A Street Tree Survival Strategy in Toronto

Clean Air Partnership

Acknowledgements

Executive Director:
Eva Ligeti, Clean Air Partnership

Authors:
Jesse Auspitz, Ryerson University
Michelle Sawka

Advisors, Reviewers & Editors:
Caroline Rodgers, Clean Air Partnership
Kevin Behan, Clean Air Partnership
Eva Ligeti, Clean Air Partnership

Clean Air Partnership gratefully acknowledges the financial support of the Ontario Ministry of the Environment. We also wish to thank the representatives of the City of Toronto, who provided input to this report, and the staff who initiated and played a lead role in the development of this project.

For more information, contact:
Clean Air Partnership
75 Elizabeth Street
Toronto, Ontario. M5G 1P4, Canada
416-392-6672
www.cleanairpartnership.org

About the Clean Air Partnership
Clean Air Partnership (CAP) is a registered charity that works in partnership to promote and coordinate actions to improve local air quality and reduce greenhouse gases for healthy communities. Our applied research on municipal policies strives to broaden and improve access to public policy debate on air pollution and climate change issues. Our social marketing programs focus on energy conservation activities that motivate individuals, government, schools, utilities, businesses and communities to take action to clean the air.

January 2012

Table of Contents

Forward – Community Adaptation Initiative Case Studies

This case study is one of five produced by Clean Air Partnership for the Community Adaptation Initiative, a provincially funded program through the Ontario Ministry of the Environment that delivers climate change adaptation resources for municipalities The case studies provide detailed examples of climate change adaptation in Ontario communities. Tailored for municipal audiences, each study examines a program, plan or action with a view to encouraging replication in other municipalities confronting similar challenges. To this end, important data relating to regional background, planning process, challenges and lessons learned have been highlighted.

Climate change is expected to place increased stress on natural, social and built environments. It will also create challenges for municipalities as they work to minimize the impacts of climate change through the development and implementation of climate change adaptation plans. Municipalities must be prepared for increasing variability in temperature and precipitation patterns and increasing occurrences of extreme events such as droughts, extreme heat, storms and other expected impacts. Climate change will place additional stress on infrastructure, planning and social services, environmental conditions and buildings.

Existing municipal efforts primarily focus on mitigating climate change. However, through adaptation, municipalities can implement plans or take action to reduce the more immediate impacts of climate change. This process may involve altering existing policies, or creating new ones that address observed or expected climate changes. Ultimately, adaptive action at this juncture will prepare municipalities for future climate change impacts that threaten their populations, infrastructure and daily operations.

Executive Summary

Street trees help moderate urban temperatures and can help reduce the impacts of certain storm events on city infrastructure, residents and business. As such, they are an important component of many climate change adaptation strategies. Yet urban trees face extremely difficult growing conditions, which tend limit their lifespan, preventing them from providing their full environmental benefits. Street trees are themselves quite sensitive to climate related impacts. This creates an interesting paradox where street trees are both a mechanism for addressing climate impacts, and are themselves more vulnerable due to climate change.

The City of Toronto Urban Forestry Services has responded to this problem by implementing and promoting the use of new planting techniques that encourage street tree survival in an urban environment consistent with the concept of a *working tree* that provides ecological services to the City.

This case study examines the policy developments and research that encouraged the implementation of street tree survival initiatives, as well as the technological approaches that have been used to implement the new policies. It provides details of two specific techniques that have been used by the City of Toronto to encourage the long term survival of street trees; continuous trenches and soil cells.

This case study concludes with six lessons learned that may help other cities implement street tree survival initiatives in order to maximize the contribution of their street trees to climate change adaptation.

1 Introduction

1.1 Introduction to Sustainable Street Trees Case Study

In urban environments, trees can yield a host of benefits including: providing shade, reducing stormwater runoff, improving air quality, reducing electricity use, and improving residents' quality of life. Despite their importance, street trees in urban centres often die relatively young. In Toronto, street trees live to an average age of only seven years, therefore limiting the environmental benefits they contribute (Weiditz & Penney, 2007).

The City of Toronto's Urban Forestry Services has been implementing and promoting the use of new planting techniques that will help street trees live long enough to achieve mature canopies, and therefore deliver the maximum level of benefits. Technologies including soil cells and continuous soil trenches allow for the expansion of root systems, reduce soil compaction, and can increase the longevity of street trees. To date, these new technologies have been used to plant more than 500 street trees in Toronto, with the goal of extending lifespan to 30- 40 years.

