Oakville's

Urban Forest:

Our Solution to Our Pollution

Town of Oakville
Parks and Open Space Department, Forestry Section

OAKVILLE

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Executive Summary

The Urban Forest Effects Model (UFORE), designed by the United States Department of Agriculture, Forest Service (USDA Forest Service), has been used to quantify urban forest structure and numerous urban forest effects in cities across the world. Randomly generated sample plots combined with local pollution and weather data measure the air quality benefits provided by trees, shrubs and other types of vegetation growing throughout Oakville. These benefits are then converted to their economic value. Over the summer of 2005, approximately 500 residents and businesses participated in the Town's UFORE project. A total of 372 plots were measured. Through UFORE, a scientifically sound analysis of the structure, function and value of Oakville's urban forest including its role in greenhouse gas mitigation is provided for the first time (Section 7).

The results of the Town's UFORE project will provide support and background for the Town's Urban Forest Strategic Management Plan - a major 2006 project of the Parks and Open Space Department. Urban forest canopy cover targets will optimize the potential benefits trees provide to our ecosystem. In order to realize this potential, it is essential for the community to plan, design and maintain an urban forest as green infrastructure. Research has concluded that most of the benefits are derived from large-stature trees (McPherson 2004) and woodlots (Nowak 2006). New urban design techniques and management approaches to realize these potentials are presented in Section 9. Next steps are summarized in Section 10.

MAJOR FINDINGS

FEATURE	MEASURE
Number of trees in Oakville	1.9 million
Number of trees owned by the Town	820,000 (43%)
Top 3 species by leaf area	sugar maple, Norway maple, silver maple
Average Urban Forest Canopy Cover	29.1%
Urban Forest Canopy Cover in 2046 (UFORE Grow-out Module simulation)	40%
Replacement value of the urban forest	$878 million
Carbon sequestration	6,000 tonnes/year ($141,000)
CO_2 filtered by all trees	22,000 tonnes
CO_2 filtered by Town trees	6,300 tonnes (28% of total CO2 filtered)
Criteria pollutants removed	172 tonnes ($1.12 million)
Energy savings	$840,000
Major pest damage threat	Emerald Ash Borer, $86.1 million

"People who will not sustain
trees will soon live in a world
which cannot sustain people."

-Bryce Nelson-

A large-stature tree
London Plane: *Platanus x acerifolia*

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"Trees are the best monuments that a man can erect to his own memory. They speak his praises without flattery, and they are blessings to children yet unborn."

-Lord Orrery, 1749-

Glossary of Terms

Carbon Sequestration: amount of carbon removed annually by trees.

Carbon Storage: carbon currently held within tree tissue (roots, stems, and branches).

Dbh: diameter at breast height (approximately 1.3 meters from the ground).

Rooftop Garden: rooftop gardens, are specialized roof systems that support vegetation growth. With technical advances in roofing materials and components, [rooftop garden] systems can now be successfully installed in most climates, providing an attractive design option, especially in urban areas where land available for parks and green space is limited.

Greenhouse Gas (GHGs): gases in the atmosphere that trap energy from the sun. Water vapor (H_2O), carbon dioxide (CO_2) methane (CH_4), nitrous oxide (N_2O) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere (Environment Canada).

Integrated Pest Management (IPM) : an environmentally responsible and economically practical method of controlling pest populations incorporating a variety of cultural, biological and chemical methods to efficiently manage pest populations while lowering dependence on chemical means of control (University of Georgia USA).

Large-Stature Tree: a tree greater than 12m tall and wide with trunk diameters (dbh) commonly over 76 cm at maturity - 40 years after planting (Center for Urban Forest Research, Davis, CA 2004).

Naturalization: The process of using local plant material to create an area of structural and botanical diversity for educational, social and environmental benefits.

Paradigm Shift: Major shift in a certain thought pattern - a radical change in personal beliefs, complex systems or oganizations, replacing the former way of thinking with a radically different way of thinking or organizing. (Wilkipedia.org Aug 16, 2006).

Rain gardens: are built in low spots in the landscape and are planted with a selection of wetland edge vegetation, such as sedges, rushes, ferns, shrubs and trees to absorb the excess water, and hold the soil in place.

Small-Stature Tree: a tree less than 7.6 m tall and wide with trunk diameters (dbh) less than 51 cm at maturity - 40 years after planting (Center for Urban Forest Research, Davis, CA 2004).

Study Area: Town of Oakville, south of Dundas Street.

Tree: UFORE Model defines a "tree" to be any woody plant with a dbh larger than 2.5 centimeters (1 inch).

Tonne: a metric measure of mass equal to 1,000 kilograms or 2,204.6 pounds.

Urban Forest Canopy Cover: the proportion of area occupied by tree canopies when viewed from above (Nowak and McPherson 1993).

Urban Forest: the sum of all woody and associated vegetation in and around dense human settlements (Miller 1988).

Volatile Organic Compounds (VOCs): molecules containing carbon and varying proportions of other elements such as hydrogen, oxygen, fluorine, and chlorine. They are the "precursors" that react in sunlight and heat to form ground-level ozone.

Woodlot: defined by Region of Halton By-law # 121-05 as an area greater than 0.5 hectares with a density of trees that is not less than:

a) 1,000 trees of any size per hectare or
b) 750 trees, measuring over 5 centimeters in dbh per hectare or
c) 500 trees, measuring over 12 centimeters in dbh per hectare or
d) 250 trees, measuring over 20 centimeters in dbh per hectare.

Highlights

Oakville's urban forest makes people healthier and performs a valuable role, on a local basis, in dealing with climate change by filtering harmful pollutants.

- The annual environmental benefit of the ecological services provided by trees within the Town of Oakville is $ 2.1 million.
- The amount of air pollution filtered by Oakville's urban forest is equivalent to: all (102%) of the local industrial and commercial emissions of particulate matter (PM_{10}) and 15% $PM_{2.5}$ and over two times (243%) the amount of sulpher dioxide plus other criteria pollutants; or 6% of the local vehicle emissions of carbon dioxide and over four times (425%) the amount of PM_{10} emissions plus other criteria pollutants.
- There are 1.9 million trees in Oakville; 43 % are Town owned trees and 57% are distributed over 9 Land Use types on private property and lands owned by other levels of government as well as non government agencies.
- Oakville's urban forest canopy cover averages 29.1% and is highly influenced by land use type ranging from a low of 6.3% in the 'Commercial' Land Use to a high of 90.3% in the 'Woodlots' Land Use. The Community with the highest urban forest canopy cover is Eastlake (48.7%) and the lowest urban forest canopy cover is QEW East Industrial (6.6%).
- Using a UFORE-Grow out Module simulation, Oakville's average urban forest canopy cover is projected to reach 40% by the year 2046; this will meet the minimum recommended standard of American Forests. Future UFORE model simulations of Oakville will define the number of trees and locations to be planted in order to sustain an urban forest canopy cover goal for Oakville as defined through the Urban Forest Strategic Management Plan.
- In 2005, Oakville's urban forest removed 172 tonnes of criteria pollutants from the air. The air pollutant that was most reduced was ground level ozone (85 tonnes) which is part of smog.
- A total of 22,000 tonnes of carbon dioxide were sequestered.
- The annual carbon credits generated from the 1,010 tonnes of carbon dioxide that municipally-owned trees sequester under the CCX's "Forestry Offset Project" program had a trading value of $5,191 on the Chicago Climate Exchange (CCX) on June 21, 2006.
- A total of 133,000 tonnes of carbon are stored in biomass form (branches, trunk, roots, etc).
- An additional emission of 1,200 tonnes of carbon were not put into the atmosphere in 2005 from power generating facilities through the offsetting effects of trees on the energy requirements of buildings in Oakville.
- The largest economic advantage of trees' ability to reduce building energy costs is for communities with many large-stature trees; for example, Eastlake's annual savings are valued at $280,539 with an average annual energy savings of $82 per residence unit (apartment, condo, freehold home, etc).
- The urban forest canopy is dominated by three species of trees: sugar maple (*Acer saccharum*), Norway maple (*Acer platanoides*), and silver maple (*Acer saccharinum*) because they have the greatest leaf surface area.
- The 'Woodlots' Land Use category makes the largest single contribution in terms of total carbon storage (47%) and sequestration (40%).
- The UFORE-Tree Locator Module can be used to identify the optimum locations and species to achieve a Parks and Open Space Department objective of naturalization of the Parks system. It can also be used to help meet the Corporate greenhouse gas emission reduction objective under the Partners for Climate Protection program.
- Emerald Ash Borer threatens to kill all 176,000 ash trees in Oakville which would result in an economic loss of $ 86.1 million, assuming the insect’s population reaches an extreme level.
- The condition of trees in Oakville is mixed: 11.2% trees were found to be in 'poor' or 'fair' condition and 76.8% in 'good' or 'excellent' condition. However, since urban trees have deadwood removed for safety requirements the sampling methodology produced results that are higher than expected.

Major Conclusions:

I. Oakville's urban forest canopy cover filters the majority of the criteria pollutants generated by Oakville commercial and industrial sources; however, it does not filter much of the criteria pollutants generated by Oakville vehicles as well as non local sources.

II. Municipal trees can contribute to a Corporate greenhouse gas emission reduction program.

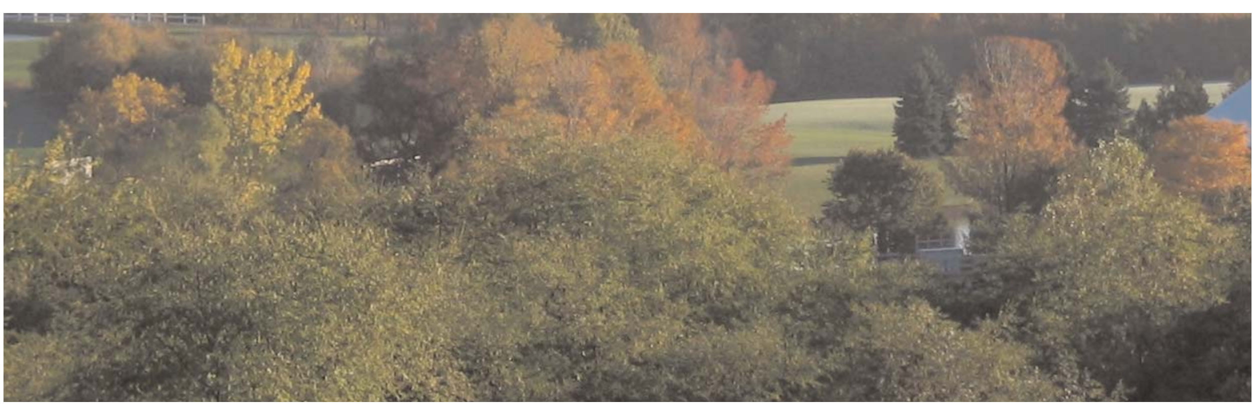
III. Trees play a role in contributing to the health of people in Oakville. Trees can reduce the number of premature deaths, hospital admissions and emergency room visits due to air pollution. An approximate number is to be the focus of an analysis expected in 2006/2007, working in conjunction with the Halton Region Health Department.

IV. A paradigm shift in urban design towards recognizing the urban forest as 'green infrastructure' is required in order to create and maintain the type of tree habitat necessary to grow and support a healthy urban forest canopy and recognize that expenditures in the urban forest are an investment in a healthier environment.

Next Steps:

- Implement the Action Items summarized in Section 10.1 through the Town's Urban Forest Strategic Management Plan (UFSMP) 2007-2026.
- Create an interdepartmental/interagency technical Advisory Committee that will identify, through the UFSMP, a range of future potential urban forest canopy cover targets for Oakville.
- Develop a private stewardship incentive program for residents and local businesses through initiatives in order to support the potential urban forest canopy targets.
- Commit the Forestry Section to deliver a State of the Urban Forest report by updating UFORE each term of Council.
- The inventory project for municipally owned and managed urban forest should investigate incorporating the USDA's "i-Tree" model (Section 9.5) to quantify the cost benefit ratio of Town trees.
- Investigate the feasibility of the Town exchanging carbon credits.
- Quantify how much the municipal urban forest can contribute to the Corporate initiative to reduce greenhouse gas emissions under the Partners through Climate Protection Program.

This Forestry staff report is intended to be read as a companion document to the Resource Bulletin expected to be published by the USDA Forest Service in 2006.



1 Introduction

Although municipalities occupy only a very small proportion of the earth's total land surface, almost half of the world's population lives in urban areas (United Nations 2001). In the United States, national assessments of the urban forest resource are being conducted using new satellite imagery, national urban forest ground-based inventory procedures are being field tested, local city analyses are being completed, and a number of new urban forest assessment tools are being developed to aid in urban forest analysis, management, and design. With the exception of limited local level initiatives, this is not being done in Canada (Kenney 2005). The Canadian Urban Forest Strategy 2004 - 2006 is a call to action to address this crisis: http://www.treecanada.ca/programs/urbanforestry/cufn/cufn.html (Appendix 1).

"Urbanization and urban forests are likely to be the greatest forest influence and influential forest of the 21st Century." (Nowak et al. 2005).

Some Canadian municipalities such as the Town of Oakville, are applying these assessments and tools to aid in the planning and management of their urban forest - the green infrastructure of the community. The urban forest plays a significant role in the community's quality of life (Nowak 2006). Before UFORE, no baseline data were available about Oakville's urban forest structure, health, functions and value. This situation is common in municipalities throughout Canada. Oakville is only the third Canadian municipality to undertake a UFORE project; the other municipalities are the cities of Calgary and Toronto. This growing Canadian awareness, still in its infancy, is reflected in the 2004-2005 Annual Report of the Environmental Commissioner of Ontario. Gord Miller in his report to the Speaker of the Legislative Assembly notes:

"Maintaining the forest cover in urban centers is becoming an increasing challenge, especially for trees situated near roads, in parking lots and on boulevards…U.S. cities like Chicago have created very detailed rules about the sizes of tree to be planted in new developments; the required soil volumes, guard rails and protections; the amount of tree cover relative to paved surface; and the spacing of trees for property frontages. Larger urban centers like Toronto, Mississauga, Hamilton, London or Windsor could consider imposing these rules. Working out such rules would be a worthwhile initiative in light of the province's plan for urban intensification under its Places to Grow initiative…Finally, as mentioned, some urban forests are aging and dying, often without a replacement plan or budget at the local level. For all of these reasons, greater resources and attention will need to be paid to the trees of urban Ontario in order even to maintain the forest cover that exists at present in certain areas of the province."

This report helps to deliver on this need. It quantifies, for the first time, the function of the urban forest in Oakville with respect to air pollution reduction, provides details about its structure, and quantifies its value to people living and working in Oakville. It also identifies how the quantity and quality of the urban forest canopy cover depends on land use type. The potential urban forest canopy cover by the year 2046 is also presented. Finally, it identifies the paradigm shift in urban design required in order to realize this potential: link the green infrastructure - trees - with the grey infrastructure so that both function optimally.

"It is time to make some changes in the design and construction of our cities (…) Just planting more trees is not the answer. Trees have long been fit into spaces left over after everything else is written into the design. This approach will not work if we want our trees to be a major element in a city's structure." (Moll and Ebenreck 1989).

2 Pollution Effects On Human Health

The Criteria Pollutants

An air pollutant for which acceptable levels of exposure can be determined and for which an ambient air quality standard has been set. Examples include ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, PM_{10} and $PM_{2.5}$.

Source: CA Air Resources Board

Criteria air pollutants - referred to as "criteria air contaminants" by Environment Canada- include carbon monoxide (CO), sulphur oxides (SO_x), nitrogen oxides (NOx), ozone (O_3), and particulate matter (PM_{10} and $PM_{2.5}$). They have been linked to a negative impact on human health causing headaches, lung, throat and eye irritation respiratory and heart disease and cancer (Kenney 2001). Carbon monoxide (CO) for instance, binds with hemoglobin in humans, which lowers the capability of the blood to carry oxygen; particulate matter (< 5µm diameter) may cause serious health problems because these small particles can pass through upper respiratory tract defense mechanisms and enter lungs (Kenney 2001). Evidence is emerging in other parts of the world that it may be the smaller sized particles less than 2.5 microns in size, that cause most of the health effects. In Great Britain, an estimated 8,100 annual deaths and 10,500 hospital admissions in urban populations are due to the poor air quality (United Kingdom Department of Health 2002).

The medical profession in Ontario recognizes the health costs of air pollution. In 2005, the Ontario Medical Association estimated the number of Ontarians admitted to hospitals with health problems related to air pollution exposure was approximately 17,000 while the number of emergency room visits was estimated at almost 60,000. By 2026, these rates are expected to jump to over 24,000 and 88,000 respectively. The 2005 estimates for Halton included 190 premature deaths, 540 hospital admissions and 2,010 emergency room visits per year resulting in an estimated $18 million in healthcare costs (not including visits to family doctors) and $13 million in lost productivity costs (as employees were too sick to go to work due to poor air) (OMA 2005).

The Ontario Ministry of the Environment monitors six key air pollutants to calculate the Air Quality Index (AQI). In a typical year in Oakville there are between 15 to 20 days with "poor" air quality. In 2005, the number of days was 48, but more typical conditions are expected in 2006 (Halton Partners for Clean Air 2006).

The data has clearly identified that action is required to mitigate the health impacts of poor air on the population. Many municipalities have developed action strategies to address climate change, reduce greenhouse gas emissions and respond to poor air quality situations. Oakville works with the Halton Partners for Clean Air to implement the Clean Air Plan, through an updated Smog Response Plan, recently endorsed by Town Council, on August 10, 2006 (Halton Partners for Clean Air 2006).

In 2004, Halton Regional Council addressed this significant public health issue by endorsing the

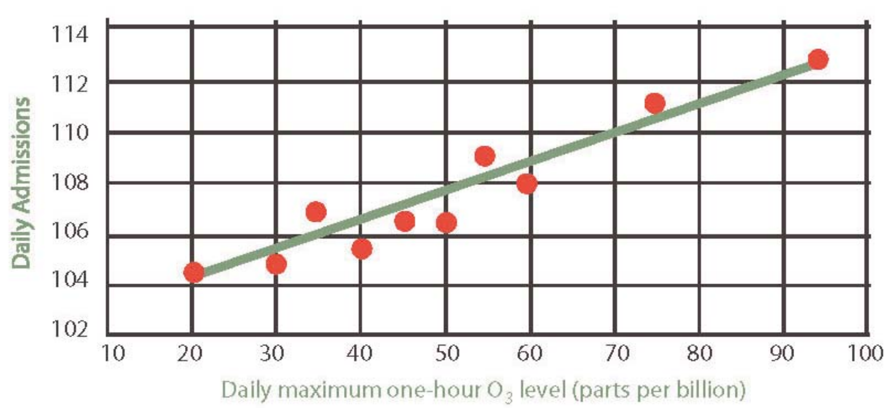


Figure 1. Relationship between hospital emergency respiratory admissions and O_3 levels. Source: Health Canada, 1994

following strategic goal: "Work to improve air quality in cooperation with other orders of government, businesses and the community" (Nosal 2005).

“Protecting and enhancing the urban forests" is one of the solutions included in the Town of Oakville Official Plan to reduce local emissions and improve air quality (general policies; subsection10.4b, 2004). Health Canada is developing a computer model, Air Quality Benefits Assessment Tool (AQBAT). Halton Region Health Department staff is expected to work with Oakville Forestry staff in 2006 to use AQBAT in conjunction with UFORE to obtain detailed outputs on human health benefits of Oakville's urban forest. Studies in Great Britain have suggested that "doubling the number of trees in the West Midlands could reduce excess deaths due to particles in the air by up to 140 per year" (Hewitt 2003).

