Kelowna's Urban Forest:

Urban Forest Effects (UFORE) Analysis

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Acknowledgements

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Executive Summary

A growing body of research demonstrates that trees and other vegetation provide important “ecosystem services”, providing benefits such as clean water and air, climate regulation, cultural and recreational benefits, and supporting wildlife and biodiversity. The Urban Forest Effects (UFORE) model was developed by the US Forest Service to help quantify some of the key benefits provided by urban vegetation.

During the summer of 2007, 150 randomly located plots were assessed by a ground crew to characterize the structure of Kelowna’s urban vegetation. These data were analyzed in the UFORE model, to produce the following key findings:

Feature	Measure
Major tree species, by % canopy cover	▪ Douglas-fir (33%) ▪ Ponderosa pine (24%) ▪ Apple (19%) ▪ Other (24%)
Estimated number of trees in Kelowna	3.3 million
Total replacement value of Kelowna’s trees	$ 1.1 billion
Total carbon stored in Kelowna’s trees	126,900 metric tonnes
Carbon sequestered annually by Kelowna’s urban forest	7,500 metric tonnes
Susceptibility to exotic and native pests (% susceptible host by leaf area)	▪ Asian longhorned beetle (34%) ▪ Pine beetle (24%) ▪ Gypsy moth (23%) ▪ Dutch elm disease (4%) ▪ Emerald ash borer (1.6%)
Pollution removed annually by urban forest and value of the removal	195 tonnes ($1.1 million)
Volatile Organic Compounds (VOC’s) produced annually by trees	43 tonnes
Ozone index score*	94 (out of 100)
Annual energy savings due to trees and annual carbon emission reductions due to power savings	$ 19.4 million / 1,800 tonnes carbon
Average vegetation cover, plantable space and impervious surfaces	▪ Trees - 12.8% ▪ Shrubs - 9.1% ▪ Grass - 42.3% ▪ Plantable space - 27.3% ▪ Buildings, impervious – 12%

* A perfect score of 100 represents forest composition where all species have the maximum effect on reducing ozone (lowest possible VOC emissions).

The top three species in Kelowna, Douglas-fir, ponderosa pine and apple, comprise 76% of the total tree canopy, indicating a low level of diversity overall. Most of these species are located on natural, undeveloped lands, or on agricultural lands, indicating the high importance of these areas for providing ecosystem services. As some of these areas are developed in the future, some ecosystem services will be lost and may have to be replaced through investments in stormwater, water purification or other “grey infrastructure” improvements.

The major threats to Kelowna’s urban forest in the next decade are mountain pine beetle, development, and wildfire. The model estimates that Kelowna has about 606,000 ponderosa pine trees, with a replacement value of $181 million. According to the provincial government, we are likely to lose about 80% of these trees (primarily mature trees) due to pine beetle.

Kelowna’s current tree canopy is only about 13%, on average, although there is another 27% plantable space. Areas with the highest tree cover include vacant / wildland (23%), and agriculture and rural lands (15%), while the lowest cover (3%) occurs on land zoned as commercial / industrial and transportation.

Strategies to enhance the ecological services of urban trees in Kelowna include:

1) Aiming for species, size and age diversity (reduces the impact of pests);
2) Increasing the number of healthy trees;
3) Maximizing the use of low VOC emitting trees to improve air quality;
4) Sustaining and increasing existing tree cover;
5) Sustaining large, healthy trees (greater benefits per tree);
6) Using long-lived species (reduces carbon emissions from planting and removal activities);
7) Using low-maintenance trees (reduces fossil fuel requirements for maintaining vegetation);
8) Planting trees in energy-conserving locations;
9) Planting trees as part of transportation corridors (extends the life of streets, reduces carbon dioxide emissions) and parking lots (cooling effect and reduction of VOC emissions from parked vehicles);
10) Planting trees in polluted areas;
11) Avoiding pollution sensitive tree species;
12) Utilizing evergreen trees for particulate matter reduction (year-round removal of pollutants).

1.0 Introduction

The Urban Forest Effects (UFORE) computer model was developed by the USDA Forest Service as part of the i-Tree Software Suite. UFORE is designed to use standardized field data from randomly located plots throughout a community, along with hourly air pollution and meteorological data, to quantify the structure and function of the urban forest. The model calculates the following information:

- Urban forest structure (e.g. species composition, tree density, tree health, leaf area, leaf and tree biomass, species diversity, etc.);
- Hourly pollution removal by the urban forest and associated percent improvement in air quality (pollution removal is calculated for ozone (O_3), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and particulate matter (PM_{10}));
- Total carbon stored and net carbon sequestered annually by the urban forest;
- Effect of trees on building energy use for heating and cooling as well as the subsequent associated carbon dioxide emissions reductions; and
- Compensatory value of the urban forest, **as well as** the value for air pollution removal and carbon storage and sequestration

To date, UFORE analyses have been completed by three other Canadian cities: Toronto, Calgary, and Oakville. Kelowna is therefore the first community in British Columbia to successfully complete a UFORE analysis.

1.1 Rationale

Over the next decade and beyond, Kelowna's urban forest is likely to face three major threats: pine beetle, development, and wildfire.

The mountain pine beetle epidemic continues to spread throughout British Columbia's interior, affecting over 8 million hectares of pine forest in the central and southern regions of the province. According to projections by the Ministry of Forests and Range the infestation will likely continue to until 2018 and will kill approximately 80% of provincial pine volume in the central and southern Interior (MoFR 2007). Consequently, Kelowna is likely to see a dramatic change in forest structure and composition as both the western pine beetle (*Dendroctonus brevicomis)* and mountain pine beetle (*Dendroctonus ponderosae)* continue to attack native ponderosa pine (*Pinus pondersa*) as well as exotic pines planted in landscapes. Significant mortality in Kelowna's mature pine forests has been observed in recent months and as a result local canopy cover is quickly declining, a trend which is likely to continue in the future. The UFORE analysis will not only aid in the estimation of the potential impact of the pine beetle epidemic, it will also identify and prioritize areas for future tree planting initiatives. In addition, the study will provide a baseline for future research.