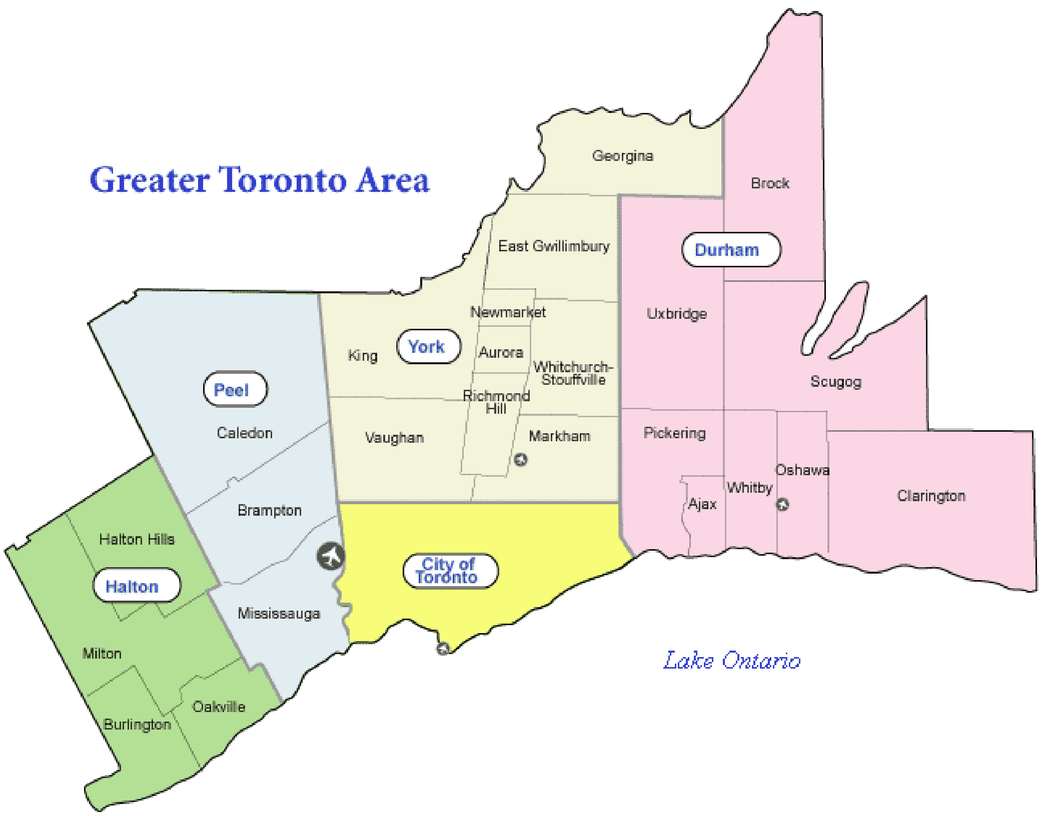
Trees grow slowly; consequently current decisions regarding forest management will play out over several decades. In order to address the vulnerability of trees to climate change and also leverage the benefits trees can provide, climate change needs to become part of today's decision-making. Specific impacts of climate change are unpredictable, so street tree strategies should ensure a diverse and resilient street tree population to gain the maximum benefit. This case study describes street tree survival initiatives and the technological approaches that have been used to support Toronto's street trees.

1.2 Geographic Context

The City of Toronto is located in the Greater Toronto Area on the north shore of Lake Ontario in southern Ontario. The City of Toronto has a population of 2.61 million and lies along the "Windsor-Quebec" corridor, the most populated and industrialized region of Canada. By 2031, the current population of Greater Toronto (5.84 million) is forecasted to increase by 2.7 million, with as much as 20% of this increase expected to occur within the City of Toronto (City of Toronto, 2010b).