ACTION ITEM 1: Obtain detailed outputs on the human health benefits from Oakville's urban forest by combining the results of the AQBAT and UFORE in conjunction with the Halton Region Health Department.

Air Pollution Control - The Tree Factor

Source: Centre for Urban Forest Research, Davis, CA, USDA Forest Service

3 Urban Forest Benefits

Today, there is a clear public understanding and recognition of the active role trees play in improving the urban environment. A study conducted by Environics Research Group in 2001 in Ontario revealed that 84% of urban residents polled expressed their belief that trees are "very important."

Around the world people are taking action to change their urban environments into a better place to live. Trees for Cities, hosted the world's first Tree-Athlon in Battersea Park, London, UK on September 24, 2005 to raise money for local and international projects in cities such as Addis Ababa, Bucharest, Madrid and Nairobi, where more trees are desperately needed to tackle climate change and reforest areas that have seen a dramatic loss of trees and green space in recent years. In addition, London, Bristol and Manchester have launched a campaign for a Million More Trees by 2010.

Urban and community forests can strongly influence the physical/biological environment and mitigate many impacts on urban development by moderating climate, conserving energy, carbon dioxide and water, improving air quality, controlling rainfall runoff and flooding, lowering noise levels, harboring wildlife and enhancing the attractiveness of cities. Urban forests can be viewed as a 'living technology' - a key component of the urban infrastructure that helps maintain a healthy environment for urban dwellers (Dwyer et al. 1992). Studies estimate that a typical person's oxygen needs for a year can be produced by two healthy 9.8m (32-foot) tall ash trees (Elmendorf 2004).

Trees provide multiple benefits such as:

- **Engineering benefits:**
  Acoustical control - a screen of dense coniferous trees 30 meters wide can absorb 6-8 decibels;
  Traffic control - direction for pedestrian or vehicular-safety barriers between pedestrians and vehicles, screen headlight glare from traffic (Faulkner 2004);
  Pavement performance - 20% shade improves pavement condition by 11% resulting in 60% saving for resurfacing in 30 years (McPherson et al. 1999).

- **Economic benefits:** Consumer behaviour - shoppers pay 12 % more for goods in a tree-lined area, property values are an average of 6 % greater in areas with trees (Hastie 2003);
  Trees pay us back- a cost benefit analysis of 100 trees over 40 years resulted in a net benefit of $244,000 U.S. (McPherson 2005).

- **Environmental benefits for humans and animals (Hastie, 2003):**
  Wind control - reduce heat loss from buildings;
  Sun control - hardwood species reduce solar radiation during the summer and 'provide' sunlight during the winter;
  Precipitation and humidity control - control snow, reduce fog, rain screen, reduce run-off and create a habitat for wildlife.

- **Architectural benefit (Faulkner, 2004)**:
  Privacy control - space articulators;
  Screen objectionable views;
  Gradual unfolding of a view.

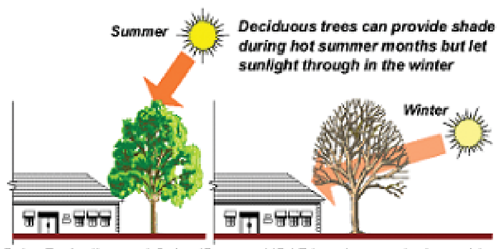
- **Aesthetic benefits (Faulkner, 2004):**
  Softens, complements or enhances architecture by bringing natural elements into urban surroundings;
  Emphasizes change of seasons;
  Provides 'play' areas;
  Add beauty through their shape, texture, color, and fragrance.

- **Social benefits:**
  Crime reduction - research suggests that appropriate vegetation cover such as mowed grass and high canopy trees-reduce crime rate because "vegetation has a mitigating effect on mental fatigue, itself often a precursor of outburst of anger and violence" (Hastie 2003).

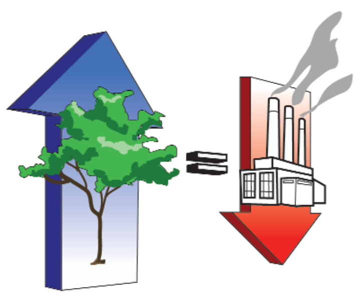
In a different perspective, trees can be seen as a "classic example of a benefit enjoyed by society as a whole coming at a cost only to the individual or agency that planted the tree" (Nowak 2001).

3.1. Energy conservation

Trees reduce building energy use by lowering temperatures and shading buildings during the summer, and blocking winds in the winter. However, they may also increase energy use by shading buildings in the winter, and by blocking summer breezes if planted in improper locations.



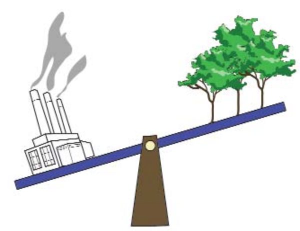
Solar Reduction and Gain. (Source: USAF Landscape design guide, 1998)


More trees = less power plants. 50,000 trees save energy produced by a 100,000 megawatt power plant. Source: USDA, Center for Urban forest research.

Proper tree placement is very important to achieve maximum building energy conservation. Urban designs and municipal landscape plans that take this into account can significantly help reduce energy use. Benefits are exponential with tree size and health. Therefore, efforts to provide adequate tree habitat with preference given to large- stature trees can lay the foundation in creating conditions to maximize benefits. "Shade tree programs can be a very cost effective measure for conserving energy, especially peak load demands. Strategically locating trees to shade west walls and windows in climate regions where the benefits are highest will save energy dollars and postpone, if not eliminate the need for some power plants." (McPherson 2005). When building energy use is lowered, pollutants emissions from power plants are also lowered.

3.2. Addressing Climate Change through air pollution removal by trees

Growing global concern about climate change and the on-going search for solutions to reduce the impact of "man-made" pollutants has lead to the Kyoto Protocol, signed by Canada in 2003. On April 13, 2005 the former Federal government announced its climate change plan *'Moving Forward on Climate Change: A Plan for Honoring our Kyoto Commitment'* that outlined Canada's commitment to reduce its greenhouse gas emissions to six percent below 1990 levels. The current Federal government is developing climate change policy expected in Fall 2006. "Human activities add greenhouse gases to the atmosphere…..enough to exceed the balancing effects of natural sinks" (Geiger 2005). *Therefore, even small gains in the filtration rate of criteria pollutants by trees can be significant.*



The United Nations Framework Convention on Climate Change (UNFCCC) defines "sink" as "any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere." A relatively cost-effective way of combating climate change, according to the UNFCCC, can be achieved either by increasing the sink through planting trees or managing forests or by reducing emissions.

Separating the *local* vs. *regional* scale of human produced greenhouse gas emissions is critical to understanding the potential influence initiatives such as tree planting can do to help restore the balance of "sink" and "source." This is also very important to keep in mind when assessing the results of the UFORE Model.

In other words, while "…trees are highly efficient at reducing air pollution, their contribution to the overall reduction of air pollutants is fairly small, amounting to only about 2 percent of total emitted"(Geiger 2005).

Therefore, trees alone will not be able to solve such regional level issues as transboundary pollution reduction objectives between Canada and the United States as set by the Ontario Ministry of the Environment, Transboundary Air Pollution in Ontario (June 2005).

The Transboundary Air Pollution in Ontario Report (Yap et al. 2005) "confirms that much of the air pollution in Ontario comes from the United States. Airborne pollutants are carried into Ontario on the prevailing winds mainly from Ohio, Illinois, Minnesota, Michigan, Pennsylvania, New York, Tennessee, Indiana and Kentucky. From May to September each year - the period now known as 'smog season' in Ontario - transboundary pollution from neighboring U.S. states is the dominant factor that determines Ontario's air quality." Despite this large contribution from our neighbours, local emission problems are still present within Ontario (Yap et al. 2005).

Source: Region of Halton Air Quality Management Strategy, January 2004

The UFORE project in the City of Toronto, 2000 showed that the urban forest reduced the levels of nitrogen dioxide and PM_{10} produced by industrial facilities within the City of Toronto by 100% (Dr. Andy Kenney personal communication 2005). In other words, trees filtered from the air an amount equal to all of the nitrogen dioxide and PM_{10} that was produced within the City of Toronto in 2000 by industrial facilities. Similarly, when UFORE analyzed the role that the urban forest plays in reducing local industrial and commercial greenhouse gas emissions in Oakville, the results were significant. ***These are examples of how the urban forest can act a local solution to a local pollution problem.***

The studies demonstrated that trees play a role in reducing air pollution. Trees remove gaseous air pollution primarily by uptake via leaf stomata, though some gases are removed by the plant surface. Once inside the leaf, gases diffuse into intercellular spaces and may be absorbed by water films to form acids. Trees also remove pollution by intercepting airborne particles. Some particles can be absorbed into the tree, though most particles that are intercepted are retained on the plant surface.

The standardized pollution removal rates differ among cities according to the amount of air pollution, length of in-leaf season, precipitation, and other meteorological variables (Nowak 1995).

The cumulative and interactive effects of trees on meteorology, pollution removal, and **volatile organic compounds** (VOC) and power plant emissions determine the overall impact trees have on air pollution. Emissions of volatile organic compounds (biogenic VOC) by some species of trees can contribute to the formation of ozone and carbon monoxide. However, because VOC emissions are temperature dependent and trees generally lower air temperatures, increased tree cover can lower overall VOC emissions and, consequently, ozone levels in urban areas. For example, trees in parking lots reduce air temperature through tree shade, and indirectly reduce the emissions of some pollutants that are temperature dependent, such as hydrocarbons released through gasoline evaporation from parked cars (Cappiella 2005, Pollution Probe 2002). The Town of Oakville is participating in Partners for Climate Protection (PCP) program, a network of more than 126 Canadian municipal governments who have committed to reducing greenhouse gases and act on climate change. The Town's urban forest can play a role in contributing to the Town's Action Plan to achieve a reduction in greenhouse gas emissions for the community.

Using UFORE is a significant step towards understanding the dynamics of Oakville's urban forest as presented in Section 7. The study results give decision makers the tools they need to manage, maintain, and balance the green infrastructure with the grey infrastructure. Other tools such as "i-Tree" combine UFORE with street tree inventories and other data for urban forest analyses specifically for street trees.

Trees remove air pollutants such as carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, and particulate matter, which are called 'criteria pollutants'. Trees also absorb carbon dioxide during the photosynthesis process (Center for Urban Forest Research 2005).

Tree transpiration and tree canopies affect air temperature, radiation absorption and heat storage, wind speed, relative humidity etc. Reduced air temperature due to trees can improve air quality because the emissions of many pollutants and/or ozone-forming chemicals are temperature dependent (Nowak 1995).

4 Project Goals

The results of this project will also provide support and background for the Town's Urban Forest Strategic Management Plan - a major 2006 project of the Parks and Open Space Department. Optimizing the potential benefits trees provide to our ecosystem - as translated into potential urban forest canopy cover targets - is presented in Section 8. In order to realize this potential, it is essential for the community to plan, design and maintain an urban forest as green infrastructure. Research has concluded that most of the benefits are derived from large-stature trees (McPherson 2004) and woodlots (Nowak 2006). New urban design techniques and management approaches to realize these potentials are presented in Section 9. Next steps are summarized in Section 10.

http://www.ufore.org/

The UFORE computer model was developed to help managers and researchers quantify urban forest structure and functions based on standard inputs of field, meteorological and pollution data (Nowak et al. 2005).

Another major goal of this project is to outline the implications of this analysis for urban forest management in Oakville by focusing on urban forest canopy cover and the management tools that support it.

A major goal of this project is to quantify for the first time Oakville's urban forest:

(1) Structure - species diversity, density, health, etc;

(2) Functions - energy conservation, air pollution removal;

(3) Values - the economic importance of the forest functions such as pollution removal, carbon storage, energy savings as well as the estimated worth of each tree as it exists in the landscape.

The model currently calculates the following parameters based on local measurements:

- Urban forest structure by land cover type (species composition, number of trees, diameter, tree density, tree health, leaf area, and biomass of leaves and trees).
- Hourly amount of pollution removed by the urban forest and associated percent air quality improvement throughout the year.
- Hourly urban forest volatile organic compound (VOC) emissions and the relative impact of tree species on net ozone and carbon monoxide formation throughout the year.
- Total carbon stored and net carbon annually sequestered.
- Effects on building energy use and consequent effects on carbon dioxide emissions from power plants.
- Replacement value of the forest, as well as the dollar value of air pollution removal and carbon storage and sequestration.

5 Project Methodology

5.1 Plot selection: Level of Accuracy

The number and distribution of the 372 plots have resulted in reliable results for Oakville. For example, the actual number of trees in Oakville is within ±10% of the estimate with a 67% level of accuracy and is within ± 20% of the estimated number with a 95% level of accuracy. In order to achieve significantly greater levels of accuracy a 100% inventory, or census, would be required (Nowak personal communication 2006).

In accordance with the UFORE Field Data Collection Manual, a plot size of 400 m^2 was considered appropriate (Nowak et al. 2005).

Oakville's UFORE project analysis was based on a randomized grid sample of the entire Town stratified by community type as well as land use type. This required that the Town's Zoning layer be modified from 8 to 11 land use categories. The modification also created the new layer called *Woodlots* and separated the *Residential land use into Residential High Density, Residential Medium Density and Residential Low Density* (Figure 2). This change improved the ability of the model to quantify the effect that land use has on trees.

5.2 Stratification of the urban forest

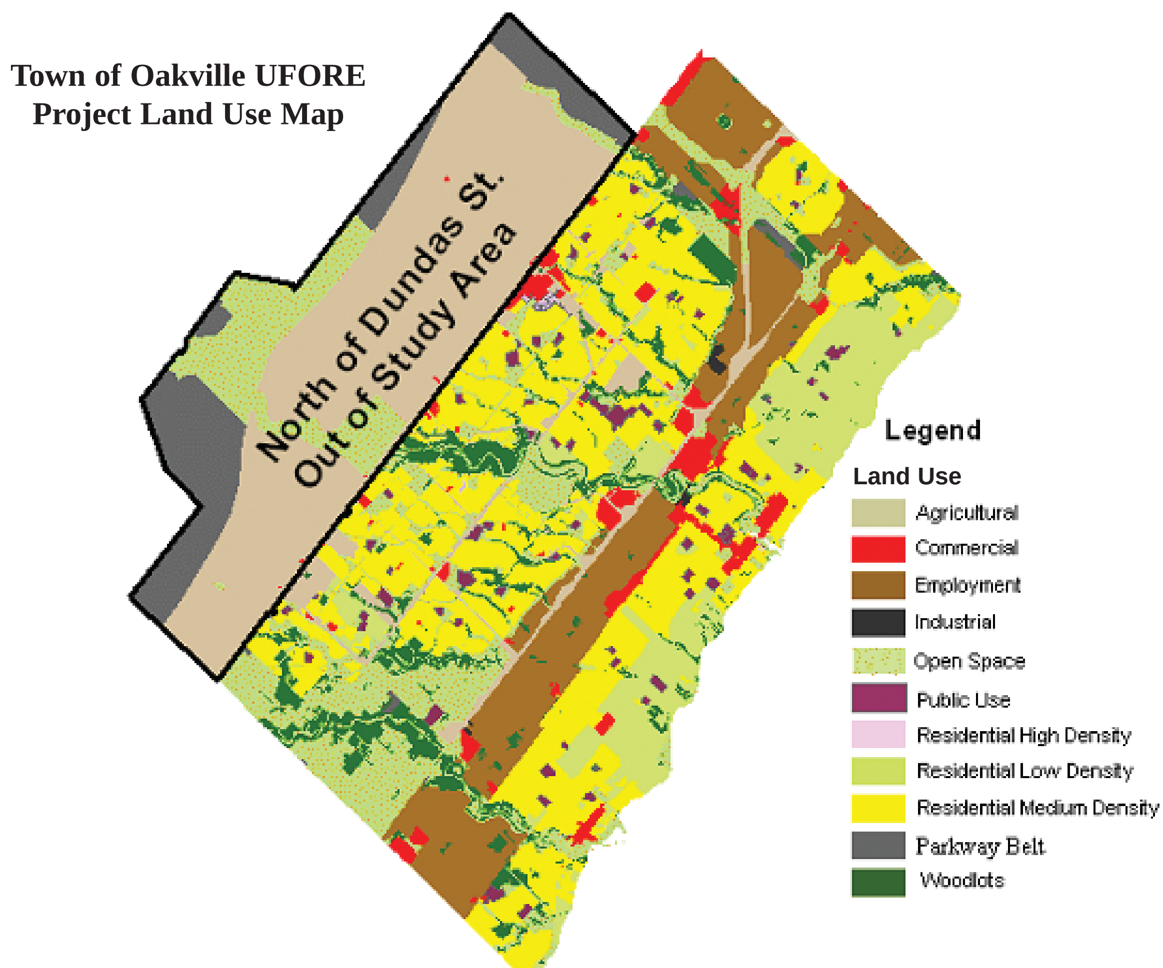


Figure 2. UFORE project customized Land Use map

The Town's GIS Services Section contributed to the UFORE project performing a number of tasks such as base data acquisition, collection and distribution, data analysis services, data management services and general consulting services (Steve Czajka, Manager of Oakville's GIS Services, personal communication 2005). The GIS team provided special services such as producing the UFORE Plot Atlas. This atlas was used to navigate to each survey site otherwise known as a UFORE plot. This atlas included a one-page map of each plot site (Appendix 2). The map included a detailed 10cm resolution orthophoto image with the 11.28m radius indicated, site identification markings such as ID number, street names, addresses, map coordinates, and navigational maps.

GIS Services also performed spatial data analysis to merge different land use definitions into one layer, and essentially overlay a "customized land use" layer with the UFORE plots layer. This data was later sent to the US Forest Service. All of these data are managed in one central server - the data layers are posted on the Town's internal GIS for the UFORE team to review and plot maps.

A new GIS layer called 'woodlots' was created for this project. All private woodlots 0.5 ha and larger plus all municipal woodlots of any size became the new 'Land Use' type called "woodlots." This woodlot data will contribute to the Parks and Open Space Department's Parkland mapping project, which is currently underway.

The Planning Services Department was also asked to perform a number of tasks as part of the UFORE project. These tasks included the acquisition and analysis of base data on a predetermined set of criteria. Planning Services extracted over 650 sub classes of residential land uses and correlated each of those sub classes to the permitted frontyard building setbacks. Each of the 'subclasses' was categorized into one of three 'classes': Low, Medium and High Residential Density - according to the potential impact on tree development as follows:

- ***Low Density Residential: frontyard setbacks greater than 7.5m***
- ***Medium Density Residential: frontyard setbacks between 3.0m and 7.5m, and***
- ***High Density Residential: frontyard setbacks less than 3.0m***

Each of these 'classes' matches the corresponding definition of 'Low', 'Medium' and 'High' density Residential Land Use in the 2004 Oakville Official Plan (Part D, Land Use Policies; Section 1.2, Density Categories). When the Class category cross reference to the subclass table was completed the data was transferred to the GIS Department for mapping (Don Parsons, personal communication 2006).

