Emerald Ash Borer (EAB) Management Plan

City of Cornwall, Ontario January 9, 2014

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EXECUTIVE SUMMARY

Emerald Ash Borer (EAB) (*Agrilus planipennis* Fairmaire) is an introduced, invasive wood-boring beetle which currently threatens billions of ash (genus *Fraxinus*) trees across North America. The beetle has already killed millions of ash trees across the American Northeast and Midwest, along with many millions of trees in Southern Ontario. EAB infestation is ongoing across Southern Ontario, and was confirmed in Cornwall in June 2013.

It is anticipated that EAB will kill virtually every ash tree within the City of Cornwall within 10-15 years The EAB population will likely build and disperse steadily for several years before a large-scale population explosion. Ultimately, virtually all untreated ash trees will likely be killed. The impacts of ash canopy loss will be significant – increased stormwater runoff, ultraviolet light exposure and urban heat island effects, reduced carbon sequestration and air pollution filtration, and loss of aesthetic and property values are just some of the potential anticipated effects.

EAB demands an active management approach by municipal urban forest management staff. At a minimum, Cornwall will need to remove standing dead trees on account of the increased likelihood of ash tree uprooting failure within two years of EAB-induced tree mortality, due to the rapid onset of root decay. Improved management may include activities such as infestation surveying, insecticidal control, pre-emptive tree removal and tree replacement. Four proposed strategies, which include a wide range of management options, are presented in this report and accompanied with detailed cost forecasting models. The estimated costs of these strategies range between $3.6 million and $5.8 million over 15 years, with potential ash street, park and other municipally-owned tree losses between 59% and 98%.

Seven key recommendations proposed in this report include:

1) Maintain existing working relationships with the Canadian Food Inspection Agency (CFIA), Canadian Forest Service (CFS) and Ontario Ministry of Natural Resources (OMNR);
2) Selecting an appropriate EAB management strategy on the basis of cost and available resources;
3) Identifying suitable sites for wood waste disposal;
4) Continue and expand the use of the existing ash tree inventory GIS data;
5) Continue developing and further implementing an EAB communication strategy;
6) Collecting natural areas ash tree inventory data in spring/summer 2014; and,
7) Undertaking an annual review of the EAB management program and provide regular updates to City Council.

BACKGROUND

Emerald Ash Borer - Biology and Life Cycle

The Emerald Ash Borer (EAB) (*Agrilus planipennis* Fairmaire) is a non-native wood-boring beetle (Coleoptera: Buprestidae) native to Eastern Asia, where it does not pose a significant threat due to the existence of natural predators. With the potential to kill individual trees of species of ash (genus *Fraxinus*) in the United States and Canada, EAB is considered to be one of the worst invasive forest pests ever to be introduced to North America, and threatens to eliminate ash tree populations across the continent.

Figure 1: Adult Emerald Ash Borer beetle. (Source: CFIA, http://www.inspection.gc.ca)

The adult beetles are metallic green (emerald) in appearance and typically measure 7.5 mm to 13.5 mm in length and 4.0 mm in width. The life cycle of EAB takes one year to complete, but may be protracted to two years in colder climates. Up to 300 eggs are laid by mature females within bark crevices from early May to mid-July. Approximately 10-20 days following oviposition, 26-32 mm long larva will hatch from the eggs and bore through the outer bark towards the cambium and phloem tissues of the host tree. Larvae feed upon these tissues, producing signature S-shaped feeding tunnels, or galleries. After feeding the insect will overwinter as prepupae within chambers in the sapwood or bark of its host. After pupating in April, adult beetles begin chewing their way from the pupal chambers to the surface of the bark, emerging during the early spring to late summer. Following their emergence, adult beetles will feed on the foliage of nearby ash crowns in order to complete their maturation and prepare to mate, continuing the EAB life cycle.

Figure 2: Emerald Ash Borer larvae, showing three instar stages. (Source: CFIA, http://www.inspection.gc.ca)

Emerald Ash Borer - Hosts, Dispersal and Range

An invasive pest, the Emerald Ash Borer targets all true ash (genus *Fraxinus*) species in Southern Ontario. Over the past several decades, ash trees have become a popular street and landscape tree due to the species' large mature size, fast growth, relatively strong insect and disease resistance, and tolerance for urban conditions. Ash served as a particularly suitable replacement for the once-ubiquitous white elms (*Ulmus americana*) killed by Dutch Elm Disease (*Ophiostoma novo-ulmi*) since the 1960s. Although there are some indications of varying degrees of EAB susceptibility between ash species, no species is completely resistant. It is predicted that virtually all untreated ash trees will succumb to the beetle if left unchecked, resulting in the loss of up to 7.5-10 billion ash trees across North America. Furthermore, EAB is indiscriminate in affecting urban, suburban and natural forest landscapes. Trees typically undergo extreme decline and death 1-3 years following initial infestation. Aside from municipalities, the hardwood forest industry and woodlot owners face significant economic losses, as green (*Fraxinus pennsylvanica*) and white ash (*F. americana*) are important species used in the manufacture of products such as cabinetry and sporting goods.

The first documented case of EAB in Canada was reported in Windsor, ON, and concurrently in Detroit, Mich., in July of 2002. Over 5,000 ash trees were lost in Windsor, at a cost of approximately $4 million for tree removal and stumping. Windsor has passed the peak of ash mortality, but will likely continue incurring additional removal, disposal and replanting costs for years to come.

The beetle is capable of dispersal up to several kilometers, although an opportunistic preference is shown for nearby hosts. Research suggests (McCullough *et al.* 2004) that adult beetles are unlikely to disperse more than 3 kilometres, although mated females have been noted to disperse up to 10 km (Taylor *et al.* 2005). Moreover, the spread of EAB has been accelerated by the inadvertent human transportation of beetle-infested wood, particularly firewood and nursery stock, prompting Ministerial Orders under the *Plant Protection Act, 1990* to prohibit the transportation of infested or potentially-infested wood materials. At present, the known range of the beetle stretches from Thunder Bay, Ontario, east to the Eastern Townships of Quebec and south as far at Georgia, US. The beetle continues to spread rapidly, leading to massive mortality of ash-dominated forest stands and urban ash trees. EAB has killed or infested an estimated 70 million ash trees since its detection in 2002, and an estimated 10 billion ash trees in Canada and the US are at risk of infestation and death.

Existing Regulations, Agencies, and Responsibilities

A review of current legislation, regulations and agencies involved in EAB management in Canada is provided in this section.

Aside from inspection by the Canadian Food Inspection Agency (CFIA) and, more recently, the Canadian Forest Service (CFS), there has been little support to date for EAB management from either the Federal or Provincial governments, forcing affected municipalities to bear the majority of costs associated with management planning, tree removal, injection treatment, and replacement planting.

Canadian Food Inspection Agency (CFIA): The CFIA is the lead agency for invasive species management in Canada, and has established a multi-agency approach to addressing the challenge of EAB by involving the Ontario Ministry of Natural Resources, Canadian Forest Service and the Ontario Ministry of Agriculture and Food. In Ontario, the CFIA began EAB management in 2002 by establishing a quarantine area in Essex County. In 2003, the agency cut and burned about 8,000 infested trees at the leading edge of the infestation, and in 2004 created the “ash-free zone” by cutting, chipping and burning approximately 80,000 trees in a 10 km wide area from Lake St. Clair south to Lake Erie. The ash-free zone proved ineffective, as infestations beyond the zone were discovered soon afterwards. The CFIA continues to administer EAB detection surveys.

The CFIA also enforces various regulations pertaining to plant protection, including prohibition of transport of regulated materials outside of Regulated Areas.

As of November 2013, the EAB Regulated Areas of Canada include:

1. All the areas within the boundaries of the Cities of Hamilton and Toronto, the Regional Municipalities of Chatham-Kent, Durham, York, Peel, Halton, Niagara and Waterloo and the Counties of Brant, Bruce, Elgin, Essex, Haldimand, Huron, Lambton, Middlesex, Norfolk, Oxford, Perth and Wellington.

2. The area within the boundaries of the City of Sault Ste. Marie.

3. The area within the boundaries of the Manitoulin district.

4. All the areas within the boundaries of the City of Ottawa, the United Counties of Leeds and Grenville and the United Counties of Prescott and Russell and the county of Frontenac in the Province of Ontario and, in the City of Gatineau, the municipalité régionale de comté (MRC) de Papineau and the MRC Les Collines-de-l'Outaouais in the Province of Quebec.

5. All the areas within the boundaries of the Municipalities of Carignan, Chambly, Richelieu, Saint-Basile-le-Grand and Saint-Mathias-sur-Richelieu, the cities of Montréal, Baie-d'Urfé, Beaconsfield, Côte-Saint-Luc, Dollard-Des Ormeaux, Dorval, Hampstead, Kirkland, Laval, L'Île-Dorval, Montréal-Est, Montréal-Ouest, Mont-Royal, Pointe-Claire, Sainte-Anne-de-Bellevue, Senneville and Westmount and the Agglomération de Longueuil.

EAB Regulated Articles include:

- ash trees (whole or parts)
- ash nursery stock
- ash logs and branches
- ash lumber
- wood packaging materials with an ash component
- ash wood or bark
- ash wood chips or bark chips
- firewood from all tree species

At a December 05, 2013, Emerald Ash Borer - Municipal Workshop held in Simcoe County, a CFIA representative outlined proposed changes to the extent of the EAB Regulated Areas of Southern Ontario, expected to come into effect at the beginning of April, 2014. The proposed expansion – concurring approximately with the Trans-Canada Highway to the North – is designed to include major highway corridors, through which EAB is spread most rapidly, along

with abutting counties that are expected to be affected by EAB in the near future. It should be noted that Cornwall is situated within the proposed area of expansion.[1]

Coinciding with the anticipated expansion of EAB Regulated Areas, there are indications that the CFIA may be curtailing its involvement in EAB detection and monitoring of EAB within areas of confirmed infestation. As a result, regions and municipalities are increasingly assuming the responsibilities for detection and identification of EAB, as well as the associated costs. As municipalities assume these expanded responsibilities, the need to establish and maintain formal working relationships with agencies such as the CFIA, in order to facilitate information sharing, becomes more critical.

Canadian Forest Service (CFS) / Natural Resources Canada (NRCAN):The Canadian Forest Service has developed and begun implementing a simplified branch sampling methodology for EAB identification in urban areas, in coordination with urban forest managers in municipalities such as Burlington and Oakville, Ontario. NRCAN has also published a number of booklets and pamphlets outlining EAB sampling techniques and management approaches, including "*A Landowner's Guide for Woodlots Threatened by Emerald Ash Borer (2006)*", "*A visual guide to detecting Emerald Ash Borer damage (2006)*" and "*Survey guide for detection of Emerald Ash Borer (2007).*"

Ontario Ministry of Natural Resources (OMNR): OMNR is not directly involved in EAB management, aside from conducting limited research and maintaining partnerships with the CFS and CFIA. The OMNR has also shared information with Cornwall staff, and conducted public information outreach related to EAB.

Recommendation: The City of Cornwall should maintain a working relationship with the CFIA, CFS/NRCAN and OMNR to facilitate information sharing, EAB surveying and monitoring, and the implementation of control measures. Maintaining this relationship should involve further staff attendance at EAB-related conferences and workshops, regular communications among and between key staff, and sharing of information about EAB infestations and management activities in the City.

Legislation and Regulations (Federal): The critical legislation supporting invasive species management in general is the Federal *Plant Protection Act, 1990.* Emerald Ash Borer is a regulated pest under the Act, which gives federal agencies the authority to regulate the movement and possession of infested or potentially-infested plant materials, and the ability to inspect plants on municipal and private property.

1 RMD-13-01: Regulated Areas for Emerald Ash Borer (EAB) (Agrilus planipennis Fairmaire). Accessed online at: http://www.inspection.gc.ca/plants/plant-protection/directives/risk-management/emerald-ash-borer/eng/1368741925939/1368741926892

Legislation and Regulations **(Municipal):** The City of Cornwall enforces by-laws which may assist in managing EAB, including By-Law No. 072-2000 – "Property Standards By-law," which states, "[a yard] shall be kept clean and free from objects or conditions that may create a health or accident hazard." The by-law stipulates that "all trees and shrubs shall be kept free from dead or dying branches and limbs, the collapse of which would be capable of causing injury or damage." Furthermore, the by-law requires that "[d]ead trees and shrubs [be] promptly removed from the property." The property standards by-law will enable the City to require the removal of hazardous or dead ash trees.

Although the City's Property Standards by-law enforces the prevention of insect pests within dwellings and dwelling units, the City currently lacks the authority to control and limit the spread of pests within private yards.

City of Cornwall – Current and Future Status of Emerald Ash Borer

Status of Infestation

According to the City of Cornwall website, Emerald Ash Borer "was first detected in Cornwall and the United Counties of SD&G in June 2013." An inventory of ash trees on City of Cornwall road rights-of-way, in parks, and on other City-owned properties was conducted in September, 2013, at which time a total of 3,472 municipal ash trees were inventoried for such attributes as species, diameter at breast height (DBH), location, condition class, and the presence of obstruction(s). At the time of the City-wide ash inventory, there were no signs or symptoms of EAB observed among Cornwall's ash trees, suggesting that City's infestation had not progressed beyond an early stage of infestation. However, infestation was visually confirmed on private properties around the McConnell Ave. and Ninth St. E/Marleau Ave. area in 2013. It is likely that this area is the first infestation 'hotspot' in the City, and that other hotspots are or will become established in the near future.

GIS-based Ash Tree Inventory

An inventory of municipally-owned ash trees on road rights-of-way, actively-managed parks and other City properties was collected in September, 2013. The inventory contains attribute data including tree location, species, diameter at breast height (dbh, 1.4 m), and condition class. The inventory was collected in ESRI-compatible Shapefile format, and is therefore potentially useful for a range of management planning and analysis applications. For example, the existing data may be used to prioritize areas for management based on factors such as ash tree population density or tree size and condition. The data may also be used to track activities such as tree removals or injection, and identify areas for replacement plantings.

Inventoried ash species in Cornwall include green ash (*Fraxinus pennsylvanica*), white ash (*F. americana*), European ash (*F. excelsior*), and black ash (*F. nigra*) (Table 1, below). In the absence of specific identification, some trees were identified to the generic level (i.e. *Fraxinus* species).

Table 1 Ash street tree species distribution, City of Cornwall, 2013.

Common name	Species	# of ash trees	% of total ash
Black ash	*Fraxinus nigra*	6	0.2%
European ash	*Fraxinus excelsior*	16	0.5%
Green ash	*Fraxinus pennsylvanica*	3,349	96.5%
Unidentified ash	*Fraxinus sp.*	15	0.4%
White ash	*Fraxinus americana*	85	2.4%
Total		3,471	100.0%

The size class distribution of inventoried live ash trees is shown in Figure 3. The average diameter at breast height (DBH) of City-owned ash trees is 28 cm. Most of the City's ash trees are in the maturing and mature physiological stages, with nearly 77% of all ash street trees ranging between 11 and 50 cm diameter at breast height (DBH). This suggests that the loss of these mature street trees will significantly and adversely affect the City's streetscape.

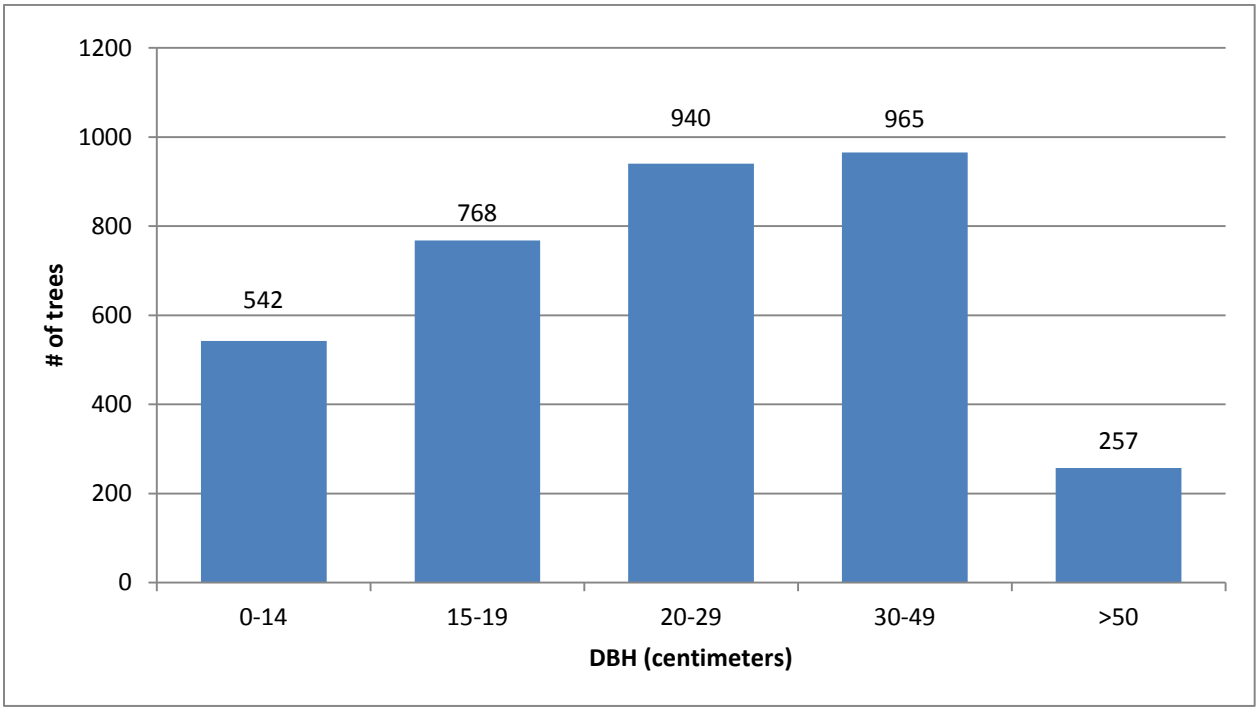

Figure 3: Ash street tree size class distribution, City of Cornwall, 2013.

Ash tree condition was determined by visual inspection and rated on a scale of Good, Moderate, Poor and Unsuitable for Treatment. See Appendix 6 for the suitability criteria for treatment of ash trees. Tree condition within each street tree size class is displayed in Figure 4.

Recommendation: Continue and expand the use of the existing ash tree inventory GIS data to support the Emerald Ash Borer management program.

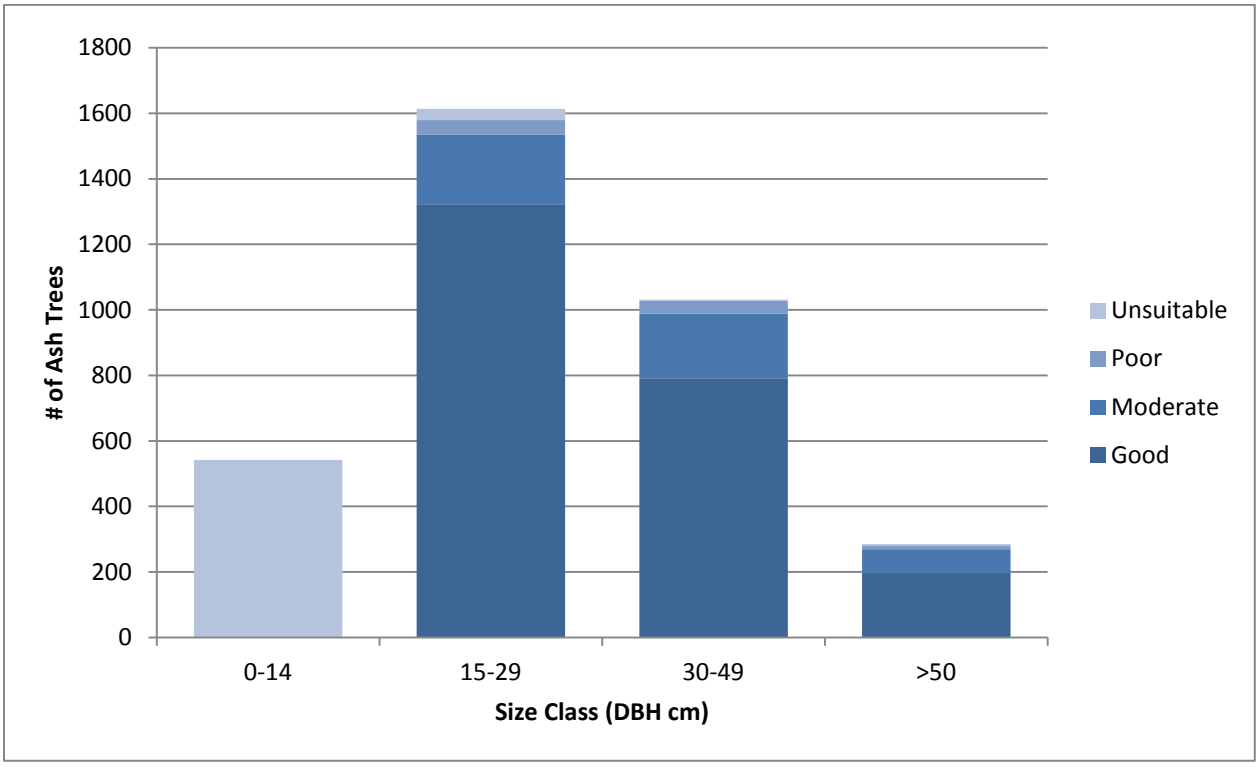

Figure 4: Ash Street Tree Condition by Size Class, City of Cornwall, 2013.

Current EAB Management

Although emerald ash borer infestation is in the early stages in Cornwall, the City has been undertaking some proactive EAB management. For example, the City has been undertaking branch sampling to detect borer galleries in ash trees which are pruned or removed during the course of general urban forest maintenance operations. To date, no galleries have been found in the canopies of sampled trees. The City will continue with branch sampling on the current basis. The City has also collaborated with the CFIA to establish survey traps, and has collaborated with the OMNR through information-sharing workshops. The City has also been undertaking 'companion planting' – planting young trees in proximity to ash trees in higher-

profile public spaces (e.g., boulevards) to begin replacing the urban forest canopy before the wide-scale EAB infestation begins.

City-owned Natural Areas

Ash trees within City-owned natural wooded areas were included in the inventory to a limited extent, for example where they presented a risk of tipping out into actively used public areas (such as parks and recreational trails) in the event of whole-tree failure (e.g, uprooting). Ash trees in the majority of the City's natural areas, however, were not included in the September, 2013, ash inventory. As these areas contain an undetermined number of ash trees, the City should consider options to complete an expanded formal inventory within all City-owned natural areas. The scope of the proposed inventory would only include trees in natural wooded zones that are within striking distance of areas actively used by the public. Such an expanded inventory would be followed by regular visual assessments of the EAB-susceptible zones, in order to monitor and track the rate of spread of infestation and adapt the management approach as necessary.