Toronto's tree canopy covers 19.9% of the city, comprising an estimated 10.2 million trees. The most common species are the Norway, Sugar, and Manitoba maple, but at least 116 different species are present, with 64% of them being native to Ontario (City of Toronto 2010b). Street trees represent 6% of the total tree population, and the City's Urban Forestry staff are responsible for the management of 500,000 City-owned street trees (Weiditz and Penney, 2007). Likely due to native trees poor tolerance of the challenging growing conditions on city streets, only 31% of the street tree population is native. Norway maple is still the dominant species, but it is followed by honey locust and crab apple. Relatively few of Toronto's street trees are in good health, and a high proportion are categorized as small (<15.2cm in diameter), with only 25% of the trees having large diameters (> 30.6cm).

Figure 1 Map of Greater Toronto Area



1.3 Street Tree Survival and Climate Change

Of all urban trees, street trees face some the most difficult growing conditions. Despite low survival odds, developers and City staff continue to plant trees, but these trees are generally not contributing their full potential to climate change adaptation efforts because they are rarely able to develop a mature canopy (Weiditz & Penney, 2007). There are many reasons that street trees fail to survive. These are outlined in Table 1 below.

Climate change is expected to exacerbate many of the existing barriers to street tree growth. The City of Toronto's (2008) Ahead of the Storm report suggests a number of future trends that Toronto can expect as a result of climate change, including:

- Increasing numbers of hot days, heat waves, and smog related events
- Warmer and shorter winters
- An increase in prevalence of vector borne diseases
- Changes in precipitation patterns which include dryer summer weather and an increase of extreme weather events
- Greater evaporation rates which will lower surface water levels.

Table 1 Barriers to Healthy Tree Growth in Urban Environments

Barrier	Description
Soil Quality	• Soil in urban environments is frequently compacted due to weight and pressure from sidewalks, which can act as a barrier to healthy root development • Soils along sidewalks where trees are planted are often nutrient poor
Soil Quantity	• Each tree requires 1.5 to 2 cubic feet of soil for every square foot of crown projection. This is seldom available for street trees
Water	• Street trees seldom receive enough water • Soils in urban environments are often unable to drain properly • Contractors who plant street trees must water and maintain the trees for two years; however, in an urban environment, trees require a longer period of care
Salt from roadways and sidewalks	• Street trees often come into contact with road salt which is toxic to trees
Infrastructure replacement	• Maintenance activities to repair or replace sewers, underground electrical or gas lines, sidewalks and streets can damage tree roots and canopy
Extreme heat	• Nearby pavement and other hard surfaces reflect heat, which causes trees to lose water, depleting already limited supplies

Sources:

1. Clean Air Partnership. (2007)
2. Bassuk, N., Grabosky, J., Trowbridge, P., & Urban, J. (1998)
3. Thompson, J. W., & Sorvig, K. (2008)
4. Urban Forestry Services. (2010b)

Planting trees and ensuring their survival in urban areas is a strategy that addresses both climate change adaptation and mitigation. Maximizing the benefits provided by trees is often difficult with the growing conditions in urban areas. Changes in precipitation, temperature, and growing periods will affect the ways in which urban trees are established and grow (Johnston, 2004). Additionally, street trees under stress from extreme heat or periods of drought will be increasingly vulnerable to existing urban stressors (air pollution, soil compaction, impervious surfaces). Coincidently, the ecological services provided by street trees will become even more valuable under future climate scenarios. Shading, cooling, and uptake of storm water will become increasingly important, particularly in those urban areas already vulnerable to the flooding and extreme heat that develops due to the extent of paved areas in cities (Johnston, 2004).

1.3.1 Climate Change Mitigation

Urban trees can help mitigate climate change through carbon sequestration and removal of atmospheric chemicals. Trees absorb and sequester CO_2 during photosynthesis and store it as cellulose in the structure of the plant. This storage of carbon within the urban forest is often referred to as a carbon sink and is beneficial in urban environments where many CO_2 producing activities take place. Along with CO_2, trees capture particulate pollutants on their leaf surfaces, and absorb gaseous pollutants directly into the leaf (Girling et al., 2008). Trees also reduce emissions from fossil fuel electricity generation by decreasing energy use for air conditioners in buildings by cooling ambient air temperatures and directly shading buildings. Carbon sequestration by Toronto's urban forest is estimated at 36,500 metric tonnes annually (City of Toronto, 2010). Though older trees store more carbon, younger rapidly growing trees have higher rates of carbon sequestration. Protection of the urban forest is important as a climate change mitigation strategy because net carbon sequestration can be negative if tree death outpaces tree establishment (Rosenzweig et al. 2006).

