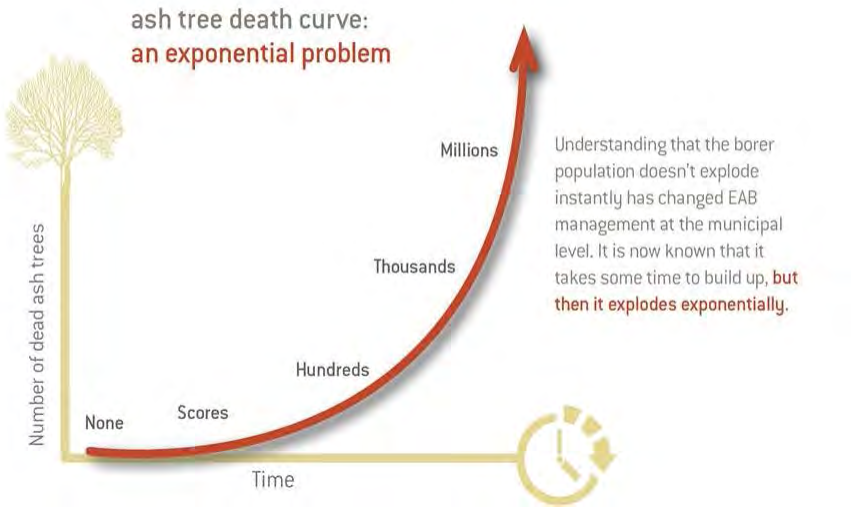


Image courtesy of Rainbow Treecare Scientific Advancements

Research also shows that when ash trees are infested with EAB, the tree becomes significantly more brittle, even in early stages of the infestation (Stone, 2014). This means that limbs from an infested ash trees pose a safety threat to people and property because they are more likely to succumb to storm and wind damage. In addition, a notch put in to fell a tree may not result in the tree falling where it is predicted, causing harm to nearby property. A standing dead ash tree can be more difficult to remove safely because it may be unsafe to climb and require heavy equipment, such as an aerial truck, and therefore cost more to remove.

Table 4: Saint Paul ash and total tree population projections

Public Trees	Baseline (2015)	10 years (2025)	20 years (2035)	30 years (2045)
# ash trees under EAB Plan	20,000	8,550 (based on average of 1145 ash removed each year for 10 years, but this number will likely be significantly lower because only 1800 ash trees will actively be immunized at this point according to pesticide treatment projections)	0	0
# total trees under EAB Plan	130,000	124,780 (based on average differential of 522 fewer trees planted than removed each year)	119,560	114,340
# ash trees under alternative plan	20,000	0 (based on assumption that all ash trees would be proactively removed and replaced)	0	0
# total trees under alternative plan	130,000	160,000 (based on average 5,000 trees planted per year, 2000 trees removed each year so net gain is 3000 trees/year)	165,000 (based on ongoing maintenance and slight increase of # trees)	170,000 (based on ongoing maintenance and slight increase of # trees)

Section 2: Health Impacts of the EAB Management Plan

Potential health impacts of EAB and selection of health determinants

The project's advisory committee began the process of identifying the potential health impacts of EAB by developing a list of the benefits provided by urban forests. The group also considered any unique contributions of ash trees specifically in the context of health benefits, and found none. The list of benefits was winnowed to focus on benefits with a direct link to human health, and resulted in the five health impacts discussed in this report: air quality, water quality, insecticide use, green space, and urban heat island. Pathway diagrams for each of these five health impacts are included in the assessment section of this HIA. The group committed to pursuing all five of these health impacts in order to best tell the story of the contributions of the urban forest to health. While certain populations are particularly affected by changes in air quality or temperature, for example, **the services provided by trees are beneficial to every resident of Saint Paul.**

Other important benefits were noted: urban forests boost property values (Kirkland, November 2011) (Arbor Day Foundation) (Wells G. , 2010) (Wolf K. , 2007), provide energy savings (Arbor Day Foundation, 2014) (Alliance for Community Trees) (Pandit, 2010), and build climate resilience and store carbon (U.S. Department of the Interior, U.S. Geological Survey, 2014) (Nowak D. J., 2013) (Cullington, 2010). Several research studies also credit urban forests with reducing crime rates (Kirkland, November 2011; Austin Troy, 2012; Donovan G. H., The effect of trees on crime in Portland, Oregon, 2012; Branas CC, 2011) and addressing urban blight (Reel, 2014) (Kaplan M. E., 2003) (Kuo F. , The Role of Arboriculture in a Healthy Social Ecology, 2003).

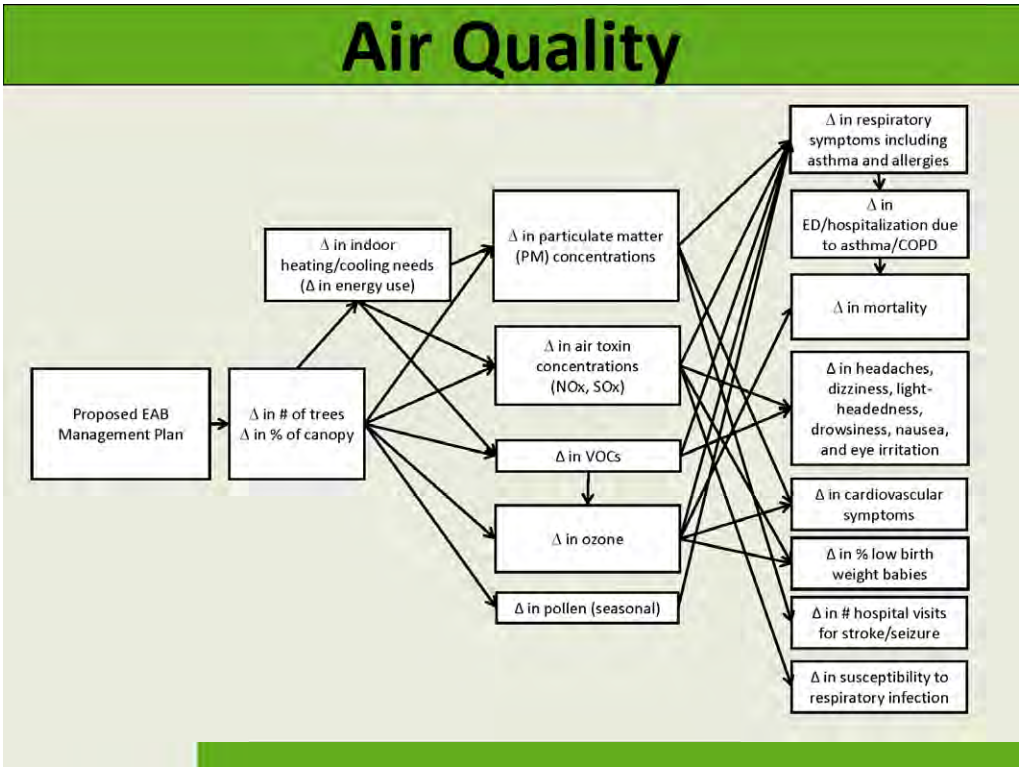
These predictions, this HIA, and Saint Paul's EAB Management Plan are limited to the public ash trees in Saint Paul, which are located either in maintained park areas or on boulevard right-of-ways. Ash trees located on private property or in wild growth park areas, such as along the Mississippi River are excluded from the scope of this report because they are not addressed in the EAB Plan. But since EAB does not know or care whether an ash tree belongs to the city or a homeowner when it infests a tree, the privately owned trees are an important part of the EAB story in Saint Paul (and elsewhere) because they are equally vulnerable to infestation but perhaps less likely to be closely monitored to detect EAB. While this HIA is focused on public trees, it is important to recognize that 1) there are approximately equal numbers of private trees and public trees in Saint Paul, 2) ALL trees provide benefits for air, water, green space, and temperature mitigation, 3) privately owned ash trees are also susceptible to EAB. Insecticide treatment of privately owned trees is discussed in Appendix 2.

Assessment

Health Impact 1: Air Quality

The health pathway for air quality in this HIA is shown in Figure 6.

Figure 6: Air Quality health pathway



Baseline air quality in Saint Paul

Air quality in Saint Paul is monitored and modeled by the MPCA, which measures ambient air in 53 locations across the state, five of which are located in Saint Paul. Data from these monitors indicate that air quality in the Twin Cities has steadily improved from 2003 to 2013 (Minnesota Pollution Control Agency, 2013). Saint Paul falls approximately in the middle of national rankings: out of 277 United States cities, the Twin Cities metro area was ranked 147th for high ozone days, 55th for 24-hour particle pollution, and 110th for annual particle pollution (Minnesota Pollution Control Agency, 2013). In 2013, Saint Paul had about as many moderate air quality index (AQI) days as good AQI days, with 179 moderate and 182 good days. There were zero days when air quality was deemed unhealthy for sensitive groups. Air is constantly moving, so while air monitors provide an indication of air quality at a specific place over a specific time, they cannot identify the sources of the pollutant(s), nor their distribution.

How trees affect air quality

According to a 2010 USDA Forest Service study, urban trees in Minnesota provide over $138 million worth of air quality services each year (Nowak, 2010). Across the nation, trees remove 17.4 tons of air pollution annually, a number that is estimated to be worth $86 billion, with human health benefit effects at $6.8 billion (Nowak D. J., 2014). The primary method by which trees remove gaseous pollution

is by uptake through leaf stomata and incorporation into intracellular space. Of the six criteria pollutants listed by the EPA: ozone, NO_2 (NO_x), SO_2, $PM_{2.5}$ and PM_{10}, and lead; stomata are most effective in the removal of NO_2, ozone, and SO_2. Trees also reduce carbon dioxide through uptake into stomata, and can impact percentages of particulate matter in the air by intercepting particulate matter on leaf surfaces. However, particulate matter can then be re-suspended by air currents, or washed off of leaf surfaces in rains, potentially impacting water quality (Nowak D. J., 2014).

Trees impact air quality by:

- Producing oxygen
- Releasing pollen (a seasonal allergen)
- Removing fine pollutant particles from the air by capturing them with tiny hairs on their leaves
- Mitigating carbon in the atmosphere by uptake into roots and tissues
- Emitting small amounts of organic volatile organic compounds (VOCs). (Either organic or non-organic VOCs must be present for the formation of ozone.)
- Altering wind flow patterns and the movement of pollutants
- Reduce ozone production by providing cooling effects both through shading and through evapotranspiration. (These are further discussed in Section 5: Urban Heat Island effect.)

How air quality affects health

Asthma and COPD are two major illnesses that directly impact lung function and overall health and thereby cause vulnerability to outdoor pollution. There are approximately 228,230 reported individuals with adult asthma, 80,160 individuals with pediatric asthma, and 118,842 individuals with COPD in the Twin Cities metro area (American Lung Association, 2013). Children and teens are a high-risk group, as higher levels of outdoor, physical activity, and immature lungs are more likely to develop infections like bronchitis after exposure to air pollution. Those over age 65 are also more likely to be vulnerable to low air quality, as aging bodies are more susceptible to respiratory and cardiovascular issues. In the Twin Cities metro area, there are 915,703 children and teens under 18, and 441,001 people over 65. (American Lung Association, 2013)

Preexisting conditions of cardiovascular disease or diabetes, two conditions with high comorbidity, can be dangerous when combined with air pollution. Exposure to low quality air can increase the risk of heart attack and stroke, and increase the frequency of hospital and emergency room admissions. Cardiovascular disease and respiratory illness are the two most common causes of death in America, respectively. 187,298 people with cardiovascular disease and 198,953 people with diabetes reportedly live in the Twin Cities area, of which there is some expected overlap due to co-occurrence. (American Lung Association, 2013)

Low income populations are another inequitably impacted population, as low cost housing is often more likely to be located near major sources of pollution, including highways. There is also a higher frequency of health conditions including cardiovascular conditions in populations defined by the U.S. as living below the poverty line. In Saint Paul, there are 22.8% or 67,231 individuals currently living in poverty (Table 1). Within all of the vulnerable populations listed, there is expected overlap. This creates particularly vulnerable populations, but decreases the total number of people who fall into a broader category of "inequitably impacted populations" (American Lung Association, 2013).

Saint Paul is home to 4 hospitals: Regions, United, Children's of St. Paul, and St. Joseph's, all of which are 501(c)(3) nonprofit organizations. Under the Affordable Care Act (ACA), Section 501(r), 501(c)(3) organizations operating more than one hospital are required to conduct a community health needs

assessment (CHNA) at least once every three years, and to create an implementation strategy (Centers for Disease Control and Prevention, 2013). In all four of the hospitals' CHNAs conducted during 2012-2013, asthma was ranked as a primary health concern (Allina Health, 2012) (Regions Hospital, 2013) (Verite Healthcare Consulting, LLC, 2013) (Wilder Research, 2012). While not all asthma can be attributed to environmental causes (for example, some asthma is exercise-induced), poor air quality can seriously affect individuals who are sensitive to air contaminants (U.S. Environmental Protection Agency, 2014) (Centers for Disease Control and Prevention, 2014).

This HIA focuses on several of the most pervasive and commonly acknowledged air pollutants that affect human health. A brief discussion on NO_x, SO_x, $PM_{2.5}$, and ozone is presented here.

Nitrogen oxides (NO_x)

Nitrogen oxides include a variety of gaseous compounds comprised of nitrogen and oxygen. These gases are formed when fossil fuels are burned. Common sources of NO_x include vehicle emissions and power plants, so individuals living and/or working near high traffic roadways and industrial areas have the greatest exposure. These individuals are the most at risk for NO_x-related health issues, which include (American Lung Association):

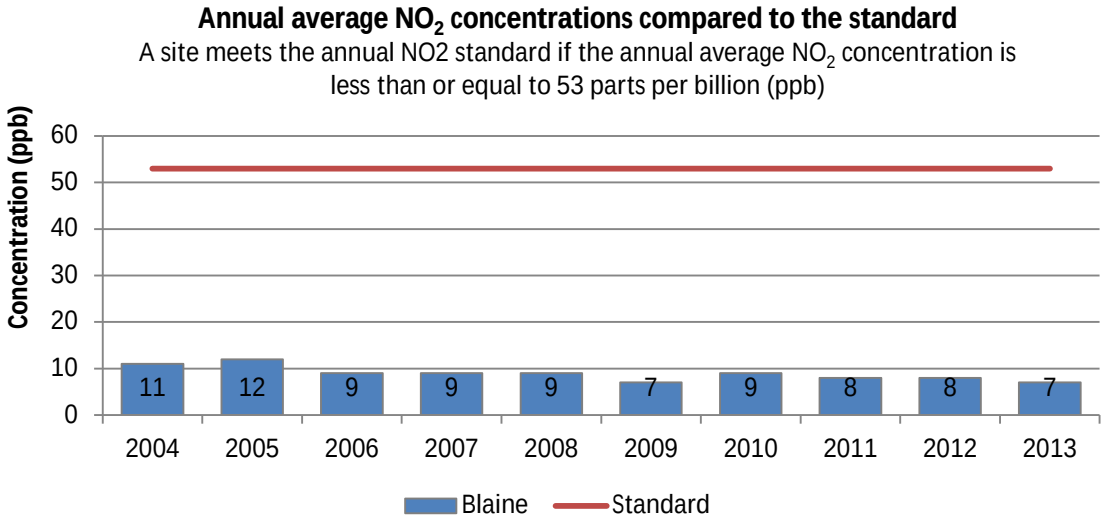
- Increased inflammation of the airways
- Worsened cough and wheezing
- Reduced lung function
- Increased asthma attacks
- Greater likelihood of emergency department and hospital admissions
- Increased susceptibility to respiratory infection, such as influenza

Even brief exposure to NO_x can affect a person's health. Current scientific evidence links short-term NO_2 exposures, ranging from 30 minutes to 24 hours, with an array of adverse respiratory effects including increased asthma symptoms, more difficulty controlling asthma, and an increase in respiratory illnesses and symptoms (U.S. Environmental Protection Agency, 2012). Due to increasingly stringent federal standards, the ambient levels of NO_x have been falling over time.

A recent study shows that levels of nitrogen dioxide are higher in non-white communities than in white communities, a finding that was true across income levels and across multiple urban areas in the United States. (Clark, 2014) This inequity is correlated to high traffic corridors and presents an environmental justice and health equity issue. One possible avenue to address the inequitable impacts of roadside pollution is the use of near-road vegetation. The idea is to strategically plant trees and other vegetative matter in a location such that the pollution coming off the road will be intercepted by the green space as it travels toward residential zones. Emerging research shows that this approach is effective in capturing up to 50 to 60% of emitted pollutants (Steffens, Wang, & Zhang, 2012) (Isakov, 2014) (Steffens J. , 2011). This could be an effective localized way to increase tree canopy and optimize benefits provided by urban trees.

Local readings of NO_x over the past 10 years from 2004-2013 are in the chart below. The closest air monitor to Saint Paul is in Blaine, MN (30 miles from Saint Paul). MPCA air quality professionals indicate that these measures are a reasonable proxy for the nitrogen dioxide levels in Saint Paul, which fall well below the national standard as identified by the U.S. Environmental Protection Agency.

