2012

City of Mississauga Emerald Ash Borer Management Plan

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For the City of Mississauga:

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PREFACE

This report was authored by Kenneth R. Marchant, Plant Health Consultant for use by The City of Mississauga. Its purpose is to provide the client with a summary of the status of the emerald ash borer in North America, its anticipated impacts on the City of Mississauga and a range of options which could be employed to manage this insect pest and mitigate its impact.

DISCLAIMER

The information contained in this report has been compiled through: personal interviews with research scientists, regulators, city foresters and others; extensive consultation with local conservation authorities and municipalities; and reviews of literature, research papers, and media reports. The author has also relied extensively upon his hands-on experience and knowledge of the issue gained in his former capacity as Emerald Ash Borer Lead Specialist for the Canadian Food Inspection Agency and as a private consultant on this issue. This report has been designed to meet the Terms of Reference specified at the outset of the project by the client and incorporates suggestions and recommendations from the City of Mississauga staff.

While considerable research has been conducted on EAB since it was first discovered in North America in 2002, there is still much to learn. For this reason there needs to be some latitude with respect to predicting its impacts, population development and the overall effectiveness of the management option selected by the client. The information and recommendations contained in this report are based on the most current scientific information and regulatory requirements as of January 1, 2012.

ACKNOWLEDGEMENTS

I would like to thank the members of the Mississauga working group (Gavin Longmuir and Sarah Jane Miller) for their guidance and contributions to this report and to the numerous persons who have provided me with the information on which it is based.

In addition to the working group members, the author was required to consult extensively with scientists, regulatory and quarantine experts, municipal officials and numerous others involved in managing or regulating EAB in Canada and the United States. Their cooperation in providing me with the information to develop this report is greatly appreciated.

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EXECUTIVE SUMMARY

The emerald ash borer (EAB), *Agrilus planipennis* Fairemaire, is considered to be one of the most damaging invasive alien forest pests to ever be introduced to North America. EAB has killed or infested, by some reports as many as 70 million ash trees since it was first detected in Michigan, and south-western Ontario in 2002; an estimated 10 billion ash trees in Canada and the US are at risk of infestation and death. Both Canada and the US consider EAB to be a pest of quarantine significance. Slowing its spread and protecting the North American ash resource is a top priority for both countries.

Despite aggressive control, regulatory and communication measures aimed at slowing its spread, new populations continue to be found at numerous locations in both countries. These are often determined upon investigation to be the result of past human activities such as the movement of infested nursery stock and forest products (especially firewood). EAB was found in Toronto in the fall of 2007 and at numerous other sites in the Greater Toronto Area (GTA), including the Town of Oakville (Halton Region), and the City of Mississauga in 2008. As of January, 2012, EAB has now been confirmed at numerous locations throughout Mississauga and is believed to be well established there.

As of March, 2011, Mississauga is included in an enlarged, amalgamated, federally regulated area which includes most south-western Ontario counties and regional municipalities. Free movement of regulated ash materials such as nursery stock, logs and firewood is now permitted within the zone. Unfortunately, while the amended zone will ease the burden on some affected stakeholders, it is accepted that it will greatly exacerbate the spread of EAB through human activities and increase the risk of EAB spreading to adjacent (but currently non-infested) areas.

Despite considerable research, the major obstacles to the effective management of EAB continue to be the extreme difficulty of reliably detecting it at low population levels and treating trees in woodland or forest settings.

TreeAzin™ (a natural pest control product derived from the neem tree, *Azadirachta indica)* has been used effectively by several municipalities over the past few years to protect street, as well as some park and cemetery trees against EAB. While the Canadian emergency registration status of this product expired on August 31, 2011 it is expected that it will receive full registration from Health Canada-Pest

Management Regulatory Agency (PMRA) over the next year and will be available for use in 2012 and beyond on a permanent basis. While there is data to support the distributor's claim that the product is both safe and efficacious, it is not considered cost effective to use this product to protect woodland trees and little can be done to save the millions of ash trees in Ontario's forests and woodlands at the present time.

The Canadian Food Inspection Agency (CFIA) is Canada's lead agency with respect to regulating or managing pests of quarantine significance such as EAB. Its current strategy is to slow-the-spread of EAB through quarantines and other regulatory initiatives as well as public awareness. Despite numerous requests from affected municipalities to the federal and provincial governments for financial assistance to mitigate the impact of EAB, none has been forthcoming. This position is unlikely to change.

This document provides a description of the pest's biology and a detailed summary of available management tools and initiatives. As well, a detailed risk analysis with respect to EAB in Mississauga is presented along with a selection of feasible management options, including their associated costs and impacts.

Assuming that EAB continues to infest and kill trees at its present rate, that biological control organisms do not emerge as a major control factor and that the current limitations on pesticide efficacy do not change, it can be expected that EAB will become pervasive throughout Mississauga and neighbouring communities over the next 10 years and kill most of the untreated ash trees. Based on comparisons with similarly affected municipalities, pockets of EAB induced mortality should be in evidence in 2012 with mass mortality expected in some areas by 2015. It is important to point out that the majority of trees are in woodlands and on private properties and while some of the management options listed in this document may delay the onset of widespread mortality somewhat and save some high value street, park and cemetery trees, there is little that can be done at this time to prevent the loss of most of the ash trees in Mississauga.

If Mississauga is to preserve some of the ash component of its urban canopy, it is highly recommended that it act now. At risk are an estimated 23,211 ash street trees (representing 9.6 percent of its total street tree inventory); and a similar number of ash park trees and cemetery trees. There are also approximately 68,000 ash trees in city-owned woodland and natural areas within the City. With removal, disposal and replacement costs estimated at around $1,200 per tree, it could cost the City of Mississauga a minimum of $57,000,000 over the next ten years just to remove and replace its dead street, park and cemetery ash trees. While trees in woodlands

cannot readily be protected from EAB, the impacts of EAB infestation can be somewhat mitigated through site management and remediation activities.

In addition to occurring naturally in large numbers, ash is also widely planted on private properties throughout the City and homeowners would be required to shoulder similar costs for removal of their dead trees. While Mississauga does not assume responsibility for trees on private property, it can order their removal under its Property Standards By-law where they are deemed to be hazardous. Costs for trees removed on private property would be assumed by the property owner.

Summary of Possible Management Options

This document provides a detailed analysis and expected outcomes of three possible options which could be employed by Mississauga and similarly affected communities to manage EAB. All options entail the replacement of removed trees with caliper trees.

The Options are:

- Minimal Management/No Management
- Active Management
- Aggressive Management

1. ***Minimal Management/ No Management*****:** Ash trees would be treated the same as any other urban tree species and would only be removed if they die or become hazardous. There would be no surveys specific to EAB, no pesticide treatments of trees and limited public awareness activities. It can be expected that much of the ash component would die over the next five years with expected mortality of untreated trees approaching 100% within 10 years. Costs to the City are estimated at **$57,000,000** over a 10 year period.

2. ***Active Management*****:** The objective of this option is to preserve a percentage of the ash component in areas of the city which would be heavily impacted by EAB over the next 10 years. To this end, Mississauga would actively conduct detection and delimitation surveys to detect pockets of infestation and prioritize areas for treatment. All known infested ash trees on City properties would be promptly removed or treated and the City would treat viable ash trees in some communities with large populations of ash street trees. The City

may, at its discretion encourage private property owners to treat ash trees on their properties but would not undertake to pay for this. The City plans to treat 5,000 ash trees in cemeteries and parks but not in woodlands. Most of the untreated trees would be expected to die and become hazardous within five years. Costs to the City are estimated at around **$51,000,000** over a 10 year period (commencing in 2013).

3. ***Aggressive Management:*** The objective of this option is to save as many ash trees as possible and slow the spread of, or even eradicate EAB at a local level. This option is best suited to lightly infested municipalities situated beyond what is considered to be the general area of infestation and where the introduction of EAB can be attributed to a singular event such as the movement of firewood or nursery stock. In areas with a pervasive, well established EAB population (such as Mississauga and its neighbouring communities), there is no expectation that this option could effectively reduce or otherwise manage EAB populations. For this option to be successfully implemented, a municipality would be required to conduct intensive detection surveys of its street and park trees to detect EAB early in the infestation. Infested trees would either be promptly removed or treated depending on their condition. Additionally, all ash trees within a defined radius (generally 0.5 to 1.0 km) of these would either be treated or removed. The main limitations of this option are the extreme challenges of detecting EAB early on in the infestation, treating woodland ash, and the inability to legally force private property owners to treat or remove infested ash. Costs to the City of Mississauga for fully implementing this option cannot be accurately predicted at this time as there is no data for woodland trees or those on private property.

In consultation with the City of Mississauga, Option 2 (Active Management) is recommended. Recent studies have concluded that treatment with pest control products such as TreeAzin™ are actually cheaper over a ten year period than pre-emptive tree removal. Additionally research currently being conducted in Canada and the US suggests the period of cost effectiveness could be as long as 20 years where other parameters (such urban environmental and real estate values) are factored in. Should less expensive products become registered over the next few years (such as TREE-äge® (Emamectin Benzoate)) it would be even more cost effective to treat than to replace healthy trees.

DEFINITIONS

Cambium/Cambial Layer:

A layer of cells that forms tissues that carry water and nutrients throughout the plant. On its outer surface, the vascular cambium forms new layers of phloem, and on its inner surface, new layers of xylem (see definitions).

Canadian Food Inspection Agency (CFIA):

A Canadian Federal agency reporting directly to the Federal Minister of Agriculture and Food and responsible for: Food Safety, Animal Health and Plant Heath (Quarantine) in Canada. Under the Canadian Food Inspection Agency Act (1997), the CFIA is Canada's National Plant Protection Organization as defined by the United Nations and is the lead agency with respect to excluding, eradicating or otherwise managing pests of quarantine significance. As well it certifies exports of agricultural and forest product for freedom from injurious and/or quarantine pests.

Disparate/Disjunct Populations:

With specific respect to the Mississauga EAB Management Plan these terms refer to populations which are separate from the general contiguous population of EAB. These are often the result of the introduction of EAB to a new area through natural dispersal or human activities **(see Outlier).**

D-03-08:

Refers to CFIA Policy Memorandum D-03-08: "Phytosanitary Requirements to Prevent the Introduction into and Spread Within Canada of the Emerald Ash Borer, *Agrilus planipennis* (Fairmaire)" [Oct. 27, 2010] http://www.inspection.gc.ca/english/plaveg/protect/dir/d-03-08e.shtml

Endemic:

Endemic means native to, or confined to an area. It can also include long established (naturalized) organisms which are now considered part of the local flora and fauna.

Epicormic Shoots:

Shoots generally produced along the trunk or main branches of a tree, often as a response to an injury or damage to the underlying tissues. These are often long and vigorous.

Extirpated:

Refers to an organism that no longer exists (extinct) in an area where it formerly occurred, but is still present (extant) in other areas

Invasive Alien Species (IAS):

IAS are organisms which originate elsewhere and are not native to the area. Human involvement is implied in their introduction to the new area (either deliberate or accidental) and there generally has to be (the potential for) economic or environmental harm before they can be classified as IAS. This term is generally synonymous with and used in place of such words as: "exotic", "foreign" or, "introduced and established" although most exotic

organisms would not qualify as IAS, because they have minimal economic or environmental impacts.

Natural Resources Canada-Canadian Forest Service (CFS):
Better known as the "CFS", this Canadian government department is responsible for conducting research on forest pests (as well as numerous other forestry related concerns). The CFS has been instrumental in conducting leading edge research on Emerald Ash Borer and providing insightful science-based advice to the CFIA and other partners.

Nested Quarantine:
This is a quarantined area, established within a larger quarantined area (or zone). It is considered a highly beneficial strategy for slowing the spread of pests of quarantine significance such as EAB, especially where they are difficult to detect in the early stages of infestation, and as well, protecting adjacent counties not believed to be infested.

Outlier:
With specific reference to invasive alien species such as EAB, an outlier is a population disjunct from a generally infested area. It is usually considered the result of an introduction event from an infested area through the movement of infested forest products such as firewood but can be the result of natural dispersal **(see Disjunct)**.

Parasitoid/Parasitoidism:
A **parasitoid** is an organism (usually an insect) that spends a significant portion of its life cycle attached to, or within a single host organism but which it ultimately consumes and kills in the process.

Phloem:
This is the tissue in a plant responsible for the active conduction of water, nutrients and metabolites throughout the plant and along with the **xylem** comprises the vascular area of the plant.

Pest of Quarantine Significance
This is a plant pest considered by virtue of pest risk assessments or past history, to pose a major economic or environmental risk to a geo-political entity (e.g., country, province or state). To be defined as such, there must be science-based evidence that the pest poses a risk to the importing country. Under the terms of the International Plant Protection Convention (United Nations), counties are not permitted to use non-quarantine pests as non-tariff trade barriers and must provide documented, science-based evidence that an organism is a pest of quarantine significance or, face stiff penalties in the event of a challenge by an importing, or competitor country. Countries are legally obligated to eradicate or prevent the domestic spread of pests of quarantine significance where these are present in their country.

Pest Risk Assessment (PRA):
PRA is the science based analysis of the potential of an organism to become a pest species. The assessment examines factors such as host and climatic suitability, pathways, vectors and

potential environmental, ecological and environmental impacts. Potential pests are usually evaluated within a logic matrix and numerical scores are assigned to the pest permitting it to be ranked and compared to other potential pests. Canada and other developed counties use PRA as a decision making tool with respect to regulating potential pests or the commodities and pathways by which they could be introduced.

Quarantine Zone:
See Regulated Area.

Regulated Area:
With specific respect to the Mississauga EAB Management Plan, **Regulated Area** refers to areas of Canada regulated under Federal Ministerial Order for Emerald Ash Borer. By way of these orders, regulated areas are quarantined with respect to the movement of the pest and articles such as ash forest products, nursery stock and firewood which have all been determined to be vectors of EAB.

Trap Trees:
Ash trees which are girdled by regulatory officials prior to the EAB flight season in order to stress them and make them more attractive to EAB adults. They are destructively sampled (cut and peeled) at the end of the growing season and analyzed.

UFORE
UFORE is an acronym for "Urban Forest Effects" and refers to a computer model that calculates the structure, environmental effects and values of urban forests. The model was developed by the USDA-Forest Service (see below) in the late 1990s and software is now in the public domain. Further information can be obtained at: http://nrs.fs.fed.us/tools/ufore/ or www.**ufore**.org/**UFORE** manual.doc

United States Department of Agriculture (USDA):
The USDA (in part) is the US counterpart to both the CFIA and CFS. APHIS (the Animal and Plant Health Inspection Service) is responsible for designing, and enforcing import, export and domestic programmes to exclude or limit the spread of pests of quarantine significance such as EAB, while the Forest Service (USDA-FS) conducts research into the management of forests pests including those of pest significance such as EAB)

Xylem:
This refers to the supporting and water conducting tissue of vascular plants, consisting primarily of tracheids and vessels. It is generally woody tissue. The **xylem** and the **phloem** comprise the vascular region of the plant and are responsible for the movement of water and nutrients within the plant.

1.0 INTRODUCTION AND BACKGROUND

1.1 Discovery in North America

EAB was first confirmed in North America in July of 2002, after it was found in declining trees in Detroit, Michigan and Windsor Ontario exhibiting "disease" symptoms. Prior to this, EAB was essentially unknown to the western world and had not been considered by plant quarantine experts to be a high risk species for entry to North America. A follow-up survey by US state and federal authorities confirmed EAB to be present at numerous sites in the greater Detroit area. It was also confirmed to be in the Windsor area of Canada by the CFIA in August of 2002, where it had apparently been present for many years and was now killing trees. In the summer of 2002, a pest risk assessment (PRA) conducted by the CFIA, concluded that EAB would likely be a serious and damaging pest of quarantine significance in North America.

1.2 Dispersal and Establishment

At the time of its discovery in North America EAB was already well established. Research has confirmed that it arrived in the Detroit area of Michigan in the early 1990s, probably with infested packaging and crating materials from China. The role that human activities played in the spread of EAB was not fully appreciated at that time and there is now evidence that it was already well established by 2002 at numerous locations throughout the mid-western US and Ontario.

While EAB can fly well and will disperse naturally, much of its distribution within North America can be directly attributed to the movement of ash nursery stock and forest products, especially firewood. It is important to note that it may take as long as five years after it has been introduced to an area before signs and symptoms are manifested in the tree (which greatly limits the effectiveness of any control actions which may be taken against it). Early (and timely) detection remains the bane of EAB management. Many outliers in Canada and the US have been confirmed to have been established long before quarantines and other control measures were enacted by either country and more are being reported weekly. As many as 70 million ash trees are now estimated by some authorities to have been killed or infested in North America since 2002, with 9-10 billion trees at risk.