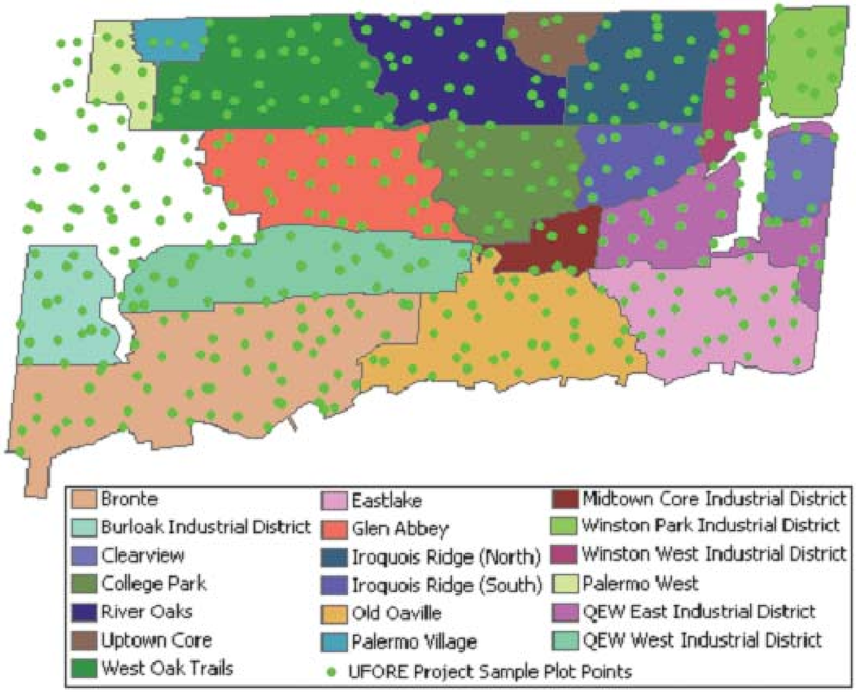
5.3. Owner contact

Another service provided by the GIS team was the notification addresses for each UFORE plot. Approximately 500 notification letters were sent out to property owners to inform them about the project, and request permission to access the property the following way: (1) a letter was sent to each residence with an enclosed prepaid envelope, outlining the project scope and duration, as well as a form granting Town staff permission to access their property (Appendix 3); (2) a follow-up phone call was made to those owners who did not respond; (3) Forestry students involved in data collection visited the owners who had not responded and in most cases obtained their permission to access the property. Upon receiving permission from an owner, the plot was accessed and the data collected. Since many of the 372 randomly located plots crossed property line, approximately 500 residents and businesses participated in the UFORE project.

5.4. Number of plots

Circular field plots were established throughout the study area based on a randomized grid approach. Using this approach, equal area cells were created across the study area and then one plot randomly located in each cell. Plots were distributed at a density of approximately one plot every 27 hectares and classified by land use type based on a customized Land Use developed for the UFORE project purpose only (Figure 3).

Figure 3. Plot distribution over the study area.



The field data collection was conducted from June 1 to August 31, 2005. "Leaf-on" conditions allowed the collection of data on crown condition characteristics. By the end of August, 372 plots were completed. ***The Industrial, Parkway Belt and Residential High Density Land Use types are small in terms of geographic size, therefore insufficient number of plots was measured; as a result the plots were combined to create a total of 8 Land Use types as shown in Table 1.***

Table 1. Completed plots by Land Use type

Land Use	Plots measured
Agricultural	18
Commercial	18
Employment + Industrial	71
Open Space + Parkway Belt	68
Woodlots	27
Public Use	7
Residential low density	50
Residential medium + high density	113
Total	**372**

5.5. Mixed conditions

As the plots were randomly selected there were situations when plots proved to be located over more than one property-especially in high-density residential areas. This resulted in lowering the number of plots measured within the specific land use category because of denied access for part of a plot. In a few situations plots fell into more than one Land Use category, which in this case did not influence the data gathering, and the plots were treated as separate plots (split plots) as per the UFORE Manual. All data were recorded on the data sheets for each Land Use specifying the 'percent in' of each Land Use that covered the plot (Appendix 4).

5.6. Field Measurements

To complement the information provided by satellite imagery, aerial photography and other types of remote sensing data, detailed ground parameters were measured according to the UFORE manual specifications:

PLOT SPECIFIC VARIABLES*

Plot ID Number
Date of data collection
Crew ID
GPS coordinates
Plot address/notes (for relocation purposes)
Number of actual land uses (split plot situations)
Land Use from the map/aerial photo
Reference object description (at least 2);
Distance and direction in relation with plot center
Actual land use
Percent of plot in each land use
Plot tree cover (%)
Plot shrub cover (%)
Plantable space (%)
Ground cover (% of each cover type)

SHRUB DATA VARIABLES*

Species ID
Shrub layer height
Shrub layer percent of area
Shrub mass percent missing (each species)

TREE DATA VARIABLES*

Tree ID (unique number)
Tree direction (from plot center)
Tree distance (from plot center)
Species or genus
Diameter
Total height
Height to crown base
Crown width (two measurements)
Percent canopy missing
Dieback (%)
Percent impervious surface under tree
Percent shrub cover under tree
Crown light exposure
Building distance and direction
Street tree (Y/N)

*For more details see UFORE manual at
http://www.fs.fed.us/ne/syracuse/Tools/UFORE.htm

Figure 4. Split plot (more than one land use)

5.7 Special situations

Plots that were on the top of a building or in the middle of a road were also visited. The variables needed to be measured were estimated using 2002 aerial photographs.

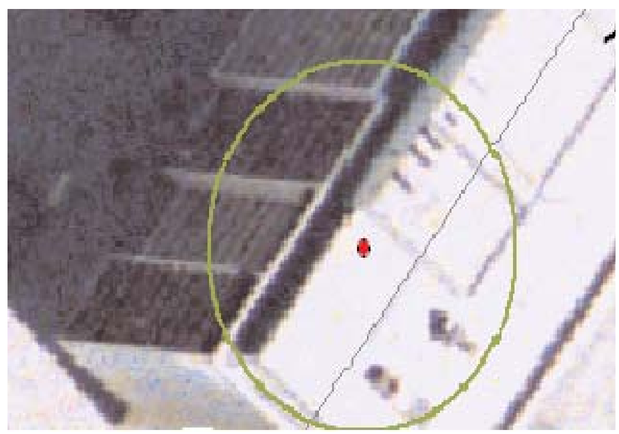


Figure 5. Plot center on building roof

There were 8 plots that needed to be relocated because of hazardous locations (i.e. drastic slopes): to avoid any bias in sampling the same Land Use type was used. As specified in the UFORE Field Data Collection Manual, a quality control procedure designed to ensure that the field data are collected accurately was followed. Quality Assurance involves a series of 'hot' (conducted by the trainer) and 'cold' checks (conducted by the project coordinator for 5% of the plots).

6 Project Costs

In 2005, Town Council approved $144,500 for the UFORE project; the Tree Canada Foundation contributed an additional $33,000 as a grant under Green Streets Canada 2005. The funds were directed as follows: $60,000 to the USDA Forest Service (layout of plots, analysis, make cover map, link field data to cover map, training of field crews, publish a Technical Bulletin, provide urban forest 'layers' for the Town's GIS); $30,000 to the Faculty of Forestry, University of Toronto (technical advisor) and $87,500 for Forestry seasonal and contract staff data collection, equipment, and report writing.

7.1 Structure

Tree benefits are directly related to the amount of healthy leaf surface area (Kenney 2005). The top three tree species that dominate in terms of 'leaf area' in Oakville are sugar maple, Norway maple, and silver maple (Figure 6).

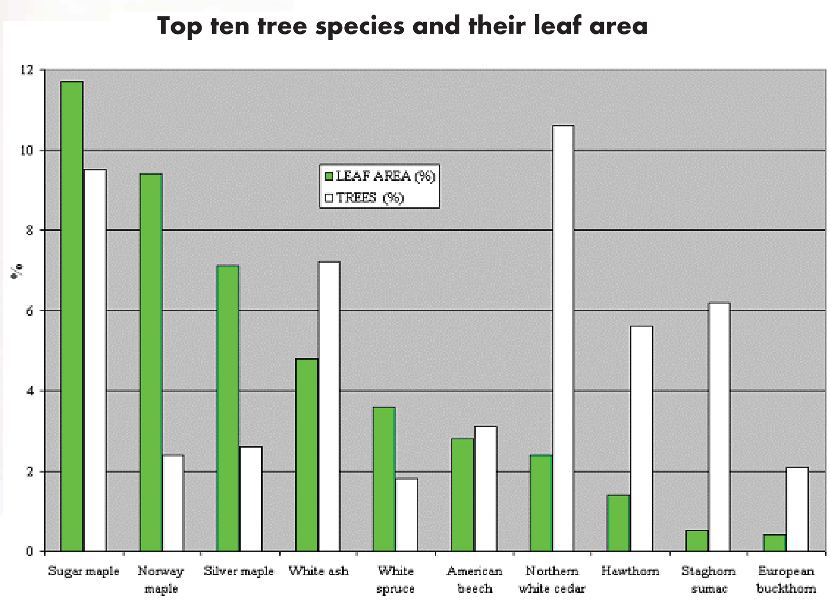


Figure 6. Comparison of the most numerous trees and their leaf area

Based on number of stems, the most common species were Northern white cedar (Thuja occidentalis) (10.6%) followed by sugar maple (9.5%) and white ash (Fraxinus americana) (7.2%). Northern white cedar dominates because of the abundance of property line hedgerows and consequently small diameters. ***Oakville's urban forest has 1,900,000 trees***; 884,000 trees (46%) are located within the Woodlot Land Use.

The UFORE Model defines a "tree" to be any woody plant with a diameter at breast height **(dbh)** larger than 2.5 centimeters. The majority of Oakville's trees (54%) are small diameter (under 8 cm) because of all the small trees present in the Woodlots and Residential Medium + Residential High Density Land Uses. It is noteworthy that all these relatively new subdivision trees require regular pruning; a 5-year pruning interval is generally considered optimum at this age to reduce future maintenance hazard tree situations and reduce long-term costs.

ACTION ITEM 2: The Finance Department and the Parks & Open Space Department should review the 10 Year Capital Forecast to ensure that operating costs for Street trees and Park trees and Woodland Parks are captured based on a maintenance standard recommended in the UFSMP.

The Oakville community with the highest urban forest cover is Eastlake with 48.7%. This community has a large proportion of Low Density Residential Land Use (Figure 7). The Oakville community with the lowest urban forestry canopy cover is QEW East Industrial (6.6%). ***The average urban forest canopy cover in Oakville is 29.1 %.***

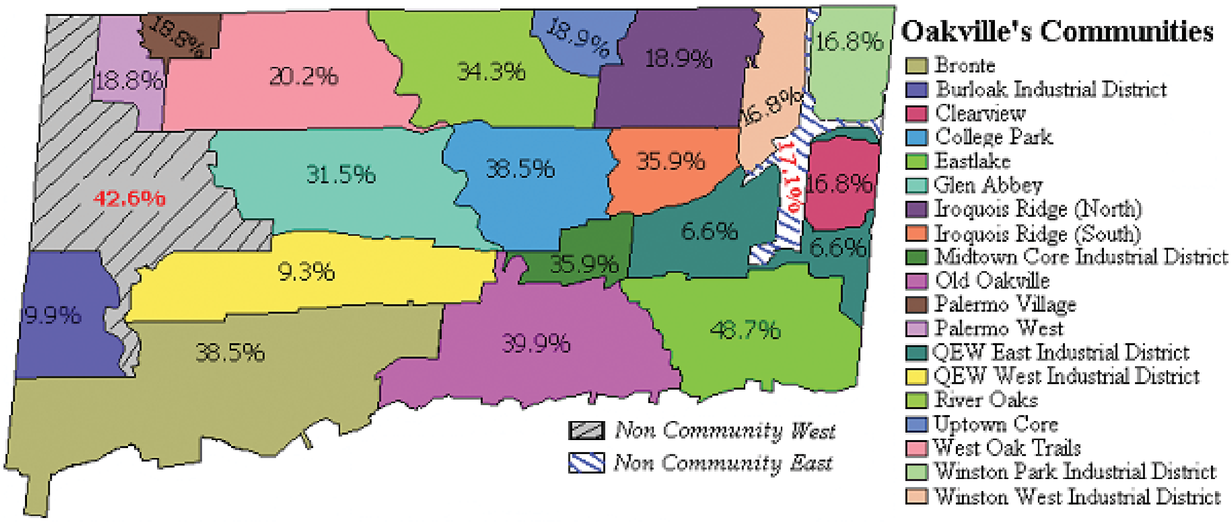


Figure 7. Existing urban forest canopy cover by community

The Burloak Industrial District has the highest percentage of trees in very poor condition (28.6%) while QEW East Industrial District has the most numerous dying trees (50.6%). This speaks to the issue of private stewardship.

ACTION ITEM 3: The UFSMP will develop a private urban forest stewardship education program

7.1.1. Urban Forest Canopy Cover

Note the influence that Land Use type has on the density of trees. For example, the size of the "Residential Medium + Residential High Density" Land Use is triple the area of the "Residential Low Density" Land Use but accounts for less than double the number of trees (Table 2).

Table 2. Tree density by Land Use type

Land use	Ha	Trees	Density(trees/ha)
Woodlots	909	883,900	972
Residential Low Density	1122	216,300	193
Open Space+ Parkway Belt	1690	303,000	179
Residential Medium + Residential High Density	3389	381,600	113
Employment+ Industrial	1670	98,200	59
Commercial	439	21,100	48
Public Use	215	3,000	14
Agriculture	461	1,300	3

Table 3. Large-stature tree distribution by Land Use type

Land Use	Large-stature Trees(#)	Density(trees/ha)
Agriculture	632	1.4
Residential Low Density	2163	1.9
Woodlots	2652	2.9
Residential Medium + High Density	3053	0.9

Forestry staff assumes that possible over planting by residents in Residential Low Density areas may have contributed to fewer large-stature trees than expected (Table 3). The Land Use that supports the greatest percent of large-stature trees is 'Woodlots.' Large-stature trees represent 0.5% of all trees in Oakville. Forestry staff would prefer future attainment of approximately 10% large-stature trees. This will be addressed in the UFSMP. For a complete breakdown of tree population by diameter class and Land Use types see Appendix 9.

"Persuade city leaders and elected officials that making a wise investment in large-stature trees is the right thing to do. For more information on the art of persuasion see our Market Research at: http://cufr.ucdavis.edu" (Centre for Urban Forest Research, CA, USDA Forest Service 2003).

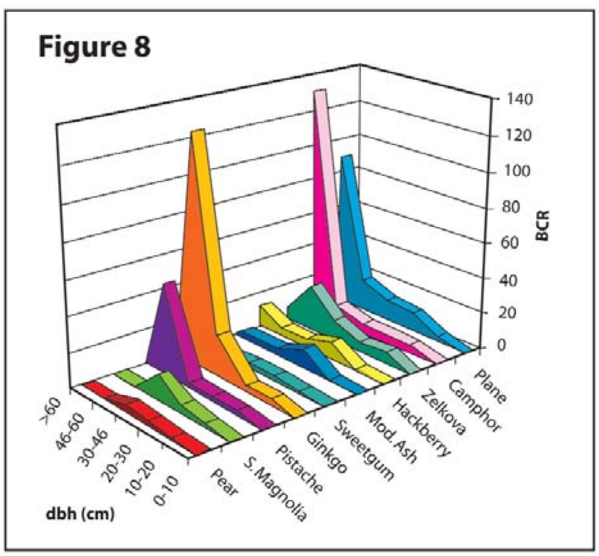


Figure 8. Distribution of benefit-cost ratios (BCR) among species by dbh class (McPherson 2003)

The City of Davis, CA Community Forest Management Plan for example, established the following standard for Citywide desired age structure: 40% young (< 6" DBH), 30% maturing (6-12" DBH), 20% mature (12-24"DBH), and 10% old (>24"DBH). Greg McPherson, Project Leader, Centre for Urban Forest Research, Davis, CA has calculated the benefit cost ratio ,"BCR", for various species of trees on a city specific basis (Figure 8).

"Setting appropriate tree canopy cover targets provides measurable goals for urban forest planning and management. However, this study suggests that the type of tree cover is just as important as the amount of tree cover. Accounting for the benefits and costs of different tree species over the long term should be one aspect of judicious tree selection" (McPherson 2003): (http://www.fs.fed.us/psw/programs/cufr/products/newsletters/UF6.pdf).

The condition of trees in Oakville varies with Land Use type. When the condition of trees was analyzed it was found that on average 11.7% of trees were found to be in 'poor' or 'fair' condition and 76.8% in 'good' or 'excellent' condition (Table 4).

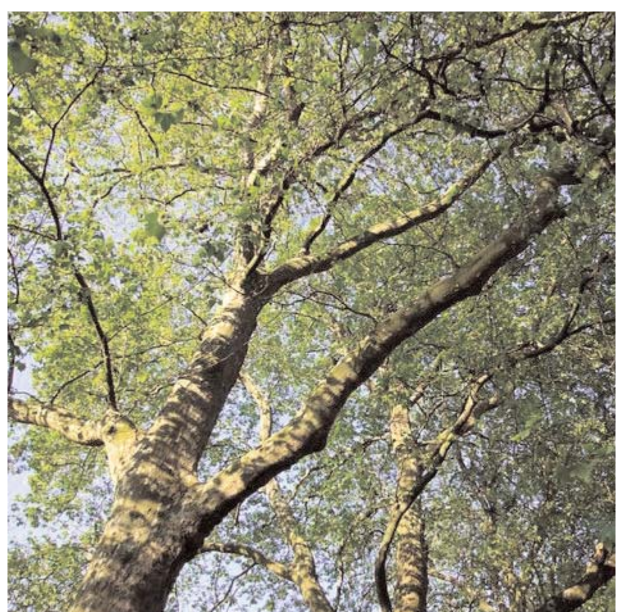


Table 4. Tree condition by Land Use type

Land Use	Excellent	Good	Fair	Poor	Dead
Agriculture	0	100	0	0	0
Commercial	68.6	20	8.6	2.9	0
Employment/Industrial	46.7	21.9	11.2	6.5	10.7
Open Space/Parkway Belt	50.5	22.3	6.5	4.9	14.8
Woodlots	54	17.8	8.4	2.3	16.3
Public Use	75	0	25	0	0
Residential Low	58.2	31.3	7.2	2.3	1
Residential Medium+High Density	64.7	21	5.2	6	2.5
TOTAL	**55.9**	**20.9**	**7.5**	**4.2**	**11.5**

However, since urban trees have deadwood removed for safety requirements Forestry staff believe the sampling methodology contributed to a result which shows better than expected tree condition.

Tree condition was assessed using the dieback factor, which considers the percent of dead branches in the canopy. Therefore, trees showing 'good' or 'excellent' condition are usually trees that are regularly pruned and as a result have less or minimal dieback. Trees in Land Use types where they present a potential hazard to people and /or property are usually targeted more for pruning and removal. The 'Woodlots' Land Use type, contain a higher percentage of poor or dead trees because of natural competition; however, a certain proportion of dead trees that are woody debris and standing snags are critical components of healthy woodlands. An alternative methodology for identify 'tree health' that has good potential for future use is presented in Section 9.4.

Table 5. Urban forest canopy cover and available plantable space by Land Use type

Land use	Canopy cover (%)	Plantable space (%)
Woodlots	90.3	8.5
Residential Low Density	47.4	22.8
Residential Medium +Residential High Density	26.4	18.9
Open space + Parkway Belt	26.1	47.3
Public use	11.2	21.6
Agriculture	9.5	39.2
Employment+ Industrial	6.8	27.4
Commercial	6.3	15.8

Average urban forest canopy cover is almost twise as high in the “Low Density Residential” Land Use type than in the “Residential Medium + Residential High Density” Land Use type and it has a higher tree density (Table 5). This Land Use type also supports more large-stature trees per unit of land and has a higher tree density than other non-natural Land Use types (Table 3). UFORE estimated the amount of available space to accommodate tree planting; this space is referred to as 'plantable space.'