1.3.2 Climate Change Adaptation

The need to manage extreme heat events and reduce the impacts of storms, and floods associated with climate change highlights the value of street trees as a means for climate change adaptation (see Table 2).

Planting policies themselves are also in need of adaptation. The harsh growing conditions of previous tree planting limited the types of street trees that were able to thrive. The new tree planting technologies described in this case study allow for an increased diversity in the species of trees that are able to survive, and thrive in the city. Having a more diverse urban forest (especially with native trees) will make it more resilient to threats from invasive species. This in turn will result in more trees surviving climate change related events, and therefore more trees present to provide benefits.

While improving air quality is not a benefit of trees in terms of climate change adaptation, it underscores the important relationship between adaptation and mitigation. The strongest climate change adaption initiatives should not increase carbon emissions further. Street trees are an opportunity to integrate adaption with mitigation benefits, hopefully helping to reduce further climate change.

Table 2 The Contribution of Trees to Climate Change Adaptation

Benefit	Description
Storm Water Management	• Urban tree canopies help to mitigate storm water runoff • A mature tree absorbs up to 42,000 litres of water in a year • Simulations that doubled the tree canopy in the Don Watershed indicate a 2.5% decrease in overall flow
Reducing Energy Demand for Buildings	• Trees shade buildings, blocking solar radiation and preventing heat absorption through windows and walls • Shade from trees can significantly reduce air conditioning use in residential households • Trees cool the air through evapotranspiration • Trees block winter winds and reduce heating demands • In Toronto, trees are estimated to reduce energy use from heating and cooling in residential buildings by 41,200 MWH ($9.7 million per year)
Reduced Temperatures	• Trees have been shown to significantly reduce the urban heat island effect and produce city-wide changes in temperature since they cool the air through evapotranspiration • Trees have been found to have the greatest potential for cooling in urban areas compared to other climate change adaptation measures
Public Health	• Trees improve public health by reducing heat stress and by reducing the build-up of temperature dependent pollutants

Sources:

1. Akbari, H., Pomerantz, M., & Taha, H. (2001).
2. Simon, P. (2011, March 11). Interview on street tree survival initiatives.
3. Rosenzweig, C., Solecki, W. D., & Slosberg, R. B. (2006).
4. Urban Forestry Services. (2011).

1.3.3 Framing Street Tree Survival in terms of Climate Change

The City of Toronto report, "Our Common Grounds", introduced the concept of a *working tree* that provides ecological services to the City. These services include sequestering CO_2, reducing heating and cooling costs, soaking up stormwater run-off, reducing the cost of water treatment, reducing erosion and improving air quality, all of which contribute to climate change adaptation and mitigation (City of Toronto, 2004). In June 2007 the City of Toronto published "Change is in the Air: Climate Change, Clean Air and Sustainable Energy Action Plan: Moving from Framework to Action". The plan was primarily concerned with climate change mitigation strategies and its goal was to encourage Torontonians to adopt more environmentally friendly lifestyles, and reduce their energy use. The document framed tree planting and tree health improvement programs as climate change initiatives. A follow up report titled "Ahead of the Storm: Preparing for Climate Change" was prepared by the Toronto Environment Office in collaboration with the City's Climate Adaptation Steering Group and the Clean Air Partnership to outline a climate change adaptation strategy. The document described some specific proposed actions to help street trees increase their contribution to the goal of expanding the city's overall tree canopy:

- Introducing a new standard to support healthy tree growth by use of continuous soil trench systems in commercial areas
- Increasing street tree planting, and
- Increasing enforcement of tree protection and planting requirements for private lands during development review.

2 Towards Street Tree Survival

The City of Toronto street tree survival initiatives are not a formal part of a strategic plan or policy, but the need for such actions can be found in a number of policies and reports.

1) "Our Common Ground" is the City of Toronto Parks, Forestry and Recreation department's strategic plan. It was approved by City Council in 2004, and set a clear direction for the future of the City's urban tree canopy. The plan recommended measures that relate to all urban trees, including a plan to increase annual tree planting, but also contains two broad goals that can used to directly support street trees survival initiatives:

- Implement an Urban Forestry Management Plan over the next 10 years to increase Toronto's current tree canopy coverage of 17 per cent to 30 to 40 percent"
- Increase the average lifespan of Toronto's sidewalk trees from 5 to 20 years by improving tree planting conditions, and by coordinating with other municipal departments to ensure soil and water conditions are adequate (City of Toronto, 2004)

"Our Common Grounds" also highlighted the need for a city-wide forest inventory and tree canopy study.