1.3 Hosts

Research has confirmed that while EAB attacks other genera of trees in Asia including elms and walnuts, only ash (*Fraxinus* spp.) are attacked in North America. While all North American ash species are considered to be susceptible, the blue ash (*Fraxinus quadrangulata)*, a rare species in the wild in Canada but often planted as an ornamental, is considerably more resistant to attack and is surviving in some areas

of south-western Ontario. Of particular concern in Ontario is the fate of the pumpkin ash (*F. profunda),* an extremely rare Carolinian species only confirmed to be present in Canada in the early 1990s (and not believed to naturally occur in Mississauga). While some seedlings are surviving in some Windsor area woodlands, mortality in Ontario pumpkin ash stands is now approaching 100 percent and there is concern that this species may be extirpated from Canada in the very near future with its inherent genetic diversity lost forever. The European ash, (*F. excelsior),* very commonly planted in urban areas of eastern Canada, is also susceptible to EAB attack. Asian species such as the Manchurian ash (*F. mandshurica)*, which are sometimes planted in Canada and have been crossed with native species to produce ornamental cultivars, have co-evolved with EAB and are relatively resistant to attack when planted in North America. Unfortunately, all hybrids currently in use are very susceptible to EAB.

1.4 Distribution in North America

As of November, 2011, EAB now generally infests much of south-western Ontario where most ash trees are now dead or dying (*see Figure: 1).* Localized, but expanding infestations are now present at numerous locations in Ontario, including Sault Ste. Marie and several sites in eastern Ontario and Québec; presumably the result of human activities and natural dispersal around introduction sites (outliers).

EAB was confirmed in Toronto in the fall of 2007, and in York, Mississauga and several other areas around the GTA in 2008. In 2009, EAB was detected in Hamilton, (at several locations), St. Catharines and Welland, Ontario. In 2010 many new counties and municipalities in southern Ontario such as the City of Burlington, Wellington, Oxford and Perth Counties as well as the Region of Waterloo were determined to be infested. In March of 2011, the CFIA amended the Ministerial Orders in force under the Plant Protection Act to include these new areas. Mississauga is now included in a greatly expanded quarantine zone that comprises much of southern Ontario (*see Figure: 1*). Recently, EAB was confirmed on Manitoulin Island in Ontario and it is apparent that EAB is now well established at many locations in Ontario and Québec with more expected to be confirmed over the coming years.

Despite aggressive control measures including eradication efforts in the state of Maryland (where it was introduced on illegally moved nursery stock in 2002), State and Federal quarantines, and public relations blitzes, EAB continues to be found in new areas of the US. EAB now infests much of the central and eastern areas of the country (*see Figure: 2).* As in Canada, most of the new infestations are attributed to past human activities such as the movement of infested firewood and forest products, and natural dispersal around these.

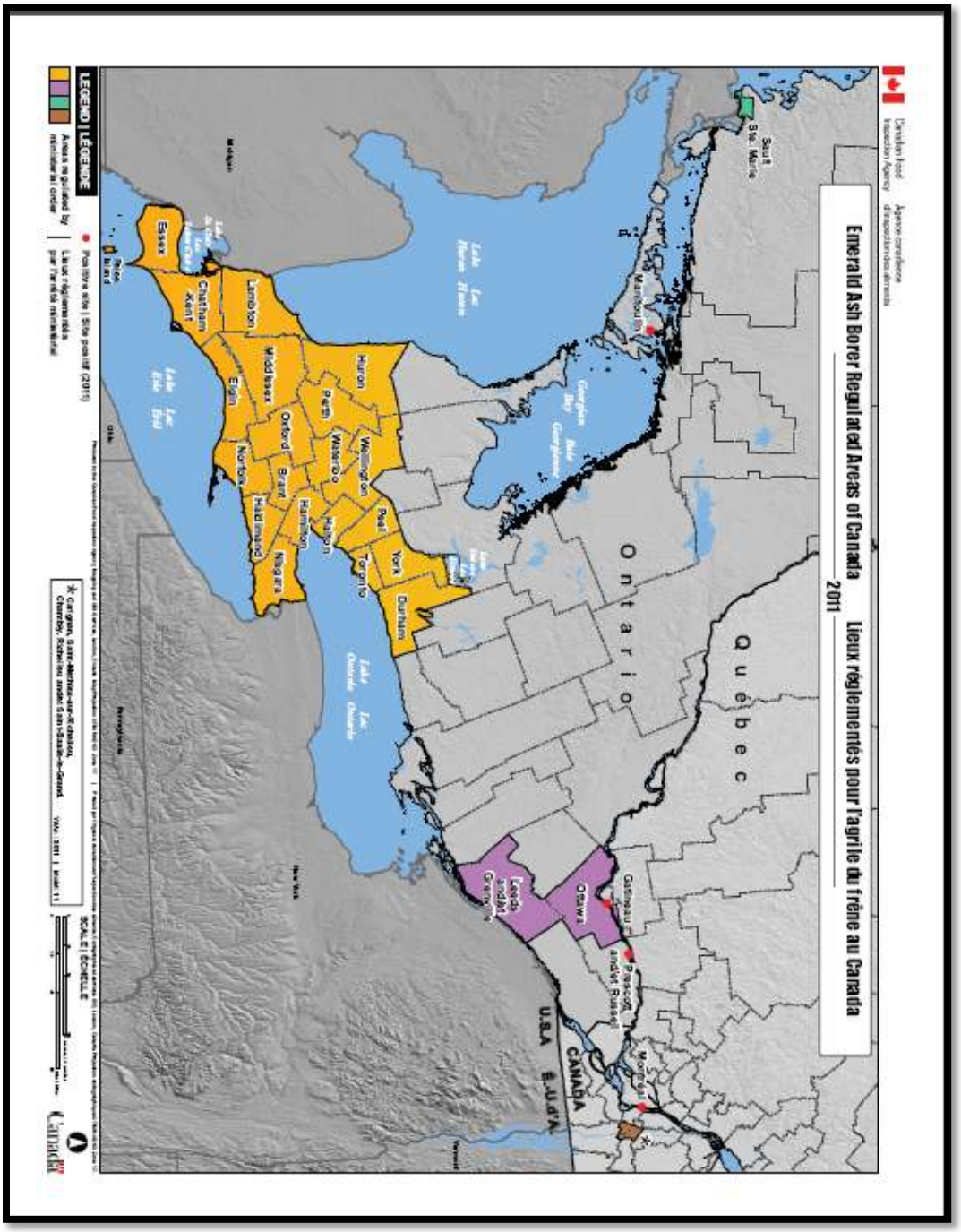


Figure 1: EAB Regulated Areas of Canada ***(current to January 30, 2012)***

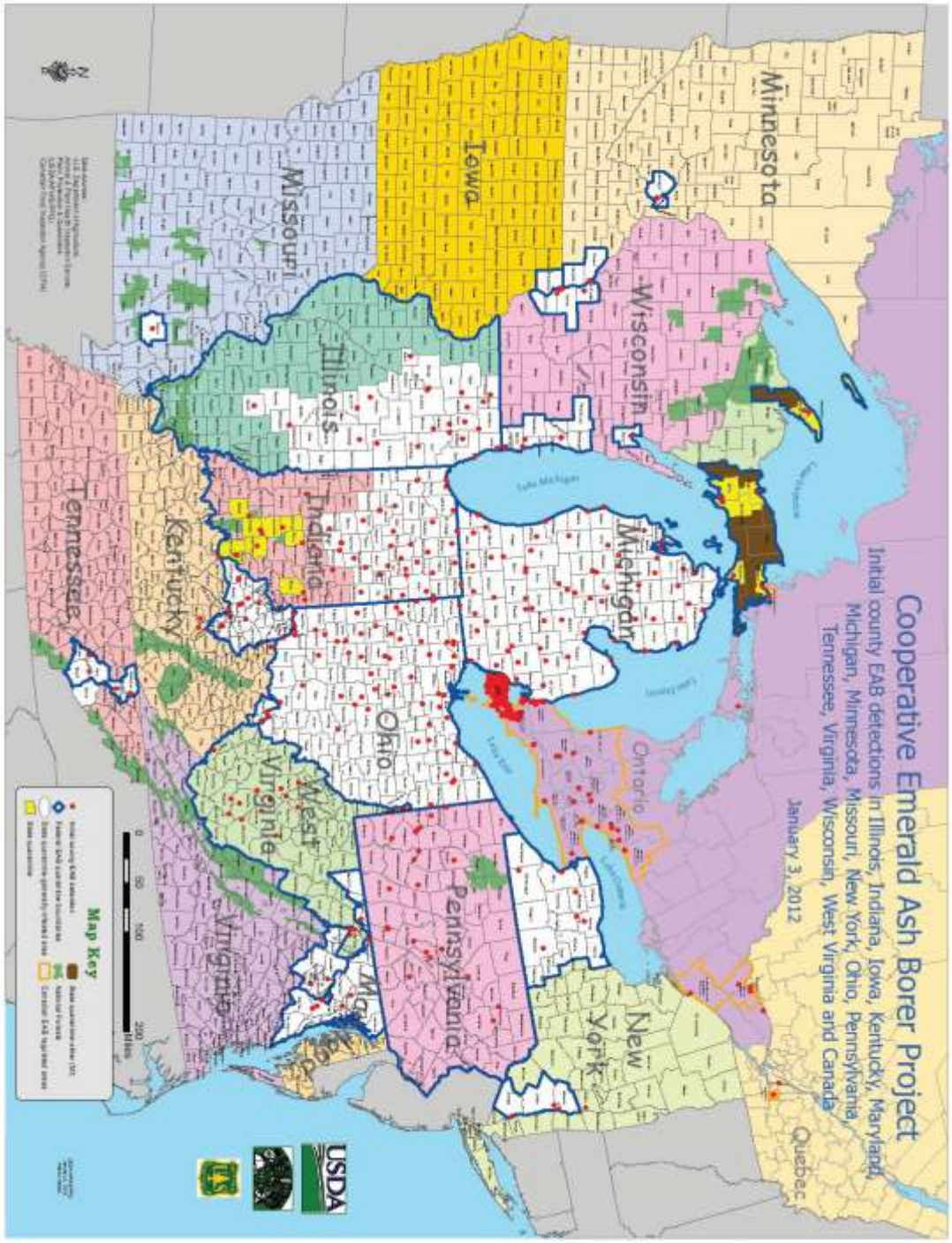


Figure 2: EAB Infested and Regulated Areas of North America ***(current to Jan. 3, 2012)***

2.0 REGULATORY AUTHORITIES AND RESPONSIBILITIES IN CANADA

2.1 Canadian Food Inspection Agency

Canada is a signatory to several international treaties under which it is required to report, monitor and take appropriate actions against pests of quarantine significance such as EAB. Failure to do so could result in economic sanctions being taken against Canada, loss of access to markets for agricultural and forestry products, and other penalties.

Under the Canadian Food Inspection Agency Act, the CFIA has been designated Canada's official national plant protection (and quarantine) organization and is the lead agency in Canada with respect to developing regulatory policies for forest and agricultural pests of quarantine significance such as EAB. The CFIA is empowered under the Plant Protection Act and Regulations which give it the authority to enact and enforce regulations and policies to protect Canada's agricultural and forestry production base, environment and natural resources and to take all necessary actions to exclude, eradicate or otherwise manage invasive pests of quarantine significance. To this end, the CFIA works in close cooperation with other Canadian federal and provincial government partners as well as the USDA to develop science-based import and domestic movement regulations as well as inspection, surveillance and suppression strategies for EAB and other quarantine pests.

2.2 Provincial Governments

In Canada, provincial governments are responsible for the management of natural resources such as woodlands and forests, as well as environmental protection. Additionally they must approve the use of registered pesticides. While provincial statutes are not permitted to contradict or limit federal legislation, provinces have the authority to enact laws to strengthen or augment federal acts and regulations where they see the need. In Ontario, the Ontario Ministry of Natural Resources (OMNR) has taken a major, albeit non-regulatory role in combating EAB. With specific reference to EAB, they have provided assistance in training CFIA inspectors (and others) on detection and surveys, sponsoring and overseeing scientific research, and with public education and awareness initiatives. OMNR biologists sit on several EAB advisory panels which have provided advice to the CFIA on policy development, research prioritization and regulatory issues. The OMNR Parks Section has been a key partner in limiting the spread of EAB to provincial parks and campgrounds through pre-screening, restrictions on firewood and other activities. Additionally, the OMNR provided considerable funding in 2003 for conservation

authorities in south-western Ontario to plant non-host trees in areas devastated by EAB.

2.3 Municipalities

Municipalities and counties are responsible for managing their street trees, forests, cemeteries and woodlands and play a major role in protecting these from invasive alien species (IAS) such as EAB. Most cities, counties and regional municipalities in Ontario have briefed their respective councils on the impact that EAB will have locally and have provided training to their parks and forestry personnel on detection and recognition. Many cities such as Ottawa, London, Burlington, Hamilton, Toronto and Oakville have already drafted response plans, while several others are in the process of completing plans.

Many urbanized areas of southern Ontario have a multi-tiered municipal structure, with municipalities sharing responsibilities for management of forests, woodlands and roadside trees with the county or regional municipality in which they are situated. Forests and woodlands are not managed on a consistent basis from region to region and the degree of internal cooperation with respect to managing EAB and other forest pest issues varies considerably. Many counties and regional municipalities (especially those without a Regional Forester) leave it up to their constituent municipalities to manage woodlands, especially where these are located in or near urban areas. Despite managing sizeable tracts of woodlands in many areas, conservation authorities (CAs) are not always integrated into the decision making matrix at the county or regional municipality level.

The Regional Municipality of Peel does not have a Regional Forester and its constituent municipalities (Mississauga, Brampton and Caledon) manage their respective urban forests. Mississauga has a good rapport with its urban neighbours and works closely with the Credit Valley, and Toronto and Region Conservation Authorities.

Hazard tree removal in urban areas is non-discretionary. As dead ash trees rapidly decay, they soon pose a hazard (and as well a legal liability) and must be removed promptly. At present there are no federal or provincial monies available to assist with this and many municipalities will be severely impacted by EAB with the potential cost for tree removal alone running into the hundreds of millions of dollars over the next ten years. Accordingly, most major municipalities in Ontario have

petitioned both the federal and provincial governments for additional funding, to offset these costs[1]. To date, these have been without success.

3.0 THE DECLINE OF ASH

Ash has been extensively planted in urban environments as a street tree, and as part of reforestation initiatives. In some Canadian cities such as Ottawa, over 25 percent of the urban canopy is ash, specifically red/green ash (*F. pennsylvanica)*. In addition, most species of ash thrive in disturbed habitats and are often grossly over-represented in both urban and woodland communities as a result of over-planting and past human activities such as logging, animal husbandry or agriculture (ash is thought to have represented only around three percent of the pre-settlement forests of southern Ontario). One of the reasons EAB has had such an enormous impact in Ontario and many areas of the US is the large ash component of many woodlots, especially those in low-lying areas. For instance, prior to the EAB epidemic, it was not uncommon for the ash component of many woodlots in south-western Ontario to exceed 50 percent, with some low-lying woodlots being over 90 percent. This situation has greatly exacerbated the impact of EAB. (*Figure: 3)*

With the anticipated death of millions of ash trees in south-western Ontario alone, EAB is likely to "normalize" the composition of many Ontario woodlots and forests which, in turn will impact on the epidemiology of EAB. Many experts predict EAB populations will sharply decline with the loss of ash and future outbreaks are likely to be far less damaging. EAB is not likely to disappear however, and populations are likely to rebound with the recovery of the ash component of our forests in future years. Generally speaking the impacts of IAS such as EAB are often attenuated over time as a result of the introduction and/or emergence of biological control agents such as parasitoids, predators and diseases and selection of natural resistance in the host.

In addition to being a major forest pest, EAB has seriously impacted urban forests and streetscapes *(Figure: 4).* According to a recent US study[2], it is estimated that nearly 38 million ash grow on developed land in at-risk US states and are expected to perish over the next decade. The annual cost to treat, or remove, and replace

[1] A petition was forwarded to federal and provincial politicians in April 2011 by the Association of Municipalities of Ontario, the Federation of Canadian Municipalities and the Northwestern Ontario Municipal Association

[2] K.F. Kovacs et al. Ecological Economics (2009)

dead trees in these areas will exceed $1 billion per year for the next 10 years. If all dead ash trees in developed areas were removed and replaced, the costs would exceed $25 billion for the same period.

Lastly (and perhaps most importantly), EAB has already had an enormous impact on the genetic diversity of the genus *Fraxinus*. As with other trees genera, our native ash are the result of millions of years of evolution and natural selection and trees are often well suited to local climate and soil types. The anticipated death of hundreds of millions of ash trees is expected to impact the gene pool and will greatly limit the ability of our native ash to rebound once EAB comes into natural balance with the ecosystem. Ash seed has a very limited viability and there is evidence that natural seed banks in heavily infested areas will soon be depleted, limiting the ability of ash to rebound and recover its former prominence. To that end, Natural Resources Canada-Canadian Forest Service (CFS) and other agencies are attempting to preserve some seed representative of the Canadian ash genome.

