# Modeling the potential of Oakville's Private Tree Protection By-law to mitigate the impact of Bill 23 on achieving 40% canopy cover across residential lands south of Dundas

*October 11, 2023*

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# Executive Summary

In November 2022, Ontario passed an omnibus Bill (More Homes Built Faster Act, 2022) to expedite construction of new housing consistent with growth targets under Ontario's Growth Plan. The changes include reduced scope of site plan control in the Town of Oakville, as elsewhere in Ontario. They were made without any analysis of the impacts on Official Plan natural heritage and environmental objectives, including impacts to the Town's urban forest and tree canopy. Other municipalities in Ontario face the same challenges.

Urban Forestry commissioned the following study to help inform expected changes to the Town's tree canopy from building out low and medium density land uses south of Dundas. The study made use of 2018 airborne laser scanner (LiDAR) data and satellite imagery to locate, map and classify individual trees on residential parcels to species groups. The Town's 2010 and 2022 forest inventory date were used first to model annual growth increments, and subsequently to derive predictive equations for diameter at breast height (DBH) based on tree heights, and canopy expansion, to predict the potential impacts of Bill 23 on tree canopy cover under various residential development and/or redevelopment scenarios.

This work is intended to help the Town understand the potential of the Private Tree Protection By-law, particularly its associated tree replacement requirements, to mitigate the impact of Bill 23 on achieving 40% canopy cover in lands zoned low and medium density residential, south of Dundas, by 2057.

Two scenarios for tree removal and two sets of tree replacement combinations were modeled for Residential Class A[1] and Residential Class B[2] parcels, respectively. Both scenarios assumed a redevelopment rate of 5% of parcels over 20 years. Both scenarios assumed that trees located within the maximum allowable building footprint would be lost and not replaced upon redevelopment. Under the first scenario, 100% of By-law protected trees on residential parcels but not within building footprints were removed as a consequence of redevelopment of those parcels. Under the second scenario, only 50% of By-law protected trees were removed.

According to the By-law, the planting of replacement trees is required at a quantitative ratio determined by tree size. The two different tree replacement combinations modeled for both the 100% and 50% tree removal scenarios either included or excluded cedar in tree replacement species combinations. Given the choice, many landowners currently plant cedar as a replacement tree since this is currently allowed. Our results demonstrate that achieving canopy cover targets is very sensitive to including cedar in the combination of replacement trees, due to their limited crown width at maturity in comparison to deciduous broadleaf trees and other coniferous tree species.

[1] Residential Class A: Residential Low (RL1 and RL2) zonings
[2] Residential Class B: Residential Low (RL3-RL11) and Residential Medium (RM1-RM4) zonings

The main findings of the study were that:

1. The 2057 canopy cover targets for Residential Class A and Residential Class B will not be met if the town continues to consider cedar a suitable replacement tree for By-law protected trees when permits are issued for their removal.
2. The 2057 canopy cover targets for Residential Class A and Residential Class B will be further compromised if the town continues to accept cash compensation in-lieu of replanting within these residential zones to replace By-law protected trees when permits are issued for their removal.
3. The adverse impacts of removing 100% of By-law protected trees from parcels slated for development/redevelopment are far greater than when 50% of those trees are retained.

Given these findings, we recommend that:

1. Cedar be excluded from the list of suitable replacement trees when permits are issued to remove By-law protected trees.
2. Cash compensation in-lieu of tree replacement as a condition of tree removal permits should not be accepted. The replacement trees should be planted within the same residential class zones from which By-law protected trees are to be removed.
3. The Town avoids issuing permits for the removal of all By-law protected trees from private properties if reasonable opportunities exist to retain some proportion of By-law protected trees when those properties are slated for development/redevelopment.

The detection, mapping and inventory of privately owned trees developed for this study combined several novel approaches to map, measure, and classify trees on private land using remotely sensed data. The accompanying canopy removal and growth models leveraged the Town’s street and park tree inventory data from 2010 and 2022 to determine growth increments for species groups, as well as predictive models of the growth and canopy expansion of both inventoried trees and modeled replacement plantings.

As a result, the Consultant in partnership with the Town, now has a powerful new tool and associated workflow procedures to model the effects of different build-out scenarios on the urban tree canopy. In cooperation with other Town departments, Urban Forestry can use this insight to influence improvements to the Private Tree Protection By-law, in order to minimize development related impacts to Oakville’s urban forest.

# Contents

## Bill 23 (More Homes Built Faster Act)

In November 2022, the Province of Ontario passed the More Homes Built Faster Act, 2022 (Bill 23)[3]. The Act is an omnibus piece of legislation and part of Ontario's Housing Supply Action Plan that made changes to many Ontario laws/statutes to expedite building 1.5 million homes in the next 10 years, requiring municipalities to meet provincial housing 'quotas' either through intensification or expanded development.

The Bill implemented significant changes to the land use planning regime in Ontario, in order to enable the rapid development of housing to meet targets under the province's Growth Plan. This included changes to the *Conservation Authorities Act*, reducing the powers and mandate of CAs to protect natural heritage lands as well as undermining protection for wetlands through changes to the Ontario Wetland Evaluation System. Several changes to the *Planning Act* as a result of the Bill also have implications for the ability of municipalities to meet urban forest and natural heritage objectives and targets.

Ontario's Growth Plan mandates that each Greater Toronto and Hamilton Area (GTAH) municipality must absorb its fair share of growth. For Oakville, this means growing from the current 231,000 population to approximately 375,000 people and 180,000 jobs by 2051 within the town's existing boundaries, requiring that at least 50 per cent of all residential developments each year must be within existing built-up areas.[4]

The changes from Bill 23 will both increase pressure on and reduce protection for existing tree canopy. They will also limit the Town's ability to require new development to integrate new or replace lost tree canopy, formerly possible through site plan control.

### Development in Oakville

The province, as part of its Growth Plan, has assigned municipal housing targets to 29 of the region's largest and fastest-growing municipalities. The Town of Oakville was assigned a housing target of 33,000 units as part of the province's overall target of 1,229,000 homes. This represents 3,300 units per year for the next 10 years (compared to approximately 2000/yr for the last 10 years).

As per the Town's Official Plan (Liveable Oakville, Part D - Land Use) the majority of intensification and development within the Town is to occur within the Growth Areas. Intensification outside of the Growth Areas within the stable residential communities is subject to policies that are intended to maintain and protect the existing character of those communities. These historically included site plan controls, which have been reduced in scope through changes introduced under Bill 23.

### Site Plan Control

The site plan control process is a tool that enables Oakville and other municipalities to exercise site-specific controls over development. The site plan approval process provides municipalities with an opportunity to review and approve plans and drawings related to a proposed development.

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[3] More Homes Built Faster Act, 2022 (Bill 23). Available online: https://www.ola.org/en/legislative-business/bills/parliament-43/session-1/bill-23

[4] 2022 Ontario Budget: Ontario's Plan to Build. The Honourable Peter Bethlenfalvy, Minister of Finance. Government of Ontario

The approval process is technical in nature and used to manage implementation details related to a development before the issuance of building permits or the commencement of site works. These details can relate to matters such as grading, drainage, tree preservation, landscaping, the exterior design of buildings, the location of garbage facilities, and vehicular and pedestrian traffic movement, both within the site and in areas where there are connections to public roads and sidewalks.

Site plan control is a tool that ensures that a development proposal is well designed, fits in with the surrounding uses and minimizes any negative impacts. It was previously used by the Town to ensure that tree canopy was taken into consideration in landscaping design, as part of meeting Oakville's tree canopy goals.

Bill 23 introduces changes to section 41 of the Planning Act, including the following amendments to the scope of site plan control:

- Limiting application of site plan control (e.g., reducing the scope of site plan control approvals, including exempting residential buildings with less than 10 units from site plan control - this can be in any form – a single-detached house up to a townhouse development of 9 units.
- Removing landscape design aesthetics from the list of matters to be addressed through site plan control, subject to limited exceptions
- Changing how planning authority is exercised in upper-tier and lower-tier municipalities in the Greater Toronto and Hamilton Area.

The reduced scope of site plan control over residential development significantly affects the ability of municipalities to protect and enhance tree canopy and preserve growing sites in new housing development. Preservation and protection of trees are not prescribed through the Building Code. These developments are inconsistent with natural heritage and urban forestry goals set in the Official Plan.

The removal of the ability to secure certain exterior design features and elements from the scope of Site Plan approval also limits the Town's ability to integrate sustainable performance measures that address site matters including urban heat island impacts; reduction of greenhouse gas emissions from heating and cooling through strategic tree planting; restoration and enhancement of the natural heritage system and the urban forest.

The inability to require robust landscaping could undermine the municipal tree canopy objectives and the ability to establish appropriate screening and buffering between adjacent properties. Furthermore, Oakville has seen an increasing trend of redevelopment of single lot residential properties, or "tear down/rebuilds". Typically, this involves a large lot with a small home, and replacing it with a larger dwelling along with hardened amenity spaces including patios, pools, and decks. This trend has already exacerbated the availability of long-term growing space for trees, along with new pressure to increase density in residential neighbourhoods.

From a natural heritage, greenspace and urban forest perspective the Bill will not support the creation of livable communities. Rather, it creates a race to the bottom for developers by eliminating many of the policies and incentives for prioritizing environmental quality as well as housing supply and affordability.

*Modeling the potential of Oakville's Private Tree Protection By-law to mitigate the impact of Bill 23 on achieving 40% canopy cover across residential lands south of Dundas*

## Oakville's urban forest policy

Oakville has long been a leader in urban forest protection and management. Other cities look to Oakville to inform strong policies and programs for the enhancement of the urban forest. The city set an ambitious but achievable target of 40% tree canopy in its Official Plans. Much of the opportunity to maintain and expand the tree canopy is on private lands in south Oakville, particularly in residential areas.

For several decades, Oakville has invested in and prioritized the urban forest as part of the Town's natural heritage, with a significant international body of research suggesting that urban forests have many social, environmental and economic benefits, including contributing to long-term prosperity by making the Town an attractive place to live and work. Urban trees and forests are considered an essential part of municipal infrastructure. Oakville's investment has seen results, with past studies showing an increase in tree canopy cover over recent years.

The increase in tree canopy has been achieved through strong protections for existing trees as well as stringent requirements to replace tree canopy lost or impacted by development. Historically, this has included requirements to integrate trees in the context of landscaping standards in development applications and plans of subdivision, as well as having standards for soil quality that support the Town's long-term investments in tree planting. The Town's policies have supported a steady increase in urban tree canopy where other cities have seen a decline. These include the Town's Tree Protection and Tree Canopy Preservation Policy[5] and the Town's Urban Forest Strategic Management Plans (UFSMPs).

Changes to the scope of site plan control under Bill 23 could undermine several key environmental and social objectives outlined in the *Planning Act*, as well as undermining the Town's urban forestry objectives and policies, including protection and enhancement of the urban forest.

The Town's OP (Livable Oakville Plan, 2009) speaks to important natural heritage objectives, including the need to "*preserve, enhance and protect the Town's environmental resources, natural features and areas, natural heritage systems and waterfronts*" (Part B: Mission Statement and Guiding Principles, 2.2.3 b)). This includes the urban forest.

Section 6.10 (Landscaping, Part C, General Policies) of the LOP lays out the characteristics of good development, which according to the plan should:

"6*.10.2 Preserve and enhance the urban forest by:*

> *a) maintaining existing healthy trees, where possible;*
> *b) providing suitable growing environments;*
> *c) increasing tree canopy coverage;*
> *d) incorporating trees with historic or cultural significance; and,*
> *e) integrating a diverse mix of native plant species.*

[5] Tree Protection and Tree Canopy Preservation Policy. Available online: https://www.oakville.ca/town-hall/policies-procedures/tree-protection-and-tree-canopy-preservation-policy/

*6.10.3 Landscaping should be incorporated to provide shade and wind protection.*

*6.10.4 Landscaping treatments should preserve and complement the existing natural landscape.*

*6.10.5 Landscaping shall enhance natural areas and open space features by incorporating native and non-invasive species."*

In Part C, General Policies, the Town committed to maintaining and enhancing the urban forest as follows, identifying a specific objective of increasing the tree canopy to 40%:

"*10.1.1 Objectives*

*The general objectives for sustainability are:*

*a) to minimize the Town's ecological footprint;*
*b) to achieve sustainable building and community design;*
*c) to preserve, enhance and protect the Town's environmental features, natural heritage systems and waterfronts;*
*d) to enhance the Town's air and water quality;*
*e) to maintain the existing urban forest; and,*
*f) to progressively increase the urban forest to achieve a canopy cover of 40% Town-wide beyond the life of this Plan."*

At the same time, there has been no analysis of the potential impacts to inform future approaches to meeting housing targets. The following study aims to help the Town understand and mitigate the impacts of new housing development on the urban forest.