Figure 7: Annual average NO_2 concentrations compared to the standard

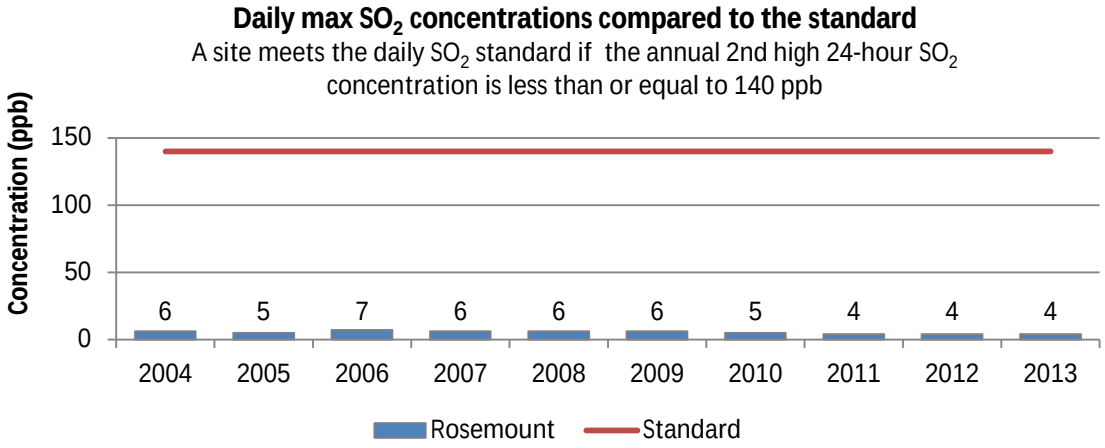


Source: (Minnesota Pollution Control Agency, 2013)

Sulfur Oxides (SO_x)

Sulfur oxides are a group of gaseous compounds. The most common source of SO_x is from burning fossil fuels at power plants. Sulfur dioxide is known to cause bronchoconstriction and increased symptoms of asthma (U.S. Environmental Protection Agency, 2012) (Linn, 1987). Sulfur dioxide is also correlated with increases in hospital and emergency room visits for stroke and seizure (Szyszkowicz, 2012) and low birth weight babies (Rogers, 1999). It has been associated with cardiovascular disruption in animal studies (Woerman & Mendelowitz, 2013). A study performed in Milan, Italy, over nine years found a positive association between daily SO_2 concentration and number of deaths and hospital admissions for respiratory causes in the city. On top of this, PM concentration combined with SO_2 and total suspended particulates (TSP) concentration correlated with higher mortality rates among the elderly. This study confirmed similar findings in other European cities (Vigotti, 1996). Local measurements of SO_x are found in Figure 8. The closest air monitor is located in Rosemount, MN (21.5 miles away). MPCA air quality professionals indicate that these measures are a reasonable proxy for Saint Paul's sulfur dioxide readings, which all fall below the standard.

Figure 8: Daily max SO_2 concentrations compared to the standard



Source: (Minnesota Pollution Control Agency, 2013)

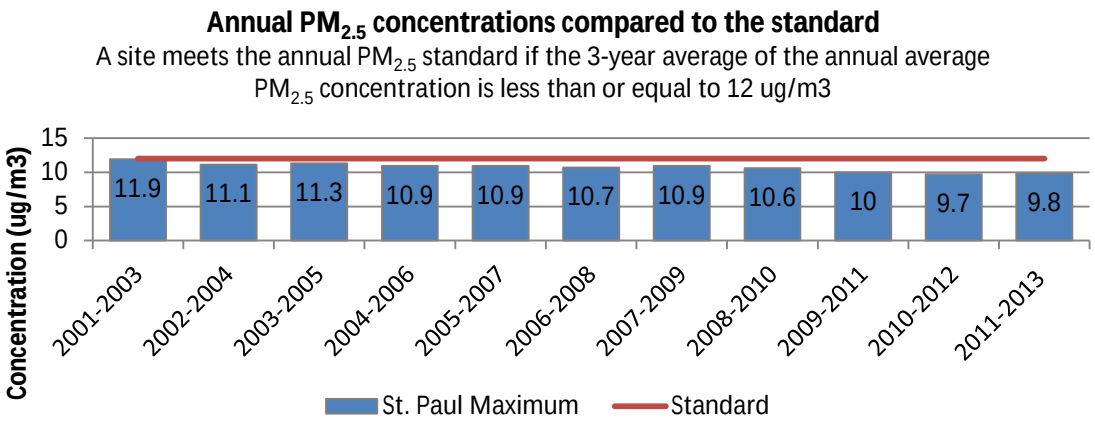
Particulate Matter (PM)

Particulate matter or PM is also known as particle pollution. These particles are small and light enough to be airborne and therefore pose a threat to human health by being inhalable. PM is classified by size, usually subcategorized as PM_{10} and $PM_{2.5}$. $PM_{2.5}$ or "fine particles" refers to particles that are smaller than 2.5 micrometers. PM is small enough that particles can make their way into lungs and even into the bloodstream. Numerous scientific studies have linked particle pollution exposure to a variety of problems (Zanobetti, 2001) (National Research Council, 2004) (Pearson JF, 2010) (Lepule, 2012), including:

- premature death in people with heart or lung disease
- nonfatal heart attacks
- irregular heartbeat
- aggravated asthma
- decreased lung function and
- increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing

$PM_{2.5}$ and PM_{10} pose a risk to human health, especially in people with asthma, preexisting heart conditions, or diabetes (Zanobetti, 2001) (National Research Council, 2004) (Pearson JF, 2010) (Lepule, 2012). People with heart or lung diseases, children and older adults are the most likely to be affected by particle pollution exposure. However, even healthy people may experience temporary symptoms from exposure to elevated levels of particle pollution. Reduced ambient PM measures are even associated with increase in life expectancy (Correia, 2013) (Caiazzo, 2013). PM measures for Saint Paul for 2001-2011 are presented in Figure 9, and fall within the national standard.

Figure 9: Annual $PM_{2.5}$ concentrations compared to the standard



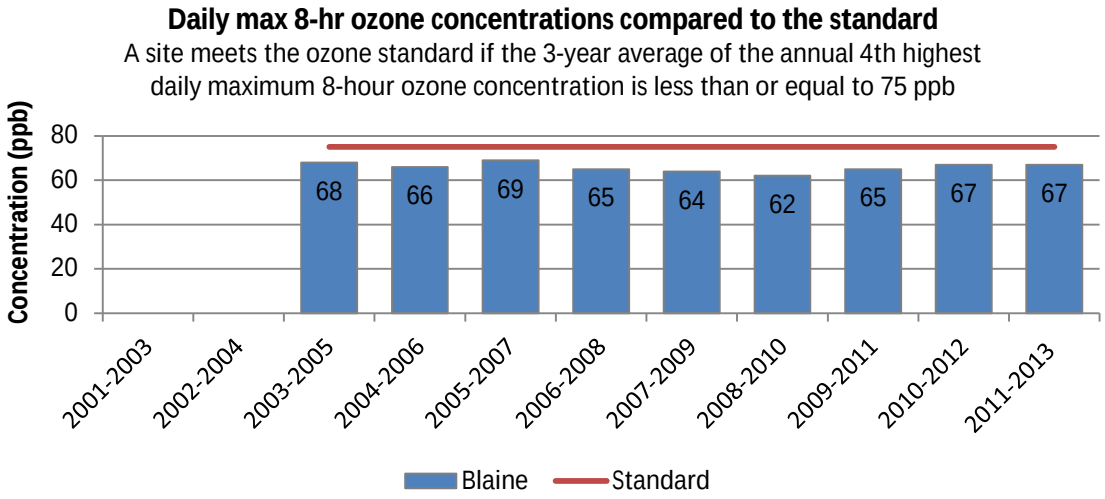
Source: (Minnesota Pollution Control Agency, 2013)

Ozone

Ozone is a special case because of its impacts on human health. There are significant immediate results of ozone exposure, ranging from premature death; shortness of breath and chest pain; wheezing and coughing; inflammation of the lining of the lungs; increased susceptibility to respiratory infections; increased risk of asthma attacks; and increased need for medical treatment and hospitalization for people with lung diseases, including asthma or chronic obstructive pulmonary disease (COPD) (American Lung Association, 2013). Yet the impacts of ozone stretch beyond immediate health impacts. Children exposed to ozone early in life are more likely to be admitted into hospitals if they have experienced chronic ozone exposure; infants are more likely to be of low birth and decreased lung function if mothers were chronically exposed (Lin, 2008) (Islam, 2009) (Salam, 2005) (Morello-Frosch, 2010) (Hansen, 2008) (Mannes, 2005). It may be possible that decreased lung function in exposed children mature may create a positive feedback leading to increased ozone sensitivity and respiratory disease later in life.

Local ozone measures for the past nine years are indicated in Figure 10. The closest ozone monitor to Saint Paul is located in Blaine, MN (20 miles away). Air monitoring professionals at the MPCA indicate that these measures are a reasonable proxy for ozone measurements in Saint Paul. These data from 2003-2013 indicate that local ozone falls within the standard.

Figure 10: Daily max 8-hr ozone concentrations compared to the standard



Source: (Minnesota Pollution Control Agency, 2013)

Table 5: Projected impacts of the current EAB Plan on air quality and health

What does the evidence say about how the decision will impact health through pathways?							
Health Determinant (Air Quality)	**Positive or negative health effect of current EAB Plan (direction)**	**Positive or negative health effect of alternative plan (direction)**	**Likelihood of impact (likelihood)**	**How strong is the health impact? (magnitude)**	**Who will be impacted? (distribution)**	**Strength of evidence supporting impact on health (strength of evidence)**	**Uncertainties and contextual comments**
Change in particulate matter concentrations	-	=/+	Likely	Moderate	Everyone, but especially individuals with asthma and other respiratory conditions	Very strong	
Change in NO_x and SO_x	-	=/+	Likely	Moderate		Very strong	
Change in VOCs	-	=/+	Likely	Moderate		Very strong	Trees do emit some VOCs but it is generally agreed that their overall effect is positive.
Change in ozone	-	=/+	Very likely	Moderate	Everyone	Very strong	

Legend
Direction: positive(+), negative (-), mixed (+/-), unable to assess (?)
Likelihood: very likely, likely, possible, unlikely, uncertain
Magnitude: low (<500), moderate (500-1,000), high (>10,000)
Severity: low (transient/minimal health symptoms), moderate (chronic/more severe transient health symptoms), high (severe chronic symptoms or death)
Distribution: population most likely to be affected by the changes due to tree canopy change
Strength of Evidence: very strong (strong, quality evidence base), strong (strong evidence base with some conflicting evidence but generally supporting the pathway), fair (moderate strength/quality evidence base with conflicting evidence but majority supports pathway), weak (little evidence that is of moderate or weak quality), none (no evidence)

Under the current EAB Plan, the number of trees in Saint Paul will be reduced, and result in a corresponding reduction in beneficial health effects. Based on the literature reviewed and guidance from subject matter experts, fewer trees will mean less absorption of air pollutants (particulate matter, NO_x, SO_x, VOCs). Fewer trees will also mean a likelihood of more ozone production due to reduced temperature mitigation and increased amounts of VOCs. Fewer trees will result in poorer air quality. Poorer air quality will result in poorer health, both in terms of increased risk to vulnerable populations and increased impact to general populations.

With the alternative plan, trees that are lost will be replaced between 2015-2025 and additional trees will be replanted (2 trees planted for every 1 removed). While this means an increase in the total number of trees, there will be a temporary decrease in the canopy cover because even two small trees will require years of growth in order to replace one large tree in terms of canopy. In twenty to thirty years, the urban forest canopy will be restored to 2014 conditions or even increase, dependent on ongoing funding to ensure timely maintenance of trees as well as the potential effects of other invasives and diseases. As a result, the capacity of the urban forest to mitigate air pollutants (particulate matter, NO_x, SO_x, VOCs, and ozone) will be maintained or increase. This will result in a no impact (equal canopy) or positive increase (more canopy) in health effects.

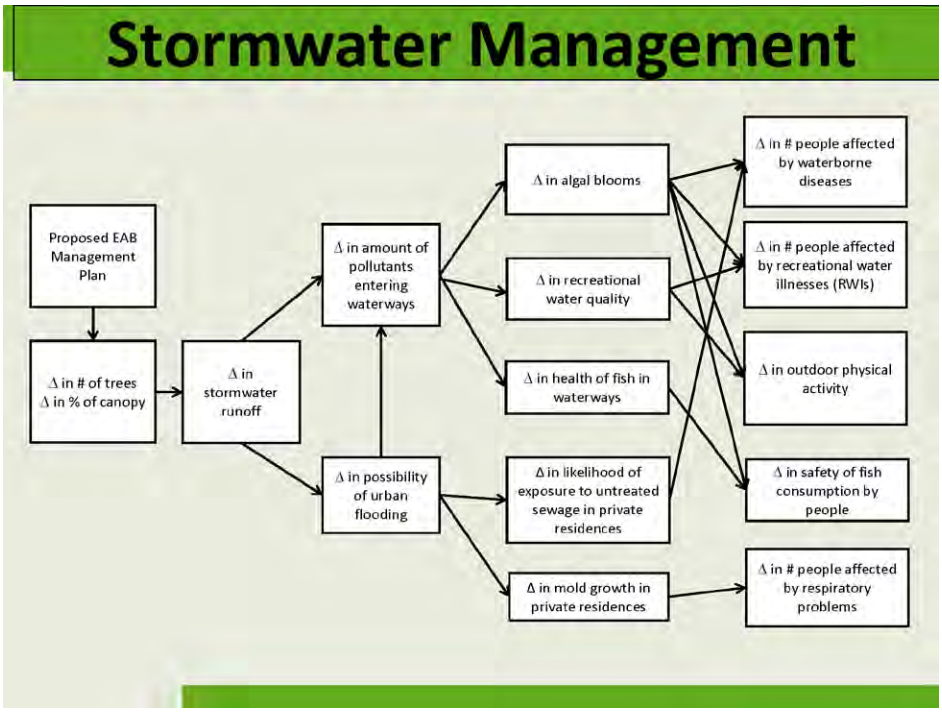
Recommendations

1. Saint Paul Forestry works with Saint Paul-Ramsey Public Health and Saint Paul Mayor's Office to identify target neighborhoods where increased tree presence would be especially beneficial, based on:
   - existing tree canopy percentage
   - expected loss of ash trees (some neighborhoods will be more impacted than others)
   - population of vulnerable individuals (% under age 5 and above age 65)
   - proximity to sources of air pollution (industry, high traffic corridors)
2. Saint Paul Forestry partners with MnDOT and community groups to conduct a near-road vegetation project. The goal of this project would be to demonstrate the feasibility and effectiveness of near-road vegetation to serve as a physical barrier between sources of airborne pollutants and nearby housing.

Health Impact 2: Stormwater Management

The health pathway for stormwater management in this HIA is shown in Figure 11.

Figure 11: Stormwater Management health pathway



Cities must work to ensure water quality across different stages of the water cycle, often organizing water jurisdiction with the following categories:

Stormwater: excess precipitation not absorbed into the soil that is relocated via a formal or informal drainage system

Surface water: lakes, rivers, and streams that support aquatic life and/or recreation

Groundwater: the water table, located beneath the ground and fed by underground sources

Drinking water: water piped into homes and businesses for everyday use

While these forms of water are interrelated, trees have the biggest potential health impact on stormwater. *Stormwater* is water that originates from precipitation events, such as rain or snowfall. *Stormwater runoff* is water from rain or melting snow that "runs off" across the land instead of seeping into the ground. Oftentimes this runoff accumulates dissolved or solid matter as it washes off driveways, parking lots, roads yards, rooftops, and other hard surfaces as it ultimately travels to the Mississippi River (in the case of Saint Paul). Projected health impacts of the current EAB Plan and alternative plan on surface water, groundwater and drinking water are discussed in the Insecticide Use section.

Baseline condition and management of stormwater in Saint Paul

Saint Paul has a strong legacy of progressive stormwater management, based in part on the significant presence of water in the city (most notably the Mississippi River, Lake Phalen, and Como Lake, pictured in Figure 2) and residents' ongoing recognition of the importance of those waters in providing recreational and wildlife opportunities. A recent survey of Saint Paul residents showed that they overwhelmingly want to protect and preserve water resources. (Capitol Region Watershed District, 2012)

Over time, Saint Paul has developed and maintained an approach to stormwater that is focused not only on the stormwater infrastructure itself but also on its impact to the environment. Years ago, stormwater and sewer management systems were linked, but in the 1980s and 1990s, a $217 million dollar investment of combined federal, state and city dollars created fully separate systems. (Roger Puchreiter, 1996) The next hurdle was to address areas prone to flooding during weather events, and as part of the $217 million storm/sewer separation program, the city constructed fourteen storm water ponds, which provide critical detention and flood relief during major rain events. The city has also taken on need-based neighborhood-specific projects, such as the Hillcrest Knoll area on the east side of the city. After a major flood in 1997, to solve the recurring flooding issues, homes were moved off a two block area and a stormwater detention basin was designed to function as a park. Features include trails, pergola, sitting areas, lighting, and substantial plantings involving many oak trees and two acres of native shortgrass prairie. In 2012 the area was further updated to incorporate a large multipurpose "green infrastructure" system, allowing stormwater to percolate into the subsurface soil, promoting groundwater recharge. During the past decade, the focus has been largely on improving runoff water quality (Saunders-Pearce, 2014).