2) "Every Tree Counts: A Portrait of Toronto's Urban Forest" is a report developed as a direct result of "Our Common Grounds". It was completed in collaboration with the USDA Forest Service and Spatial Analysis Laboratory at the University of Vermont. The study considered Toronto's entire urban tree canopy. Though street trees only compromise 6% of the City's total tree population, the study conducted additional analysis on them, separate

from the city wide results, because they contend with very unique stresses. This analysis supported the hypothesis that street trees are not maximizing their benefit potential because there is a shortage of trees in the mid to large size categories. Beyond the issue of lifespan, the study also found that only 49% of Toronto's street trees were in good or excellent health compared to 81% of the overall tree population. This study's results clearly demonstrate that Toronto's street trees are not providing their full benefits because they are not thriving and are rarely reaching maturity. As a result, street trees represent a climate change adaptation opportunity that is being underutilized by the city.

3) The Green Development Standard and Guidelines: Toronto Streetscape Manual.
The Toronto Green Development Standard was developed to generate awareness of green development practices, and to inspire developers to incorporate environmental considerations into their plans. As of January 31, 2010 new planning applications and site plan approvals are required to meet the Tier 1 environmental performance measures which include requirements for new residential and commercial developments to encourage healthy tree growth. These measures include minimum soil volumes for trees planted in hardscaping (including street trees). Tier 2 provides voluntary higher level environmental performance guidelines. The requirements aim to assist trees in reaching mature statures (Simon, 2011).

The Toronto Streetscape Manual is an urban design reference tool for the improvement of the City's roads (City of Toronto Planning, 2010). The manual focuses on design quality in the public right-of-way and has policies specific to street trees (City of Toronto Planning, 2010). The Toronto Streetscape Manual contains suggestions for meeting the requirements of the Green Development Standard and provides a variety of options for planting in hard surfaces. The manual asserts that in order to plant street trees that mature and thrive, they must be recognized as part of the city's infrastructure (such as street lights, litter bins, and utilities) and considered integral to a complete street. The manual focuses on the design of the planting environment, and highlights 5 key issues that should be considered when planting street trees:

- Ensuring adequate soil volume
- Providing good quality soil
- Coordinating with the location of above and below-grade utilities
- Providing adequate watering and proper drainage
- Establishing maintenance routines and responsibilities

2.1 Sustainable Street Tree Planting Techniques to Improve Tree Health and Increase Tree Longevity

There are several techniques that can be used to encourage healthy tree growth and longevity. The primary challenge in utilizing these measures is determining the most effective tool for the given setting. Toronto Urban Forestry Services and developers trying to meet emerging building requirements have been experimenting with a variety of techniques and technologies that include continuous trenches, and soil cells. The projects, varying in size and level of completion, enable us to consider each approach.

2.1.1 Continuous Trenches

Continuous trenches stretch from tree to tree, sometimes under paving strengthened by reinforcement, and greatly increase the soil volume that is available to each tree (Thompson & Sorvig, 2008). This allows the tree access to enough root space to survive in urban settings. It requires slightly different sidewalk construction compared to traditional sidewalks, with variations on the design used for different urban situations (plazas, sidewalks, etc.). Currently, there are three standard continuous soil trench design specifications that have been approved by Urban Forestry Services: open planting beds (Figure 1 and Figure 2*)*, raised planters, and soil beds covered with precast concrete planter covers (Figures 3 and 4) (City of Toronto Planning, 2010). Developers can submit other designs which may be approved on a case by case basis. There are many benefits to continuous soil trenches both from policy and design perspectives. These include:

- Continuous trench technology is not trademarked, which allows it to be easily outsourced in a competitive bidding process (Urban Design, 2011)
- Continuous trenches can ensure that trees receive optimal soil volume (Urban Design, 2011)
- Urban Forestry Services has taken into consideration maintenance issues in their design of the tree trench details, and developed a relatively easy one-step repair process compared to traditional sidewalks. The process is simpler because a utility repair team can simply lift the lids, complete the repairs, and put the lids back in place. (Simon, 2011; Urban Design, 2011)[1]