# Methodology

## Study area

In order to gauge the potential impacts of Bill 23 on development-related tree loss on private lands, low (RL) and medium (RM) density residential parcels classified as Residential Class A[6] and Residential Class B[7] in the Urban Forest Sustainable Management Plan (UFSMP) were identified and mapped. All lands subject to Bill 97 that were located within 300 m of railways and within 120 m from Lake Ontario were excluded and removed from the study area. The remaining mapped residential parcels constituted the study area (Figure 1).

Because trees located outside of residential parcel boundaries often have canopies that overhang portions of residential parcels, we included areas outside of residential parcels in the study area in order to be able to model canopy expansion and mortality of trees with canopies that overhang residential parcels at the same time as changes in canopy cover of trees located within parcel boundaries. Thus, the study area consisted of Residential Class A and Residential Class B zones made up mostly of residential

[6] Residential Class A: Residential Low (RL1 and RL2) zonings
[7] Residential Class B: Residential Low (RL3-RL11) and Residential Medium (RM1-RM4) zonings

parcels. The total area included in Residential Class A zones was 832 ha, with a total parcel area of 620 ha. The total area included in Residential Class B zones was 3377 ha, with a total parcel area of 2443 ha (Figure 1).

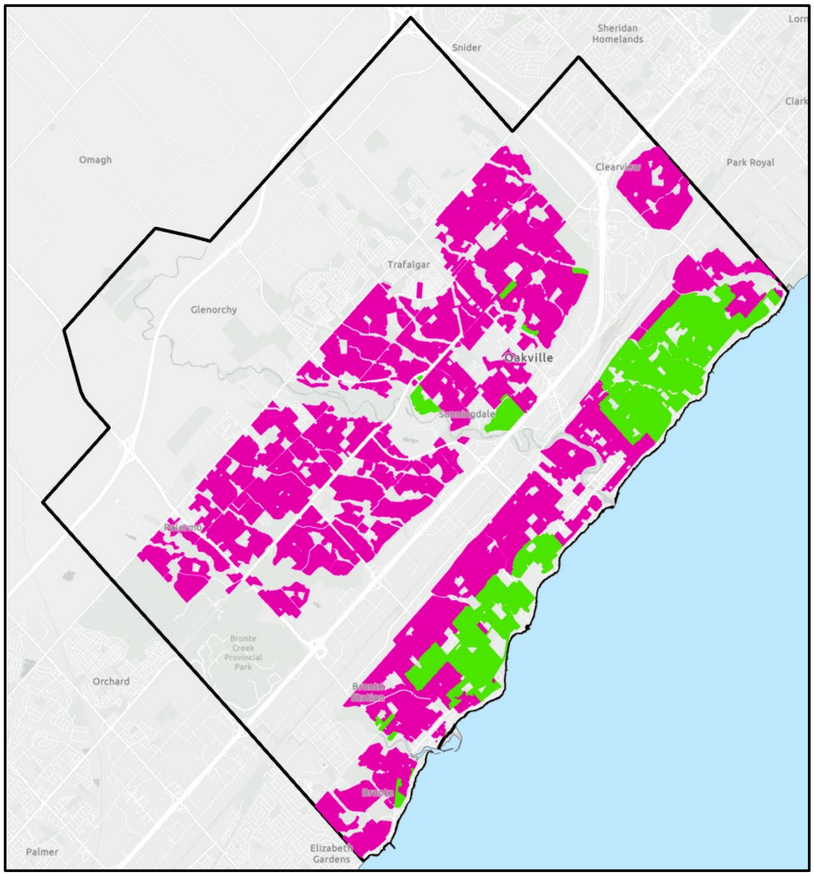


*Figure 1. Study area consisting of low and medium density residential parcels with Residential Class A shown in green and Residential Class B shown in pink.*

## Modeled Impact Scenarios

We set out to gauge the potential impact of Bill 23 on Oakville's urban forest canopy cover by modeling the following residential property development/re-development scenarios:

1. 100% removal of unprotected trees (trees within maximum building footprints) and By-law protected trees in the development/redevelopment of residential parcels included in the study over 20 years

2. 100% removal of unprotected trees (trees within maximum building footprints) and 50% removal of By-law protected trees in the development/redevelopment of residential parcels included in the study over 20 years

In addition, for both scenarios, we modeled changes in canopy cover attributable to canopy expansion and mortality of trees that remained on undeveloped parcels at each 1-year time step in our models, both during the first 20 years, and beyond. All modeled scenarios assumed an annual background mortality rate of 1.42%, which was applied to the entire tree population located within parcels considered in our models. For town trees and trees on easements located outside of parcels with overhanging canopies, we assumed a mortality rate 4.32% [8].

Urban tree mortality rates for urban trees vary widely due to a number of complicating factors. The above-mentioned average background mortality rate used in this study aligns with a 2019 peer-reviewed study of urban tree mortality that considered mortality rates for street, park and private land trees reported in 56 urban tree mortality studies[9]. Vancouver's Diamond Head Consulting Inc. has applied this average background mortality rate in multiple urban canopy studies for Canadian municipalities.

The tree inventory for this study was derived from 2018 LiDAR and imagery data. We have therefore assumed these data to be representative of the tree population in 2023 for modeling purposes. The tree population at the end of the development/redevelopment modeling scenarios is therefore assumed to represent the tree population in the year 2043.

Beyond the year 2043, we continued to model tree growth and associated changes in canopy cover percent according to attributes of the tree population in 2043, but without any further modeled development/redevelopment related tree removals. We continued however to apply the background 1.42% mortality rate to the entire tree population within parcels, and a mortality rate of 4.32% for trees located outside residential parcels but with canopies that overhung those parcels.

We did so because according to our modeling approach, all residential parcels would have been developed/redeveloped by that time, and we were interested in modeling the time it would take for canopy cover to recover to the 35% and 25% canopy cover targets for Residential Class A and Residential Class B parcels called for in the UFSMP to achieve an overall canopy cover percent of 40% by 2057.

## Regulated trees under Oakville's Private Tree Protection By-law and exceptions

Within parcels, the maximum allowable building footprints or envelopes[10] were delineated according to zoning regulations. In this way, trees located within the maximum allowable building envelope of a parcel could be identified. These were trees that existed in 2018 but may be lost to development/redevelopment in the years since and into the future; they are not By-law protected so their removal does not require tree replacement.

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[8] The mortality rate for town trees was provided by Forestry Section, Town of Oakville

[9] Hilbert et al. 2019. Urban Tree Mortality, A literature Review. Arboriculture & Urban Forestry 2019. 45(5):167–200

[10] A 1.5 m buffer was delineated surrounding maximum building envelopes and added as part of the maximum allowable building envelope to account for site disturbance during construction

Trees located on private property outside of maximum allowable building envelopes, however, are By-law protected. The removal of these trees from private properties requires a permit and tree replacement on the basis of the removed tree's size: 1 replacement tree for every 10 cm of diameter at breast height (DBH) of the removed tree allowed according to the Private Tree Protection By-law. For trees with canopies that overhang residential parcels, we assumed that most would be street trees and due to limited growing space would only be replaced on a ratio of 1:1.

## Tree inventory: Tree detection, mapping, and species group assignment.

Trees were detected using a combined approach of height normalized airborne laser scanner LiDAR point cloud data fused with normalized difference vegetation index (NDVI) data from high-resolution multispectral satellite imagery (50cm Worldview-2). The LiDAR point cloud was generated from an acquisition over March to June of 2018 with a flight altitude of 1200m, vertical accuracy of 10 cm, and a pulse density of 12.8 pls/sq m. A function for a variable size window filter was produced by analyzing the height and canopy widths of a subset of trees measured on the ground belonging to Oakville's street and park tree inventory. This function was applied to process the point cloud data to detect local maxima (tree tops) and segment the point cloud into LiDAR returns that most likely belonged to individual trees. A Lidar derived canopy height model with Gaussian smoothing fused with the NDVI layer was used to refine the tree assignment of points in the segmented point cloud. For the selection of points belonging to a tree; each tree was given a unique identification number (Figure 2).

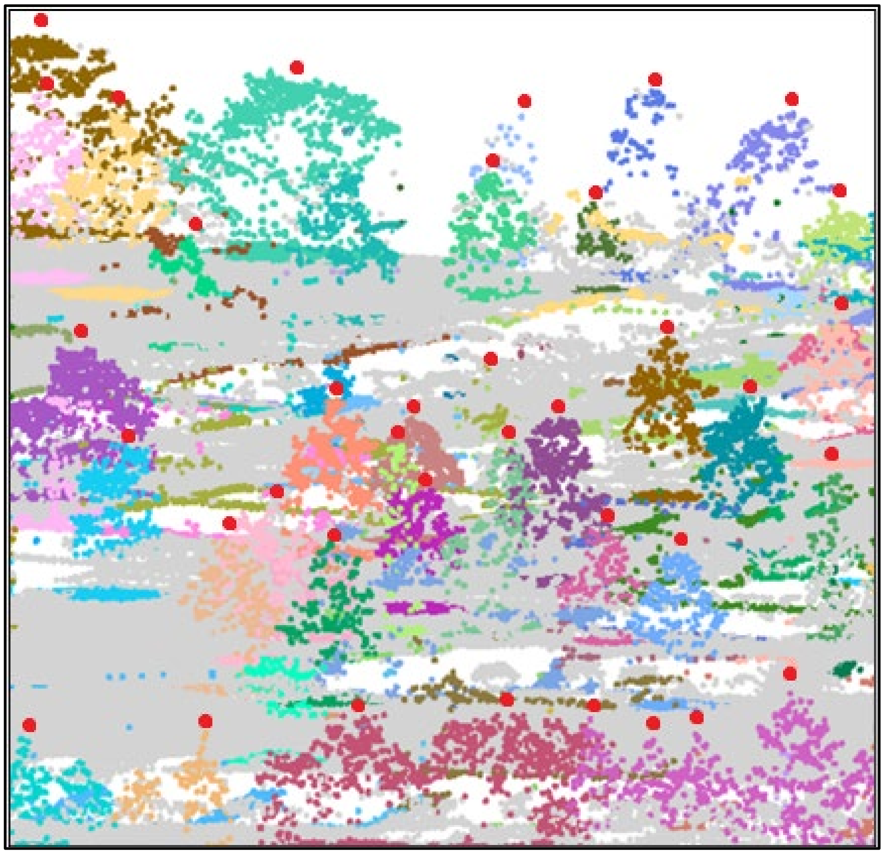

*Figure 2. Segmented LiDAR point cloud data for the study area colourized by tree identification number with tree tops identified with a red circle.*

Convex hulls were drawn around the outermost Lidar returns belonging to individual trees and then smoothed to represent delineated tree crowns (Figure 2). Tree detection was validated using the existing spatial inventory and produced a true positive rate of .74 *(n = 186)*, meaning a 74% probability of an actual tree centroid was positively detected. Negative results were generally attributable to smaller trees and shrubs or trees in the understory hidden by larger canopies. All trees within the study area were detected including trees on private and public property within a 5 m buffer of the study area (Figure 3).

The spectral signature of species from multiple imagery datasets in combination with LiDAR data allowed trees to be identified and classified into species groups. Species group membership was assigned using a supervised-vector machine learning algorithm and a training dataset of 272 individual trees consisting of cedar (*n=62),* other conifers *(n=68),* shade-tolerant trees *(n=77),* and shade-intolerant trees *(n=65)*. Species group classification relied upon 8-band multispectral Worldview-2 imagery, 3-band aerial orthophoto, and LiDAR point cloud statistics. Species group membership was validated using a subset of Oakville's street and park tree inventory. This analysis determined a true positive rate, or the probability at which a test positive is an actual positive of .60 (*n=122)* when classifying for species types and .93 (*n*=122) when classifying for conifer or broadleaf.