This "infrastructure and impact to the environment" approach continues to evolve with ongoing developments in best practices. Storm sewers have historically been the traditional method of managing stormwater, by capturing runoff from rain events and spring melt and directing it off streets. Now, stormwater experts recognize the importance and enduring value of incorporating natural elements such as trees, bioswales, and rain gardens (Center for Watershed Protection and US Forest Service , 2008). These features not only provide ecosystem services but also provide a way to include natural beauty and living things in an urban landscape.

The city seeks opportunities for pursuing innovative practices, as they continue to encourage developers to do the same. This takes place through a variety of mechanisms (Saunders-Pearce, 2014):

1. Developments are reviewed by the city's Site Plan Committee. This is a formal meeting and site plan designs are discussed with the developer and/or engineer. In this forum staff can encourage projects to consider innovation in stormwater design including green roofs, integrated tree trench designs, etc.
2. Saint Paul has a Sustainable Building Policy for projects receiving public funds (current policy is $200,000 or more in public funds). The policy requires stringent stormwater practices and as such provides an opportunity to encourage and integrate innovative practices.
3. Saint Paul has an annual Sustainable Saint Paul award competition. This award recognizes exemplary projects which have gone above and beyond minimum standards for stormwater. The city encourages developers to consider, and apply for, this award as a means to incentivize innovation.
4. Key projects are invited to share preliminary development concepts with the St. Paul Design Center (SPDC) project team (http://www.riverfrontcorporation.com/what-we-do/what-we-do-tools-resources-v2/) which includes the Central Corridor Design Center established in 2007 under the SPDC.

Currently, the City of Saint Paul has several demonstration projects in process. These projects include permeable alleys and parking lots, green roofs, rainwater harvesting and reuse such as for the Lowertown ballfield, and perhaps most notably the integrated tree trench system along the Green Line light rail which captures stormwater for use by over 1,000 street trees. (Saunders-Pearce, 2014)

Stormwater and health

One avenue by which human health is impacted by stormwater is through residential flooding events. Stormwater that is improperly or inadequately managed can cause flooding, which can lead to costly economic and health impacts, including water damage to homes, buildings and city infrastructure, mold,

bacteria growth, disrupted services and transportation modes, and additional stress. Excess stormwater runoff that does not drain, even without flooding, can cause exposure to harmful bacteria including cryptosporidium which causes gastrointestinal distress (Gaffield, 2003) While this parasite can be spread in several different ways, water (drinking water and recreational water) is the most common method of transmission. People most susceptible to cryptosporidium include small children, childcare professionals, travelers with exposure to potentially unsafe water for drinking or swimming, and people who use contaminated water sources (rivers, lakes, streams.) *Cryptosporidium* is one of the most frequent causes of waterborne disease among humans in the United States. (Centers for Disease Control and Prevention, 2013). Tainted stormwater eventually makes its way to surface water, where it can also result in swimmers itch (a parasite that enters the skin, causing an itchy rash) (Centers for Disease Control and Prevention, 2014) and algal blooms (nutrient overload in surface water, which can produce dangerous toxins) (U.S. Environmental Protection Agency, 2014).

In some cities, when systems are overloaded, stormwater and sewage management infrastructure can overflow into one another, becoming intermingled. This may impact surface water, water present on streets and in or near homes, and the safety of water for swimming and recreating. Saint Paul has separate storm and sewer management systems, so this is not an issue. Unlike many larger cities that are utilizing green infrastructure primarily as a means to address combined storm/sewer overflow while acknowledging numerous other co-benefits, Saint Paul's use of green infrastructure enhanced the city's health, resiliency, and livability.

Stormwater runoff has the potential to greatly impact the health of the Mississippi River, and therefore on Saint Paul's drinking water and recreation. Runoff is filtered by catch basins before it is deposited into the Mississippi River, but this filtration captures only large objects (leaves, tennis balls, sticks, etc.) and does not address any soil particles or dissolved chemicals that may be carried by the runoff. Although they are more likely to be found in waste/sanitary streams, it is also possible that other pollutants, such as endocrine disrupters, may find their way into runoff. Stormwater is not currently monitored for these pollutants, which if present could impact human health directly (through stormwater's eventual path to drinking water) and indirectly (through potential use of water to grow food.)

Stormwater in Saint Paul also has literal downstream impacts on human health because of the city's northern position relative to the current of the Mississippi River. Pollution originating in Saint Paul has the potential to move downriver through the United States, impacting waters all the way to the Gulf Coast. In the 1930's, the Mississippi was described as having floating islands of sewage solids, scum on the water surface, and an abundance of dead fish. Typhoid fever outbreaks were frequent because of a contaminated water supply. (City of Minneapolis, 2012) Although practices have changed since then, the city's proximity to the river means that potential downstream effects should always be considered.

Stormwater can seriously impact human health because it carries potential pollutants to other waters that eventually become surface water, ground water and drinking water. Studies have shown that stormwater runoff management is the most impactful public health practice at the least cost, and concluded, "The estimated annual cost of waterborne illness is comparable to the long-term capital investment needed for improved drinking water treatment and stormwater management." (Gaffield, 2003)

Impact of trees on stormwater

> *"Tree planting policies have been justified on the financial benefits associated with their stormwater management function alone, notwithstanding the broader spectrum of benefits they provide within the urban environment." (Stovein, 2008)*

Though trees represent just one part of a stormwater management plan, the numerous benefits that trees provide may have such a high monetary value that they return the money invested in their planting in stormwater runoff reductions alone (Bartens, 2009). Trees improve soil absorption as their roots and the root plate area aerates the soil and allows for faster and greater rates of permeability during rainfall. Through evapotranspiration, water vapor evaporates from leaf surfaces during normal tree respiration process and transfers water from the soil into the air. Trees intercept rain with their leaves, thereby decreasing the velocity of the water and increasing the likelihood that the water will permeate the ground. All of these tree-provided ecosystem services are effective at treating stormwater runoff, so cities should ensure that resources and land are allocated for their planting (Bartens, 2009) (Center for Watershed Protection and US Forest Service , 2008).

While trees have long been informally acknowledged for these contributions, in early 2014 the MPCA issued its revised online Stormwater Manual (Minnesota Pollution Control Agency, 2014), which includes the nation's first provision systematically accounting for trees as part of an integrated stormwater management plan. (Root, 2014) The manual includes an online calculator that allows a city or jurisdiction to calculate the impact of various components of their stormwater management activities, including a per-tree benefit calculator. This allows Saint Paul and other cities to incorporate trees into their stormwater management systems, and perhaps more importantly, use stormwater funds for tree planting, maintenance, and ongoing management.

Ash trees mitigate a significant portion of stormwater taken up by trees in Saint Paul. In the West Side neighborhood for example, of 8,849,329 gallons of stormwater taken up by trees, 2,470,844 gallons are accounted for by ash trees, making up a significant 28% of stormwater mitigated by trees in this area alone (Saint Paul Forestry Unit, 2011). As mentioned in the Introduction, ash trees account for 18% of the trees in Saint Paul, but contribute 27% of the stormwater mitigation benefits (Jorgensen, 2014). This is likely due to their over representation in addition to mature age and size relative to the other trees in the city. While this is currently beneficial, it is important for city foresters to plan for species and size diversity so that in the future, a species-specific loss will not result in a disproportionate loss of benefits as well.

Tree canopy serves three important roles during rainfall: 1) it intercepts the raindrops, slowing the velocity of rain as it hits the ground and increasing the likelihood of it permeating the soil instead of running off, 2) root systems absorb water in soil, creating empty spaces in the soil to capture the next rainfall, and 3) trees evapotranspirate water from the ground back into the air (Center for Watershed Protection and US Forest Service , 2008) A well-watered tree can evapotranspirate up to 40,000 gallons of water per year (US Geological Survey, 2014) so Saint Paul's ash trees have the capacity of evapotranspirating millions of gallons each year. Finally, tree roots increase the permeability of the soil beneath a tree through aeration, allowing water to more easily absorb into the ground instead of running off.

In addition to their positive contributions to stormwater management, trees can also contribute pollutants. In particular, seasonal leaf drop can contribute to significant phosphorus loads in stormwater runoff, leading to algal blooms and other negative effects on surface water and aquatic life. A recent street sweeping study was conducted in Prior Lake, MN (33 miles from Saint Paul). Findings from the study showed that street sweeping can successfully be timed to minimize leaf litter in runoff and thereby mitigate the risks by preventing leaves from entering the stormwater system. (Kalinosky, 2012)

Table 6: Projected impact of current EAB Plan on stormwater management and health

What does the evidence say about how the decision will impact health through pathways?							
Health Determinant (Stormwater)	**Positive or negative health effect of current EAB Plan scenario (direction)**	**Positive or negative health effect of new Scenario (direction)**	**Likelihood of impact (likelihood)**	**How strong is the health impact? (severity)**	**Who will be impacted? (distribution)**	**Strength of evidence supporting impact on health**	**Uncertainties and contextual comments**
Change in possibility of urban flooding	-	+	Likely	Moderate	Everyone	Very strong	
Change in pollutants entering waterways	-	+	Very Likely	Moderate		Very strong	
Change in soil moisture and groundwater recharge	-	+	Very Likely	Moderate		Very strong	

Legend
Direction: positive(+), negative (-), mixed (+/-), unable to assess (?)
Likelihood: very likely, likely, possible, unlikely, uncertain
Magnitude: low (<500), moderate (500-1,000), high (>10,000)
Severity: low (transient/minimal health symptoms), moderate (chronic/more severe transient health symptoms), high (severe chronic symptoms or death)
Distribution: population most likely to be affected by the changes due to tree canopy change
Strength of Evidence: very strong (strong, quality evidence base), strong (strong evidence base with some conflicting evidence but generally supporting the pathway), fair (moderate strength/quality evidence base with conflicting evidence but majority supports pathway), weak (little evidence that is of moderate or weak quality), none (no evidence)

Projected health impacts on stormwater management

Under the current EAB Plan, the number of trees will be reduced. This will result in more stormwater runoff (less absorption into the soil) and consequently increased likelihood of urban flooding, increased amounts of pollutants entering waterways, and reduced soil moisture and groundwater recharge. There will be associated negative impacts on human health due to increased possibility of urban flooding and increased numbers of pollutants entering waterways. There will be an associated reduction in soil moisture and groundwater recharge, which has an indirect and long-term effect on human health. Reduced soil moisture and increased runoff results in less healthy soil, which impacts the growth of trees and other green infrastructure and reduces their contributions to health and the environment. Reduced groundwater recharge could impact drinking water supply and general availability of water resources.

Under the alternative plan, the number of trees will be maintained or increase slightly. This will result in maintaining existing levels or a slight increase in the benefits provided by trees for stormwater management. Reduced urban flooding means fewer health issues related to mold and stress. Reduced pollutants entering waterways means cleaner water for recreation, drinking water, and fish consumption. Better soil moisture means healthier trees and plants, which can continue to provide health benefits. More groundwater recharge means ongoing availability of water supply for various uses in the short and long term.

Recommendations

1. Saint Paul stormwater staff should recommend to the city council an approach whereby stormwater fees can be used to support tree planting (including adequate site preparation) and maintenance.
2. Saint Paul's stormwater and natural resources staff, in partnership with local soil and water districts, should develop a special program for boulevard rain gardens to capture stormwater, for heavily impacted streets with severe tree loss due to EAB, especially during the 0-20 year timeframe when new boulevard trees are being established.
3. The City of Saint Paul should partner with professional and trade organizations such as BOMA, state chapter of AIA, USGBC north star chapter and others to educate property owners, developers, architects, and engineers about the benefits of urban trees (including but not limited to the online Stormwater Manual), and develop design tools to more easily integrate and account for trees, so that more trees can be included in the original design phase of new projects.
4. Saint Paul stormwater staff should explore whether current testing for potential pollutants in urban runoff is adequate, and determine whether additional testing should be done for unconventional parameters such as endocrine disrupters/pharmaceuticals, which typically appear in waste/sanitary streams but may be in runoff due to improper disposal or other pathways.
5. Saint Paul's Public Works staff should continue to plan street sweeping to coincide with annual tree cycles of seed and leaf drop to minimize phosphorus loads.

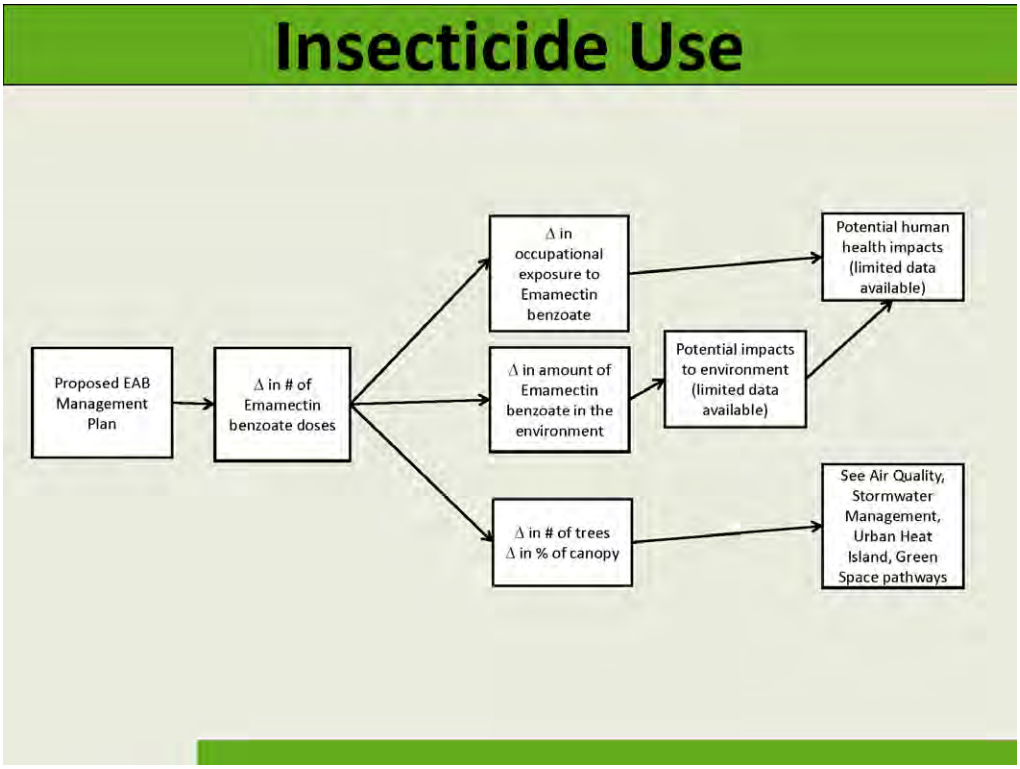
Health Impact 3: Insecticide Use for EAB Management in Saint Paul

The health pathway for insecticide use in this HIA is shown in Figure 12.

Baseline of insecticide use for EAB management in Saint Paul

The current EAB Plan includes the use of Emamectin benzoate as an injection for ash trees to prevent EAB infestation and control pest pressure. While the current EAB Plan places top priority on removal and replacement of ash trees, a few hundred healthy ash trees are treated each year on behalf of the City, with 5000 total trees slated to be preserved through the next 10 years. However, funding limitations will likely prohibit the full implementation of this plan. The alternative plan would follow the same plan, but would be fully implemented with dedicated funding resources.

Figure 12: Insecticide Use health pathway



Ash trees receiving treatment must meet a number of qualifying criteria:

- Good size: 10-20 inch DBH
- Good health: without structural or other defects
- Good site location: wide boulevard, no overhead utilities

Treated ash trees bear a label on them indicating the year(s) in which they were treated.

Emamectin benzoate is a systemic insecticide, which means it is absorbed and transported throughout the tree material (Texas A&M Agrilife Extension). It is applied as a trunk injection, which generally involves drilling through the bark and into the outer sapwood at the base of the tree (Arborjet). Emamectin benzoate has been proven to effectively destroy EAB larvae within a tree when used in this way. While early research suggested reapplications are needed every 2 years, emerging field tests point

to the effectiveness of up to three and possibly four years between injections. (USDA Forest Service, Michigan State University, Purdue University and Ohio State University, 2014)

Over the next 10 years, Saint Paul plans to treat and preserve a total of 4500 right-of-way (boulevard) ash trees (Table 8) and another 506 ash trees located in parks (Table 9) with re-applications every third year. As the plan states, "For a chosen tree's survivability, treatments must be repeated at regular intervals (every 2-3 years) for the life time of the tree, creating an ongoing, ever-increasing expense to the City, both in number of trees treated and the cumulative amount of pesticide needed per tree." (Saint Paul Forestry Unit, 2013) The benefits provided by these trees are not insubstantial, as shown in Table 7.