Figure 3: Ash Killed as a Result of EAB Near Staples, Ont. (Essex Co). Aug. 2009[3]

[3] Photo credit: Ken Marchant

Figure 4: A residential Toronto street where EAB infested trees had to be removed[4]

[4] Photo credit: Jozef Ric, City of Toronto.

4.0 BIOLOGY AND LIFE CYCLE

EAB (*Agrilus planipennis* Fairmaire) is a beetle belonging to the Buprestidae family (commonly known as flat-headed or metallic wood-boring beetles). The adult is usually green with black eyes, (although ruby coloured and golden eyed "morphs" have been observed) approximately 10 to 13 mm long, with a metallic, iridescent lustre, especially on its ventral surface (underside).

There are four life stages: egg, larva, pupa and adult (*Figures: 5-9)*. The adults, which fly well, begin to emerge in late May and can fly up to 5 km at a time with average dispersal being 10 km/year. Most, however, only disperse a short distance (100m) from where they emerged if suitable host material is present in the vicinity.

It is the larval stage which damages the tree by feeding on, and destroying, the phloem and outer xylem layers of the tree under the bark. Larvae feed unseen under the bark and disrupt the flow of vital nutrients throughout the tree including the roots; heavily infested trees soon starve to death. By the time signs and symptoms develop the tree is usually in serious decline and may die soon afterwards. In areas with established EAB populations trees can be mass attacked and killed in one or two seasons.

Eggs, (which are extremely small), are only laid on ash trees from June to late August. These soon hatch into tiny larvae which then mine through the outer bark into the cambial layer beneath where they rapidly grow and undergo four larval stages (or instars). EAB overwinter under the bark as either immature larvae or in a pre-pupal larval stage. Pupation takes place from early spring until early summer. Peak emergence of adults in Canada is from mid- to late June. Adults are rarely observed after mid-August.

Depending on the time of year they were laid, tree health and summer temperatures, the life cycle may be either one, or two years. In general, healthier trees in the early stages of infestation or those subjected to low EAB populations are better able to resist attack and delay the development of the larvae resulting in a life cycle that may take in excess of one year to complete. Where eggs are laid later in the season, the beetle is less likely to complete its life cycle within a year. In colder areas such as northern Michigan and northern Ontario, the two year life cycle appears to be prevalent.

In its natural range of eastern Asia, EAB occurs in areas of extreme temperatures and is very cold tolerant. Research has confirmed that EAB is capable of surviving anywhere in Canada where ash will grow and there is no reason to believe that climate will limit its ultimate range in North America.

5.0 SIGNS AND SYMPTOMS OF INFESTATION

EAB populations are usually at low levels following its introduction into a new area and it is extremely difficult to detect. Once established, populations build up exponentially to epidemic levels but it is usually four years or more after the initial infestation before signs and symptoms are manifested in the host tree and EAB can be reliably detected. Recent research[5] confirms that attack is often initially confined to branches in the canopy and that no signs of EAB may be evident in the trunk until later in the infestation when populations are much higher and the tree is declining. This is a major limitation to early detection and management.

5.1 Signs of EAB infestation are:

- Presence of EAB life stages (adults, larvae, pupae[6] -*Figures: 5-9)*
- Serpentine galleries (often in evidence beneath cracks) *(Figure: 10)*
- Presence of D-shaped adult emergence holes in the bark *(Figure: 11)*
- Evidence of larval feeding by woodpeckers and squirrels *(Figures: 12 and 13)*

5.2 Symptoms of EAB infestation are:

- Death of tree or parts thereof
- Thinning and yellowing of crown, especially late in the summer *(Figure: 14)*
- Cracks in the bark along trunk and branches *(Figure: 15)*;
- Presence of epicormic shoots on stems and branches *(Figure: 16)*

[5] *Krista Ryall, Detection of Emerald Ash Borer in Urban Environments Using Branch Sampling, 2010. Natural Resources Canada, Canadian Forest Service, Technical Note 111*
[6] Eggs are extremely small and are not used as a diagnostic feature

Figures 5-9: EMERALD ASH BORER LIFE STAGES

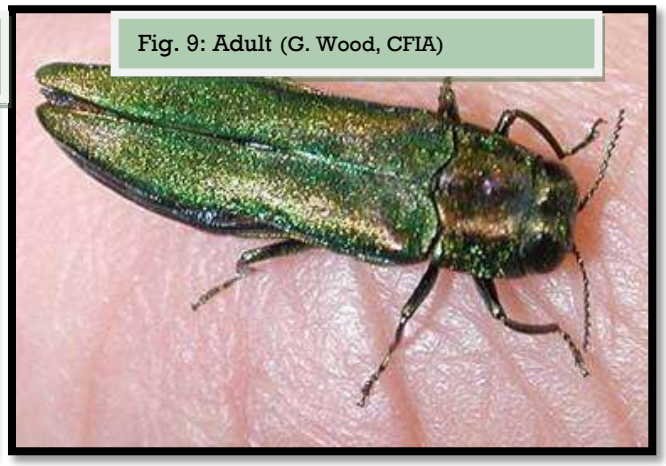
Fig. 5: Egg

Fig. 6: Mature Larva

Fig.7: Pupa

Fig. 8: Emerging Adults

Fig. 9: Adult (G. Wood, CFIA)



All Photos courtesy of B. Lyons, CFS, except as noted

Figures 10-11: EAB SIGNS AND SYMPTOMS

Fig. 10: Serpentine Galleries under Bark

Fig. 11: D-shaped Emergence Holes

Photographs courtesy CFIA/CFS

Figures 12 and 13: EAB SIGNS AND SYMPTOMS

Fig.12

Evidence of Woodpecker Feeding

Fig. 13

Photo Credit: Sarah Jane Miller, City of Mississauga

Figures 14 and 15: EAB SIGNS AND SYMPTOMS

Fig. 14: Thinning/Yellowing Crowns

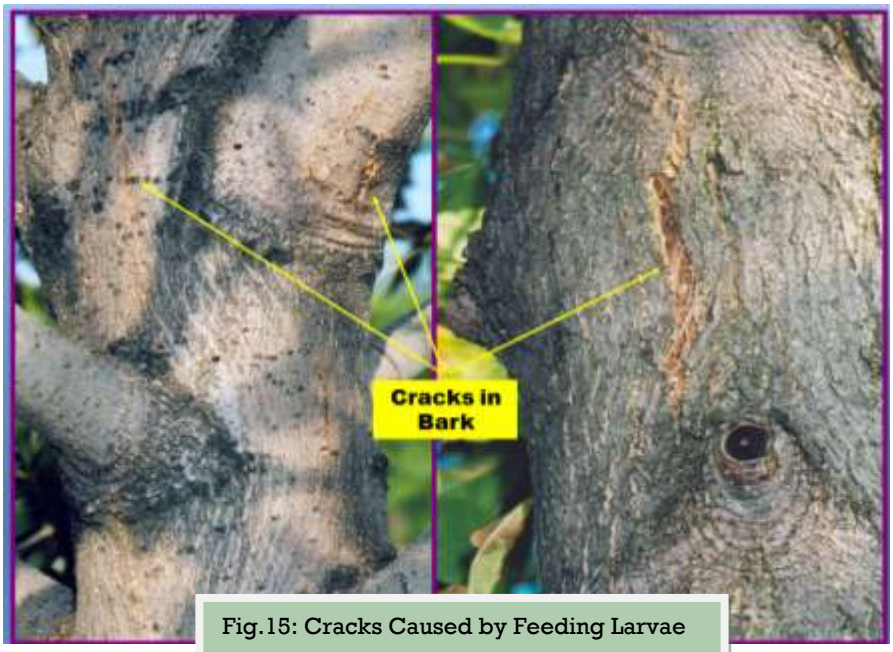
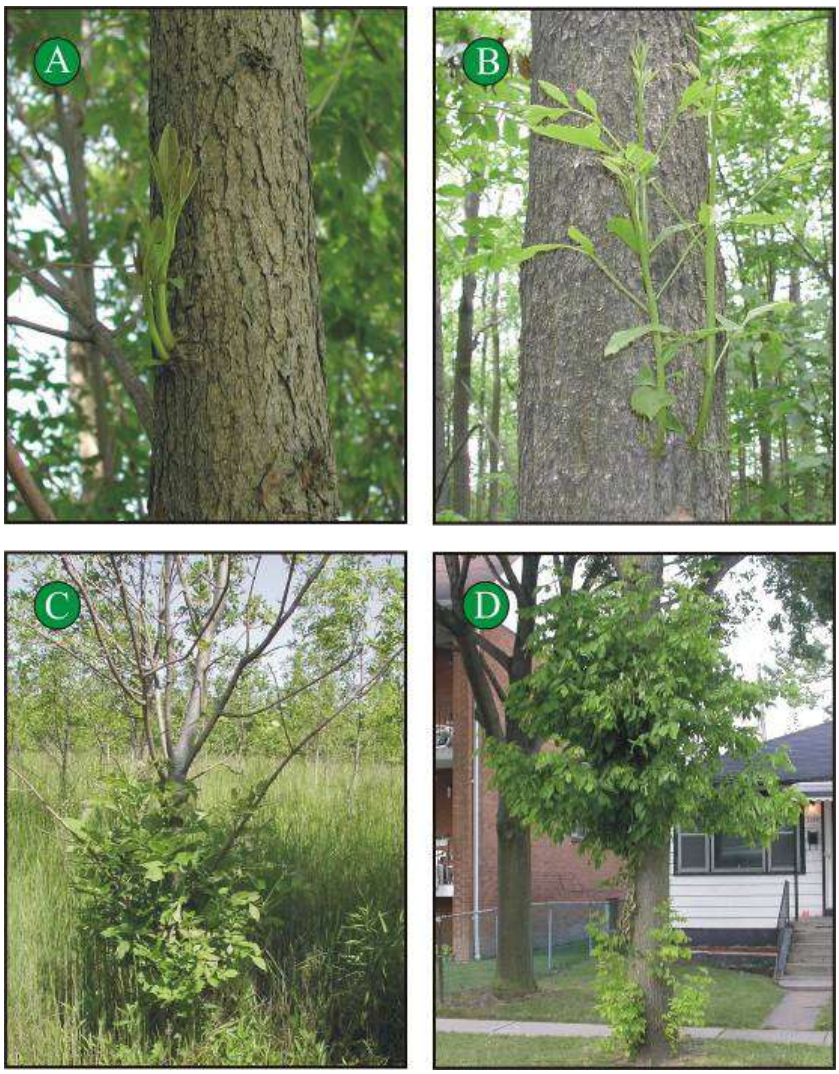


Fig.15: Cracks Caused by Feeding Larvae

All photographs – K.R. Marchant

Figure 16: EPICORMIC SHOOTS/BRANCHING



Photographs courtesy Barry Lyons, CFS

6.0 STRATEGIES TO COMBAT INVASIVE ALIEN PEST SPECIES

Numerous strategies are employed by plant quarantine specialists and agencies to combat IAS such as EAB. Ideally, these are science based and rely on Pest Risk Assessments to score out the potential for an organism to become a damaging pest in a new area. Strategies to mitigate the impact of potential plant pests include but are not limited to:

6.1 Exclusion

This entails the elimination of pathways for the introduction of a potential pest to a new area through the enactment of stringent import regulations which may prescribe treatment of the commodity (such as heat or pesticides), or outright prohibition of the commodity in its raw form. Exclusion is often the most effective of the mitigation options but is often influenced by political considerations and can lead to retaliatory actions by trading partners if there is not the science to justify it;

6.2 Eradication

This strategy entails the eradication of a potential pest prior to it multiplying and spreading in a new area. This is the preferred option where introduced pests are encountered but often can't be realized as rigid criteria must be met in order for it to be successful (e.g., the target pest must be readily detectable and treatable, and preferably slow moving). This is the strategy of choice for such pests as Asian Long-Horned Beetle which is under active eradication in Canada and parts of the US;

6.3 Suppression

With this strategy, actions are taken to keep the population at low levels through intervention. These actions greatly lower the risk of spread to new areas and can leave the door open to future eradication of the pest and as well, can protect natural resources and the environment;

6.4 Containment

This strategy entails the taking of pro-active measures to prevent the movement of pests through enactment of quarantine measures and targeted control measures. Containment is the strategy of choice for slow-moving and/or non-vectored pests for which it is not possible and/or cost effect to eradicate;

6.5 Slow-the-Spread

This is a specific strategy employed by regulatory agencies such as the CFIA which combines regulatory initiatives such as quarantines with targeted control actions. Although similar to containment, there is no expectation with this strategy that the

advancement of the pest can be stopped indefinitely. Generally speaking, there would have to be merit in slowing its spread (such as the protection of woodlands, maintaining access to export markets and buying time for new detection and management strategies to be developed). This is the option of choice for many regulatory agencies for well established IAS of quarantine significance such as EAB, Pine Shoot Beetle and Gypsy Moth;

6.6 Management

This strategy entails living with the pest but mitigating its potential for damage and dispersal on a localized basis through best management practices including biological, chemical, or physical controls etc., integrated pest management, public awareness and effective partnerships. Most damaging agricultural and forestry pests (many of which are long established) fall into this category. Not all damaging pests can be successfully managed;

6.7 No Action

For most exotic organisms (many of which are benign or even beneficial, or whose impact has been attenuated through biological control or natural selection of host resistance) there is no need to take aggressive action to contain or otherwise manage them. Many exotic plants and animals in Canada are long established with little or no economic or environmental impact. Some examples of beneficial or benign exotic organisms are honey bees, earth worms[7] and most of our field crops, fruit trees and ornamental plants. Most ornamental plants used in Canada are introduced from elsewhere; some of these, such as buckthorn, garlic mustard, autumn olive, honeysuckle and dog-strangling vine were deliberately introduced and can be very serious woodland pests on occasion.

7.0 MANAGEMENT TOOLS

7.1 Surveillance

Having a spatial inventory of its ash resource and determining where EAB is present allows a municipality to focus its management and/or impact mitigation activities. Despite considerable scientific advances in recent years in surveillance technology and methodology, there is still no reliable method for early detection of EAB at low population levels. While essential to successful management programmes this is likely to remain a limiting factor for the foreseeable future.

[7] Earthworms can be a serious pest when introduced into woodlands but are generally considered beneficial

Two complementary surveillance strategies are commonly used in the management of quarantine pests such as EAB, namely: **detection**, and **delimitation.**

7.1.1 Detection Surveys

Detection surveys are used to determine the presence or absence of a pest in a target area. They are not generally useful in determining epicentres of infestation or the intensity or age of the infestation.

Detection surveys are designed to gather qualitative, rather than quantitative data; it is generally not important to regulatory officials to know how many insects are present in an area, just whether they are present or not. On the basis of these data, quarantines may be imposed on defined areas (such as counties or regional municipalities). Statistical significance can be an issue, especially where traps (or other tools) are unable to consistently detect the presence of the target organism at low levels (with specific respect to EAB there is a yet-to-be determined population threshold at which the statistical accuracy is unacceptably low, and false negatives occur). Conversely, insects may be blown or otherwise transported into the target area, resulting in false positive results.

EAB detection surveys (usually conducted by regulatory agencies such as the CFIA) are most often predicated on finding physical evidence of a life stage of the insect in a host tree or nearby trap. Until recently, the CFIA relied on visual detection of signs and symptoms in the tree. Priority was given to surveys around high risk sites where EAB is likely to have been introduced through human activities. In recent years, the CFIA has incorporated the use of prism traps into its detection survey protocol.

High risk sites are:

- Campgrounds and trailer parks
- Sawmills and firewood purveyors
- Tree nurseries and garden centres
- Traffic corridors (such as rest-stops along major highways)
- Industrial areas which receive off-shore shipments

Targeted detection surveys have proven quite effective in finding some previously undetected outlier infestations and have helped the CFIA and other regulatory agencies focus often limited resources on key result areas.

Many Ontario municipalities are now using prism traps in conjunction with their EAB management programmes.

Of note is that the CFS is currently working on amending its branch sampling protocol to make it a more cost-effective detection survey tool.

7.1.2 Delimitation Surveys

Delimitation surveys are used to determine how far a population has spread from, or around an established outlier or point of introduction. Delimitation surveys are generally used in areas known to be infested and are designed to gather quantitative data. For this reason they are best suited to situations where it is important to determine the density and distribution of the pest around what is perceived to be the point of introduction to the area (an outlier), or conversely, determine the leading edge of an infestation. While delimitation surveys are more accurate with respect to determining the age and severity of an infestation, they are generally far more labour-intensive and expensive to conduct than detection surveys. They are potentially useful to municipalities and others wishing to monitor EAB population build-up and dispersal and to target areas for treatment. Several Ontario municipalities are now conducting delimitation surveys in conjunction with tree protection programmes.