The 2006 Census revealed that Kelowna's population grew by 10.6% from 2001 to 2006, thus making it one of the fastest growing municipalities in the province. The growth rate between 2007-2017 is projected the City Planning Department to be 25%, *with most of the growth occurring in areas that are currently forested or natural areas*. As the city continues to grow, increasing pressure will be placed on the existing forest cover to provide essential environmental, economic, and social services. In particular, demand for air pollution abatement and local climate change mitigation will surely increase. Yet at the current pace of expansion a reduction in canopy cover will be seen as forested areas are cleared for residential developments.

Significant areas of forest have already been lost due to 2003 wildfires in the southwest corner of the city and in the adjacent Crown forests. Catastrophic wildfire continues to be a major threat to Kelowna's forests although management activities over the last several years have helped to lower the risk to forests, people and property. However, the desire to retain trees and vegetation will also have to be balanced with the need to thin and remove vegetation in order to mitigate the risk of wildfire.

By quantifying the current structure of Kelowna's urban forest, the UFORE project will help guide future canopy cover targets which will optimize the potential benefits of urban trees. Ultimately the results of the UFORE analysis will assist in the future management and planning of the community's green infrastructure.

1.2 The Role of the Urban Forest

Trees greatly impact the quality of urban life by providing a number of valuable environmental, economic, and recreational services. The urban forest directly benefits the community by improving local air quality, reducing energy consumption, increasing land values and local tax bases, enhancing public safety, conserving water resources, and reducing soil erosion. In addition, city trees beautify the landscape and provide invaluable psychological benefits to urban dwellers.

1.2.1 Air Quality

Urban air pollution can have direct impacts on human health. By significantly reducing the amount of airborne pollutants trees can mitigate the potential health problems associated with poor air quality. Ground level ozone (O_3) and airborne particulate matter (PM_{10}) are two pollutants which pose a significant threat to human health. Ozone is not emitted directly but rather is created by chemical reactions between oxides of nitrogen (NO_X) and volatile organic compounds (VOCs) such as gasoline fumes, in sunlight. Trees also produce their own VOC's, with some species producing higher levels than others. However, in the absence of nitrogen oxides (which come almost entirely from human sources), these VOC's can actually reduce ozone concentrations. 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. Thus, urban trees, particularly species which emit low levels of VOCs, are a viable strategy to reduce urban O_3 levels (Cardelino and Chameides 1990; Nowak et al. 2000a).

Air borne particulates consist of microscopic solids or liquid droplets, often originating from smoke and diesel soot, which form in the air from oxides of nitrogen and sulphur. These harmful pollutants are problematic as they can irritate and damage lung tissue. Trees reduce the amount of particulate matter by intercepting and storing large airborne particulate on outer leaf surfaces, rough branches and bark surfaces (Nowak et al. 2006). In addition, trees improve air quality by binding or dissolving water soluble pollutants onto moist leaf surfaces. Other gaseous air pollutants, such as carbon monoxide and sulphur dioxide, are removed primarily by leaf stomatal uptake (Smith 1990).

Urban forests also play an integral role in the mitigation of high levels of atmospheric carbon dioxide (CO_2), an important greenhouse gas which contributes to global warming. Anthropogenic production of CO_2 is most notably a result of fossil fuel combustion and large-scale deforestation. Trees reduce atmospheric CO_2 levels through photosynthetic uptake and subsequent carbon sequestration in woody biomass. Furthermore, trees which are adjacent to buildings can reduce the demand for heating and air conditioning through their moderating influence on solar insolation, wind speed, and air temperature. This in turn reduces the emissions associated with fossil fuel combustion which are a direct result of heating and the provision of electric power for cooling (Simpson and McPherson, 2000**).**

1.2.2 Regional Climate Change

The "urban heat island" phenomenon describes urban and suburban temperatures that are 1 to 6°C warmer than nearby rural areas. Urban heat islands form as cities replace natural land cover with pavement, buildings, and other infrastructure. Increasing the canopy cover of the urban forest is an effective way to mitigate the heat island effect. The shade generated by tree canopies reduces the amount of solar radiation transmitted to underlying surfaces. Consequently, cooler surfaces lessen the heat island effect by reducing heat transfer to the surrounding air. Furthermore, evapotranspiration can result in peak summer temperature reductions of 1° to 5°C in urban areas

(EPA 2007). Every 1% increase in canopy cover results in maximum mid-day air temperature reductions of 0.04° to 0.2°C (Simpson 1998).

1.2.3 Energy Conservation

Trees can reduce summer temperatures substantially by providing localized shade and wind speed reductions. Trees also ameliorate climate by transpiring water from their leaves, which has a cooling effect on the atmosphere. Thus, the effective placement of a tree or shrub can efficiently lower building temperatures and decrease the demand for cooling. Simpson and McPherson (1999) report that shade from two large trees planted on the west side of a house and one on the east side can save up to 30% of a typical residence's annual air conditioning costs. During winter months trees which are properly placed to create windbreaks can also decrease heating requirements and produce savings of up to 25% on winter heating costs (Heisler 1986).

1.2.4 Water Conservation

When stormwater hits impervious surfaces common in urban areas the water is heated and various pollutants, including lawn fertilizers and oils on roadways, are picked up by the runoff. Water quality problems then arise when large volumes of heated and polluted stormwater flow into receiving waters, posing threats to temperature sensitive species as well as providing conditions for algal blooms and nutrient imbalances. Tree cover helps intercept rainwater, thus reducing the amount, and speed, of stormwater in addition to filtering pollutants that eventually flow to receiving waters (Kollin 2006). A portion of the intercepted water evaporates back into the atmosphere while the remaining water soaks into the ground thereby reducing the total amount of runoff that must be managed in urban areas. Thus, the costs associated with stormwater management are much lower when significant urban canopy cover is maintained.

1.2.5 Social Benefits

Although more difficult to quantify the urban forest provides a variety of important social benefits. Urban trees have been found to significantly reduce crime levels. For example apartment buildings with high levels of greenery had 52% fewer crimes than those without trees (Kuo and Sullivan 2001). Furthermore, hospital patients were found to recover from major surgery more quickly and with fewer complications when provided with a view of trees (Ulrich 1984). Trees and urban parks also improve mental health and over all well-being by conveying a sense of calm and beauty as well as facilitating relaxation and outdoor activity. In addition, trees can offer screening, or reduce noise pollution by absorbing unwanted sound.