Table 7: Annual projected benefits of 5000 ash trees protected with insecticide

Annual projected benefits of 5000 Trees											
DBH in inches	Projected # of trees	Total Benefits $	Stormwater $	Gallons	Property $	Energy $	Mw	Therms	Air Quality $	CO2 $	lbs of CO2/yr
10	212	17,232.72	4,314.20	159,212	7,205.88	4,228.64	25	3,392	788.64	695.36	92,644
11	361	33,473.65	8,743.42	322,734	13,396.71	8,333.61	51	6,498	1,610.06	1,389.85	185,193
12	435	45,310.97	12,219.15	451,095	17,500.05	11,407.07	71	8,700	2,262.00	1,922.70	256,215
13	493	57,355.48	15,761.21	581,740	21,366.62	14,844.09	93	11,339	2,923.49	2,460.07	327,845
14	556	71,044.62	19,927.04	735,588	25,831.76	18,485.94	117	13,900	3,708.52	3,091.36	411,996
15	538	74,903.84	21,369.36	788,708	26,674.04	19,575.92	126	14,526	3,986.58	3,297.94	439,546
16	538	80,042.25	24,102.40	889,314	27,819.98	20,507.17	129	15,602	4,153.36	3,459.34	461,066
17	653	103,388.42	32,571.64	1,202,173	35,157.52	26,020.98	159	20,243	5,250.12	4,388.16	585,088
18	521	87,470.33	28,634.16	1,056,588	29,160.37	21,662.82	130	17,193	4,355.56	3,657.42	487,656
19	430	75,986.19	25,817.20	952,880	24,987.30	18,301.69	109	14,620	3,732.40	3,147.60	419,680
20	263	48,992.43	17,129.19	631,989	15,843.12	11,649.06	68	9,468	2,367.00	2,004.06	267,208
Total	**5,000**	**695,200.90**	**210,588.97**	**7,772,021**	**244,943.35**	**175,016.99**	**1,077**	**135,481**	**35,137.73**	**29,513.86**	**3,934,137**

Source: Saint Paul Forestry staff

While preserving these trees will ensure that the benefits provided by these 5000 established trees will continue over the next decade, it also means that thousands of "doses" of Emamectin benzoate will be injected into trees. Though there are no significant side effects known at this time, (Hahn) and use of Emamectin benzoate is encouraged by EAB experts, there is a limited amount of data available about the long-term effects of this chemical on the environment and human health.

Table 8: Saint Paul's Right of Way Trees Insecticide Treatment Plan

ROW Pesticide Treatment

YEAR	2011	2012	2013	2014	2015	2016	2017	2018	TOTAL/YR	
2011	**300**								300	
2012		**400**							400	
2013	*300*		**200**						500	
2014				**800**					800	
2015		*400*			**700**				1100	
2016	*300*		*200*			**700**			1200	
2017				*800*			**700**		1500	
2018		*400*			*700*			**700**	1800	**4500**
2019	*300*		*200*			*700*			1200	
2020				*800*			*700*		1500	
2021		*400*			*700*			*700*	1800	
2022	*300*		*200*			*700*			1200	
2023				*800*			*700*		1500	
2024		*400*			*700*			*700*	1800	

Source: City of Saint Paul Forestry Unit

The chart above shows the plan to treat 4500 right of way trees, which are trees on boulevards in Saint Paul. These trees are high quality trees meeting the good size, good health, good location criteria in the EAB Management Plan. In accordance with this insecticide treatment plan, 300 trees were treated in 2011. These same trees were re-treated in 2013 and will need another treatment in 2016, 2019, and 2022 to remain protected through 2024. The bold numbers indicate the new trees that will be treated for the first time that year. Starting in 2019, no new trees will be treated that year but re-treatments of 1200 trees will occur. This plan, if fully operationalized, will protect 4500 right of way trees on Saint Paul's boulevards through 2024.

Table 9: Saint Paul's Park Tree Insecticide Treatment Plan

Parks Pesticide Treatment

YEAR	2013	2014	2015	2016	2017	2018	TOTAL/YR	
2013	**6**						6	
2014		**100**					100	
2015			**100**				100	
2016	*6*			**100**			106	
2017		*100*			**100**		200	
2018			*100*			**100**	200	**506**
2019	*6*			*100*			106	
2020		*100*			*100*		200	
2021			*100*			*100*	200	
2022	*6*			*100*			106	
2023		*100*			*100*		200	
2024			*100*			*100*	200	

Source: City of Saint Paul Forestry Unit

The above chart is similarly structured to Table 8 but shows insecticide treatment of ash trees located in city parks. The plan for treating park trees is significantly more modest than the plan to treat boulevard trees, with a goal of 506 total trees treated through 2024. This is because there are comparatively fewer ash trees in parks than on boulevards, and also because the available funding for right of way trees is much greater than available funding for park trees, even when adjusting for total populations of boulevard trees versus park trees.

How insecticide use affects health

There is very little information available about the potential impact of Emamectin benzoate on humans. Because Emamectin benzoate is applied as a tree injection in the case of EAB, human exposure is relatively limited due to the decreased likelihood of occupational or incidental inhalation or ingestion. Research shows that transfer of Emamectin benzoate into ash tree leaves occurs at just 4 ppb, and since it is also known to break down in sunlight, exposure to humans due to leaf fall is relatively minimal. (McCullough, 2011)

The challenge is that decisions must be made about the use of Emamectin benzoate in the absence of scientific proof of its safety. In keeping with the precautionary principle, (Science and Environmental Health Network, 2014), an argument could be made for erring on the side of caution and refraining from use of insecticide until such proof exists. For example, Minneapolis' EAB Plan consists of removals and reforestation and zero insecticide treatment (Minneapolis Park and Recreation Board, 2014). Conversely, an argument could also be made for extensive treatment of ash trees, in order to preserve them and the important contributions they provide to the urban forest and to human health.

The U.S. EPA is charged with the responsibility for oversight of insecticides and determining whether they are safe to be used and how they are to be applied. There is a rigorous process through which these chemicals are tested to determine any and all potential effects to the environment and to people. However, when deemed necessary, this process can be circumvented with a fast-track approval process called a Section 3 Request, and this fast-track process is used when an insecticide is identified that can address an invasive species concern. While advantageous because it allows the non-native to be addressed more immediately, it also means that these insecticides enter the market without the rigorous process that is otherwise required. It offers less certainty about this insecticide in terms of its effects on other organisms, its stability as a chemical compound, how it breaks down over time, how these components might react with other things in the environment, how it behaves once within the tree, and what residues are released if it is burned as firewood. In addition, the effects of this chemical on birds and mammals is not fully understood, especially for sap sucking birds and for birds and mammals that eat leaves, bark and seed from treated trees. Directly relevant to this HIA, the EPA's ecological risk assessment memorandum for Emamectin benzoate, dated January 13, 2009 states:

> "There is no standard methodology currently used by EFED (Environmental Fate and Effects Division) to evaluate potential ecological risks from tree injection of insecticides. However, this screening risk assessment identified potential risks to terrestrial invertebrates that forage on treated trees. Potential risks to birds, mammals, and terrestrial invertebrates also presumably exceed levels of concern, and potential risks to aquatic invertebrates could not be precluded." (U.S. Environmental Protection Agency, 2009)

This statement highlights that the EPA does not have a standard methodology to evaluate potential ecological risks from tree injection of insecticides. Therefore, it is unknown how the insecticide translocates within the tree once it is injected, whether and how much it leaches out the roots into the soil, whether and how much it goes into the leaves, what happens to the insecticide when the leaves fall off the tree, and how much of the chemical ends up in the seeds. It is also unstudied whether the injection itself has an impact on a tree, and whether repeated injections may negatively affect a tree. In the EPA's evaluation using a screening risk assessment for spray application of Emamectin benzoate on crops (in the absence of standard methodology for injections), potential risks were identified to terrestrial invertebrates, birds, mammals, and aquatic invertebrates (U.S. Environmental Protection Agency, 2009).

The Section 3 Request report indicates that **insufficient data are available to fully assess risk associated with the use of Emamectin benzoate as a tree injection.** Further studies are recommended. It is unlikely that further studies will take place in the near future, however, because there is no standard methodology for evaluating what happens when insecticide is applied via tree injections, so this methodology would have to be developed first.

With the major wave and impacts of EAB pest pressure in Saint Paul expected in the next five years (Jorgensen, 2014), it is doubtful that sufficient scientific evidence will be available in time to allow us to make a fully informed decision about the use of Emamectin benzoate and its potential health impacts.

Insecticide use and health in Saint Paul

Saint Paul does not require tracking of the use and application of insecticides, including Emamectin benzoate. The city's Forestry department contracts with an independent service provider to conduct the tree injections so the trees are tracked but the city does not track the individuals conducting the work. No occupational hazard is identified in the EPA memorandum.

How insecticide use affects trees

There are a variety of insecticide choices available to address EAB, which are outlined in a brochure published by leading EAB researchers in Michigan (Herms DA, 2014). Saint Paul has elected to use Emamectin benzoate to treat its ash trees. Emamectin benzoate is proven to kill all EAB larvae located within a tree. Because it is systemic, it stays active within the tree for up to four years and protects the tree from EAB larvae during this time period.

Emamectin benzoate is applied to a tree via injection. A hole is drilled in the tree, and the insecticide is injected into the tree much like a person receiving a flu shot. Over time, the tree grows new wood to close the wound. While it is theoretically possible that this hole could serve as a stressor to the tree, thus far there is no evidence to prove that it affects the tree. However, there is also no other situation when trees have received multiple injection treatments over the course of many years, so it is unknown how multiple injections affect trees in the long term.

Trees in Saint Paul are selected to receive injections of Emamectin benzoate in order to prolong the life of the tree. While "saving" a mature tree for one or more additional years of service provides benefits to us and to the environment, insecticide treatment is viewed by the city as a way to both control the pest pressure (amount of active EAB in the city) and control the timing of what is considered the inevitable removal and replacement of the city's ash trees. The Forestry Unit considers pesticide treatment a temporary delay on the inevitable mortality of ash trees, and a measure to spread the impact of EAB over time to enable the city to effectively address the crisis without placing acute strain on staff and financial resources.

Table 10: Projected impact of current EAB Plan on pesticide use and health

What does the evidence say about how the decision will impact health through pathways?							
Health Determinant (Pesticide Use)	**Positive or negative health effect of current EAB Plan scenario (direction)**	**Positive or negative health effect of new Scenario (direction)**	**Likelihood of impact (likelihood)**	**How strong is the health impact? (severity)**	**Who will be impacted? (distribution)**	**Strength of evidence supporting impact on health**	**Uncertainties and contextual comments**
Change in amount of Emamectin benzoate in the environment	**?**	**?**	Possible	Unknown	Everyone. Those with occupational exposure to Emamectin benzoate may be at greatest risk.	none (unknown)	There is little or no research on effects of Emamectin benzoate on health. It is acknowledged that Emamectin benzoate is likely harmful to mammals.
Change in exposure to Emamectin benzoate (occupational, residential, recreational)	**?**	**?**	Possible	Unknown		None (unknown)	

Legend Direction: positive(+), negative (-), mixed (+/-), unable to assess (?)
Likelihood: very likely, likely, possible, unlikely, uncertain
Magnitude: low (<500), moderate (500-1,000), high (>10,000)
Severity: low (transient/minimal health symptoms), moderate (chronic/more severe transient health symptoms), high (severe chronic symptoms or death)
Distribution: population most likely to be affected by the changes due to tree canopy change

Strength of Evidence: very strong (strong, quality evidence base), strong (strong evidence base with some conflicting evidence but generally supporting the pathway), fair (moderate strength/quality evidence base with conflicting evidence but majority supports pathway), weak (little evidence that is of moderate or weak quality), none (no evidence)

Under the current EAB Plan, hundreds of trees will be immunized with Emamectin benzoate each year for approximately the next 10 years. Because this use and application method of Emamectin benzoate (tree injection) is relatively new, there is a lack of available scientific data about potential health effects to trees and to humans for repeated applications and long term use/exposure. It is unknown whether Emamectin benzoate exposure has a health impact to people and if so, what that impact might be. It should be noted that use of Emamectin benzoate will result in "saving" approximately 5000 ash trees which would otherwise be expected to become infested with EAB and be removed. Saving these trees also means saving the benefits they offer to the environment and to human health. These benefits are discussed in the other four health pathways in this report.

Under the alternative plan, Saint Paul would likely maintain its insecticide treatment plan. Although additional funds would be available and could be used to pre-emptively remove ash trees, the benefits from these 5000 trees could be retained during the next 10 years by using Emamectin benzoate. The city could increase its preparedness and the resilience of its urban forest to future pests and diseases by focusing resources on planting additional trees and ensuring that they, along with existing healthy trees, receive adequate attention through watering, pruning, and ongoing monitoring.

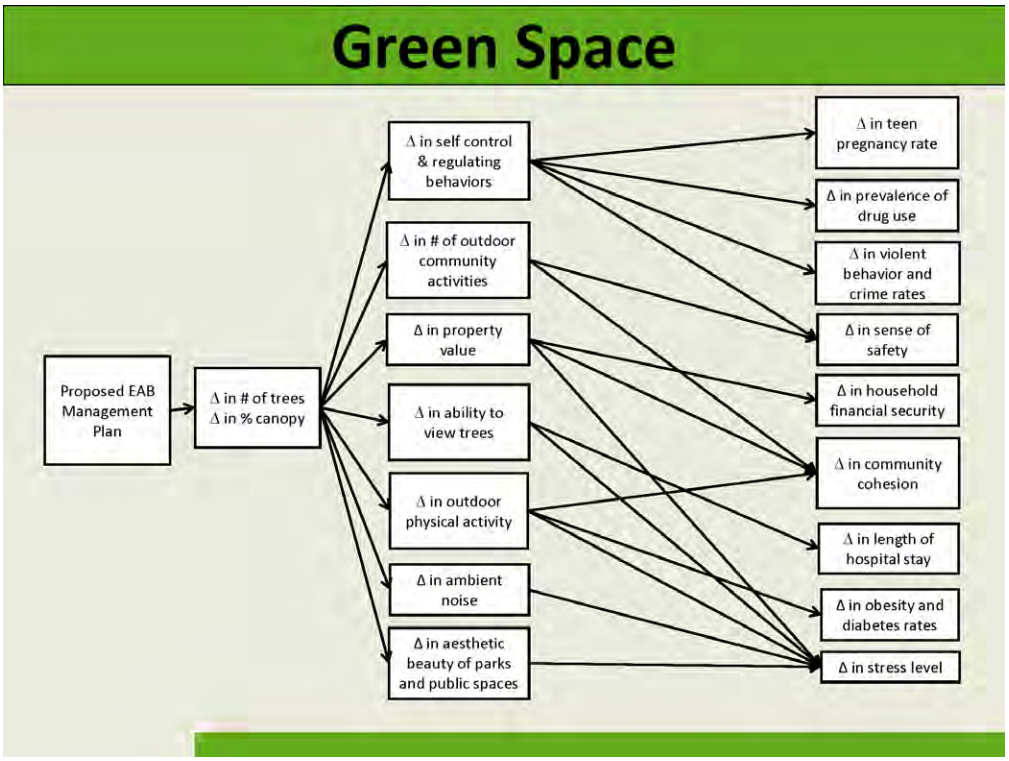
Recommendations

1. Minnesota Department of Agriculture develops protocol for soil and leaf sampling to determine and track presence of insecticides used for EAB, including Emamectin benzoate. Samples are tested annually to provide scientific evidence of ongoing safety of insecticide use.
2. Saint Paul has good information available to help educate residents about EAB and management tactics, including insecticide use and structured removal. Saint Paul should increase its efforts across the city (not just Forestry) to educate the interested public about EAB and the benefits of urban trees. Example opportunities: brochures in the waiting areas for city permits, parking tickets, in district council offices, at recreation centers, at summer gatherings (example: Music in Mears Park, Flint Hills Children's Festival) cable access show or "commercials" with info about trees and/or EAB. Partner with Ramsey County Master Gardeners to educate them about Saint Paul's approach so they can serve as community ambassadors. Offer a free community education class about the benefits of trees.
3. Saint Paul should work to ensure that citizens have adequate access to information so they can make informed decisions about whether and how to treat privately owned ash trees.
4. Saint Paul Forestry continues to stay abreast of emerging research about EAB insecticides, including options for alternative treatments as well as potential health and environmental impacts of ongoing use.

Health Impact 4: Green Space

The health pathway for green space in this HIA is shown in Figure 13.

Figure 13: Green Space health pathway



Baseline of green space in Saint Paul

Saint Paul is known for its many parks, including its flagship Como Park and several downtown parks including Mears Park, Rice Park, Harriet Island and the Mississippi River corridor. Saint Paul has more miles of Mississippi River than any other municipality along the entire length of the river. Saint Paul's 17-mile river valley includes vibrant neighborhoods, active commercial sites, important transportation corridors and more than 20 public parks providing over 3,500 acres of public green space for outdoor recreation, special events, wildlife habitat and scenic views (Riverfront Development Corporation).

The National Parks and Recreation Association recommends that there be park space within 2 miles of every residence (with ¼- to ½-mile distances optimal for walkability) and that a city's park system provide 5 to 8 acres of park space for every 1,000 residents. Saint Paul is in good standing with regard to these recommendations: 96% of residents live within ½ mile of a park and there are 14.73 acres of park space for every 1,000 residents (City of Saint Paul, 2008).