Management requirements will vary for each affected area, from the removal of individual ash trees to the long-term intensive management and restoration of ecologically sensitive or otherwise significantly impacted woodland edges. Specific recommended courses of action may include a) the pre-emptive removal and disposal of ash trees within tip-out zones (approximately 1.5x tree height), b) annual monitoring and (if necessary) removal of dying and dead ash trees within tip-out zones, or c) a combination of pre-emptive action and ongoing monitoring/removals.

An example of a City-owned natural area for which only partial ash tree inventory information is available is Guindon Park in the west end of Cornwall. Guindon Park is home to a network of roadways and all-season recreational trails that may be within striking distance of potential ash tree tip-out. The extent of Guindon Park trails and the possible size of the Park's natural ash population prohibit stem-injectable pesticide treatment as a time- and cost-effective management option, except where the retention of significant specimens may be desired. As with other City-owned natural areas, however, the selection, development and implementation of an appropriate ash tree management strategy for Guindon Park will depend on the completion an expanded natural areas ash tree inventory.

Recommendation: The City of Cornwall should begin collection of natural area ash tree inventory data in spring/summer 2014.

EMERALD ASH BORER MANAGEMENT PLAN

The purpose of this document is to investigate and propose cost-effective and sustainable management strategies in order to *manage* the anticipated EAB infestation in the City of Cornwall, *reduce* the impacts of the beetle, and *enable* the City to dictate the terms and timing of the loss of many of its ash trees. The strategies are designed to establish a framework for local EAB preparedness, community engagement and budget direction by outlining the major issues and providing guidance on how to address them effectively. The strategies are based on a precautionary principle, as it has been determined that not taking action until EAB infestation is confirmed through widespread tree mortality is a poor management decision, and would put the City of Cornwall several years behind in addressing the threats posed by Emerald Ash Borer.

The strategies are based on a 15-year planning horizon, providing a realistic timeframe to manage the costs and activities anticipated as a result of the inevitable EAB infestation. As such, the strategies have been developed with the underlying assumption that EAB is already present in Cornwall, and that widespread infestation is on the horizon. Active and enhanced management of EAB must begin in the very near term to provide the City with a head-start on addressing this serious threat to urban forest health and sustainability.

The potential impacts of EAB in Cornwall are severe. Without proactive management, including identification, monitoring, pre-emptive tree removal and treatment, EAB will ultimately kill virtually all of Cornwall's municipally and privately owned ash trees. Potential management issues associated with EAB-infested ash trees include, among others, increased risks to people, property and infrastructure from failure of dead and dying trees; decreased provision of urban forest benefits due to tree mortality and canopy/leaf area loss; loss of important wildlife habitat and natural heritage, and increased costs associated with tree removal and replacement.

Although this strategy document presents several strategies, as the Emerald Ash Borer infestation progresses, beetle and ash tree population dynamics may change to such a degree that management strategies and budgets may have to be re-evaluated and redefined.

Components of an effective EAB management plan include:

- Program Oversight
- Identification
- Detection and Monitoring
- Prevention and Control
- Removal and Disposal
- Restoration and Rehabilitation

- Research
- Communications
- Management Strategies and Options
- Program Evaluation

Program Oversight

Cornwall's EAB management program will require a dedicated commitment of staff or consultant time and effort to oversee various aspects of implementation. Examples of required program management activities may include Request for Proposal and contracted service tender document development, contract supervision, field auditing of contracted services such as tree removal and stem injection, public liaison, and internal and external communications. The current City staffing level cannot undertake these additional required activities as part of the existing work program. As such, a dedicated staff person or contracted service provider (consultant) will likely be required to undertake oversight of the City's EAB management program.

Identification

Conclusive identification of EAB infestation requires the observed presence of one or more positive signs or symptoms. Signs are physical indicators of the presence of EAB, while symptoms are a display of the tree's reaction to such infestation.

Signs of EAB infestation may include:

- S-shaped feeding galleries/bark cracking – An infested host tree may respond to larval feeding by forming callus tissue at the site of the feeding. The formation of callus tissue may result in the vertical splitting, or cracking, of the bark to expose the underlying feeding galleries.
- Exit holes – The chewing action of the adult beetle upon emergence from the host tree in mid to late summer generates D-shaped holes (Figure 5), 3.5 mm to 4.1 mm in size, in the bark of the infested tree.

In the absence of galleries and exit holes to confirm infestation, several weaker indicators, or symptoms, are available to aid in detection:

- Crown yellowing, thinning, and/or dieback – Symptoms of infestation first appear within the crown of host trees, and may include foliar chlorosis, wilting, and even death. The larval feeding galleries disrupt the flow of nutrients through the vascular tissues of the host, an action that eventually will girdle the tree. Where larval feeding is sufficiently

advanced, the host will exhibit progressive crown thinning, followed by dieback of the upper portions of the crown.

- Epicormic shoots – To compensate for the stress caused by losing crown foliage, host trees may develop epicormic shoots on the trunk, often located below the point of larval feeding and adult emergence.
- Wildlife damage – Another symptom on infestation is woodpecker feeding damage to the bark of a host tree. Several species of woodpecker are known to strip bark and excavate holes in search of the larvae of insects such as EAB. Bark stripping and larval feeding has also been documented among squirrels.

Figure 5: D-shaped exit hole (left) and typical feeding gallery.

Detection and Monitoring

The lack of detection of EAB infestation in North America for close to a decade is attributable to the fact that low density populations are very difficult to detect and can spread before resource managers even know the beetle is present. Therefore, the development and implementation of an EAB survey and detection program is an essential component of an effective management strategy. The scope, intensity and cost of inspections vary widely, from simple ground-based visual inspection to canopy assessments using aerial lift devices or by tree climbers. Certain techniques may be more suitable for use in high-risk areas, while others may be more suitable for widespread surveys. In many cases, a combination of the techniques described below may be useful.

Visual survey: Visual survey techniques include looking for the visible signs and symptoms that are exhibited by infested ash trees, and formed a component of the City-wide ash tree

inventory (described above) that was conducted in September, 2013. This survey method requires the least amount of resources, and a large area can be covered in a short amount of time. The main disadvantage of visual surveys is that by the time visual symptoms of EAB are present, the infestation has likely been in the area for several years and protection measures may be ineffective on a large scale. Ground-based visual inspection is best suited to small and medium-stature trees.

Branch sampling: Scientists at the Great Lakes Forestry Centre (GLFC) of Natural Resources Canada's Canadian Forest Service (CFS) have been working to improve EAB detection methods. Standard visual inspections of a tree's crown and trunk are a first step to confirming the presence of EAB. However, a study by GLFC scientist K. Ryall found that only 20% of visually surveyed trees at an EAB infested site showed outwardly-visible signs of infestation. With the branch sampling technique, close to 80% of the same trees were found to be actually infested. The ability to detect very low EAB populations can provide forest managers with more time to make informed decisions to better manage EAB infestation. The branch sampling method has been instrumental in the positive identification of EAB infestation and in infestation delimitation surveys in several Ontario municipalities.

Under the branch sampling protocol developed by the CFS, a one kilometre grid is overlaid on a map of the municipality to be surveyed. All ash trees in the inventory should be displayed on the map(s). Circular sample plots are then drawn around each grid intersection point.

Once sample plots are established, a field crew is dispatched to each plot to collect branch samples. Tree information such as species, DBH, and height are recorded along with any visual signs of EAB. Ten or more ash trees are selected, starting from the center of each plot. Sample trees can be selected at random, or based on criteria such as condition or size. Typically, visually symptomatic trees will be targeted to optimize the efficiency of resources used to sample or fell trees. Two branches are removed from each tree using a pole pruner. Experience suggests that more larvae/galleries have been found on the top of branches, and that visual and hidden evidence of infestation can typically be found more often on the south and west facing sides of infested ash trees. Branches should be a minimum of 5-7 cm diameter and at least 50cm long. Branch samples are labelled on the cut ends. It is estimated that 25 mid-sized trees (50 branches) can be sampled per day by a two-person crew.

Branch samples are then taken to a lab or other facility where the bark is removed to expose the phloem. Branch samples are typically secured in a table vise and the bark is removed using a draw knife. Once the bark is removed, thin slices of phloem are shaved off to expose larvae/galleries. If branches are inspected in the fall the shavings of phloem should be very thin (1mm), to ensure that no larvae or galleries are missed. Thicker shavings are possible in the spring when larvae have matured. All signs of EAB are recorded, including the number of larvae,

number of galleries (old and new), number of eggs, etc. The inspected branches are then collected into two categories; infested and not infested.

Trapping: An attractant-baited survey trap capable of detecting EAB adults at low densities is a potentially useful tool for detecting new infestations and monitoring management areas. Purple prism traps are placed in ash trees prior to beetle flight, left in place for the duration the season, and regularly inspected. The CFS and other agencies have been testing trap efficiency and found the most effective combination to be a light green prism trap baited with (Z)-3-hexonol (a green leaf volatile). Recent studies by Francese *et al.* (2007) have demonstrated that purple prism traps catch significantly more adult EAB when positioned at mid-to-high levels in the tree canopy then when hung at lower, more easily-accessible heights.

Prevention and Control

Biological control: Natural enemies such as insect parasites, predators and pathogens have played an important role in many integrated pest management (IPM) strategies. The objective of biological Emerald ash borer control is to have natural enemies kill enough EAB life stages to minimize the population growth of the beetle. Biological control strategies will not outright eliminate EAB, but can slow rates of spread and reduce the overall level of tree mortality. EAB, like many introduced insects, has an array of natural enemies in its native range, but few exist in North America. Some research has been conducted into the feasibility of releasing several non-native wasp species (*Spathius agrili, Tetrastichus planipennisi* and *Oobius agrili*) to detect or control EAB. Although previous trial results have suggested that biological control may be unfeasible as a long-term solution, the Canadian Forest Service has recently initiated the release of *T. planipennisi* in Southwestern Ontario to evaluate its efficacy in controlling EAB population levels. The research is on-going and further data are required before this type of biological control can be considered for large-scale application by municipalities.

Chemical control: The use of insecticides is an option for the retention of individual or groups of trees, and is particularly suited to applications on park and street trees. A number of different application methods are available for use in the United States, including soil treatments, cover sprays, cap methods and trunk injections. In Canada, however, the only currently permitted application method is trunk injection of insecticides. Currently, three trunk-injectable insecticides are available for the control of EAB in Canada – TreeAzin (azadirachtin 5%), Confidor 200 SL (imidacloprid 17.1%), and Acephate (ACECAP ® 97). TreeAzin is the only chemical control treatment that has experienced widespread adoption by municipal programs and private tree care companies for the control of EAB infestation.

TreeAzin

TreeAzin is a trunk-injectable insecticide derived from neem tree (*Azadirachta indica*) seeds. Although limited peer-reviewed data are available to support claims of the product's efficacy, although the manufacturer reports that a biennial treatment schedule is sufficient to control 95% of larvae and reduce female fecundity. Currently, TreeAzin is widely utilized by the tree care industry, but its widespread usage may be cost-prohibitive.

According to pesticide label instructions, TreeAzin is to be injected at a rate of 2 ml per cm DBH as a prophylactic (preventive) treatment, and 5 ml per cm DBH for attacked trees or trees greater than 30 cm DBH. According to BioForest Technologies, early summer injections at the higher rate provide effective control of EAB for up to two seasons by preventing complete larval development, reducing female fecundity, and limiting egg viability.

Long-term, peer-reviewed and scientific efficacy data for TreeAzin is not readily available. The average cost of treatment using TreeAzin may range from $4-7 per cm DBH, or $160-280 for a 40 cm DBH tree, every two years.

Chemical Control Decision Tree

Not all municipally-owned ash trees will be suitable for chemical control (i.e., stem injection treatment) for EAB. While several scenarios considering different tree-specific criteria for injection suitability are outlined in the "Potential Management Strategies" section of this report, the City will ultimately need to select which trees are appropriate candidates for injection. A basic EAB injection treatment decision tree is outlined in Figure 6.

Removal and Disposal

The anticipated mortality of a significant portion of the City's ash canopy presents a long-term financial and management challenge for Cornwall. This section outlines strategies for the removal and disposal of non-retainable, near-dead, and dead ash trees.

The pre-emptive removal of live, non-retainable ash trees is effective in distributing the long-term costs associated with eventual tree loss and removal, which may otherwise exceed the City's financial resources as the ash mortality curve rises. When pre-emptive tree removals are undertaken, an appropriate approach towards minimizing the visual and amenity impact upon ash-dominated streets is to remove alternating trees along a roadway, with particular focus on poor and fair-condition trees, which may already be infested, offering residents and communities a few more years of a sustained canopy. It should be noted that it is currently unknown what effect pre-emptive tree removal may have upon the population dynamics of the borer, and the tactic may not significantly delay EAB population growth.

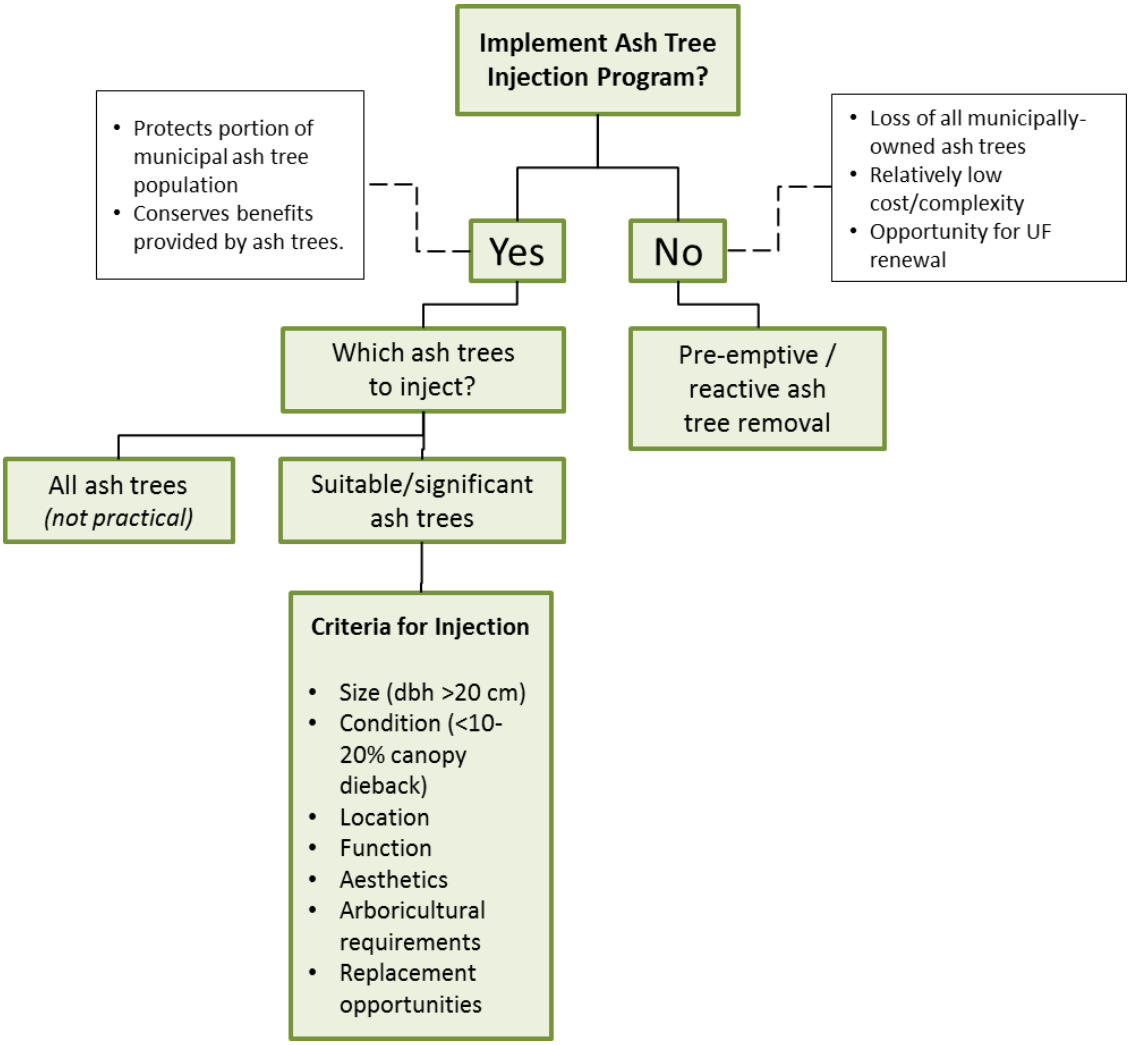

Figure 6: EAB injection treatment decision tree.

The removal of infested trees may be immediate or deferred, depending upon a variety of factors such as tree size, condition and location, value of the tree, etc. Pre-emptive tree removals could have a significant visual and environmental impact upon some areas of Cornwall, where large groups of trees or significant individual trees may be recommended for removal. Therefore, it may be desirable to defer a portion of removals for several years through temporary stem injection treatments.

Following mortality, ash trees often become brittle within 9-12 months. Bark is shed in sheets, large limbs may be shed spontaneously and shatter upon impact, and failure at the base becomes increasingly likely. As such, the costs and complexity associated with removal of dead trees increase substantially, and it may be difficult to obtain timely tree removal services from

contracted service providers at a reasonable cost. Therefore, it will be imperative that Cornwall staff maintain vigilant observation of the ash tree population and schedule any standing dead and near-dead trees for removal as soon as they are observed.

All removed ash trees (infested, non-infested, dead and near-dead) should be processed and disposed of in a manner that eliminates host suitability for all EAB life stages. The stumps of removed trees should be ground out in the same season as tree removal, or in the following season. Stumps must be ground to a depth of at least 15-30 cm to prevent resprouting, which can be prolific.

At such a time that Cornwall becomes regulated under Ministerial Orders, no wood materials will be allowed to leave the Regulated Area, and wood storage/disposal facilities will need to be found within the Regulated Area. As well, private contractors operating on non-municipal lands will be expected to dispose of wood in accordance with Federal regulations. However, the City is not currently in a position to enforce or monitor private contractor compliance with such regulations. In any case, the City should review the capacity of the City Landfill Site, which presently houses a waste wood recycling pad and yard waste composting site, to accommodate further wood waste. Should the capacity of the Landfill Site be exceeded by the expected increased influx of ash wood materials, arrangements for an additional wood disposal site will have to be made. Irrespective of the ultimate waste wood storage facilities, the selected site(s) may need to be secured in order to prevent unauthorized removal of unchipped wood.

Removed trees should be chipped finely to kill EAB larvae. Wood chips may subsequently be composted if the City can accommodate a sufficiently large area for a composting cycle of 2+ years. The expected influx and surplus of wood chips from dead ash trees can complement the City's supplies for mulching programs, and can be given away to residents for use in gardens. Giving away mulch is a common practice is many municipalities, and is often a key component of community environment days and other similar activities.

The City currently lacks a complement of full-time arboricultural staff that would enable it to fulfill requirements for EAB-related tree removals in a timely manner. As such, the City will need to consider the hiring of contractors, if not additional staff, in order to execute this portion of the management strategy.

Recommendation: The City of Cornwall should identify suitable sites for wood waste disposal and woodchip composting within regulated boundaries.

Restoration and Rehabilitation

Replacement of removed trees: Replacement planting should be undertaken when trees are removed to offset the loss of tree canopy and associated benefits. Site-specific planting plans may need to be developed for areas where large numbers of ash trees will require removal. Removed trees should be replaced with native, non-ash tree species that are hardy and tolerant of urban condition, and have low pest susceptibility (see Appendix 5 for a list of potential replacement species). All removed trees should be replaced at a minimum replacement ratio of 1:1 (removal to planting), and replacement trees should be planted as soon as possible in an appropriate planting season.

During the peak of the EAB infestation, the number of annual replacement plantings that are necessitated by the removal of dead ash trees may exceed the City's capacity to allocate sufficient resources for removal and replanting operations. As an alternative to scheduling replacement plantings in response to and following tree removal, the City may consider adopting a pro-active planting schedule whereby the anticipated volume of replacement plantings is distributed across the planning horizon. Such an approach reduces year-to-year demands placed on planting resources and furthermore aligns well with a pre-emptive removal strategy.

Rehabilitation of natural areas: The substantial forthcoming loss of tree cover as a result of EAB will have far-reaching and significant impacts on the structure and composition of Cornwall's natural areas. One significant impact may be the proliferation of invasive plant species. EAB-induced mortality will create large gaps in the forest cover of ash-dominated stands, exposing forest floors to greater amounts of sunlight. The result will be an acceleration of the colonization of invasive plant species, such as buckthorn (*Rhamnus cathartica)*, Manitoba maple (*Acer negundo*) or garlic mustard (*Alliara petiolata*), which typically grow at a rapid rate and out-compete native vegetation for water, light and nutrients. Ash and other native vegetation will face greater pressure as invasive plant populations continue to grow. The long term ecological implications may include a disruption to the natural stand dynamics and ecosystem functions of the forest, as well as the degradation of ecologically sensitive riparian and wildlife habitats.

Due to the complexity of natural ecosystem processes, the rehabilitation of disturbed natural forest areas can be a challenging undertaking. In response to the anticipated loss of ash trees in natural areas, strategies for rehabilitation include the planting of appropriate native non-ash species and the removal of invasive plant species. However, where they do not present a hazard to people or property, dead ash trees should be left to undergo stand dynamics, including the decomposition and natural recycling of organic materials to the forest floor and successive plant communities.

Current Research

Researchers continue to advance knowledge of effective management approaches to EAB, including control and detection methods, and the societal effects of tree loss resulting from EAB infestations. Outlined in this section are several recent research findings bearing on EAB management.

Management: Knight *et al*. (2012) demonstrate that a reduction in ash population densities does not have the predicted effect of improving the survivability of residual ash trees. The results of this study suggest that the dilution of urban ash populations, though removal and species diversification, will not significantly retard the spread of EAB infestation, highlighting the need for ash retention through treatment. Kovacs *et al*. (2013) conclude that management approaches centered on insecticidal treatment, which preserve greater net benefits provided by healthy trees, outperform approaches based on pre-emptive removal and disposal. These results are supported by a recent evaluation (Vannatta *et al*., 2012) of the economic implications of three candidate management options. Results demonstrate that, over a simulation period of 20 years, the greatest preservation of net benefits is achieved by retaining ash trees with insecticidal treatment, followed by a do-nothing approach, a pre-emptive removal and replacement approach, and a pre-emptive removal without tree replacement approach, in that order.

Simulations conducted by McCullough & Mercadera (2012) examined the efficacy of systemic insecticidal treatments on different proportions of total ash population. Results suggest the optimal treatment strategy – the treatment of 20% of the ash population on an annual basis – may protect up to 99.5% of treated trees over a ten year period, compared to protection of only 75% of treated trees, over the same time period, under annual treatment of 10% of the ash population.

Societal effects of infestation and tree loss: The relationship between urban ash trees and human health was recently explored by Donovan *et al*. (2013), who found EAB-induced ash loss to be linked to increased human mortality due to cardiovascular and lower-respiratory-tract related illnesses. The study tracked the loss of ash population and related effects between the years 1990-2007, across 15 U.S. states, and recorded the greatest impacts in counties with above-average median household income and where infestations had progressed the furthest.