*Modeling the potential of Oakville's Private Tree Protection By-law to mitigate the impact of Bill 23 on achieving 40% canopy cover across residential lands south of Dundas*

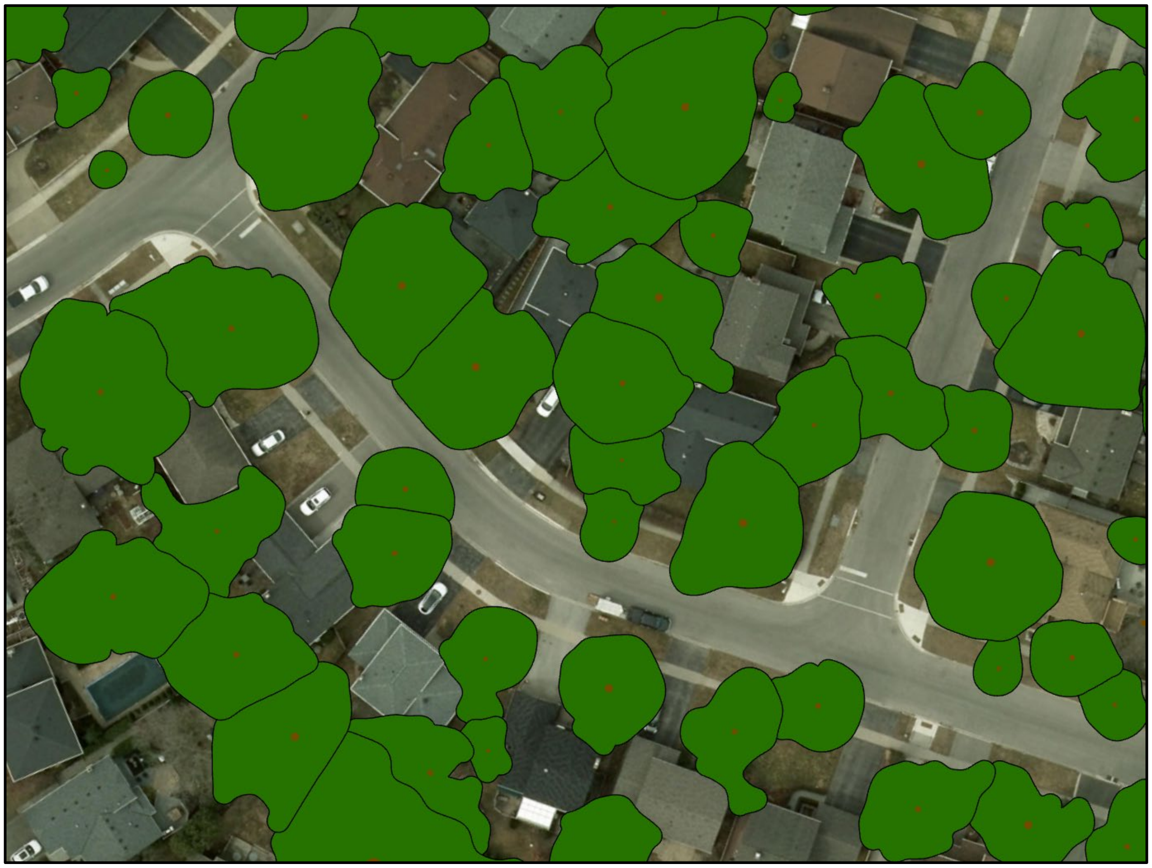

*Figure 3. Tree segmentation results for a portion of the study area showing tree crowns and buffered centroids corresponding to their main stems.*

In order to investigate the potential of the Town's Private Tree Protection By-law to mitigate the impact of Bill 23 on Oakville's urban forest canopy cover, trees within the maximum allowable building envelope or footprint on residential properties in the study area had to be identified since those trees no longer require replacement if they are removed during development/redevelopment. By contrast, we assumed that the trees located within residential parcels but outside of the maximum building envelope in the front, back and side yards of the properties would be By-law protected, meaning their removal would require a permit and that replacement trees normally be planted in their place; alternatively the Town has historically provided landowners removing By-law protected trees with a "cash in lieu" option to fund tree planting on town properties if they do not desire to replant replacement trees on their properties.

By-law protected trees were identified if their main stems were located within building setbacks prescribed by zoning regulations, and outside of the maximum building envelope for each parcel. Property boundaries were buffered spatially to identify front, back and side yards according to specific setback distances for each zone type to adhere to Zoning By-Law 2014-014. Reverse geocoding was used to separate each parcel's front, back and side line segments and determine the frontage of each parcel based on matching street address and road buffer overlap. Distance analysis was subsequently used to identify each property's back and side line segments in order to apply the proper buffer.

A maximum building footprint polygon was drawn anchored to the centroid of the current building footprint and expanded with coordinate analysis to scale to the appropriate amount of either maximum lot coverage area or maximum residential floor area ratio based on the size of the parcel. The size was checked against a parcel/building footprint ratio and iterated against until reaching its maximum. Zone specific buffers were used to bound the drawn polygons and an additional 1.5m buffer was delineated surrounding maximum building footprints to account for trees that may be affected by construction activities that are also no longer protected in the absence of site plan control. To represent the actual size of the stem in relation to the buffers and building footprints, the tree centroids were buffered according to their attributed dbh value and these stem buffers were used to determine if the stem would be impacted by development. Figure 4 depicts the shapefile layers used for selecting the buffered tree stems. All other trees located outside of the maximum building footprint polygon for each parcel were included in a separate database for by-law protected trees (Figure 5).

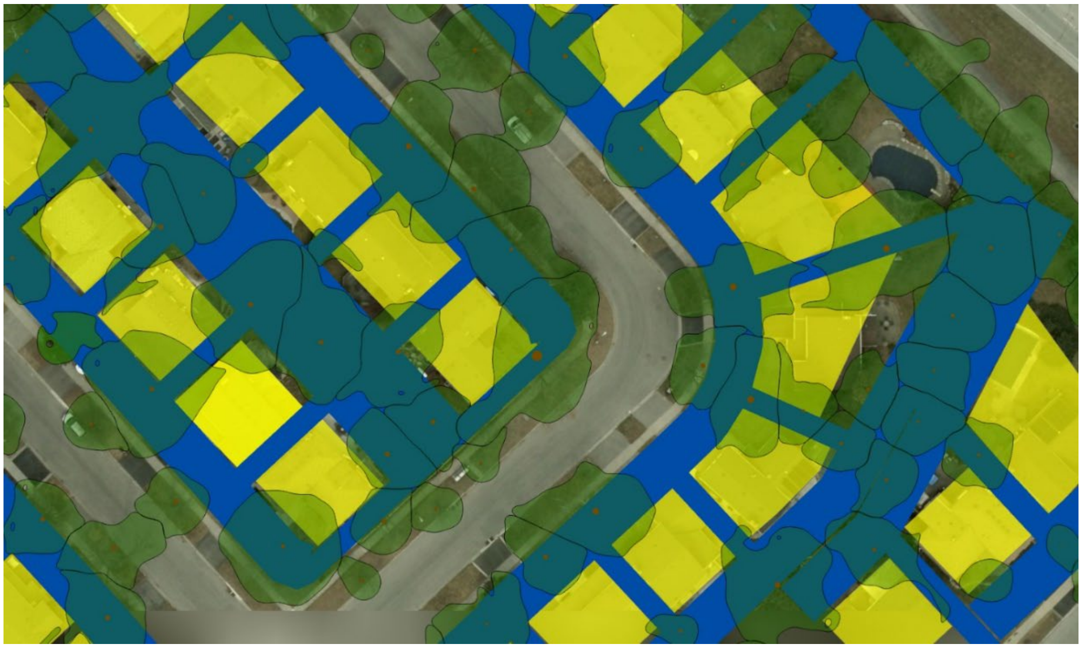

*Figure 4. Maximum building footprints in yellow, front, back and side yard buffers in blue, tree crowns in green, and buffered tree centroids representing main stems in brown.*

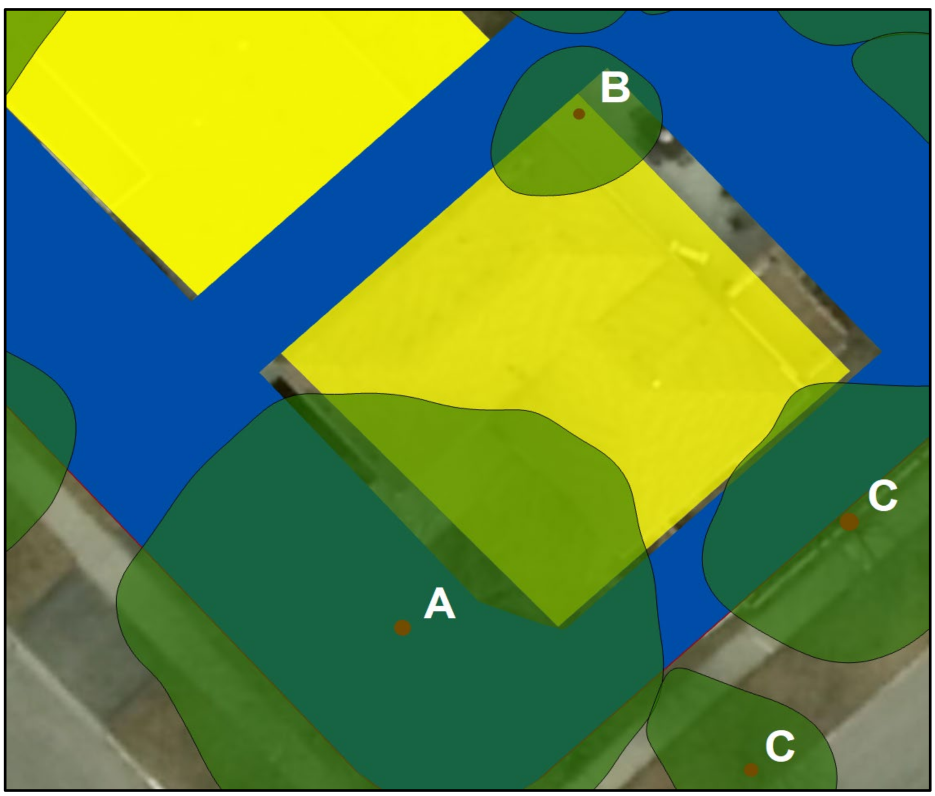


*Figure 5. Stem locations inside minimum yard setback buffer (A), inside maximum building footprint (B) and outside parcel area (C).*

## Canopy cover calculations

Because the study area was made up of discontinuous parcels, parcel areas were summed to determine the total measurable extent of the study area to enable canopy cover calculations. Canopy cover associated with the Residential Class A and Residential Class B zones across the study area was calculated on an area basis by summing the area of canopy cover associated with trees located in study area parcels and the area of canopy cover of tree canopies that overhung parcel boundaries to ensure 100% of canopy cover within the parcel boundaries would be included. Only the canopy area extending into the study area was included for these trees. The canopy cover area associated with each parcel was used to determine total canopy cover extent, by dividing that by the total measurable extent of each parcel, and multiplying the result by 100.

## Tree diameter and canopy width growth increment models developed from Oakville's street and park tree inventory data from 2010 and 2022

Oakville's 2010 and 2022 inventory data for street and park trees in South Oakville were analyzed to identify and extract inventory records for trees that were included in both the 2010 and 2022 inventories, by genus-based species group (Table 1).

Table 1. Species included in genus-based species groups derived from Oakville's 2010 and 2022 tree inventory data for South Oakville.

| Species Group | Species from 2010 and 2022 street and park tree inventory data included in genus-based species group |
|---|---|
| Birches | "Birch - Betula spp."; "Birch, European white (weeping or silver) - Betula pendula"; "Birch, grey or wire - Betula populifolia"; "Birch, paper - Betula papyrifera";"Birch, river - Betula nigra"; "Birch, yellow - Betula alleghaniensis" |
| Cedars | "Cedar, Atlantic white - Chamaecyparis thyoides"; "Cedar, atlas - Cedrus atlantica"; "Cedar, eastern red - Juniperus virginiana"; "Cedar, emerald green - Thuja occidentalis 'emerald'"; "Cedar, white - Thuja occidentalis" |
| Maples | "Maple - Acer spp.";"Maple, Manitoba (box elder) (Mm) - Acer negundo"; "Maple, Manitoba (box elder) - Acer negundo"; "Maple, Norway - Acer platanoides"; "Maple, amur - Acer ginnala"; "Maple, black (hard maple) - Acer nigrum"; "Maple, freemanii - Acer freemanii"; "Maple, red 'Columnare' - Acer rubrum 'Columnare'"; "Maple, red (soft maple) - Acer rubrum";"Maple, silver (soft maple) - Acer saccharinum"; "Maple, sugar (hard maple) - Acer saccharum" |
| Oaks | "Oak - Quercus spp."; "Oak, English - Quercus robur"; "Oak, black - Quercus velutina"; "Oak, bur (mossy cup oak) - Quercus macrocarpa"; "Oak, chinquapin - Quercus muehlenbergii"; "Oak, pin - Quercus palustris"; "Oak, red - Quercus rubra"; "Oak, swamp white - Quercus bicolor"; "Oak, white - Quercus alba" |
| Locusts | "Locust, black - Robina pseudoacacia"; Locust, honey - Gleditsia triacanthos" |
| Spruces | "Spruce - Picea spp."; "Spruce, Norway - Picea abies"; "Spruce, Serbian - Picea omorika"; "Spruce, blue - Picea pungens"; "Spruce, white - Picea glauca" |
| Lindens | "Linden spp. - Tilia spp.";"Linden, big leaf - Tilia platyphyllos"; "Linden, little leaf 'Greenspire' - Tilia cordata 'Greenspire'"; "Linden, little leaf - Tilia cordata"; "Basswood - Tilia americana"; "Basswood - Tilia spp." |
| Poplars | "Aspen, large tooth (bigtooth) - Populus grandidentata"; "Aspen, trembling - Populous tremuloides"; "Cottonwood, black - Populus balsamifera ssp. Trichocarpa"; "Cottonwood, eastern - Populus deltoides var. deltoides"; "Poplar - Populus spp."; "Poplar, balsam - Populus balsamifera ssp. Balsamifera"; "Poplar, silver (white poplar) - Populus alba"; "Poplar, lombardy - Populus nigra 'Italica'" |
| Elms | "Elm - Ulmus spp."; "Elm, American (white) - Ulmus americana";"Elm, Chinese - Ulmus parvifolia"; "Elm, accolade - Ulmus japonica x wilsoniana 'Morton'"; "Elm, liberty - Ulmus amaricana 'libertas'"; "Elm, siberian - Ulmus pumila" |
| Pines | "Pine - Pinus spp."; "Pine, Austrian - Pinus nigra"; "Pine, Scots (Scotch) - Pinus sylvestris"; "Pine, easter white - Pinus strobus"; "Pine, eastern white - Pinus strobus"; "Pine, jack - Pinus banksiana"; "Pine, red - Pinus resinosa" |

These street and park tree inventory genus-based species groups were in turn rolled up into 2018 LiDAR- and imagery-based tree inventory species groups (Cedar, Other Conifer, Shade Intolerant and Shade Tolerant; Table 2). Trees were subsequently grouped by tree diameter-based size classes within those species groups. Within species group size class thresholds for small, medium and large size classes were determined using percentiles of the frequency distribution of dbh values for each species group; specifically, the dbh values at which the within group cumulative percent of trees reached ~40%, ~ 80% and ~100% within species groups. Small, medium and large size class dbh thresholds for species groups are listed in Table 3.