As with detection surveys (and with specific reference to EAB), delimitation surveys become statistically inaccurate below a yet-to-be determined population threshold and are unlikely to detect low level infestations. Detection thresholds have yet to be determined by researchers.

7.1.3 Survey Methodology

Four survey methodologies are currently employed in Canada and the US for EAB:

- Prism traps baited with plant volatile lures and short range or contact pheromones
- Visual (examination of trees for signs and symptoms of EAB such as emergence holes, galleries and canopy decline)
- Branch sampling[8]
- Aerial and Hyperspectral Imaging (HSI)

7.1.3.1 Prism Traps

The CFIA and CFS currently recommend the use of green prism traps to detect EAB. These are baited with chemical lures known to be attractive to EAB and are coated on their outside surface with a sticky substance to trap adults beetles.

Research conducted in Canada and the US has confirmed that prism traps are now relatively effective in detecting EAB prior to signs and symptoms being manifested in infested trees and are significantly more reliable than visual survey alone.

Prism traps are most effective when used in a detection context and for that reason are used by the CFIA and other quarantine agencies whose priority it is to ascertain

[8] *Krista Ryall, Detection of Emerald Ash Borer in Urban Environments Using Branch Sampling, 2010. Natural Resources Canada, Canadian Forest Service, Technical Note 111*

the presence or absence of EAB in a given area. Data are not quantitative and the inconsistencies in the efficacy of the lures (as well as other sensitive parameters) do not allow for comparison between areas, or different years[9]. While traps are unable to determine with any accuracy how many trees in a target area are infested, they are effective at determining the presence or absence of EAB in the area with a certain degree of statistical accuracy. At low population levels, there is a high risk of false negative data and it cannot be assumed that a given area is free from EAB if no adults are captured. Conversely, adult beetles may be blown in or otherwise transported to the survey area resulting in false positive results.

When deployed in a grid pattern in urban areas or along the edge of woodlands, they can provide an indication and early warning as to the presence of EAB. The actual density of traps required to provide confidence that EAB is/is not present is still unknown and more research is required[10]. Traps should only be placed in areas where ash trees are present and the density should be increased in areas deemed to be higher risk (such as around parks, sawmills, highway rest stops, firewood purveyors and campgrounds and industrial parks).

Detection thresholds have not been established for prism traps and their degree of attractiveness is thought to vary from year to year and location to location[11]. To this end, researchers are currently working on correlating the number of beetles caught in the traps to populations in local trees.

To be effective, traps must be deployed immediately prior to the emergence of adult beetles (which is late May to early June in southern Ontario in most years) and checked at regular intervals. Traps must be removed at the end of the flight season (usually mid-August) and all suspect insects collected and identified at that time.

Of note is that traps used in Canada are green and baited with Z-3-Hexenol (a synthetic green leaf volatile compound known to be attractive to Buprestids and other insects) and short range or contact pheromones; the US uses a purple version of the trap baited with manuka and/or phoebe oils. Trapping is the detection methodology of choice in the US due to its lower costs as compared to the destructive sampling of trap trees (which was previously used).

[9] Personal Communication OMNR/CFS,
[10] Personal Communication CFS
[11] Personal Communication CFS

7.1.3.2 Visual

Visual surveys entail the examination of trees for EAB infestation from the ground or/and or canopy level. They rely on the physical manifestation of signs and symptoms in the tree which may not be apparent for as long as five years after the initial attack and can easily be missed in their initial stages.

Visual surveys are ponderous and time consuming and, when compared to other survey methodologies such as branch sampling are far less accurate. It is often impractical to inspect all trees in an area, and for this reason, regulatory agencies which rely on visual surveys select trees which are deemed higher risk by virtue of their being situated adjacent to lumber yards, campground, parks, sawmills or firewood purveyors.

Sample size is an issue. EAB does not randomly attack trees. There are little or no statistical data by which to determine confidence intervals and scientists have yet to determine the threshold for providing confidence that EAB is not present in the target area.

7.1.3.3 Branch Sampling

The delimitation tool of choice in Canada is now branch sampling, using a technique recently developed by Natural Resources Canada-Canadian Forest Service (CFS). This technology entails the sampling and dissection of several branches from the crown of at-risk ash trees. While the statistical accuracy of the methodology is still being worked out, research conducted by the CFS has confirmed that this technique is far more accurate with respect to early detection of EAB than visual inspection for signs and symptoms and allows EAB to be detected and quantified in an area several years earlier than previously experienced.

While considerably more labour intensive (and expensive) than deploying traps or conducting visual surveys, branch sampling provides information on the severity and age of the infestation and the potential distribution and dispersal of EAB around the outlier's epicentre (generally the point of introduction).

It can, however, be integrated with routine maintenance activities conducted by municipal forestry departments and peeling and debarking operations (which should optimally be done indoors) can be scheduled for non-peak periods. For this reason it is recommended for use by municipalities interested in managing, mapping or otherwise determining the extent of confirmed EAB infestations and protecting trees.

It is conceded that more research is required in order to standardize the interpretation of data collected from branch sampling, especially when it is used for determining whether trees should be removed or treated[12].

Many of the experts contacted for this report believe a strategy combining both trapping and branch sampling is preferable where management is the desired objective.

The CFS is currently developing a modified, scaled down version of the branch sampling technique to make it more useful and cost effective as a detection survey tool.

7.1.3.4 Hyperspectral Imaging (HSI)

The Natural Resources Canada-Canada Centre for Remote Sensing defines Hyperspectral Imaging as: "The simultaneous acquisition of images of the same area in many (usually 100 or more), narrow, contiguous, spectral bands. The detailed spectrum resulting from hyperspectral imaging allows the comparison of the remotely-acquired spectrum to the spectra of known materials".

Plainly speaking, HSI is a type of remote sensing whereby data are collected for specific bandwidths of reflected light (usually infrared), rather than the multispectral (visual light) images acquired from satellites or aircraft. While still in its developmental stage and highly proprietary, HSI could prove to be a useful tool to identify and map trees and other vegetation from the air, and to possibly differentiate healthy from unhealthy trees. With specific reference to EAB, HSI has recently been assessed in both Milwaukee, WI, and Oakville, Ontario (2010).

For HSI to work as a tree identification tool, it first requires spectral data to be collected by a handheld recorder from several individual trees of a target species. Each species is believed to have a unique spectral signature and with the aid of advanced software, "algorithms" are developed for each species which allow them to be mapped.

The second phase of the operation is the collection of aerial data using low flying aircraft equipped with specialized sensors. Numerous flight paths are required to collect sufficient data and there are many variables such as time of day, and season which have to be taken into account. Current technology allows for the collection of high resolution spectral images which can be superimposed on visual maps, correlated with the data collected by handheld recorders and then integrated with GPS (and LIDAR[13]) data. Theoretically, it could be possible to accurately identify

[12] Personal Communication OMNR/CFS
[13] LIDAR is an acronym for Light Detection And Ranging

street and woodland trees from the air without the need for extensive ground-truthing.

The major issues (and barriers) with respect to recognizing HSI as a valid tool at the present time are cost, and the absence of many articles published in peer-reviewed journals. Much of the research being done on HSI is industry-driven, with the technology being developed and evaluated being both cutting edge and highly proprietary. Of note, is that the USDA-Forest Service was involved in a trial conducted in Oakville in 2010 and has agreed to analyze data collected there. Preliminary results from the Oakville trial show HSI to have been around 80 percent accurate in the identification of ash trees from the air (which meets the original target accuracy set at the outset of the trial).

While HSI is an exciting, cutting edge technology holding lots of promise, it has yet to be proven to work well enough to be recommended for use by municipalities or others interested in managing EAB or other forest pests. Furthermore, it is expensive, with these costs being fixed, and even if its accuracy can be improved, municipalities and other jurisdictions in Canada may wish to opt for more cost effective and proven methods of data collection with respect to the management of urban forests and woodlands. For these reasons, HSI cannot be recommended at this time for use in either identifying ash, or as a detection tool for EAB.

7.1.4 Biological Survey Tools: *Cerceris fumipennis*

The CFIA and US regulatory agencies are currently assessing the use of a native wasp species, *Cerceris fumipennis* to detect EAB adults in newly infested areas. This wasp actively searches out EAB and its North American relatives (genus *Agrilus*) and may be of use in detecting low-level infestations in the future. Colonies of this wasp can be moved from one location to another and research is continuing in both Canada and the US on its potential use as a detection tool. Of note, is that several southern Ontario municipalities (including Mississauga) are currently involved in a cooperative research project being conducted by a University of Toronto graduate student to assess the viability of *Cerceris*''.

7.2 Pre-emptive Tree Removal

This strategy entails the removal of all ash trees in an area, regardless of infestation status, prior to their death from EAB. While priority would be given to the removal of structurally unsound or unhealthy trees, all ash trees would be pre-emptively removed prior to the onset of EAB induced mortality. While large scale ash removal would have only a minimal impact on reducing overall EAB populations in a

generally infested area (such as southern Ontario), it can mitigate long-term costs and liabilities associated with passive or reactive management strategies. All major cities interviewed in conjunction with this report were of the opinion that having a management plan which included proactive tree removal as a component would result in considerable cost-efficiencies as well as reducing the potential for hazards and liabilities[14].

7.3 Treatment with Registered Pest Control Products

Pesticides have now been proven to be effective in prolonging the life of many infested trees if administered to the tree in the initial stages of infestation. They may also be effectively used on a prophylactic basis for non-infested trees in high risk areas. In order to be effective, pest control products used against wood boring insects need to be systemic and the most effective means of getting these into the tree is to inject them under pressure into the trunk (several systems are available)[15]. For this technology to work, the tree has to be in good health and have a relatively intact vascular system to permit translocation of the product. Unfortunately, by the time EAB many infested ash trees express symptoms such as crown thinning or die-back, they are usually heavily infested and their vascular tissues extensively damaged and they cannot be successfully treated. While the continued use of some pressurized injection systems has been shown to damage the tree around the injection site and predispose it to rot inducing organisms and other mortality factors, this has not been identified as a major issue to date for trees injected for control of EAB in Canada.

The current product of choice in Canada is Azadirachtin (TreeAzin™) -a natural product insecticide extracted from the neem tree *(Azadirachta indica).* There is now published, peer-reviewed data that confirm that this product can provide good protection against EAB for a two year period when injected into a relatively healthy ash tree. Furthermore, injections with this product using the patented EcoJect® system do not appear to be as damaging as other injectable pest control products using other application devices. To afford the tree an acceptable level of protection, TreeAzin™ only needs to be applied every second year.

At present TreeAzin™ is NOT registered in Canada; emergency registration granted by Health Canada-Pest Management Regulatory Agency (PMRA) on an annual basis since 2008 expired August 31, 2011. Full registration is pending and is expected to

[14] Recent studies indicate that it is often cheaper to treat trees over a ten year period than to remove them
[15] Some products such as Imidacloprid can be applied by way of a soil drench but this formulation is not registered in Canada at present for use against EAB and research confirms it to be of limited efficacy

be in place for the 2012 season. In the event that this does not take place before May 2012, the patent holder and distributor (BioForest Technologies Inc.) is confident that emergency registration status will be granted again for the 2012. TreeAzin™ may only be administered using the EcoJect® injection device developed for BioForest. Technicians injecting the product must hold the appropriate Ontario Pesticide Applicator's Certificate and for this reason, the product will not be made available for use by homeowners.

At the present time, there are only two products specifically registered in Canada for EAB. ACECAP®97, an organophosphate systemic insecticide implant received a label extension in 2010 from PMRA to include EAB, and the label for Confidor 200SL was extended by PMRA in May 2011.

ACECAP®97 is effective against a large number of tree insects and is approved for use on a broad range of hosts. While trials conducted in the US conclude that it can kill EAB larvae, it is not as effective as other products on the market and may not work where populations of EAB are high. The label approved by the PMRA in June of 2010 for ACECAP®97 states:"Treatment reduces populations of emerald ash borer larvae and the damage they cause, but may not provide control of this pest". While significantly less expensive than TreeAzin™, its mammalian toxicity is much higher and it must be injected yearly. Furthermore, the hole into which the ACECAP®97 implant is placed is considerably larger than that used for TreeAzin™ with greater potential for rot inducing organisms to be introduced into the tree.

Confidor 200SL is a formulation of Imidacloprid previously approved for use on a variety of forest pests in Canada and the US. It has been assessed in both Canada and the US for use against EAB and was not considered effective enough to be recommended by most researchers and quarantine experts. Its label, approved by the PMRA lists it as a Restricted Use Product and "it can only be used in conjunction with federal, provincial, or municipal control programs"; a permit is required from "pesticide regulatory authorities" prior to use.

Neither ACECAP®97 nor Confidor 200SL is considered by the Provincial Forest Entomologist or CFS researchers to be acceptable for controlling EAB, especially when populations are high and for this reason the author does not endorse their use in Canada for the management of EAB at this time.

As of May 2010, TREE-äge® (Emamectin Benzoate) has full registration in the US as a restricted use pesticide and is widely used in most states with EAB infestations. Research conducted in the US confirms that it is highly effective for at least two years making it a cost-effective alternative to cutting. Its drawbacks are its relatively high mammalian toxicity, when compared to TreeAzin, and its high residual activity.

Despite its efficacy, it is not registered for use against EAB in Canada at this time. While interest has been expressed by some parties in pursuing registration, this is not likely to take place in the near future.

7.4 Consultation, Public Education and Outreach

Recent interviews conducted with US and Canadian officials stressed the importance of public education and outreach programmes. It is vitally important to have the public and other stakeholders, including property owners, industry, and public interest and environmental groups made aware of the perils of EAB and brought on-side. This is best accomplished through effective messaging and consultation. Depending on the management option selected, it may be desirable to conduct public meetings to explain what actions are required and how these will affect property owners.

7.5 Staff Awareness and Education

Parks, forestry and other maintenance personnel who work with trees need to be able to identify ash trees and as well, signs and symptoms of EAB infestation. Training should be provided by municipalities to this end.

7.6 Trees on Private Property Affected by EAB

In most instances, municipalities rarely take responsibility for the removal of trees on private properties. Exceptions are where trees pose a hazard of falling and causing injury or property damage, or where a tree encroaches on both municipal and private property. In this instance action may be taken under property standards legislation to remove the hazard tree. Generally, the property owner is liable for all costs related to treatment or removal of dead or damaged trees.

7.7 Regulatory

In support of its preferred management strategy, Mississauga may wish to explore the possibility of enacting new, or alternatively, strengthen existing by-laws to provide for the right of municipal employees to enter onto private property for the purposes of inspecting trees suspected of being infested with EAB or other IAS.

8.0 SELECTING THE APPROPRIATE RESPONSE STRATEGY

For newly established plant pests of potential quarantine significance, regulatory agencies such as the CFIA are generally required to complete a PRA which outlines the risk posed to the country by an organism. PRAs take into consideration such factors as: potential pathways, potential of the organism to inflict damage, potential to establish in the country, climatic suitability, host suitability, impact on markets, environment, etc. Prior to making a decision on the appropriate strategy, it is common practice for the regulatory agency to establish expert panels consisting of scientists and regulatory specialists from government, industry and academia to provide it with advice. The selected action must be:

- Science-based,
- Transparent,
- Easily communicated and understood,
- Defendable,
- Cost effective and
- Legal within the purview of the Plant Protection Act and Regulations, and other applicable legislation

As a general rule, if the CFIA or other regulatory agency elects to undertake proactive measures such as eradication, containment, slow-the-spread etc., there must be a realistic chance for success, and/or measurable results of mitigating the impact of the IAS. An integral part of the decision making process is an environmental assessment of the potential impact of the pest, as well as any proposed actions to manage it. For these reasons, control actions are generally not taken against many IAS pests; it is simply not cost effective to do so, and there is little likelihood of a successful outcome.

9.0 A HISTORY OF EAB MANAGEMENT IN NORTH AMERICA

9.1 Canada

Soon after the initial discovery of EAB in the Detroit and Windsor areas in 2002, the top regulatory specialists and quarantine scientists in North America met to develop strategies to address what they perceived to be a very serious threat. The conclusions from this meeting were that EAB would likely become a very serious and damaging urban and forest pest in North America with severe and lasting

environmental and economic consequences. Additionally, it was forecast that there would be little chance of eradicating it or even containing it, but that every attempt should be made to do so. The strategy of choice was "Slow-the-Spread", with the hoped-for outcome being that natural or introduced biological controls would eventually emerge or could be introduced from eastern Asia. This strategy would also allow for science to "catch up" with respect to survey technology and the development of effective insecticides or bio-controls. While it was believed at that time that EAB had likely spread beyond south-eastern Michigan and south-western Ontario, few experts realized at that time how widespread the actual infestation was.