Communications

Effective management of EAB in Cornwall will require the timely communication of:

- Identification of ash trees and EAB signs and symptoms;

- the threat of the Emerald Ash Borer;
- the status of the infestation;
- current and proposed management activities, including pre-emptive tree removal;
- reporting procedures for suspected EAB infestation;
- the responsibilities of residents to monitor privately-owned trees which may die and become hazardous as a result of EAB infestation;
- the rights of the City to require removal of hazardous or dead private trees;
- the susceptibility of ash trees to failure/uprooting within 2 years of mortality;
- what to look for in a reputable tree service company; and;
- external resources including identification guides, management strategies, agencies and scientific publications.

Good communication may help encourage cooperation such as abiding by wood materials quarantine regulations and reporting possible new infestations, and may calm potential anxieties regarding the threat of EAB or possible solutions. Poor communication may erode support for the EAB management program, increase losses of trees and their associated benefits, and lead to a general misunderstanding or mistrust of the agencies involved.

A combination of communication and outreach tools will be necessary to reach the largest possible number of potentially affected individuals, businesses and organizations in Cornwall.

Internet: As increasing numbers of people turn to the internet as a primary source of information, a webpage (part of the City's website) dedicated to EAB-related information will be among the most effective means of communication. As the City has already created such an EAB webpage, future efforts to enhance the existing webpage should focus on providing additional links to external resources, updates about the management program, and other information described above. This webpage should also be promoted on the City's main site through the "Highlights" and "News" sections.

Media and Paid Advertising: Additional communications should include regular updates through local media, including informational advertising as well as articles in local news outlets. The primary means of delivering information to the media is through press releases. Press releases, or press advisories, may be issued as necessary to announce program initiatives, community meetings, delimitation survey results, and related information. The City should be well prepared to interact with and inform members of the media shortly after implementation of this Plan, especially should EAB infestation be confirmed.

Public Information Centres: The City should also be prepared to communicate with residents through public information centres and other community forums. Forums or open houses allow citizens the opportunity to speak with and question managers directly, and express concerns or gather more information. Experience in other municipalities shows that vocal resident delegations on both sides of the spectrum may be expected: residents opposed to the application of insecticides may need to be informed about the necessity of protecting ash trees using such methods, while others may need to be shown the high costs and impracticability of wide-scale injection.

Printed Materials: Printed materials, such as flyers, pamphlets or door hangers, can provide residents with a wide range of information. If distribution is not feasible across the entire city, it can be targeted towards areas with single-family detached dwellings (more likely to contain ash trees) or areas with high ash street tree density.

Door-to-Door Outreach: Face-to-face communication, combined with delivery of printed materials, may be the most effective communication tool to spread important information. This method has been applied in the City of Milwaukee, which visited over 26,000 residences to inform citizens of the EAB infestation and control strategy. This tactic may be costly, but can be conducted by volunteers. It is best left as a last resort should the EAB infestation become very heavy and if municipal inspection of private property becomes required.

Internal Communication: Successful public communication of EAB-related information begins with strong internal communications. The City should take steps to ensure that all appropriate City staff and departments have access to the most up-to-date EAB information. Improved internal communications may include such measures as coordinating regular inter-departmental meetings and information sessions, providing opportunities for staff education and training, and broadening intranet access to City documents and materials related to EAB.

Recommendation: The City of Cornwall should continue to develop and further implement a communication strategy to provide timely and accurate information regarding Emerald Ash Borer and the EAB management program to residents and other stakeholders.

Potential Management Strategies

A key component of this management plan is the investigation of strategies to address an EAB infestation. The costs and components of 4 potential management strategies are investigated. These strategies are based on currently available methods and materials, and take into account the input costs of the proposed management activities. Several assumptions have been made to permit budget forecasting:

- The average cost of tree removal, including stumping, is $800 per tree;
- The average cost of replacement tree planting is $350 per tree; and,
- Based on present knowledge of the ash tree mortality distribution curve, EAB populations will begin a nearly exponential level of growth, doubling the amount of annual tree mortality between 2014 and 2019, and subsequently tapering off until 98% of the City's untreated ash tree resource has been destroyed.

Four potential management strategies are outlined below. More detailed descriptions of each strategy, including cost estimates and assumptions, are found in Appendix 3.

These strategies only account for the management of inventoried, municipally-owned ash trees in the municipal road right-of-way, in City parks, and on other municipally-owned properties. The strategies do not account for the potential costs associated with natural areas management, which may include activities such as tree removals, trail closures, fencing and signage, and replanting or restoration.

The potential management strategies and associated costs span a 15-year time period. Depending upon the rate of spread of EAB and resultant ash tree mortality, the program may need to be implemented over a shorter (e.g., 10-year) time period, which will necessitate increasing annual program funding. Regular and effective monitoring of the EAB population and ash mortality will be required to inform active adaptive management and the potential need to accelerate implementation of the management program. Cost models for implementation of the four potential management strategies on a 10-year program are outlined in Appendix 4.

1. ***'Reactive Management***' – This approach includes:

- Annual ground-based visual tree inspections for signs of disease or mortality;
- Immediate removal and disposal of dead ash trees; and,
- Limited public communication program.

Under the 'Reactive' approach, the EAB infestation is permitted to run its course with minimal intervention from the City. The City does not actively manage Emerald Ash Borer, except to mitigate risk by contracting annual tree inspections and the removal of dead ash trees. A limited public communications program is expected to be administered by existing City staff and internal resources, and a $50,000 annual program administration cost is estimated for budget purposes.

The expected outcome of the 'Reactive' approach is the near complete destruction of Cornwall's existing ash tree population. As no replacement plantings are undertaken under this

strategy, the City incurs a significant loss to its urban tree canopy. The costs associated with the removal of dead trees account for the majority (97%) of total annual program costs, which rise exponentially with the progression of the EAB infestation, through to the year 2023. Following peak annual ash mortality at this time, the year-to-year rates of ash tree death and removal decline steadily until the City's ash population is virtually exhausted in 2028.

The 'Reactive' approach is an unfeasible management scenario, and is investigated for purposes of context and comparison. The total estimated cost of implementing this approach over **15 years is $3.6 million**.

2. ***'Moderate Management'*** – This approach includes:

    - Annual ground-based visual tree inspections for signs of disease or mortality;
    - Immediate removal and disposal of dead ash trees;
    - Replanting of removed trees;
    - Public communications program; and,
    - Plantable spaces inventory and planting strategy.

Similar to the 'Reactive' approach, the 'Moderate' approach sees the EAB infestation advance with minimal intervention from the City. EAB is not actively managed, and equivalent annual program costs are incurred through contracted annual tree inspections and dead ash tree removal.

The 'Moderate' management approach departs from the 'Reactive' approach in several respects. Cost estimates include a $10,000 per year public communications program that is bolstered by additional outreach activities such as paid advertising and printed materials, as well as a one-time $20,000 plantable spaces inventory and planting strategy. Program administration is estimated to cost $50,000 annually. The approach further assumes that one of three modeled replacement planting scenarios will be adopted in response to widespread ash tree mortality:

    a. Removed trees are replaced on a 1:1 removal to replacement ratio, in which every removed ash tree is replaced with one native, non-ash tree species. The total 1:1 replacement planting cost over 15 years is $5.6 million.

    b. Removed trees are replaced on a 1:2 removal to replacement ratio, in which every removed ash tree is replaced with two native, non-ash tree species. The total 1:2 replacement planting cost over 15 years is $7.4 million.

c. Removed trees are replaced on a 1:3 removal to replacement ratio, in which every removed ash tree is replaced with three native, non-ash tree species. The total 1:3 replacement planting cost over 15 years is $9.2 million.

The predicted costs of replacement plantings in each scenario are spread out equally over the 15-year planning horizon to avoid cost spikes during intervening years.

Although the 'Moderate' approach predicts the near complete loss of the City's ash trees over 15 years, the selection and planting of appropriate replacement tree species allows the City to compensate for its losses and pursue greater species diversification. The total estimated cost of implementing this approach over **15 years is between $5.6 and $9.2 million**.

3. ***'Active Management'*** - This approach includes:

- Annual ground-based visual tree inspections for signs of disease or mortality;
- Immediate removal and disposal of dead ash trees;
- Pre-emptive removal of untreated trees;
- Replacement planting of removed ash trees;
- Bi-annual treatment of mature ash trees that are in good condition;
- Public communications program; and,
- Plantable spaces inventory and planting strategy.

As with the 'Moderate Management' approach, cost estimates for the 'Active Management' approach include contracted annual tree inspections and dead ash tree removals, a $10,000 per year public communications program and a one-time $20,000 plantable spaces inventory and planting strategy. Program administration is estimated to cost $50,000 annually. The approach also assumes that removed trees are replaced on a 1:1 removal to replacement ratio, with replacement planting distributed equally over the 15-year horizon.

Under this management approach, the City elects to more actively manage the EAB infestation. Ash trees greater than or equal to 30 cm DBH and in 'Good' condition are considered candidates for stem injection treatment with TreeAzin (azadirachtin). However, the condition ratings applied in the 2013 Cornwall ash inventory represent the overall condition of inventoried trees at the time of assessment, and do not express the specific suitability of trees for stem injection treatment. Therefore, it is assumed that among trees meeting the treatment criteria for 'Active Management' (>=30 cm DBH, 'Good' condition), there are degrees of suitability for injection. In order to account for this assumed variability among candidate trees, the strategy is modeled at four rates of injection:

a. 100% of candidate trees are injected: At this rate it is assumed that all candidate trees are suitable for injection. However, as this assumption is considered to be unrealistic, the 100% injection rate is investigated principally for context and comparison. The estimated cost of injecting 100% of candidate trees under Active Management is $5.9 million over 15 years.

b. 75% of candidate trees are injected. At this rate it is assumed that three quarters of candidate trees are suitable for injection. The estimated cost of injecting 75% of candidate trees under Active Management is $5.8 million over 15 years.

c. 50% of candidate trees are injected: At this rate it is assumed that half of the candidate trees are suitable for injection. The estimated cost of injecting 50% of candidate trees under Active Management is $5.7 million over 15 years.

d. 25% of candidate trees are injected. At this rate it is assumed that only a quarter of candidate trees are suitable for injection. It is unlikely that such a low proportion of candidate trees would meet suitability requirements; therefore, the results of the 25% are considered for context and comparison purposed only. The estimated cost of injecting 25% of candidate trees under Active Management is $5.7 million over 15 years.

Whereas the 'Reactive' and 'Moderate' management approaches each predict the loss of 98% of the City's ash resource within 15 years, the 'Active' approach limits ash tree losses to between 82% and 94% of present levels. Moreover, the component of the urban canopy preserved under this approach is made up of vigorous and mature ash trees, which by virtue of their size and leaf area contribute exponentially greater social, economic and environmental benefits to the City. Compared to the 1:1 'Moderate Management' approach, this represents a considerable improvement in program outcomes at comparable 15-year cost estimates.

In sum, the estimated cost of implementing the 'Active Management' approach over **15 years is between $5.7 and $5.9 million**.

4. ***'Aggressive Management'*** **-** This approach includes:

- Annual ground-based visual tree inspections for signs of disease or mortality;
- Immediate removal and disposal of dead ash trees;
- Pre-emptive removal of untreated trees;
- Replacement planting of removed ash trees;

- Bi-annual treatment of mature and near-mature ash trees that are in moderate-to-good condition;
- Public communications program; and,
- Plantable spaces inventory and planting strategy.

Cost estimates for the 'Aggressive Management' approach include contracted annual tree inspections and dead ash tree removals, a $10,000 per year public communications program and a one-time $20,000 plantable spaces inventory and planting strategy. Program administration is estimated to cost $50,000 annually. The approach assumes that removed trees are replaced on a 1:1 removal to replacement ratio, with replacement planting distributed equally over the 15-year horizon.

Under the 'Aggressive' approach, the City mounts a more proactive and vigorous defense of its ash tree resource. Ash trees greater than or equal to 20 cm DBH, and in 'Good' or 'Moderate' conditions, are considered candidates for stem injection treatment with TreeAzin (azadirachtin). The approach assumes that 75% of candidate trees (>= 20 cm DBH, 'Good' and 'Moderate' condition) are suitable for injection treatment.

The estimated cost of implementing this approach over **15 years is $5.7 million.**

Cost comparisons of the four management approaches over the next 15 years are shown below in Figures 6 and 7, in which the 1:1 scenario of the 'Moderate' approach and the 75% injection scenario of the 'Active' approach are selected for comparison purposes.

The 'Reactive' and 'Moderate' approaches have lower immediate annual costs than the 'Active' and 'Aggressive' approaches (Figure 7), a difference explained by the lack of injection treatment and pre-emptive removal costs incurred by the former approaches. However, whereas the annual costs of the 'Active' and 'Aggressive' approaches decline over the 15 year planning horizon, annual costs of the 'Reactive' and 'Moderate' approaches begin to increase exponentially in 2019 with the progression of the EAB infestation and the rising costs of dead ash tree removal. A comparison of the 15-year costs of implementing each management approach (Figure 8) reveals that total program costs are lowest for the 'Reactive' approach ($3.6 million), followed by the 'Moderate' approach ($5.9 million). The highest total program costs are produced by the 'Active' approach ($5.8 million).

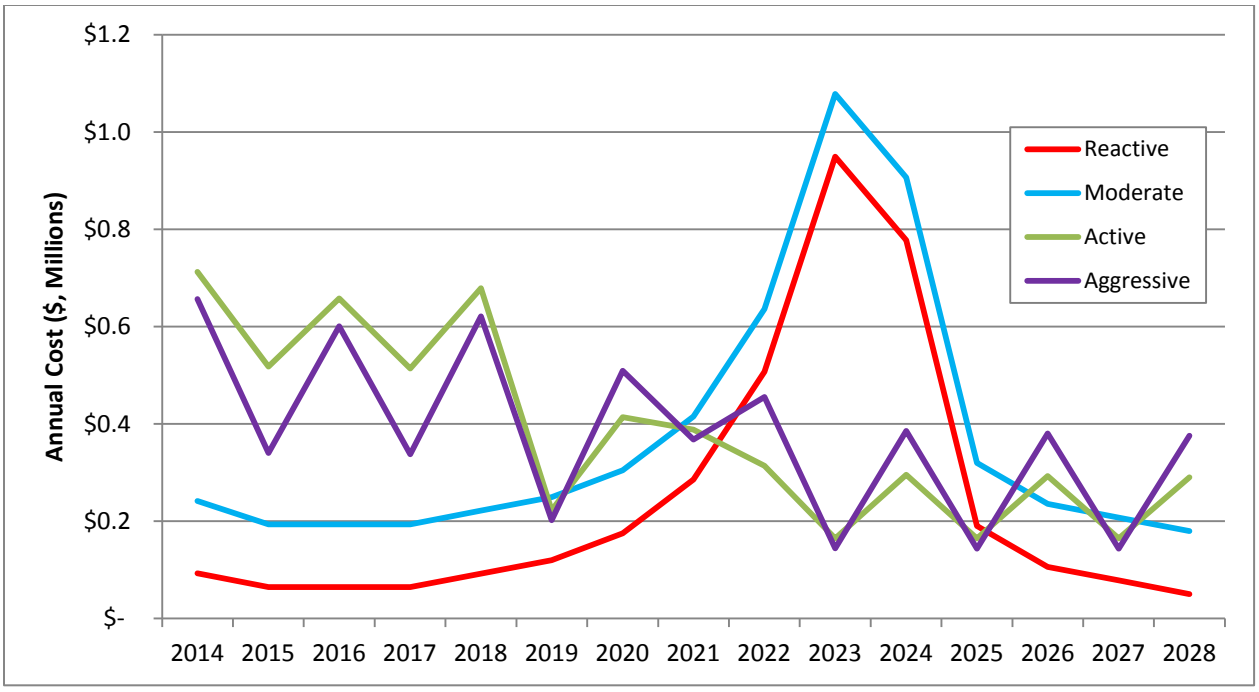

Figure 7: Annual cost comparison for EAB management strategies

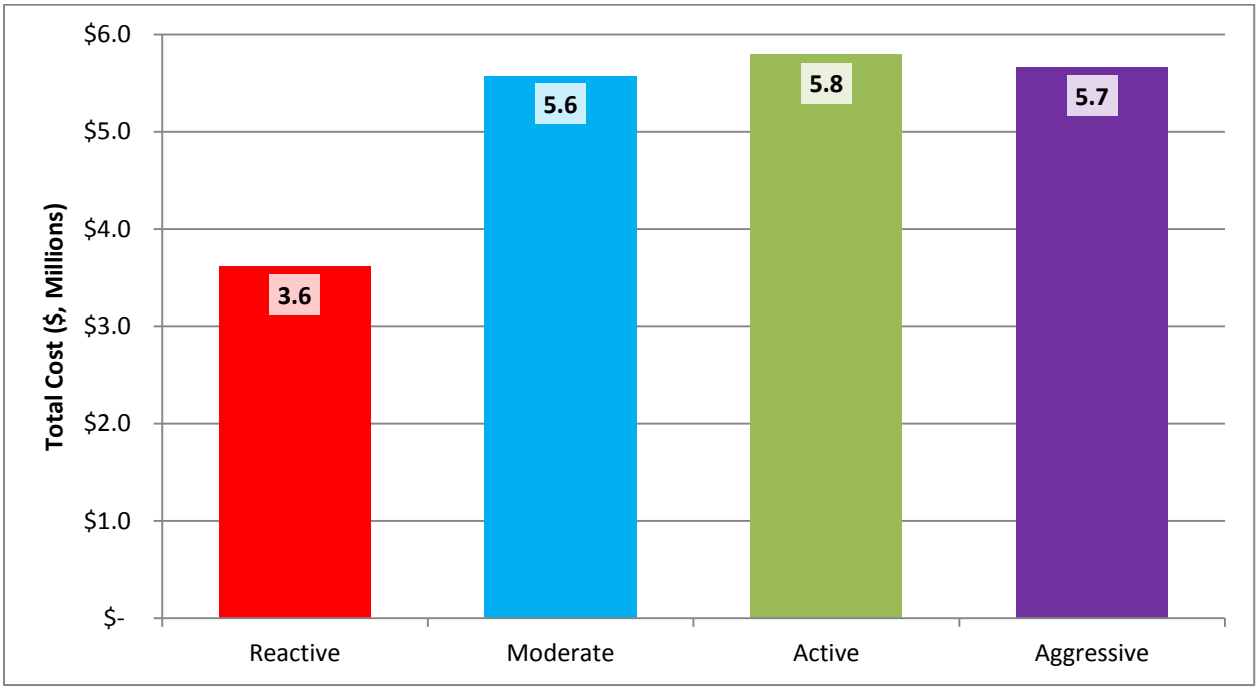

Figure 8: 15-year total cost comparison for EAB management strategies

Program Evaluation

To supplement the costs comparison of each management approach, an additional evaluation of program outcomes was conducted to assess the relative cost effectiveness of each management approach. The evaluation accounts for changes to the total dollar amount of the appraised value of the City's ash tree population, as well as total ash tree benefits accrued, over 15 years of program implementation. It is worth noting that the evaluation of program outcomes considers only the costs, values and benefits that are associated with or derived from the City's right-of-way (ROW) trees, and not all City-owned ash trees. A full accounting of other City-owned ash trees is not included due to limitations of currently available methods, principally the lack of benefits data for non-ROW trees.

Appraised values are calculated using the trunk formula method put forward by the Council of Tree and Landscape Appraisers (CTLA). The trunk formula method derives the value of an urban tree as a function of the basic tree cost, adjusted for species, condition and location factors. Table 2 summarizes program costs and appraised values for the four management approaches; included are the initial appraised value of the City's present-day ash ROW inventory, the appraised value expected to be lost over the course of implementing each management approach, and the final appraised value.

Table 2 Comparison of program costs and ash tree appraised values for the four management approaches. (All dollar figures in present value.)

	Reactive	Moderate	Active	Aggressive
Program Cost ($)	723,538	1,343,888	1,547,490	1,483,749
Initial Appraised Value (2013) ($)	3,034,997	3,034,997	3,034,997	3,034,997
Appraised Value Lost ($)	3,034,026	2,982,710	2,419,042	2,088,033
Final Appraised Value (2028) ($)	972	52,288	615,956	946,964
Preserved Appraised Value	0%	2%	22%	34%
Overall Cost ($) (Program Cost + Value Lost)	3,757,564	4,326,598	3,966,532	3,571,782

As indicated in Table 2, the management approach with the lowest program costs, including the costs of inspection, injection, removal, etc., is the Reactive approach ($723,538); the approach with the highest program costs is the Active approach ($1.5 million). Although program costs are lowest for the Reactive approach, this management strategy preserves only $972 – effectively 0% – of an approximately $3 million initial appraised value, representing the greatest loss of ash tree value among the four management approaches. The Aggressive approach, by comparison, preserves the greatest amount of the initial appraised value (34% preserved).

Although program costs for the Aggressive approach amount to roughly twice those of the Reactive approach, the Aggressive approach sees a nearly thousand fold increase in the dollar amount of preserved value ($946,964) over the Reactive approach ($972). The Aggressive approach similarly outperforms the Active (22% preserved) and Moderate (2% preserved) approaches. Of the four management approaches, the Aggressive approach preserves the greatest amount of appraised value, both in absolute terms and per dollar spent on program costs.

For each of the proposed management approaches the City can expect to confront certain financial implications, both in the cost of program implementation and the amount of appraised value that is lost due to ash tree mortality. This gross financial liability is expressed in Table 2 as the overall cost, which is calculated for each approach by summing the program cost and the amount of appraised value that is lost over the 15 year planning horizon. As seen in Table 2, the overall cost is lowest for the Aggressive approach and highest for the Moderate approach – $3.6 million and $4.3 million, respectively. The performance of the Aggressive approach, in both preservation of appraised value and overall cost metrics, suggests that the greatest cost effectiveness may be achieved by the adoption of the Aggressive approach.

The total costs and benefits associated with each of the four management approaches are considered next (Table 3).

Table 3 Comparison of costs and benefits of the four potential management approaches. (All dollar figures in present value.)

	Reactive	Moderate	Active	Aggressive
Total Cost ($)	723,538	1,343,888	1,547,490	1,483,749
Total Benefits ($)	565,094	992,110	613,614	942,456
Benefit-Cost Ratio	0.78	0.74	0.40	0.64

The total cost for each approach remains unchanged from Table 2. For the purposes of this analysis, benefits are taken to be the monetary valuation of social, environmental and economic gains provided to a community by its trees. Such gains include, for example, CO_2 sequestration and energy conservation. Total benefits (Table 3), calculated using the i-Tree Streets software, are the cumulative annual benefits provided by City ROW ash trees over a 15-year span.