Table 2. 2018 LiDAR and Imagery-based inventory species groups from tree detection and mapping analysis.

| Species Group | Street and park tree inventory species groups included in 2018 LiDAR- and imagery-based species groups |
|---|---|
| Cedar | Cedars |
| Other Conifer | Spruces; Pines |
| Shade Intolerant | Birches; Poplars; Locusts |
| Shade Tolerant | Maples; Oaks; Lindens; Elms |

Table 3. Small, medium and large tree diameter (DBH) size class thresholds for 2018 Inventory species groups used in modeling tree crown width annual growth increments.

| Species Group | Small size class DBH range (cm) | Medium size class DBH range (cm) | Large size class DBH range (cm) |
|---|---|---|---|
| Cedar | DBH ≤ 10 | DBH > 10 ≤ 22 | DBH > 22 |
| Other Conifer | DBH ≤ 27 | DBH > 27 ≤ 46 | DBH > 46 |
| Shade Intolerant | DBH ≤ 19 | DBH > 19 ≤ 49 | DBH > 49 |
| Shade Tolerant | DBH ≤ 30 | DBH > 30 ≤ 50 | DBH > 50 |

Average annual growth increments for tree diameter by species group and size class were subsequently calculated according to the within-species and size class group mean of individual tree annual growth increments for tree diameter (Table 4).

Table 4. Average annual growth increments calculated for tree diameter by species group and size class based upon 2012 and 2022 street and park tree inventory data.

| Species Group | Size Class | DBH growth increment (cm/yr) |
|---|---|---|
| Cedar | Large | 0.580281515 |
| Cedar | Medium | 0.289049027 |
| Cedar | Small | 0.125471698 |
| Other Conifer | Large | 0.707743857 |
| Other Conifer | Medium | 0.650142967 |
| Other Conifer | Small | 0.58330314 |
| Shade Intolerant | Large | 1.032694848 |
| Shade Intolerant | Medium | 0.897548804 |
| Shade Intolerant | Small | 0.552124834 |
| Shade Tolerant | Large | 1.051903419 |
| Shade Tolerant | Medium | 0.906901326 |
| Shade Tolerant | Small | 0.731892329 |

## Regression models developed from Oakville's street and park tree inventory data from 2022 to predict tree diameter based on LiDAR data derived tree heights.

Because it is not possible to measure tree diameter at breast (DBH) directly using LiDAR point cloud data, LiDAR data derived tree heights (the local maxima of tree segments) were used to model the DBH of trees at the start of the modeling exercise. These predictive models were informed by regression analyses of tree diameters and heights of trees included in Oakville's 2022 street and park tree inventory for which those attributes were most recently measured on the ground.

All paired individual tree diameter (dbh) and tree height measures from the 2022 inventory data were combined by species group (cedar, other conifer, intolerant, and tolerant species groups). We obtained species group specific equations to predict tree diameter from height by species group by means of either linear regression with dbh as the dependent variable and height as the sole predictor variable, or by quadratic least squares regression with dbh as the dependent variable and height and height squared as predictor variables. In some cases, outliers were removed if their removal improved model fit statistics.

For the cedar species group, the best model for predicting dbh was a quadratic least squares regression on the complete dataset of cedars measured in 2022 (n = 6,956). The model was highly significant (p<

0.001; $R^2 = 0.28$), as were parameter estimates for height, height squared and the intercept ($p < 0.001$ for all; Figure 6).

For the other conifer species group, the best model for predicting dbh was a linear regression on a dataset of other conifers measured in 2022 for which outliers were removed (n = 7109). The model was highly significant ($P < 0.001$; $R^2 = 0.62$), as were both the parameter estimates for height and the intercept ($p < 0.001$ for both; Figure 7).

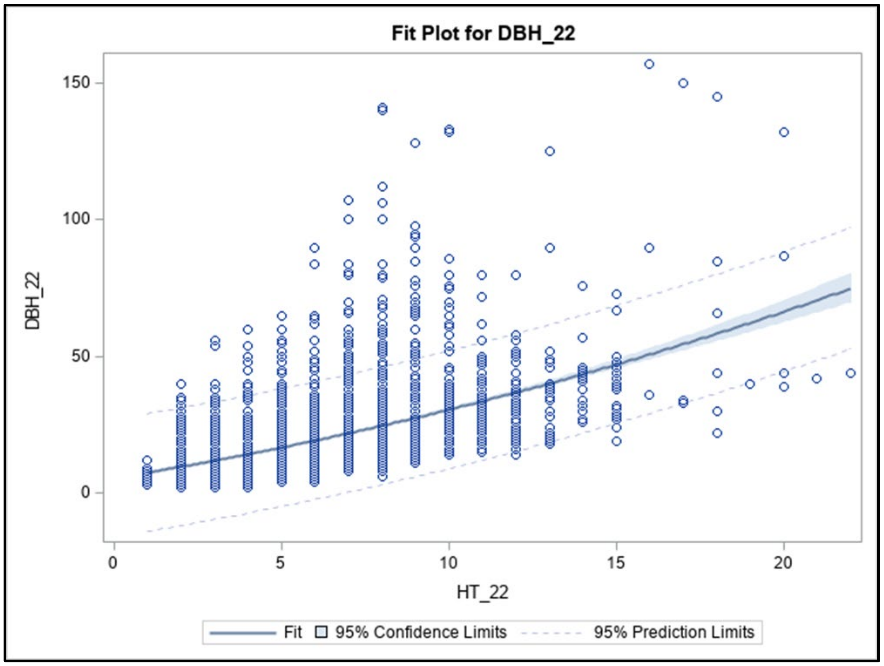


*Figure 6. Fit plot for quadratic least squares regression to predict tree diameter (dbh) from LiDAR derived tree height for the cedar species group.*

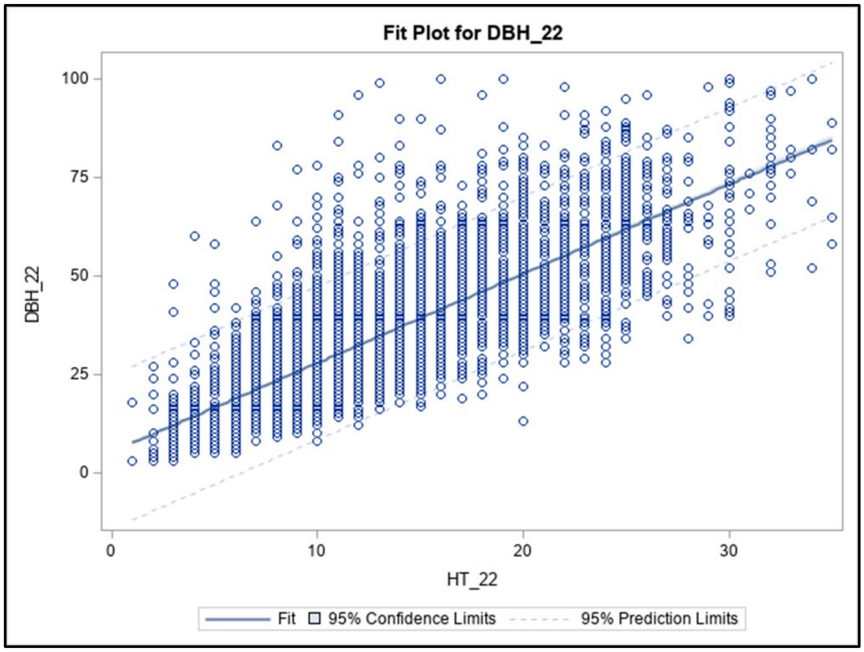


*Figure 7. Fit plot for linear regression to predict tree diameter (dbh) from LiDAR derived tree height for the other conifer species group.*

For the intolerant species group, the best model for predicting dbh was a quadratic least squares regression on an intolerant species group dataset for which outliers were removed (n = 3,724). This model was highly significant ($p< 0.001$; $R^2 = 0.62$), as were parameter estimates for height, height squared, and the intercept ($p< 0.001$ for all; Figure 8).

Lastly, the best model for predicting dbh for the tolerant species group was a linear regression on a 2022 inventory dataset for which outliers were removed (n = 14,357). This model was also highly significant ($p< 0.001$; $R^2 = 0.67$), as were parameter estimates for height, height squared, and the intercept ($p< 0.001$ for all; Figure 9).

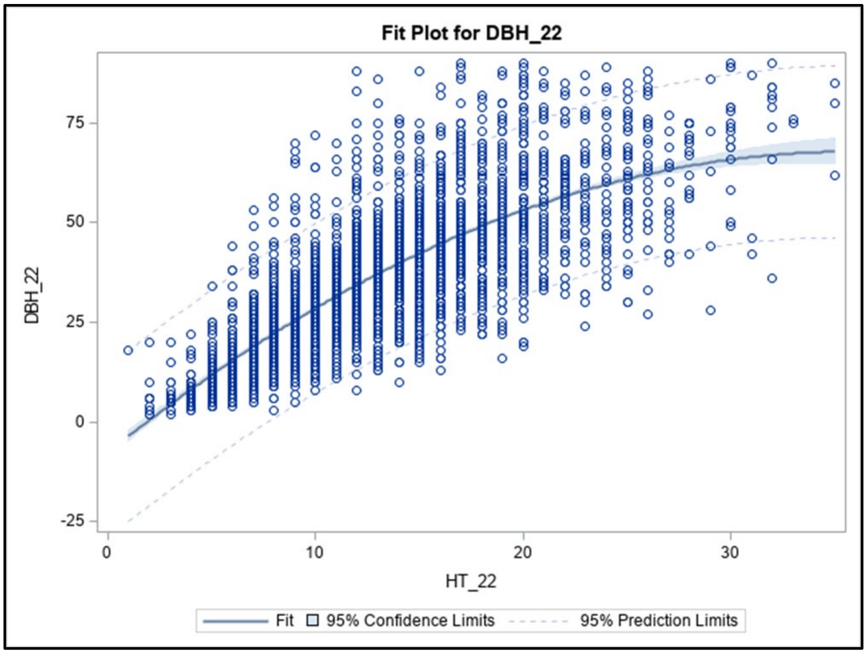


*Figure 8. Fit plot for quadratic least squares regression to predict tree diameter (dbh) from LiDAR derived tree height for the intolerant species group.*

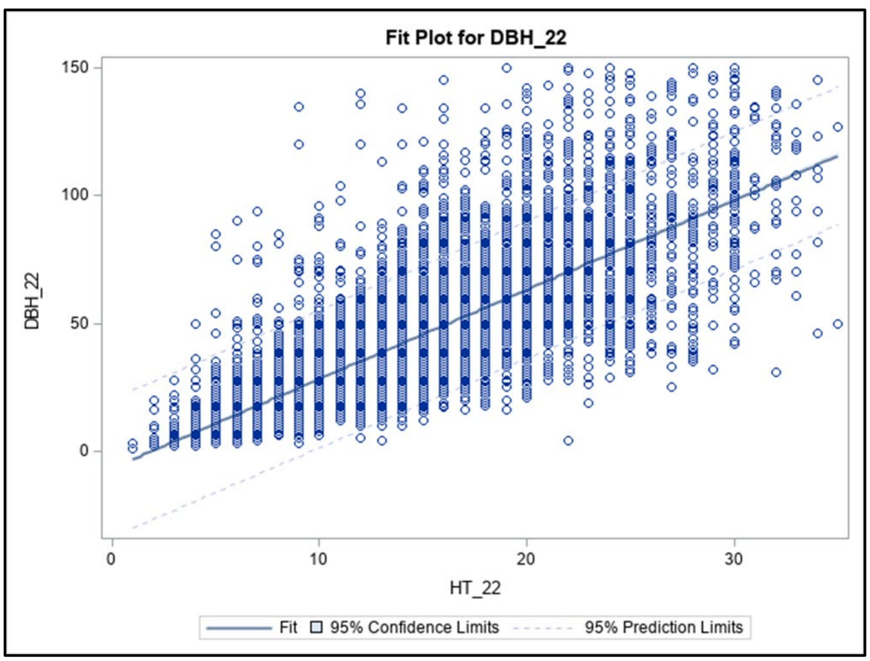


*Figure 9. Fit plot for linear regression to predict tree diameter (dbh) from LiDAR derived tree height for the tolerant species group.*

## Regression models developed from Oakville's street and park tree inventory data from 2010 and 2022 to predict crown width as a function of tree diameter at breast height.