9.1.1 2002-2003

From the out-set, the position of the CFIA and its Canadian partners was that EAB could not be eradicated but that there was significant merit in slowing its spread or even containing it within Essex County. Accordingly, the CFIA concentrated its efforts on western Essex, where it was believed EAB was confined. Additional measures taken to prevent the movement of potentially infested ash materials to other parts of Canada were:

- Issuance of a federal Ministerial Order (MO) by which the western portion of Essex County was placed under quarantine;
- Issuance of quarantine notices to property owners with infested trees;
- Removal of all ash trees within a 500m radius of infested trees (over 20,000 trees were removed in Essex County)
- Development of Policy Memorandum D-03-08 which outlined import and domestic movement restrictions
- Placement of notices along major highways
- Other communications initiatives to advise people of quarantine restrictions
- Investigation of the source of outliers
- Consultation with other government departments, USDA, affected municipalities, property owners and affected industries advising of impacts and recommended course of action

9.1.2 Ash Free Zone

In the fall of 2003, a decision was made by the CFIA on the advice of its EAB Science Committee and with the full support of its partners, to establish an ash-free or "firebreak" zone on the western end of Chatham-Kent. This strategy entailed the designation of a defined geographical area to the east of what was perceived to be the leading edge of the EAB population at that time, and creating a barrier to its natural spread by removing all ash trees within the zone which could support brood populations. In order to achieve this, federal regulations were developed under the Plant Protection Act which mandated the removal of ash trees from private

properties in the zone. This area was selected for the zone because of its extremely low percentage of forest cover (estimated at less than two percent), the presence of Lakes Erie and St. Clair which would act as natural barriers and because there was no physical evidence at that time that EAB was established in areas to the east of the zone. Work began on removing ash trees from the 10 km wide zone during the winter of 2003-04, and an estimated 85,000 ash trees were removed by contractors. Despite an endorsement from the CFIA's partners and Ontario municipalities, a provision for compensation to affected property owners, and a generous tree replacement programme, the creation of the ash-free zone proved immensely unpopular with residents and property rights activists and received considerable bad press. It represented, what most scientists felt was the last chance to confine EAB to south-western Ontario and save the estimated billion ash trees in areas of Canada to the east. While it undoubtedly provided a significant barrier to the natural dispersal of EAB to areas east of the zone, it was very costly to establish and maintain. In 2004 and 2005, EAB was detected to the east of the zone in Chatham-Kent and an additional 50,000 trees were removed in support of the zone. With the finding of numerous well-established EAB outliers in 2004 and 2005 in areas to the east of the zone including Lambton, Elgin and Chatham-Kent, the zone was deemed redundant and the Regulation by which it had been created was retracted. In 2005, tree cutting to slow the spread of EAB was officially abandoned as a viable strategy by the CFIA, although some trees around new outliers would continue to be removed in conjunction with scientific research conducted by the CFS and CFIA.

9.1.3 2005-07

In 2005 and 2006, the CFIA's strategy shifted away from tree cutting with the new focus being on public messaging ("Don't Move Firewood") and quarantine actions to slow the spread. Two major components were:

- The use of 5 km radial zones around known positive trees (nested quarantine zones) to augment the quarantines already in place at the county level;
- Revisions to policy memorandum D-03-08 to relieve the burden on affected industries and property owners. This revised document outlined a detailed quality management programme to permit the movement of potentially infested ash materials to registered facilities in non-regulated areas, where the risk of EAB being moved had been mitigated through processing and other precautions.

While the overall effectiveness of these policies is difficult to quantify, the consensus of most quarantine specialists and research scientists is that they were highly effective in staunching the establishment of new outliers through natural dispersal

and human activities. It is believed that EAB would be far more prevalent today across much of Ontario had the actions not been taken.

9.1.4 Current Status

9.1.4.1 Changes to the Policy Governing the Issuance of Ministerial Orders (MOs)

In 2009, the CFIA abandoned the use of nested quarantines due to the expense of maintaining them and concerns regarding their overall effectiveness. Many experts believed that this change in policy was likely to exacerbate the spread of EAB in lightly infested counties and that neighbouring counties currently free of the pest would be subject to increased risk of infestation. The current CFIA policy (October, 2011) is to amalgamate quarantine zones of presumed similar infestation status and associated risk under a single MO[16]. The CFIA's objective is to limit the long-distance spread of EAB and protect other areas of Canada through movement restrictions on high-risk commodities (the premise being that EAB is now likely pervasive across most of southern and eastern Ontario). To this end, all municipalities in southern Ontario with contiguous populations of EAB (including Peel Region) are included in one regulated area under a single MO as of March, 2011. Refer to *Figure: 1*.

Of major concern is that municipalities, conservation authorities and private property owners located in regulated areas and wishing to protect their ash resource are essentially on their own. There are no restrictions in place to prevent the movement of infested materials within the areas regulated by a single MO, even those apparently EAB free. Infested trees are no longer removed by the CFIA other than for research purposes and infested municipalities are not eligible for compensation or tree replacement initiatives from the CFIA (or other government agencies) for damages resulting from EAB.

9.1.4.2 Survey Policy

The current policy of the CFIA as it relates to non-regulated counties and regional municipalities is to conduct risk-based detection surveys with the emphasis on areas around campgrounds, sawmills, and parks. The CFIA has indicated that it will continue to assist the CFS and other research organizations in assessing scientific research on new protocols such as traps and baits. Where EAB is detected in previously unregulated counties or municipalities, CFIA policy will continue to be to:

[16] A federal statute that designates a geopolitical area as infested and imposes restrictions on the movement of ash materials and firewood

- Conduct delimitation surveys around the site to determine the extent of the infestation,
- Place a Notice of Prohibition of Movement order on the affected property (which prohibits the movement of ash from the premises) pending the inclusion of the county or regional municipality in a regulated area

The decision to regulate a newly detected area under a MO is generally made by the CFIA when surveys have been completed for the season and the data analysed. Notices of Prohibition of Movement on affected properties are rescinded where counties or regional municipalities are regulated under ministerial orders.

The CFIA does not conduct surveys in regulated or known infested areas.

9.1.5 Summary

While the CFIA has reiterated its commitment to slow the spread of EAB within Canada and maintain market access, there is no plan on its part to undertake any active control measures; it will continue to rely on surveillance, early detection, broad-based quarantine measures and public communications initiatives to achieve this goal.

9.2 Managing EAB in the United States

Since the initial discovery of EAB in the summer of 2002, Canada and the US have cooperated extensively on research and the development of science-based management strategies. From the out-set, there has been a full sharing of scientific data and an open dialogue with respect to the development of survey protocols and setting research priorities. Where the two countries have differed is their policies on the use of pest control products to combat EAB and on detection survey strategies.

9.2.1 Regulatory Framework and Responsibilities

In the US, the lead federal agency is the USDA-Animal and Plant Health Inspection Service (APHIS). As with the CFIA, APHIS develops national policies and frameworks for the management of IAS such as EAB and, in cooperation with their Forest Service and state co-operators, sets research priorities. Similar to the CFIA, APHIS relies on expert panels and science committees to provide it with science-based advice and to ratify its regulatory policies and decisions prior to implementation.

Unlike Canada, the USDA has a prescribed cooperative agreement with State governments for the delivery of survey and pest mitigation activities for pests of

quarantine significance. While these are federally funded for the most part, there is a fair amount of latitude on the part of the state as to how the programmes are interpreted and delivered. Where states do not deliver a national programme to federal specifications however, monies can be withheld.

State governments also have the option of funding their own programmes for quarantine pests as they see fit. States are empowered to impose their own quarantines and place restrictions on the intrastate movement of regulated pests and articles.

9.2.2 Pest Control Products

While the USDA has been in agreement with Canada that pesticides are relatively ineffective as a quarantine tool and have never officially advocated their use, several states have used pesticides such as Imidacloprid (various formulations including Merit, Imicide, Confidor, and Pointer) and other products in their response programmes. A key difference between Canada and the US is the general availability of these products for use by governments, tree service professionals and private citizens. While products used in both countries must be proven by the manufacturer to be safe, Canada's regulations are deemed to be more restrictive than those of the US and many products registered in the US and readily available there cannot be sold in Canada. Until recently, state programmes have relied on Imidacloprid based products. These are applied either as a soil drench around the roots of the tree, or injected into the tree under pressure. While, under some circumstances they can be effective in preserving the life of tree they are not effective where the tree's vascular tissues have been damaged by EAB or where the tree is under stress and its ability to uptake the chemical has been compromised. Furthermore, continued treatment via injection on an annual basis can damage the vascular area of the tree and provide entry sites for disease organisms.

As of May 2010, TREE-äge (Emamectin Benzoate) has full registration in the US as a restricted use pesticide and is widely used. Research conducted in the US confirms that it is highly effective for two years making it a cost-effective alternative to cutting. Its drawbacks are its relatively high mammalian toxicity, when compared to TreeAzin™, and its high residual activity. Despite its efficacy, it is unlikely that the product will be registered in Canada for use against EAB in the near future. There is however, interest by some parties in getting this product registered as soon as possible.

9.2.3 The Early Years (2002-2004)

In the initial stages of the EAB emergency response, State governments relied heavily on intensive surveys in conjunction with tree cutting to slow the spread.

Several states including Ohio initially attempted to eradicate EAB but soon abandoned this goal when additional, long established outliers were found throughout the state. Both Michigan and Ohio initially removed all ash trees within ¼ mile (approximately 400 metres) of known infested trees, which resulted in the destruction of hundreds of thousands of trees. In 2004, the US attempted to establish a management zone similar to the Canadian Ash-Free Zone, but on a much larger scale. This initiative, which would have seen potentially millions of ash trees removed from around the perimeter of Michigan, was abandoned as a result of budget cuts and the discovery of EAB in numerous new areas well beyond the proposed zones.

9.2.4 Survey Strategies

While Canada relied on visual surveys during the early years of EAB, (examining trees for signs and symptoms), the official US federal policy was geared towards the placement of "trap" trees (see definition). Despite initially cutting tens of thousands of detection trees in the early years, the US has since abandoned this strategy and now uses purple prism traps baited with lures as the centre-piece of its surveillance programme. The purple traps are highly visible and result in free publicity for the agency.

9.2.5 Outreach and Communications

In support of their regulatory and surveillance programmes, the USDA and its state co-operators have invested heavily in public education. This initiative comprises: websites, media blitzes and billboards emphasising the perils of EAB and imploring residents to not move firewood. In the early years, inspection stations targeting people illegally moving firewood were established along major transportation corridors.

9.2.6 Current Status and Summary

In summary, despite numerous new finds well beyond the original epicentre in Michigan, and the recent addition of several states with very large ash populations (i.e., Minnesota, and New York with 937 and 900 million ash trees respectively, Wisconsin, Kentucky, Iowa and others), the US continues to consider slowing the spread of EAB and protecting its ash resource a top priority. For this reason, Canada will be required to maintain its domestic and import regulations and to fund EAB research in order to maintain market access for hardwood forest products and avoid trade sanctions.

10.0 EAB MANAGEMENT PROGRAMMES IN ONTARIO

Several communities abutting Mississauga were selected for comparison purposes and discussion. Details of actions by these municipalities to manage EAB appear below.

10.1 Brampton

EAB was first detected in 2008 in Brampton and is now well established there with several pockets of significant mortality in evidence in 2011. Brampton estimates that it has around 22,000 ash street trees and possibly a similar number in parks and cemeteries. Ash is believed to comprise 10-13% of its urban canopy. There is no estimate for the number of trees in woodlands but this is likely to be less than 10%. Brampton has an estimated 6% of its land mass in woodland.

Because it is a relatively new city, a large proportion of its ash trees (especially those in parks) are less than 20cm dbh and can be removed (and replaced) without a major impact on their urban canopy.

Brampton is currently developing an EAB management plan with the aid of a consultant which should be ready in the spring of 2012. In preparation for this, Brampton is currently reviewing its ash inventory and determining the extent of the EAB infestation there.

While plans have been developed to replace and possibly treat some urban ash trees, approval has yet to be received from City Council. There are no plans *per se* to treat or otherwise manage woodland ash and no pre-emptive removal or salvage logging operations are planned for these areas. While some work has been done with respect to public education they expect to increase their communication activities once their plan is finalized.

No financial estimates are available at this time with respect to impact.

10.2 Burlington

EAB was first detected in Burlington in the spring of 2010; branch sampling confirmed that it was well established and had been present (but sub-detectable) in the community for many years. Although trap and branch-sampling surveys conducted in 2010 failed to detect any addition infestations elsewhere in the City, EAB was detected in August of 2011, at the Royal Botanical Gardens in the southwest corner of the City.

Burlington estimates that it has 7000 ash street trees and 1300 trees in its parks and managed woodlands; this comprises about 9.5% of its total urban canopy.

Burlington drafted a Management Plan in 2009, which outlined four options for dealing with its urban ash trees. While initial recommendations called for no treatment of its ash and the proactive removal of all street ash trees over a 10 year period, this position was modified in 2010 with published data to support the use of TreeAzin to save some high value urban trees. To that end, over 500 trees were successfully treated in 2010 and, an additional 750 trees in 2011. There are plans to treat more trees in 2012.

On May 25, 2011, Burlington City Council approved an aggressive action plan to preserve the ash component of its urban canopy with a gradual transition to non-ash species over the next 20 years. $11 million has been budgeted over a 10 year period for this initiative. Despite this investment, the total number of street and park ash treated under this programme will only amount to 0.3% of its urban canopy.

The city's action plan is currently being reviewed with the aid of a consultant and will be adjusted annually in order to reflect the latest scientific information available.

Burlington plans to defer the removal of confirmed infested trees until visible decline is in evidence; it feels this approach will help with public acceptance of its plan and is manageable.

There are no plans to use HSI at this time as the city already has good inventory data, and it feels that the HSI technology is not cost effective to its purposes.

Burlington is currently working with a consultant to review and update its survey protocols and management plan.

10.3 Hamilton

EAB was first detected in Hamilton in 2009, but surveys indicate that is had been established there for several years prior to this. EAB induced mortality and decline were in evidence in several areas of the City in 2010. Hamilton has an estimated 11,078 ash street trees (representing 7% of all species); and 12,000 ash park trees and cemetery trees. There are also numerous ash trees in city-owned woodland and natural areas within the City for which there are no estimates. Disposal and replacement costs are estimated at $1,080 per tree. Ash is also widely planted on private properties throughout the City and homeowners could expect to shoulder similar costs for removal of their dead trees. While the City does not assume responsibility for trees on private property, it can order their removal under its

property standards bylaw where they are deemed to be hazardous to adjacent properties. Costs for this would continue to be assumed by the property owner.

A Strategic Management Plan was prepared by a private consultant for the City Hamilton in the fall of 2010 and presented to City Council. Four options were developed for consideration:

After due consideration, City of Hamilton staff selected pre-emptive management (which would see most of its ash trees removed prior to mortality as a result of EAB) as the preferred strategy of choice. The rationale for their decision was that EAB was likely already well established at numerous locations throughout the city and they would rather remove and replace their ash trees rather than commit to treatment over an extended period.

As of December, 2011, Council has yet to approve this plan and has asked staff to review the management options and come back with a management plan for early 2012. Hamilton staff is currently working with a consultant to revise their EAB strategy.

While Hamilton has only conducted limited surveys for EAB, its parks and forestry staff have been trained to recognize its signs and symptoms and are on the lookout. Hamilton does not plan to use HSI to detect ash trees at any time in the near future as it has a good tree inventory.

TreeAzin™ was used to treat eight high value trees in one of its major parks. Despite the recommendation for pre-emptive removal of its ash trees, Hamilton has yet to remove any non-infested/asymptomatic trees. As of December, 2011, EAB induced mortality is in evidence at several locations in the City and numerous removals were required over the summer. The City has been advising affected property owners by way of a postcard developed for this purpose.

Along with many other Ontario municipalities, Hamilton is seeking financial assistance from the federal and provincial levels of government and is lobbying, along with other municipalities for increased funding for EAB related research.

10.4 London

As an outcome of UFORE surveys, City of London estimates that it has 440,000 ash trees (which comprise around 6% of street trees and 10% of its parks and woodlands). This has been confirmed by an actually physical inventory and GPS based counts.