Results indicate that the Moderate approach yields the greatest total benefits ($992,110) over the 15-year planning horizon, followed closely by the Aggressive approach ($942,456). By comparison, the Reactive approach yields the least total benefits ($565,094). The meager benefits generated by the Active approach, relative to the Moderate and Aggressive approaches, are explained by the accelerated conversion of City ash trees to replacement

benefits generated by the Active approach, relative to the Moderate and Aggressive approaches, are explained by the accelerated conversion of City ash trees to replacement plantings as a result of pre-emptive removals, in conjunction with the treatment and preservation of fewer mature ash trees, as pursued in the Aggressive approach.

The benefit-cost ratio – that is, the benefits generated by an approach relative to its cost inputs, and taken to be a measure of the overall value of pursuing the approach – is less than one for each management approach. It is unsurprising that no approach would result in benefits exceeding costs, as management of EAB is expected to be a cost-intensive undertaking. Of the four management approaches, the greatest total benefits are returned by the Reactive approach (0.78 dollars of benefit for each dollar of cost) and the Moderate approach (0.74 dollars of benefit for each dollar of cost). However, the process of selecting the most appropriate management approach must be guided less by opportunities for positive returns on investment than by a consideration of broader program outcomes and overall cost effectiveness. The total benefits of the Reactive approach are realized chiefly because the approach includes no replacement planting costs, resulting in lower total program costs. However, as reported in Table 2, the adoption of the Reactive approach sees the near complete loss of the City's ash tree population, as well as the loss of 100% of appraised value (Table 2). Similarly for the Moderate approach, 74 cents of benefits are returned for each dollar of cost, yet the outcome is one for which only 2% of the present-day ash population remains in 2028. Under this approach, the comparatively sizable benefits are conferred largely by trees that are planted to replace lost ash trees; however, these replacement plantings amount to only 2% of the appraised value of the present-day ash canopy (Table 2). In light of these considerations, the Active and Aggressive approaches remain the only two options whose outcomes include a favourable degree of preservation of present-day ash population and appraised value, while also achieving an acceptable return of benefits.

Conclusion

No individual management approach is recommended for implementation at this time. A thorough review and investigation of the available resources and other local factors affecting management must be conducted prior to embarking upon a management direction. It must also be anticipated that management strategies can and will change over time in response to a variety of factors which cannot be accurately predicted at this time.

Recommendation: The City of Cornwall should consider the range of proposed management approaches and select the most appropriate approach for implementation, as determined by cost, complexity, available resources and other factors.

The ultimate trajectory of the EAB infestation cannot be comprehensively and accurately predicted. As with all aspects of urban forest management, EAB management will need to remain flexible to respond to unanticipated events or changes in circumstance. As such, any EAB management program adopted by the City should be reviewed on an annual basis. Staff should also report to City Council on a regular basis to provide updates on the course of the infestation and information about the progress of the management program and its resource requirements.

Recommendation: The City should undertake an annual review of the EAB management program and provide regular updates to City Council.

RECOMMENDATIONS

	Recommendation	Timing / Responsibility	Cost	Priority
1	Maintain existing **working relationships** with the Canadian Food Inspection Agency (CFIA), Canadian Forest Service (CFS) and Ontario Ministry of Natural Resources (OMNR) to cooperatively monitor and manage Emerald Ash Borer.	Immediate / In-house in coordination with CFIA, CFS and OMNR	Existing work plan	High
2	**Consider the range of proposed management strategies** and select the most appropriate strategy for implementation, as determined by cost, complexity, available resources and other factors.	Investigation: Immediate / In-house Implementation: 2014-2038	$2.9 million - $8.3 million over 15 years (depending upon selected approach)	Very High
3	Identify suitable sites for **wood waste disposal and woodchip composting** within municipal boundaries.	2014 / In-house	Existing work plan	High-Moderate
4	Continue and expand the use of the existing ash tree inventory GIS data to support the Emerald Ash Borer management program.	Immediate / In-house	Existing work plan	Moderate

5	Continue to develop and further implement a **communication strategy** to provide timely and accurate information regarding Emerald Ash Borer and the EAB management program to residents and other stakeholders.	Immediate / In-house or contracted	$10,000/ year	High
6	Begin collection of **natural area ash tree inventory** data in spring/ summer 2014.	2014 / Contracted	$45,000	High
7	The City should undertake an **annual review of the EAB management program** and provide regular updates to City Council.	2014-2023 / In-house	Existing work plan	Moderate

REFERENCES

Donovan, G. H., Butry, D. T., Michael, Y. L., Prestemon, J. P., Liebhold, A. M., Gatziolis, D., & Mao, M. Y. (2013). The relationship between trees and human health: evidence from the spread of the Emerald Ash Borer. *American journal of preventive medicine*, *44*(2), 139-145.

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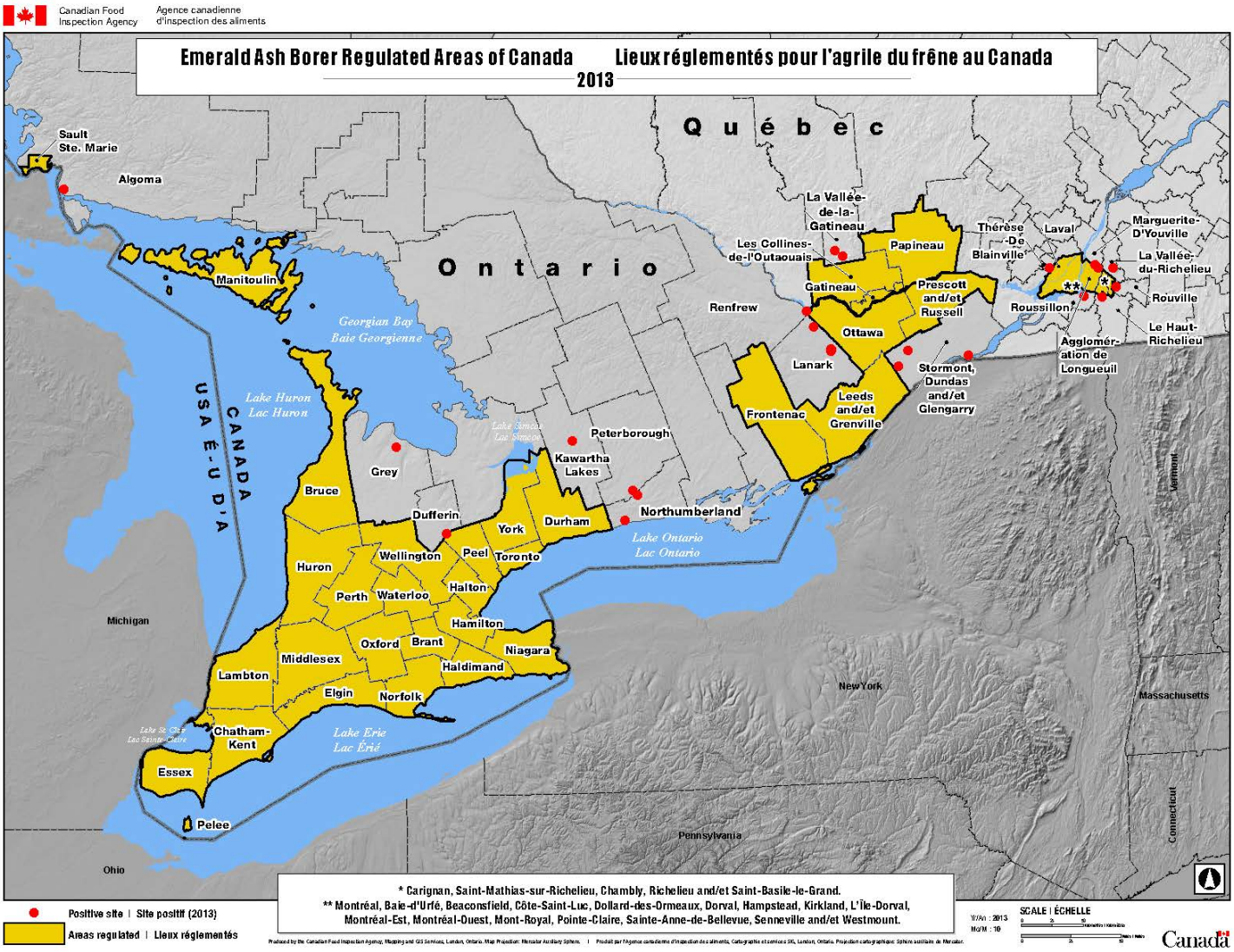
Kovacs, K. F., Haight, R. G., Mercader, R. J., & McCullough, D. G. (2013). A bioeconomic analysis of an Emerald Ash Borer invasion of an urban forest with multiple jurisdictions. *Resource and Energy Economics.*

McCullough, D., & Mercader, R. (2012). Evaluation of potential strategies to slow ash mortality (slam) caused by Emerald Ash Borer (Agrilus planipennis): Slam in an urban forest. *International Journal of Pest Management*, *58*(1), 9-23.

Vannatta, A. R., Hauer, R. H., & Schuettpelz, N. M. (2012). Economic analysis of Emerald Ash Borer (Coleoptera: Buprestidae) management options. *Journal of economic entomology*, *105*(1), 196-206.

APPENDIX 1 - QUARANTINE MAPS

Areas Regulated under Ministerial Orders, Canada - 2013



Ontario

- Cities of Hamilton, Toronto and Sault Ste. Marie
- Regional Municipalities of Durham, York, Peel, Halton and Niagara
- Counties of Brant, Bruce, Elgin, Essex, Haldimand, Huron, Lambton, Middlesex, Norfolk, Oxford, Perth and Wellington
- Manitoulin district
- Municipality of Chatham-Kent and the Counties of Elgin, Essex, Lambton and Middlesex

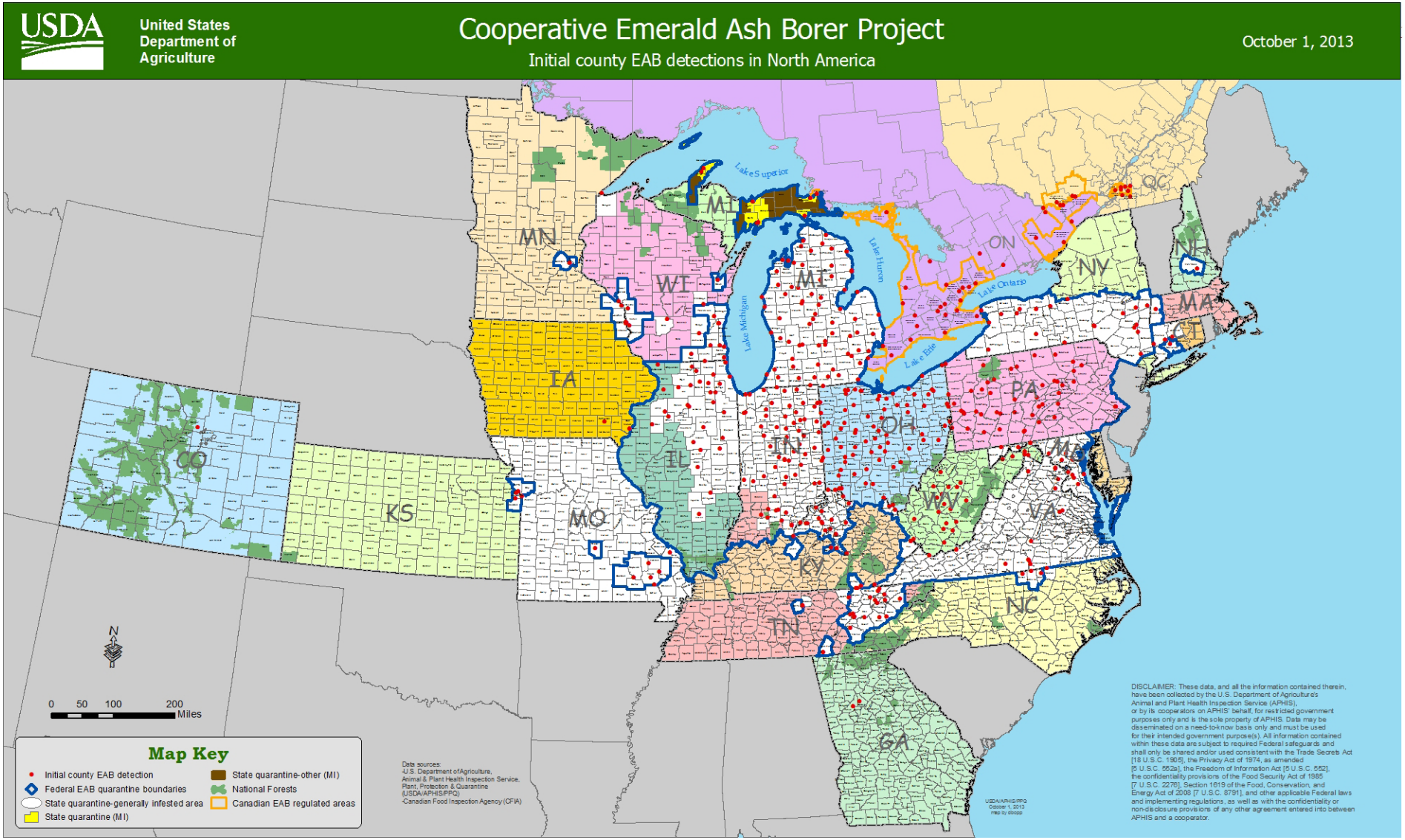
Ontario – Quebec

- City of Ottawa, the United Counties of Leeds and Grenville and the United Counties of Prescott and Russell and the county of Frontenac in the Province of Ontario and, in the City of Gatineau, the municipalité régionale de comté (MRC) de Papineau and the MRC Les Collines-de-l'Outaouais in the Province of Quebec.

Quebec

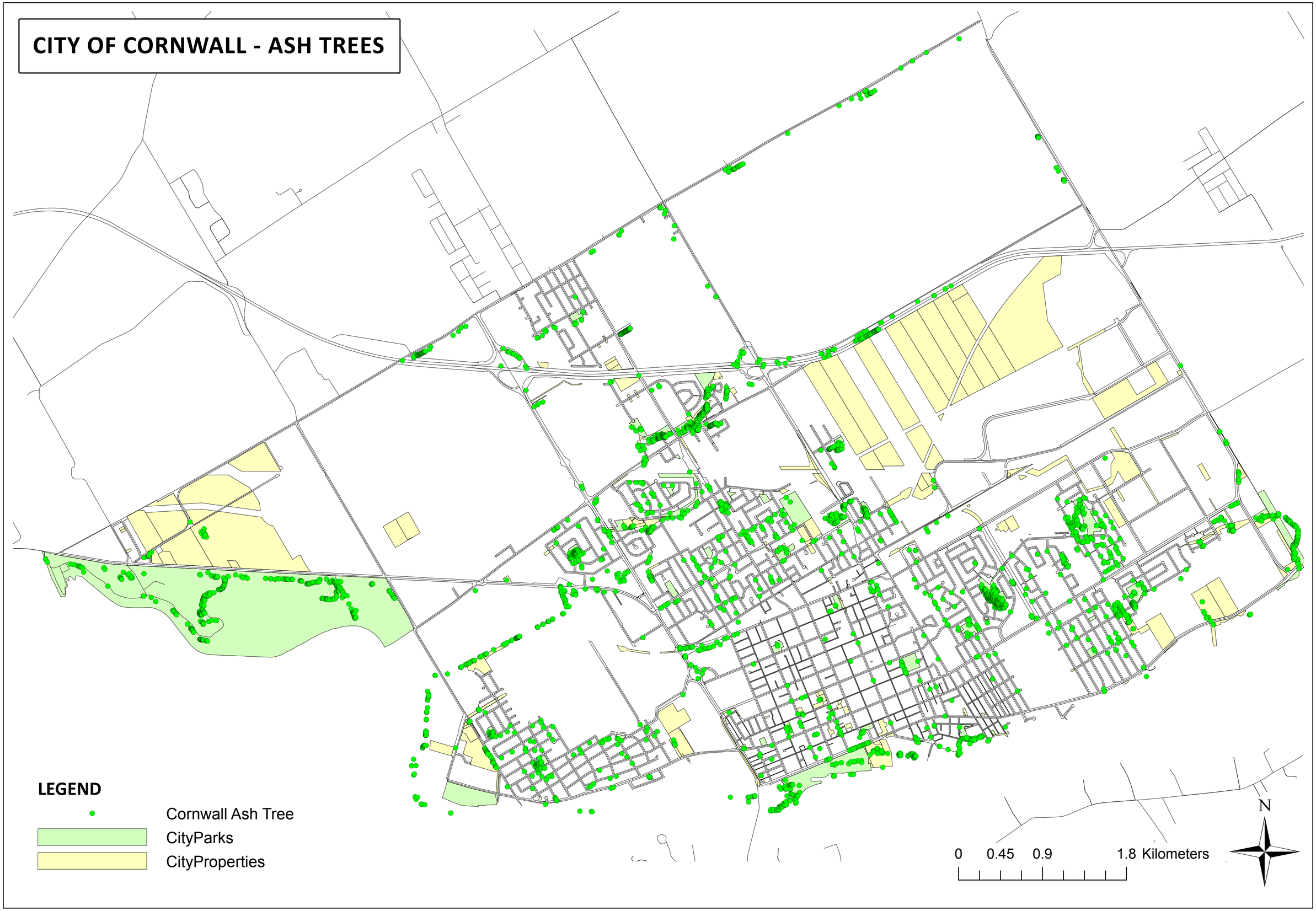
- Municipalities of Carignan, Chambly, Richelieu, Saint-Basile-le-Grand and Saint-Mathias-sur-Richelieu, the cities of Montréal, Baie-d'Urfé, Beaconsfield, Côte-Saint-Luc, Dollard-Des Ormeaux, Dorval, Hampstead, Kirkland, Laval, L'Île-Dorval, Montréal-Est, Montréal-Ouest, Mont-Royal, Pointe-Claire, Sainte-Anne-de-Bellevue, Senneville and Westmount and the Agglomération de Longueuil.