Trees and attractive landscaping are an important part of the “liveability” of a city and improving quality of life.

1.2.6 Economic Benefits

Trees and attractive landscaping are known to raise property values; there is also a link between proximity to green space and higher property values (Table 1). Furthermore, research shows that shoppers in well-landscaped business districts are willing to pay more for both parking and goods and services (Wolf 1999) and commercial properties can be receive higher rent with attractive landscaping (Table 1).

Table 1. Summary of research on price increase due to trees and landscaping (from Wolf 2007).

Price Increase	Condition
2%	Single mature yard tree (>9” diameter)
3-5%	Trees in front yard landscaping
4.9%	Multi-family unit with view of forested open spaces
7%	Rental rates for properties with quality landscaping
8%	House with a park view
6-9%	Good tree cover in a neighbourhood
9-12%	Increased consumer spending in forested business districts
10%	Inner-city home within ¼ mile (400 m) of a park
10-15%	Mature trees in high-income neighbourhoods
18%	Building lots with substantial mature tree cover
19%	Home adjacent to a passive park area
22%	Tree-covered undeveloped acreage
32%	Residential development adjacent to greenbelt
19-35%	Lots bordering suburban wooded preserves
37%	Open land that is 2/3 wooded

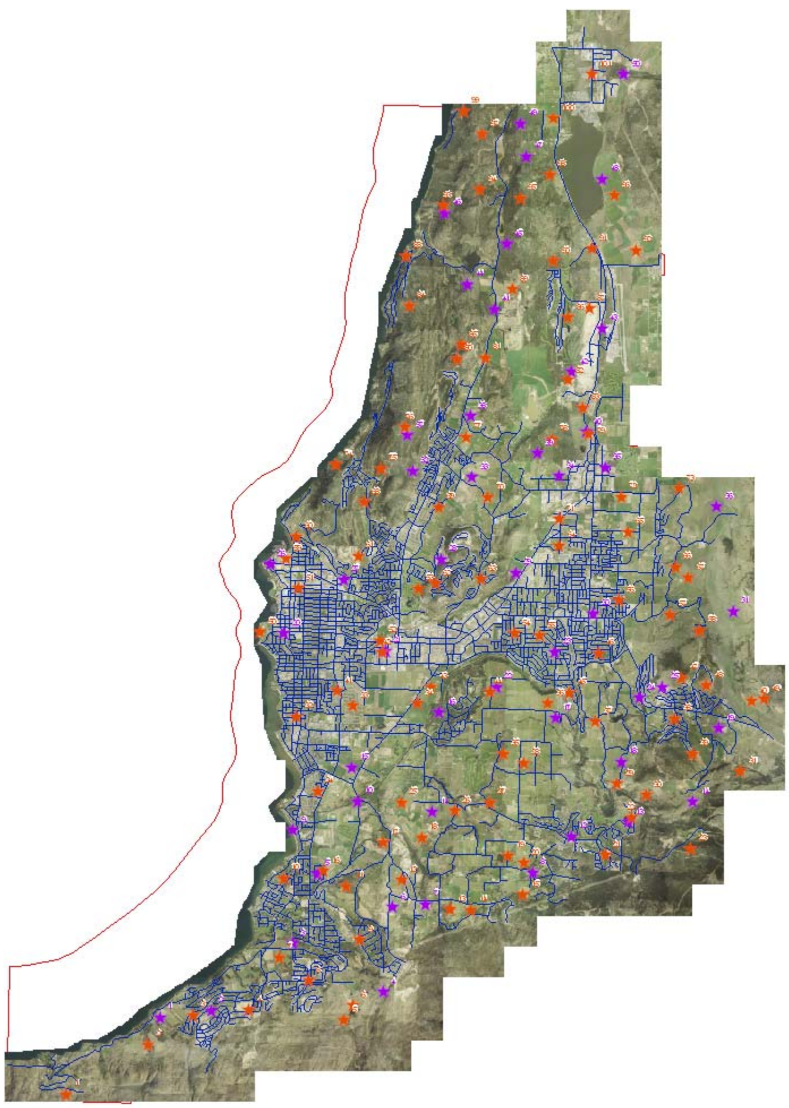
2.0 Methodology

2.1 Plot Selection

Kelowna’s UFORE analysis was based on a randomized sampling scheme in which 150 circular plots (10 meters in radius) were positioned at randomly selected locations, on a grid, throughout the 48,640 ha study area (Figure 1). In order to provide a more confident estimate of the population the number of plots was increased from the original 100 to 150. Although a higher sample size would yield more accurate results, the number of plots surveyed provided an acceptable level of standard error when weighed against the time and financial constraints associated with additional field data collection.

Each individual plot was identified in the City's mapping system and a high resolution orthophoto image was produced with the plot centre and site identification markings clearly indicated. GPS coordinates were also generated in order to facilitate accurate navigation to plot centre (see Appendix 1). Prior to entry, private property owners were contacted by telephone or through written communication in order to obtain permission to access their property. In the instance that a phone number could not obtained the field crew requested permission to access the property in person. If permission was not granted or access was restricted due to physical / topographic barriers, the field crew recorded measurements from the nearest representative location (Appendix 1).

Fig. 1. Plot locations in the City of Kelowna (red and purple stars).



2.2 Data Collection

Field data collection was conducted by a two member field crew during the summer leaf-on season of 2007. At each plot the present land-use was determined (e.g. residential) and detailed vegetation information was recorded in accordance with the UFORE manual specifications. Variables measured included ground cover types, shrub characteristics, foliage parameters and individual attributes of tree species. Specific tree measurements included diameter at breast height (DBH), height, crown width, percent canopy missing, crown dieback, and distance and direction to residential buildings. For a complete description of variables visit the UFORE manual at http://www.fs.fed.us/ne/syracuse/Tools/UFORE.htm.