EAB was first found in London during the fall of 2006 and spring of 2007 at three disparate sites. An investigation concluded that it had been established at these for

several years prior its initial detection and that there were likely other sites to, or from which it had spread. The initial response by London was to attempt to limit the spread of EAB within the City. To this end, the CFIA removed three infested trees in the fall of 2006 and several infested trees in a public park were cut and chipped in 2007. In order to comply with CFIA quarantine requirements and slow the spread of EAB within London, the City provided several areas where residents and tree service companies could drop off ash logs and debris. Material taken to these sites was tub-ground prior to it being removed to a recycling facility north of London. A major complication for the City and the CFIA was that the privately owned recycling facility to which London took its yard waste was outside of the three 5 km nested[17] quarantine zones which had been established by the CFIA. This seriously affected the collection of yard waste materials as the City could not guarantee that these would not contain potentially infested ash materials. As a result, yard waste materials had to be processed prior to transfer to the recycling facility and the City was forced to incur significant additional costs (estimated at $500,000) to comply with the federal quarantine. With additional finds of EAB in 2008 at several locations in Middlesex County, a decision was made by the CFIA to discontinue the nested quarantine zones within the City and to permit the movement of untreated yard wastes to London's recycling facility. This has resulted in a considerable cost savings to the City with probably little increased risk of EAB being spread in these materials.

In 2007, several heavily infested areas were found on numerous private properties (including a college and a large hospital) and it was evident that EAB was well established in London.

Several areas within the City which were thought to be EAB free were surveyed by the CFS in 2009 in conjunction with a research initiative and were determined to be heavily infested. Some trees in these areas were in serious decline by the end of the summer of 2009, demonstrating how rapidly populations can build up to tree-killing levels in apparently healthy trees. 37 trees were treated with TreeAzin on an experimental basis that year.

Branch sampling conducted by the CFS over the winter and spring of 2010/11, confirmed EAB to be established throughout the City. As of September, 2011, EAB induced mortality was evident at many locations throughout the city with many areas severely impacted. Despite the relatively low percentage of ash in London, the City's forestry crew was overrun with requests for removal and whole streets heavily planted to ash had to be cut. While there were no plans to pre-emptively remove

[17] These are internal quarantined zones within an already regulated area… the goal is to slow the spread of EAB within the larger zone and protect adjacent (and non-infested) areas.

ash within the City to control EAB, infested street or park trees which become hazardous have to be removed. To that end, the City plans to remove 1,000 trees per year (although this process may have to be accelerated as a result of the massive mortality being experienced). The EAB project manager maintains that it is cheaper and easier to remove trees prior to death. Trees will be replaced with non-host species for an estimated cost of $750/tree (including removal, stumping and replanting).

The City of London has developed an EAB management plan with the aid of a consultant. Many areas of London have high numbers of large ash trees along their streets and there is considerable interest in conserving these through the use of TreeAzin™. London is currently looking at a 10-12 year treatment period. 400 city-owned trees were injected in 2011. According to the project manager, it was difficult to find enough candidate trees to meet their target due to the high levels of infestation observed. Additionally, London is encouraging its citizens to treat privately owned trees and has developed a webpage to address citizen's concerns. Without treatment, it is acknowledged that the remainder of London's estimated 30,000 street, park and backyard ash trees are likely to die in the near future and will have to be removed.

Recent media reports[18] claim that the city has only been able to find 384 city-owned trees worthy protection with TreeAzin with the remainder slated for removal. An estimated 10,000 trees along streets and in parks will need to be cut in the near future at a cost of $14,000,000. The city is recommending to its private property owners that they employ the services of certified professional arborists to evaluate the health of their ash trees.

10.5 Oakville

Oakville developed an emergency response plan for EAB in 2008 and posted a strategic management plan on its website (Dec 14, 2011). Oakville's plan outlines three possible options for managing EAB.

The first option is to "let nature take its course" and to not intervene in the EAB outbreak. This would see most of the Town's 14,500 street and park ash trees die over the next 5 to 10 years. Even where most of these are replanted, it would take many years for Oakville to regain the canopy is would lose.

[18] London Free Press, January 13, 2012

The second option considered by Oakville in its plan is to undertake to preserve 25% of the street and park ash canopy through the use of TreeAzin™. This equates to 1,700 trees which would have to be treated bi-annually over a 15 year period and is actually a continuation of the programme initiated by Oakville in 2008. With this option, Oakville estimates that it would still have to plant 12,800 trees over the next few years to replace those killed by EAB.

Option 3 would be to preserve 75% of the municipal ash canopy through the use of TreeAzin and would see 5,700 street and park ash treated bi-annually. This is identified by Oakville Staff as their preferred option. Oakville's premise is that is it significantly cheaper to treat trees over a given period (15 years in this case) than to proactively remove them, and has provided data with their report to support this position.

Despite preserving a significant portion of their publicly owned ash trees, it is realized that a large number of trees are on private property. Accordingly, a major tenet of Oakville's programme is to engage private property owners in preserving ash. To this end, Oakville has placed an interactive feature on its web that links Hyperspectral Imagery (HSI) data collected in 2010 to GPS based property data and assists property owners in indentifying ash on their properties. Oakville openly encourages private property owners to treat their ash trees but is not prepared to fund this.

In support of its research and management activities, Oakville has placed considerable emphasis on the development of public education and outreach materials, which are posted on its site. It has created an interactive internet site called "The Canopy Club" and has a FACEBOOK page that is proving quite popular with residents.

In addition to the prism trap and branch sampling surveys it conducted, Oakville contracted AMEC Earth and Environmental Inc., a remote sensing company, in 2010 to conduct research into the possible use of Hyperspectral Imagery HSI to detect ash in the urban canopy and possibly, EAB infested trees. A statement posted on Oakville's website (August, 2011) maintains that their HSI trial was 80% effective in discerning ash from other tree species (which met the original target accuracy set at the outset of the trial).

While Oakville was also hopeful that HSI could be used to detect EAB infested trees there is not data at this time to show that this component of the trial was successful.

Oakville, along with many other EAB affected communities has attempted to secure financial assistance from the federal and provincial governments… without success to this point.

10.6 Toronto

The City of Toronto has an estimated 860,000 ash trees (8.4% of its total trees) in its urban canopy. 340,000 are owned or managed by the City. Of these, 32,400 are street trees and 50,000 are park trees. Of these, an estimated 1,350 trees have been killed thus far by EAB and 150 have been removed for research purposes. All dead and dying trees will be removed prior to 2012. An estimated nine percent of its privately owned trees are ash, and EAB could have a major impact on the urban canopy if not held in check.

With the detection of EAB at one site in the fall of 2007, federal quarantines were placed on Toronto by the CFIA. While it was hoped that this find was a one-off outlier, numerous other well-established infestations were found throughout 2008 and 2009 in the City and adjacent municipalities. Prior to the initial detection of EAB, the Toronto Urban Forestry Department had prepared a detailed report to council outlining the potential impact of EAB. Toronto estimates that 98% of its ash trees could die by 2017.

Toronto has cooperated extensively with the CFS and other researchers on the development of the branch sampling protocol and on the treatment of trees with TreeAzin™. Data from trials conducted there in 2008 and 2009 indicate that the pest control product was quite effective in killing all stages of larvae and could be used to preserve high-value trees. Toronto's management plan (still under development) calls for the gradual replacement of most ash trees with non-host species and the preservation of high value trees with TreeAzin™. Prior to 2011, 444 trees on municipally owned golf courses and in parks were successfully treated and there were plans to treat more in 2011.

Toronto's EAB management plan (2011) calls for an emphasis on public consultation and engagement, and continued liaison with the research community. Toronto does not plan to treat a significant number of trees; this has been sharply criticised in the media and by tree advocates.

Toronto has been surveying for EAB since 2003 and employs traps, visual inspections and branch sampling to detect EAB. Toronto has no plans to use HSI in their surveys as they feel other tools give them the data they need to manage their program at a lower cost.

Toronto estimates that removing its 32,000 city owned street ash will cost $60 million; this figure does not include ash trees in parks, cemeteries and woodland areas or on private properties. No estimate is available for this although replacement costs generally average around $450/tree.

Because of a current quarantine in place for the Asian Long-Horned Beetle, Toronto is required by a Federal Ministerial Order to double grind all yard waste collected from the ALHB regulated area. No special treatment is planned for ash waste originating in areas outside of the ALHB regulated area as EAB is considered well established throughout much of the city.

For 2012, Toronto estimates that they will have to remove 4760 dead and dying ash trees and are looking into the feasibility of expanding their treatment programme to 4000 trees/year. This would be done to defer the number of removals projected for the years 2013 to 2016. Toronto anticipates being overrun by the number of dead trees within the next few years.

11.0 SITUATION REPORT: MISSISSAUGA

11.1 Background and Current Status

EAB was confirmed in the City of Mississauga on private property in the vicinity of Pearson International Airport in 2008 where it had been well established for at least several years prior to detection. The origin of the localized infestation was not determined. As a result all ash in the area were visually examined and the results mapped. 35 trees on City and private properties were determined to be infested (based on the presence of signs and symptoms) and removed.

In 2009, 40 woodlots were surveyed for EAB with no evidence of EAB at that time. As well, sampling was done in 60 woodlots to provide baseline data which were subsequently extrapolated to estimate the relative density of ash in city owned woodlands. Using a plot sample method, all ash trees greater than 10 cm dbh in City woodlands were visually examined for EAB signs and symptoms with none being found.

In 2010 training for parks and forestry staff on EAB recognition and survey tactics was conducted. Mississauga city forestry staff conducted branch sampling using the protocol developed by the CFS. 602 trees citywide were examined with two being found infested and subsequently removed. Staff responded to resident inquiries in

regards to EAB and conducted inspections on trees on private property where deemed appropriate.

During 2011, the City placed 100 green prism traps baited with Z-3-hexenol lures at 1 km intervals on a grid pattern (excluding Malton where EAB was known to occur in large numbers). This resulted in EAB being detected at five new locations throughout the City. City Staff continue to respond to resident inquiries and additional areas of infestation are likely to be plotted.

Throughout 2011, staff continued to sample branches that were suspected to be infested. Training for parks and forestry staff was again conducted. A University of Toronto at Mississauga student is currently working with staff to further delimit the infestation in Mississauga using positive trap locations as a starting point. Staff is working with University of Toronto post doctoral candidates in identifying wooded areas suitable for their research into the presence of parasitoid wasps and their potential to be used as a tool in controlling EAB populations. Inspections on City property continues as does inspections on a requested basis on private property ash trees.

On the basis of these results, it is apparent that EAB is established in Mississauga and populations could reach epidemic levels within the next few years (2015).

The City of Mississauga has an accurate street tree inventory and has established that it has 23,311 ash street trees (estimated to be 9.6% of its street tree population). Of these, 95.5% are considered in **good** or **fair** condition (using the City's rating criteria). The combined distribution of trees in these categories is:

- 6,542 trees (28.3%) less than 10 cm
- 6732 trees (29.1%) between 10 cm and 20 cm
- 8816 trees (38.1%) greater than 20 cm

While there are currently no data for parks and other public lands excluding woodlands, the number of ash there is estimated to be around 23,000 based on comparisons with similar southern Ontario municipalities. Mississauga estimates that there are approximately 70,000 ash trees in its city-owned wooded areas (comprising 9.26% of the total trees).

Unknown is the number of trees on private properties (mostly backyards and some private woodlots). While few cities have accurate inventories of trees on private property, many municipalities accept that this number is, at minimum, equal to the number of street trees, (but in some cases can be a 3:1 ratio).

As of March 2011, Mississauga, along with most other southern Ontario regional municipalities and counties is included in the south-western Ontario EAB Regulated Area (quarantine zone) and regulated materials such as ash nursery stock, logs and firewood can move freely (within this zone) regardless of their infestation status.

11.2 Prognosis: Potential Impact and Costs

EAB has probably been present in the City for at least 8-10 years and has likely dispersed to many other locations within and around the city during this period. Assuming there is no human intervention, such as tree removal or pesticide treatments, and that other mitigating factors such as biological control or host resistance do not come into play, most of Mississauga's ash trees can be expected to be infested within five years, with close to 100 percent mortality expected within 10 years.

Mississauga sees EAB as a very serious problem that will have a significant and lasting impact on its ash street trees, parks, cemeteries and woodlands. While EAB is well established in several areas of the City, there is still time for treatment with pesticides to effectively protect some urban trees for the foreseeable future. While this will be an expensive undertaking recent research supports the position that it is less expensive to treat trees than to remove them over a 10 year period.

Dead ash trees rot fairly quickly and it can be expected that large infested trees would soon become hazardous and would have to be removed as soon as possible. Failure to pre-emptively and proactively plan for EAB could result in a glut of dead trees that would have to be removed once the insect reaches epidemic levels resulting in significant, and non-discretionary budget pressures on the city.

As it is not practical or cost effective to save all urban ash trees, it is critical to have inventory data and well developed selection criteria prior to undertaking any control actions. In addition to actions to protect street trees, Mississauga realizes that ash in parks and cemeteries also need to be protected. These trees are a valuable but often overlooked component of the urban canopy and are more likely to contain specimen or heritage trees worthy of preservation.

Lastly, few municipalities in North America have elected to preserve trees in woodland settings; while theoretically possible, this can be enormously expensive with limited payback. While the genus *Fraxinus* is a component of many eastern Canadian and US woodland canopies, it is not considered to be a successional climax genus and other species will quickly fill the canopy gaps left by ash. At its discretion, Mississauga may elect to protect some woodlands where ash plays a prominent role, especially those deemed to be ecologically fragile.

Assuming that:

- No mitigation efforts are undertaken to reduce the anticipated 99% mortality of Mississauga's ash trees over the next ten years
- The average cost to remove, stump and dispose of an average-sized tree remains at:
    - $500 for trees less than 20cm and
    - $1000 for trees greater than 20 cm
- It costs $450 to replace a removed tree with a 5 cm caliper size tree,

Mississauga could be hit with a minimum cost of **$57,000,000** just to remove and replace street, park and cemetery trees killed by EAB. A general "rule of thumb" is that the number of trees on private properties in municipal areas is at least equal to the number of publicly owned trees. To that end, Mississauga property owners can expect to face even greater costs for the removal of dead ash on their properties.

Additionally, these estimates do not reflect costs associated with environmental impacts such as diminished air, water and soil quality, increased energy consumption, degradation of watersheds and wetlands through increased erosion and runoff and silting, and exacerbation of impacts from invasive alien plants such as buckthorn, dog-strangling vine (swallowwort), garlic mustard etc.

Lastly, trees, especially large specimen trees, have considerable aesthetic qualities and can appreciably add to the value of the properties on which they are located.

11.3 Public Outreach and Education

Mississauga has placed EAB related information on its web. Additionally, it provides information to the public via Councillor mail-outs, presentations and media interviews. All EAB related calls received by its 311 Call Centre are directed to Forestry staff for response, even where these apply to private lands.

Mississauga has conducted workshops and training sessions for its parks and forestry staff and has worked closely with neighbouring municipalities on developing survey protocols.

12.0 MANAGEMENT OPTIONS

Three management options were developed in consultation with Mississauga staff. They reflect the latest science around EAB as well as synopses of the various approaches employed by US and Canadian municipalities to manage EAB. The estimated costs associated with each option are based on a detailed cost-analysis which takes into consideration such parameters as: ash populations, projected mortality over a ten year period, and costs associated with tree removal, replacement and treatment. They are best-guess estimates and are subject to numerous external variables such as the impact of biological control organisms on EAB populations, and the future availability and cost of effective pest control products.