EAB Locations in Canada and the USA as of October 1, 2013

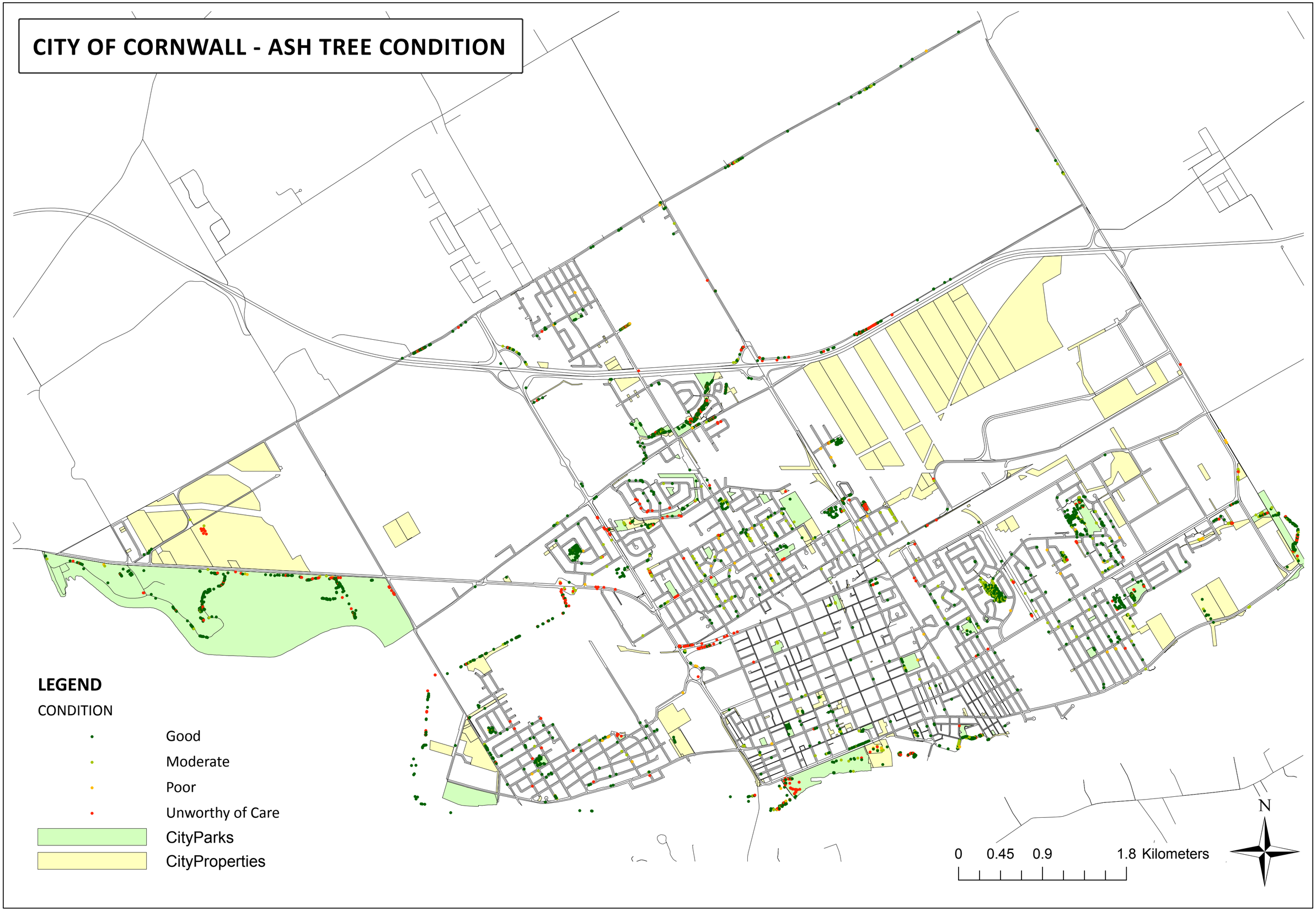


APPENDIX 2 - CITY OF CORNWALL MAPS

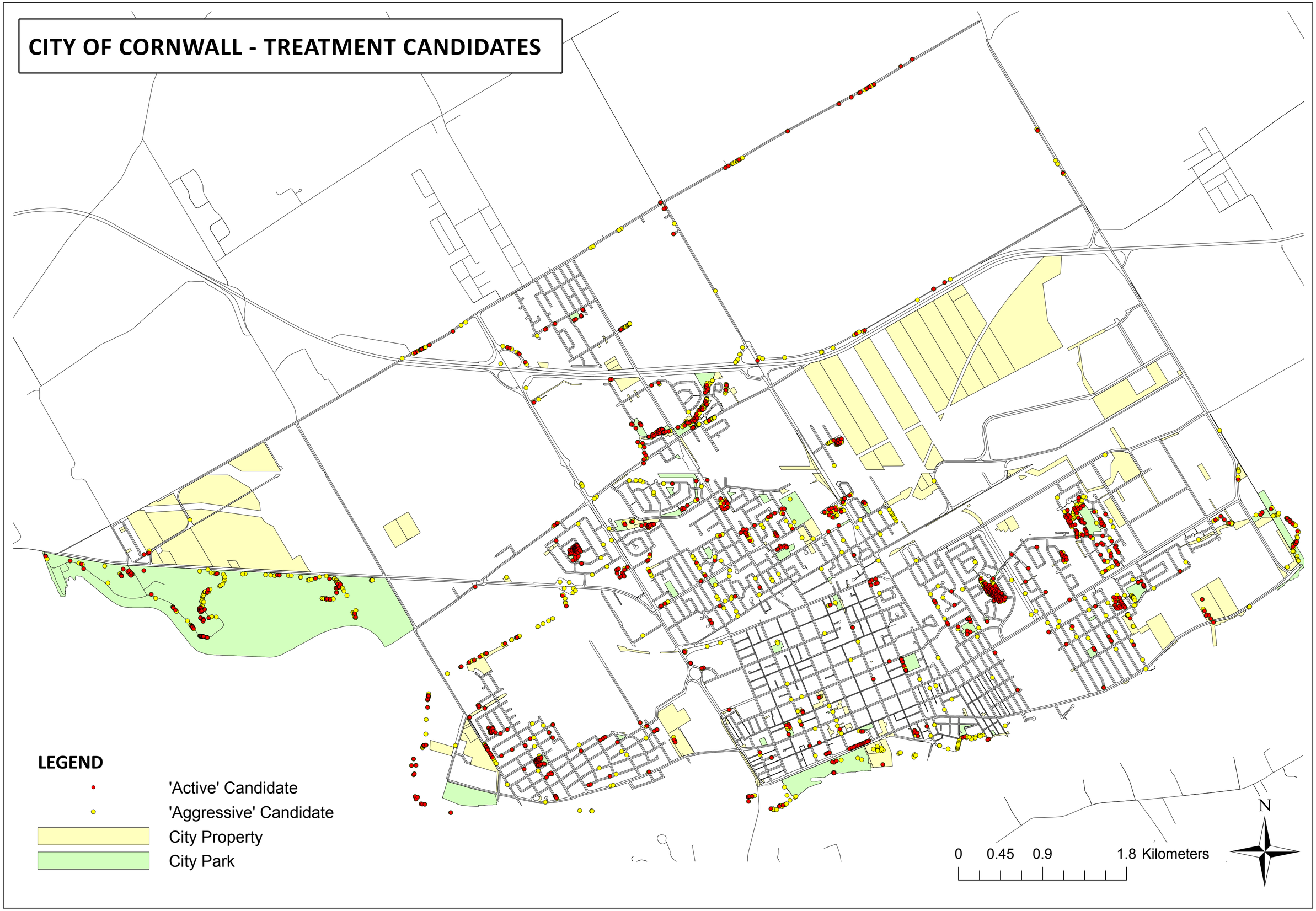
CITY OF CORNWALL - ASH TREES



CITY OF CORNWALL - ASH TREE CONDITION



CITY OF CORNWALL - TREATMENT CANDIDATES



APPENDIX 3 - MANAGEMENT STRATEGY COST MODELS, 15-YEAR MANAGEMENT PROGRAM

APPENDIX 3 – MANAGEMENT STRATEGY COST MODELS, 15-YEAR MANAGEMENT PROGRAM

Cost Model

STRATEGY	***1***	***2***	***3***	***4***
NAME	**Reactive**	**Moderate Management**	**Active Management**	**Aggressive Management**
Management components				
Public Communications	x	x	x	x
Visual inspection at ground level	x	x	x	x
Remove dead trees	x	x	x	x
Plantable spaces inventory & planting strategy		x	x	x
Replace removed trees with new trees		x	x	x
Preemptive felling of the non-retainable trees			x	x
TreeAzin 30+			x	
TreeAzin 20+				x
Parameters				
Number of trees	3472	3472	3472	3472
Average DBH (cm) treated trees	0	0	43	36
Infection Rate (%) treated	1	1	1	1
Yearly communications budget	$ -	$ 10,000.00	$ 10,000.00	$ 10,000.00
Administrative/Implementation	$ 50,000.00	$ 50,000.00	$ 50,000.00	$ 50,000.00
Plantable spaces inventory & planting strategy	$ -	$ 20,000.00	$ 20,000.00	$ 20,000.00
Removal costs one tree	$ 800.00	$ 800.00	$ 800.00	$ 800.00
Replanting costs one tree	$ 350.00	$ 350.00	$ 350.00	$ 350.00
No of yearly inspection rounds	1	1	1	1
No of trees inspected per day	150	150	150	150
Tree inspection costs per hour	$ 80.00	$ 80.00	$ 80.00	$ 80.00
Percentage of trees treated	0	0	28	63
Number of pre-emptive replacements (annual)	0	0	431	237
Treatment cost per cm DBH (annual)	$ -	$ -	$ 4.50	$ 4.50

1. Reactive

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				0 per year		*100%*				*0%*					*$ 800.00 per tree*	*none*	*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*- cm DBH/tree AVG*	*$ - per cm DBH*	*$ - per year*	*$ 50,000.00 per year*		
2013		3472																								
2014	3472	3437	3472	0	3472	1%	35	3437	0	1%	0	0	35	35	$ 27,776.00	0	$ -	3,472	23	$ 14,813.87	-	$ -	$ -	$ 50,000.00		$ 92,589.87
2015	3437	3437	3437	0	3437	1%	0	3437	0	1%	0	0	0	0	$ -	0	$ -	3,437	23	$ 14,665.73	-	$ -	$ -	$ 50,000.00		$ 64,665.73
2016	3437	3437	3437	0	3437	1%	0	3437	0	1%	0	0	0	0	$ -	0	$ -	3,437	23	$ 14,665.73	-	$ -	$ -	$ 50,000.00		$ 64,665.73
2017	3437	3437	3437	0	3437	1%	0	3437	0	1%	0	0	0	0	$ -	0	$ -	3,437	23	$ 14,665.73	-	$ -	$ -	$ 50,000.00		$ 64,665.73
2018	3437	3403	3437	0	3437	2%	35	3403	0	1%	0	0	35	35	$ 27,776.00	0	$ -	3,437	23	$ 14,665.73	-	$ -	$ -	$ 50,000.00		$ 92,441.73
2019	3403	3333	3403	0	3403	4%	69	3333	0	1%	0	0	69	69	$ 55,552.00	0	$ -	3,403	23	$ 14,517.59	-	$ -	$ -	$ 50,000.00		$ 120,069.59
2020	3333	3194	3333	0	3333	8%	139	3194	0	1%	0	0	139	139	$ 111,104.00	0	$ -	3,333	22	$ 14,221.31	-	$ -	$ -	$ 50,000.00		$ 175,325.31
2021	3194	2916	3194	0	3194	16%	278	2916	0	1%	0	0	278	278	$ 222,208.00	0	$ -	3,194	21	$ 13,628.76	-	$ -	$ -	$ 50,000.00		$ 285,836.76
2022	2916	2361	2916	0	2916	32%	556	2361	0	1%	0	0	556	556	$ 444,416.00	0	$ -	2,916	19	$ 12,443.65	-	$ -	$ -	$ 50,000.00		$ 506,859.65
2023	2361	1250	2361	0	2361	64%	1111	1250	0	1%	0	0	1111	1111	$ 888,832.00	0	$ -	2,361	16	$ 10,073.43	-	$ -	$ -	$ 50,000.00		$ 948,905.43
2024	1250	347	1250	0	1250	90%	903	347	0	1%	0	0	903	903	$ 722,176.00	0	$ -	1,250	8	$ 5,332.99	-	$ -	$ -	$ 50,000.00		$ 777,508.99
2025	347	174	347	0	347	95%	174	174	0	1%	0	0	174	174	$ 138,880.00	0	$ -	347	2	$ 1,481.39	-	$ -	$ -	$ 50,000.00		$ 190,361.39
2026	174	104	174	0	174	97%	69	104	0	1%	0	0	69	69	$ 55,552.00	0	$ -	174	1	$ 740.69	-	$ -	$ -	$ 50,000.00		$ 106,292.69
2027	104	69	104	0	104	98%	35	69	0	1%	0	0	35	35	$ 27,776.00	0	$ -	104	1	$ 444.42	-	$ -	$ -	$ 50,000.00		$ 78,220.42
2028	69	69	69	0	69	98%	0	69	0	1%	0	0	0	0	$ -	0	$ -	69	0	$ 296.28	-	$ -	$ -	$ 50,000.00		$ 50,296.28
	Remaining trees	***2.0%***												***3,403***	***$ 2,722,048.00***	***-***	***$ -***				***Total 15 yr***	***$ -***	***$ -***	***$ 750,000.00***		***$ 3,618,705.28***

2a. Moderate Management (yearly inspections, removal of dead trees, replacement at 1:1 ratio)

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				0 per year		*100%*				*0%*					*$ 800.00 per tree*		*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*- cm DBH/tree AVG*	*$ - per cm DBH*	*$ 10,000.00 per year*	*$ 50,000.00 per year*	*$ 20,000.00*	
2013		3472																								
2014	3472	3437	3472	0	3472	1%	35	3437	0	1%	0	0	35	35	$ 27,776.00	340	$ 119,089.60	3,472	23	$ 14,813.87	-	$ -	$ 10,000.00	$ 50,000.00	$ 20,000.00	$ 241,679.47
2015	3437	3437	3437	0	3437	1%	0	3437	0	1%	0	0	0	0	$ -	340	$ 119,089.60	3,437	23	$ 14,665.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 193,755.33
2016	3437	3437	3437	0	3437	1%	0	3437	0	1%	0	0	0	0	$ -	340	$ 119,089.60	3,437	23	$ 14,665.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 193,755.33
2017	3437	3437	3437	0	3437	1%	0	3437	0	1%	0	0	0	0	$ -	340	$ 119,089.60	3,437	23	$ 14,665.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 193,755.33
2018	3437	3403	3437	0	3437	2%	35	3403	0	1%	0	0	35	35	$ 27,776.00	340	$ 119,089.60	3,437	23	$ 14,665.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 221,531.33
2019	3403	3333	3403	0	3403	4%	69	3333	0	1%	0	0	69	69	$ 55,552.00	340	$ 119,089.60	3,403	23	$ 14,517.59	-	$ -	$ 10,000.00	$ 50,000.00		$ 249,159.19
2020	3333	3194	3333	0	3333	8%	139	3194	0	1%	0	0	139	139	$ 111,104.00	340	$ 119,089.60	3,333	22	$ 14,221.31	-	$ -	$ 10,000.00	$ 50,000.00		$ 304,414.91
2021	3194	2916	3194	0	3194	16%	278	2916	0	1%	0	0	278	278	$ 222,208.00	340	$ 119,089.60	3,194	21	$ 13,628.76	-	$ -	$ 10,000.00	$ 50,000.00		$ 414,926.36
2022	2916	2361	2916	0	2916	32%	556	2361	0	1%	0	0	556	556	$ 444,416.00	340	$ 119,089.60	2,916	19	$ 12,443.65	-	$ -	$ 10,000.00	$ 50,000.00		$ 635,949.25
2023	2361	1250	2361	0	2361	64%	1111	1250	0	1%	0	0	1111	1111	$ 888,832.00	340	$ 119,089.60	2,361	16	$ 10,073.43	-	$ -	$ 10,000.00	$ 50,000.00		$ 1,077,995.03
2024	1250	347	1250	0	1250	90%	903	347	0	1%	0	0	903	903	$ 722,176.00	340	$ 119,089.60	1,250	8	$ 5,332.99	-	$ -	$ 10,000.00	$ 50,000.00		$ 906,598.59
2025	347	174	347	0	347	95%	174	174	0	1%	0	0	174	174	$ 138,880.00	340	$ 119,089.60	347	2	$ 1,481.39	-	$ -	$ 10,000.00	$ 50,000.00		$ 319,450.99
2026	174	104	174	0	174	97%	69	104	0	1%	0	0	69	69	$ 55,552.00	340	$ 119,089.60	174	1	$ 740.69	-	$ -	$ 10,000.00	$ 50,000.00		$ 235,382.29
2027	104	69	104	0	104	98%	35	69	0	1%	0	0	35	35	$ 27,776.00	340	$ 119,089.60	104	1	$ 444.42	-	$ -	$ 10,000.00	$ 50,000.00		$ 207,310.02
2028	69	69	69	0	69	98%	0	69	0	1%	0	0	0	0	$ -	340	$ 119,089.60	69	0	$ 296.28	-	$ -	$ 10,000.00	$ 50,000.00		$ 179,385.88
	Remaining trees	***2.0%***												***3,403***	***$ 2,722,048.00***	***5,104***	***$ 1,786,344.00***				***Total 15 yr***	***$ -***	***$ 150,000.00***	***$ 750,000.00***		***$ 5,575,049.28***

2b. Moderate Management (yearly inspections, removal of dead trees, replacement at 1:2 ratio)

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				0 per year		*100%*				*0%*					*$ 800.00 per tree*		*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*- cm DBH/tree AVG*	*$ - per cm DBH*	*$ 10,000.00 per year*	*$ 50,000.00 per year*	*$ 20,000.00*	
2013		3472																								
2014	3472	3437	3472	0	3472	1%	35	3437	0	1%	0	0	35	35	$ 27,776.00	684	$ 239,229.20	3,472	23	$ 14,813.87	-	$ -	$ 10,000.00	$ 50,000.00	$ 20,000.00	$ 361,819.07
2015	3437	3437	3437	0	3437	1%	0	3437	0	1%	0	0	0	0	$ -	684	$ 239,229.20	3,437	23	$ 14,665.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 313,894.93
2016	3437	3437	3437	0	3437	1%	0	3437	0	1%	0	0	0	0	$ -	684	$ 239,229.20	3,437	23	$ 14,665.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 313,894.93
2017	3437	3437	3437	0	3437	1%	0	3437	0	1%	0	0	0	0	$ -	684	$ 239,229.20	3,437	23	$ 14,665.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 313,894.93
2018	3437	3403	3437	0	3437	2%	35	3403	0	1%	0	0	35	35	$ 27,776.00	684	$ 239,229.20	3,437	23	$ 14,665.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 341,670.93
2019	3403	3333	3403	0	3403	4%	69	3333	0	1%	0	0	69	69	$ 55,552.00	684	$ 239,229.20	3,403	23	$ 14,517.59	-	$ -	$ 10,000.00	$ 50,000.00		$ 369,298.79
2020	3333	3194	3333	0	3333	8%	139	3194	0	1%	0	0	139	139	$ 111,104.00	684	$ 239,229.20	3,333	22	$ 14,221.31	-	$ -	$ 10,000.00	$ 50,000.00		$ 424,554.51
2021	3194	2916	3194	0	3194	16%	278	2916	0	1%	0	0	278	278	$ 222,208.00	684	$ 239,229.20	3,194	21	$ 13,628.76	-	$ -	$ 10,000.00	$ 50,000.00		$ 535,065.96
2022	2916	2361	2916	0	2916	32%	556	2361	0	1%	0	0	556	556	$ 444,416.00	684	$ 239,229.20	2,916	19	$ 12,443.65	-	$ -	$ 10,000.00	$ 50,000.00		$ 756,088.85
2023	2361	1250	2361	0	2361	64%	1111	1250	0	1%	0	0	1111	1111	$ 888,832.00	684	$ 239,229.20	2,361	16	$ 10,073.43	-	$ -	$ 10,000.00	$ 50,000.00		$ 1,198,134.63
2024	1250	346	1250	1	1249	90%	903	346	0	1%	0	0	903	904	$ 722,976.00	684	$ 239,229.20	1,249	8	$ 5,328.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 1,027,533.93
2025	346	171	346	2	344	95%	174	171	0	1%	0	0	174	176	$ 140,480.00	684	$ 239,229.20	344	2	$ 1,468.59	-	$ -	$ 10,000.00	$ 50,000.00		$ 441,177.79
2026	171	98	171	3	168	97%	69	98	0	1%	0	0	69	72	$ 57,952.00	684	$ 239,229.20	168	1	$ 715.09	-	$ -	$ 10,000.00	$ 50,000.00		$ 357,896.29
2027	98	59	98	4	94	98%	35	59	0	1%	0	0	35	39	$ 30,976.00	684	$ 239,229.20	94	1	$ 401.75	-	$ -	$ 10,000.00	$ 50,000.00		$ 330,606.95
2028	59	54	59	5	54	98%	0	54	0	1%	0	0	0	5	$ 4,000.00	684	$ 239,229.20	54	0	$ 232.28	-	$ -	$ 10,000.00	$ 50,000.00		$ 303,461.48
	Remaining trees	***1.6%***												***3,418***	***$ 2,734,048.00***	***10,253***	***$ 3,588,438.00***				***Total 15 yr***	***$ -***	***$ 150,000.00***	***$ 750,000.00***		***$ 7,388,993.95***

2c. Moderate Management (yearly inspections, removal of dead trees, replacement at 1:3 ratio)

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				0 per year		*100%*				*0%*					*$ 800.00 per tree*		*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*- cm DBH/tree AVG*	*$ - per cm DBH*	*$ 10,000.00 per year*	*$ 50,000.00 per year*	*$ 20,000.00*	
2013		3472																								
2014	3472	3437	3472	0	3472	1%	35	3437	0	1%	0	0	35	35	$ 27,776.00	1,025	$ 358,843.80	3,472	23	$ 14,813.87	-	$ -	$ 10,000.00	$ 50,000.00	$ 20,000.00	$ 481,433.67
2015	3437	3437	3437	0	3437	1%	0	3437	0	1%	0	0	0	0	$ -	1,025	$ 358,843.80	3,437	23	$ 14,665.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 433,509.53
2016	3437	3437	3437	0	3437	1%	0	3437	0	1%	0	0	0	0	$ -	1,025	$ 358,843.80	3,437	23	$ 14,665.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 433,509.53
2017	3437	3437	3437	0	3437	1%	0	3437	0	1%	0	0	0	0	$ -	1,025	$ 358,843.80	3,437	23	$ 14,665.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 433,509.53
2018	3437	3403	3437	0	3437	2%	35	3403	0	1%	0	0	35	35	$ 27,776.00	1,025	$ 358,843.80	3,437	23	$ 14,665.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 461,285.53
2019	3403	3333	3403	0	3403	4%	69	3333	0	1%	0	0	69	69	$ 55,552.00	1,025	$ 358,843.80	3,403	23	$ 14,517.59	-	$ -	$ 10,000.00	$ 50,000.00		$ 488,913.39
2020	3333	3194	3333	0	3333	8%	139	3194	0	1%	0	0	139	139	$ 111,104.00	1,025	$ 358,843.80	3,333	22	$ 14,221.31	-	$ -	$ 10,000.00	$ 50,000.00		$ 544,169.11
2021	3194	2916	3194	0	3194	16%	278	2916	0	1%	0	0	278	278	$ 222,208.00	1,025	$ 358,843.80	3,194	21	$ 13,628.76	-	$ -	$ 10,000.00	$ 50,000.00		$ 654,680.56
2022	2916	2361	2916	0	2916	32%	556	2361	0	1%	0	0	556	556	$ 444,416.00	1,025	$ 358,843.80	2,916	19	$ 12,443.65	-	$ -	$ 10,000.00	$ 50,000.00		$ 875,703.45
2023	2361	1250	2361	0	2361	64%	1111	1250	0	1%	0	0	1111	1111	$ 888,832.00	1,025	$ 358,843.80	2,361	16	$ 10,073.43	-	$ -	$ 10,000.00	$ 50,000.00		$ 1,317,749.23
2024	1250	346	1250	1	1249	90%	903	346	0	1%	0	0	903	904	$ 722,976.00	1,025	$ 358,843.80	1,249	8	$ 5,328.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 1,147,148.53
2025	346	171	346	2	344	95%	174	171	0	1%	0	0	174	176	$ 140,480.00	1,025	$ 358,843.80	344	2	$ 1,468.59	-	$ -	$ 10,000.00	$ 50,000.00		$ 560,792.39
2026	171	98	171	3	168	97%	69	98	0	1%	0	0	69	72	$ 57,952.00	1,025	$ 358,843.80	168	1	$ 715.09	-	$ -	$ 10,000.00	$ 50,000.00		$ 477,510.89
2027	98	59	98	4	94	98%	35	59	0	1%	0	0	35	39	$ 30,976.00	1,025	$ 358,843.80	94	1	$ 401.75	-	$ -	$ 10,000.00	$ 50,000.00		$ 450,221.55
2028	59	54	59	5	54	98%	0	54	0	1%	0	0	0	5	$ 4,000.00	1,025	$ 358,843.80	54	0	$ 232.28	-	$ -	$ 10,000.00	$ 50,000.00		$ 423,076.08
	Remaining trees	***1.6%***												***3,418***	***$ 2,734,048.00***	***15,379***	***$ 5,382,657.00***				***Total 15 yr***	***$ -***	***$ 150,000.00***	***$ 750,000.00***		***$ 9,183,212.95***