2.3 Data Analysis

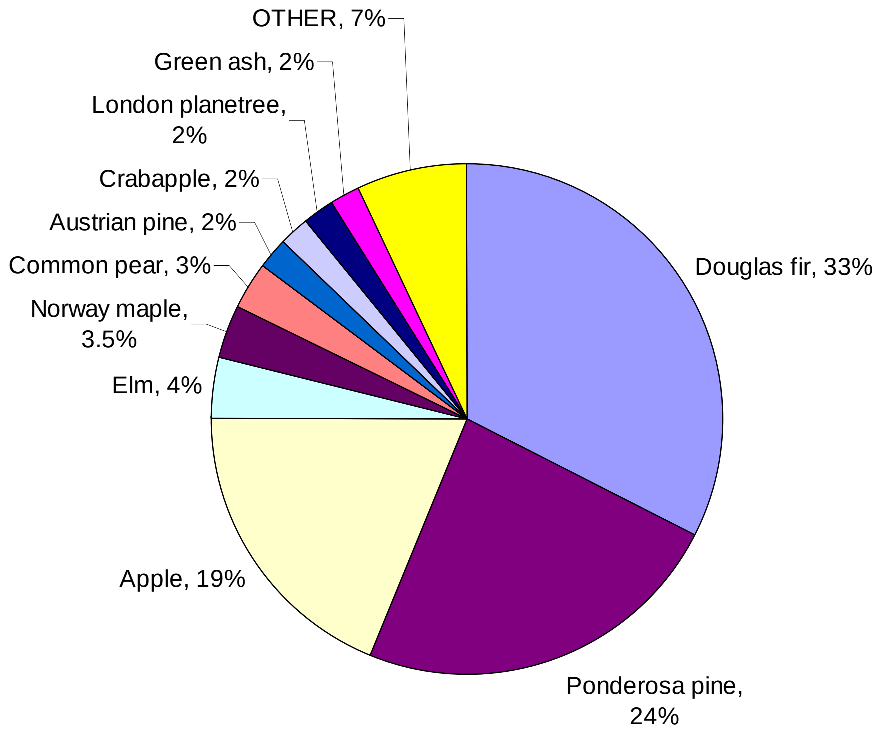
Data were input into excel spreadsheets in accordance with UFORE manual specifications, which were then submitted to the USDA Forest Service in Syracuse for analysis. Data processing was completed by the Forest Service and relevant output files were then forwarded to the Kelowna Parks Department for full interpretation.

3.0 Results and Discussion

3.1 Urban Forest Structure

Figure 2 illustrates the top ten tree species in Kelowna, by percentage canopy cover. Kelowna's urban forest has low diversity overall, as 75% of the total tree canopy is comprised of only three species, Douglas-fir, ponderosa pine and apple. An urban forest with higher diversity is more resilient to pest outbreaks, drought, disease, climate change or other disturbances. However, the ability to increase diversity in Kelowna's natural areas will be very limited due to the hot, dry climate. There are opportunities, however, to increase diversity in the urbanized areas where non-native species can be grown. These species will have to be chosen carefully, however, to avoid invasive species as well as species with high water (irrigation) requirements.

Fig. 2. The top ten tree species in Kelowna, by canopy cover.



Orchard trees (apple, pear and cherry) comprise almost 22% of the total tree canopy. Although these trees tend to be small and require irrigation, they are producing significant benefits for Kelowna residents. As agricultural lands are converted to other crop types (grapes or field crops), or lost to development, some of these benefits will be lost.

The total number of trees in Kelowna is approximately 3.3 million, with a replacement value of $1.1 billion (Table 2). Replacement value is based upon accepted formulae for estimating individual tree values; it is not the ecological or societal value of the tree.

Trees act as “carbon sinks”, and can help mitigate global warming by removing (sequestering) carbon dioxide from the atmosphere. However, as trees eventually decay, die or burn in wildfires, this carbon is released back into the atmosphere. Kelowna’s trees sequester about 7,400 metric tonnes of carbon per year (Table 2) and currently store about 127,000 tonnes of carbon. Net carbon sequestration rates, per tree, generally increase as Kelowna’s trees get larger (Fig. 3).

Most trees in Kelowna are small. Approximately 94% of the tree population is less than 30cm in diameter at breast height (DBH) (Fig. 4).

Table 2. Summary of Kelowna's tree species.

Species	No. Trees %	No. Trees #	Net Carbon Sequestered (metric tonnes/yr)	Leaf Area %	Replacement Tree Value $
Apple	39.2	1,296,000	3,180	18.7	438,763,000
Douglas fir	23.1	762,00	750	32.6	159,669,000
Ponderosa pine	18.4	607,000	1,400	23.8	181,019,000
Common pear	5.5	180,000	600	2.7	84,288,000
Hedge cedar	2	68,000	110	1	10,135,000
Austrian pine	1.7	57,000	80	2.2	15,929,000
Elm	1.4	47,000	180	4	29,460,000
Crabapple	1.1	36,000	130	1.9	15,181,000
Juniper	0.8	27,000	20	0.3	556,000
Quaking aspen	0.6	19,000	6	0.1	446,000
London planetree	0.6	18,000	70	1.7	13,428,000
Black cottonwood	0.5	18,000	160	1.4	18,194,000
Red maple	0.4	14,000	40	0.7	6,158,000
Norway maple	0.4	13,500	150	3.5	37,394,000
Sweet cherry	0.4	13,500	95	0.2	11,504,000
Red cedar	0.4	13,500	25	0.1	7,275,000
Black locust	0.3	11,000	45	0.8	6,881,000
Poplar	0.3	10,500	10	0.3	856,000
Japanese maple	0.3	9,000	50	0.5	6,521,000
Hawthorn	0.3	9,000	45	0.4	5,244,000
Lodgepole pine	0.3	9,000	5	0.1	296,000
Paper birch	0.3	8,700	70	0.4	9,896,000
Freeman maple	0.3	8,500	7	0.1	1,712,000
Common chokecherry	0.3	8,500	40	0.4	5,028,000
Honeylocust	0.2	7,000	10	0	2,019,000
Aspen	0.2	7,000	2	0	151,000
Green ash	0.1	4,500	40	1.6	14,350,000
White spruce	0.1	4,500	15	0.2	601,000
Mugo pine	0.1	4,500	2	0	183,000
Prunus spp.	0.1	4,500	7	0	599,000
Mountain ash	0.1	4,500	20	0.2	2,881,000
Douglas maple	0.1	1,800	1	0.1	23,000
TOTALS	**100**	**3,300,000**	**7,400**	**100**	**$1,086,640,579**

Fig. 3. Per-Tree Net Carbon Sequestration (kg per year) for Kelowna's trees, by diameter class (DBH, in centimetres).