The Options are:

1. Minimal Management/No Management
2. Active Management
3. Aggressive Management

12.1 Option 1: Minimal Management/No Management

Description and Elements:

All publicly owned ash trees would be treated the same as any other tree genus. They would receive no special consideration for conservation or protection and would be removed where they are deemed to be hazardous or an obstruction

- No surveys specific to EAB would be conducted by the City
- No EAB control actions would be undertaken by the City
- Tree replacement would be consistent with existing protocols and policies
- Communication and public education activities specific to EAB would be minimal
- The expected cost is **$ 57,200,000** over a 10 year period (2013-2022)

PROs:

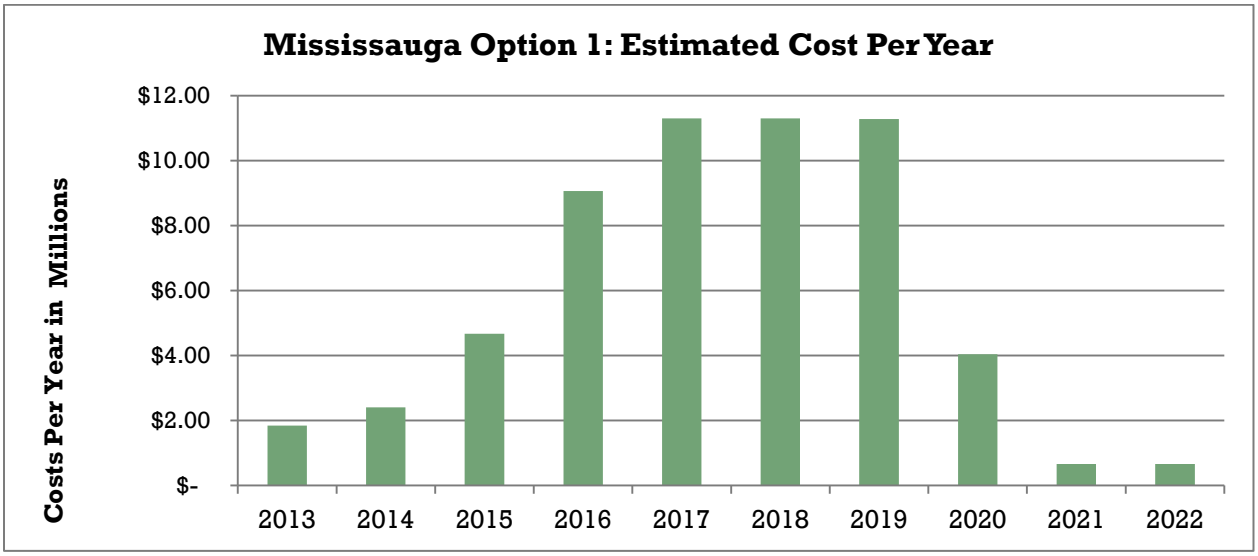
- Pro-Active spending on EAB would be kept to a minimum with minimal upfront costs
- Clear, straight-forward and easy to understand and communicate

CONs:

- There would be little impact on the expected outcome (which is ~100% ash mortality over the next 10 years)
- Street, park and other publicly owned trees would die, become hazardous and would have to be removed notwithstanding… where large numbers of trees have to be removed it is often more cost effective to do this proactively (rather than reactively)
- The absence of survey data would make it harder to plan for efficient detection, removal and replacement of hazard trees or to provide informed advice to property owners wishing to preserve trees on private properties
- There would be no mitigation of the anticipated environmental impact of losing trees
- There would be an overall loss of biodiversity and environmental degradation in heavily affected parks, woodlands, and natural areas
- There would be a significant and possibly permanent loss of genetic diversity for the genus *Fraxinus* which could impact on the ability of ash to recover in the wake of EAB
- Aesthetic considerations… EAB infestation would result in the death of thousands of trees along streets and in parks and woodlands with associated reduction in private property values

Discussion:

There is little evidence to this point that many ash trees are inherently resistant to EAB. Without intervention most of Mississauga's street, woodland, park and cemetery ash trees will die over the next 10 years. Trees that are killed and/or removed as a result of EAB can be replaced but it will take decades to regain the relative percentage of the canopy lost to EAB; little can be done to save the ash component of woodlands and they are usually more difficult to remediate than streetscapes. For these reasons, preserving significant numbers of street and park trees has merit from aesthetic, financial and environmental perspectives.



This Chart depicts the costs associated with this option of managing EAB over a 10 year period. Costs are low for the period 2012 to 2015 because populations have yet to build up to damaging levels. For the period 2015 to 2019, EAB is at epidemic levels and tree mortality, and resulting costs are rampant. Costs decline for the period 2020 and beyond because most ash have already died and have had to be removed. Costs are limited to replacement during this period with this option.

12.2 Option 2: Active Management

Description and Elements:

The **tenets** of this option are:

- Maintenance of the overall percentage of Mississauga's urban canopy
- Preservation of many urban ash trees (with priority given to areas where ash comprises the majority of street trees and removal would have environmental and aesthetic impacts on the streetscape)
- Reduction on the impact to homeowners with publicly owned ash street trees

The **elements** of this option are:

- **Survey:** The City would conduct annual detection surveys to locate new and previously undetected infested sites. The tool of choice would be baited prism traps in combination with visual surveys and branch sampling. At the City's discretion, delimitation surveys (using branch sampling) would be conducted around newly detected sites to determine their extent and assess the potential to effectively treat these areas)
- Tree **Removal**: Infested, moribund or at-risk street, park and cemetery trees as well as those adjacent to park and woodland trails and other public areas would be removed once they are determined to be infested (or at risk of imminent infestation due to their proximity to a known infested site). This would be done once signs and symptoms have manifested and ideally prior to the on-set of mortality thus allowing for more efficient management of the problem and overall reduction of risk and liability to the City
- **Replacement:** all ash street trees, where removed by the City, would be replaced on a 1:1 basis with non-ash. The City would develop a policy for determining which park and woodland trees need to be replaced
- **Treatment:** There is an opportunity to save a significant percentage of the urban ash canopy through treatment with registered pest control products. This is especially important in areas with established ash trees and ash monocultures. Mississauga plans to treat over 15,000 street, and 5,000 park and cemeteries ash trees
- **Communications** and **public education** initiatives would be based on distribution of existing delivery mechanisms and resource materials
- Costs are dependent on the number of trees treated: a cost chart is included below. Assuming 65% of the trees are treated (as planned), the costs to Mississauga over a 10 year period would be around **$50,800,000**

PROs:

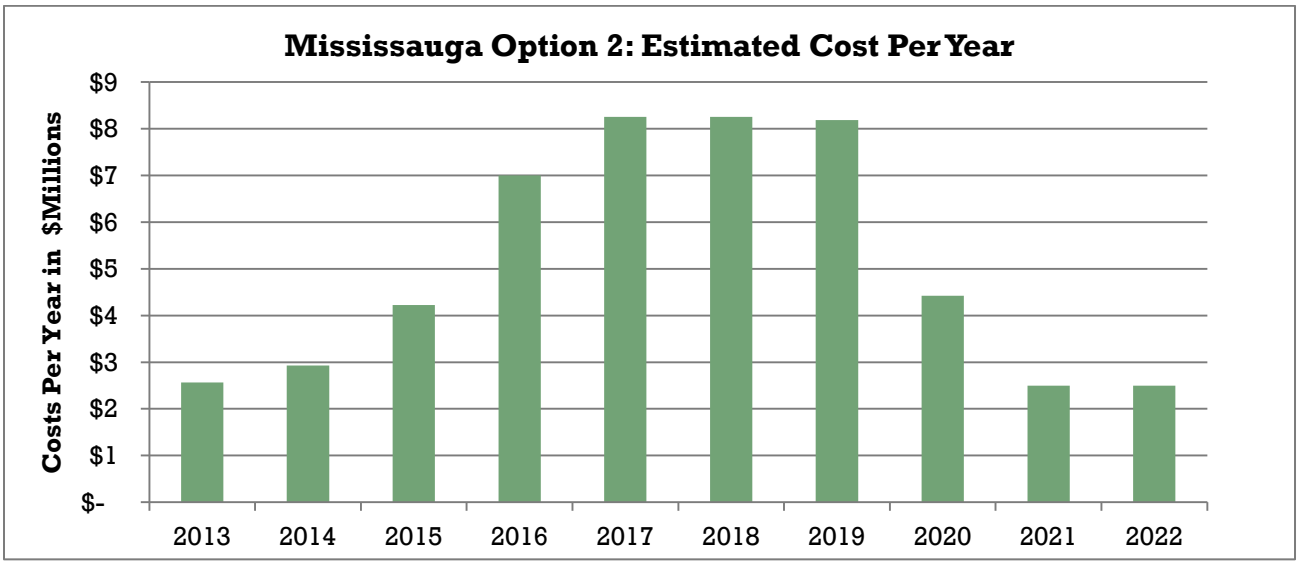
- Research confirms that it is more cost-effective to treat trees over a 10 year period than to remove and replace them; treating 15,000 street, and 5,000 park and cemeteries ash trees rather than removing them will lower costs over the next 10 years
- This option accepts the reality that most untreated ash trees in Mississauga will perish over the next 10 years and offers a sound, cost-effective alternative to doing "nothing"
- When compared to option 1, this is a more pro-active, environmentally sensitive and responsible approach to managing costs and resources
- Annual surveys will permit earlier detection of outliers and will allow the City to more accurately assess the impact that EAB will have, focus treatment and removal programmes and develop timelines for these
- Prompt detection, treatment or removal of infested or at-risk trees will improve aesthetics and possibly result in some efficiency of scale with respect to removal and replacement activities and may slightly impact the epidemiology of the insect
- Tree replacement in urban areas will help maintain urban canopy as well as aesthetic considerations
- Public outreach and education initiatives will permit private property owners to make informed decisions with respect to their trees and ensure public buy-in to the City's management plan

CONs:

- Urban ash street trees are usually cloned cultivars and/or nursery reared trees selected for aesthetic virtues and are not representative of the genetic makeup of the "wild" populations in woodlands
- To date, there is no cost-effective or practical way to preserve the ash trees in woodlands and forests. This option does little or nothing to address this and it is predicted that most untreated ash in the area will die over the next 10 years irrespective of any actions to save street or park trees. This will result in a heavy environmental impact to areas with significant numbers of ash, a loss of biodiversity and a permanent loss of genetic diversity for genus *Fraxinus* in much of southern Ontario
- Treating urban street and park ash will provide little or no long-term mitigation of the environmental impacts or epidemiology of the EAB outbreak

Discussion:

This has been identified by Mississauga as their **preferred option**. The objective of this option is to responsibly manage and potentially off-set the impact of EAB rather than try to manage the pest *per se*. While there are some cost inputs, it is cost-effective, science-based, environmentally responsible and compatible with current best management practices employed to manage EAB.



This Chart depicts the costs associated with this option of managing EAB over a 10 year period. Costs are low for the period 2012 to 2015 because populations have yet to build up to damaging levels. For the period 2015 to 2019, EAB is at epidemic levels but costs are reduced when compared to Option 1 because of the relatively high numbers of treated trees. Costs decline for the period 2020 and beyond because most untreated ash have already died and have had to be removed. Costs during the later stages are for replacement and continued treatment.

12.3 Option 3: Aggressive Management

Description and Elements:

This option differs from Option 2 (Active Management) in that it is an active suppression strategy for EAB (see **Discussion** below). The objective of this option is to save as many trees as possible and retain the ash component of the canopy. This would be accomplished through:

- Intensified detection and delimitation surveys (as compared to other options)
- Aggressive removal or treatment of all known infested trees and those within a prescribed radius around them
- The use of TreeAzin™ or other registered (and effective) pest control products to protect as many ash trees as possible on streets, and in parks and cemeteries
- A programme to protect ash in adjacent woodland areas
- By-laws or other municipal legislation to require private property owners to treat or remove ash trees (including woodlands and parks)
- Expanded communications, outreach and public education programmes (as compared to option 2) to encourage private property owners to treat their ash
- Cooperation with/from other levels of government and neighbouring municipalities
- Costs cannot be calculated at this time, due to incomplete data with respect to woodland and private property ash inventories and associated treatment costs. It would be considerably more expensive than Option 2

***PROs*:**

- Would maintain a majority of the ash currently in the urban canopy
- Could delay the build-up and spread of EAB somewhat and allow time for other options to be implemented
- Could possibly result in the extirpation of EAB at a local level (see **Discussion**) below

CONs:

- For this option to be effective the area would have to be well isolated from other infested areas and all ash would either have to be removed or treated and; it is unlikely that municipalities would be able to pass legislation under the **Ontario Municipal Act** that would force private property owners to treat or remove ash trees
- Municipalities would be on their own with little assistance expected from other levels of government or neighbouring communities in many instances
- Expensive, with little payback (EAB would still spread and ash mortality would occur)
- Woodland trees cannot be adequately or cost-effectively protected at the present time
- For communities in generally infested areas, EAB would continue to invade from adjacent areas
- Not defendable from either a scientific or financial perspective at present (for eastern Canada)

Discussion:

This strategy is practical only in urban areas which are remote to generally infested areas and have high numbers of treatable ash trees. There is merit in aggressively suppressing or even eradicating EAB at the local level for municipalities where ash is extremely valuable as an urban street tree, which are not located in generally infested areas and are fortunate enough to detect EAB in the initial stages of infestation. In the opinion of the author, this is not a viable option for any southern or eastern Ontario municipality, including Mississauga. It could be practical in western Canadian cities such as Winnipeg, Edmonton or Calgary (for example) where EAB is not believed to have established, where there are only two or three genera of trees suitable for street planting (ash being one of them) and where ash is not a major component of surrounding woodlands or wild areas. Few eastern Canadian cities meet these criteria. No histogram or "bottom line" are provided here (as with other options) because costs for treating, removing and replacing woodland trees cannot be accurately calculated and the graph would be misleading to the reader.

13.0 RECOMMENDED OPTION AND ACTION PLAN

13.1 Preamble

Following a review of the data and a detailed analysis of the various options available to it, Mississauga has selected option 2 (Active Management) as the best option to mitigate the expected impact from EAB.

As EAB is likely well established at numerous locations throughout the City, it is anticipated that most ash trees within Mississauga will either die or become heavily infested within the next ten years without intervention.

Depending on the number of trees treated, the cost of Option 2 will vary. At present it considers that 65% of the street trees will be treated and 5,000 park and cemetery trees will be treated. It is estimated to cost around **$50,800,000** over a 10 year period assuming management activities in support of this option commence in 2012.

13.2 Rationale supporting decision:

- Regardless of human intervention, EAB will likely become pervasive throughout Mississauga (as well as adjacent municipalities) over the next 10 years and most unprotected ash trees will die during that period[19]
- Despite recent advances in survey and treatment science and technology, there are still no effective strategies for detecting EAB early enough to effectively manage it or protect woodland areas and most trees in natural areas will be lost over the next 10 years
- This option places the emphasis on maintenance of the urban canopy (65% of the ash street trees will be protected)
- It also provides for the protection of high value specimen or heritage trees in parks and cemeteries
- It is the most cost-effective option available… cost analyses conducted by similar municipalities support the implementation of a conservatively pro-active approach as less expensive over a 10 or even a 20 year[20] period than a re-active (do-nothing) approach.

[19] While populations of some invasive pests can decline rapidly due to biological control, there is no expectation amongst scientists and regulatory experts that this will occur anytime soon with EAB

[20] If the full value of an urban tree is considered there is (unpublished) data to suggest that treatment will be cost effective over a 20 year period

13.3 Monitoring and Surveillance

13.3.1 Description

As previously discussed in this document, there are two different survey strategies employed in the management of quarantine pests such as EAB: namely, **detection** and **delimitation**. Details pertaining to the methodology for these strategies are included on page 32.

Objectives	Activities Required to Meet Objectives
Conduct Detection Surveys to detect outlier populations outside of generally infested areas	• Deploy prism traps, or conduct modified branch sampling survey at strategic locations throughout the City in densities sufficient to provide statistical confidence that EAB is **NOT** present • Analyse and map data
Conduct Delimitation Surveys to monitor EAB dispersal and the rate of spread around known outliers	• Branch sampling • Visual surveys for signs and symptoms such as crown decline • Analyse and map data

13.3.2 Cost (Financial Forecast)

The survey component of Option 2 is estimated by Mississauga to cost $500,000 over a 10 year period. This does not include the cost of a project manager to coordinate treatment and removal activities (which is estimated will cost $640,000 over a ten year period).

13.3.3 Comments

Accurate inventory and survey data are paramount with respect to making informed management decisions. Early detection of EAB outliers will allow for targeting of tree protection, removal and replacement initiatives and will help the City estimate future costs for these.

13.4 Tree Protection

13.4.1 Description

With specific respect to EAB, tree protection means treatment with registered pest control products to prolong the life of a tree that would otherwise be killed by EAB. Without intervention, it is anticipated that close to 100% of Mississauga's street, woodland, and park ash trees will be killed over the next 10 years. There are now data to show that the timely application of pest control products such as TreeAzin™ can effectively save at-risk trees and that over a 10 year period treatment can be less

expensive than removing urban trees. Under the terms of registration for this product, it may only be applied by certified applicators using the EcoJect® system under patent to BioForest Inc. This is the only pest control product recommended in Canada at present.[21] [22]

The use of pesticides by Mississauga will be restricted to the protection of healthy street trees and possibly some high value park and cemetery trees. There are no plans at present to preserve ash trees in woodlands. The reasons for this are:

- Ash tends to be greatly over represented in many woodlands as a result of past disturbances and other human activities. While a valuable component of the woodland canopy, the loss of canopy will be off-set by the succession of other climax trees in the overstorey and understorey such as oaks and maples
- It is generally not practical or cost-effective to treat large numbers of woodland ash; funds are better spent on the preservation of street trees in vulnerable areas (streets planted to monocultures etc.) and in parks and cemeteries
- Not all street and roadside trees are worthy of preservation due to size or general condition; in some cases it may be best to proactively remove and replace these with non-host species
- Most municipalities affected by EAB have elected to remove trees less than 10 cm dbh (and in some cases <20cm) rather than treat them because of their limited contribution to the overall percentage of the canopy, ease of replacement and the prospect of having to treat them for an extended period

Irrespective of actions taken by Mississauga to preserve the ash component of its urban canopy, private property owners may opt to treat high value ash on their respective properties and it is incumbent on the City to provide them with informed advice in this regard. Only products legally registered for use in Canada may be used against EAB. At present, all three products currently available in Canada **may only be** applied by a registered pest control operator as the products must be injected under pressure, or inserted into the trunk of the tree.