3a. Active Manage 100% of >=30cm Good

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				431.2 per year		*72%*				*28%*					*$ 800.00 per tree*		*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*43 cm DBH/tree AVG*	*$ 4.50 per cm DBH*	*$ 10,000.00 per year*	*$ 50,000.00 per year*	*$ 20,000.00*	
2013		3472																								
2014	3472	2996	2484	431	2053	1%	35	2018	988	1%	10	978	45	476	$ 380,640.00	262	$ 91,779.18	2,053	14	$ 8,759.03	42,824	$ 192,709.22	$ 10,000.00	$ 50,000.00	$ 20,000.00	$ 753,887.44
2015	2996	2555	2018	431	1587	1%	0	1587	0	1%	10	968	10	441	$ 352,784.96	262	$ 91,779.18	1,587	11	$ 6,771.11	-	$ -	$ 10,000.00	$ 50,000.00		$ 511,335.25
2016	2555	2114	1587	431	1156	1%	0	1156	968	1%	10	959	10	441	$ 352,706.71	262	$ 91,779.18	1,156	8	$ 4,931.31	41,972	$ 188,874.31	$ 10,000.00	$ 50,000.00		$ 698,291.51
2017	2114	1674	1156	431	724	1%	0	724	0	1%	10	949	10	441	$ 352,629.24	262	$ 91,779.18	725	5	$ 3,091.52	-	$ -	$ 10,000.00	$ 50,000.00		$ 507,499.95
2018	1674	1198	724	431	293	2%	35	259	949	1%	9	940	44	475	$ 380,328.55	262	$ 91,779.18	293	2	$ 1,251.73	41,137	$ 185,115.71	$ 10,000.00	$ 50,000.00		$ 718,475.17
2019	1198	1119	259	0	259	4%	69	189	0	1%	9	930	79	79	$ 63,068.63	262	$ 91,779.18	259	2	$ 1,103.59	-	$ -	$ 10,000.00	$ 50,000.00		$ 215,951.40
2020	1119	971	189	0	189	8%	139	50	930	1%	9	921	148	148	$ 118,545.46	262	$ 91,779.18	189	1	$ 807.31	40,318	$ 181,431.90	$ 10,000.00	$ 50,000.00		$ 452,563.85
2021	971	912	50	0	50	16%	50	0	0	1%	9	912	59	59	$ 47,559.04	262	$ 91,779.18	50	0	$ 214.75	-	$ -	$ 10,000.00	$ 50,000.00		$ 199,552.98
2022	912	903	0	0	0	32%	0	0	912	1%	9	903	9	9	$ 7,293.37	262	$ 91,779.18	0	0	$ 0.39	39,516	$ 177,821.41	$ 10,000.00	$ 50,000.00		$ 336,894.35
2023	903	894	0	0	0	64%	0	0	0	1%	9	894	9	9	$ 7,220.44	262	$ 91,779.18	0	0	$ 0.39	-	$ -	$ 10,000.00	$ 50,000.00		$ 159,000.01
2024	894	885	0	0	0	90%	0	0	894	1%	9	885	9	9	$ 7,148.24	262	$ 91,779.18	0	0	$ 0.38	38,730	$ 174,282.76	$ 10,000.00	$ 50,000.00		$ 333,210.56
2025	885	876	0	0	0	95%	0	0	0	1%	9	876	9	9	$ 7,076.75	262	$ 91,779.18	0	0	$ 0.38	-	$ -	$ 10,000.00	$ 50,000.00		$ 158,856.31
2026	876	867	0	0	0	97%	0	0	876	1%	9	867	9	9	$ 7,005.99	262	$ 91,779.18	0	0	$ 0.37	37,959	$ 170,814.54	$ 10,000.00	$ 50,000.00		$ 329,600.08
2027	867	858	0	0	0	98%	0	0	0	1%	9	858	9	9	$ 6,935.93	262	$ 91,779.18	0	0	$ 0.37	-	$ -	$ 10,000.00	$ 50,000.00		$ 158,715.48
2028	858	850	0	0	0	98%	0	0	858	1%	9	850	9	9	$ 6,866.57	262	$ 91,779.18	0	0	$ 0.37	37,203	$ 167,415.33	$ 10,000.00	$ 50,000.00		$ 326,061.44
	Remaining trees	***24.5%***												***2,622***	***$ 2,097,809.88***	***3,933***	***$ 1,376,687.73***				***Total 15 yr***	***$1,438,465.17***	***$ 150,000.00***	***$ 750,000.00***		***$ 5,859,895.78***

3b. Active Manage 75% of >=30cm Good

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				431.2 per year		*79%*				*21%*					*$ 800.00 per tree*		*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*43 cm DBH/tree AVG*	*$ 4.50 per cm DBH*	*$ 10,000.00 per year*	*$ 50,000.00 per year*	*$ 20,000.00*	
2013		3472																								
2014	3472	2999	2731	431	2300	1%	35	2265	741	1%	7	734	42	473	$ 378,664.00	283	$ 99,214.39	2,300	15	$ 9,812.80	32,118	$ 144,531.91	$ 10,000.00	$ 50,000.00	$ 20,000.00	$ 712,223.10
2015	2999	2560	2265	431	1834	1%	0	1834	0	1%	7	726	7	439	$ 350,828.72	283	$ 99,214.39	1,834	12	$ 7,824.87	-	$ -	$ 10,000.00	$ 50,000.00		$ 517,867.97
2016	2560	2122	1834	431	1403	1%	0	1403	726	1%	7	719	7	438	$ 350,770.03	283	$ 99,214.39	1,403	9	$ 5,985.08	31,479	$ 141,655.73	$ 10,000.00	$ 50,000.00		$ 657,625.23
2017	2122	1683	1403	431	971	1%	0	971	0	1%	7	712	7	438	$ 350,711.93	283	$ 99,214.39	972	6	$ 4,145.29	-	$ -	$ 10,000.00	$ 50,000.00		$ 514,071.61
2018	1683	1210	971	431	540	2%	35	506	712	1%	7	705	42	473	$ 378,430.41	283	$ 99,214.39	540	4	$ 2,305.50	30,853	$ 138,836.78	$ 10,000.00	$ 50,000.00		$ 678,787.08
2019	1210	1134	506	0	506	4%	69	436	0	1%	7	698	76	76	$ 61,189.47	283	$ 99,214.39	506	3	$ 2,157.36	-	$ -	$ 10,000.00	$ 50,000.00		$ 222,561.21
2020	1134	988	436	0	436	8%	139	297	698	1%	7	691	146	146	$ 116,685.09	283	$ 99,214.39	436	3	$ 1,861.08	30,239	$ 136,073.93	$ 10,000.00	$ 50,000.00		$ 413,834.49
2021	988	703	297	0	297	16%	278	19	0	1%	7	684	285	285	$ 227,733.28	283	$ 99,214.39	297	2	$ 1,268.52	-	$ -	$ 10,000.00	$ 50,000.00		$ 388,216.19
2022	703	677	19	0	19	32%	19	0	684	1%	7	677	26	26	$ 21,054.03	283	$ 99,214.39	20	0	$ 83.41	29,637	$ 133,366.06	$ 10,000.00	$ 50,000.00		$ 313,717.88
2023	677	670	0	0	0	64%	0	0	0	1%	7	670	7	7	$ 5,415.33	283	$ 99,214.39	0	0	$ 0.29	-	$ -	$ 10,000.00	$ 50,000.00		$ 164,630.01
2024	670	663	0	0	0	90%	0	0	670	1%	7	663	7	7	$ 5,361.18	283	$ 99,214.39	0	0	$ 0.29	29,047	$ 130,712.07	$ 10,000.00	$ 50,000.00		$ 295,287.92
2025	663	657	0	0	0	95%	0	0	0	1%	7	657	7	7	$ 5,307.57	283	$ 99,214.39	0	0	$ 0.28	-	$ -	$ 10,000.00	$ 50,000.00		$ 164,522.23
2026	657	650	0	0	0	97%	0	0	657	1%	7	650	7	7	$ 5,254.49	283	$ 99,214.39	0	0	$ 0.28	28,469	$ 128,110.90	$ 10,000.00	$ 50,000.00		$ 292,580.06
2027	650	644	0	0	0	98%	0	0	0	1%	7	644	7	7	$ 5,201.94	283	$ 99,214.39	0	0	$ 0.28	-	$ -	$ 10,000.00	$ 50,000.00		$ 164,416.61
2028	644	637	0	0	0	98%	0	0	644	1%	6	637	6	6	$ 5,149.93	283	$ 99,214.39	0	0	$ 0.27	27,903	$ 125,561.49	$ 10,000.00	$ 50,000.00		$ 289,926.08
	Remaining trees	***18.4%***												***2,835***	***$ 2,267,757.41***	***4,252***	***$ 1,488,215.80***				***Total 15 yr***	***$1,078,848.88***	***$ 150,000.00***	***$ 750,000.00***		***$ 5,790,267.66***

3c. Active Manage 50% of >=30cm Good

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				431.2 per year		*86%*				*14%*					*$ 800.00 per tree*		*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*43 cm DBH/tree AVG*	*$ 4.50 per cm DBH*	*$ 10,000.00 per year*	*$ 50,000.00 per year*	*$ 20,000.00*	
2013		3472																								
2014	3472	3001	2978	431	2547	1%	35	2512	494	1%	5	489	40	471	$ 376,688.00	305	$ 106,649.59	2,547	17	$ 10,866.56	21,412	$ 96,354.61	$ 10,000.00	$ 50,000.00	$ 20,000.00	$ 670,558.76
2015	3001	2565	2512	431	2081	1%	0	2081	0	1%	5	484	5	436	$ 348,872.48	305	$ 106,649.59	2,081	14	$ 8,878.63	-	$ -	$ 10,000.00	$ 50,000.00		$ 524,400.70
2016	2565	2129	2081	431	1650	1%	0	1650	484	1%	5	479	5	436	$ 348,833.36	305	$ 106,649.59	1,650	11	$ 7,038.84	20,986	$ 94,437.15	$ 10,000.00	$ 50,000.00		$ 616,958.94
2017	2129	1693	1650	431	1218	1%	0	1218	0	1%	5	475	5	436	$ 348,794.62	305	$ 106,649.59	1,219	8	$ 5,199.05	-	$ -	$ 10,000.00	$ 50,000.00		$ 520,643.27
2018	1693	1222	1218	431	787	2%	35	753	475	1%	5	470	39	471	$ 376,532.28	305	$ 106,649.59	787	5	$ 3,359.26	20,568	$ 92,557.85	$ 10,000.00	$ 50,000.00		$ 639,098.98
2019	1222	1148	753	0	753	4%	69	683	0	1%	5	465	74	74	$ 59,310.31	305	$ 106,649.59	753	5	$ 3,211.12	-	$ -	$ 10,000.00	$ 50,000.00		$ 229,171.03
2020	1148	1005	683	0	683	8%	139	544	465	1%	5	460	144	144	$ 114,824.73	305	$ 106,649.59	683	5	$ 2,914.84	20,159	$ 90,715.95	$ 10,000.00	$ 50,000.00		$ 375,105.12
2021	1005	722	544	0	544	16%	278	266	0	1%	5	456	282	282	$ 225,891.52	305	$ 106,649.59	544	4	$ 2,322.29	-	$ -	$ 10,000.00	$ 50,000.00		$ 394,863.40
2022	722	451	266	0	266	32%	266	0	456	1%	5	451	271	271	$ 216,830.69	305	$ 106,649.59	267	2	$ 1,137.18	19,758	$ 88,910.70	$ 10,000.00	$ 50,000.00		$ 473,528.16
2023	451	447	0	0	0	64%	0	0	0	1%	5	447	5	5	$ 3,610.22	305	$ 106,649.59	0	0	$ 0.19	-	$ -	$ 10,000.00	$ 50,000.00		$ 170,260.00
2024	447	442	0	0	0	90%	0	0	447	1%	4	442	4	4	$ 3,574.12	305	$ 106,649.59	0	0	$ 0.19	19,365	$ 87,141.38	$ 10,000.00	$ 50,000.00		$ 257,365.28
2025	442	438	0	0	0	95%	0	0	0	1%	4	438	4	4	$ 3,538.38	305	$ 106,649.59	0	0	$ 0.19	-	$ -	$ 10,000.00	$ 50,000.00		$ 170,188.16
2026	438	433	0	0	0	97%	0	0	438	1%	4	433	4	4	$ 3,502.99	305	$ 106,649.59	0	0	$ 0.19	18,979	$ 85,407.27	$ 10,000.00	$ 50,000.00		$ 255,560.04
2027	433	429	0	0	0	98%	0	0	0	1%	4	429	4	4	$ 3,467.96	305	$ 106,649.59	0	0	$ 0.18	-	$ -	$ 10,000.00	$ 50,000.00		$ 170,117.74
2028	429	425	0	0	0	98%	0	0	429	1%	4	425	4	4	$ 3,433.28	305	$ 106,649.59	0	0	$ 0.18	18,602	$ 83,707.66	$ 10,000.00	$ 50,000.00		$ 253,790.72
	Remaining trees	***12.2%***												***3,047***	***$ 2,437,704.94***	***4,571***	***$ 1,599,743.87***				***Total 15 yr***	***$ 719,232.58***	***$ 150,000.00***	***$ 750,000.00***		***$ 5,721,610.29***

3d. Active Manage 25% of >=30cm Good

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				431.2 per year		*93%*				*7%*					*$ 800.00 per tree*		*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*43 cm DBH/tree AVG*	*$ 4.50 per cm DBH*	*$ 10,000.00 per year*	*$ 50,000.00 per year*	*$ 20,000.00*	
2013		3472																								
2014	3472	3004	3225	431	2794	1%	35	2759	247	1%	2	245	37	468	$ 374,712.00	326	$ 114,084.80	2,794	19	$ 11,920.32	10,706	$ 48,177.30	$ 10,000.00	$ 50,000.00	$ 20,000.00	$ 628,894.42
2015	3004	2570	2759	431	2328	1%	0	2328	0	1%	2	242	2	434	$ 346,916.24	326	$ 114,084.80	2,328	16	$ 9,932.39	-	$ -	$ 10,000.00	$ 50,000.00		$ 530,933.43
2016	2570	2136	2328	431	1897	1%	0	1897	242	1%	2	240	2	434	$ 346,896.68	326	$ 114,084.80	1,897	13	$ 8,092.60	10,493	$ 47,218.58	$ 10,000.00	$ 50,000.00		$ 576,292.65
2017	2136	1703	1897	431	1465	1%	0	1465	0	1%	2	237	2	434	$ 346,877.31	326	$ 114,084.80	1,466	10	$ 6,252.82	-	$ -	$ 10,000.00	$ 50,000.00		$ 527,214.92
2018	1703	1234	1465	431	1034	2%	35	1000	237	1%	2	235	37	468	$ 374,634.14	326	$ 114,084.80	1,034	7	$ 4,413.03	10,284	$ 46,278.93	$ 10,000.00	$ 50,000.00		$ 599,410.89
2019	1234	1163	1000	0	1000	4%	69	930	0	1%	2	233	72	72	$ 57,431.16	326	$ 114,084.80	1,000	7	$ 4,264.89	-	$ -	$ 10,000.00	$ 50,000.00		$ 235,780.84
2020	1163	1021	930	0	930	8%	139	791	233	1%	2	230	141	141	$ 112,964.36	326	$ 114,084.80	930	6	$ 3,968.61	10,080	$ 45,357.98	$ 10,000.00	$ 50,000.00		$ 336,375.75
2021	1021	741	791	0	791	16%	278	513	0	1%	2	228	280	280	$ 224,049.76	326	$ 114,084.80	791	5	$ 3,376.06	-	$ -	$ 10,000.00	$ 50,000.00		$ 401,510.61
2022	741	226	513	0	513	32%	513	0	228	1%	2	226	516	516	$ 412,607.34	326	$ 114,084.80	514	3	$ 2,190.95	9,879	$ 44,455.35	$ 10,000.00	$ 50,000.00		$ 633,338.44
2023	226	223	0	0	0	64%	0	0	0	1%	2	223	2	2	$ 1,805.11	326	$ 114,084.80	0	0	$ 0.10	-	$ -	$ 10,000.00	$ 50,000.00		$ 175,890.00
2024	223	221	0	0	0	90%	0	0	223	1%	2	221	2	2	$ 1,787.06	326	$ 114,084.80	0	0	$ 0.10	9,682	$ 43,570.69	$ 10,000.00	$ 50,000.00		$ 219,442.64
2025	221	219	0	0	0	95%	0	0	0	1%	2	219	2	2	$ 1,769.19	326	$ 114,084.80	0	0	$ 0.09	-	$ -	$ 10,000.00	$ 50,000.00		$ 175,854.08
2026	219	217	0	0	0	97%	0	0	219	1%	2	217	2	2	$ 1,751.50	326	$ 114,084.80	0	0	$ 0.09	9,490	$ 42,703.63	$ 10,000.00	$ 50,000.00		$ 218,540.02
2027	217	215	0	0	0	98%	0	0	0	1%	2	215	2	2	$ 1,733.98	326	$ 114,084.80	0	0	$ 0.09	-	$ -	$ 10,000.00	$ 50,000.00		$ 175,818.87
2028	215	212	0	0	0	98%	0	0	215	1%	2	212	2	2	$ 1,716.64	326	$ 114,084.80	0	0	$ 0.09	9,301	$ 41,853.83	$ 10,000.00	$ 50,000.00		$ 217,655.36
	Remaining trees	***6.1%***												***3,260***	***$ 2,607,652.47***	***4,889***	***$ 1,711,271.93***				***Total 15 yr***	***$ 359,616.29***	***$ 150,000.00***	***$ 750,000.00***		***$ 5,652,952.92***

4. Agressive Man 75% of >=20cm Good & Moderate

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				237 per year		*52%*				*48%*					*$ 800.00 per tree*		*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*36 cm DBH/tree AVG*	*$ 4.50 per cm DBH*	*$ 10,000.00 per year*	*$ 50,000.00 per year*	*$ 20,000.00*	
2013		3472																								
2014	3472	3184	1820	237	1583	1%	35	1548	1652	1%	17	1636	51	288	$ 230,434.00	205	$ 71,783.90	1,583	11	$ 6,754.62	59,411	$ 267,348.53	$ 10,000.00	$ 50,000.00	$ 20,000.00	$ 656,321.06
2015	3184	2931	1548	237	1311	1%	0	1311	0	1%	16	1619	16	253	$ 202,525.82	205	$ 71,783.90	1,312	9	$ 5,596.13	-	$ -	$ 10,000.00	$ 50,000.00		$ 339,905.85
2016	2931	2678	1311	237	1075	1%	0	1075	1619	1%	16	1603	16	253	$ 202,394.96	205	$ 71,783.90	1,075	7	$ 4,585.78	58,229	$ 262,028.30	$ 10,000.00	$ 50,000.00		$ 600,792.94
2017	2678	2425	1075	237	838	1%	0	838	0	1%	16	1587	16	253	$ 202,265.41	205	$ 71,783.90	838	6	$ 3,575.43	-	$ -	$ 10,000.00	$ 50,000.00		$ 337,624.74
2018	2425	2138	838	237	601	2%	35	566	1587	1%	16	1571	51	287	$ 229,913.16	205	$ 71,783.90	601	4	$ 2,565.07	57,070	$ 256,813.93	$ 10,000.00	$ 50,000.00		$ 621,076.06
2019	2138	2052	566	0	566	4%	69	497	0	1%	16	1556	85	85	$ 68,122.19	205	$ 71,783.90	566	4	$ 2,416.93	-	$ -	$ 10,000.00	$ 50,000.00		$ 202,323.01
2020	2052	1898	497	0	497	8%	139	358	1556	1%	16	1540	154	154	$ 123,548.48	205	$ 71,783.90	497	3	$ 2,120.64	55,934	$ 251,703.34	$ 10,000.00	$ 50,000.00		$ 509,156.36
2021	1898	1605	358	0	358	16%	278	80	0	1%	15	1525	293	293	$ 234,528.04	205	$ 71,783.90	358	2	$ 1,528.08	-	$ -	$ 10,000.00	$ 50,000.00		$ 367,840.02
2022	1605	1509	80	0	80	32%	80	0	1525	1%	15	1509	95	95	$ 76,380.84	205	$ 71,783.90	80	1	$ 342.97	54,821	$ 246,694.44	$ 10,000.00	$ 50,000.00		$ 455,202.14
2023	1509	1494	0	0	0	64%	0	0	0	1%	15	1494	15	15	$ 12,074.87	205	$ 71,783.90	0	0	$ 0.64	-	$ -	$ 10,000.00	$ 50,000.00		$ 143,859.42
2024	1494	1479	0	0	0	90%	0	0	1494	1%	15	1479	15	15	$ 11,954.12	205	$ 71,783.90	0	0	$ 0.64	53,730	$ 241,785.22	$ 10,000.00	$ 50,000.00		$ 385,523.88
2025	1479	1465	0	0	0	95%	0	0	0	1%	15	1465	15	15	$ 11,834.58	205	$ 71,783.90	0	0	$ 0.63	-	$ -	$ 10,000.00	$ 50,000.00		$ 143,619.11
2026	1465	1450	0	0	0	97%	0	0	1465	1%	15	1450	15	15	$ 11,716.24	205	$ 71,783.90	0	0	$ 0.62	52,661	$ 236,973.69	$ 10,000.00	$ 50,000.00		$ 380,474.45
2027	1450	1435	0	0	0	98%	0	0	0	1%	14	1435	14	14	$ 11,599.07	205	$ 71,783.90	0	0	$ 0.62	-	$ -	$ 10,000.00	$ 50,000.00		$ 143,383.59
2028	1435	1421	0	0	0	98%	0	0	1435	1%	14	1421	14	14	$ 11,483.08	205	$ 71,783.90	0	0	$ 0.61	51,613	$ 232,257.92	$ 10,000.00	$ 50,000.00		$ 375,525.51
	Remaining trees	***40.9%***												***2,051***	***$ 1,640,774.87***	***3,076***	***$ 1,076,758.51***				***Total 15 yr***	***$1,995,605.37***	***$ 150,000.00***	***$ 750,000.00***		***$ 5,662,628.16***

No.	*Strategy*	*% remaining ash trees after 15 years*	*Total $ spent in 15 years*
1	**Reactive**	2%	$ 3,618,705
2a	**Moderate Management (1:1 replacement)**	2%	$ 5,575,049
2b	**Moderate Management (1:2 replacement)**	2%	$ 7,388,994
2c	**Moderate Management (1:3 replacement)**	2%	$ 9,183,213
3a	**Active Management (100%)**	24%	$ 5,859,896
3b	**Active Management (75%)**	18%	$ 5,790,268
3c	**Active Management (50%)**	12%	$ 5,721,610
3d	**Active Management (25%)**	6%	$ 5,652,953
4	**Aggressive Management**	41%	$ 5,662,628

Year	Strategy No. 1	2a	2b	2c	3a	3b	3c	3d	4
2014	$ 92,589.87	$ 241,679.47	$ 361,819.07	$ 481,433.67	$ 753,887.44	$ 712,223.10	$ 670,558.76	$ 628,894.42	$ 656,321.06
2015	$ 64,665.73	$ 193,755.33	$ 313,894.93	$ 433,509.53	$ 511,335.25	$ 517,867.97	$ 524,400.70	$ 530,933.43	$ 339,905.85
2016	$ 64,665.73	$ 193,755.33	$ 313,894.93	$ 433,509.53	$ 698,291.51	$ 657,625.23	$ 616,958.94	$ 576,292.65	$ 600,792.94
2017	$ 64,665.73	$ 193,755.33	$ 313,894.93	$ 433,509.53	$ 507,499.95	$ 514,071.61	$ 520,643.27	$ 527,214.92	$ 337,624.74
2018	$ 92,441.73	$ 221,531.33	$ 341,670.93	$ 461,285.53	$ 718,475.17	$ 678,787.08	$ 639,098.98	$ 599,410.89	$ 621,076.06
2019	$ 120,069.59	$ 249,159.19	$ 369,298.79	$ 488,913.39	$ 215,951.40	$ 222,561.21	$ 229,171.03	$ 235,780.84	$ 202,323.01
2020	$ 175,325.31	$ 304,414.91	$ 424,554.51	$ 544,169.11	$ 452,563.85	$ 413,834.49	$ 375,105.12	$ 336,375.75	$ 509,156.36
2021	$ 285,836.76	$ 414,926.36	$ 535,065.96	$ 654,680.56	$ 199,552.98	$ 388,216.19	$ 394,863.40	$ 401,510.61	$ 367,840.02
2022	$ 506,859.65	$ 635,949.25	$ 756,088.85	$ 875,703.45	$ 336,894.35	$ 313,717.88	$ 473,528.16	$ 633,338.44	$ 455,202.14
2023	$ 948,905.43	$1,077,995.03	$1,198,134.63	$1,317,749.23	$ 159,000.01	$ 164,630.01	$ 170,260.00	$ 175,890.00	$ 143,859.42
2024	$ 777,508.99	$ 906,598.59	$1,027,533.93	$1,147,148.53	$ 333,210.56	$ 295,287.92	$ 257,365.28	$ 219,442.64	$ 385,523.88
2025	$ 190,361.39	$ 319,450.99	$ 441,177.79	$ 560,792.39	$ 158,856.31	$ 164,522.23	$ 170,188.16	$ 175,854.08	$ 143,619.11
2026	$ 106,292.69	$ 235,382.29	$ 357,896.29	$ 477,510.89	$ 329,600.08	$ 292,580.06	$ 255,560.04	$ 218,540.02	$ 380,474.45
2027	$ 78,220.42	$ 207,310.02	$ 330,606.95	$ 450,221.55	$ 158,715.48	$ 164,416.61	$ 170,117.74	$ 175,818.87	$ 143,383.59
2028	$ 50,296.28	$ 179,385.88	$ 303,461.48	$ 423,076.08	$ 326,061.44	$ 289,926.08	$ 253,790.72	$ 217,655.36	$ 375,525.51
Total	**$ 3,618,705.28**	**$ 5,575,049.28**	**$ 7,388,993.95**	**$ 9,183,212.95**	**$ 5,859,895.78**	**$ 5,790,267.66**	**$ 5,721,610.29**	**$ 5,652,952.92**	**$ 5,662,628.16**