Saint Paul park usership is high: recreation centers across the city tallied 2 million total visits in 2013 and nearly 18,000 activity registrations from residents of all ages and abilities. In all, the city has 179 parks and natural areas and 500,000 park and boulevard trees. (City of Saint Paul, 2013) Saint Paul's walking and biking paths adjacent to the Mississippi River are consistently populated with people out for a bike, jog, or walk. Saint Paul's parks provide recreational opportunities for individuals of all ages and abilities.

Green space and health

This HIA uses the U.S. EPA definition of green space: "land that is partly or completely covered with grass, trees, shrubs, or other vegetation." (U.S. Environmental Protection Agency, 2012) Green space

has long been recognized in some capacity as beneficial to human health, but today, an increasing breadth of empirical research exists to support this idea.

Green space is good for mental health. In a recent study involving over 1000 people, researchers in Britain found that simply living in a greener environment provided mental health benefits. They found that, on average, those who moved to greener areas experienced an immediate improvement in mental health that was sustained for at least three years after they moved. (Alcock, 2013) Even in smaller "doses," like proximity to green plants in an office setting or having a view of green space from a window, the experience of nature helps to restore the mind from the mental fatigue of work or studies, contributing to improved work performance and satisfaction (Kaplan S. , 1995) (Lohr, 1996) (Kaplan R. , 1993) (Shibata, 2002).

Studies show that being near trees reduces stress. Researchers found a dose-response curve between exposure to urban trees and stress reduction. Analysis revealed a positive, linear association between the density of urban street trees and self-reported stress recovery (Jiang, A Dose-Response Curve Describing the Relationship Between Urban Tree Cover Density and Self Reported Stress Recovery, 2014). Another impact of stress reduction due to trees is a positive impact on birth weight. In one study, researchers found a relationship between tree cover within 50 meters of an expectant mother's house and a reduced risk of her baby being born underweight (Kirkland, November 2011). Stress reduction responses to trees varies by gender. One study found that women's stress responses were not dependent upon density of urban trees, but that men's stress responses varied according to canopy percentages. A positive correlation was noted for men's stress responses by increasing canopy cover from 1.7% to 24%, remained constant from 24% to 34%, and tree densities above 34% were associated with slower response times (Jiang, A dose of nature: Tree cover, stress reduction, and gender differences, 2014).

Green space and nature feature prominently in Attention Restoration Theory, a theory advanced by Rachel and Stephen Kaplan in the 1980s in their book *The experience of nature: A psychological perspective.* Since the book's publication, this theory has been upheld both in medical outcomes and in intellectual task attention. The idea is that human attention falls into two categories: directed attention (when we focus on something intentionally) and involuntary attention (when something draws us to it or captures our attention). After a period of directed attention, directed attention fatigue sets in, making it difficult to maintain our concentration. Taking a short break to spend time in nature or even nature-like settings can restore attention.

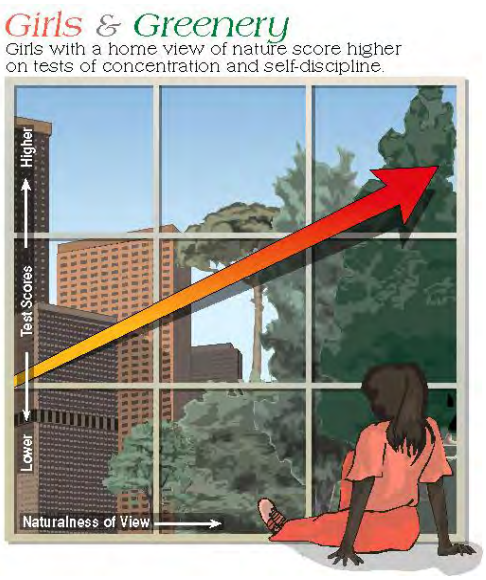
Researchers who work with children with attention deficit disorders including attention deficit hyperactivity disorder (ADHD) and attention deficit disorder (ADD) have embraced attention restoration theory. Researchers found that children with ADHD concentrated better after a walk in the park than after a downtown walk or the neighborhood walk, and concluded that "doses of nature" might serve as a safe, inexpensive, widely accessible new tool in the tool kit for managing ADHD symptoms. (Kuo F. , Children With Attention Deficits Concentrate Better After Walk in the Park, 2008) Ensuring that children have regular and adequate access to green space both at school and at home could prove therapeutic.

A very recent study examined the effects of group nature walks on health, and found that group walks in nature were associated with significantly less depression, perceived stress, and negative affect along with greater positive affect and mental well-being (Marselle, 2014). Considering the numerous individuals who suffer from health issues that can be improved with physical inactivity (obesity, diabetes, cardiovascular disease) as well as mental health issues, exposure to nature is a promising, accessible, and inexpensive treatment option.

Many green spaces invite physical activity. Watch any schoolyard as children emerge from the door and run to the open space to play with their friends. Children who live near natural settings have lower stress levels than their peers (Wells N. , 2003). It will come as no surprise that green space promotes physical activity, which leads to better overall health and a decreased likelihood of numerous health conditions including obesity, diabetes and cardiovascular disease. People who use parks and open spaces are three times more likely to achieve recommended levels of physical activity than nonusers (Wolf D. K., 2014). In one study elderly people that had nearby parks, tree-lined streets, and space for taking walks showed higher longevity over a 5-year study period. (Wolf D. K., 2014) There is evidence from a study in Chicago showing that teen girls with a view of nature from their window ranked higher in self-control and impulsive behavior than those without a view of nature (Faber Taylor, 2002). Other research shows a correlation between a view of nature from a hospital window and shorter hospital stays (Ulrich, 1984).

Although crime factors are a complex mix of social and environmental conditions, more green space may reduce crime. Houses on blocks with more street trees and houses with large yard trees report lower levels of crime (Kirkland, November 2011). These results hold for total-crime rates as well as specific property crimes such as vandalism and burglary. Trees may reduce crime by signaling that a neighborhood is well cared for. The exception to this finding is for houses with many smaller trees. Research posit that this is likely because small trees obscure clear sight lines and can provide shaded cover for criminal activity (Kirkland, November 2011).

Figure 14: Girls & Greenery



Source: (Kuo F. , Views of Greenery Help Girls Succeed)

People also perceive the safety of green space differently depending on the setting, whether it is nicely treed and inviting or the overgrown shrubbery might shade undesirable activity. In a study done in a public housing development in Chicago comparing reports of aggression and violent behavior, those living with a view of green space reported 27% less incidences than those with a non-green view (Kuo F. a., 2001). In this case, even small amounts of greenery (a small patch of grass and a few trees) made a measurable difference. It may be that the physical presence of green space offers a mental respite such as that described in the attention restoration theory, while the neighborhood context and type of potential criminal activity play a more specific local role. In any case, mature trees have been shown to

increase property value and well-tended green space often characterizes well-tended neighborhoods, which themselves deter crime.

Impact assessment: green space and health in Saint Paul

Health impacts associated with green space include physical activity (obesity, diabetes), and mental health. Childhood obesity was ranked 4th in a list of top 10 Ramsey County health concerns in a survey conducted in Spring 2013 (Saint Paul-Ramsey County Public Health, 2013). Data from 2010 shows that of all Minnesota 9th graders, 15% of males and 11% of females were overweight and 12% of males and 6% of females were obese (Minnesota Department of Health, 2012). Even small children are not exempt from this trend: 13 percent of children 2-5 years of age enrolled in the Supplemental Nutrition Program for Women, Infants and Children (WIC) were obese (Minnesota Department of Health, 2012).

Based on the evidence reviewed, it is reasonable to assume that reduced green space will mean fewer health benefits in terms of mental health, physical health, and reduced crime, as discussed above.

Table 11: Projected impact of current EAB Plan on green space and health

What does the evidence say about how the decision will impact health through pathways?							
Health Determinant (Green Space)	**Positive or negative health effect of current EAB Plan scenario (direction)**	**Positive or negative health effect of new Scenario (direction)**	**Likelihood of impact (likelihood)**	**How strong is the health impact? (severity)**	**Who will be impacted? (distribution)**	**Strength of evidence supporting impact on health**	**Uncertainties and contextual comments**
Mental health	-	+	Likely	Moderate	Everyone, though vulnerable populations will be affected more	Strong	
Physical health	-	+	Likely	Moderate		Strong	

Legend
Direction: positive(+), negative (-), mixed (+/-), unable to assess (?)
Likelihood: very likely, likely, possible, unlikely, uncertain
Magnitude: low (<500), moderate (500-1,000), high (>10,000)
Severity: low (transient/minimal health symptoms), moderate (chronic/more severe transient health symptoms), high (severe chronic symptoms or death)
Distribution: population most likely to be affected by the changes due to tree canopy change
Strength of Evidence: very strong (strong, quality evidence base), strong (strong evidence base with some conflicting evidence but generally supporting the pathway), fair (moderate strength/quality evidence base with conflicting evidence but majority supports pathway), weak (little evidence that is of moderate or weak quality), none (no evidence)

Under the current EAB Plan, there will be fewer trees, resulting in a decrease in the mental and physical health impacts of Saint Paul's urban forest on residents. Trees create welcome environments for physical activity including walking and jogging. Fewer trees could subtly change the "invitingness" of outdoor spaces, particularly along designated pathways along the Mississippi River and in city parks, but also along boulevards commonly used for exercise (e.g. Summit Avenue).

It is also worth noting that a reduction in trees may have an impact on visitors and tourism to the area, as the "greenness" of the city, the downtown parks, and the Harriet Island outdoor venue provide a draw for events. While this may not have a direct health impact on residents, if economic vitality is negatively impacted, trickle down effects would be expected in terms of fewer employment opportunities, less vibrant local commerce, and possible reduction in infrastructure (e.g., number of hotel rooms, restaurants and shops in Saint Paul.)

Under the alternative plan, there will be an equal or slightly greater number of trees in Saint Paul. This means that current levels of mental and physical health benefits of trees will remain constant or increase proportionately.

Recommendations

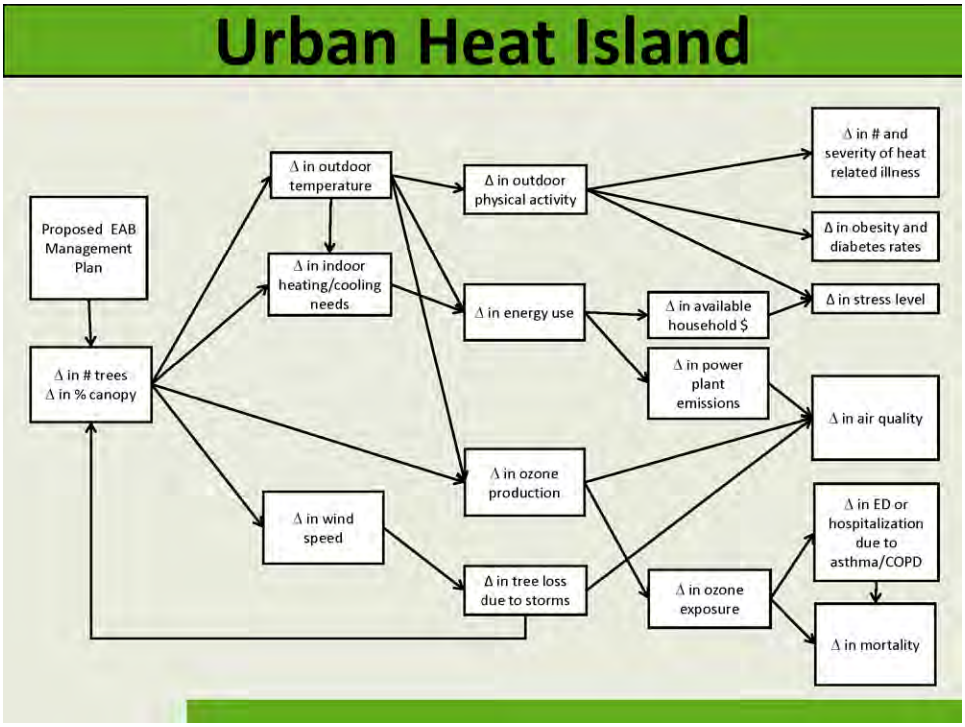
1. Saint Paul Forestry is adequately resourced (staff + equipment) by city budgets (City Council and Mayor's office) to provide routine maintenance for the urban forest to ensure ongoing quality of the city's green spaces.
2. Saint Paul Forestry identifies major biking and exercise paths in the city, and works to ensure a high presence of trees along those corridors.
3. Saint Paul Forestry, should advance an understanding among city leadership of the numerous benefits offered by urban trees to the city, including health (as discussed in this HIA) and non-health benefits (property value increase, overall appeal of the city for tourism and special events, energy savings, urban blight, climate preparedness) and promote the use of trees to address multiple issues at once.

Health Impact 5: Urban Heat Island Effect

The health pathway for urban heat island effect in this HIA is shown in Figure 15.

Trees improve human health by cooling summer temperatures and reducing energy use. The net cooling effect of a young, healthy tree is equivalent to 10 room-size air conditioners operating 20 hours a day (U.S. Department of Agriculture). Trees provide shade and also reduce temperatures through evapotranspiration (Donovan G. H., The value of shade: Estimating the effect of urban trees on summertime electricity use, 2009). Dr. Greg McPherson of the Center for Urban Forest suggests, "If you plant a tree today on the west side of your home, in 5 years your energy bills should be 3% less. In 15 years the savings will be nearly 12%." (Arbor Day Foundation)

Figure 15: Urban Heat Island health pathway

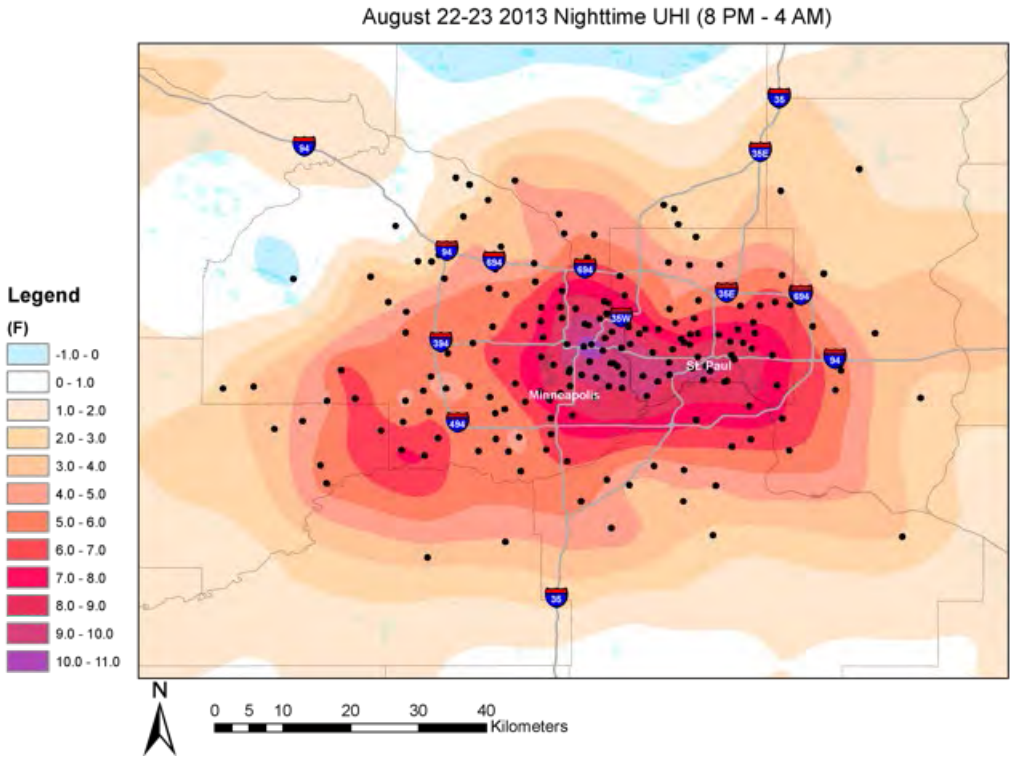


Tree temperature mitigation has impacts on both the urban heat island effect and the heat index. The urban heat island effect was first recognized in the early 19th century by researchers in Great Britain, who realized that day and night temperatures in the urban core were measurably different than temperatures in outlying areas (CUNY, 2013). The phrase "urban heat island" was later applied to this phenomenon: the temperature differential between the urban core and outlying areas. This happens because the built environment absorbs and retains warmth and radiation from the sun during the day, which is then slowly released during the evening (U.S. EPA) (U.S. EPA, 2014) (University of Minnesota, 2011). During both day and evening, the temperatures in the urban area exceed those of the outlying areas. Though natural areas receive similar amounts of sun during the day, trees and other vegetation absorb heat differently and also cool differently at night. Thus, the annual mean air temperature of a city with 1 million people or more can be 1.8–5.4°F (1.0–3.0 °C) warmer than its surroundings. In the evening, the difference can be as high as 22°F (12°C). (U.S. EPA, 2014)

Baseline of urban heat island in Saint Paul

The urban heat island effect is not a constant, so measuring it is merely a "snapshot" moment in time of ever-evolving temperature and weather conditions. In Figure 16, the UHI effect August 22-23, 2013 is shown for the Twin Cities metropolitan area. According to Professor Peter Snyder of the University of Minnesota's Islands in the Sun research project (University of Minnesota, 2011), this map shows a typical nighttime UHI in the Twin Cities area, where, as expected, the urban core is the hottest and concentric rings around the metro area become cooler and cooler as you move towards the suburbs.