The quantity of urban forest canopy cover in Oakville can be increased in two ways: (1) growth of existing trees and (2) planting the area identified as "plantable space" within each Land Use type (Table 5). This plantable space represents 25.9% of the study area. This scenario assumes these initiatives are done in conjunction with protecting the current urban forest canopy cover.

The quality of urban forest canopy cover in Oakville can be increased in four ways:(1) ensure the 'plantable space' is not encroached by human activities (Action Item 17); (2) design plantable space to support trees- this is the focus of Section 9; (3) favor local species with a high 'BCR' (Figure 8); and (4) provide scheduled tree care and maintenance (Action Item 2).

Figure 9. Ownership of the urban forest based on frequency of stems Note: within the study area 49% of the 'woodlots' land use is owned by the Town.

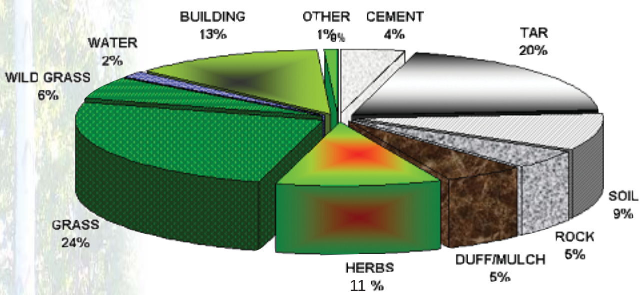


Figure 10. Ground cover distribution. Impervious surfaces cover 37% of Oakville and porous surfaces cover 63 %. Note: based on field data estimations and measurements.

7.2. Functions

The annual per tree gross sequestration of a small-stature tree (12 to 25cm dbh) is negligible compared to the contribution of a large-stature tree (88 to 101cm+ dbh) - Figure 11.

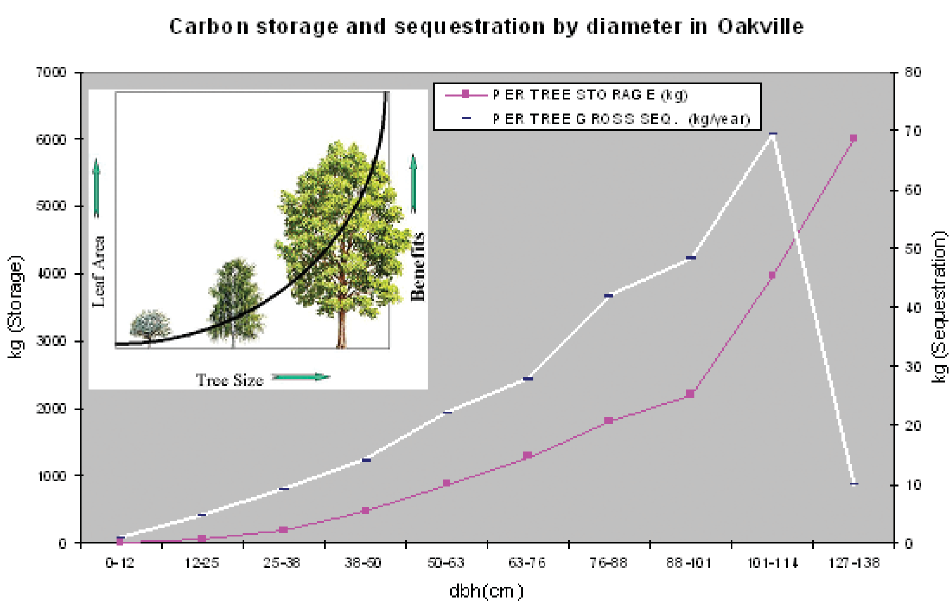


Figure 11. Relationship between size of the tree (diameter at breast height, dbh) and average carbon storage and sequestration.

Annual per tree gross sequestration drops off after 110 cm dbh. This suggests that trees have reached the carrying capacity of the site. ***A healthy large-stature tree has more leaves (higher leaf surface areas), and greater leaf biomass than a small-stature tree, thus providing substantially greater benefits.*** This emphasizes the importance of achieving tree size that equals the "peak carbon filtration point" (110cm dbh) in order to maximize ecological benefits in Oakville.

The 'Woodlots' Land Use is the most efficient carbon 'sink' (Figure 12). It is not surprising that the 'Public Use' Land Use is the least efficient given the poor tree habitat conditions (compacted clay soils with little organic matter to store carbon) found at many school properties in north Oakville.

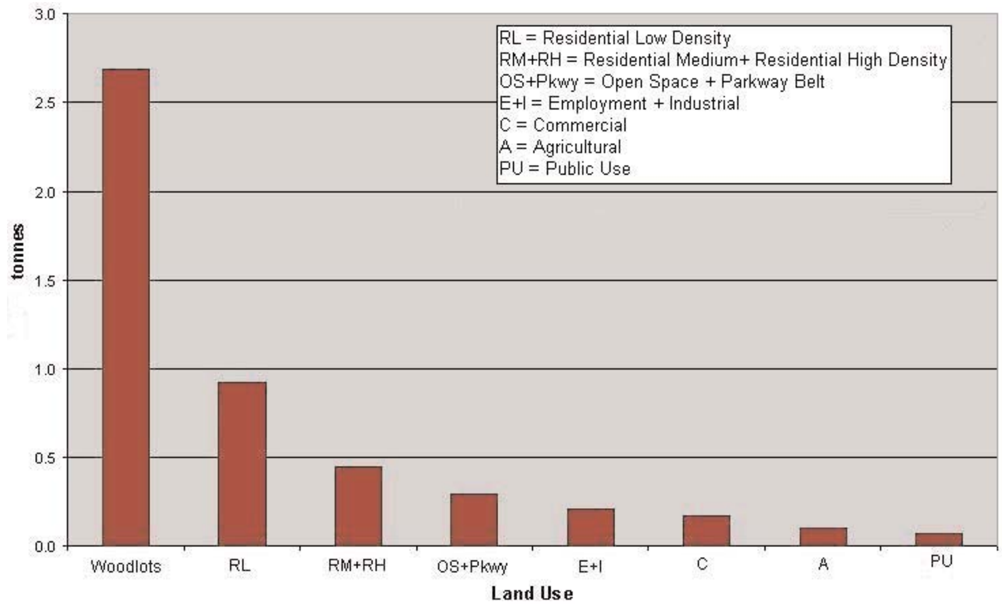


Figure 12. Carbon sequestration efficiency in tonnes per hectare by Land Use

Moreover, studies suggest that forest stands in urban environments have the potential to sequester and store more carbon than rural stands of the same canopy species composition. Soil carbon pools are roughly three times larger than the carbon stored in all land plants (Pouyat et al. 2002). This suggests that the Woodlots Land Use filters much more carbon than that quantified by the UFORE model.

UFORE results reported by Land Use type were used to determine the amount of pollutants removed by Town trees. Town-owned trees contribute 29% of the total air pollution filtration by trees in Oakville (Figure 13), yet they account for 43% of the trees in Oakville by stem count (Figure 9).

This is explained by the distribution of the large-stature trees among the Land Uses type and their influence on pollution reduction. Most of the trees owned by the Town are located within the "Woodlots" Land Use. Woodlots contain most of the young, small trees (49% of the woodlots in the study area are owned by the Town).

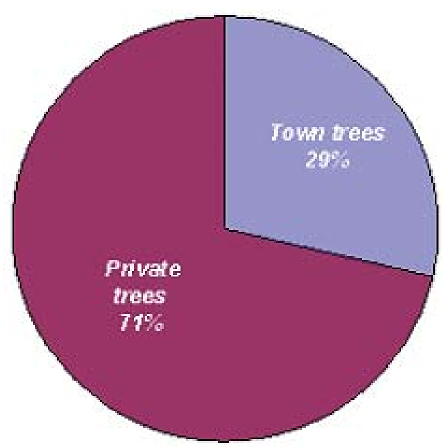


Figure 13. Contribution to pollution reduction: Town trees and Private trees.

Three species of trees- sugar maple, white ash and Norway maple - contribute almost one quarter of all carbon sequestration because they are large-stature trees, widely planted in the middle of the last century, on Land Use types that can support their full development.

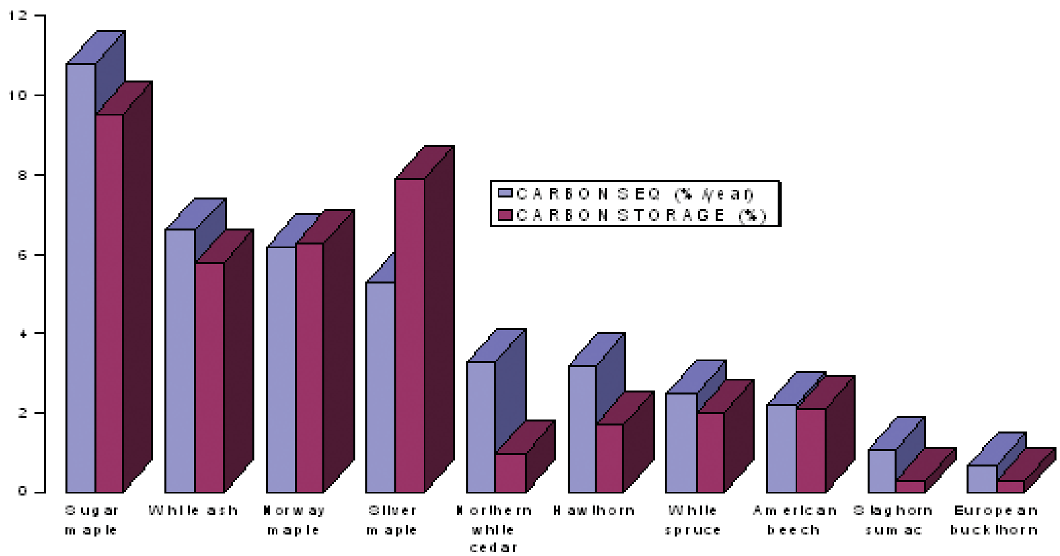


Figure 14. Top ten species and their contribution to carbon storage and sequestration

Two species of trees- Norway maple and Silver maple- have passed their peak carbon filtration point: this is the point where carbon storage surpasses carbon sequestration. These trees have entered into a stage of net negative energy balance and will decline in health. This suggests the need for the creation of a pro-active underplanting program in neighbourhoods dominated by old Norway maple and silver maple trees.

ACTION ITEM 4: The UFSMP should outline the creation of a pro-active under planting program in those Communities at risk of decreasing urban forest canopy cover due to aging trees.

Smog day occurrences have increased over the last decade due to increase in temperatures and higher levels of O_3 and PM (the main components of smog). Air quality readings of 'moderate' and 'poor' for Oakville are most common during the months of June to August when smog day alerts are issued (MOE 2005). Ground level ozone (O_3) is created through a chemical reaction between the pollutants NO_x and VOCs in the presence of sunlight. Ground level ozone combined with fine particulate matter (PM) results in the formation of smog especially during the hot, humid summer days.

In the year 2000, the average Canadian light-duty gasoline vehicle emitted approximately:

4480 kg of CO2	.89 kg of SO_x
200 kg of CO	.14 kg of PM_{10}
20 kg of VOC_s	.13 kg of $PM_{2.5}$
22 kg of NO_x	

Source: Pollution Probe 2005

Oakville's urban forest canopy cover filtered 172 tonnes of criteria pollutants (Table 6). This is equivalent to spending $1,128,000 on pollution removal by conventional methods.

By limiting the emissions of ozone precursors (VOCs and NOx), it is possible to limit the formation of ground level ozone. When considering the local industrial and commercial emissions of criteria air pollutants in Oakville (Table 7), trees and shrubs removed 26% of NO_2, one of the ground-level ozone precursors, and all 50.1 tonnes PM_{10}, another pollutant with drastic effects on human health (excluding emissions by vehicles licensed in the Town).

Table 6. Pollutants removed in 2005 by Oakville's urban forest.

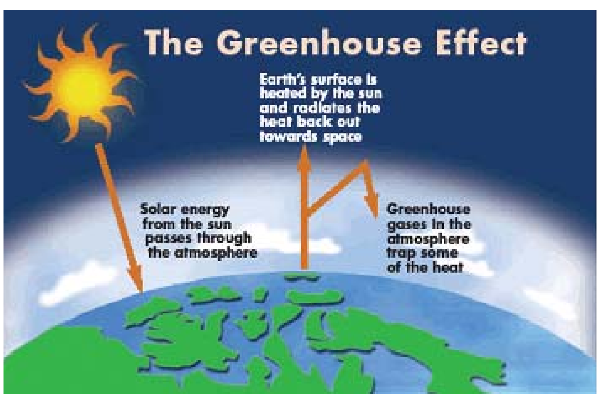
Criteria Pollutants	Tonnes	$*
CO	3.5	4,000
NO2	21.2	167,000
O3	85.4	671,000
PM10	50	263,000
SO2	11.9	23,000
Total	**172**	**1,128,000**

** the cost needed to remove the pollutants by conventional (mechanical) methods*

Table 7. Pollutants emitted by local industrial facilities that were removed by Oakville's urban forest in 2005
*data from National Pollutant Release Inventory (NPRI), Environment Canada. Petro Canada was removed from the data set because the Oakville refinery ceased refining processes by December 31, 2004.
(See http://www.petro-canada.ca/eng/media/10326_8938.htm)

Pollutants	Source* (tonnes)	Sink (tonnes)	Percent filtered
PM_{10}	48.9	50.1	102
$PM_{2.5}$	16.5	2.5	15
NO_2	80.6	21.2	26
SO_2	4.9	12.0	243
CO	68.5	3.5	5

National programs such as 20/20 The Way to Clean Air, and the former One Tonne Challenge, aim at reducing greenhouse gas emissions by 20% or more. It is estimated that one Canadian produces about five tonnes of greenhouse gas emissions each year. Within Oakville, air pollution originates from a variety of sources, with the main source being vehicle emissions (Region of Halton Health Department 2005). It is widely accepted that cars are becoming more fuel-efficient and less polluting. However, the growing number on the roads offsets some of the improved automotive technologies.



Based on statistics from the Town of Oakville Transportation Master Plan, the total number of households in Oakville in 2004 was 49,500 and the average number of vehicles per household is 1.7; therefore, it is estimated that there were 84,000 vehicles in Oakville in 2004. These vehicles emitted approximately 397,000 **tonnes** of harmful pollutants during the year 2004.

It is estimated that the trees in Oakville removed 22,000 tonnes of CO_2 in 2005. This is equivalent to the carbon emissions from 4,880 vehicles assuming each vehicle emits annually 4,480kg CO_2 (Pollution Probe 2005). Cars are also a source of particulate matter, which is a concern in communities because of their effect on human health. ***Oakville's urban forest filtered 6% CO_2, 16% SO_2 and more than four times (425%) the amount of PM_{10} emitted by vehicles licensed in the Town in 2005*** (excluding Oakville based industrial and commercial emissions). Studies have shown that a rise in PM_{10} concentrations is associated with an increase in mortality (Hewitt 2003). Therefore, any reduction in PM_{10} concentrations would be beneficial to human health.

Particulate matter (specifically PM_{10} and $PM_{2.5}$) combines with ozone to cause smog – a deadly human health risk. This was the inspiration for the title of this staff document because our urban forest pays a role in reducing the risks to the health of Oakville residents by reducing the amount of smog formed from the local emissions of criteria pollutants.

7.3. Values

When analyzing the benefits trees provide in terms of energy conservation, it is estimated that in 2005 Oakville's urban trees through their placement in relationship with buildings prevented an additional 1,200 tonnes of carbon emissions from power plants from being released into the atmosphere. In other words, the demand for heating and air conditioning in 2005 was reduced for Oakville's buildings by 55,400 Mbtu and 2,500 Mwh. The estimated cost reduction to Oakville residents is approximately $ 812,000 in annual savings. The largest savings in energy costs are in communities with high urban forest canopy cover such as Eastlake ($280,539). Conversely, communities such as Palermo and Burloak Industrial have little or no energy costs savings because of less canopy cover.

ACTION ITEM 5: It is recommended that the USDA modify the UFORE plot tally sheet to record the type of energy used for heating (gas, electricity, oil, etc) on each household where trees are over 20 feet tall and within 60 feet of residential buildings three stories or less in height in order to more accurately calculate the value of energy savings.

7.3.1 Potential pests' impacts on Oakville's urban forest

The UFORE study analyzed the impact of four exotic pests that have a great potential impact on trees: Asian long horned beetle, ALB, (*Anoplophora glabripennis*), gypsy moth (*Lymantria dispar*), emerald ash borer, EAB, (*Agrilus planipennis*), and Dutch elm disease (a combination of *Ophiostoma ulmi* and *Scolytus multistriatus*). The Canadian Food Inspection Agency (CFIA) considers ALB and EAB as 'primary tree killers' because they can directly kill healthy trees. The impact that each pest could have on Oakville's urban forest should it reach an extreme level is listed in Table 8.

Table 8. Potential impact of pests on Oakville's urban forest

PEST	KNOWN HOST (number of trees)	TREE VALUE ($ millions)
Dutch Elm Disease	39,000	14.5
Emerald Ash Borer	176,000	86.1
Gypsy Moth	419,000	264.5
Asian Long Horned Beetle	760,000	456.7

Asian Longhorn Beetle
Photo: Klaus Bolte

ALB is an exotic insect that bores and kills a wide range of hardwood species. The potential risk of ALB to Oakville's urban forest is a loss of $ 456.7 million in damage to the structural value (39.8% of the population). In 2003 Oakville Forestry staff assisted the municipalities of Toronto and Vaughan in performing ALB surveys. In 2004 Forestry staff conducted spot-check for ALB in vulnerable areas in Oakville. No positive results were found.

EAB is another exotic insect pest that has already killed tens of thousand of trees in Ontario and Michigan. Native to eastern Asia, the pest was first discovered in Canada and the U.S. in 2002. In Oakville, EAB has the potential to affect 9.3% of the urban forest, or $ 86.1 million loss in structural damage. The CFIA's current strategy with respect to EAB moving towards the GTA is to slow the spread. The Forestry Section stopped planting ash in its street tree program in 2002; other Sections are encouraged to do the same. It would be in the best interest of the Town to prepare an EAB response plan as part of the UFSMP.

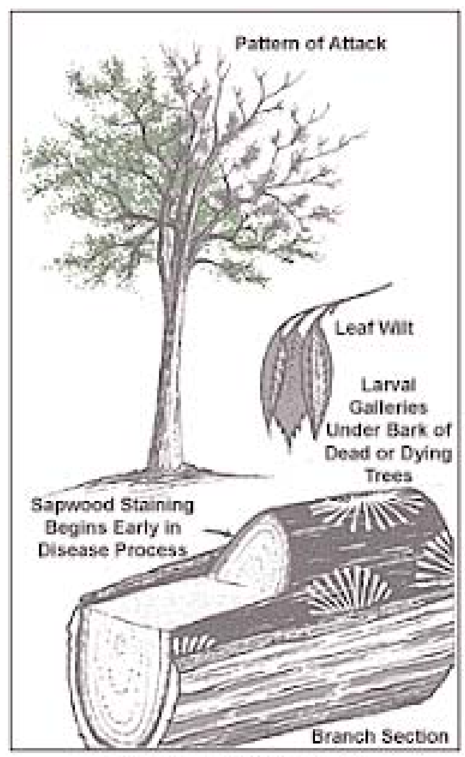
Emerald Ash Borer
Photo: Klaus Bolte

ACTION ITEM 6: The Town should prepare an EAB Action Plan.