Despite these benefits, there are some design challenges that must be considered when using continuous trench technologies. For example:

- There are difficulties in achieving large widths for continuous soil trenches because structural support for the sidewalk above the trench is provided along the length of the trench. Currently the standard size for continuous soil trenches is 1.8 metres across (Urban Design, 2011)
- The accepted width standard for continuous soil trenches is not compatible with the dimensions of many urban streets (Urban Design, 2011)

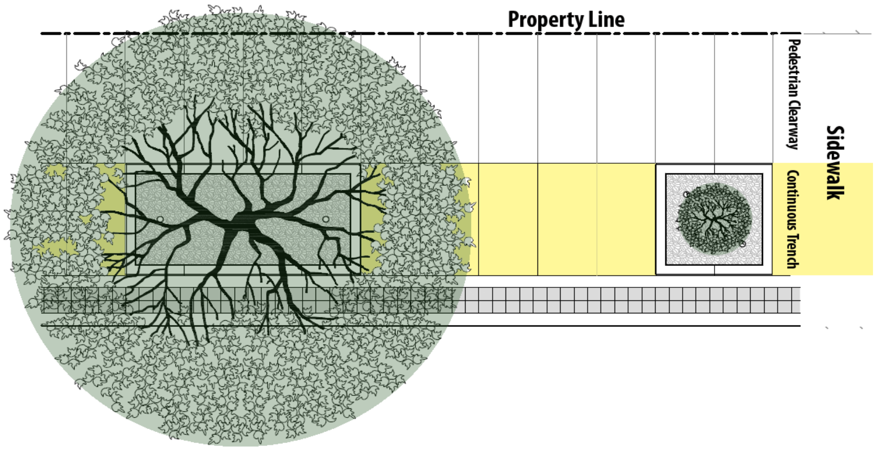
Since continuous soil trenches have been standardized in the Green Development Standard, they have been frequently used in new development projects such as those on the Queensway, University Avenue, Roncesvalles Avenue, Dundas Street, and many private development initiatives (see Figure 3 and 4). The reconstruction at Roncesvalles extended to include planning and coordination between the area's Business Improvement

---

[1] In a two-step repair process a utilities company would remove a section of a sidewalk conduct repairs, and temporarily repair the section of the sidewalk with asphalt. When there are a significant number of asphalt patches Transportation Services would repair the piece of sidewalk. A one-repair process allows the trench to be easily disassembled and reassembled, requiring no follow up repair.

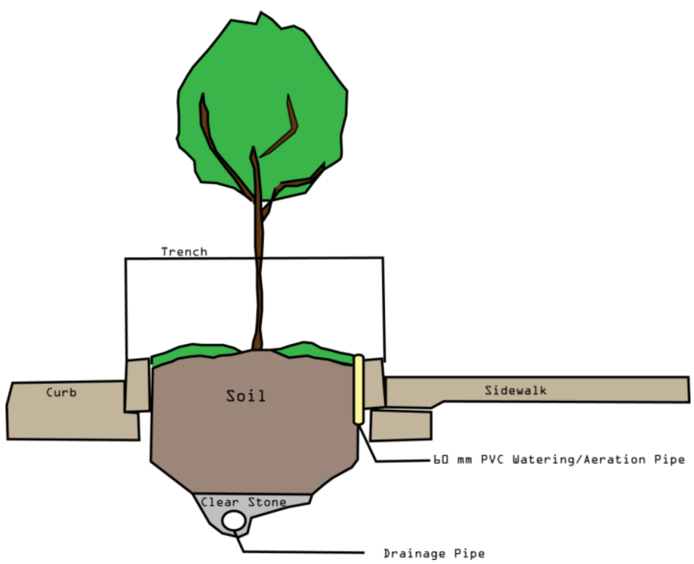
Association (BIA), the councillor's office, and community groups. At the behest of the local BIA, the local councillor engaged the Urban Forestry Department in the planning and implementation of a continuous trench along Roncesvalles. Work was completed on the trenches in the summer of 2011.