Lidar-derived tree heights were used to determine starting diameter at breast height (dbh) for all trees in all species groups. In order to model canopy width expansion at each time step in the temporally dynamic canopy cover modeling scenarios, we chose to calculate dbh at each time step in modeled scenarios by adding annual growth increments for tree diameter to the starting dbh for all trees by species group and by size class. The resulting dbh values at each time step were used as input variables for regression models used to predict canopy width.

All paired tree dbh and canopy width measures from both the 2010 and 2022 inventory datasets were combined by species group to increase sample sizes. We obtained equations to predict crown width from tree diameter (dbh) by species group by means of quadratic least squares regressions with canopy width as the dependent variable and dbh and dbh squared as predictor variables.

For the cedar species group, the best model to predict canopy width was a quadratic least squares regression on the complete dataset of cedars measured in both 2010 and 2022 (n = 13,918). The model was highly significant ($p < 0.001$; $R^2 = 0.42$), as were parameter estimates for dbh, dbh squared and the intercept ($p < 0.001$ for all; Figure 10).

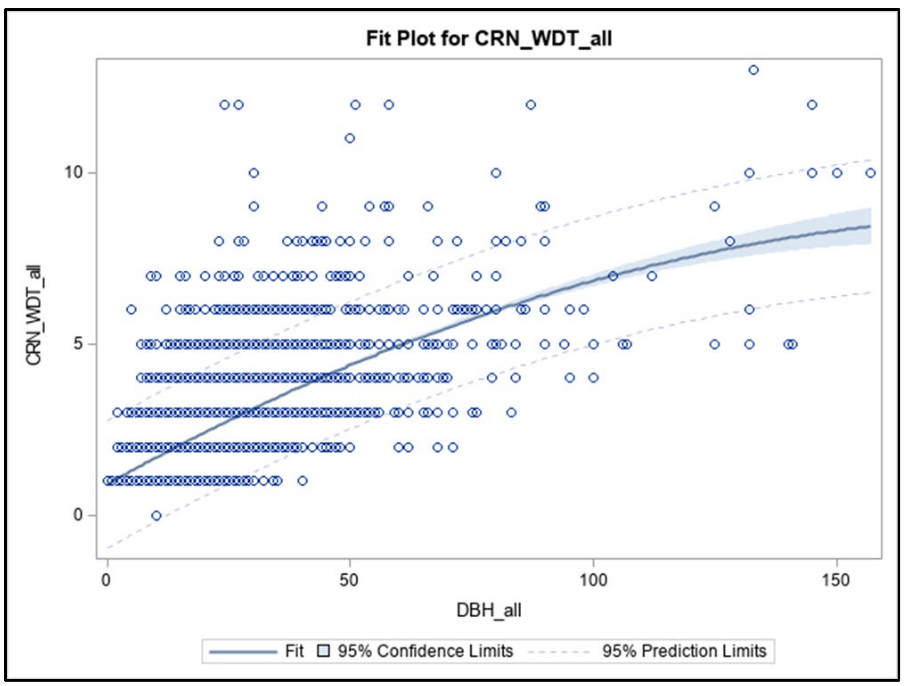


*Figure 10. Fit plot for quadratic least squares regression to predict crown width from tree diameter (dbh) for the cedar species group.*

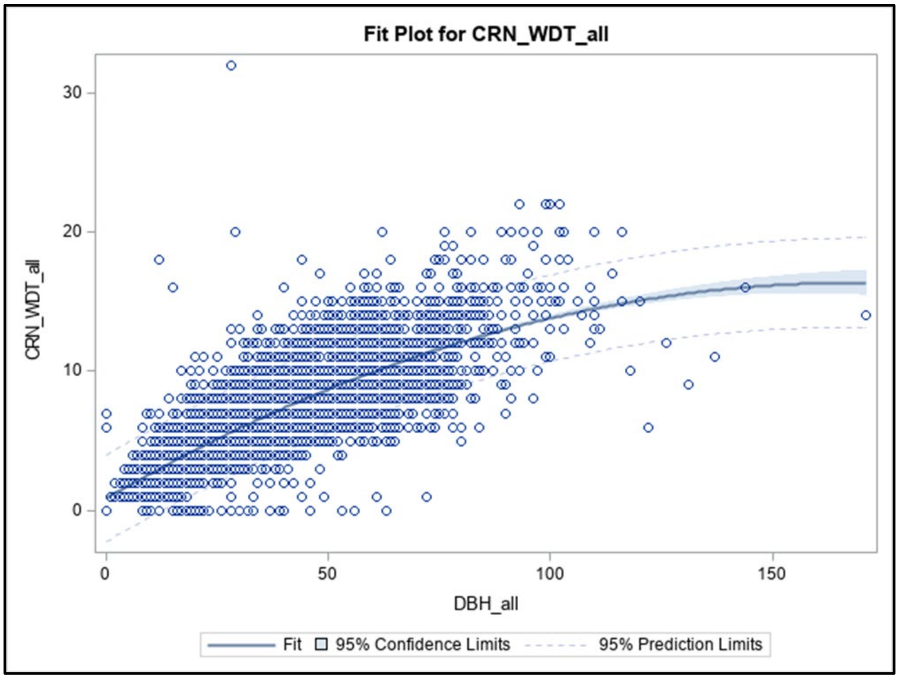


*Figure 11. Fit plot for quadratic least squares regression to predict crown width from tree diameter (dbh) for the other conifer species group.*

For the other conifer species group, the best model to predict canopy width was a quadratic least squares regression on the complete dataset of other conifers measured in both 2010 and 2022 (n = 14,268). The model was highly significant (P< 0.001; $R^2$ = 0.71), as were parameter estimates for dbh, dbh squared, and the intercept (p< 0.001 for all; Figure 11).

For the intolerant species group, the best model to predict canopy width was a quadratic least squares regression on the complete intolerant species group dataset measured in both 2010 and 2022 (n = 7,562). This model was highly significant (p< 0.001; $R^2$ = 0.72), as were parameter estimates for DBH, DBH squared, and the intercept (p< 0.001 for all; Figure 12).

Lastly, the best model to predict canopy width for the tolerant species group was a quadratic least squares regression on the complete tolerant species group dataset measured in both 2010 and 2022 (n = 28,840). This model was also highly significant (p< 0.001; $R^2$ = 0.80), as were parameter estimates for height, height squared, and the intercept (p< 0.001 for all; Figure 12).

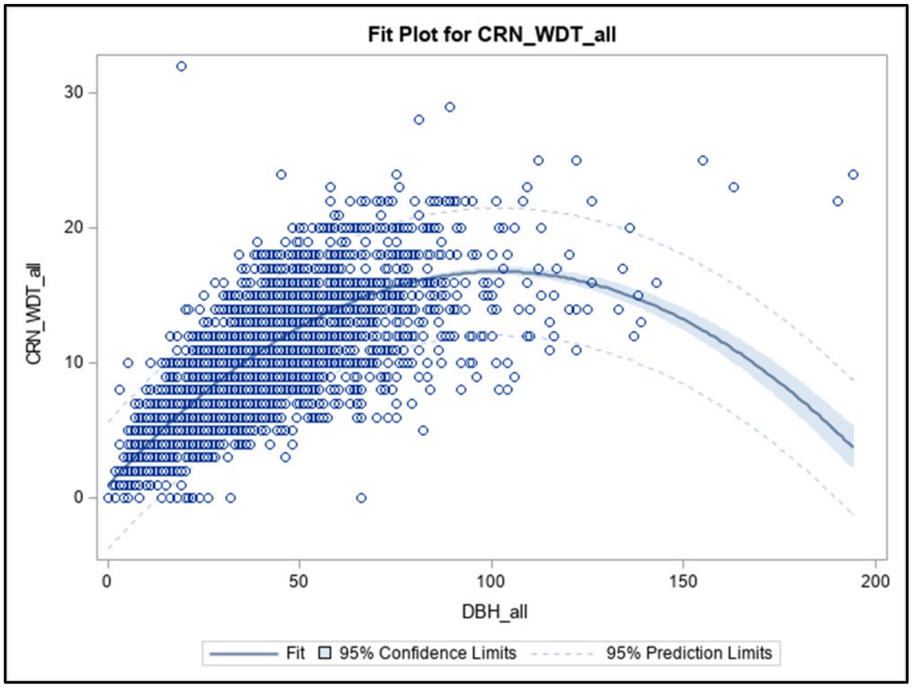


*Figure 12. Fit plot for quadratic least squares regression to predict crown width from tree diameter (dbh) for the intolerant species group.*

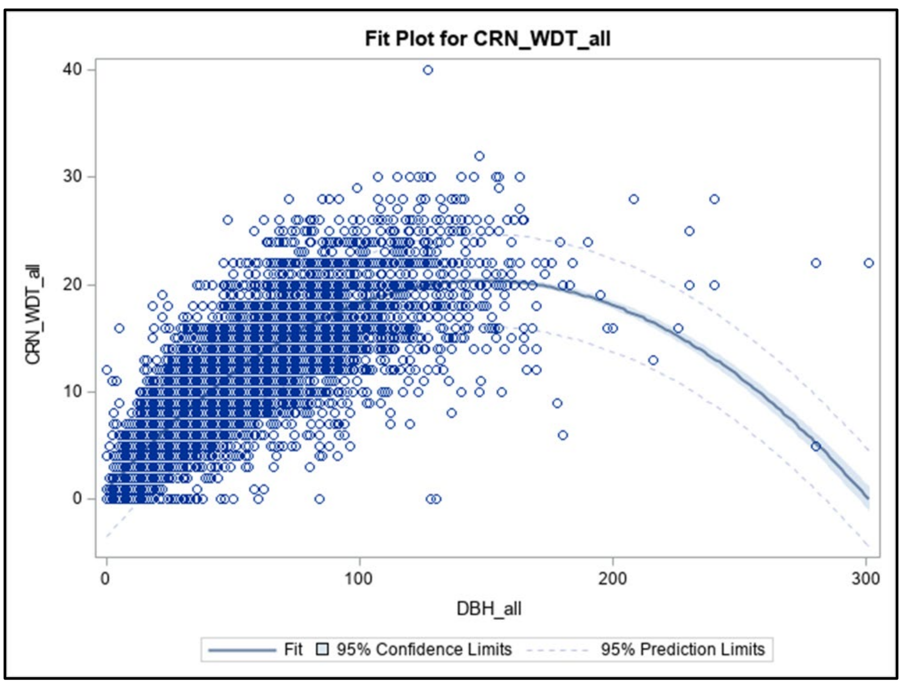


*Figure 13. Fit plot for quadratic least squares regression to predict crown width from tree diameter (dbh) for the intolerant species group.*

Statistically, the regression models and parameters used to parameterize growth equations used in this study were all highly significant. These models' $R^2$ values, which are key model fit statistics, were somewhat lower than anticipated, especially for the cedar species group, given that all predictor variables in all models were highly significant in addition to the models themselves. However, this could be explained by the high number of trees with the same diameter (dbh) but different heights and crown widths in the street and park tree inventory data, and the relatively high proportion of small stature trees in the cedar species group. This being the case, we are confident that the regression-based growth models developed for this study were suitable for predicting tree diameter based upon tree height, and for predicting growth in tree diameter and crown expansion over time.

## Temporarily dynamic model to predict canopy cover under modeled development related tree removal scenarios: model design and function.

The analysis of canopy change consisted of two key models: a 20-year model representing scenarios for 100% and 50% removal of trees, and companion extended models that forecasted canopy cover recovery beyond the first 20 years for both the 100% and 50% tree removal scenarios. The key difference was that the models that forecast canopy cover recovery beyond the first 20 years did not include tree removals from development, because by year 20, 100% of parcels had already been subject to development-related tree removals. These canopy cover recovery models were set to run additional years into the future, and simply predicted annual growth and mortality, in the absence of modeled tree removals. These models were used to identify the years in which the canopy cover targets of 35% for Residential Class A parcels, and 25% for Residential Class B parcels would be met following 20 years of intensive development/redevelopment.

Starting inputs for 20-year models included a database of detected tree centroids (a.k.a. the detected trees database) that had attributes for dbh, species, crown width, a parcel ID and zone ID corresponding parcel and zoning designation, with By-Law protection status for trees within parcels determined by their position in relation to buffered maximum building envelopes.