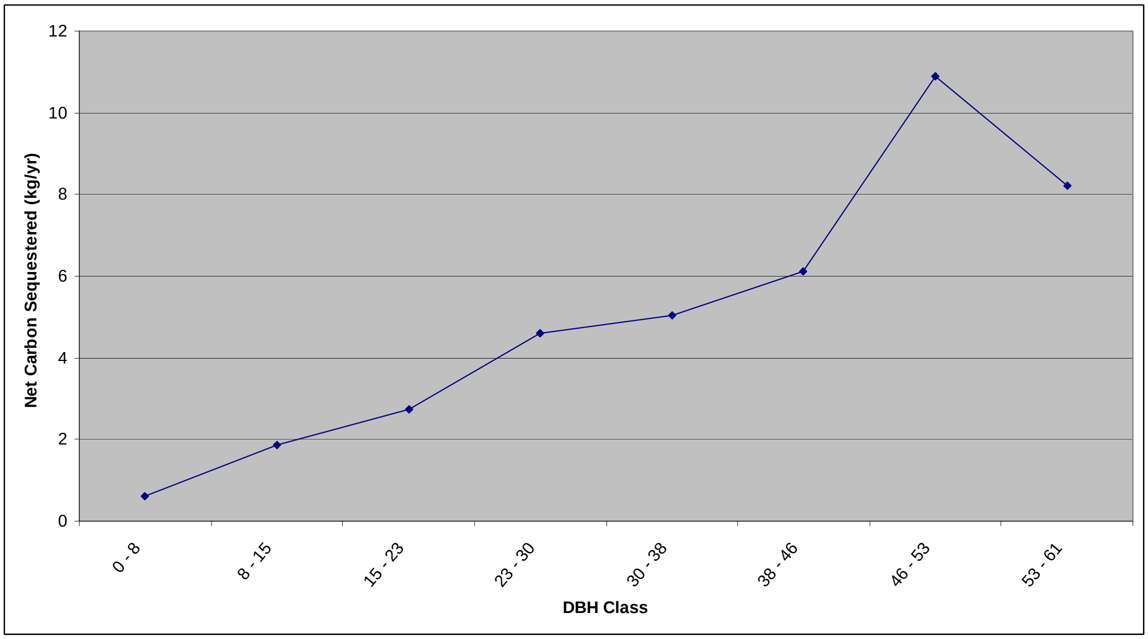
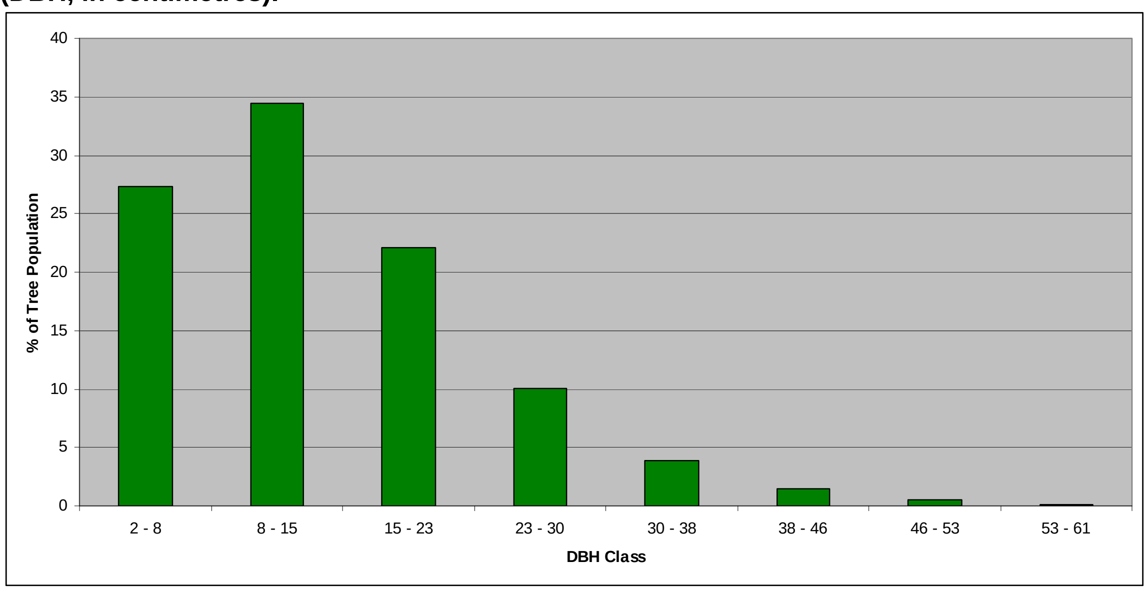
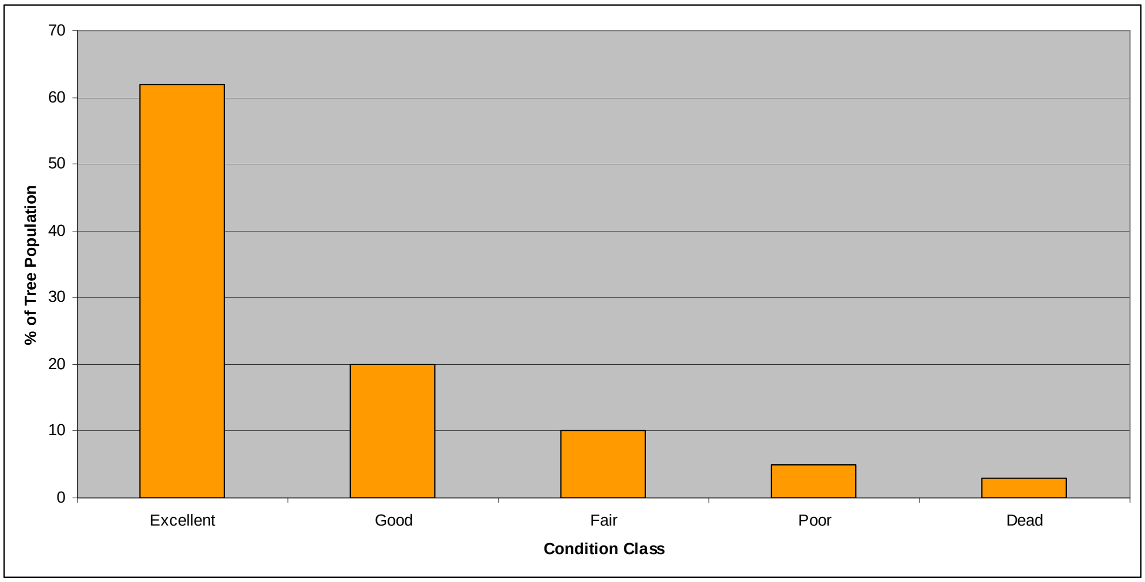


Fig. 4. The size of Kelowna's trees, shown as a percentage of trees by diameter class (DBH, in centimetres).