APPENDIX 4 - MANAGEMENT STRATEGY COST MODELS, 10-YEAR MANAGEMENT PROGRAM

APPENDIX 4 - MANAGEMENT STRATEGY COST MODELS, 10-YEAR MANAGEMENT PROGRAM

Cost Model

STRATEGY	***1***	***2***	***3***	***4***
NAME	**Reactive**	**Moderate Management**	**Active Management**	**Aggressive Management**
Management components				
Public Communications	x	x	x	x
Visual inspection at ground level	x	x	x	x
Remove dead trees	x	x	x	x
Plantable spaces inventory & planting strategy		x	x	x
Replace removed trees with new trees		x	x	x
Preemptive felling of the non-retainable trees			x	x
TreeAzin 30+			x	
TreeAzin 20+				x
Parameters				
Number of trees	3472	3472	3472	3472
Average DBH (cm) treated trees	0	0	43	36
Infection Rate (%) treated	1	1	1	1
Yearly communications budget	$ -	$ 10,000.00	$ 10,000.00	$ 10,000.00
Administrative/Implementation	$ 50,000.00	$ 50,000.00	$ 50,000.00	$ 50,000.00
Plantable spaces inventory & planting strategy	$ -	$ 20,000.00	$ 20,000.00	$ 20,000.00
Removal costs one tree	$ 800.00	$ 800.00	$ 800.00	$ 800.00
Replanting costs one tree	$ 350.00	$ 350.00	$ 350.00	$ 350.00
No of yearly inspection rounds	1	1	1	1
No of trees inspected per day	150	150	150	150
Tree inspection costs per hour	$ 80.00	$ 80.00	$ 80.00	$ 80.00
Percentage of trees treated	0	0	28	63
Number of pre-emptive replacements (annual)	0	0	431	237
Treatment cost per cm DBH (annual)	$ -	$ -	$ 4.50	$ 4.50

1. Reactive

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/ Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				0 per year		*100%*				*0%*					*$ 800.00 per tree*	*none*	*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*- cm DBH/tree AVG*	*$ - per cm DBH*	*$ - per year*	*$ 50,000.00 per year*		
2013		3472																								
2014	3472	3437	3472	0	3472	1%	35	3437	0	1%	0	0	35	35	$ 27,776.00	0	$ -	3,472	23	$ 14,813.87	-	$ -	$ -	$ 50,000.00		$ 92,589.87
2015	3437	3403	3437	0	3437	2%	35	3403	0	1%	0	0	35	35	$ 27,776.00	0	$ -	3,437	23	$ 14,665.73	-	$ -	$ -	$ 50,000.00		$ 92,441.73
2016	3403	3333	3403	0	3403	4%	69	3333	0	1%	0	0	69	69	$ 55,552.00	0	$ -	3,403	23	$ 14,517.59	-	$ -	$ -	$ 50,000.00		$ 120,069.59
2017	3333	3194	3333	0	3333	8%	139	3194	0	1%	0	0	139	139	$ 111,104.00	0	$ -	3,333	22	$ 14,221.31	-	$ -	$ -	$ 50,000.00		$ 175,325.31
2018	3194	2916	3194	0	3194	16%	278	2916	0	1%	0	0	278	278	$ 222,208.00	0	$ -	3,194	21	$ 13,628.76	-	$ -	$ -	$ 50,000.00		$ 285,836.76
2019	2916	2361	2916	0	2916	32%	556	2361	0	1%	0	0	556	556	$ 444,416.00	0	$ -	2,916	19	$ 12,443.65	-	$ -	$ -	$ 50,000.00		$ 506,859.65
2020	2361	1250	2361	0	2361	64%	1111	1250	0	1%	0	0	1111	1111	$ 888,832.00	0	$ -	2,361	16	$ 10,073.43	-	$ -	$ -	$ 50,000.00		$ 948,905.43
2021	1250	556	1250	0	1250	84%	694	556	0	1%	0	0	694	694	$ 555,520.00	0	$ -	1,250	8	$ 5,332.99	-	$ -	$ -	$ 50,000.00		$ 610,852.99
2022	556	139	556	0	556	96%	417	139	0	1%	0	0	417	417	$ 333,312.00	0	$ -	556	4	$ 2,370.22	-	$ -	$ -	$ 50,000.00		$ 385,682.22
2023	139	69	139	0	139	98%	69	69	0	1%	0	0	69	69	$ 55,552.00	0	$ -	139	1	$ 592.55	-	$ -	$ -	$ 50,000.00		$ 106,144.55
Remaining trees		***2.0%***												***3,403***	***$ 2,722,048.00***	***-***	***$ -***				***Total 10 yr***	***$ -***	***$ -***	***$ 500,000.00***		***$ 3,324,708.10***

2a. Moderate Management (yearly inspections, removal of dead trees, replacement at 1:1 ratio)

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/ Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				0 per year		*100%*				*0%*					*$ 800.00 per tree*		*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*- cm DBH/tree AVG*	*$ - per cm DBH*	*$ 10,000.00 per year*	*$ 50,000.00 per year*	*$ 20,000.00*	
2013		3472																								
2014	3472	3437	3472	0	3472	1%	35	3437	0	1%	0	0	35	35	$ 27,776.00	340	$ 119,089.60	3,472	23	$ 14,813.87	-	$ -	$ 10,000.00	$ 50,000.00	$ 20,000.00	$ 241,679.47
2015	3437	3403	3437	0	3437	2%	35	3403	0	1%	0	0	35	35	$ 27,776.00	340	$ 119,089.60	3,437	23	$ 14,665.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 221,531.33
2016	3403	3333	3403	0	3403	4%	69	3333	0	1%	0	0	69	69	$ 55,552.00	340	$ 119,089.60	3,403	23	$ 14,517.59	-	$ -	$ 10,000.00	$ 50,000.00		$ 249,159.19
2017	3333	3194	3333	0	3333	8%	139	3194	0	1%	0	0	139	139	$ 111,104.00	340	$ 119,089.60	3,333	22	$ 14,221.31	-	$ -	$ 10,000.00	$ 50,000.00		$ 304,414.91
2018	3194	2916	3194	0	3194	16%	278	2916	0	1%	0	0	278	278	$ 222,208.00	340	$ 119,089.60	3,194	21	$ 13,628.76	-	$ -	$ 10,000.00	$ 50,000.00		$ 414,926.36
2019	2916	2361	2916	0	2916	32%	556	2361	0	1%	0	0	556	556	$ 444,416.00	340	$ 119,089.60	2,916	19	$ 12,443.65	-	$ -	$ 10,000.00	$ 50,000.00		$ 635,949.25
2020	2361	1250	2361	0	2361	64%	1111	1250	0	1%	0	0	1111	1111	$ 888,832.00	340	$ 119,089.60	2,361	16	$ 10,073.43	-	$ -	$ 10,000.00	$ 50,000.00		$ 1,077,995.03
2021	1250	556	1250	0	1250	84%	694	556	0	1%	0	0	694	694	$ 555,520.00	340	$ 119,089.60	1,250	8	$ 5,332.99	-	$ -	$ 10,000.00	$ 50,000.00		$ 739,942.59
2022	556	139	556	0	556	96%	417	139	0	1%	0	0	417	417	$ 333,312.00	340	$ 119,089.60	556	4	$ 2,370.22	-	$ -	$ 10,000.00	$ 50,000.00		$ 514,771.82
2023	139	69	139	0	139	98%	69	69	0	1%	0	0	69	69	$ 55,552.00	340	$ 119,089.60	139	1	$ 592.55	-	$ -	$ 10,000.00	$ 50,000.00		$ 235,234.15
	Remaining trees	***2.0%***												***3,403***	***$ 2,722,048.00***	***3,403***	***$ 1,190,896.00***				***Total 10 yr***	***$ -***	***$ 100,000.00***	***$ 500,000.00***		***$ 4,635,604.10***

2b. Moderate Management (yearly inspections, removal of dead trees, replacement at 1:2 ratio)

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/ Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				0 per year		*100%*				*0%*					*$ 800.00 per tree*		*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*- cm DBH/tree AVG*	*$ - per cm DBH*	*$ 10,000.00 per year*	*$ 50,000.00 per year*	*$ 20,000.00*	
2013		3472																								
2014	3472	3437	3472	0	3472	1%	35	3437	0	1%	0	0	35	35	$ 27,776.00	681	$ 238,179.20	3,472	23	$ 14,813.87	-	$ -	$ 10,000.00	$ 50,000.00	$ 20,000.00	$ 360,769.07
2015	3437	3403	3437	0	3437	2%	35	3403	0	1%	0	0	35	35	$ 27,776.00	681	$ 238,179.20	3,437	23	$ 14,665.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 340,620.93
2016	3403	3333	3403	0	3403	4%	69	3333	0	1%	0	0	69	69	$ 55,552.00	681	$ 238,179.20	3,403	23	$ 14,517.59	-	$ -	$ 10,000.00	$ 50,000.00		$ 368,248.79
2017	3333	3194	3333	0	3333	8%	139	3194	0	1%	0	0	139	139	$ 111,104.00	681	$ 238,179.20	3,333	22	$ 14,221.31	-	$ -	$ 10,000.00	$ 50,000.00		$ 423,504.51
2018	3194	2916	3194	0	3194	16%	278	2916	0	1%	0	0	278	278	$ 222,208.00	681	$ 238,179.20	3,194	21	$ 13,628.76	-	$ -	$ 10,000.00	$ 50,000.00		$ 534,015.96
2019	2916	2361	2916	0	2916	32%	556	2361	0	1%	0	0	556	556	$ 444,416.00	681	$ 238,179.20	2,916	19	$ 12,443.65	-	$ -	$ 10,000.00	$ 50,000.00		$ 755,038.85
2020	2361	1250	2361	0	2361	64%	1111	1250	0	1%	0	0	1111	1111	$ 888,832.00	681	$ 238,179.20	2,361	16	$ 10,073.43	-	$ -	$ 10,000.00	$ 50,000.00		$ 1,197,084.63
2021	1250	556	1250	0	1250	84%	694	556	0	1%	0	0	694	694	$ 555,520.00	681	$ 238,179.20	1,250	8	$ 5,332.99	-	$ -	$ 10,000.00	$ 50,000.00		$ 859,032.19
2022	556	139	556	0	556	96%	417	139	0	1%	0	0	417	417	$ 333,312.00	681	$ 238,179.20	556	4	$ 2,370.22	-	$ -	$ 10,000.00	$ 50,000.00		$ 633,861.42
2023	139	69	139	0	139	98%	69	69	0	1%	0	0	69	69	$ 55,552.00	681	$ 238,179.20	139	1	$ 592.55	-	$ -	$ 10,000.00	$ 50,000.00		$ 354,323.75
	Remaining trees	***2.0%***												***3,403***	***$ 2,722,048.00***	***6,805***	***$ 2,381,792.00***				***Total 10 yr***	***$ -***	***$ 100,000.00***	***$ 500,000.00***		***$ 5,826,500.10***

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2c. Moderate Management (yearly inspections, removal of dead trees, replacement at 1:3 ratio)

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/ Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				0 per year		*100%*				*0%*					*$ 800.00 per tree*		*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*- cm DBH/tree AVG*	*$ - per cm DBH*	*$ 10,000.00 per year*	*$ 50,000.00 per year*	*$ 20,000.00*	
2013		3472																								
2014	3472	3437	3472	0	3472	1%	35	3437	0	1%	0	0	35	35	$ 27,776.00	1,021	$ 357,268.80	3,472	23	$ 14,813.87	-	$ -	$ 10,000.00	$ 50,000.00	$ 20,000.00	$ 479,858.67
2015	3437	3403	3437	0	3437	2%	35	3403	0	1%	0	0	35	35	$ 27,776.00	1,021	$ 357,268.80	3,437	23	$ 14,665.73	-	$ -	$ 10,000.00	$ 50,000.00		$ 459,710.53
2016	3403	3333	3403	0	3403	4%	69	3333	0	1%	0	0	69	69	$ 55,552.00	1,021	$ 357,268.80	3,403	23	$ 14,517.59	-	$ -	$ 10,000.00	$ 50,000.00		$ 487,338.39
2017	3333	3194	3333	0	3333	8%	139	3194	0	1%	0	0	139	139	$ 111,104.00	1,021	$ 357,268.80	3,333	22	$ 14,221.31	-	$ -	$ 10,000.00	$ 50,000.00		$ 542,594.11
2018	3194	2916	3194	0	3194	16%	278	2916	0	1%	0	0	278	278	$ 222,208.00	1,021	$ 357,268.80	3,194	21	$ 13,628.76	-	$ -	$ 10,000.00	$ 50,000.00		$ 653,105.56
2019	2916	2361	2916	0	2916	32%	556	2361	0	1%	0	0	556	556	$ 444,416.00	1,021	$ 357,268.80	2,916	19	$ 12,443.65	-	$ -	$ 10,000.00	$ 50,000.00		$ 874,128.45
2020	2361	1250	2361	0	2361	64%	1111	1250	0	1%	0	0	1111	1111	$ 888,832.00	1,021	$ 357,268.80	2,361	16	$ 10,073.43	-	$ -	$ 10,000.00	$ 50,000.00		$ 1,316,174.23
2021	1250	556	1250	0	1250	84%	694	556	0	1%	0	0	694	694	$ 555,520.00	1,021	$ 357,268.80	1,250	8	$ 5,332.99	-	$ -	$ 10,000.00	$ 50,000.00		$ 978,121.79
2022	556	139	556	0	556	96%	417	139	0	1%	0	0	417	417	$ 333,312.00	1,021	$ 357,268.80	556	4	$ 2,370.22	-	$ -	$ 10,000.00	$ 50,000.00		$ 752,951.02
2023	139	69	139	0	139	98%	69	69	0	1%	0	0	69	69	$ 55,552.00	1,021	$ 357,268.80	139	1	$ 592.55	-	$ -	$ 10,000.00	$ 50,000.00		$ 473,413.35
	Remaining trees	***2.0%***												***3,403***	***$ 2,722,048.00***	***10,208***	***$ 3,572,688.00***				***Total 10 yr***	***$ -***	***$ 100,000.00***	***$ 500,000.00***		***$ 7,017,396.10***

3a. Active Manage 100% of >=30cm Good

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/ Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				431.2 per year		*72%*				*28%*					*$ 800.00 per tree*		*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*43 cm DBH/tree AVG*	*$ 4.50 per cm DBH*	*$ 10,000.00 per year*	*$ 50,000.00 per year*	*$ 20,000.00*	
2013		3472																								
2014	3472	2996	2484	431	2053	1%	35	2018	988	1%	10	978	45	476	$ 380,640.00	258	$ 90,246.47	2,053	14	$ 8,759.03	42,824	$ 192,709.22	$ 10,000.00	$ 50,000.00	$ 20,000.00	$ 752,354.72
2015	2996	2520	2018	431	1587	2%	35	1552	0	1%	10	968	45	476	$ 380,560.96	258	$ 90,246.47	1,587	11	$ 6,771.11	-	$ -	$ 10,000.00	$ 50,000.00		$ 537,578.53
2016	2520	2010	1552	431	1121	4%	69	1052	968	1%	10	959	79	510	$ 408,258.71	258	$ 90,246.47	1,121	7	$ 4,783.18	41,972	$ 188,874.31	$ 10,000.00	$ 50,000.00		$ 752,162.66
2017	2010	1431	1052	431	620	8%	139	481	0	1%	10	949	148	580	$ 463,733.24	258	$ 90,246.47	620	4	$ 2,647.11	-	$ -	$ 10,000.00	$ 50,000.00		$ 616,626.82
2018	1431	940	481	431	50	16%	50	0	949	1%	9	940	60	491	$ 392,744.55	258	$ 90,246.47	50	0	$ 214.76	41,137	$ 185,115.71	$ 10,000.00	$ 50,000.00		$ 728,321.49
2019	940	930	0	0	0	32%	0	0	0	1%	9	930	9	9	$ 7,516.63	258	$ 90,246.47	0	0	$ 0.40	-	$ -	$ 10,000.00	$ 50,000.00		$ 157,763.49
2020	930	921	0	0	0	64%	0	0	930	1%	9	921	9	9	$ 7,441.46	258	$ 90,246.47	0	0	$ 0.40	40,318	$ 181,431.90	$ 10,000.00	$ 50,000.00		$ 339,120.23
2021	921	912	0	0	0	84%	0	0	0	1%	9	912	9	9	$ 7,367.04	258	$ 90,246.47	0	0	$ 0.39	-	$ -	$ 10,000.00	$ 50,000.00		$ 157,613.91
2022	912	903	0	0	0	96%	0	0	912	1%	9	903	9	9	$ 7,293.37	258	$ 90,246.47	0	0	$ 0.39	39,516	$ 177,821.41	$ 10,000.00	$ 50,000.00		$ 335,361.64
2023	903	894	0	0	0	98%	0	0	0	1%	9	894	9	9	$ 7,220.44	258	$ 90,246.47	0	0	$ 0.39	-	$ -	$ 10,000.00	$ 50,000.00		$ 157,467.29
	Remaining trees	***25.7%***												***2,578***	***$ 2,062,776.41***	***2,578***	***$ 902,464.68***				***Total 10 yr***	***$ 925,952.54***	***$ 100,000.00***	***$ 500,000.00***		***$ 4,534,370.78***

3b. Active Manage 75% of >=30cm Good

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/ Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				431.2 per year		*79%*				*21%*					*$ 800.00 per tree*		*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*43 cm DBH/tree AVG*	*$ 4.50 per cm DBH*	*$ 10,000.00 per year*	*$ 50,000.00 per year*	*$ 20,000.00*	
2013		3472																								
2014	3472	2999	2731	431	2300	1%	35	2265	741	1%	7	734	42	473	$ 378,664.00	280	$ 98,064.85	2,300	15	$ 9,812.80	32,118	$ 144,531.91	$ 10,000.00	$ 50,000.00	$ 20,000.00	$ 711,073.56
2015	2999	2525	2265	431	1834	2%	35	1799	0	1%	7	726	42	473	$ 378,604.72	280	$ 98,064.85	1,834	12	$ 7,824.87	-	$ -	$ 10,000.00	$ 50,000.00		$ 544,494.44
2016	2525	2018	1799	431	1368	4%	69	1299	726	1%	7	719	77	508	$ 406,322.03	280	$ 98,064.85	1,368	9	$ 5,836.94	31,479	$ 141,655.73	$ 10,000.00	$ 50,000.00		$ 711,879.55
2017	2018	1440	1299	431	867	8%	139	728	0	1%	7	712	146	577	$ 461,815.93	280	$ 98,064.85	867	6	$ 3,700.87	-	$ -	$ 10,000.00	$ 50,000.00		$ 623,581.66
2018	1440	724	728	431	297	16%	278	19	712	1%	7	705	285	716	$ 572,862.41	280	$ 98,064.85	297	2	$ 1,268.53	30,853	$ 138,836.78	$ 10,000.00	$ 50,000.00		$ 871,032.57
2019	724	698	19	0	19	32%	19	0	0	1%	7	698	27	27	$ 21,221.47	280	$ 98,064.85	20	0	$ 83.42	-	$ -	$ 10,000.00	$ 50,000.00		$ 179,369.74
2020	698	691	0	0	0	64%	0	0	698	1%	7	691	7	7	$ 5,581.09	280	$ 98,064.85	0	0	$ 0.30	30,239	$ 136,073.93	$ 10,000.00	$ 50,000.00		$ 299,720.17
2021	691	684	0	0	0	84%	0	0	0	1%	7	684	7	7	$ 5,525.28	280	$ 98,064.85	0	0	$ 0.29	-	$ -	$ 10,000.00	$ 50,000.00		$ 163,590.43
2022	684	677	0	0	0	96%	0	0	684	1%	7	677	7	7	$ 5,470.03	280	$ 98,064.85	0	0	$ 0.29	29,637	$ 133,366.06	$ 10,000.00	$ 50,000.00		$ 296,901.23
2023	677	670	0	0	0	98%	0	0	0	1%	7	670	7	7	$ 5,415.33	280	$ 98,064.85	0	0	$ 0.29	-	$ -	$ 10,000.00	$ 50,000.00		$ 163,480.47
	Remaining trees	***19.3%***												***2,802***	***$ 2,241,482.31***	***2,802***	***$ 980,648.51***				***Total 10 yr***	***$ 694,464.41***	***$ 100,000.00***	***$ 500,000.00***		***$ 4,565,123.81***