To model tree planting, an empty database was created to accommodate future By-law replacement trees. Additionally, a parcel ID tracking mechanism was implemented to randomly designate and monitor parcel IDs earmarked for development each yearly iteration in the models. At each iteration 5% of parcels were randomly selected and all trees with matching parcel IDs were selected for removal in the 20-year models. In so doing, 100% of parcels underwent redevelopment over the 20-year modeling time horizon. For the 100% tree removal scenario, all trees with matching parcel IDs were selected from the 5% of parcels selected randomly for redevelopment annually. For the 50% removal scenario, a random selection of 50% of the trees within those parcels were selected for removal.

If the tree was By-Law protected then planted trees were generated the following year in a replacement trees database based on individual trees' replacement criteria: 1 replacement tree for every 10 cm of dbh of the tree removed. Parcel IDs were assigned randomly from the current list of unique parcel IDs or were assigned to a zone area outside of a parcel and species were assigned to newly planted trees randomly in proportion to 1) the most commonly planted trees in genus-based species groups; the relative proportion of replacement trees planted by species group were set to 10% intolerant, 10% other conifer, 30% cedar, and 50% tolerant species group trees, and 2) commonly planted trees but with cedar excluded; the relative proportion of replacement trees planted by species group were set to 20% intolerant, 20% other conifer, and 60% tolerant species group trees. For planted trees, growth in tree diameter and canopy width was modeled according to annual growth increments, and equations from the regression analysis of Oakville's 2010 and 2022 street and park inventory to predict canopy width as a function of tree diameter.

The initial dbh of all planted trees was set to 6 cm for modeling purposes. At the beginning of each iteration following the first year, tree diameters increased according to annual growth increments for dbh by species group and size class, and the Detected Trees Database was updated with the removed trees from the previous year.

In order to calculate crown area for trees in the detected tree and planted trees databases, an assumption was made that each tree crown would have a roughly circular shape corresponding to their width and crown area was calculated for each year and summed by residential class using the zone attribute information. Trees outside of development parcels with canopies that overhang the study area, or were located within public right-of-ways and easements within the study area, were tracked with the in a separate database. These trees were replaced on a 1:1 ratio with similar species of the removed tree and randomly assigned within the study area. Thus, the contribution of overhanging tree canopy to canopy cover in the study area was calculated and included in our models.

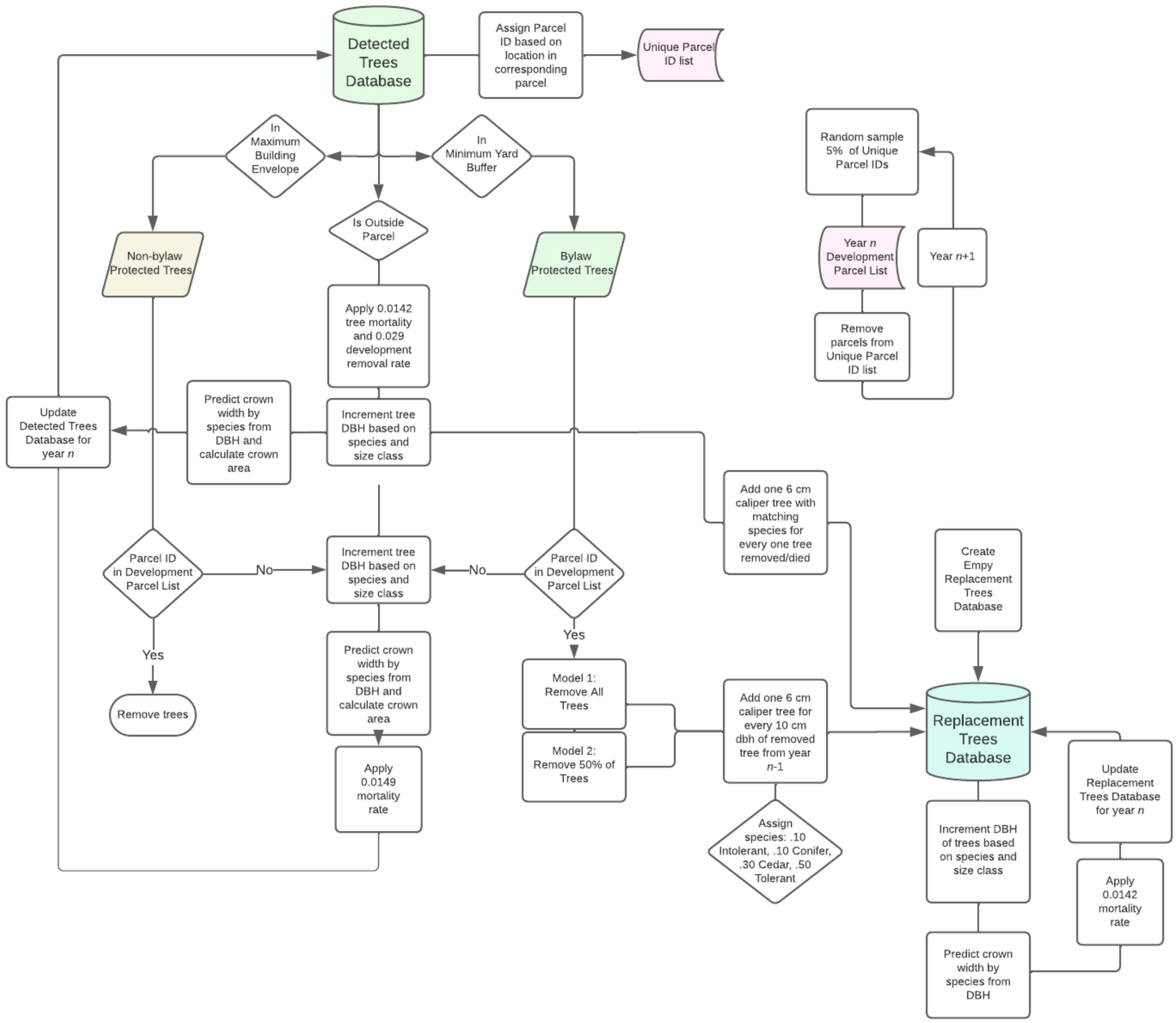


*Figure 14. Flow chart depicting key steps in the 20-year models used to model both the 50% and 100% removal scenarios.*

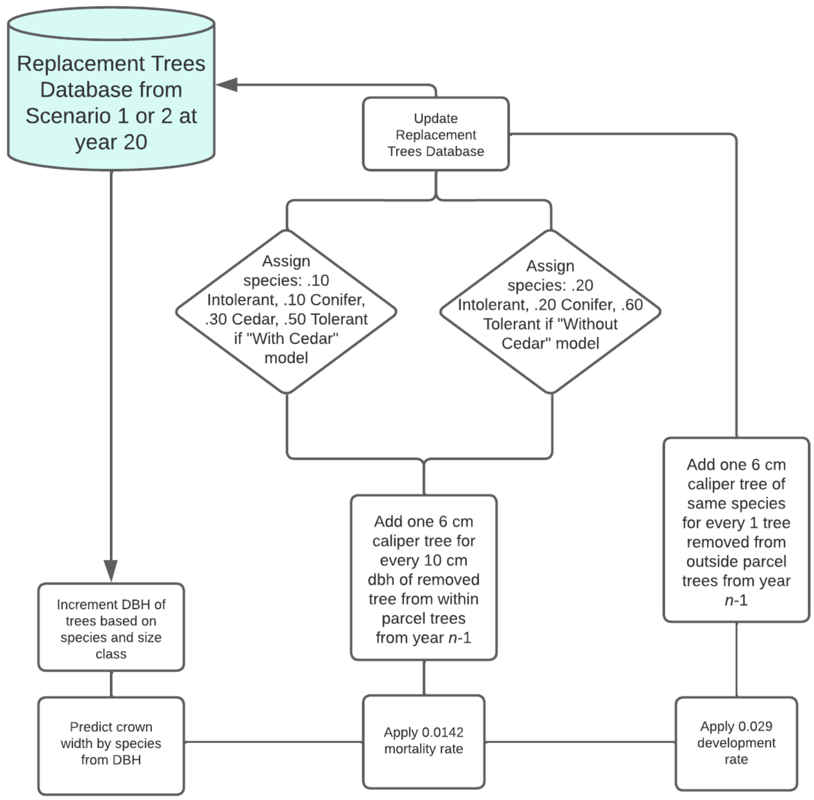


*Figure 15. Flow chart depicting key steps in the 100-year (i.e., 2043 - 2123) models used to model both the 50% and 100% removal scenarios.*

# Results

Tree detection and mapping detected a total of 109,275 trees within the study area. Of those, 59,316 were located in residential yards and were By-Law protected, 10,862 trees were located within maximum building footprints and construction activity zone buffers that would be removed and not replaced if all parcels were developed/redeveloped to the maximum allowable building footprint. The remaining 39,098 trees were located in the study area but outside of parcels on easements and within natural areas or other zones overhanging and contributing to the canopy cover in the study area. Canopy cover for the study area at the beginning of the modeling exercise was calculated to be 47.4% for parcels zoned Residential Class A, and 24.2% for parcels zoned Residential Class B.

Results for the 100% tree removal and replacement scenarios with and without planted cedar over 20 years are summarized in Figures 16 & 17. Under this scenario, when cedar was included and made up 30% of replacement trees, canopy cover declined from 47.4% to 25.5% over the 20 year time horizon in Residential Class A parcels. Canopy cover for Residential Class B parcels also declined, from 24.2% to 9.8% by the end of the 20 year modeling time horizon (Figure 16).

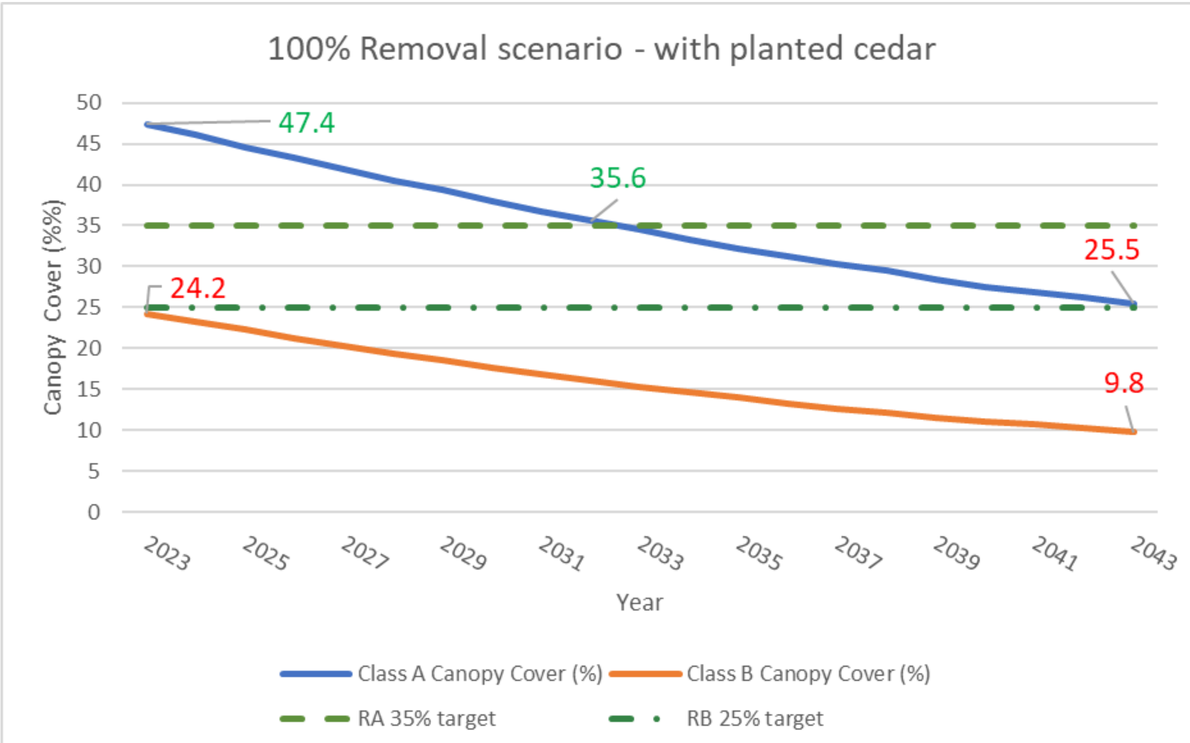


*Figure 16. Decline in canopy cover for Residential Class A and Residential Class B zones under a 100% tree removal scenario with cedar included as potential replacement trees and a parcel development/redevelopment rate of 5% by area, annually for 20 years. Canopy cover percent numbers in green font indicate canopy cover at those times remained above the 2057 canopy cover targets of 35% for Residential Class A, and 25% for Residential Class B, set in the UFSMP; numbers in red font indicate the opposite.*

When cedar was excluded from potential replacement trees in the 100% removal scenario, canopy cover declined from 47.4% to 28% over the 20-year time horizon in Residential Class A parcels. Canopy cover for Residential Class B parcels also declined, from 24.2% to 11.4% by the end of the 20-year modeling time horizon (Figure 17).