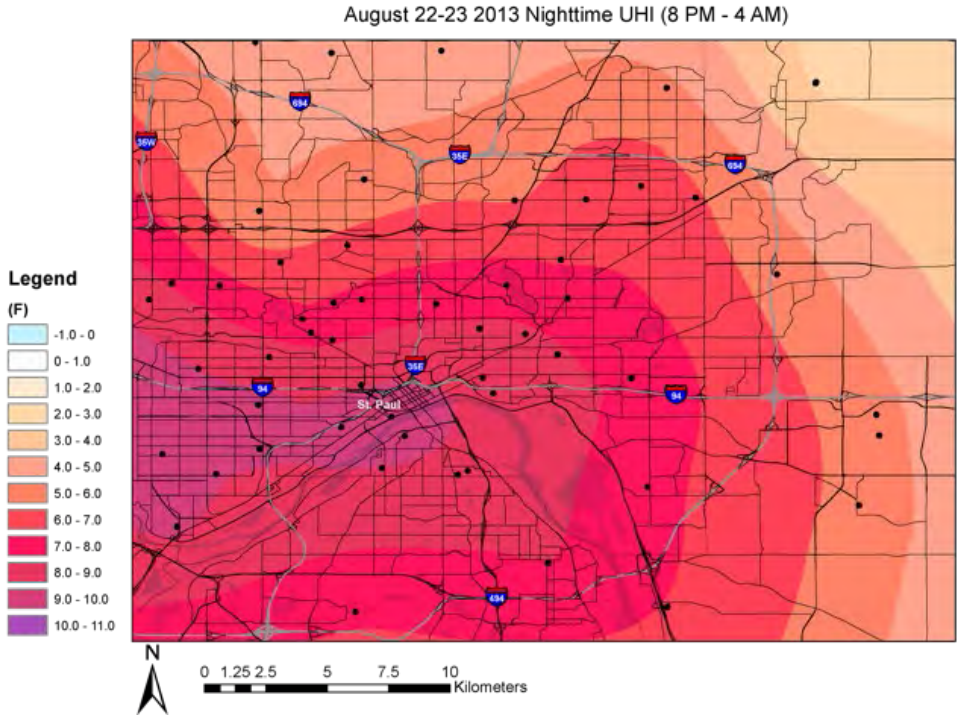
Figure 16: August 22-23 2013 Nighttime UHI, Twin Cities' Metro Area



Source: Dr. Peter Snyder, University of Minnesota

As illustrated in Figure 17, for the same event and time as shown in Figure 16 for the entire metro, the City of Saint Paul has a lower urban heat island than Minneapolis. The bull's eye of the metro area's UHI is centered on the intersection of I94 and I35W in Minneapolis, so Saint Paul's urban heat island is lower than that of the overall metro area. These differences are partly due to the industrial and highway development along the 35W corridor south of downtown Minneapolis, as well as the relatively high tree canopy cover (32.5%) and available green space (trees, parks, lawns, etc.) in Saint Paul. Still, areas of the city had up to a 9° Fahrenheit temperature differential than outlying areas, but did not reach the dark 10+ degree differential seen in areas of Minneapolis.

Figure 17: August 22-23 2013 Nighttime UHI for Saint Paul



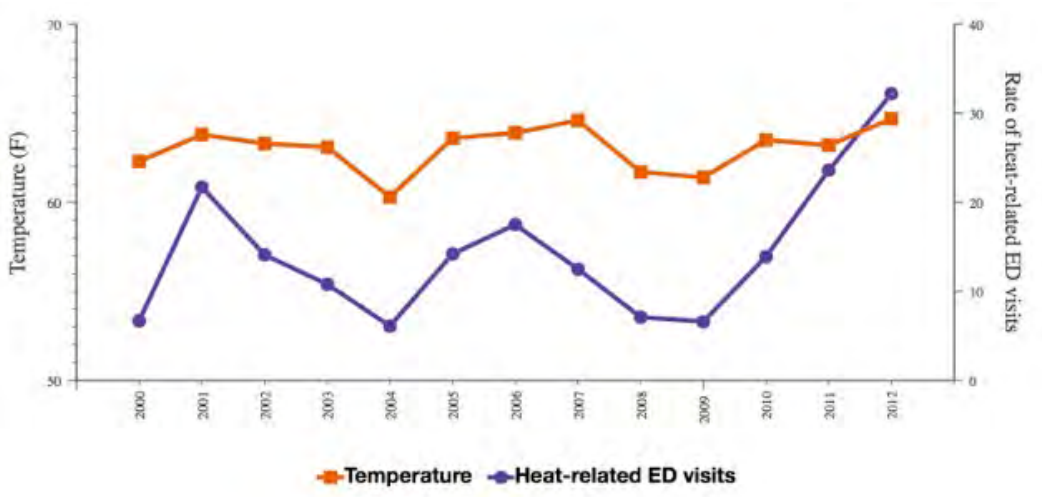
Source: Dr. Peter Snyder, University of Minnesota

How temperature affects health

The human experience of temperature affects not only our behavior but also our health. Extreme heat takes a toll on people's health. High temperatures are correlated with increased visits to the emergency department for heat related illness. Moreover, rates of heat related illness in Minnesota *more than doubled* between 2009 and 2012. Individuals aged 15-34 and above age 65 are most likely to visit the ER for heat related illness (Minnesota Department of Health).

As shown in Figure 18, the rate of ED visits due to heat-related illness parallels the average summer temperatures. This graph does not prove causation, but demonstrates an association between average summer temperatures and number of ED visits. The summers of 2001, 2006, and 2012 had higher average temperatures and higher rates of heat-related illness ED visits.

Figure 18: Heat-related illness ED visits and temperature

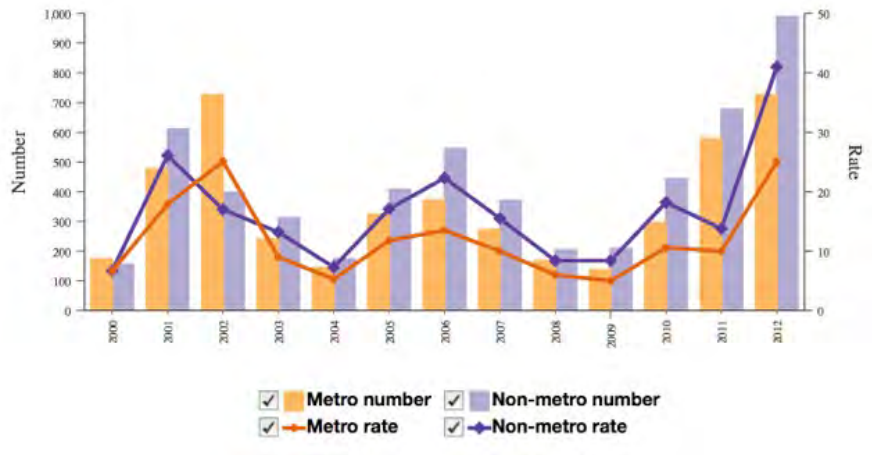


Emergency department (ED) visits are directly heat-related. Temperature is the average summer temperature. Rates are age-adjusted, per 100,000 people in Minnesota. Temperature data source: National Climatic Data Center, National Oceanic and Atmospheric Administration

Source: (Minnesota Department of Health)

As shown in Figure 19, while the metro population (Anoka, Hennepin, Ramsey, Washington, Carver, Scott, and Dakota counties) is considered more at risk to heat-related illness due to the urban heat island effect, this chart demonstrates that the non-metro population (all other counties in Minnesota) experiences more heat-related illness ED visits overall than the metro population (Minnesota Department of Health).

Figure 19: Heat-related illness ED visits by region



Source: (Minnesota Department of Health)

Children, adolescents, and the elderly are among the most vulnerable to heat because their bodies adjust more slowly to environmental temperatures (Centers for Disease Control and Prevention, 2012). The elderly are also more likely to have a chronic medical condition and/or be on medication that may affect their body's ability to adjust to temperature (Minnesota Department of Health).

Maintaining moderate temperatures will be increasingly important in the next 20 to 30 years as the population ages and baby boomers move into their 70s, 80s and 90s (U.S. Census/National Institute on Aging, 1996). Temperatures in Saint Paul are expected to increase by approximately 4.4 degrees Fahrenheit by 2041 (U.S. Global Change Research Program, 2014). Trees planted now will be large enough in 20 to 30 years to provide these temperature buffering effects (Johnson, 2014).

How trees affect temperature

Trees work to mitigate the urban heat island effect in two ways: evapotranspiration and shading. The leaves and branches of a tree absorb sunlight and shade the area beneath the canopy. In the summertime, generally 10 to 30% of the sun's energy reaches the area below a tree (U.S. EPA). By extension, a tree prevents 70 to 90% of the sun's energy from reaching the ground. Thus, a city's tree canopy cover can dramatically reduce the amount of sunlight reaching the ground. Using an estimate of 80% (the midpoint between the 70 and 90%), St. Paul's current overall canopy cover is 36%, which means that in approximately 1/3 of the city, trees in St. Paul are absorbing/reflecting 80% of the sunlight.

A single properly watered tree can "evapotranspire" 40 gallons of water in a day – offsetting the heat equivalent to that produced by one hundred 100-watt lamps, burning eight hours per day. Evapotranspiration refers to the movement of water to the air through both evaporation (from the ground and other surfaces) and transpiration (from plant respiration). A tree will uptake water from the soil and emit it through leaf stomata. This is the process through which the 40 gallons can be evapotranspirated.

Trees properly placed around buildings can reduce air conditioning needs by 30% and can save 20–50% in energy used for heating (Arbor Day Foundation).

Planting more trees is only part of the answer. To optimize the temperature buffering benefits of trees, they should be strategically located. Strategically placed trees not only provide shade, but also provide energy savings through their cooling effects. For residences, trees should be planted on the west side of houses. Trees can also provide effective shading for or near large open areas such as parking lots, schoolyards, ball fields and playgrounds.

Table 12: Projected impact of current EAB Plan on urban heat island effect and health

What does the evidence say about how the decision will impact health through pathways?							
Health Determinant (Temperature Mitigation)	**Positive or negative health effect of the current EAB Plan scenario (direction)**	**Positive or negative health effect of new Scenario (direction)**	**Likelihood of impact (likelihood)**	**How strong is the health impact? (severity)**	**Who will be impacted? (distribution)**	**Strength of evidence supporting impact on health**	**Uncertainties and contextual comments**
Heat-related illness	-	+	Likely	Moderate	Everyone, though vulnerable populations will be affected more	Strong	
Strength of urban heat island effect (degree differential between city and outlying areas)	-	+	Likely	Moderate		Strong	

Legend
Direction: positive(+), negative (-), mixed (+/-), unable to assess (?)
Likelihood: very likely, likely, possible, unlikely, uncertain
Magnitude: low (<500), moderate (500-1,000), high (>10,000)
Severity: low (transient/minimal health symptoms), moderate (chronic/more severe transient health symptoms), high (severe chronic symptoms or death)
Distribution: population most likely to be affected by the changes due to tree canopy change
Strength of Evidence: very strong (strong, quality evidence base), strong (strong evidence base with some conflicting evidence but generally supporting the pathway), fair (moderate strength/quality evidence base with conflicting evidence but majority supports pathway), weak (little evidence that is of moderate or weak quality), none (no evidence)

Under the current EAB Plan, there will be fewer trees, so the temperature mitigating effects of the trees will be diminished. Saint Paul will likely experience higher temperatures and more extreme urban heat island effect. This increase in temperature will likely result in more people experiencing heat-related illness, and vulnerable populations increasing in vulnerability, particularly those living in the urban core without access to air conditioning. Even general populations are likely to experience increased discomfort with increased heat.

Under the alternative plan, there will be equal or slightly more numbers of trees, so the temperature mitigating effects of the trees will be sustained or even increase. Assuming average temperatures stay constant (although they are expected to increase in the coming years due to climate change), trees will continue to offer the same or slightly increased temperature mitigation effects, which will be even greater if placement of new trees is optimized to yield better shading and cooling results. This means that the number of people affected by heat related illness will likely stay constant (without accounting for projected changes in average temperature.)

Recommendations

1. City of Saint Paul identifies neighborhoods with lower canopy cover and higher rates of vulnerable populations (individuals aged 15-34 and over 65). If possible, also identify neighborhoods (or even pockets of specific housingstock) with less access to air conditioning. Target these neighborhoods for new tree planting.
2. Saint Paul Forestry and Saint Paul Chamber of Commerce work together to develop an incentivized plan to reach out to businesses and property management companies in the city that would benefit from reduced heating and cooling needs. Such a plan could offer bare root tree stock or other reduced cost trees for them to incorporate into the landscape near their properties. This program could also include an education component about how to select the proper trees for the site, how to properly plant and care for the trees to promote establishment and long term tree vitality.
3. City of Saint Paul Planning and Economic Development integrates urban trees into plans for climate resilience and/or disaster preparedness as a temperature buffering strategy (with many other co-benefits, including flood management).

Summary of findings

Below is a summary of the impacts of urban trees on human health. While there are additional important immediate and long term benefits of urban trees, including climate resilience and climate adaptation, these fall outside the scope of this HIA and are therefore not included in this discussion.

Table 13: Impacts of urban trees on human health

What does the evidence say about how the decision will impact health through pathways?							
Health Determinant	**Positive or negative health effect of the current EAB Plan scenario (direction)**	**Positive or negative health effect of new scenario (direction)**	**Likelihood of impact (likelihood)**	**How strong is the health impact? (severity)**	**Who will be impacted? (distribution)**	**Strength of evidence supporting impact on health**	**Uncertainties and contextual comments**
Change in particulate matter concentrations	-	=/+	Likely	Moderate	Everyone, but especially individuals with asthma and other respiratory conditions	Very strong	
Change in NO_x and SO_x	-	=/+	Likely	Moderate		Very strong	
Change in VOCs	-	=/+	Likely	Moderate		Very strong	Trees do emit some VOCs but it is generally agreed that their overall effect is positive.
Change in ozone	-	=/+	Very likely	Moderate	Everyone	Very strong	
Change in possibility of urban flooding	-	+	Likely	Moderate	Everyone	Very strong	
Change in pollutants entering waterways	-	+	Very Likely	Moderate		Very strong	
Change in soil moisture and groundwater recharge	-	+	Very Likely	Moderate		Very strong	

What does the evidence say about how the decision will impact health through pathways?							
Health Determinant	**Positive or negative health effect of the current EAB Plan scenario (direction)**	**Positive or negative health effect of new scenario (direction)**	**Likelihood of impact (likelihood)**	**How strong is the health impact? (severity)**	**Who will be impacted? (distribution)**	**Strength of evidence supporting impact on health**	**Uncertainties and contextual comments**
Change in amount of Emamectin benzoate in the environment	**?**	**?**	Possible	Unknown	Everyone. Those with occupational exposure to Emamectin benzoate may be at greatest risk.	None (unknown)	
Change in exposure to Emamectin benzoate (occupational, residential, recreational)	**?**	**?**	Possible	Unknown		None (unknown)	
Mental health	**-**	**+**	Likely	Moderate	Everyone, though vulnerable populations will be affected more	Strong	
Physical health	**-**	**+**	Likely	Moderate		Strong	
Heat-related illness	**-**	**+**	Likely	Moderate	Everyone, though vulnerable populations will be affected more	Strong	

What does the evidence say about how the decision will impact health through pathways?							
Health Determinant	**Positive or negative health effect of the current EAB Plan scenario (direction)**	**Positive or negative health effect of new scenario (direction)**	**Likelihood of impact (likelihood)**	**How strong is the health impact? (severity)**	**Who will be impacted? (distribution)**	**Strength of evidence supporting impact on health**	**Uncertainties and contextual comments**
Strength of urban heat island effect (degree differential between city and outlying areas)	-	+	Likely	Moderate		Strong	

Legend
Direction: positive(+), negative (-), mixed (+/-), unable to assess (?)
Likelihood: very likely, likely, possible, unlikely, uncertain
Magnitude: low (<500), moderate (500-1,000), high (>10,000)
Severity: low (transient/minimal health symptoms), moderate (chronic/more severe transient health symptoms), high (severe chronic symptoms or death)
Distribution: population most likely to be affected by the changes due to tree canopy change
Strength of Evidence: very strong (strong, quality evidence base), strong (strong evidence base with some conflicting evidence but generally supporting the pathway), fair (moderate strength/quality evidence base with conflicting evidence but majority supports pathway), weak (little evidence that is of moderate or weak quality), none (no evidence)

Summary of recommendations

General/broad recommendations

1. Given a) national trends of urban tree loss over the past 50 years, b) the current threat of EAB, c) anticipated future threats to the urban forest such as temperature extremes, increased drought, increased severe storms, and other invasive pests, and d) recognition of the multifaceted benefits of trees, City of Saint Paul policymakers should increase the priority of the city's urban forest.
2. Saint Paul Forestry should regularly convene a group of city employees involved with trees, including representatives from city departments: stormwater, public schools, planning and economic development, public works, disaster preparedness. This convening is an opportunity to develop/share a unified plan for how to address urban trees, anticipated challenges (example: onset of new disease and how to manage), what species to plant/avoid, updates of the city's urban forest as a whole. The goal is for everyone involved with trees to be aware of the activities of one another so they can all work in concert toward the good of the overall urban forest.
3. Saint Paul Forestry should pursue implementation of a high functioning citizen volunteer program to meet the needs of the urban/community forestry program.
4. Saint Paul Forestry should develop a five-year community forestry master plan with measurable goals and accountability for implementation. Such a plan should include outreach, education, community partnerships.
5. Saint Paul Forestry, Public Works, Planning & Economic Development departments should work together to implement best practices for site preparation to better ensure healthier trees that are able to contribute to healthier lives. Tree sites should provide a minimum of 2 cubic feet of "soil" for each square foot of projected canopy, adequate moisture for the life of the tree, and soil oxygen. Innovative trials, such as the Minneapolis/U of MN biochar project currently underway, should be monitored so that these practices can be integrated if found effective.
6. Saint Paul Park and Rec should partner with Saint Paul Convention and Visitors Bureau to demonstrate economic impact of green space on the city (Crompton, 2010).