The health of Kelowna's trees is currently very good, with 92% of the tree population rated as "Fair" or better (Fig. 5).

Fig. 5. Tree health (condition class).



3.2 Vegetation Cover and Plantable Space

Because of the limited number of samples, several of the landuse types from the Kelowna Official Community Plan (OCP) were combined for the comparisons shown in Table 3.

Table 3. Percentage cover comparisons by landuse type.

	Percentage covered by:							
Landuse Type	**Plantable Space**	**Impervious (concrete, asphalt buildings)**	**Herbs**	**Grass**	**Water**	**Shrubs**	**Other**	**Trees**
Agriculture / Rural	17.6%	0.1%	33.8%	42.7%	0%	7.6%	0.8%	15%
Commercial / Industrial / Transportation	12.3%	47.7%	5%	6.5%	0%	5%	2.7%	3.1%
Park / Wetland / Private Recreation / Golf	27.4%	5.9%	7.4%	66.5%	2.6%	6.5%	1.2%	8.2%
Residential	35%	28.9%	5.2%	36%	0.8%	10.4%	1.5%	10.5%
Vacant / Wildland	55%	1.3%	17.3%	43.7%	0%	18.1%	0.8%	23.4%
CITY TOTAL	**27.3%**	**12%**	**18.3%**	**42.3%**	**0.6%**	**9.1%**	**1.2%**	**13%**

Average tree cover throughout the city is 13%. American Forests, a tree research and education group, recommends 25% tree cover for cities in dry areas of western North America (Table 4). The national average tree canopy for cities in the U.S. is 27% (Anonymous 2007). Average tree canopy in some of the other cities in North America is compared to Kelowna's tree canopy in Table 5. Vacant / wildland areas and agriculture lands have the highest tree canopy (23 and 15%, respectively), while the commercial / industrial / transportation zoning types have the least (3%).

The City has 27% plantable space where trees could be planted, on average. Most plantable space is in vacant / wildland areas (55%), followed by residential (35%).

Grasses (native, or planted) are the highest overall cover in the city (42%). Shrubs cover another 9% of the city. These cover types are not evaluated in detail by UFORE but do contribute ecological benefits to the city in terms of stormwater management, cooling and interception of dust or pollutants.

Impervious surfaces (concrete / tar and buildings) comprise a total of about 12% of the city area, on average. Impervious surfaces are highest in commercial / industrial / transportation areas (48%), followed by residential (29%).

Table 4. Recommended tree canopy goals for metropolitan areas of the Southwest and Dry West (American Forests 2007):

Landuse Type	Percent Cover
Average tree cover for all zones	25%
Suburban residential zones	35%
Urban residential zones	18%
Central business districts	9%

Table 5. Average tree canopy in selected North American cities*:

City	Average Canopy
San Diego, CA	7%
Calgary, AB	7.1%
Jersey City, NJ	11.5%
Kelowna, BC	**13%**
Philadelphia, PA	15.7%
Los Angeles, CA	18%
Seattle, WA	18%
Toronto, ON	20.5%
New York City, NY	21%
Boston, MA	22.3%
Syracuse, NY	24.4%
Baltimore, MD	25.2%
Oakville, ON	29.1%
Atlanta, GA	36.7%

Sources: Anonymous, 2007; USDA Forest Service, 2007.

3.3 Pest Susceptibility

UFORE assesses susceptibility of the urban forest to various exotic pests (which are not currently present in Kelowna) such as Asian longhorned beetle (ALB), gypsy moth, or Dutch Elm Disease (Table 6). If these pests became established here, this shows the proportion of the urban forest that is "at risk". Most of these exotic pests have only been detected in Eastern Canada to date, although Dutch elm disease is present in Washington State.

The most imminent threat to Kelowna's urban forest at this time is mountain and western pine beetle. UFORE estimates that Kelowna has about 606,000 ponderosa pine trees, with a replacement value of $181 million, representing about 24% of the total canopy cover (Table 2). According to the B.C. Provincial government, Kelowna is likely to lose about 80% of these trees, primarily the larger mature pines. These mature trees also contribute the most ecological benefits to the city.

Table 6. Proportion of Kelowna's urban forest that is at risk due to exotic and native pests.

Pest	% Susceptible Host, by Tree Cover
Asian Longhorned Beetle	39%
Mountain & western pine beetle	24%
Gypsy moth	23%
Dutch elm disease	4%
Emerald ash borer	2%

3.3 Pollution Removal by the Urban Forest

Kelowna's urban forest removes more than 195 tonnes of pollutants annually, and the value of this removal is estimated at $1.1 million per year (Table 7). These values are based upon an estimate of the societal cost of pollutant emissions / formation (Nowak et. al 2000b).

Trees also produce Volatile Organic Compounds (VOCs) which can be converted into ozone and affect air quality when they react with nitrogen oxides from human-sources of pollution. Kelowna's trees produce about **43** metric tons of VOCs per year. However, the **Ozone Index Score** of Kelowna's urban forest is quite high, at **94** (out of 100). A score of 100 represents forest composition where all species have the maximum effect on reducing ozone (lowest possible VOC emissions).

Certain species of trees are better at reducing ozone levels than others. The best trees and shrubs in Kelowna for reducing ozone (index values >99) include:

> Pear (*Pyrus*), apple (*Malus*), hawthorn (*Crataegus*), mountain ash (*Sorbus*), Saskatoon (*Amelanchier*), Mock orange (*Philadelphus*), snowberry (*Symphoricarpos*), rose (*Rosa*), sumac (*Rhus*), grape (*Vitis*), cotoneaster (*Cotoneaster*), weigela (*Weigela*), honeysuckle (*Lonicera*), raspberry (*Rubus*), Japanese rose (*Kerria*), and spiraea (*Spiraea*).