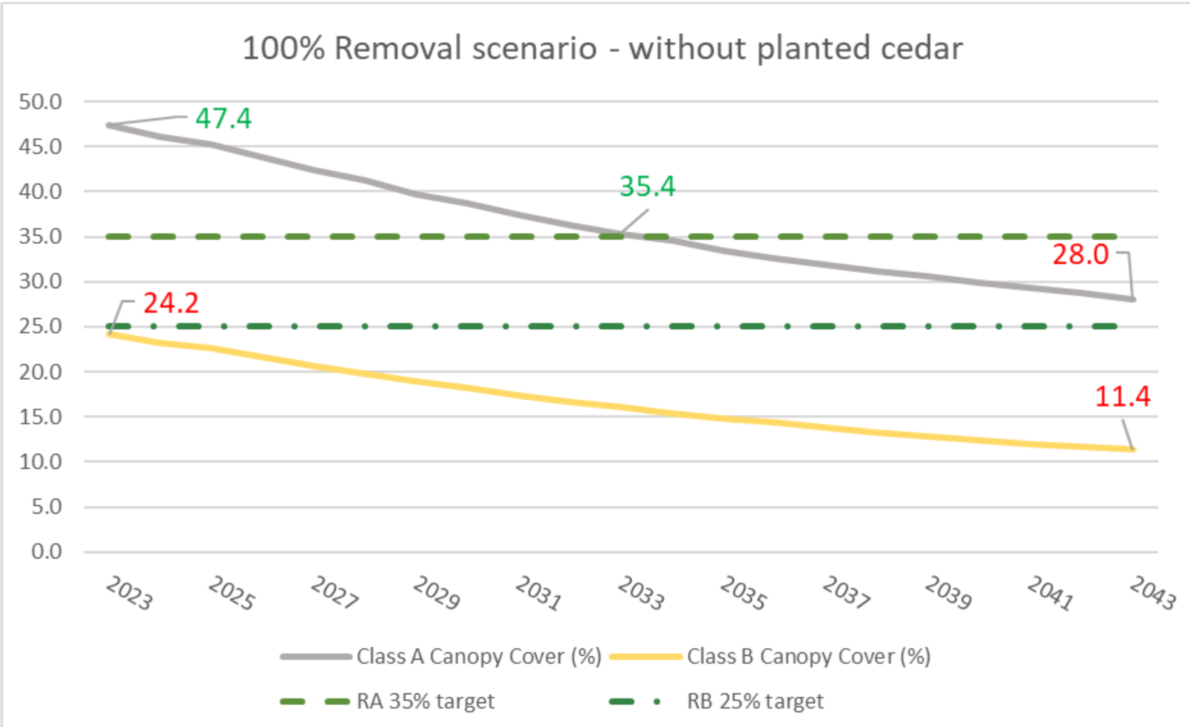


*Figure 17. Decline in canopy cover for Residential Class A and Residential Class B zones under a 100% tree removal scenario with cedar excluded from potential replacement trees and a parcel development/redevelopment rate of 5% by area, annually for 20 years. Canopy cover percent numbers in green font indicate canopy cover at those times remained above the 2057 canopy cover targets of 35% for Residential Class A, and 25% for Residential Class B; numbers in red font indicate the opposite.*

The number of trees removed from Residential Class A and Residential Class B parcels, and number of trees planted varied annually due to variable numbers and sizes of trees in each year's random selection of parcels. For the 100% removal scenario, results indicated that a total of 59,316 By-law protected trees, and 10,862 non-By-law protected trees, will be removed from Residential Class A and Residential Class B parcels over the 20-year model time horizon. The loss of the 10,862 trees within building footprints, and canopy cover associated with these, would not be replaced.  A total of 13,002 and 61,918 replacement trees would be planted to replace By-Law protected trees in Residential Class A and B parcels, respectively, over the same time period.

Tree removals and replacement were substantially higher in Residential Class B parcels, primarily due to a larger proportion of parcels in the study area belonging to this group.  As expected, non-By-law protected trees were removed at lower rates than By-law protected trees, most often by an order of magnitude. Results for the 100% removal scenario also indicated that the canopy cover target for

Residential Class A of 35% could no longer be met beyond 2032. The canopy cover target of 25% for Residential Class B was not achieved in any year under the 100% removal scenario.

Results for the 50% tree removal scenario over 20 years are summarized in Figures 18 & 19. Under this scenario, when cedar was included and made up 30% of replacement trees, canopy cover declined annually from 47.4% to 33.4% over the 20-year time horizon in Residential Class A parcels. Canopy cover for Residential Class B parcels also declined annually, from 24.2% to 15.8% by the end of the 20-year model time horizon (Figure 18).

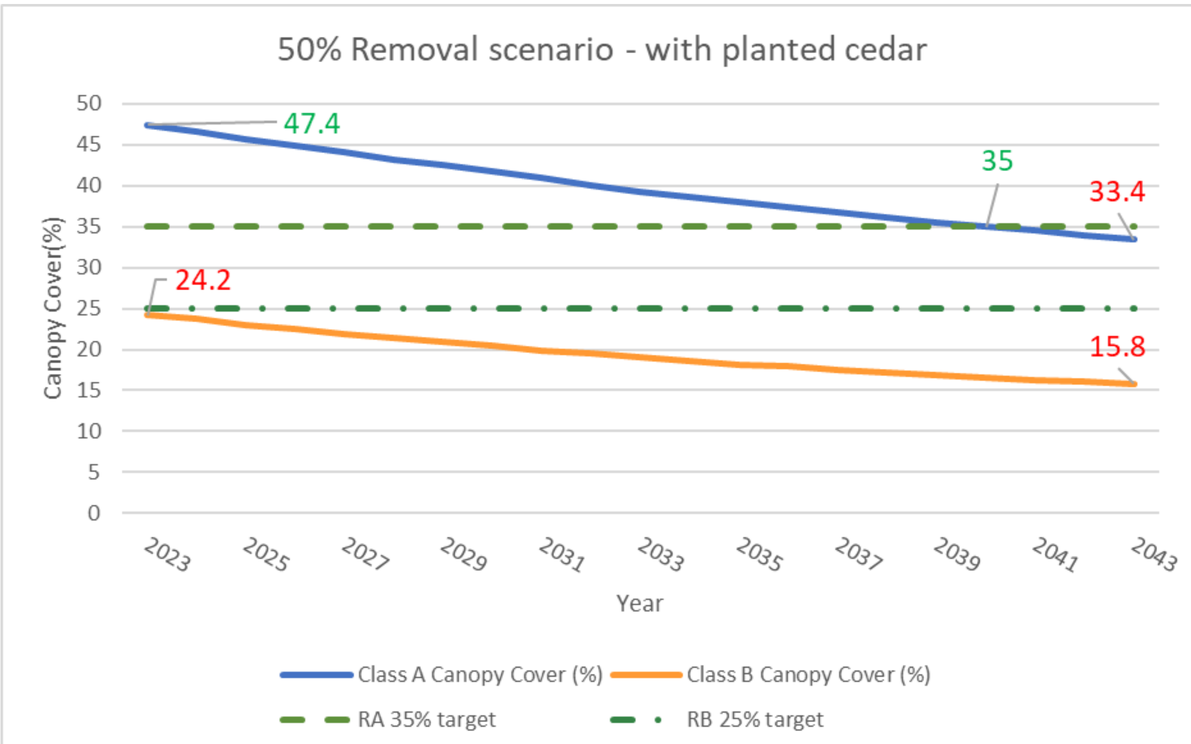


*Figure 18. Decline in canopy cover for Residential Class A and Residential Class B zones under a 50% tree removal scenario with cedar included as potential replacement trees and a parcel development/redevelopment rate of 5% by area, annually for 20 years. Canopy cover percent numbers in green font indicate canopy cover at those times remained above the 2057 canopy cover targets of 35% for Residential Class A, and 25% for Residential Class B; numbers in red font indicate the opposite.*

When cedar was excluded from potential replacement trees in the 50% removal scenario, canopy cover declined from 47.4% to 35.1% over the 20-year time horizon in Residential Class A parcels. Canopy cover for Residential Class B parcels also declined, from 24.2% to 17.5% by the end of the 20-year modeling time horizon (Figure 19).

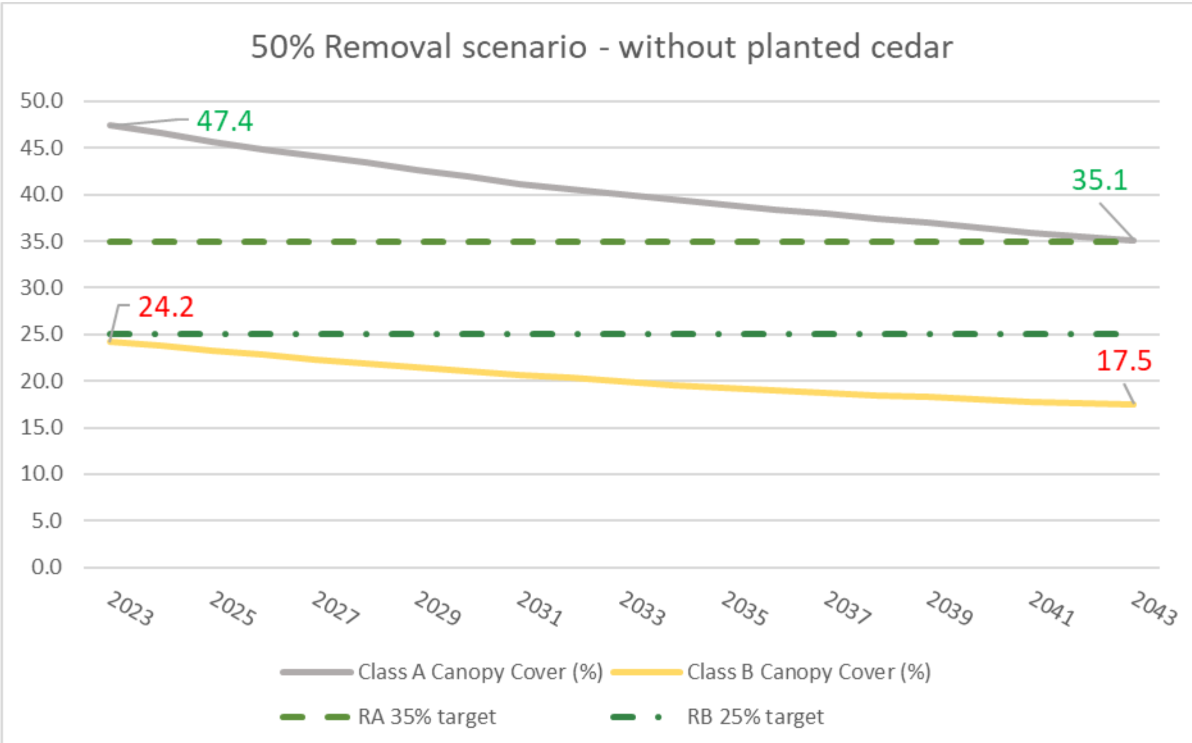


*Figure 19. Decline in canopy cover for Residential Class A and Residential Class B zones under a 50% tree removal scenario with cedar excluded from potential replacement trees and a parcel development/redevelopment rate of 5% by area, annually for 20 years. Canopy cover percent numbers in green font indicate canopy cover at those times remained above the 2057 canopy cover targets of 35% for Residential Class A, and 25% for Residential Class B; numbers in red font indicate the opposite.*

The number of trees removed from Residential Class A and Residential Class B parcels, and number of trees planted again varied annually due to variable numbers and sizes of trees in each year's random selection of parcels. For the 50% tree removal scenario, results indicated that a total of 29,658 By-law protected trees, and 5,430 non-By-law protected trees, will be removed from Residential Class A and Residential Class B parcels over the 20-year model time horizon. The loss of the 5,430 non-By-law protected trees, and canopy cover associated with these, would be permanent. A total of 7,318, and 33,072 replacement trees would be planted to replace By-law protected trees in Residential Class A and B parcels, respectively, over the same time period.

As was the case for the 100% tree removal scenario, tree removals and replacement were substantially higher in Residential Class B parcels under the 50% tree removal scenario, and, as expected, non-By-law protected trees were removed at lower rates than By-law protected trees, in this case at all times by an order of magnitude. However, unlike the 100% removal scenario, results for the 50% removal scenario indicated that the canopy cover target for Residential Class A of 35% could be met until 2042; never did it fall below the canopy cover target of 35%. The canopy cover target of 25% for Residential Class B was again not achieved in any year under the 50% removal scenario.

When the extended models were run beyond 2043, after all of the parcels had been fully developed/redeveloped, and no further By-law protected tree removals were modeled, the modeled scenarios showed a range of recovery times, i.e., the time elapsed post-development to the year in which the canopy cover targets of 35% for Residential A and 25% for Residential B were met. The only exception was canopy cover in Residential Class A under the 50% tree removal scenario that excluded cedar from replacement trees, since it stayed above 35% by 2043 and only increased in the years that followed (Figures 20 & 21).