Gypsy Moth
Photo: Klaus Bolte

Gypsy moth (GM) is a defoliator that feeds on many species and can cause the death of trees if combined with other biotic and abiotic factors. It is estimated that a potential outbreak of this pest would cause a loss of $264.5 million affecting 21.9% of the urban forest of Oakville. At the time of writing this report, Forestry staff retained a consultant to determine the potential threat of GM to Oakville in 2006 because it is reported by the Ontario Ministry of Natural Resources that the population of GM is in a cyclical phase of population build up.

Dutch elm disease, (DED) first discovered in Canada in 1944, has killed millions of elm trees across the country. For Oakville, it has the potential to destroy over 39,000 trees ($14.5 million in structural damage). However, these are primarily second and third generation small diameters elm trees, that are usually killed once they attain sizes averaging 25cm dbh, that have regenerated since the first wave of DED killed most of the stately elm trees throughout the GTA and the Province in the 1960s and 1970s.Sadly, only small scale programs to find effective treatments (University of Toronto) and identify genetically resistant elms (University of Guelph) are active in Ontario today. In contrast, the City of Winnipeg supports the Coalition to Save the Elms, Manitoba Inc. Founded in 1992 to save the largest American elm population in North America, it is dedicated to the stewardship of the elm and other trees, forests and the urban environment.



Dutch elm disease
Source: Natural Resources Canada

8 Implications for Urban Forest Management

American Forests, a leading urban forestry advocacy organization in North America, has conducted research on the ecological services of the urban forest and concludes that: ***"The physical framework of a community is called its infrastructure. These utilitarian workhorses of a city can be divided into green and gray. Green infrastructures are areas covered with trees, shrubs, and grass; gray infrastructures are areas of buildings, roads, utilities, and parking lots. Green infrastructure is porous, allowing water to soak into soil, which naturally filters pollutants before entering rivers. Gray infrastructure is impervious, forcing water to runoff and which must be managed and cleaned before entering rivers.***

A planimetric map of a Washington DC neighborhood shows a neighborhood's gray infrastructure including buildings and roads (left). Classified high-resolution satellite imagery adds a green infrastructure data layer (trees and other vegetation) with its associated environmental benefits (right).

Unlike gray infrastructure, the functional role of trees, as green infrastructure in cities is not adequately documented. Without quantifying its value, trees are not factored into the budget process. The size, shape, and location of a city's green infrastructure can be measured and the public utility functions they perform can be accurately calculated. While both gray and green infrastructure are important in a city, communities that foster green infrastructure wherever possible are more livable, produce fewer pollutants, and are more cost effective to operate. However, balancing the gray with the green can be a serious challenge for a local government manager.

To establish a healthy balance of gray and green infrastructure, communities can now:

- ***Quantify the presence of green infrastructure and its function for air and water improvement.***
- ***Once quantified, designate green infrastructure as a public utility (just as gray infrastructure is) in the budget process***
- ***Establish a tree canopy goal or target as part of every development and management project to utilize its functional potential***
- ***Adopt public policies, regulations, and incentives to increase and protect green infrastructure***

With the advent of geographic information systems (GIS) that most cities currently use, staff can integrate the value of green infrastructure, as well as model the impacts of development scenarios into daily planning and management.
http://www.americanforests.org/resources/urbanforests/greeninf.php

American Forests advocates that every city set a tree canopy goal for their community as an important step in ensuring that their valuable green infrastructure is maintained at minimum thresholds, even as the community continues to develop. American Forests offers some general goal guidelines based on climate conditions and zoning categories. Each community must first identify what their tree canopy cover is, and then set their own goals to help meet environmental and quality of life goals, including federal and local clean air and water regulations. Once a specific goal is determined, the local government can pursue that goal using policies, procedures, and budget.

Setting Tree Canopy Goals

American Forests recommends an average 40% tree canopy, east of the Mississippi and in the Pacific Northwest. Refer to the chart below for tree cover percentages based on land use and geographic area. These recommendations come from 20 years of analysis interpretation of tree coverage. In 1991 American Forests measured tree cover in 440 communities and found that most established communities in the Southeast U.S. had over 60% canopy coverage. The potential for tree cover in urban areas is generally 60% to 80% depending on land use, so the 40% average recommendation is a very attainable goal. While the goals listed below provide general guidelines, each community is encouraged to develop their own tree cover targets based on their unique mix of climate, geography, land cover, and land use patterns.

Why Set Tree Canopy Goals?
Tree cover in urban areas east of the Mississippi has declined by about 30% over the last 20 years while the footprint of the urban areas has increased by 20%. With this decline in tree cover, significant air and water management costs have increased. Tree cover is directly related to environmental quality. Maintaining a robust enough tree cover to function as green infrastructure reduces the need and expense of building infrastructure to manage air and water resources."

Average tree cover counting all zones	40%
Suburban residential zones	50%
Urban residential zones	25%
Central business districts	15%

(American Forests undated).

8.1 UFORE Grow-out Module: urban forest canopy cover in 2046

Oakville's average urban forest canopy cover is 29.1%. While below the minimum target recommended by American Forests, this reflects that Oakville has a significant proportion of its urban forest in new subdivisions which contain young, small trees.

The UFORE model is able to run simulations of the urban forest and display the results of future urban forest canopy cover (green image in the illustration below) up to 100 years into the future:

A UFORE Grow-out Module simulation was used to estimate the potential future urban forest canopy cover in 40 years. The following assumptions were made: none of the 'plantable space' identified in Table 5 was planted (the number of trees planted each year is assumed to be zero) - this models the growth of Oakville's existing tree cover (assuming the cover in woodlots and shrub cover stay the same over the years); tree mortality was assumed to average 2%. ***Under the forgoing assumptions, on a conservative basis, it will take the Town 40 years to attain American Forests' minimum target by reaching 40% average urban forest canopy cover in 2046.*** Under this scenario, the cover will continue to increase for another decade after 2046 and then decline (Figure 15 and Appendix 10).

The decline in urban forest canopy cover would be unacceptable. Additional urban forest canopy cover, over and above American Forests' minimum target, may be achievable; and it may be achieved sooner than 2046 if the 'plantable space' (Table 5) is planted on a 'front load' basis over the next decade and tree mortality rates did not increase or were able to be decreased. A tree crown cover for urban environments of 36% to 55% is considered adequate while >75% is viewed as excellent (Morsink 2000). Other UFORE Grow-out Module simulations will be

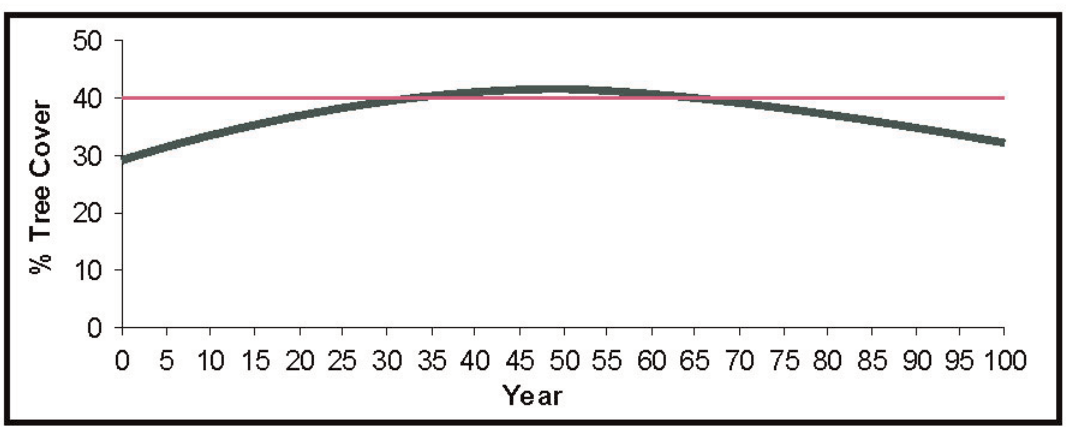


Figure 15: Oakville's urban forest canopy cover - simulation #1.

run and the optimum urban forest canopy cover target for Oakville - and how to sustain it over the next 100 years - will be addressed by the UFSMP (ACTION ITEM 11). It is important to note that the simulations in UFORE Grow-out Module required an assumption of 2% for Oakville's tree mortality rate since it is unknown at present. It is necessary to measure Oakville's tree mortality rate to improve the accuracy of UFORE's modules. This will be calculated when the next UFORE project is completed in 2009 (ACTION ITEM 25).

"Urban Forest Canopy Cover looks at the urban forest from a perspective that addresses the canopy in two dimensions (length and width). It should be noted that there are more sophisticated models that look at this from a perspective that addresses the canopy cover in three dimensions by measuring total leaf area (height).Leaf Area Density provides a more comprehensive approach to characterizing the urban forest canopy (…) and can be used as an urban forestry planning and management tool" (Kenney 2000).

ACTION ITEM 7: It is recommended that UFORE consider incorporating Leaf Area Density and Potential Leaf Area Density.

8.2. UFORE Tree Locator Module: Priority Areas to plant to improve air quality in Oakville

The UFORE model identifies the best locations for trees to maximize air pollution filtration. To help determine the priority areas to plant, an "environmental equality" index was developed by the USDA Forest Service that focuses tree planting priorities in areas with many people but relatively low tree cover. The map details the index along with available planting spaces (Appendix 7). Based on the UFORE species selection program, 833 tree species listed in the USDA Forest Service Resource Bulletin as adapted to hardiness zone 6 were ranked relative to their ability to clean the air. Overall, the best species for improving Oakville's air quality include tulip tree (*Liriodendron tulipifera*), American basswood (*Tilia americana*), Japenese Zelkova (*Zelkova serrata*) and Horsechestnut (*Aesculus hippocastanum*) (Appendix 8). However, the list of species given does not consider those attributes about a species that make it suitable for a particular location (e.g. pest susceptibility and invasiveness). Local experience with these species should be used in making the proper species selection for the Town of Oakville.

The UFORE Tree Locator Module (Appendix 7) could also be used to help the Parks and Open Space Department achieve its objective of naturalizing Parkland. UFORE can identify the optimum locations and species as well as how many trees to plant per year to maximize the ecological services of trees in Town Parks; a similar simulation for the entire Town identifies the optimum tree planting locations in Oakville through ACTION ITEM # 4 and ACTION ITEM # 11. It is appropriate to undertake a Parks Naturalization Project given that the Parks and Open Space Land Use contains the most readily accessible 'plantable space' in the study area (Table 5).

Urban trees have the potential to *increase* their contributions to the community by increasing carbon storage and sequestration (Figure 16).

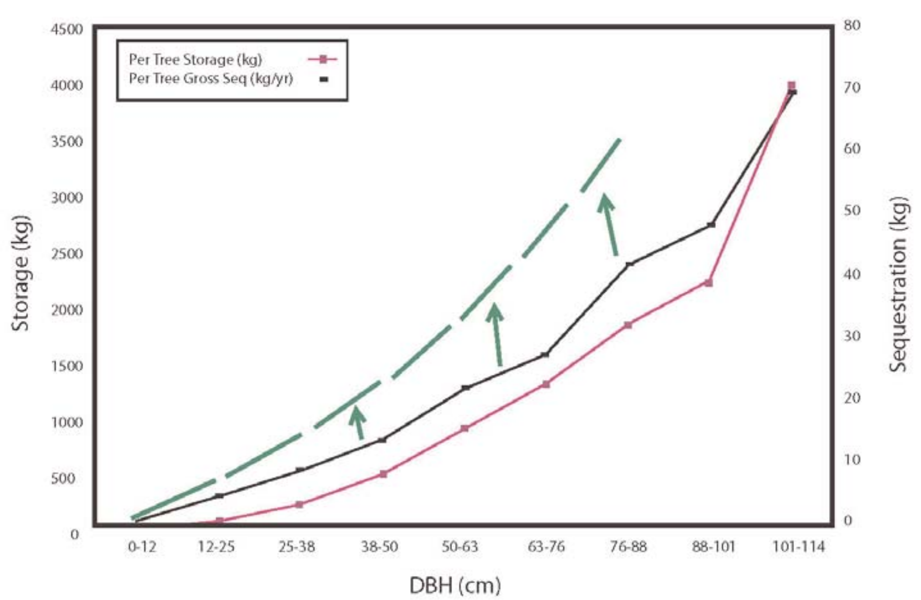


Figure 16: Potential increase in the Carbon Sequestration contributions of trees.

One way to achieve this potential would be through faster rates of annual growth. Traditionally in forestry this is accomplished through sophisticated genetic research based tree improvement programs. A second way to improve tree efficiency is to improve the quality of the site- specifically the soil quality and quantity. This is the focus of Section 9.

Programs such as the former "One-Tonne Challenge", which was cancelled by the Federal government in April, 2006, provided Canadian citizens with options and solutions for reducing their GHG emissions. Similar programs could be created to recognize the contribution of trees to the reduction of GHG emissions by encouraging people to maintain and improve the health of large-stature trees on their properties through an incentive program. An example of such an incentive program for private woodland owners is Ontario's Managed Forest Tax Incentive Program
(www. ontariosforests.mnr.gov.on.ca/mftip.cfm).

Municipalities could consider a similar approach for encouraging the management of private large-stature trees that make a significant contribution to filtering criteria pollutants and GHG's.

ACTION ITEM 8: The Town should investigate the feasibility of an incentive program for private large-stature trees in order to maximize filtration of criteria pollutants and GHG's.

ACTION ITEM 9: The Forestry Section should work with the Forest Gene Conservation Association to create a gene conservation program for the Town.

ACTION ITEM 10: The Parks and Open Space Department should identify opportunities for Parks Naturalization that contributes to the forest canopy and prepare capital budget costs.

ACTION ITEM 11: The Forestry Section should Chair an interdepartmental/interagency Technical Advisory Committee to develop through the UFSMP:
a) Urban forest canopy cover targets for Oakville and;
b) How key Town Departments can contribute to achieving these targets.

8.3 Rooftop Gardens

Studies show that **rooftop gardens** offer more than a green oasis in the concrete jungle. They can help urban areas adapt to climate change and also decrease greenhouse gas emissions by reducing the energy spent on heating and cooling. A National Research Council of Canada report (2002) concludes that: ***"Rooftop gardens can also moderate heat flow through the roof through the effects of shading, insulation and evaporation. This reduces the energy demand for space conditioning significantly in spring and summer. In addition, rooftop gardens delay run-off and reduce the run-off rate and volume. These qualities are important in storm water management strategies in big cities. The findings are significant under the current climate regime and they may prove to be of even greater significance in the future when increased variability from climate change is manifested at the regional scale. Proven to greatly mitigate these impacts, vertical and rooftop gardening has seen a widespread renaissance in Europe in recent years, but is still little used in North America. To investigate its application in Canada, Environment Canada and several private sector partners recently completed a report on the benefits of rooftop and vertical gardens, titled Greenbacks from Green Roofs: Forging a New Industry in Canada, for the Canada Mortgage and Housing Corporation" (The Science and The Environment Bulletin 1999).***
Rooftop gardens have the potential to increase urban forest canopy cover by planting trees and shrubs thereby increasing the range of naturalization options in urban landscapes.

ACTION ITEM 12: The Town should undertake a pilot rooftop garden demonstration project that can contribute to forest canopy coverage.

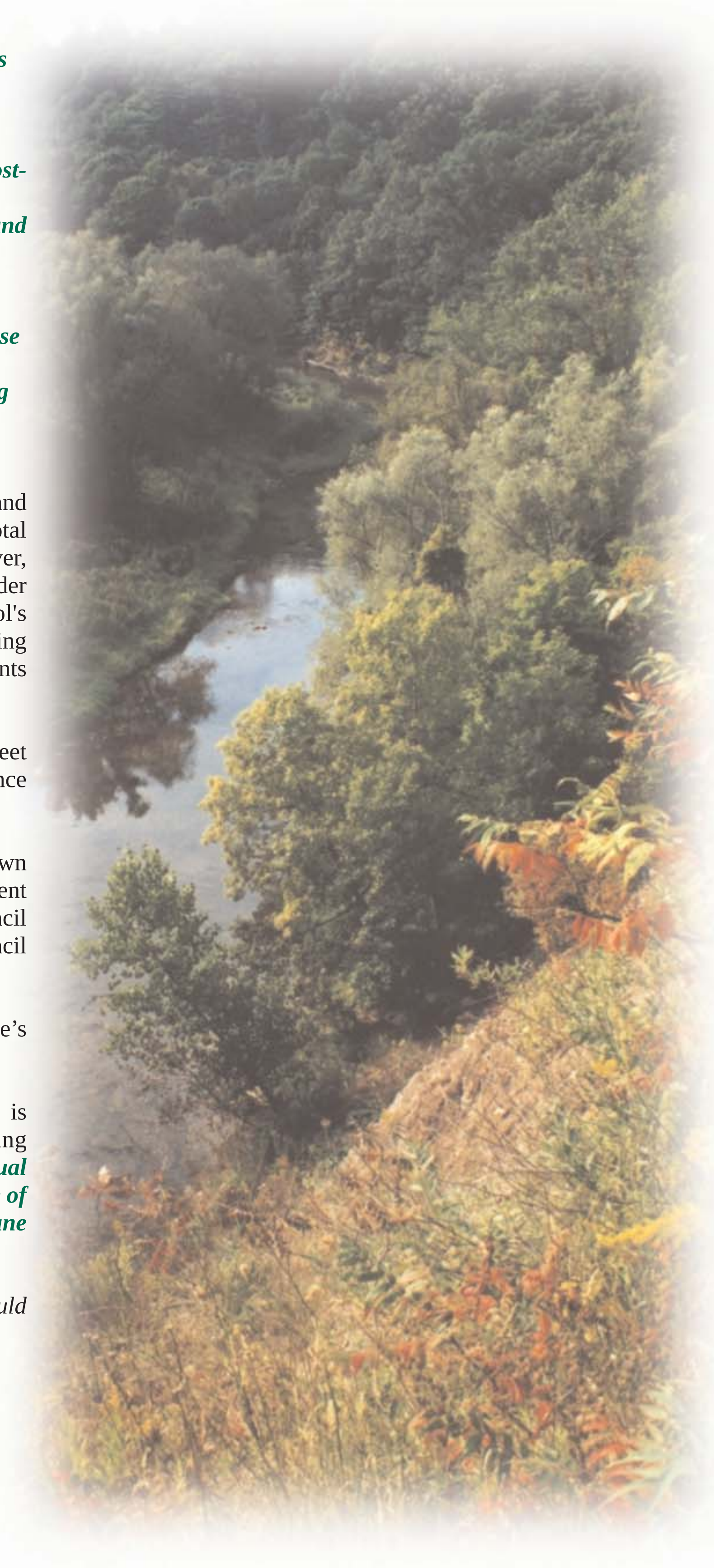
8.4 Trading Carbon Credits

"The Chicago Climate Exchange (CCX) is North America's only, and the world's first, greenhouse gas (GHG) emission registry, reduction and trading system for all six greenhouse gases (GHGs). CCX is a self-regulatory, rules based exchange designed and governed by CCX Members. Members make a voluntary but legally binding commitments to reduce GHG emissions. By the end of Phase I (December, 2006) all Members will have reduced direct emissions 4% below a baseline period of 1998-2001. Phase II, which extends the CCX reduction program through 2010, will require all Members to reduce GHG emissions 6% below baseline.