Overall, Kelowna's urban forest produces significant net benefits for residents in terms of air quality improvement. Mature trees produce more benefits than small trees; a large tree removes about 2.0 kg of pollution per year, about 65 times more pollution than a small tree (Nowak et al. 2000b).

Table 7. Pollution removal by Kelowna's urban forest.

Pollutant	Metric tonnes removed annually	$ Value of removal
CO	2	$ 1,800
NO_2	17	$ 115,000
O_3	83	$ 558,500
PM10	89	$ 400,200
SO_2	5	$ 8,100
	195	**$1,084,000**

3.4 Energy Savings

Only **residential** trees were found to have a significant contribution to energy savings in Kelowna. Trees save energy in the summer by shading buildings and avoiding power plant emissions due to electricity savings. Trees help save energy in the winter, through acting as a windbreak and by avoiding power plant emissions due to gas and electricity savings. However, shading of buildings during the winter months can lead to increased power usage.

Net energy savings are **$19 million** per year in Kelowna, due to residential trees. Tree cover also helps to avoid the release of **1,800 metric tonnes** of carbon into the atmosphere each year.

4.0 Conclusion and Recommendations

Kelowna faces an increasing threat of tree loss due to factors such as mountain pine beetle attack, development, and wildfire. Although mountain pine beetle appears to be the most imminent threat, trees that are lost can be replanted or regenerated over time as long as natural areas are preserved. Urbanization is the greatest long-term threat to Kelowna's urban forest, since it reduces the overall plantable space and the ability to replace areas of lost forest.

As areas of urban forest or green infrastructure are lost, the ecosystem services they provide may need to be replaced with investments in grey infrastructure such as drainage improvements, water filtration, and larger power plants for providing electricity or fossil fuels. These practices are not sustainable in the long run and can be very costly.

Strategies and tactics to enhance the ecological services of urban trees include (Nowak et al. 2000b):

1) **Aiming for species, size and age diversity (reduces the impact of pests);**
    - Increase species diversity in urbanized parks where appropriate
    - Provide the public with information on additional tree species choices, that are pest and drought tolerant, non-invasive and will help improve diversity
    - Encourage local nurseries to provide a greater variety of species

2) **Increasing the number of healthy trees;**
    - Educate the public about the benefits of proper tree care and least-toxic pest management solutions
    - Educate the public about proper tree selection, to avoid problem-prone species

3) Maximizing the use of low VOC emitting trees to improve air quality;

- Provide information on preferred tree species to minimize VOC emissions

4) Sustaining and increasing existing tree cover;

- Set a city-wide tree canopy goal in the OCP, through input from citizens, City Council, staff
- Increase planting on city-owned properties where appropriate
- Promptly replant city owned areas affected by pine beetle, fire or other disturbance and encourage the same on private properties
- Utilize techniques such as “under planting” to ensure adequate recruitment of young trees as mature trees decay or die
- Explore incentives, partnerships, and education to encourage additional planting on private properties. This might include partnerships or subsidies to provide low cost trees to private properties
- Change city policies and bylaws, such as the subdivision bylaw, zoning bylaws, hillside development guidelines, road design standards, landscaping and parking lot standards, etc. to maximize the amount of tree retention and new planting associated with development
- Explore the use of “carbon credits”, e.g. the sale or trading of carbon savings generated by Kelowna’s urban forest, to help fund increased tree planting
- Monitor the long-term success of these efforts, by periodically performing new UFORE analyses, or by using aerial photography or GIS analyses to determine changes in forest canopy over time

5) Sustaining large, healthy trees (greater benefits per tree);

- Educate the public about proper tree selection and care, to increase the number of large specimens in the future
- Change city policies and bylaws, such as subdivision, or road design standards to increase the amount of space available for mature trees to develop

6) Using long-lived species (reduces carbon emissions from planting and removal activities);

- Educate the public on preferred species types
- Gradually replace short-lived species on city properties with longer-lived varieties

7) Using low-maintenance trees (reduces fossil fuel requirements for maintaining vegetation);

- Educate the public on preferred species types
- Gradually replace high maintenance and problem-prone species with lower maintenance species

8) **Planting trees in energy-conserving locations;**
   - Incorporate appropriate tree planting into the design of city-owned buildings
   - Educate the public about the best locations for tree planting to reduce energy use

9) **Planting trees as part of transportation corridors (extends the life of streets, reduces carbon dioxide emissions) and parking lots (cooling effect and reduction of VOC emissions from parked vehicles);**
   - Incorporate tree planting into all new collector / arterial road designs
   - Increase standards for planting in parking lots and implement monitoring to ensure trees survive over time
   - Ensure that adequate space is provided in transportation corridors and parking lot design, particularly adequate soil volume for the development of large trees which will help to reduce storm water runoff from impervious surfaces and maximize shading

10) **Planting trees in polluted areas;**
   - Increase plantings along major transportation routes and in industrial areas to improve interception of pollutants

11) **Avoiding pollution sensitive tree species;**
   - Public education on appropriate tree species

12) **Utilizing evergreen trees for particulate matter reduction (year-round removal of pollutants).**
   - Encourage the use of evergreens, particularly in high-pollution areas or as windbreaks in winter.

These recommendations will help to preserve and improve the quality of Kelowna’s urban forest and improve the liveability of Kelowna, and are also compatible with Kelowna’s Sustainability Objectives.