For the 100% tree removal scenario, when cedar was included as a potential replacement tree, canopy cover percent for Residential Class A parcels recovered from a low of 28% in 2043 to above target 35.2% in 2074. Canopy cover for Residential Class B recovered from a low of 9.8% to above target 25.3% in 2081. Under this scenario, when cedar was excluded from potential replacement trees, canopy cover in Residential Class A recovered more quickly, to 35.2% in 2061. Canopy cover for Residential Class B also recovered more quickly than when cedar was included as a replacement tree, to 25.1% in 2071 (Figure 20).

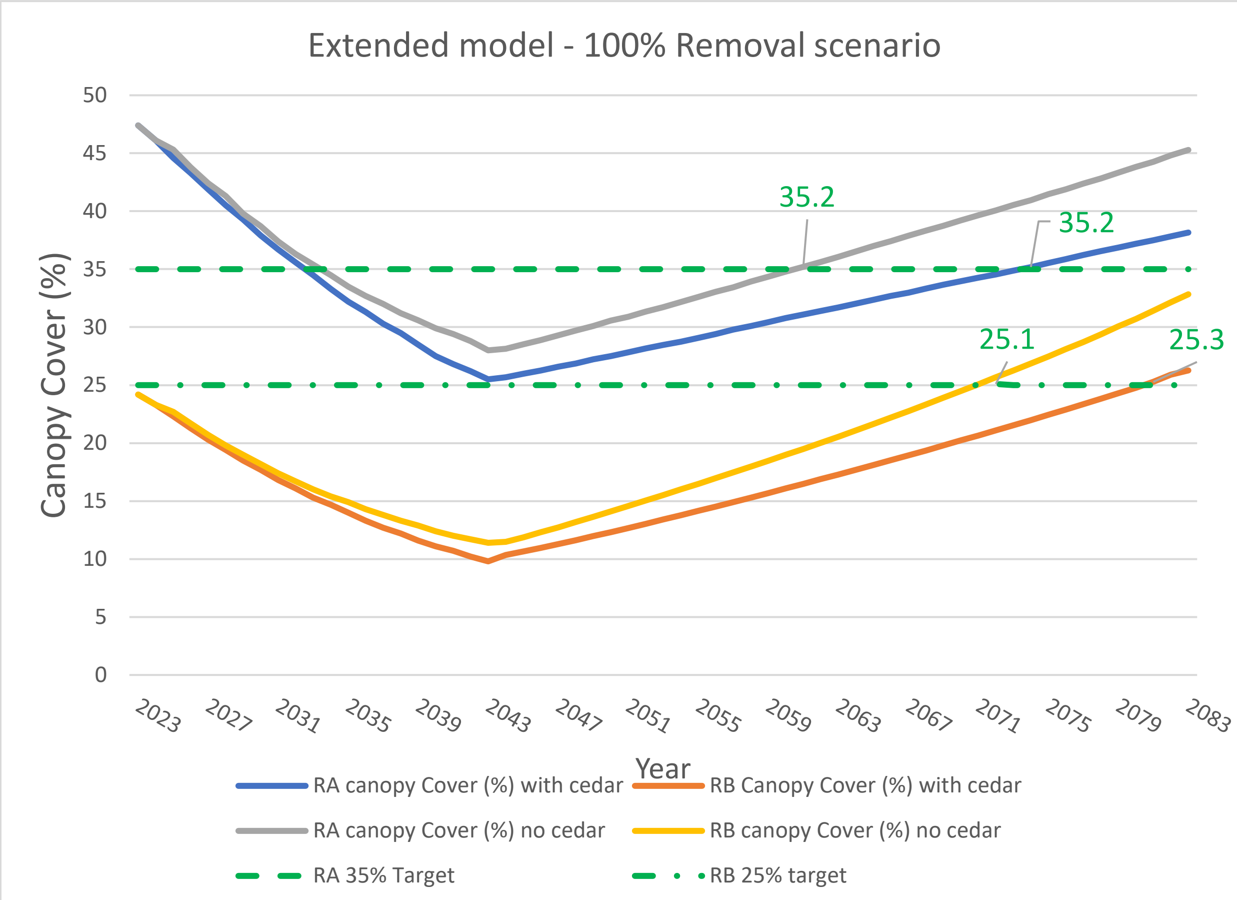


*Figure 20. Extended model results showing canopy cover recovery following the development/redevelopment of all Residential Class A, and Residential Class B lands, modeled under a 100% tree removal scenario with a parcel development/redevelopment rate of 5% by area, annually for 20 years until 2043. Canopy cover percent numbers in green font indicate canopy cover at those times will have recovered to the 2057 canopy cover targets of 35% for Residential Class A, and 25% for Residential Class B.*

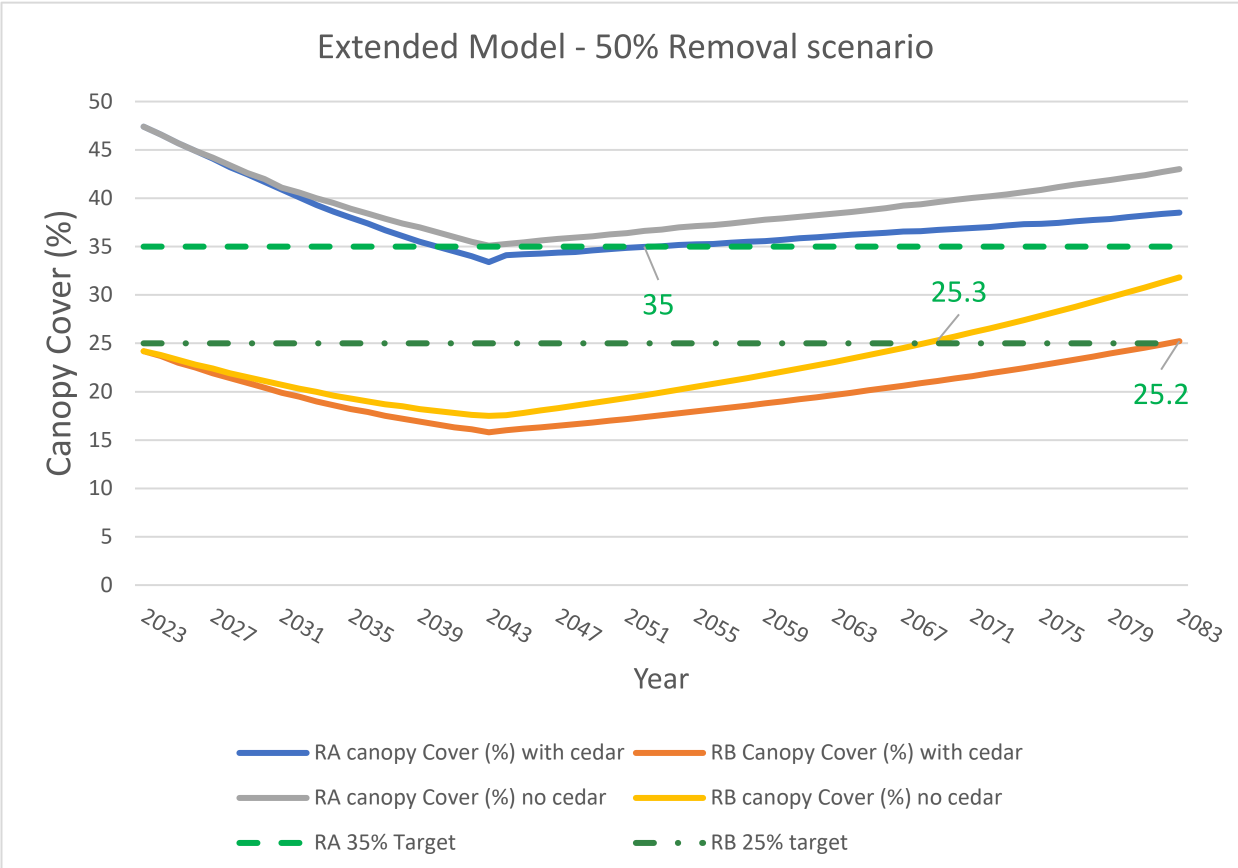


*Figure 21. Extended model results showing canopy cover recovery following the development/redevelopment of all Residential Class A, and Residential Class B lands, modeled under a 100% tree removal scenario with a parcel development/redevelopment rate of 5% by area, annually for 20 years until 2043. Canopy cover targets are indicated by dashed and dotted lines.*

For the 50% tree removal scenario, when cedar was included as a potential replacement tree, canopy cover percent for Residential Class A parcels recovered to the target 35% in 2052. Canopy cover for Residential Class B recovered to above target 25.2% in 2083. Under this scenario, when cedar was excluded from potential replacement trees, canopy cover in Residential Class A remained above the 35% target over the entire modeling time horizon. Canopy cover for Residential Class B recovered to above target 25.3 in 2069 (Figure 22).

## Conclusions and Recommendations

This study demonstrated the utility of LiDAR, multispectral satellite imagery and machine learning algorithms (Artificial Intelligence) used in combination to detect and measure privately owned trees, and assign trees to species groups, for all trees located in parcels zoned Residential Class A and Residential Class B in the Town of Oakville. It also demonstrated how Oakville's street and park tree inventories from 2010 and 2022 could be used to train machine learning models to classify trees to species groups, and subsequently be used to model tree diameter based on LiDAR derived measures of tree height, as well as to model growth in tree diameter and canopy width over time. These data were used to parameterize models of canopy cover growth and loss under different development scenarios over time, such that key questions surrounding the potential of the Town's Private Tree Protection By-law to mitigate the impact of Bill 23 on Oakville's tree canopy could be addressed.

Statistically, the regression models and parameters used to parameterize growth equations used in this study were all highly significant. These models' $R^2$ values, which are key model fit statistics, were somewhat lower than anticipated, especially for the cedar species group, given that all predictor variables in all models were highly significant in addition to the models themselves. However, this could be explained by the high number of trees with the same diameter (dbh) but different heights and crown widths in the street and park tree inventory data, and the relatively high proportion of small stature trees in the cedar species group. This being the case, we are confident that the regression-based growth models developed for this study were suitable for predicting tree diameter based upon tree height, and for predicting growth in tree diameter and crown expansion over time.

Results of the 20-year and extended models of changes in canopy cover associated with the removal of privately owned trees under different residential parcel development/redevelopment scenarios showed that the potential impacts of Bill 23 on Oakville's urban forest canopy were severe, with all but the 50% tree removal scenario that excluded cedar replacement trees in the 20-year model indicating that canopy cover would decline to below the canopy cover targets set for Residential Class A and Residential Class B.

These results are concerning, as modeling results for both the 100% and 50% tree removal scenarios in both the 20-year and 100-year models show that canopy cover in Residential Class A and Residential Class B parcels exhibit a declining canopy cover trend in the face of development, and all but one modeled scenario (50% tree removal without cedar included in replacement trees) indicated canopy cover percent will, by 2057, fall below the canopy cover targets for those residential property classes set in the UFSMP. Moreover, it is clear from our results that planting replacement trees for By-law protected trees that are removed for development/redevelopment is essential in order for canopy cover to recover from development related canopy loss.

The pace of and severity of declines in canopy cover were shown to be particularly sensitive to whether cedars were included as potential replacement trees or not. When included, a high proportion of the replacement tree populations modeled were cedar (30%), a species that contributes relatively little to canopy cover in comparison to canopy expansion modeled for species in the other species groups. This was further evidenced in the length of time required for canopy cover targets to be met following development related tree removals. For most modeled scenarios, it took substantially longer for canopy cover to recover to target levels when cedar was included as a potential replacement tree species.

Thus, the main findings of the study were that:

1. The 2057 canopy cover targets for Residential Class A and Residential Class B will not be met if the town continues to consider cedar a suitable replacement tree for By-law protected trees when permits are issued for their removal.
2. The 2057 canopy cover targets for Residential Class A and Residential Class B will be further compromised if the town continues to accept cash compensation in-lieu of replanting within these residential zones to replace By-law protected trees when permits are issued for their removal.
3. The adverse impacts of removing 100% of By-law protected trees from parcels slated for development/redevelopment are far greater than when 50% of those trees are retained.

Given these findings, we recommend that:

1. Cedar be excluded from the list of suitable replacement trees when permits are issued to remove By-law protected trees.
2. Cash compensation in-lieu of tree replacement as a condition of tree removal permits should not be accepted. The replacement trees should be planted within the same residential class zones from which By-law protected trees are to be removed.
3. The Town avoids issuing permits for the removal of all By-law protected trees from private properties if reasonable opportunities exist to retain some proportion of By-law protected trees when those properties are slated for development/redevelopment.

Overall, the results of this study confirm that the potential adverse impacts of Bill 23 on Oakville's canopy cover percent and canopy cover targets are substantial. How these results may be used to inform changes in policy and the regulatory regime for trees that make up Oakville's urban forest will determine if, and how, these adverse impacts may in the future be mitigated by the protection afforded trees under the Private Tree Protection By-law.