The goals of CCX are:

- ***To facilitate the transaction of greenhouse gas emissions allowance trading with price transparency, design excellence and environmental integrity***
- ***To build the skills and institutions needed to cost-effectively manage greenhouse gas emissions***
- ***To facilitate capacity-building in both pubic and private sector to facilitate greenhouse gas mitigation***
- ***To strengthen the intellectual framework required for cost effective and valid greenhouse gas reduction***
- ***To help inform the public debate on managing the risk of global climate change"***

  (Source: http://www.chicagoclimatex.com/)



Oakville's municipal trees in woodlots, parks and streets filtered 6,300 tonnes* of CO_2 (28% of the total filtered by the entire Town's urban forest). However, only 1,010 tonnes qualifies as a 'carbon credit' under the CCX program. Under the Kyoto Protocol's UNFCCC Article 3.4, Forest Management, qualifying Forestry Offset Projects, in the case of CCX applicants such as the Town, must consist of:

(1) Carbon sequestered only from the municipal street trees and Park trees that Oakville has planted since 1990;

(2) The additional carbon sequestered in our Town woodlots as a direct result of forest management improvements under the Forest Stewardship Council certification program; a program that Town Council approved on March 6, 2006.

It is estimated that approximately 16% of Oakville's municipal urban forest qualifies.

While a formal inventory (ACTION ITEM 24) is required to confirm the number of qualifying municipal trees an estimate of the ***Town's annual qualifying carbon credits produced a trading value of $5,191 on the Chicago Climate Exchange on June 21, 2006.***

ACTION ITEM 13: The Town of Oakville should investigate the feasibility of trading carbon credits.

* conversion formula for carbon sequestered to CO_2 filtered: tonnes of carbon sequestered x 44/12 (USDAForest Service).

9 Implications for Urban Forest Management: Tools for Building the Urban Forest Canopy

"Climatologists refer to cities as heat islands where temperatures can be nine to twelve degrees (Fahrenheit) hotter than the countryside (...) trees that survive in most cities are tough trees that can tolerate drought, poor soils, and periodic beatings. According to recent surveys, the average city tree lives only thirty-two years and dies just when it is beginning to reach the most valuable stage of its life...Urban trees, just like forests everywhere, respond to good management. We can extend the lives of urban trees...far longer-and in the process double or triple the benefits each tree confers on the community. Good forest management doesn't cost. It pays" (Moll and Ebenreck 1989).

The urban forest needs to be recognized as the "green infrastructure" of the community. For example, when federal programs are announced for new infrastructure, trees - as a “public utility” - should be included along with pipes and roads following a linked approach for the grey and green infrastructure. This paradigm shift can be initiated at the local level.

"England is recognized to have one of the most advanced and tree friendly urban planning systems in the world. The United Kingdom updated Town and Country Planning Act, requires developers to make detailed plans for tree preservation and planting before receiving permission to build. Furthermore, U.K. national legislation allows any citizen to ask local government to grant a Tree Protection Order (TPO) for a tree, group of trees or a woodland area. The tree(s) need not to be on their own property. If granted, the TPO makes it a criminal offence to cut down, top, uproot, or willfully damage a tree. Even pruning requires the permission of the local authority. Once in place, the TPO remains in force throughout the tree's life and covers tree planted to replace it. TPOs are strictly enforced, and the penalties for ignoring them are severe: the tree's owner and the arborist who performed the work face fines of up to $40,000 for illegal tree removal and $5,000 for illegal tree pruning" (Wells 2006).

ACTION ITEM 14: Amend the Town's Official Plan, Part C, Section 10.4 to recognize the municipal urban forest as a component of the municipality's "infrastructure."

This is intended to build on the Town's existing Tree Protection Policy (Corporate Policy # 01-03-08). Key departments can advance the contribution of the urban forest to support the health of the people of Oakville (ACTION ITEM 11).

9.1. Improving the Quality & Quantity of Potential Planting Locations

Table 9, tree habitat design guidelines, was developed by Forestry staff with input from Development Services. It establishes the optimum soil quantity required in order for an urban tree to attain its growth potential over time, or ecological 'service life.'

Three categories of trees are identified: large-stature trees, medium-stature and small-stature.

Table 9. Tree Habitat Design Guidelines for Oakville

Minimum soil quantity to support a healthy tree to maturity *1

	Soil Volume *2 (m3)	Growing Space dimension*3 Length *4 (m)	Width (m)
Size of tree at maturity			
Large-stature tree	98	12	9
Medium-stature tree	44	8	6
Small-stature tree (*5)	16	8	2

1. maturity = peak carbon filtration point , Figure 11, and is assumed to be 80-100 years
2. Calculated based on:
   a- Average crown diameter of 1700 street trees measured in a pilot project in the Town of Oakville in 2003, as follows: large stature tree= 14 meter crown diameter, medium stature tree=10 meters crown diameter and small stature tree= 3 meter crown diameter.
   b- "Trees in Urban Landscape", page 81, Dr. Nina Bassuk
3. Based on 0.9 meter growing depth for root system
4. 12 meter planting interval is based on Oakville Corporate Policy # 08-03-07, Street Tree Planting
5. Aesthetic purposes only; negligible environmental services value

ACTION ITEM 15: The Tree Habitat Design Guidelines for Oakville should be reviewed with the interdepartmental technical Advisory Committee identified in ACTION ITEM 11 to incorporate them into the Town's urban design standards of key Town Business Units.

It should be noted that “Landscape Design Guidelines” should be consistent with Table 9 in order to optimize ecological services from trees. **A paradigm shift in landscape design is required.** When sites are over planted with trees, after 10-20 years the trees have outgrown the location and start to decline in health. The trees will never contribute to their carbon storage and sequestration potential as per Figure 16. An alternative landscape design which optimizes ecological services would be to plant fewer large-stature trees. Over time, this will attain the optimum carbon storage and sequestration potential, assuming suitable tree maintenance.

Street tree habitat is influenced by the engineering road cross section (Appendix 6). ***The Town has taken a leadership position in this area: the Oakville Utilities Coordinating Committee developed engineering road cross sections that Council approved which strike a reasonable balance between the needs of the grey and green infrastructure.*** For example, on roads less than 30m in width the Town of Oakville's standard location for the street tree is 0.5 m off property line; this protects the Town tree by providing maximum separation from underground utilities as well as de-icing salts used during winter control operations. When combined with sufficient front yard house setback, identified as 7.5m, this has created very close to the conditions set in Table 9. Future enhancements may include reviewing the soil specification for roadside berms and use of structural soil (Section 9).

The following "formula" recognizes the fact that trees require a larger volume of (good quality) soil as they grow larger (Figure 17):

(Street) Tree Habitat = Zoning* + Engineering**

* Density & front yard setbacks
** Engineering Road Cross Section

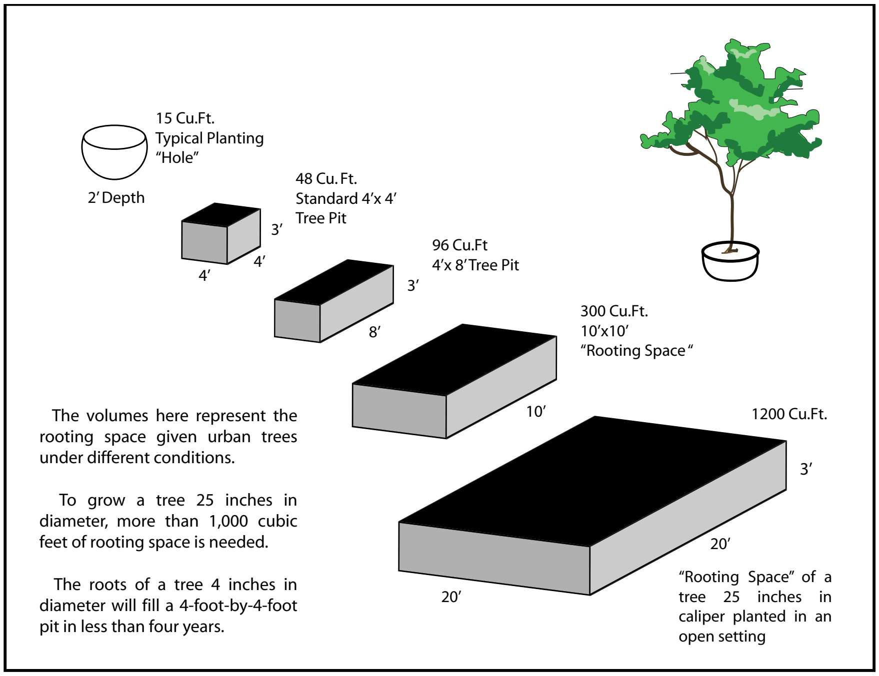


Figure 17. Minimum growing space in relation with tree size. (Source: Shading Our Cities, Figure 16.3, Moll & Ebenreck 1989)

"The urban forest canopy must be considered as an equal partner in the community infrastructure at the time of planning and not as an 'add on' after the hard surface and utilities are accommodated" (Kenney 2000).

ACTION ITEM 16: Town Council should endorse the initiative of the International Society of Arboriculture, Ontario Chapter which calls upon the Ontario Ministers of Municipal Affairs & Housing and Natural Resources to support healthy urban forests in Ontario as outlined on the web site of the Canadian Urban Forest Network: http://www.treecanada.ca/programs/urbanforestry/cufn/cufn.html (Appendix 1).

Tree habitat affected by Zoning By-laws

Figure 18. Inadequate tree habitat. Lack of growing space (top photo) causes root restrictions resulting in short lived trees (bottom photo).

Why do we see large-stature trees that seem to grow out of the very concrete that surround their trunk? The answer lies in recognizing the gradual process of 'human encroachment.' This tree attained most of its current size before human encroachment began: before the road was widened from 2 to 4 lanes; before the building lot was severed into two building lots; before the building addition was constructed; before the driveway was widened; before front yard parking was permitted; before the water, stormwater and sanitary mains were replaced when the former lines reached the end of their service life; before the new gas line was installed; before the sidewalk was re-placed; before the lateral waterline servicing the home was brought up to new Building Code standards by open trenching beside the trunk; before the capacity of the hydro line was increased by installing taller poles. All these necessary improvements to the grey infrastructure could be completed without cutting down the tree…but was the tree saved? The stresses from these improvements negatively affected the energy balance in the tree: this was manifested in the shedding of biomass- roots and branches. The tree's canopy cover gradually shrank to perhaps two-thirds of its previous size. The tree's decline may have taken a decade or more. No one tied its decline to the cause: human encroachment. Only if an insect or disease issue occurs will anyone notice that the tree is 'infected'; by then the process of compartmentalization and decay associated with the negative energy loss may have created a tree without sufficient holding wood to keep it from becoming structurally hazardous. The final indignity is that the reduced permeable surface is now too small to support another large-stature tree. Man continues his "taking relationship" with trees (Shigo 1988).

The foregoing paragraph does not imply a 'Trees First' philosophy. In fact, if the tree just described was planted in the wrong spot for example, too close to an existing house or road or overtop a utility corridor- then these impacts were unavoidable. However, provided the tree was planted in a designated location for trees (Appendix 6) which contributes to a long-term urban forest canopy cover target (Figure 15) and that had been coordinated using the 'formula' for (Street) Tree Habitat, supported by an urban design that reflects a true balance of both the grey and green infrastructure interests, in accordance with formal policy and design standards which span Departments, then the municipal tree may be considered to be managed as green infrastructure. ***This is also a challenge for the arborist and landscape architect as it requires a paradigm shift from a "the right tree for the right site" reactive approach to a "right site for the right tree" proactive approach.***

ACTION ITEM 17: The interdepartmental/interagency Technical Advisory Committee, identified in Action Item # 11, should investigate the potential role of zoning by-laws to reserve the land which supports the tree.

In order to make meaningful progress towards attainment of increasing urban forest canopy cover beyond the amounts outlined in Figure 15, a paradigm shift needs to occur in urban design. Compromise is crucial since innovative urban designs are limited by available space:

"Urban trees experience a litany of environmental insults: soil and air pollution, heat loads, deicing salts, and impacts from utilities, vehicles, and buildings. The most significant problem that urban trees face, however, is the lack of useable soil volume for root growth [Figure 18], since trees are often an afterthought in city planning and streetscape design...Healthy trees need a large volume of non-compacted soil with adequate drainage and aeration and reasonable fertility.
CU-Structural Soil™ meets these needs while also fulfilling engineers' load-bearing requirements for base courses under pavement" (Bassuk et al. 2005): (http://www.hort.cornell.edu/uhi/outreach).

Moll and Ebenreck (1989) consider that ***"modern engineering should use techniques like boulevards and wide tree lawns to make space for trees (...) the traditional tree pits must undergo some innovative redesign. The technical designs used on traditional landscape drawings are grossly inadequate to grow healthy trees. In a natural environment, tree roots may reach hundreds of feet from the trunk in search of nutrients. So it makes sense that in the confined spaces of the city, we must engineer sites that are more fertile pound for pound than the average rural site. What our spaces lack in size, they must pick up in quality (...) Trees have long been fit into spaces left over after everything else is written into design. This approach will not work if we want our trees to be a major element in a city's structure."***

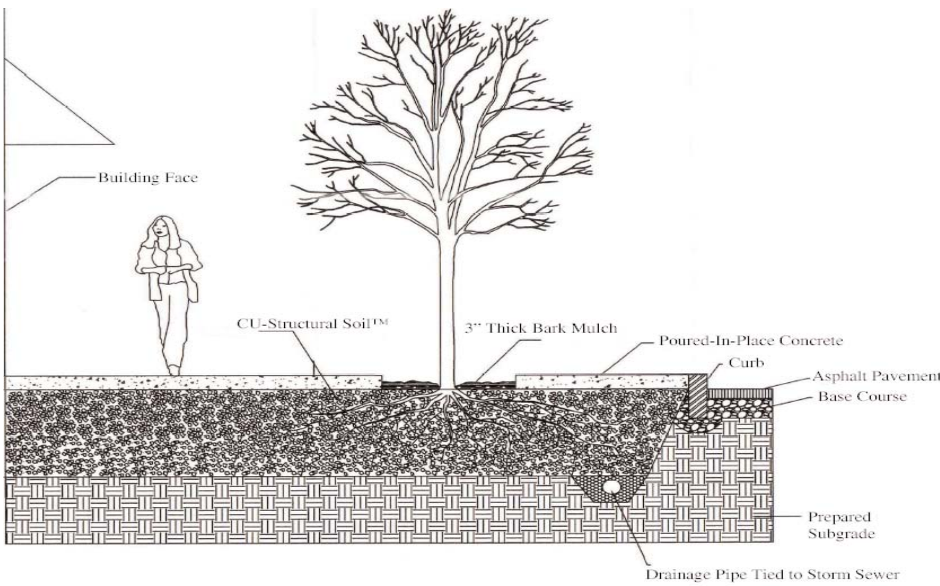
In contrast, many urban streetscapes follow a cyclical pattern of repeated street tree failure (Figure 19).

Figure 19. Ineffective Urban design approach.

Source for photographs: Centre for Urban Forest Research, Davis, CA, USDA Forest Service

One solution to this cyclical problem is to design adequate tree habitat (Figure 20).

Step 1. Before planting



Step 2. Implement Tree Habitat techniques

(e.g. "CU Structural Soil" combined with appropriate Zoning* + Engineering**)

* 6m building setback for medium–stature trees (Table 9)

** utilities and trees separated (Appendix 6)

Step 3. After planting.

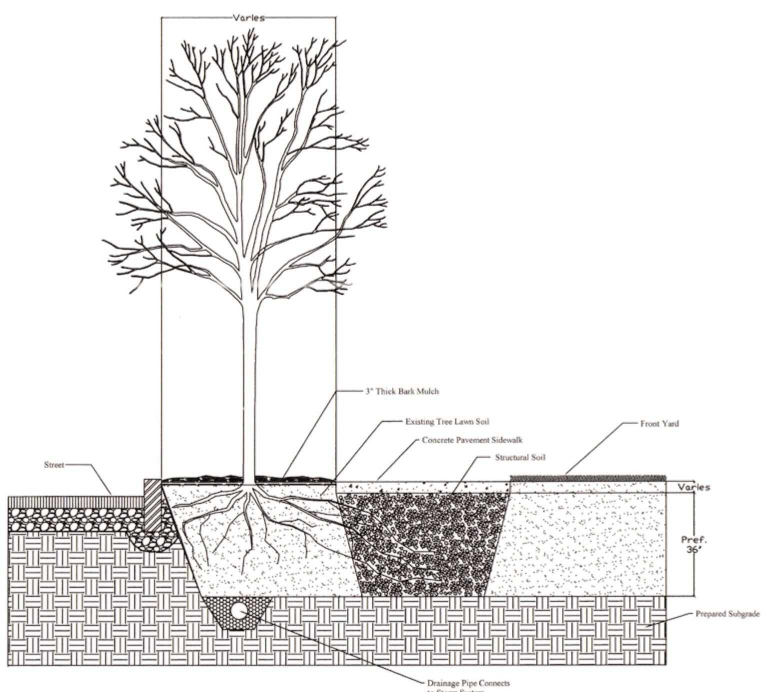
Sustainable. No replanting necessary

Figure 20. Effective Urban design approach

Figure 20 could also be rendered as follows:
A coordinated effort is required to design and construct adequate tree habitat.

NY State Dept of Transportation installation of CU Structural Soil in Ithaca, NY 1997. Fifty trees of five species planted into continuous trenches.
Source: http://www.hort.cornell.edu/uhi/outreach/csc/ssoils/sld033.htm

A third version of Figure 20 could further increase tree habitat by linking the root zone from the boulevard, or 'tree lawn', to the "front yard" by placing CU-SOIL underneath the sidewalk to act as a 'bridge' for root expansion. The City of Kitchener has built this version.



STRUCTURAL SOIL BREAK-OUT ZONE FROM NARROW TREE LAWN TO FRONT YARD

ACTION ITEM 18: The Forestry and the Design & Construction Sections will work together to expand the CU- SOIL pilot project which was initiated in Uptown Core in 2005.

9.1.1. Towards a focus on Prime Sites

"The average city today has a tree canopy over about one-third of its area, and the health of the trees forming this green umbrella is declining. Growing space is probably the most significant element limiting urban forest potential. Preliminary data show that the closer we get to the city's center, the shorter the life of the average tree. Longevity and size of trees is directly related to the size and quality of space in which they have to grow. The city of the twenty-first century needs to double its tree cover from one-third to two-thirds of the total land area. It also needs to increase the life span of the average tree from thirty-two to sixty years" (Moll and Ebenreck 1989).

Given the current urban design in various land uses throughout Town, Forestry staff has identified the concept of 'Prime Sites' for their ability to provide optimum potential 'tree habitat' for large-stature trees (assuming adequate soil compaction conditions). Examples of prime sites include: parkland, road side berms, low density residential properties and low density industrial properties. The UFORE Planting Module can be combined with the Best Species for Air Quality Improvement Guideline (Appendix 8) to focus on a Prime Site Management approach: plant the best sites with the best tree species. This will optimize air quality improvement. This is the same approach identified in the Forest Regeneration and Silvicultural Plan Council approved for the Town's woodlands at Iroquois Shoreline Woods Park to address Oak Decline.

ACTION ITEM 19: THE UFSMP to identify a Prime Site Management Program for Large-stature and Medium-stature trees.

9.1.1.1. Radial Trenching & Air Spading

As mentioned in the preceding Section, tolerable limits to soil compaction are fundamental to proper urban forest management. "Between 0 and 200 psi, roots will have no problem growing. However, between 200 and 300 psi, root growth will be inhibited. At 300 psi or greater, root growth is stopped" (Trowbridge and Bassuk 2004).

Compaction may be corrected by techniques called (a) 'radial trenching' (b) air spade and (c) sub-soiling in addition to specifying adequate soil composition with sufficient granular structure (sand). Sub-soiling is used by the City of Toronto's Forestry Section as outlined in the Toronto Star article “Why the Suburbs will Never have Tall Trees” (Kidd 2006).