5.0 References

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Appendix 1. Plot Locations (GPS Coordinates)

GPS Coordinates for original 100 plots (plots #1-101):

ID	X-Coordinates	Y-Coordinates
1	315206.976828	5516776.214540
2	317294.833259	5518054.341910
3	318438.964887	5518806.123160
4	319882.896053	5518935.139410
5	322311.421366	5518675.175140
6	322543.874170	5519046.166840
7	320656.647448	5520280.160620
8	321398.086621	5519695.848120
9	322727.401081	5520737.424370
10	320762.600880	5522321.428960
11	322377.598877	5522118.604310
12	323773.902244	5522271.492330
13	325034.910969	5521522.846740
14	325569.898260	5521497.738340
15	326905.362539	5521897.801050
16	321792.083368	5522501.866260
17	323321.458449	5523237.240250
18	324305.221601	5523362.756550
19	326530.961057	5522892.527590
20	326921.913248	5522714.758730
21	329001.469608	5522911.500340
22	329673.862071	5523875.208970
23	331200.192770	5523071.513030
24	321625.789342	5524551.507170
25	323791.688779	5524256.212520
26	325141.706151	5524046.849750
27	326051.502183	5524267.760180
28	326923.823446	5525273.106430
29	329314.563169	5524737.466650
30	330062.325611	5524452.512770
31	332474.437067	5525065.693900
32	321095.858100	5526463.848830
33	322526.594628	5526741.151310
34	324196.964589	5526809.488570
35	326401.371165	5525507.484330
36	327538.119402	5526799.293160
37	328764.984974	5526341.988410
38	330794.381175	5526407.402940
39	331239.833920	5525505.823750
40	332744.222585	5526860.755630
41	322134.853763	5527119.728410
42	323301.377006	5528116.192440
43	324551.823361	5527220.931750
44	326048.896627	5527087.276940
45	328097.479099	5527075.550300
46	328826.438245	5528094.861160
47	330969.857261	5527462.888190
48	331603.186160	5527265.310660
49	333073.491337	5526920.477460
50	320163.452948	5528638.946730
51	321147.429789	5529770.087160
52	323244.369935	5528414.595300
53	324209.622574	5529755.544260
54	326689.352905	5528610.243880
55	327331.498580	5528550.178190
56	329364.259698	5529448.718140
57	330672.642293	5529082.078510
58	331432.227041	5528680.406960
59	320814.917014	5530516.212840
60	321097.188629	5531080.120100
61	322678.882967	5530585.094410
62	324647.884111	5529881.407600
63	325820.063190	5530001.430400
64	327837.544115	5530848.448110
65	329588.130923	5531206.031300
66	330815.096402	5530298.626370
67	331140.315459	5530026.840260
68	322830.584007	5531969.561190
69	324734.741465	5531839.518960
70	326008.199690	5532085.203600
71	327826.051536	5531540.283170
72	329419.691676	5532094.462080
73	330896.586540	5532324.974150
74	322117.698236	5532933.517430
75	323267.753506	5532832.550430
76	323881.199561	5533881.974130
77	325431.162384	5533639.232270
78	327648.837140	5533579.914160
79	328592.401675	5533721.105630
80	325199.078160	5535636.657400
81	325928.091422	5535674.037100
82	328057.788515	5535105.456080

ID	X-Coordinates	Y-Coordinates
83	328439.739379	5534391.398930
84	323978.248278	5537012.305310
85	325324.892407	5536007.325460
86	328060.020634	5536705.565590
87	328596.589783	5536935.140030
88	323905.460092	5538285.726710
89	326633.833509	5537430.241040
90	327689.335304	5538150.490340
91	328662.404264	5538477.231420
92	329794.426354	5538425.387660
93	324870.916014	5539571.994890
94	325797.599073	5539986.585360
95	326827.587166	5539765.244460
96	329233.482198	5539843.752140
97	325856.342372	5541400.268160
98	327578.292002	5540371.647430
99	325385.136910	5542006.485290
100	327688.584442	5541810.072060
101	328670.921147	5542949.088080

GPS Coordinates for additional 50 plots (plots #1-50):

ID	X-Coordinates	Y-Coordinates
1	317591.701290	5518740.644370
2	318897.044205	5518924.502620
3	320989.070184	5520647.594550
4	323318.519928	5519396.359360
5	321635.428210	5522432.827910
6	323563.971180	5521570.849070
7	324397.444958	5521654.362480
8	327152.005445	5522458.381730
9	321000.605451	5523550.753260
10	322643.449003	5524290.886390
11	324571.226329	5524010.021070
12	328131.614987	5523391.038710
13	329592.714322	5523757.206200
14	331259.906151	5524274.590780

ID	X-Coordinates	Y-Coordinates
15	322521.122610	5525163.056930
16	324757.660867	5526570.293400
17	327735.055796	5526424.717010
18	329420.927734	5525306.657650
19	331916.572311	5526171.473280
20	320780.034369	5528608.281210
21	323376.721892	5528150.268530
22	326213.094036	5527218.479500
23	327713.431618	5528126.888490
24	329885.645766	5526949.173110
25	330473.901042	5527217.200480
26	320417.610469	5530374.621450
27	322309.442617	5529979.060170
28	324799.248659	5530507.595040
29	326714.735596	5530158.790910
30	328703.197215	5529104.019210
31	332288.433223	5529173.066470
32	324068.954665	5532776.143670
33	325597.386568	5532614.492930
34	327813.104122	5532637.276220
35	329010.445148	5532854.801730
36	331866.790175	5531858.748410
37	323947.566286	5533685.500050
38	325545.974432	5534184.003200
39	327262.654517	5533221.578150
40	328520.896302	5533774.417550
41	326166.631277	5536924.522360
42	328151.120367	5535310.446490
43	328917.540175	5536421.995500
44	325478.672430	5537560.717990
45	326477.350914	5538585.450670
46	324896.222118	5539392.156850
47	326988.707082	5540836.446600
48	328932.330430	5540257.833370
49	326844.930634	5541679.380760
50	329492.178715	5542946.221000

Plots that had to be moved to alternate locations, due to lack of access or permission was not granted by the landowner:

Plot #	Original Coordinates	Modified Coordinates	Description
30	330062.325 x 5524452.512	331544.554 x 5524779.828	~ 1500m west of original
31	332474.437 x 5525065.693		~ 1km south of original
90	327689.335 x 5538150.490	327433.933 x 5537739.096	~ 300m SW of original
94	325797.599 x 5539986.585	326109.914 x 5539735.296	~ 400m SE of original
95	326827.587 x 5539765.244	326401.000 x 5539825.167	~ 350m west of original
133	324068.954 x 5532766.143	324264.293 x 5532952.321	~ 300m SW of original
145	326477.350 x 5538585.450	326168.761 x 5537772.159	~ 850m south of original
147	326988.707 x 5540836.446	327492.468 x 5541137.415	~ 675m NE of original
149	326844.930 x 5541679.380	326239.558 x 5538042.373	~ 4km south original