Recap of recommendations previously listed in each health pathway

- Saint Paul Forestry should work with Saint Paul-Ramsey Public Health and Saint Paul Mayor's Office to identify target neighborhoods where increased tree presence would be especially beneficial, based on:
  - existing tree canopy percentage
  - expected loss of ash trees (some neighborhoods will be more impacted than others)
  - population of vulnerable individuals (% under age 5 and above age 65)
  - proximity to sources of air pollution (industry, high traffic corridors)
- Saint Paul Forestry should partner with MnDOT and community groups to conduct a near-road vegetation project. The goal of this project would be to demonstrate the feasibility and effectiveness of near-road vegetation to serve as a physical barrier between sources of airborne pollutants and nearby housing.
- Saint Paul stormwater staff should recommend to the city council an approach whereby stormwater fees can be used to support tree planting (including adequate site preparation) and maintenance.

- Saint Paul's stormwater and natural resources staff, in partnership with local soil and water districts, should develop a special program for boulevard rain gardens to capture stormwater, for heavily impacted streets with severe tree loss due to EAB, especially during the 0-20 year timeframe when new boulevard trees are being established.
- The City of Saint Paul should partner with professional and trade organizations such as Building Owners and Managers Association, state chapter of American Institute of Architects, U.S. Green Building Council and others to educate property owners, developers, architects, and engineers about the benefits of urban trees (including but not limited to the online Stormwater Manual), and develop design tools to more easily integrate and account for trees, so that more trees can be included in the original design phase of new projects.
- Saint Paul's Public Works staff should continue to plan street sweeping to coincide with annual tree cycles of seed and leaf drop to minimize phosphorus loads.
- The City of Saint Paul should partner with the Minnesota Department of Agriculture to conduct soil and leaf sampling on a regular basis to determine and track presence of insecticides used for EAB, including Emamectin benzoate.
- Saint Paul has good information available to help educate residents about EAB and management tactics, including insecticide use and structured removal. Saint Paul should increase its efforts across the city (not just Forestry) to educate the interested public about EAB and the benefits of urban trees. Example opportunities: brochures in the waiting areas for city permits, parking tickets, in district council offices, at recreation centers, at summer gatherings (example: Music in Mears Park, Flint Hills Children's Festival) cable access show or "commercials" with info about trees and/or EAB. Partner with Ramsey County Master Gardeners to educate them about Saint Paul's approach so they can serve as community ambassadors. Offer a free community education class about the benefits of trees.
- Saint Paul should work to ensure that citizens have adequate access to information so they can make informed decisions about whether and how to treat privately owned ash trees.
- Saint Paul Forestry should continue to stay abreast of emerging research about EAB insecticides, including options for alternative treatments as well as potential health and environmental impacts of ongoing use.
- Saint Paul Forestry should be adequately resourced (staff + equipment) by city budgets (City Council and Mayor's office) to provide routine maintenance for the urban forest to ensure ongoing quality of the city's green spaces.
- Saint Paul Forestry should ensure that major biking and exercise routes in the city include a high presence of trees along those corridors.
- Saint Paul Forestry should advance an understanding among city leadership of the numerous benefits offered by urban trees to the city, including health (as discussed in this HIA) and non-health benefits (property value increase, overall appeal of the city for tourism and special events, energy savings, urban blight, climate preparedness) and promote the use of trees to address multiple issues at once.
- City of Saint Paul in partnership with Saint Paul-Ramsey County Public Health should identify neighborhoods with lower canopy cover and higher rates of vulnerable populations. If possible, also identify neighborhoods (or even pockets of specific housingstock) with less access to air conditioning. Target these neighborhoods for new tree planting.
- Saint Paul Forestry and Saint Paul Chamber of Commerce should work together to provide incentives to businesses and property management companies to reduce heating and cooling costs.

- Saint Paul Planning and Economic Development incorporates urban tree approaches into plans for climate resilience and/or disaster preparedness as a temperature buffering and flood management strategy.
- Saint Paul stormwater staff should explore whether current testing for potential pollutants in urban runoff is adequate, and determine whether additional testing should be done for unconventional parameters such as endocrine disrupters/pharmaceuticals, which typically appear in waste/sanitary streams but may be in runoff due to improper disposal or other pathways.

Appendix 1: Primer on EAB

About Emerald Ash Borer

Emerald Ash Borer (EAB) is a green beetle native to Asia. Researchers believe it first came to the USA in 2002 when it was discovered in shipping materials in Michigan. Since then, the infestation has spread concentrically from the Detroit area and now affects 24 states (United States Department of Agriculture, 2014) and is expected to eventually destroy ash trees across North America. There are no known natural predators of EAB in North America and it has a near-100% mortality rate on ash tree populations in areas where it is active.

EAB kills trees by destroying the inner bark and cambium of a tree. The inner, living bark is the layer which transports water and nutrients throughout the tree. The cambium is the layer of cells immediately inward from the inner bark that produces the cells that move water, nutrients and photosynthates (starch, sugars) throughout the tree. (Johnson, 2014) Mature EAB insects enter the tree and lay their eggs on the cambium. When the eggs hatch, the larvae eat their way through the inner bark and cambium, creating little tunnels known as galleries. Over time, many galleries are created, interrupting the flow of nutrients more and more, until the tree eventually dies from lack of nutrients. EAB spreads when adult insects migrate from one tree to the next, either through their own power (EAB have the ability to fly up to half a mile) or more commonly when people knowingly or unknowingly transport infested wood. (USDA Forest Service, Michigan State University, Purdue University and Ohio State University, 2014)

Symptoms of EAB include canopy dieback, stunted growth, cracked bark and clumped foliage (aka witches' brooms). Signs of EAB include increased woodpecker activity, D-shaped exit holes in the outer tree bark, and the presence of adult EAB insects around a tree. Tree experts can also conduct branch sampling to examine the inside of the tree for EAB activity. Early on, arborists found it difficult to detect EAB in a tree until it was too late, but emerging techniques allow tree specialists to identify early symptoms of EAB infestation with the opportunity to treat and save the tree.

Structurally, due to their opposite branching form, even healthy ash trees tend to be more fragile than other species and more prone to breakage and storm damage. When infested with EAB, this issue becomes even more significant. One study found that infested ash tree wood was significantly drier than healthy ash wood, even in trees with only 1 to 2 years' infestation. (Persad, 2013) Ash trees have opposite branching, so are structurally more likely to break when stressed. They also become very brittle when compromised, leading to further breakage. (Stone, 2014) A standing dead or damaged ash tree can pose a hazard to nearby structures, vehicles, and people because of the possibility of breakage and subsequent damage, and should be removed as soon as possible.

Appendix 2: Imidacloprid

While not of immediate concern to the plan created by the City of Saint Paul, the use of imidacloprid to treat ash trees is still relevant to this HIA and the health of communities in Saint Paul. This is because of its accessibility to homeowners. Imidacloprid is widely available at home improvement warehouses and garden supply stores in Minnesota, and is relatively inexpensive. It is a neonicotinoid and therefore functions as a neurotoxin to insects, binding differently to insects than to mammals. However, neonictinoids have been found to negatively affect bees and other pollinators. While ash trees are not considered targets for pollinators, serious caution should be taken when using imidacloprid to ensure that it is being applied correctly and to optimum benefit. For example, if bee-attracting flowers are growing beneath an ash tree, remove the plants before applying the systemic imidacloprid to minimize exposure to pollinators in flowers. Imidacloprid for EAB control should be used in spring at bud break. Homeowner use in midsummer may result in movement into surrounding soils and vegetation.

Impacts of imidacloprid on human health

Imidacloprid has been found to leach into groundwater. In a study performed in the New York, NY area, imidacloprid was positively identified in well water (New York State Department of Environmental Conservation, 2004). This is especially concerning because the study was done in a Long Island community, where use of imidacloprid is restricted to professional applications, pointing to a greater likelihood of improper use/application. So despite proper use, imidacloprid was still found in groundwater. Considering potential misuse, including higher than recommended application per acre, soil drenching followed by unanticipated rain event, or improper application, this could lead to higher than expected impacts on groundwater if people choose to treat their ash trees themselves.

Cost comparison of Imidacloprid vs. Emamectin benzoate

While the St. Paul EAB Plan applies only to publicly owned trees (those on boulevards and parks), EAB does not respect property lines. Ash trees on private property are just as vulnerable to EAB, and perhaps more so, since homeowner awareness of EAB identification, monitoring, and treatment options unlikely to be as robust as that of forestry professionals. Costs to treat a tree professionally with Emamectin benzoate is approximately $150 to $300 per tree, but because imidacloprid has not been designated a restricted use pesticide, a homeowner can apply imidacloprid themselves for a cost of about $35 per gallon. With professional treatment ranging anywhere from 5 to 9 times more expensive than the DIY option, there is an obvious incentive for homeowners to choose store-bought imidacloprid. Imidacloprid available to homeowners is particularly harmful to the ecosystem in which it is applied because these products are designed to dump into the soil by a tree's roots. This not only allows the imidacloprid to impact flowering plants at the base of the tree, but it also allows the pesticide to leech into groundwater. Imidacloprid can become bound to the soil (Goulson, 2013). Once it contaminates the soil, imidacloprid does not show a significant decrease in concentration as it has been measured to date. This means that each time the pesticide is reapplied, its concentrations simply become higher. The utility of imidacloprid, and a primary reason for its broad use is that the pesticide does not lack effects on vertebrate species (a class including humans), but that it impacts insects at much lower concentrations. Needless to say, accumulations of imidacloprid from use year after year should elicit concern.

Dr. Vera Krischik, who has done significant amounts of research on bees and pollinators, has stated that use of imidacloprid by homeowners to treat ash trees is permissible, and recommends the following application approach:

I would support that homeowners should use a soil drench under an ash tree in spring at bud break when trees are using water from the soil to expand leaves. If flowering plants are under the tree, then they should be removed. I would recommend that the area under the tree be watered for 5 mins each day for five days and then lightly watered for 5 min twice a week for 2 weeks. Watering lightly will help make the insecticide leach into the ground.(Krischik, 2014)

Appendix 3: Dissemination Plan

Dissemination Plan – Saint Paul's Emerald Ash Borer Management Plan HIA					
Goal		**Audience**	**Dates**	**Notes**	**Responsible party**
Inform appropriate decision-makers about the HIA findings and recommendations.	Oral Presentations Executive Summary	Saint Paul Mayor Saint Paul City Council Saint Paul Parks/Rec Director Mike Hahn	Spring 2015	Work with Anne Hunt (Mayor's office) and Cy Kosel (Forestry/Parks & Rec) to schedule meetings	Sarah Rudolf
Share the final report with HIA Stakeholder Group	Meeting	HIA Stakeholder Group	Spring 2015	Identify "best" date and schedule a meeting	Sarah Rudolf
Inform forestry professionals in Minnesota about the HIA report	MnSTAC meeting Shade Tree Short Course workshop	Minnesota arborists and forestry professionals	Spring 2015 Spring 2015		Sarah Rudolf
Inform interested public (Saint Paul) about urban forestry HIA report	Website Press release	General public	Spring + Summer 2015		Sarah Rudolf
Inform national forestry stakeholders about a new urban forestry HIA report	Website EAB University (webinar)	Forestry professionals across the nation	Spring 2015	Work with Jill Johnson (USFS Midwest urban forestry coordinator). Centers for Disease Control recently promoted HIAs for park/trail access and we may be able to utilize similar network to disseminate this info.	Sarah Rudolf

Appendix 4: EAB HIA process evaluation

The process evaluation below outlines the six steps of HIA and a consideration of how the EAB HIA adhered to these steps and best practices of HIA. The purpose of this process evaluation is to identify challenges that occurred in the process to inform future HIAs. The process evaluation also highlights the fact that HIA is an iterative learning process, and that results are not merely measured by the publication of a report or in a decision being made but also as part of conducting the HIA itself.

Screening

Screening for the HIA took place as part of the pre-application process for the Pew HIA grant. The grant application process occurred simultaneously with the screening process, which is likely a challenge faced by many HIA projects funded by outside sources. Looking back, one of the things that made this project more challenging is the lack of a specific decision point, in terms of presenting decision alternatives and framing the overall HIA.

Scoping

The scoping step for this HIA was conducted by the HIA project coordinator with support from the stakeholder group. There was general consensus about the project scoping among the group. The geographic boundaries were determined as part of the original grant proposal as the city limits of Saint Paul. The EAB Management Plan applied only to public trees. The temporal boundaries were identified by a local EAB research expert. The health pathways were identified by the HIA project coordinator and confirmed by the group. The group also agreed that these did not need to be prioritized but all five were of great importance both with regard to health and the acknowledgement of trees' contribution to the health pathway. Other benefits of urban trees were identified but not included in the HIA because they did not have a strong correlation with health: property value increase, climate mitigation and adaptation, and energy savings. The final HIA was relatively consistent with the scoping plan. The original mental health and physical health pathways were collapsed into one pathway called "Green Space" because we recognized that mental and physical health were the benefits but the pathway was due to the presence/availability of green space.

Assessment

Assessment took place during Summer and Fall 2014. Duties were shared by the HIA project coordinator and the HIA student worker. In retrospect, these activities could have been streamlined better to reduce duplication and increase efficiencies by creating a more systemized way of conducting the literature review. Interviews with subject matter experts took place during the same timeframe and helped to inform the overall development of the assessment narrative and in many cases also helped to identify new/other sources for the literature review.

This HIA made judgments about positive and negative health effects of the change in tree canopy over time. While not as quantified as originally conceived (e.g. insufficient data exists to connect the benefits of trees directly to asthma, or the change in number of trees to the change in number of children affected by or school days missed due to asthma), the co-benefits of trees on health are sufficiently substantiated in the literature to be confidently included in this report.

Assumptions and limitations were identified and discussed in the Methods section of the report. Recommendations were supported by evidence, most often from the literature and enforced by other sources such as subject matter experts or nationally recognized best practices of urban forestry.

Attempts were made at including community experience, including inviting a multitude of community-based organizations and civic groups to participate in this HIA. At this time, the general public lacks awareness of the connection between personal heath and the urban forest. Similarly, EAB does not seem to be a major problem on the public radar; while people may have heard about EAB, the infestation has not yet significantly affected the tree population in numbers alarming enough to be identified as a crisis.

Potential health impacts of policy alternatives were explored: in general, more trees = more benefits = better health. What complicates the story is that the health of trees is interdependent upon many factors, and the forestry timeframe of tree lifespans encompasses many sociopolitical and budgetary changes. Thus, to ensure the ongoing health benefits of the urban forest, we must ensure the health of the urban forest itself, which is neither simple nor straightforward nor a short term commitment.

New research continues to be done on health issues related to the HIA. The U.S. Forest Service is currently working to upgrade its iTree software to include a way to measure tree benefits to human health. Recent research on urban forestry has an increased focus on health-related benefits, so this will likely be a topic of ongoing interest in the near future.

Developing recommendations

Initial recommendations were developed by the HIA project coordinator and student worker and presented to the stakeholder group at a meeting in August 2014. The group reviewed the findings and discussed the recommendations. There were no major disagreements with the recommendations, though in a few cases the language was adjusted to more accurately reflect the intention of the recommendation or the on-the-ground tree reality. The stakeholder group and subject matter experts were invited to contribute suggestions for recommendations throughout the HIA process. The city's Forestry staff was also invited to submit suggestions for recommendations and was also asked to review the recommendations to identify any potential unintended consequences and offer input on any challenges that might be incurred if/upon implementation.

Reporting & communications

This HIA brought together a number of co-benefits of the urban forest in one report, and involved numerous stakeholders specializing in different fields. The HIA process therefore connected the dots around the EAB Plan and urban forestry in general by offering a platform for people to come together around a specific issue.