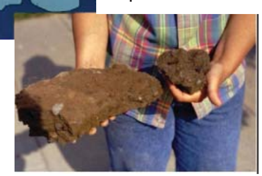
In 2005 and 2006 the Forestry Section undertook projects to test each technique. The following areas in the Clearview Community were used as the pilot for a 'Tree Habitat Restoration Project in 2005': (1) Kingsford Garden Park was used for Air Spading and (2) a section of Sherwood Heights Drive was used for Radial Trenching. In 2006 a Section of Third Line was rehabilitated. The expectation is that root growth can now proceed without confinement; this will significantly improve the health of the trees because the berm locations- as treated- provide superior tree habitat to boulevard locations and should be favored as a tree planting location; however, the soil compaction issue in any untreated engineered feature first needs to be addressed.

Trees respond to their habitat. In this photograph (on right) the street trees on the right are in poor health and the street trees on the left are in good health.

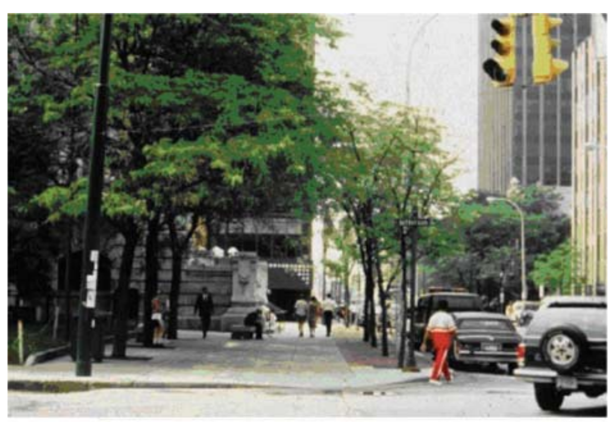
Soil with granular structure.

Macropores
- the relatively large spaces between peds
- water drains quickly through macropores
- air diffuses through macropores

Macropores are the spaces between the peds.



Compacted soil showing loss of structure.



Volume effects on tre growth.Honeylocust in Syracuse,NY.Those on the right are in tree pits. Those on the left are in tree pits but with small park "break-out" area to their left.

Source:http://www.hort.cornell.edu/uhi/outreach/csc/ssoils/s/d002.htm

The Forestry section has initiated a tree habitat improvement project on selected 'prime sites.' In the photograph below the compacted clay soil is replaced with sandy loam and mulch using radial trenching combined with air spading.

Radial Trenching

ACTION ITEM 20: The Parks and Open Space Department to establish a 'soil restoration program' as part of its 'Prime Site' Management Program, to be outlined within the Urban Forest Strategic Management Plan.

9.2. Stewardship: Towards Scheduled Woodland & Tree Care

On March 6, 2006 Town Council approved the Memorandum of Understanding with the Eastern Ontario Model Forest. ***Oakville became the first low-tier municipality in Canada to have its woodlands certified as sustainable by SMARTWOOD in accordance with the standards of the Forest Stewardship Council (***http://www.fsccanada.org/Certification.htm***).*** A basic principle used in managing forest health under this program is a pro-active approach. This approach can be applied to the Heritage Tree Care Business Unit in the Forestry Section by adopting a "pruning cycle" for Town trees. This could become a model for the community.

ACTION ITEM 21: The UFSMP will establish a recommended pruning cycle for Town trees.

9.3. Effect of tree cover on parking lots

A recent study looked at the effect of commercial parking lot location on the health of trees 10 years after planting. It found that Chinese elm trees planted in the median of parking lots surrounded by expansive areas of asphalt (analogous to a boulevard) were about 60% shorter, 52% smaller in diameter and had 57% less foliage than their counterparts planted in large landscape areas around the parking lot perimeter (Celestian and Martin 2005).

Some of the harshest sites can be made suitable as tree habitat. In the photographs below, parking lots in the City of Ithaca, New York have been re-designed using structural soil.

Asphalt removed 15' into the parking lot from the tracks, continuously for 60'. Structural soil placed 30" deep and asphalt reload. Trees in second year of growth after transplanting. Source: http://www.hort.cornell.edu/uhi/outreach/csc/ssoils/sld041.htm

Potential use of structural soil in enlarge planting islands in parking lots without taking parking space.
Source: http://www.hort.cornell.edu/uhi/outreach/csc/ssoils/sld049.htm

City of Sacramento parking lot ordinance:

An example of successfully combining parking lot re-design with municipal regulation is the City of Sacramento. Their parking lot tree shading ordinance requires that all new parking lots include tree plantings designed to result in 50 percent shading of parking lot surface areas within 15 years. This approach results in reduced air temperature through tree shade, and indirectly reduces the emissions of some pollutants that are temperature dependent, such as hydrocarbons released through gasoline (Section 3.2). This 'cool parking lot' initiative can complement the 'Prime Site Management' initiative for high density urban design. (Source:http://www.cityofsacramento.org/parksandrecreation/urbanforest/pdf/shading_guidlines_06-05-03.pdf). This intiative could consider options to increase canopy coverage and may also be useful for stormwater management, i.e. **rain gardens**.

ACTION ITEM 22: Review the Site Plan design guidelines for parking lot design with respect to tree habitat and establish targets for urban forest canopy cover attainment linked to ACTION ITEM 11.

9.4 Identification of tree stress using remote sensing infrared imagery (IR)

The Town purchased digital color infrared photography at sub-meter resolution level for the U.S. Forest Service as a prerequisite for developing a digital cover map. Staff put the photography to an innovative use: interpreting forest health (Figure 21).

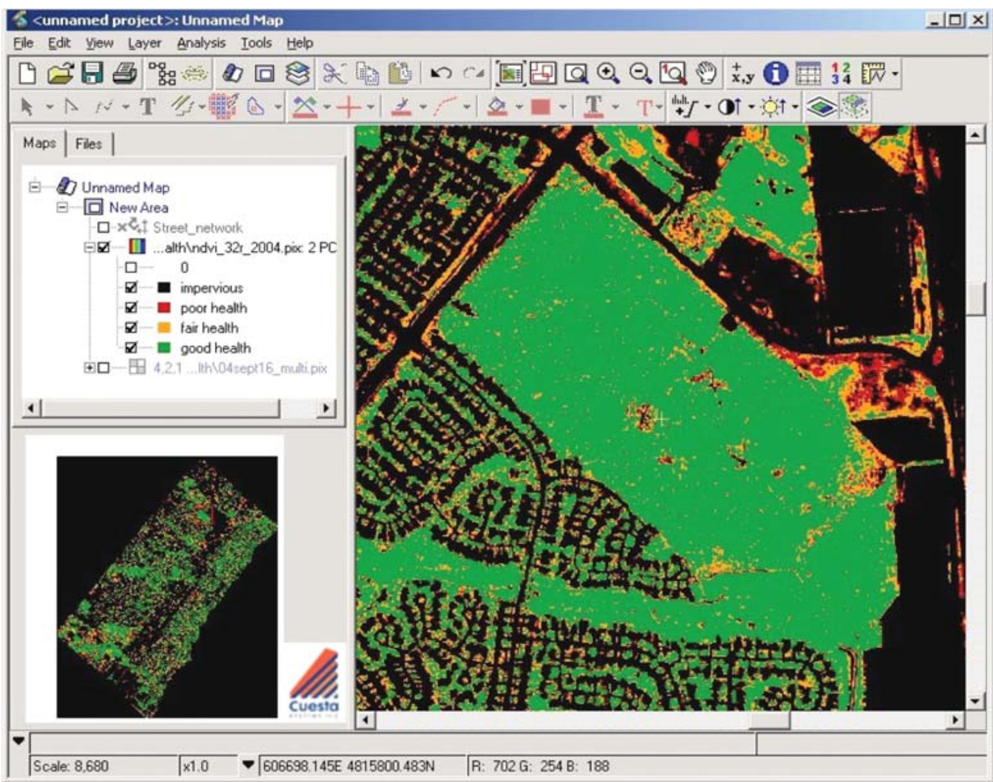


Figure 21. Assessing tree health using IR photography (Image showing Iroquois Shoreline Woods Park).

There is literature based merit in this approach. Once refined, this approach could become a cost effective method to identify hazard trees especially along the Town's 125 + km of nature trails. Forestry staff found a correlation between tree health and degree of site alteration: trees located near compacted soil conditions due to construction, for example along nature trails, appear to exhibit a pattern of color on the infra-read photo that indicates fair to poor health.

ACTION ITEM 23: Forestry staff to conduct a pilot project to fine-tune IR photography as a cost saving technique to identify areas that contain hazard trees.

9.5 Towards an Inventory-based maintenance management system

From a 2003 case study conducted by the Forestry Section, the average cost to collect tree inventory data with the records required by Town of Oakville Tree Management System, TOTMS was in the range of $6-7 per tree. The Forestry Section has worked with the GIS Section to try and develop cost effective methods to inventory 'Heritage Trees' (as defined by the Ontario Heritage Tree Alliance). Another key inventory tool, developed by the USDA Forest Service in Davis, CA is i-Tree. It will calculate the cost-benefit ratio of investing in the Town's urban forest. The photograph below is from the U.S. Forest Service i-Tree web page.

ACTION ITEM 24: The Forestry Section to submit a 2007 Capital project budget request to conduct an inventory of Town owned street trees, Town Woodlands plus Heritage trees as well as develop a capital budget schedule to inventory the balance of the Town trees in the Open Space Land Use type.

9.6. Next steps

9.6.1 Measuring Ecological Services

"The term urban forestry is often considered a contradictory term-rather like jumbo shrimp, freezer burn, and military intelligence. But urban forestry is not a contradiction of terms; it's an integral part of a city's infrastructure, just like the street systems, water systems, and lighting systems. If trees are a part of the infrastructure, then they must be managed like any other part in order to maximize their benefits and minimize their costs" (Moll and Ebenreck 1989).

"Urban natural capital requires careful management to grow and enhance its quality for the life of future generations; is something that cities simply cannot afford to waste" (Wilkie and Roach 2004).

Now that UFORE has established 372 permanent sample plots throughout Oakville, Forestry staff can measure and analyze changes in the urban forest over time (Appendix 9).

ACTION ITEM 25: The Forestry Section will update UFORE every four years and provide a State of the Urban Forest Report to Council.

Source: http:/www.itreetools.org/

10 Conclusion and Recommendations

The Town of Oakville has demonstrated that municipalities can take a scientific approach towards measuring the suite of ecological services provided by their urban forest. This leadership role in Canada is timely given that a NASA study pegged 2005 as the warmest year on record (Globe and Mail 2006).

Strategies to enhance urban trees' ecological services (Nowak undated):

- Aiming for species, size and age diversity (reduces the impact of pests)
- Increasing the number of healthy trees
- Maximizing use of low VOC emitting trees
- Sustaining and increasing existing tree cover
- Sustaining large, healthy trees (greatest per tree effects)
- Using long-lived trees (reduces long-term pollutant emissions from planting and removal)
- Using low-maintenance trees (reduces fossil fuel use in maintaining vegetation)
- Planting trees in energy conserving locations
- Planting large trees as part of transportation corridors (extend the life of streets, reduce CO_2) and parking lots whenever possible (cooling and reduction effect on VOC's emissions by parked vehicles)
- Planting trees in polluted areas or heavily populated areas
- Avoiding pollutant sensitive species
- Utilizing evergreen trees for particulate matter reduction (year-round removal of particles)

10.1. Summary of Action Items

ACTION ITEM 1: Obtain detailed outputs on the human health benefits from Oakville's urban forest by combining the results of the AQBAT and UFORE models in conjunction with the Halton Region Health Department. Page 5.

ACTION ITEM 2: The Finance Department and the Parks & Open Space Department should review the 10 Year Capital Forecast to ensure that operating costs for Street trees and Park trees and Woodland Parks are captured based on a maintenance standard recommended in the UFSMP. Page 16.

ACTION ITEM 3: The UFSMP will develop a private urban forest stewardship education program. Page 17.

ACTION ITEM 4: The UFSMP should outline the creation of a pro-active under planting program in those Communities at risk of decreasing urban forest canopy cover due to aging trees. Page 22.

ACTION ITEM 5: It is recommended that the USDA modify the UFORE plot tally sheet to record the type of energy used for heating (gas, electricity, oil, etc) on each household where trees are over 20 feet tall and within 60 feet of residential buildings three stories or less in height in order to more accurately calculate the value of energy savings. Page 23.

ACTION ITEM 6: The Town should prepare an EAB Action Plan. Page 24.

ACTION ITEM 7: It is recommended that UFORE consider incorporating Leaf Area Density and Potential Leaf Area Density. Page 27.

ACTION ITEM 8: The Town should investigate the feasibility of an incentive program for private large-stature trees in order to maximize filtration of criteria pollutants and GHG's. Page 28.

ACTION ITEM 9: The Forestry Section should work with the Forest Gene Conservation Association to create a gene conservation program for the Town. Page 28.

ACTION ITEM 10: The Parks and Open Space Department should identify opportunities for Parks Naturalization that contributes to the forest canopy and prepare capital budget costs. Page 28

ACTION ITEM 11: The Forestry Section should Chair an interdepartmental/interagency Technical Advisory Committee to recommend:

b) Urban forest canopy cover targets for Oakville and;
b) How key Town Departments can contribute to achieving these targets. Page 28.

ACTION ITEM 12: The Town should undertake a pilot rooftop garden demonstration project that can contribute to forest canopy coverage. Page 28.

ACTION ITEM 13: The Town should investigate the feasibility of trading carbon credits. Page 29.

ACTION ITEM 14: Amend the Town's Official Plan, Part C, Section 10.4 to recognize the municipal urban forest as a component of the municipality's "infrastructure." Page 30.

ACTION ITEM 15: The Tree Habitat Design Guidelines for Oakville should be reviewed with the interdepartmental technical Advisory Committee identified in ACTION ITEM #11 to incorporate them into the Town's urban design standards of key Town Departments. Page 30.

ACTION ITEM 16: Town Council should endorse the initiative of the International Society of Arboriculture, Ontario Chapter which calls upon the Ontario Ministers of Municipal Affairs & Housing and Natural Resources to support healthy urban forests in Ontario as outlined on the web site of the Canadian Urban Forest Network (http://www.treecanada.ca/programs/urbanforestry/cufn/cufn.html). Page 31.

ACTION ITEM 17: The interdepartmental Technical Advisory Committee, identified in Action Item #11, should investigate the potential role of zoning by-laws to reserve for the use of the tree the land which supports the tree. Page 32.

ACTION ITEM 18: The Forestry and the Design & Construction Sections will work together to expand the CU- SOIL pilot project which was initiated in UpTown Core in 2005. Page 35.

ACTION ITEM 19: THE UFSMP to identify a Prime Site management Program for Large-stature and Medium-stature trees. Page 36.

ACTION ITEM 20: The Parks and Open Space Department to establish a 'soil restoration program' as part of its 'Prime Site' management program. Page 37.

ACTION ITEM 21: The UFSMP will recommend a pruning cycle for Town trees. Page 37.

ACTION ITEM 22: The Town to review the Site Plan design guidelines for parking lot design with respect to tree habitat and establish targets for urban forest canopy cover attainment linked to ACTION ITEM 11. Page 38.

ACTION ITEM 23: Forestry staff to conduct a pilot project to fine-tune IR photography as a cost saving technique to identify areas that contain hazard trees. Page 38.

ACTION ITEM 24: The Forestry Section to submit a 2007 Capital project budget request to conduct an inventory of Town owned street trees, Town Woodlands plus Heritage trees as well as develop a capital budget schedule to inventory the balance of the Town trees in the Open Space Land Use type. Page 39.

ACTION ITEM 25: The Forestry Section will update UFORE every four years and provide a State of the Urban Forest Report to Council. Page 39.

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Appendix 1: Letters to the Government of Ontario

ONTARIO CHAPTER
INTERNATIONAL SOCIETY OF ARBORICULTURE

ISA Ontario Inc.
200 Consumers Road
Suite 107
North York, Ontario
M2J 4R4

Telephone
1.888.463.2316

Facsimile
416.493.4608

Ministry of Municipal Affairs & Housing
777 Bay Street, 17th Floor
Toronto ON M5C 2E5
Feb. 16, 2006

Dear Minister John Gerretrsen

I am writing to you as a citizen of Ontario, to express my concerns about the state of our urban forests and with provincial government's limited involvement in its planning and administration.

I am a member of the International Society of Arboriculture, (ISA) the largest organization of professional tree care workers in the world. The organization has over 20,000 members with 37 chapters (one of which being the Ontario chapter), in 17 different countries. The 500 members who make up the Ontario chapter are municipal employees, owners and workers in private tree care companies, as well as people who support the industry, suppliers, manufacturers, and people within educational institutions. (see www.isaontario.com)

Our mission is to enhance and promote the care and benefit of trees for present and future generations in Ontario through education, research and awareness.

Our vision for Ontario towns and cities is a canopy of trees sheltering and protecting our communities as part of a green infrastructure that promotes habitat, healthy air, clean water quality of life and economic prosperity.

It is becoming increasingly more difficult to maintain that vision as our urban centers continue to expand and our urban forests decline while having to deal with escalating adversities. Our urban forests are in a perilous situation. The combine effects of a warmer, drier climate, invasive insect infestations, ageing tree populations, and high density development, make growing and maintaining trees an arduous task. In many municipalities we are actually loosing the battle, in the central section of Toronto the urban forest has shrunk from 22% crown cover in 1992 to only 16% in 2004.

If we are to change this dangerous trend, greater resources and attention is clearly needed, in the form of research, funding, communication, enhanced regulations.

In his recent 2004 - 2005 annual report Gordon Miller, the Environmental Commissioner of Ontario identified "sustaining urban forests" as one of five developing areas of concern in our province. He recommended that the Ministry of Natural Resources and the Ministry of Municipal Affairs and Housing develop a coordinated urban forest strategy to protect urban and heritage trees, working together with municipalities, ENGOs, and local agencies. (see www.eco.on.ca)

In addition a similar initiative is in place at the national level. Theme #6 of the National Forest Strategy 2003 to 2008 clearly states its objective; to actively engage Canadians in sustaining the diversity of benefits underlying the importance of Canadian's urban forest by 1. establishing mechanisms to advance the planning, maintenance and management of urban forests 2. enhancing communication and outreach programs. (see www. nfsc.forest.ca)

In recognizing the vital role our urban forests play in the quality of our environment, our organization whole heartedly supports these objectives and recommendations and would like to encourage you and your ministry colleagues to follow Mr. Miller's directive, as well as offer our assistance.

Ontario needs to move out of the "emergency mode" of responding to urban forest cries. Ontario needs an urban forest strategy so we can begin to plan and act for the future of this great province.