[21] While both ACECAP® 97 and Confidor 200SL are currently registered in Canada by the PMRA they are not recommended by the OMNR, CFS researchers or the author as effective pesticides against EAB

[22] The Emergency Registration for TreeAzin expired on August 31, 2011 but will be renewed for 2012 pending full registration of this product by Health Canada-PMRA

Objectives	Activities Required to Meet Objectives
Detect and determine extent of EAB populations in Mississauga	• Conduct surveys to ensure early detection and delimitation of infested sites • Map areas of infestation • Provide data to public via website
Selection of trees for protection	• Develop criteria for selecting trees to be treated (the use of a decision matrix is recommended to elucidate and weigh selection criteria) • Identify, prioritize and map candidate trees/areas • Develop operational plan for treatment
Cost benefit analysis of: treatment vs. non-treatment	• Determine costs for treatment of candidate trees bi-annually and extrapolate costs over 10, 15 and 20 year periods • Examine/compare different treatment scenarios in order to get the best fit for Mississauga
Ensure public is kept informed of EAB infestation status and mitigation activities in the City	• Develop a public communications plan/strategy • Post on Mississauga website • Develop Fact Sheets/Q's and A's etc. • Provide contact information for where public can access advice on treating privately owned trees

13.4.2 Cost (Financial Forecast)

Protection of candidate trees, under Option 2 is projected to cost $16,000,000 over a ten year period (commencing in 2013); this will allow for the protection of an estimated 15,000 urban street trees as well as 5,000 park and cemetery trees. While treatment would not preclude the loss of trees from other (primarily non-insect) mortality factors, it can be assumed that most of the trees selected for treatment will survive for the 10 year treatment period. Application and chemical costs are likely to change over the 10 year window thereby affecting the projected costs. New and less expensive control products and methodologies may become available over this period. Additionally, biological control and natural host resistance may play more prominent roles in mitigating ash mortality and lowering long-term costs.

13.4.3 Comments

- Areas where ash street (and alternatively park and cemetery) trees form a major component of the urban canopy can be cost-effectively protected over a ten year period
- Treating park and cemetery trees will preserve a valuable component of the Mississauga's urban canopy
- It is recommended that Mississauga's EAB action plan clearly outlines measures to protect valuable street trees. To this end, Mississauga needs to

develop a decision matrix to rate and select candidate trees (with respect to treatment)
- No attempt should be made to treat or otherwise protect woodland ash trees from EAB (exceptions to be made for heritage trees or for scientific research)

For municipalities actively treating street trees with TreeAzin™, the average cost ranges from $5 to $7 per cm dbh every second year. This translates into $150-$200 for a 20-30 cm tree. The cost of treating larger trees (>40 cm) is higher as more product and time are required and treatment may not be as effective. For the purposes of this document, a weighted average cost of $160/2years (or $80/yr) is used.

Tree Service Companies generally charge more for treating trees on private property due to increased labour costs associated with client interaction and travel.

13.5 Removal

13.5.1 Description

Removal refers to cutting ash trees as a direct result of current or impending EAB infestation. Removal may entail:

- Felling the tree *in situ* without removal from the area
- Removal of the branches and trunk of the tree (leaving the stump)
- Total removal of all parts of the tree including stumps
- Chipping or grinding -either on site or at the disposal site

This can be done in the context of:

- Hazard tree removal (removing those trees along streets, roadsides or adjacent to woodland trails which are, or will be hazardous) or ordering private property owners to remove hazard trees per the Property Standards By-law
- Pre-emptive removal (removing trees prior to infestation and/or death, regardless of health status)
- Selective tree removal (removing specific trees in conjunction with an over-all management programme to limit or mitigate EAB induced mortality and slow the spread of the pest locally)
- Other… such as the pre-emptive removal of trees as part of a woodland management programme (irrespective of EAB status)

Objectives	Activities Required to Meet Objectives
Identify and determine the number of publicly owned street, park and cemetery ash trees	• UFORE • Inventory • GPS, GIS or other mapping technologies
Identify and determine the number of potential hazard trees along Mississauga pathways and trails in parks and woodlands	• Conduct inventory of at-risk trees along Mississauga woodland trails and pathways • Categorize as to risk potential • GPS, GIS or other mapping technologies
Identify street trees to be removed	• GPS, GIS or other mapping technologies • Develop protocol for removal • Replacement (see below) • Public relations/Communications

Develop site-specific ash tree removal policies and protocols	• Develop and cost out removal strategies specific to:
	  ○ Site (e.g., streets and roadsides, trails, pathways, woodlands, road allowances, parks, cemeteries etc.)
	  ○ Size classes

Cost Analysis (specific to removal)	• Estimate the number of potential ash tree removals specific to various sites (street and parks vs. woodland) • Determine appropriate removal method for the site (e.g., cutting and removal vs. felling *in situ*) • Establish unit costs for removal and disposal • Estimate costing for 10 and 20 year periods • Determine replacement costs (see section 11.5) • Determine potential for cost recovery through salvage logging and other cost mitigation activities

13.5.2 Cost (Financial Forecast)

The removal component of Option 2 is estimated by Mississauga to cost around **$19.5 million** over a ten year period. This does not include the cost of hiring a project manager (which Mississauga estimates will cost $640,000 over the next ten years), or dealing with hazard trees in woodlands.

13.5.3 Comments

Standing dead ash trees decay rapidly and may become hazardous within a year or two after death. Publicly owned street trees and those on private property which pose a hazard have to be removed prior to, or immediately following death. Woodland trees killed by EAB generally do not have to be removed (or felled) unless they abut roads, public pathways or trails or otherwise deemed a hazard. Irrespective of the management option selected by Mississauga or available funding, this activity is non-discretionary due to the inherent liability associated with leaving standing dead trees. For this reason, there needs to be a contingency plan

for dealing with dead or dying trees prior to the onset of mass mortality predicted to occur within the next five years. Where removals are pre-emptive, they can be staged over a multi-year period based on risk and efficiency of removal. Annual detection and delimitation surveys will help Mississauga:

- Assess risk
- Predict where mass mortality is likely to occur, and
- Prioritize sites for imminent removals and/or treatment.

Where significant numbers of at-risk woodland ash are present, or pre-emptive cutting has been deemed desirable, the option exists for salvage logging by which some costs may be recovered. This will however, remain the exception rather than the rule with respect to managing Mississauga's woodlands for EAB.

13.6 Tree Replacement, Restoration and Remediation

13.6.1 Description

The **Replacement, Restoration and Remediation** component entails the replacement of trees which have died or been removed (specifically for EAB) and making the site suitable for tree replacement. In some cases site remediation is necessary where large numbers of ash trees have died and/or there has been physical damage to the site through removal activities.

Objectives	Activities Required to Meet Objectives
Prevention of urban canopy reduction due to EAB	• Develop an accurate, up-to-date tree and land use inventory • Conduct annual Detection Surveys • Develop or build on existing criteria or protocols governing tree replacement and site restoration for the various categories of trees (e.g., street and roadside, woodland, park cemetery and other) • Collaboration with partners such as conservation authorities and private tree planting groups
Mitigation of environmental and ecological impacts	• Identify particularly sensitive areas where ash plays a vital role in the ecology of site (e.g., riparian areas where sedimentation or reduction in water quality may result from mass mortality) • Develop a plan to mitigate damage to these sites (may include underplanting with non-host species in some instances, construction of berms etc.) • Naturalizing and remediating City owned areas adjacent to affected woodlots

13.6.2 Cost (Financial Forecast)

Tree replacement specific to Option 2 is estimated to cost $11.5 million over a ten year period. This does not include underplanting woodlands and forests affected by EAB or site restoration or remediation. Mississauga plans to spend an additional $750,000 over a 10 year period to remove hazardous trees in its woodlands, and another $500,000 over ten years to remediate woodlands impacted by EAB. For the most part, this would entail replanting and naturalizing city owned areas abutting woodlands.

13.6.3 Comments

Most Ontario municipalities see tree replacement as a non-discretionary activity and have committed to maintaining or increasing the relative percentage of their urban canopies; many have developed Strategic Urban Forest Management Plans to provide a framework for this. Having a management plan in place allows municipalities to plan and focus removal, restoration and replacement activities and to budget accordingly.

Ash is an important street tree genus in Mississauga, and its imminent loss could heavily impact many communities where ash represents a virtual monoculture. While ash is an important component of many woodlands, the overall impact associated with canopy reduction is not likely to be as severe as with other Ontario communities where ash often represents a much higher percentage of the trees. Notwithstanding, the various species of ash are a vital component of the ecosystems of some environmentally sensitive sites such as wetlands and riparian areas and their loss could have significant and lasting impacts on these areas. Additionally, the loss of ash could greatly degrade vulnerable habitats through increased erosion, sedimentation, and stream warming as well as the loss of browse and habitat for animals. Furthermore, these areas would also be more vulnerable to colonization by invasive alien plant species such as buckthorn, garlic mustard and honeysuckle.

Mississauga needs to identify which areas (specifically streets, parks, cemeteries and woodlands) will be most impacted and develop strategies to minimize or mitigate the damage. Depending on the site, these could include:

- Protection (see 13.4)
- Replacing trees where ash are removed in streets, parks and cemeteries
- Underplanting severely impacted woodlands with non-host trees
- Physical alterations to environmentally sensitive sites to prevent or counteract erosion and degradation of water quality

13.7 Disposal

13.7.1 Description

The disposal of trees killed by EAB can be problematic for affected communities. EAB usually reaches epidemic levels within five years of its initial detection in an area and municipalities with large numbers of ash can be overwhelmed.

Objectives	Activities Required to Meet Objectives
• Estimate the number of at risk street, park and cemetery trees • Ensure current disposal protocols are adequate to meet demand • Ensure landfills are prepared to accept the anticipated volume of dead ash trees • Budget for increased disposal activities • Investigate "green" options for disposal such as salvage logging, biofuels, diversion etc. • Provide information for private property owners wishing to dispose of their trees	• Surveys, UFORE and other census tools • Liaison and communication with Regional Municipality of Peel and other affected municipalities within and neighbouring Peel Region • Communications and public relations • Develop a policy for woodland trees • Possible development of a list of approved tree service companies?

13.7.2 Costs

The disposal component of Option 2 is estimated to cost $500,000 over a 10 year period.

13.7.3 Comments

Disposal costs are minimal for Mississauga only because much of the chipping etc. will be done on site and costs have been in included under "Removal". Currently, the Regional Municipality of Peel assumes responsibility for the collection of wood chips from Mississauga in their green recycling programme.

The $500,000 allocated to this line item over the 10 year period is for the annual rental of a tub grinder, which can efficiently process large quantities of accumulated wood waste over a short period.

While "green" disposal and recycling of ash wood waste is desirable, few municipalities affected by EAB have been successful in their efforts to salvage or recycle these materials; the very large volumes and the limited market for such products as wood chips greatly limits the options available for these materials.

13.8 Communications, Outreach and Public Education

13.8.1 Description

The objective is to develop and implement an effective EAB Communications Strategy; once urban street, park, cemetery and woodland ash trees start dying en masse, this will become paramount.

Objectives	Activities Required to Meet Objectives
• Educate and engage the public on EAB identification, anticipated impacts and planned mitigation policies • Ensure favourable media exposure (and coverage) • Provide information for private property owners wishing to treat or otherwise preserve their trees	• Define objectives • Designate spokesperson • Develop a strategic communications plan outlining time lines, key messaging, Q's and A's etc. • Develop or otherwise procure communications materials (pamphlets etc.) • Interactive on-line site linked to City website

13.8.2 Cost (Financial Forecast)

The expected costs for Communications specific to Option 2 are $355,000 over a 10 year period.

13.8.3 Comments

A sound communications strategy is required regardless of which management option is selected by the City. Ensuring the public and media are educated with respect to the expected impact of EAB and the City's management plan is paramount and instrumental to its success.

14.0 SUMMARY

EAB has behaved as a classic, albeit, worse case example of an invasive alien pest to this point. Many of the dire predictions made by scientists soon after its discovery in 2002 have proven very accurate and it is ranked as one of the worst pests to ever be introduced to this continent. It is a serious pest because:

- It is native to eastern Asia which has a similar climate and host species to eastern North America... it arrived here pre-adapted to both our climate and ash species;
- Other than blue ash, (a native, but rare tree in Ontario), natural resistance amongst North American ash species has not been observed to any significant extent
- EAB fills an ecological niche not currently occupied by any North American species;
- Its cryptic nature and the fact that it spends much of its life cycle under the bark of its host do not readily permit early detection or easy control... both critical prerequisites of a successful management programme for invasives;
- Ash (genus *Fraxinus*) are very important woodland and urban trees in North America and are often over-represented in many areas as a result of habitat disturbance (they are early successional hardwoods and rapidly colonize disturbed areas), and overplanting in urban areas;
- There is a paucity of both native and introduced biological control organisms;

In addition to the serious financial impact EAB has had (and will continue to have) on the forest industry, municipalities and property owners (costs for removal and disposal of dead trees will easily reach into the billions of dollars in future years), its primary impact will be environmental. Much of the genetic diversity of ash in Canada and the US (the result of millions of years of evolution) will be lost forever, greatly affecting the ability of this genus to rebound from EAB or adapt to future challenges. Additionally, ash-based ecosystems in Peel Region will be seriously damaged (ash is an early successional genus) and IAS "weeds" such as dog-strangling vine, autumn olive, honeysuckle, buckthorn, and privet, will become more serious and pervasive pests in years to come as the niche ash previously occupied is encroached upon by these species.

Generally speaking, IAS rarely sustain their epidemic phase and it is likely that EAB populations will crash or at least come into balance with their host at some time in the future with an ecological equilibrium being reached. In the long term, ash trees

which are genetically predisposed for resistance to EAB will be naturally selected and will play an increasingly important role in the recovery of the genus.[23]

Additionally, an apparent dearth of biocontrol organisms in the initial stages of an invasion by IAS can be overcome through the natural selection and emergence of endemic insects, nematodes and pathogens, and as well, by the deliberate introduction and release of exotic biocontrol organisms. To this end, the USDA and its co-operators have released three species of exotic parasitoids[24] collected in eastern Asia and specific to EAB at numerous US sites in the hope that these will become established in North America and effect control here. At present, this appears to have been a qualified success with there being evidence that two of the three species have successfully established.[25]

Of note is that EAB can only survive on ash and there is no indication to this point that it will jump to other species when ash disappears. Additionally, in areas with long established EAB populations such as Michigan and Essex County, Ontario where most of the ash trees have already been killed, some trees are surviving and reproducing. As well, several species of native parasitoids which naturally attack North American relatives of the EAB have been recovered in large numbers in these areas over the past two years and they appear to be having an impact on local EAB populations.

Also of note, is that effective pest control products are now available in Canada and the US and it is now possible to cost-effectively treat and preserve some ash trees in the urban canopy; this was not the case until very recently. This is seen by many forest pest management specialists as a "game changer", and gives municipal foresters an option they did not have a few years ago. New (and cheaper products) will make the preservation of urban ash even more cost effective in years to come. While treatment with pesticides is not a sustainable strategy over the life of a tree, it is only a matter of time before equilibrium is reached between EAB, its host, and its biological control factors and it becomes a normalized, naturalized and greatly attenuated species.

Unfortunately, despite the development of effective pesticides and application techniques in recent years, there is little hope that woodland ash in much of southern Ontario can be saved. In much of the south-western part of Ontario, most of the woodland ash are dead and a similar fate awaits ash in Peel Region.

[23] Resistant trees have not been observed to date in significant numbers
[24] See definition
[25] Personal Communication: Drs. Vic Mastro and Juli Gould (USDA-FS), Deb. McCullough (MSU), Barry Lyons (NRCan-CFS)

EAB is generally considered to be in an epidemic (or outbreak) mode and will pass through Peel Region like a wave. As ash populations decline, EAB populations will crash. Ash populations should eventually rebound, and EAB will likewise recover, although future outbreaks are unlikely to be as severe as what is currently being encountered. As discussed, the emergence of natural controls, EAB resistant trees and human intervention will play a major role in the recovery of ash and it is hoped that the genus will regain some of its former prominence as an important forest and urban tree at some point in the future.

In conclusion, barring a major change in the present circumstances, EAB cannot be eradicated from the City of Mississauga. The loss of most of the ash in the City and Peel Region will severely impact streetscapes, parks and woodlands and will reduce species diversity and financially affect property owners with ash trees.

Regardless of any control or management actions to suppress the insect, EAB population levels are likely to increase exponentially over the next five to ten years and infest and kill most of the ash trees in the City and environs during this period. There will be severe and lasting environmental, aesthetic and economic impacts on property owners and other stakeholders located in affected areas.

Maintaining healthy streetscapes and woodlands is integral to the urban environment and every effort must be made to maintain or even increase the number of healthy trees in urban and adjacent rural areas through visionary management, public education and replanting programmes.