It is anticipated that this report will garner discussions among decision makers and others around the tradeoffs involved with urban forestry funding decisions, and this HIA will help to bring to light some elements of the benefits that may not have been recognized in an official capacity or to their full extent.

The methods section of this HIA included a comprehensive documentation of the HIA process, and the analysis and findings were clearly included in the narrative of the report. It is anticipated that recommendations will be delivered to decision makers in early 2015 through both oral and written presentations.

As the EAB infestation in Saint Paul continues and as the EAB infestation spreads to other Minnesota cities, this HIA will likely continue to inform local, regional, and perhaps state level decisions. Momentum is building for urban forestry efforts in part due to this HIA and other actions taken by HIA stakeholders during the period of the HIA project.

The frame of the project changed over time. Toward the end of the summer, it was determined that the decision alternative should be changed from the "do-nothing" alternative (which was unrealistic, but viewed as a natural alternative) to the current investment scenario. Informed by concurrent work on urban forestry and projected climate change impacts, stakeholders determined that a more informative comparison could be made between the EAB Plan and an investment scenario in which the Forestry Unit was fully funded to not only manage the current EAB crisis but also to carry out regular maintenance activities to ensure the immediate and ongoing health of the urban forest and build resilience against future stresses due to invasives, diseases, and weather events.

Results were disseminated via a variety of methods: presentations, conferences, press releases, distribution of the report and executive summary via paper and electronic means, and sharing throughout local, state and national forestry and public health networks.

Stakeholder engagement

Stakeholders were more involved towards the beginning of the process with scoping, identifying and mapping health pathways and developing research questions. Stakeholders were tapped on a more individual basis to contribute to the assessment phase based on their areas of expertise. All stakeholders were invited to review and comment on a draft of the final report.

As noted earlier in this evaluation, many community-based and civic groups were invited to participate in the HIA, but declined. Further follow-up work could be done to determine the reasons behind their decision not to participate. It is likely that these groups, like most other civic groups, have limited bandwidth in terms of the focus of their efforts and the availability of their volunteer participants, and therefore have more of a focus on their own agenda and did not perceive the EAB HIA as aligning with their agenda.

One existing group that could have been utilized more is the Saint Paul Tree Advisory Council. This is a group convened by Saint Paul Forestry staff that meets quarterly and is comprised of concerned citizens. This group offers citizen input to Forestry staff and helps to advocate for Saint Paul's urban forestry needs.

Stakeholders participating in the HIA were able to mobilize together during the HIA process to work together on other urban forestry related initiatives. Among these initiatives were:

- Successfully applying for a 3-year, $800,000 grant from Minnesota's Environmental and Natural Resources Trust Fund (lottery dollars) focused on the development of volunteer programs to meet local urban forestry needs
- Developing a policy proposal for urban forestry as part of the state's Climate Strategies and Economic Opportunities project. The policy identifies the economic benefits to the state of investing in urban forestry with an eye towards reducing greenhouse gas emissions (carbon storage and sequestration), energy savings and stormwater management benefits. The proposal is being advanced for further consideration and is well regarded by leadership from multiple state agencies.
- Providing leadership to Clean Air Minnesota's Urban and Community Forestry workgroup
- A regional approach to EAB management and urban forestry planning

This HIA leveraged the experience, interests and concerns of stakeholders to inform the process and the report itself.

Managing the process

This HIA was carried out according to a workplan, originally developed at the project launch by the HIA project coordinator based on the six steps of HIA. This was the first HIA conducted at the MPCA, as well as the first HIA conducted by the HIA project coordinator, so there was a learning curve. Although the project received a no-cost extension, the agency used time and resources reasonably well. Some of the time during the year was directed at other tree-related initiatives that were offshoots of this HIA project. The stakeholder group welcomed and celebrated these activities and recognized the HIA process and project coordinator as playing a critical role in advancing the urban forestry agenda. The modified project timeline was adhered to and final deliverables were submitted to Pew within the designated grant period.

The estimated cost to conduct the HIA is reflected in the Pew grant award, approximately $90,000 over a 16 month period. The vast majority of these costs were directed to salary and benefits for the project coordinator and student worker.

Conducting this HIA built the organization's capacity to conduct HIAs because of the involvement of staff, both the HIA coordinator and others. Capacity was also gained by the HIA project coordinator's participation in the local HIA Coalition and Interagency HIA Work Group convened by HIA staff at the Minnesota Department of Health (MDH). Interaction and free-flowing conversation between the HIA project coordinator and MDH HIA staff allowed for quick fact checks or shared advice on approach, which was beneficial over the full timeframe of the project.

Stakeholders were not asked to sign formal agreements about their involvement in this HIA project. There was a sustained level of interest in the project both due to stakeholder recognition about the immediacy of the EAB issue in Saint Paul as well as the opportunity to participate in an HIA, which was the first such opportunity for many on the stakeholder group. Despite the lack of formal agreement, stakeholders remained engaged and interested in the project throughout the project period.

Appendix 5: Impact evaluation/monitoring plan

Impact on HIA partners and stakeholders

To examine the impact of the EAB HIA project on participants, an online survey was conducted of 34 individuals (advisory committee members and people that attended the HIA training) using Survey Monkey. The survey was open from December 10-24, 2014. Of the 34 individuals invited to participate, 20 completed the survey, which consisted of 8 questions plus an optional "further comments" section. Questions were developed based on other HIA impact evaluation survey questions. Results are summarized below.

Impact survey results

Question	Responses	%
Why is your organization/agency interested in EAB/urban forestry? (fill in the blank format)	· Managers of urban forest in SP · To help plan for loss of ash trees, which area a substantial portion of Saint Paul's urban forest · We have EAB and want to do the right thing regarding all aspects, including health consideration impacts of work to be done · It will impact our community. · health impact potential · University of Minnesota · How urban forestry might affect air pollution and GHG levels. · City of Saint Paul-Forestry, responsible for urban forestry management and directly impacted by emerald ash borer · Protecting the City of Saint Paul · Public Health Dept. and operate several residential brush collection sites; public outreach/awareness around the issue · Losing significant canopy and important soil infiltration space is vital to protecting healthy urban surface waters, and Ash trees provide habitat for a variety of species of birds and animals. We're also interested in vibrant, healthy communities and see the association between a healthy urban green space and public health. · We sell and maintain plants and landscapes · It is impacting trees within our corridor. · Emerging threat to natural resources and to overall city resiliency · It is our role to provide unbiased information and conduct ethical research on urban forest health. · Conservation of natural resources for ongoing health of the community · Several reasons, including climate adaptation, community sustainability, and air quality · yes · Currently researching EAB in urban forests	N/A

Question		Responses	%
Why did you choose to participate in the EAB HIA project?		Interested in EAB/urban forestry	70
		Want to learn more about HIA	45
		Contribute to a project connecting health with urban forestry	70
		Build relationships with others who share concerns about issues I care about	55
		Required by my job	30
		Other	0
Please rate your overall experience with the EAB HIA project		**Excellent**	**55**
		Good	**45**
		Fair	0
		Poor	0
Please rate your understanding of the following **BEFORE** the HIA:	EAB	**Excellent**	**45**
		Good	30
		Fair	25
		Poor	0
	Health impacts of EAB	Excellent	10
		Good	15
		Fair	**45**
		Poor	30
	How certain populations may be affected differently by EAB and subsequent tree loss	Excellent	10
		Good	15
		Fair	**45**
		Poor	30
	HIAs	Excellent	5
		Good	15
		Fair	**50**
		Poor	30
	The ways HIAs can	Excellent	5

Question		Responses	%
	improve decisions in non-health sectors	Good	25
		Fair	30
		Poor	**40**
Please rate your understanding of the following **AFTER** the HIA:	EAB	**Excellent**	**50**
		Good	**50**
		Fair	0
		Poor	0
	Health impacts of EAB	Excellent	35
		Good	**60**
		Fair	5
		Poor	0
	How certain populations may be affected differently by EAB and subsequent tree loss	Excellent	30
		Good	**55**
		Fair	15
		Poor	0
	HIAs	Excellent	15
		Good	**80**
		Fair	5
		Poor	0
	The ways HIAs can improve decisions in non-health sectors	Excellent	20
		Good	**80**
		Fair	0
		Poor	0
Please rate your agreement with the following statements:	HIA was informed by input from a diverse group of stakeholders	Strongly agree	40
		Agree	**55**
		Neutral	0
		Disagree	0

Question		Responses	%
		Strongly disagree	0
		Don't know	5
		Not applicable	0
	HIA process was able to incorporate new, relevant information	**Strongly agree**	**45**
		Agree	**50**
		Neutral	5
		Disagree	0
		Strongly disagree	0
		Don't know	0
		Not applicable	0
	There was a meaningful opportunity for stakeholders to comment on the final report	Strongly agree	30
		Agree	**70**
		Neutral	0
		Disagree	0
		Strongly disagree	0
		Don't know	0
		Not applicable	0
	The report was clear and easy to read	Strongly agree	20
		Agree	**80**
		Neutral	0
		Disagree	0
		Strongly disagree	0
		Don't know	0
		Not applicable	0
	I agree with the recommendations in the report	Strongly agree	10.53
		Agree	**73.68**
		Neutral	10.53
		Disagree	0
		Strongly disagree	0
		Don't know	0
		Not applicable	0

Question		Responses	%
	The HIA report addressed the most important health impacts of the EAB Plan	Strongly agree	15
		Agree	**75**
		Neutral	10
		Disagree	0
		Strongly disagree	0
		Don't know	0
		Not applicable	0
	My input was taken into account in the final report	Strongly agree	25
		Agree	**60**
		Neutral	5
		Disagree	0
		Strongly disagree	0
		Don't know	0
		Not applicable	10
	Saint Paul urban forestry decisions will be more health-supportive because of this HIA	Strongly agree	25
		Agree	**40**
		Neutral	15
		Disagree	0
		Strongly disagree	0
		Don't know	15
		Not applicable	5
	This HIA lends credibility and/or political support to other urban forestry efforts at the local or state level	**Strongly agree**	**40**
		Agree	**55**
		Neutral	5
		Disagree	0
		Strongly disagree	0
		Don't know	0
		Not applicable	0
	Comments	· I believe Saint Paul's forestry decisions will be done thoughtfully but only realized if funding becomes available to allow it to perform in the manner that is recommended. · The HIA broadens the discussion of urban forestry to include health, which is something that everyone can connect with so I	

Question		Responses	%
		think the benefits, recommendations, and decision making process of urban forestry management will be improved with these considerations. Bringing together a wide range of stakeholders will certainly increase the validity of the arguments for connecting EAB, urban forest management, and health…hopefully resulting in an enhanced and functionally vital urban forest.	
Stakeholders established project goals early in the process. In your opinion, were these goals met?	Inform the future of Saint Paul's EAB management plan and build capacity to advance recommendations emerging from this HIA	**Yes**	**85**
		No	0
		Don't Know	15
	Identify impact of trees on human health	**Yes**	**100**
		No	0
		Don't Know	0
	Advance the dialogue of how urban trees impact human health, and the importance of including human health impact as a factor in decisions about urban trees	**Yes**	**100**
		No	0
		Don't Know	0
	Forge lasting relationships among partners/stakeholders that will go beyond this HIA	**Yes**	**63**
		No	5
		Don't Know	32
	Build capacity for HIA among project partners	**Yes**	**63**
		No	0
		Don't Know	37
	Comments	· The HIA definitely will impact/inform the future of the EAB Management Plan but the question of whether capacity has been built to advance recommendations is still to be determined. · The HIA certainly expands and strengthens the dialogue and literature on urban forests and health. I'm hopeful that ongoing	

Question		Responses	%
		partnerships will continue to discuss the role of urban forests in creating urban landscapes that support the health of residents and ecological vitality of the metropolitan region. It would be great to initiate an ongoing discussion/working group to continue to develop design and management practices to further the discussion of health and the built environment…perhaps urban forestry is the first part of a broader study of the health impacts related to urban design etc…?	
Please rate your agreement with the following statements:	The HIA is useful to me or my organization	Strongly agree	35
		Agree	**50**
		Neutral	15
		Disagree	0
		Strongly disagree	0
		Don't know	0
		Not applicable	0
	The HIA has informed my opinion about Saint Paul's EAB Plan	Strongly agree	32
		Agree	**53**
		Neutral	11
		Disagree	0
		Strongly disagree	0
		Don't know	5
		Not applicable	0
	I have shared or plan to share information about this HIA with others	**Strongly agree**	**35**
		Agree	**35**
		Neutral	20
		Disagree	0
		Strongly disagree	0
		Don't know	10
		Not applicable	0
	This HIA has informed/will inform my work	Strongly agree	25
		Agree	**60**
		Neutral	10
		Disagree	0

Question		Responses	%
		Strongly disagree	0
		Don't know	5
		Not applicable	0
	I will likely participate in more HIAs in the future	Strongly agree	10
		Agree	**35**
		Neutral	**30**
		Disagree	0
		Strongly disagree	0
		Don't know	25
		Not applicable	0
	I will likely draw upon HIAs done by others in my future work	Strongly agree	10
		Agree	**45**
		Neutral	20
		Disagree	0
		Strongly disagree	0
		Don't know	25
		Not applicable	0
	Comments	The HIA process is time-consuming and there is a learning curve so I see that as challenges. For example, I'd love to see an HIA on the Dorothy Day expansion yet I've had a hard time convincing local community people involved that this would be a good platform for them to help "inform" Catholic Charities and the City.	
Further comments about this project		· Thanks, and great job, Sarah! · MPCA staff were great to work with and really care, as well did most others who participated. · Thanks for exploring the connections between trees and health it's an area that needs further literature and research and this takes a step in that direction. · Thanks for all your hard work! The HIA really brought forth new concepts on the potential effects of EAB on our community and it was great to see how many organizations and individuals were interested in collaboration.	

The survey results indicate that the HIA has built capacity among partners to conduct HIAs:

- 100% of respondents indicated an "excellent" or "good" overall experience with the EAB HIA project.
- 85% of respondents "agree" or "strongly agree" that this HIA informs their work
- 70% have shared or plan to share information about this HIA with others
- 33 individuals attended a 2-day HIA training as part of this EAB HIA project

Before and After HIA questions indicate that most participants shifted from Fair to Good in terms of their knowledge of HIAs and how the EAB HIA connects health and tree loss.

Ninety percent of participants indicated they strongly agree or agree that the HIA process was able to incorporate new, relevant information, and 95% indicate they strongly agree or agree that this HIA lends credibility and/or political support to other urban forestry efforts.

This HIA led to new partnerships and initiatives to support urban forestry at a local and state level, and in so doing, encouraged new cross-sector collaboration. Participants in the HIA advisory committee worked together to support a proposal to the state's Environmental and Natural Resources Trust Fund. The proposed project would develop a volunteer corps to support urban forests in several cities throughout Minnesota. HIA advisory committee members also worked together to advance an urban forestry policy initiative through the state's Climate Strategies and Economic Opportunities initiative. One of the community stakeholders participating in the advisory committee worked to develop a new roadside vegetation program called Community Roadside Partnership, in cooperation with MnDOT and the City of Saint Paul.

The EAB HIA engaged stakeholders in a meaningful way. According to survey results, 95% of participants strongly agree or agree that the HIA was informed by input from a diverse group of stakeholders, about 85% agree with the recommendations in the report, and 100% strongly agree or agree that there was a meaningful opportunity to comment on the final report.

Proposed indicators for continued monitoring and evaluation of the HIA's impact are outlined in the table below.

Indicators for HIA Impact

Indicator	Agency responsible for monitoring	Timing
Regular and ongoing communication among city departments regarding urban forestry	Saint Paul Forestry	2015
City stormwater staff continue to conduct innovative pilot projects involving trees	Saint Paul Office of Safety and Inspections	2015
Increased use of rain gardens on boulevards to capture stormwater	Capitol Region Watershed District Ramsey Washington Watershed District	2015-2020
Increased volunteer activity to support urban forestry	Saint Paul Forestry	2015-2018

Indicator	Agency responsible for monitoring	Timing
Replacement trees are planted at or greater than 1:1 ratio	Saint Paul Forestry	2015-2025
Vulnerable neighborhoods are identified based on canopy % and asthma/COPD diagnoses and targeted for increased urban forestry activity	Saint Paul-Ramsey County Public Health Saint Paul Forestry	2015-2020
Designated bike and walking paths have tree cover	St. Paul Smart Trips Saint Paul Parks and Recreation	2015-2020
Creation and implementation of 5-year community forestry plan	Saint Paul Forestry	2015-2020
Increased presence of trees near business and industry	Saint Paul Forestry Saint Paul Chamber of Commerce	2015-2020
Trees included in disaster planning/climate preparedness strategies	Saint Paul Department of Planning and Economic Development	2015-2020
Soil and leaf sampling occurs on an annual basis to verify safety of pesticide use	Minnesota Department of Agriculture	2015-2025
Adequate information about EAB, the city's EAB plan, and options for private trees is available	Saint Paul Tree Advisory Panel (citizen advocates)	2015-2025

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