Yours Sincerely,

ISA Ontario Inc.
200 Consumers Road
Suite 107
North York, Ontario
M2J 4R4

Telephone
1.888.463.2316

Facsimile
416.493.4608

Email
info@isaontario.com

Ministry of Natural Resources
6630 Whitney Block
99 Wellesley Street West
Toronto ON M7A 1W3

Feb. 16, 2006

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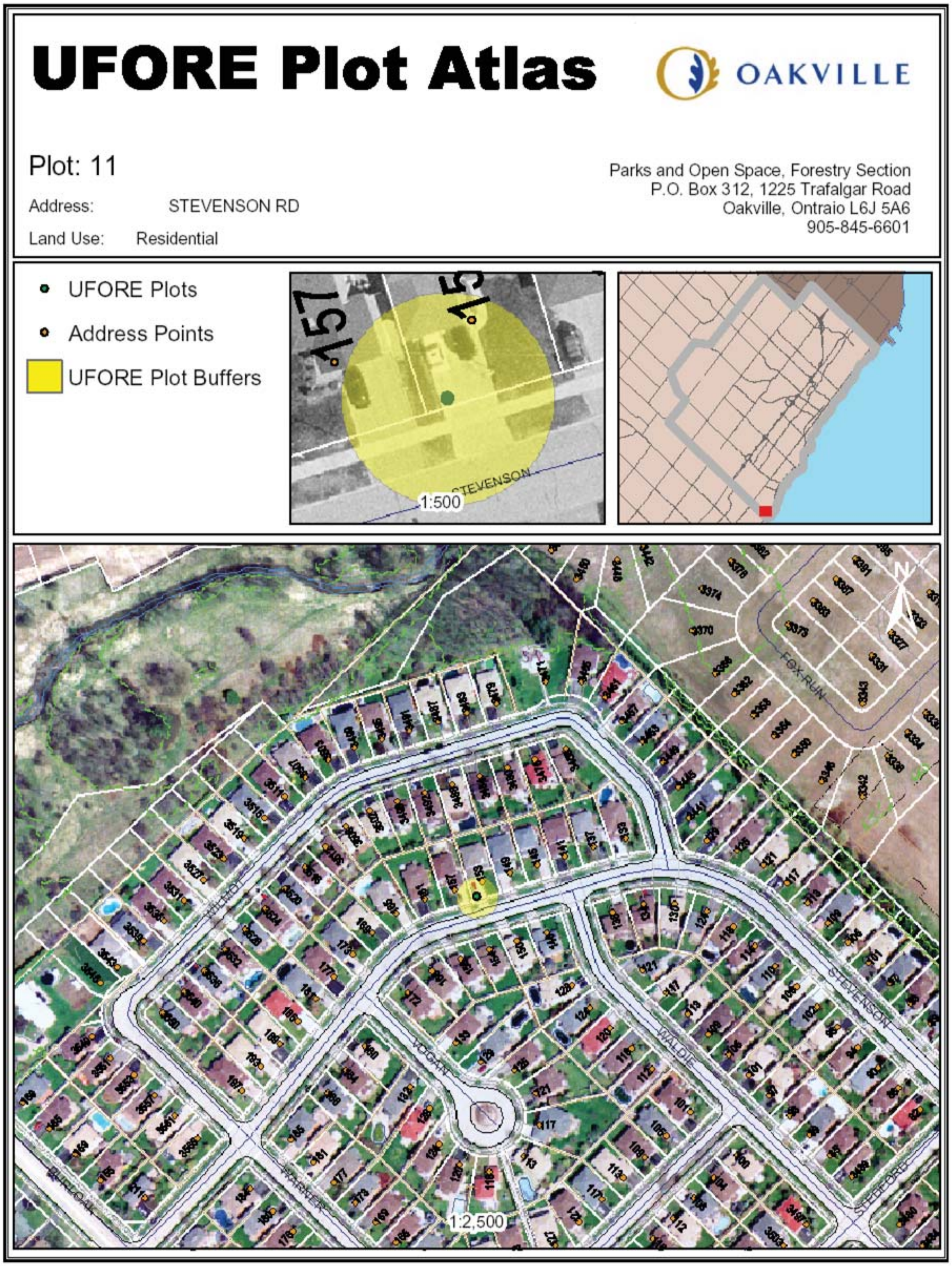
Yours Sincerely,

Appendix 2: UFORE Plot Atlas Sample Page



Appendix 3: Letter to the residents

May, 2005

Dear Sir/Madam:

The Town of Oakville in collaboration with the U.S. Forest Service and The University of Toronto, Faculty of Forestry is currently conducting a project called the Urban Forest Effects Model (UFORE). The purpose is to document the effects and benefits that trees, shrubs, and other types of vegetation that grow within the Town have on our urban environment. The results of this project will provide support and background for the Town's Urban Forest Strategic Plan. In order to accomplish this, sample plots have been located throughout the Town, including residential areas, to gather data about the vegetation.

I would like to ask your support with the accomplishment of this project by giving your permission to our crew (two persons) to access your property for the purpose of measuring and recording: % of tree cover, tree species, diameter of trees at breast height, total height of trees, ratio of height to ground base, crown width, % of canopy missing, dieback, crown light exposure, and direction and distance to buildings. The intended period of field work (for the entire town area) is set between early June-late August, during 8.00am-4.00pm, Monday to Friday. Information about your municipal address will be kept confidential.

Please feel free to contact the project coordinator, Cristofor Vava, at (905) 845-6601, ext. 3539 for any questions regarding any aspect discussed in this letter. To grant your permission please sign and return the attached permission form and return it in the posted paid envelope.

Thank you for your support and cooperation.

John McNeil, RPF, Certified Arborist
Manager of Forestry and Cemetery Services
Parks & Open Space

AUTHORIZATION

I hereby give my permission to the Town of Oakville to enter onto my property for the purpose of measuring and recording: % of tree cover, tree species, diameter of trees at breast height, total height of trees, ratio of height to ground base, crown width, % of canopy missing, dieback, crown light exposure, and direction and distance to buildings as required for the UFORE project.

Resident name (Print and sign)………………………………………………__________

ADDRESS:
____

Signature____

DATE:
____

Appendix 4: Mixed Conditions

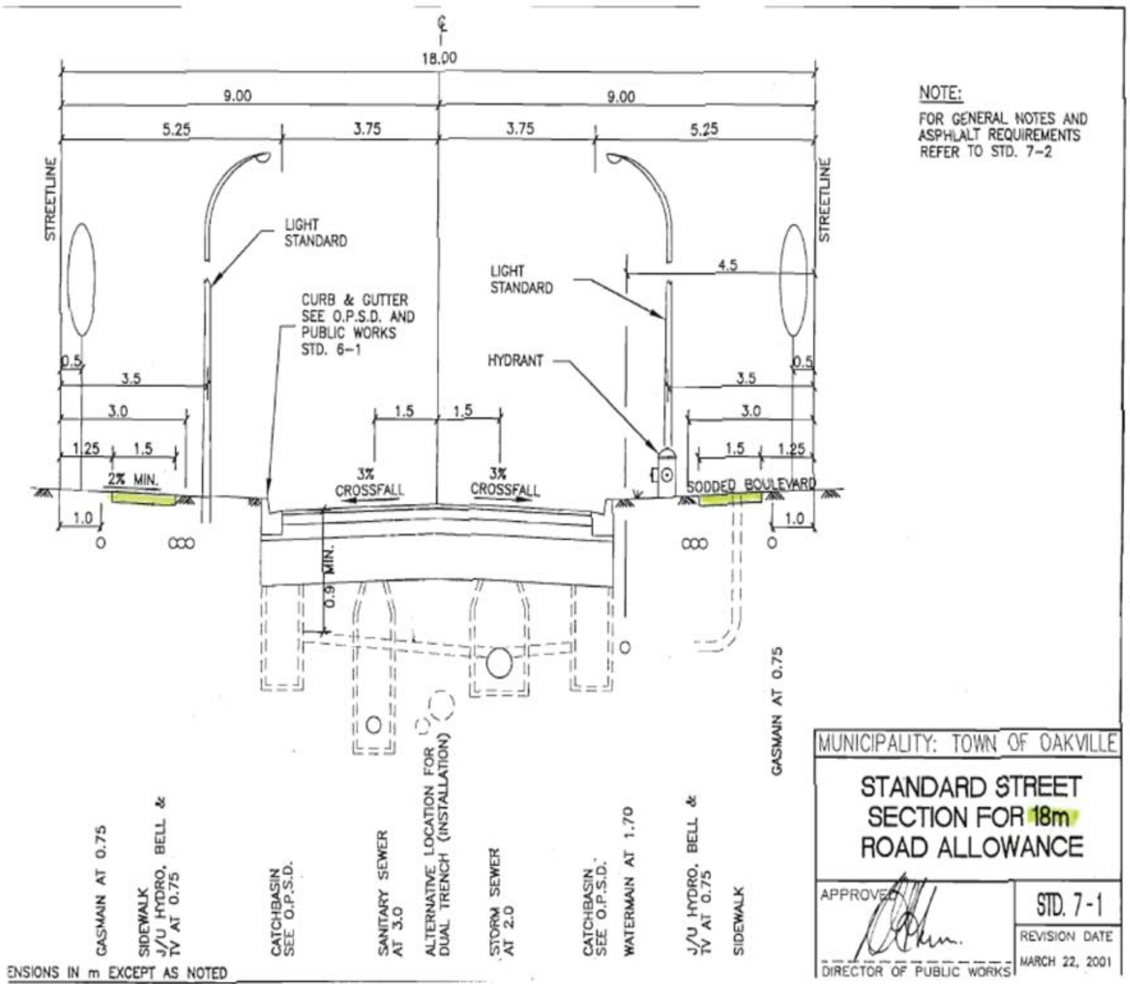
Multiple ownership

Dr. Kenney with Oakville forestry students.

Appendix 5: Land Use Type Definitions

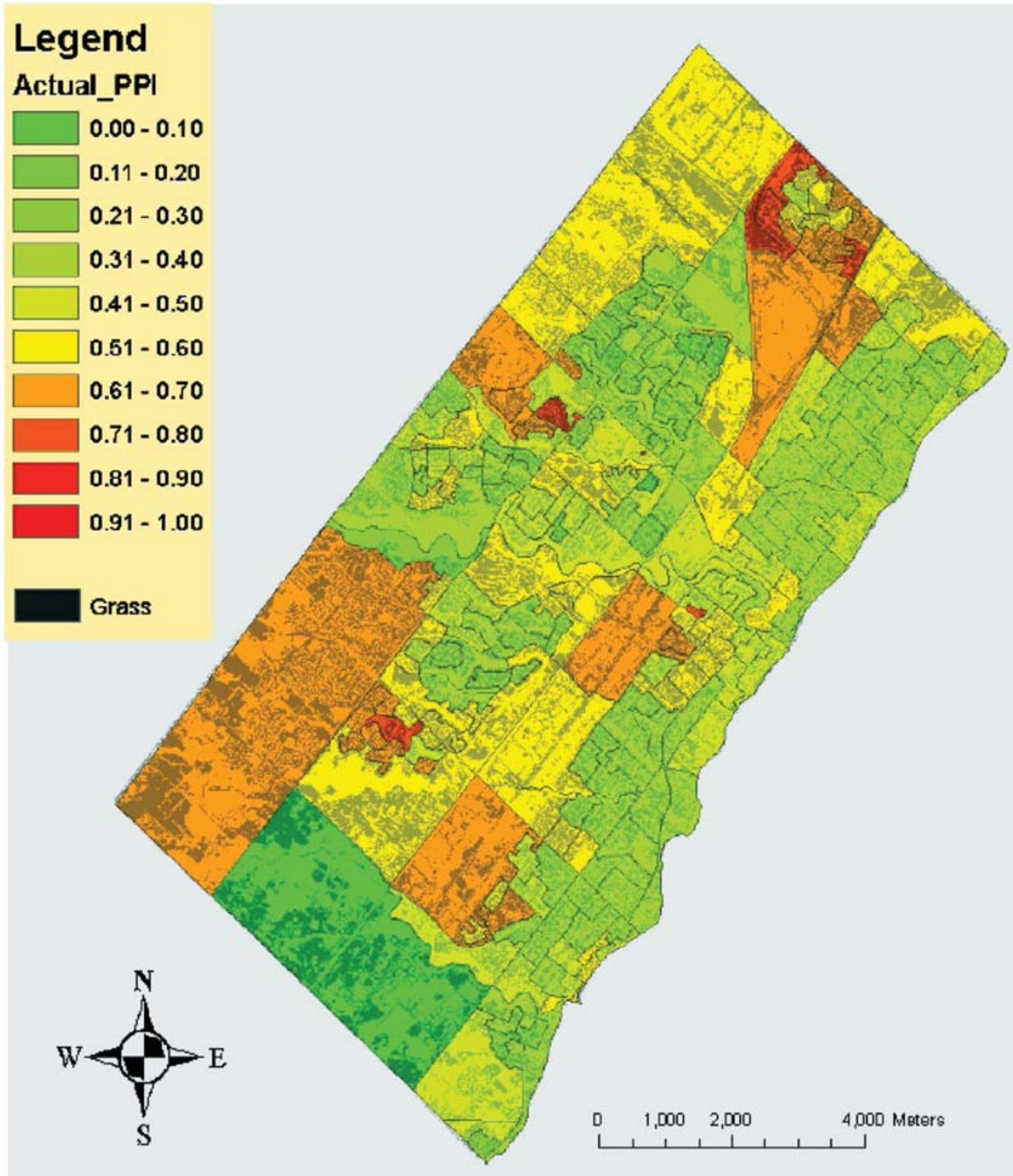
Land Use	Definition
Agriculture	The use of land, buildings & structures for the production of crops, animal husbandry or other similar uses normally associated with agriculture including residential.
Commercial/ Office	The use of land, buildings & structures for the purpose of buying and selling commodities and supplying of services including offices.
Industrial/ Employment	The use of land, buildings & structures for manufacturing, processing, fabricating or assembly of raw materials or goods, warehousing including offices.
Public Use/ Open Space	The use of land, buildings & structures for public purposes including public and private parks and schools.
Parkway Belt	A land use established by the Ontario government to protect mainly agricultural land for potential future transportation corridors and hydro transmission lines.
Residential	The use of land, building & structure for human habitation. There are numerous sub-classes within the residential designation permitting different housing types.

Source: Don Parsons, Development Services, 2006.



Source: The Corporation of the Town of Oakville; Department of Public Works; Standard Drawings 2004.

Priority Areas to plant new trees



PPI - planting priority index (0=low; 1=high)
Grass area (potential planting spaces) highlighted in gray.

Appendix 8: Best Species For Air Quality Improvement

Top 25 species - **currently used by the Forestry Section** - for air quality improvement in Oakville. Index value is based on a relative index of 0 (lowest ranked tree) to 100 (highest ranked tree) for trees suitable to hardiness

Scientific Name	Common Name	Index Value
*Liriodendron tulipifera**	Tulip tree	100.0
*Tilia americana**	American basswood	97.7
Zelkova serrata	Japanese zelkova	95.0
Aesculus hippocastanum	Horsechestnut	94.9
*Tilia cordata**	Littleleaf linden	94.8
*Acer platanoides**	Norway maple	94.3
Celtis occidentalis	Northern hackberry	94.0
Pinus strobus	Eastern white pine	93.6
Acer rubrum	Red maple	93.4
Acer x freemanii	Freeman maple	93.2
Gymnocladus dioicus	Kentucky coffee tree	93.0
Morus rubra	Red mulberry	92.9
Acer pseudoplatanus	Sycamore maple	92.6
Sassafras albidum	Sassafras	92.4
Acer saccharum	Sugar maple	92.2
Ulmus pumila	Siberian elm	92.0
Abies alba	Silver fir	91.8
Ginkgo biloba	Ginkgo	91.8
Acer saccharinum	Silver maple	91.6
Pinus sylvestris	Scotch pine	91.6
Carya cordiformis	Bitternut hickory	91.6
Ailanthus altissima	Tree of heaven	91.5
Carya ovata	Shagbark hickory	91.4
Juglans nigra	Black walnut	91.2
Acer campestre	Hedge maple	91.0

*** - species found in UFORE sample of Oakville's trees**

Appendix 9: Oakville tree distribution by diameter size (DBH)

Number of trees by land use

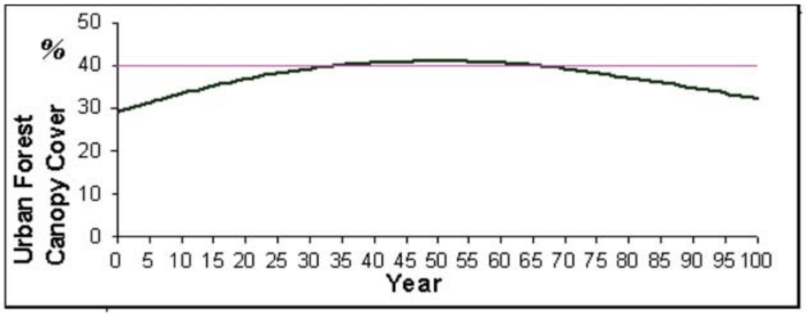
Dbh. class (cm)	A	C	E/I	OS	W	PU	RL	RM+H	Pkwy	Total
0 - 7.6	0	6624	39480	207474	491429	757	88681	200746	4900	1040092
7.7 - 15.2	0	6624	29070	46925	177657	0	68781	80146	980	410184
15.3- 22.9	0	6034	11589	17117	87503	1515	17087	50377	1960	193182
23 - 30.5	632	0	5794	13871	48613	757	11680	19846	0	101193
30.6- 38.1	0	1814	4616	4132	30051	0	10598	10304	0	61516
38.2- 45.7	0	0	2357	1181	22980	0	3893	7251	0	37663
45.8- 53.3	0	0	2946	2361	11490	0	4975	4580	0	26352
53.4- 61	0	0	589	1181	5303	0	4542	3053	0	14668
61.1- 68.6	0	0	1179	590	5303	0	2163	2290	0	11525
68.7- 76.2	0	0	589	0	1768	0	1730	0	0	4087
76.3- 83.8	632	0	0	0	1768	0	0	1527	0	3926
83.9- 91.4	0	0	0	0	0	0	1081	0	0	1081
91.5- 99.1	0	0	0	0	0	0	1081	763	0	1845
99.2- 106.7	0	0	0	0	0	0	0	763	0	763
106.8- 114.3	0	0	0	0	0	0	0	0	0	0
114.4- 121.9	0	0	0	0	0	0	0	0	0	0
122 - 129.5	0	0	0	0	0	0	0	0	0	0
129.6- 137.2	0	0	0	0	884	0	0	0	0	884
Total	1264	21097	98210	294831	884749	3029	216294	381647	7840	1908961

Appendix 9: Oakville tree distribution continued ...

Distribution of trees (%) by land use

Dbh. class (cm)	A	C	E/ I	OS	W	PU	RL	RM+H	Pkwy
0 - 7.6	0	31.4	40.2	70.3	55.6	25	41	52.6	62.5
7.7 - 15.2	0	31.4	29.6	15.9	20.1	0	31.8	21	12.5
15.3 - 22.9	0	28.6	11.8	5.8	9.9	50	7.9	13.2	25
23 - 30.5	50	0	5.9	4.7	5.5	25	5.4	5.2	0
30.6 - 38.1	0	8.6	4.7	1.4	3.4	0	4.9	2.7	0
38.2 - 45.7	0	0	2.4	0.4	2.6	0	1.8	1.9	0
45.8 - 53.3	0	0	3	0.8	1.3	0	2.3	1.2	0
53.4 - 61	0	0	0.6	0.4	0.6	0	2.1	0.8	0
61.1 - 68.6	0	0	1.2	0.2	0.6	0	1	0.6	0
68.7 - 76.2	0	0	0.6	0	0.2	0	0.8	0	0
76.3 - 83.8	50	0	0	0	0.2	0	0	0.4	0
83.9 - 91.4	0	0	0	0	0	0	0.5	0	0
91.5 - 99.1	0	0	0	0	0	0	0.5	0.2	0
99.2 - 106.7	0	0	0	0	0	0	0	0.2	0
106.8 - 114.3	0	0	0	0	0	0	0	0	0
114.4 - 121.9	0	0	0	0	0	0	0	0	0
122 - 129.5	0	0	0	0	0	0	0	0	0
129.6 - 137.2	0	0	0	0	0.1	0	0	0	0

A) 2% annual average mortality:



No tree planting needed to reach the canopy cover goal of 40%;
this would lead to a reduction in tree population after 2050

Plant 0 trees annually to reach goal

Canopy Growth > canopy loss, but population will plummet in future without new trees