3c. Active Manage 50% of >=30cm Good

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/ Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				431.2 per year		*86%*				*14%*					*$ 800.00 per tree*		*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*43 cm DBH/tree AVG*	*$ 4.50 per cm DBH*	*$ 10,000.00 per year*	*$ 50,000.00 per year*	*$ 20,000.00*	
2013		3472																								
2014	3472	3001	2978	431	2547	1%	35	2512	494	1%	5	489	40	471	$ 376,688.00	303	$ 105,883.23	2,547	17	$ 10,866.56	21,412	$ 96,354.61	$ 10,000.00	$ 50,000.00	$ 20,000.00	$ 669,792.40
2015	3001	2530	2512	431	2081	2%	35	2046	0	1%	5	484	40	471	$ 376,648.48	303	$ 105,883.23	2,081	14	$ 8,878.63	-	$ -	$ 10,000.00	$ 50,000.00		$ 551,410.34
2016	2530	2025	2046	431	1615	4%	69	1546	484	1%	5	479	74	505	$ 404,385.36	303	$ 105,883.23	1,615	11	$ 6,890.70	20,986	$ 94,437.15	$ 10,000.00	$ 50,000.00		$ 671,596.44
2017	2025	1450	1546	431	1114	8%	139	975	0	1%	5	475	144	575	$ 459,898.62	303	$ 105,883.23	1,114	7	$ 4,754.64	-	$ -	$ 10,000.00	$ 50,000.00		$ 630,536.49
2018	1450	736	975	431	544	16%	278	266	475	1%	5	470	283	714	$ 570,964.28	303	$ 105,883.23	544	4	$ 2,322.29	20,568	$ 92,557.85	$ 10,000.00	$ 50,000.00		$ 831,727.66
2019	736	465	266	0	266	32%	266	0	0	1%	5	465	271	271	$ 216,942.31	303	$ 105,883.23	267	2	$ 1,137.18	-	$ -	$ 10,000.00	$ 50,000.00		$ 383,962.73
2020	465	460	0	0	0	64%	0	0	465	1%	5	460	5	5	$ 3,720.73	303	$ 105,883.23	0	0	$ 0.20	20,159	$ 90,715.95	$ 10,000.00	$ 50,000.00		$ 260,320.11
2021	460	456	0	0	0	84%	0	0	0	1%	5	456	5	5	$ 3,683.52	303	$ 105,883.23	0	0	$ 0.20	-	$ -	$ 10,000.00	$ 50,000.00		$ 169,566.95
2022	456	451	0	0	0	96%	0	0	456	1%	5	451	5	5	$ 3,646.69	303	$ 105,883.23	0	0	$ 0.19	19,758	$ 88,910.70	$ 10,000.00	$ 50,000.00		$ 258,440.82
2023	451	447	0	0	0	98%	0	0	0	1%	5	447	5	5	$ 3,610.22	303	$ 105,883.23	0	0	$ 0.19	-	$ -	$ 10,000.00	$ 50,000.00		$ 169,493.65
	Remaining trees	***12.9%***												***3,025***	***$ 2,420,188.20***	***3,025***	***$ 1,058,832.34***				***Total 10 yr***	***$ 462,976.27***	***$ 100,000.00***	***$ 500,000.00***		***$ 4,596,847.60***

3d. Active Manag ***25%*** ***of >=30cm Good***

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/ Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				431.2 per year		*93%*				*7%*					*$ 800.00 per tree*		*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*43 cm DBH/tree AVG*	*$ 4.50 per cm DBH*	*$ 10,000.00 per year*	*$ 50,000.00 per year*	*$ 20,000.00*	
2013		3472																								
2014	3472	3004	3225	431	2794	1%	35	2759	247	1%	2	245	37	468	$ 374,712.00	325	$ 113,701.62	2,794	19	$ 11,920.32	10,706	$ 48,177.30	$ 10,000.00	$ 50,000.00	$ 20,000.00	$ 628,511.24
2015	3004	2535	2759	431	2328	2%	35	2293	0	1%	2	242	37	468	$ 374,692.24	325	$ 113,701.62	2,328	16	$ 9,932.39	-	$ -	$ 10,000.00	$ 50,000.00		$ 558,326.25
2016	2535	2032	2293	431	1862	4%	69	1793	242	1%	2	240	72	503	$ 402,448.68	325	$ 113,701.62	1,862	12	$ 7,944.47	10,493	$ 47,218.58	$ 10,000.00	$ 50,000.00		$ 631,313.34
2017	2032	1460	1793	431	1361	8%	139	1222	0	1%	2	237	141	572	$ 457,981.31	325	$ 113,701.62	1,361	9	$ 5,808.40	-	$ -	$ 10,000.00	$ 50,000.00		$ 637,491.33
2018	1460	748	1222	431	791	16%	278	513	237	1%	2	235	280	711	$ 569,066.14	325	$ 113,701.62	791	5	$ 3,376.06	10,284	$ 46,278.93	$ 10,000.00	$ 50,000.00		$ 792,422.74
2019	748	233	513	0	513	32%	513	0	0	1%	2	233	516	516	$ 412,663.16	325	$ 113,701.62	514	3	$ 2,190.95	-	$ -	$ 10,000.00	$ 50,000.00		$ 588,555.72
2020	233	230	0	0	0	64%	0	0	233	1%	2	230	2	2	$ 1,860.36	325	$ 113,701.62	0	0	$ 0.10	10,080	$ 45,357.98	$ 10,000.00	$ 50,000.00		$ 220,920.06
2021	230	228	0	0	0	84%	0	0	0	1%	2	228	2	2	$ 1,841.76	325	$ 113,701.62	0	0	$ 0.10	-	$ -	$ 10,000.00	$ 50,000.00		$ 175,543.48
2022	228	226	0	0	0	96%	0	0	228	1%	2	226	2	2	$ 1,823.34	325	$ 113,701.62	0	0	$ 0.10	9,879	$ 44,455.35	$ 10,000.00	$ 50,000.00		$ 219,980.41
2023	226	223	0	0	0	98%	0	0	0	1%	2	223	2	2	$ 1,805.11	325	$ 113,701.62	0	0	$ 0.10	-	$ -	$ 10,000.00	$ 50,000.00		$ 175,506.82
	Remaining trees	***6.4%***												***3,249***	***$ 2,598,894.10***	***3,249***	***$ 1,137,016.17***				***Total 10 yr***	***$ 231,488.14***	***$ 100,000.00***	***$ 500,000.00***		***$ 4,628,571.38***

4. Agressive Man ***75%*** ***of >=20cm Good & Moderate***

Year	Total Number of Ash Trees beginning season	Total Number of Ash Trees at end of season	Number untreated Ash Trees beginning season	Number of pre-emptive removals	Number of trees untreated	Infestation Rate	Number of Ash trees dead untreated	Number of untreated ash trees at end of season	Number of treated trees at beginning of season	Infestation rate treated group	No of Ash trees dead treated	Number of treated ash trees at end of season	Total number of Ash trees dead	Total number of Ash trees to be removed	Subtotal removal costs	Total number of Ash trees to be replaced	Subtotal replanting costs	No of inspections needed	No of tree inspection days	Subtotal tree inspection costs	No of cm DBH treated	Subtotal injection costs	Public communication costs	Administrative/ Implementation	Plantable spaces inventory	TOTAL COST PER YEAR
				237 per year		*52%*				*48%*					*$ 800.00 per tree*		*$ 350.00 per tree*	*1 per year*	*150 trees per day*	*$ 80.00 per hour*	*36 cm DBH/tree AVG*	*$ 4.50 per cm DBH*	*$ 10,000.00 per year*	*$ 50,000.00 per year*	*$ 20,000.00*	
2013		3472																								
2014	3472	3184	1820	237	1583	1%	35	1548	1652	1%	17	1636	51	288	$ 230,434.00	198	$ 69,220.72	1,583	11	$ 6,754.62	59,411	$ 267,348.53	$ 10,000.00	$ 50,000.00	$ 20,000.00	$ 653,757.87
2015	3184	2896	1548	237	1311	2%	35	1277	0	1%	16	1619	51	288	$ 230,301.82	198	$ 69,220.72	1,312	9	$ 5,596.13	-	$ -	$ 10,000.00	$ 50,000.00		$ 365,118.67
2016	2896	2574	1277	237	1040	4%	69	970	1619	1%	16	1603	86	322	$ 257,946.96	198	$ 69,220.72	1,040	7	$ 4,437.64	58,229	$ 262,028.30	$ 10,000.00	$ 50,000.00		$ 653,633.61
2017	2574	2182	970	237	734	8%	139	595	0	1%	16	1587	155	392	$ 313,369.41	198	$ 69,220.72	734	5	$ 3,131.01	-	$ -	$ 10,000.00	$ 50,000.00		$ 445,721.14
2018	2182	1652	595	237	358	16%	278	80	1587	1%	16	1571	294	530	$ 424,345.16	198	$ 69,220.72	358	2	$ 1,528.10	57,070	$ 256,813.93	$ 10,000.00	$ 50,000.00		$ 811,907.91
2019	1652	1556	80	0	80	32%	80	0	0	1%	16	1556	96	96	$ 76,754.19	198	$ 69,220.72	80	1	$ 342.99	-	$ -	$ 10,000.00	$ 50,000.00		$ 206,317.89
2020	1556	1540	0	0	0	64%	0	0	1556	1%	16	1540	16	16	$ 12,444.48	198	$ 69,220.72	0	0	$ 0.66	55,934	$ 251,703.34	$ 10,000.00	$ 50,000.00		$ 393,369.20
2021	1540	1525	0	0	0	84%	0	0	0	1%	15	1525	15	15	$ 12,320.04	198	$ 69,220.72	0	0	$ 0.66	-	$ -	$ 10,000.00	$ 50,000.00		$ 141,541.41
2022	1525	1509	0	0	0	96%	0	0	1525	1%	15	1509	15	15	$ 12,196.84	198	$ 69,220.72	0	0	$ 0.65	54,821	$ 246,694.44	$ 10,000.00	$ 50,000.00		$ 388,112.64
2023	1509	1494	0	0	0	98%	0	0	0	1%	15	1494	15	15	$ 12,074.87	198	$ 69,220.72	0	0	$ 0.64	-	$ -	$ 10,000.00	$ 50,000.00		$ 141,296.23
	Remaining trees	***43.0%***												***1,978***	***$ 1,582,187.77***	***1,978***	***$ 692,207.15***				***Total 10 yr***	***$1,284,588.54***	***$ 100,000.00***	***$ 500,000.00***		***$ 4,200,776.57***

No.	*Strategy*	*% remaining ash trees after 15 years*	*Total $ spent in 15 years*
1	**Reactive**	2%	$ 3,324,708
2a	**Moderate Management (1:1 replacement)**	2%	$ 4,635,604
2b	**Moderate Management (1:2 replacement)**	2%	$ 5,826,500
2c	**Moderate Management (1:3 replacement)**	2%	$ 7,017,396
3a	**Active Management (100%)**	26%	$ 4,534,371
3b	**Active Management (75%)**	19%	$ 4,565,124
3c	**Active Management (50%)**	13%	$ 4,596,848
3d	**Active Management (25%)**	6%	$ 4,628,571
4	**Aggressive Management**	43%	$ 4,200,777

	Strategy No.								
Year	**1**	**2a**	**2b**	**2c**	**3a**	**3b**	**3c**	**3d**	**4**
2014	$ 92,589.87	$ 241,679.47	$ 360,769.07	$ 479,858.67	$ 752,354.72	$ 711,073.56	$ 669,792.40	$ 628,511.24	$ 653,757.87
2015	$ 92,441.73	$ 221,531.33	$ 340,620.93	$ 459,710.53	$ 537,578.53	$ 544,494.44	$ 551,410.34	$ 558,326.25	$ 365,118.67
2016	$ 120,069.59	$ 249,159.19	$ 368,248.79	$ 487,338.39	$ 752,162.66	$ 711,879.55	$ 671,596.44	$ 631,313.34	$ 653,633.61
2017	$ 175,325.31	$ 304,414.91	$ 423,504.51	$ 542,594.11	$ 616,626.82	$ 623,581.66	$ 630,536.49	$ 637,491.33	$ 445,721.14
2018	$ 285,836.76	$ 414,926.36	$ 534,015.96	$ 653,105.56	$ 728,321.49	$ 871,032.57	$ 831,727.66	$ 792,422.74	$ 811,907.91
2019	$ 506,859.65	$ 635,949.25	$ 755,038.85	$ 874,128.45	$ 157,763.49	$ 179,369.74	$ 383,962.73	$ 588,555.72	$ 206,317.89
2020	$ 948,905.43	$1,077,995.03	$1,197,084.63	$1,316,174.23	$ 339,120.23	$ 299,720.17	$ 260,320.11	$ 220,920.06	$ 393,369.20
2021	$ 610,852.99	$ 739,942.59	$ 859,032.19	$ 978,121.79	$ 157,613.91	$ 163,590.43	$ 169,566.95	$ 175,543.48	$ 141,541.41
2022	$ 385,682.22	$ 514,771.82	$ 633,861.42	$ 752,951.02	$ 335,361.64	$ 296,901.23	$ 258,440.82	$ 219,980.41	$ 388,112.64
2023	$ 106,144.55	$ 235,234.15	$ 354,323.75	$ 473,413.35	$ 157,467.29	$ 163,480.47	$ 169,493.65	$ 175,506.82	$ 141,296.23
Total	**$ 3,324,708.10**	**$ 4,635,604.10**	**$ 5,826,500.10**	**$ 7,017,396.10**	**$ 4,534,370.78**	**$ 4,565,123.81**	**$ 4,596,847.60**	**$ 4,628,571.38**	**$ 4,200,776.57**

APPENDIX 5 - REPLACEMENT SPECIES

Potential Ash Tree Replacement Species

Botanical Name	Common Name	Origin	General Attributes / Comments	Potential Issues / Limiting Factors	Height Range[1]
Acer nigrum	Black maple	S. Ontario	Similar to *A. saccharum*, potentially more tolerant of difficult sites. Under-utilized and uncommon.	Similar to *A. saccharum*	16-25 m
Acer rubrum	Red maple	S. Ontario	Brilliant colour. Hardy cultivars. Generally urban tolerant.	Poor branch connections	16-25 m
Acer saccharinum	Silver maple	S. Ontario	Fast growth. Good colour. Hardy cultivars. Urban tolerant.	Poor branch connections, weak wood, aggressive roots, heavy seed. Limit use.	16-25 m+
Acer saccharum	Sugar maple	S. Ontario	Brilliant colour. Strong wood. Emblematic tree. Dense shade. Some cultivars are more tolerant.	Limited tolerance to urban conditions. Sensitive to heat and drought. Some girdling roots. Some pest issues.	16-25 m
Acer x *Freemanii*	Freeman maple	Hybrid	Hybrid of *A. rubrum* x *A. saccharinum*. Several cultivars available – select appropriate for site. Urban tolerant. Combines both good and bad traits of parent species.	Poor branch attachment in some cultivars. Roots can raise sidewalks.	16-25 m
Aesculus glabra	Ohio buckeye	N. America	Showy flowers. Dense shade. Visual interest. Under-utilized.	Heavy fruit and messy leaves. Early leaf drop. Toxic. Limit use.	15-20 m
Amelanchier canadensis (standard form)	Serviceberry (tree)	S. Ontario	Small tree, also available in shrub form. Good for compact sites. Very showy flowers. Edible berries attract wildlife.	Strongly prefers most soils with good drainage. Potential for fire blight.	5-7 m
Carpinus betulus, esp. 'Fastigata'	European hornbeam	Europe	Urban tolerant. Fastigate form good for compact sites. Tolerates heavy pruning.	Limited use as streetside tree due to low branching habit. Poor salt tolerance	10-15 m
Celtis occidentalis	Common hackberry	S. Ontario	Urban tolerant. Showy bark. Fruit attracts birds. Dense shade. Graceful mature form.	Requires careful pruning for good form in long-term. Girdling and surface roots possible. Little decay resistance. Susceptible to mechanical damage.	16-25 m
Corylus colurna	Turkish hazel, filbert	Europe/Asia	Hardy; urban and pollution tolerant. Good for smaller spaces.	Few if any issues. Nuts may be unsightly or messy to some.	12-15 m
Ginkgo biloba	Ginkgo	Asia	Urban tolerant. Light shade. Interesting foliage. Pest and disease resistant.	Use named cultivars only to ensure male trees; females develop foul-smelling fruit about 20 years after planting each fall. Prune to develop strong central leader due to tendency for co-dominant stems. Over-utilized in some areas.	15-22 m
Gleditsia triacanthos var. *inermis*	Thornless honey locust	N. America	Urban tolerant. Fast growing. Cast light shade.	Susceptible to aphids and defoliators. Over-utilized. Only thornless and seedless cultivars should be used. Branches can be brittle. Rarely grows with single leader; prune to reduce co-dominant stems and tight crotches.	15-22 m
Gymnocladus dioicus	Kentucky coffee-tree	S. Ontario (ltd.)	Urban tolerant. Winter interest. Almost entirely pest and disease-free. Relatively rare. Good canopy structure.	Male cultivars are strongly preferred due to unsightly, hard and large seed pods on female trees. Some object to sparse branching in young trees.	15-22 m
Liriodendron tulipifera	Tulip-tree	S. Ontario (ltd.)	Fairly urban tolerant. Fast- and large-growing. Good structure. Showy flowers and foliage.	Susceptible to aphids which cause honeydew drop. Not suited in proximity to sidewalks or structured due to aggressive and spreading root system.	20-30 m+
Ostrya virginiana	Ironwood	S. Ontario	Urban tolerant. Mid-sized. Few pests and diseases. Winter interest. Good for birds. Should be utilized more.	Few issues. Salt-sensitive and does not thrive in wet soils.	8-12 m
Phellodendron amurense	Amur cork-tree	Asia	Fairly urban tolerant and hardy. Virtually pest and disease-free.	Male cultivars should be used to avoid messy fruit. Potentially invasive. Needs adequate soil volume to be truly urban tolerant. Pruning required for good structure.	10-15 m
Platanus occidentalis	Sycamore	S. Ontario (ltd.)	Urban tolerant. Visual interest. Good canopy form. Prefers moist and will tolerate quite poor soils. Dense shade.	Susceptible to several diseases and pests. Massive-growing tree with an aggressive root system; generally not suitable for planting near sidewalks or structures with limited rooting zones. Drought sensitive.	20-25 m
Platanus x *acerifolia*	London plane-tree	Europe	Urban tolerant. Visual interest. Good canopy form. Drought tolerant. More pest and disease tolerant than Sycamore.	Massive-growing tree with an aggressive root system; generally not suitable for planting near sidewalks or structures with limited rooting zones.	20-25 m
Quercus bicolor	Swamp white oak	S. Ontario (ltd.)	Under-utilized and not tested, but a promising urban tolerant tree. Tolerates wet, compacted soils. Does not tolerate alkaline soils.	As most oaks, susceptible to a number of pests and diseases. Untested in urban areas. Transplant in spring.	15-20 m
Quercus macrocarpa	Bur oak	S. Ontario	Urban tolerant. Large-growing. Visual interest. Good form and strong wood. Drought tolerant and adaptable to a wide range of soils.	Like most oaks, difficult to transplant. Spring planting. Requires ample soil volume to avoid root/sidewalk conflicts.	20-25 m
Quercus muehlenbergii	Chinkapin oak	S. Ontario (ltd.)	Urban tolerant. Mid-sized. Well suited for streetscapes. Highly under-utilized and difficult to procure, should be utilized far more frequently. Few pest and disease problems. Adaptable to most soils.	Few issues. Difficult to procure. Spring planting.	12-15 m
Quercus plaustris	Pin oak	N. America	Urban tolerant in acidic soils. Good canopy form.	Chlorotic in alkaline soils (>7 pH). Susceptible to several pests and diseases.	15-20 m
Quercus robur	English oak	Europe	Urban tolerant. Adaptable to wide range of soils and moisture regimes, including drought. Fastigate and standard forms available. Few pests and diseases.	Winter-persistent leaves can be attractive or a nuisance, depending on perspective. Columnar trees may have poor structure. Large acorns may be problematic.	15-18 m
Quercus shumardii	Shumard oak	N. America	Urban tolerant. Brilliant foliage. Under-utilized. Tolerates a wide range of soils; wider than red oak.	Susceptible to gypsy moth and other pests and pathogens, but not sufficiently to preclude its use. Large-growing at maturity. Potentially difficult to procure.	20-25 m
Robinia pseudoacacia 'Purple	Black locust	N. America	Urban tolerant. Showy and fragrant flowers. Attractive to pollinators. Light shade. Decay-resistant	Invasive. Brittle branches; fine twigs can cause litter. Requires dedicated	15-20 m

Botanical Name	Common Name	Origin	General Attributes / Comments	Potential Issues / Limiting Factors	Height Range[1]
Robe' or 'Frisia'			wood.	pruning to form good structure. Use sparingly and only in difficult conditions, avoid planting in open landscapes due to invasive potential. Thorny.	
Tilia x 'Redmond'	'Redmond' basswood	N. America – cultivar	Urban tolerant. Good pyramidal form. Showy flowers. Vigorous and more decay-resistant than other lindens. Increasingly common but not over-utilized yet.	Expansive root system. Susceptible to aphids which cause honeydew drop. Occasional suckers at base.	15-20 m
Tilia cordata/tomentosa	Littleleaf/silver linden	Europe	Urban tolerant, esp. *cordata*. Adaptable to a wide range of soils. Moderately drought-tolerant.	Generally over-utilized. Susceptible to aphids which cause honeydew drop. Suckers at base when stressed. Tendency to form co-dominant stems; requires early pruning to provide good structure.	15-20 m
Ulmus americana cvs.	White elm cultivars	S. Ontario – cultivars	Urban tolerant. Graceful form reminiscent of stately elms which once dominated urban forests. Strong wood. Adaptable to a wide range of soils. Cultivars such as 'New Harmony', 'Liberty', and 'Valley Forge' appear to have some Dutch Elm Disease (DED) resistance.	All *U. americana* cultivars are still susceptible to DED to some degree, and to other pests and pathogens. Extensive shallow root system requires space. Limit use due to DED, but use where hardy trees are necessary in small numbers. Requires early pruning to develop good form and strong canopy.	20-30 m
Ulmus hybrids	Elm hybrids	Varies (typ. Asia)	Urban tolerant. A range of more DED-resistant elm hybrids are available, incl. 'Accolade', 'Cathedral', 'Homestead', etc. Wide variety in canopy shapes, from typical vase-shape to more rounded. Adaptable to wide range of soils.	DED resistance of all cultivars is not long-term tested. Some have aggressive root systems. Require early pruning to develop good form and strong canopy.	18-22 m
Zelkova serrata	Japanese zelkova	Asia	Urban tolerant. Similar in form to graceful *U. americana,* but shorter and more rounded. 'Green Vase' is closest. Adaptable to most soil types and moisture regimes. Almost pest-free. Should be planted in difficult spaces more often. Potentially large-growing.	Branches form in whorls around main stem; require pruning to select best branches and form good canopy. Subject to canker if injured/wounded. Potential for branch breakage if branches too large.	15-22 m

1 – In optimal growing conditions.

APPENDIX 6 - TREATMENT SUITABILITY CRITERIA

APPENDIX 6 SUITABILITY CRITERIA FOR TREATMENT OF ASH TREES

Category 1 (Good): Good condition, safe useful life expectancy in excess of 20 years, visual importance, forming component part of significant ash species cluster/group/avenue/feature, few adjacent trees, pruning intervention unlikely, few or no above/below ground conflicts, 'heritage' candidate tree, providing significant environmental and other benefits and/or high cost to remove if tree dies.

Category 2 (Moderate): Moderate condition, pruning intervention likely to remediate defects/conflicts, less suitable location, conflicts probable within life expectancy.

Category 3 (Poor): Moderate or poor condition, short safe useful life expectancy, pruning required to retain safely, significant present or future conflicts, tree less than 15cm diameter at breast height (DBH*) suppressing growth of better quality trees of other species, loss has little visual/environmental impact.

Not suitable for treatment: Trees less than 15cm DBH, dead/dying/decayed/ dangerous, likely to require removal within five (5) years for other reasons.