Figure 2 Example of the Open Planting Bed and Concrete Sidewalk Continuous Soil Trench by the City of Toronto (Overhead view)



Source: Adapted from City of Toronto Planning (2010). Continuous Soil Trench: Open Planting Bed and Concrete Sidewalk. *Tree Details & Drawings*

Figure 3 Example of the Open Planting Bed and Cocnrete Sidewalk Continuous Soil Trench by the City of Toronto (Simplified cross section view)



Source: Based on City of Toronto Planning (2010). Continuous Soil Trench: Open Planting Bed and Concrete Sidewalk. *Tree Details & Drawings*

Figure 4 & 5 Covering the trench during construction of a continuous trench (left). Cross section of a sidewalk during construction of a continuous trench (Right)

Copyright 2008 (left) 2010 (right) by Peter Simon.

2.1.2 Soil Cells

Soil cells are a modular subsurface composed of structural units that form a skeletal matrix. They are normally installed under paved surfaces and filled with large volumes of soil so that they may support healthy root growth. They are designed to support the growth of large trees and, by providing ample space for water to penetrate the enclosed soil can help with stormwater management (DeepRoot, 2011). The primary soil cell technology model implemented in the City of Toronto is the DeepRoot Silva Cell (*see* Figure 6: Silva Cell installation). Currently an alternate model known as the Strata Cell is under development by Citygreen Urban Landscape Systems.

There are some unique benefits to using soil cell technology:

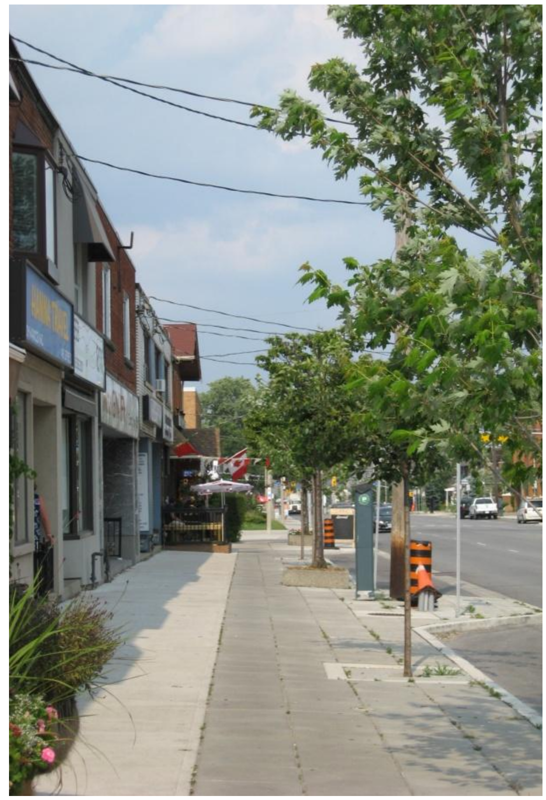
- Soil cells occupy less than 10% of the planting space, with upwards of 90% void space which can be used to hold soil and allow for root growth (Urban Design, 2011; City Green, 2011)
- Soil cell designs can support both sidewalks and road surfaces of greater widths than continuous trench designs without compromising the structural integrity or the ability to conduct underground maintenance activities
- The depth and layout of the soil volume can cover an irregular area. This increases flexibility in terms of creating appropriate tree habitat in constrained areas

Despite their ability to support healthy tree growth, there are challenges to implementing soil cells from a design and a policy context:

- Soil cell technologies cannot be prescribed, or detailed in manuals because they are proprietary products and including them may be a barrier to a fair bidding process.
- Soil cell technology takes planning and coordination to integrate with complex utility systems.

- As proprietary products, their cost may be a barrier.

Figure 5 & 7: Silva Cell construction at the Queensway (Left). Completed Silva Cell installation at the Queensway (Right)



Copyright: 2010 (left) 2008 (right) by DeepRoot

Some of the notable Silva Cell projects that have been installed in Toronto, or are currently underway, are at Bloor Street, Sugar Beach, Mill Street, and West Don Lands. The Queensway Pilot Project was a collaborative initiative between Toronto Water and Urban Forestry Services. By absorbing water from street catchment basins, it was the first to integrate both storm water management and street tree survival (DeepRoot 2011; See Figure 6 and 7).

2.2 Alternative Solutions: Structural Soil

In addition to the technologies and techniques described above, there is another option that can assist street trees in achieving a mature canopy and lengthening their lifespan. Structural soil is a pavement substrate that can meet the load bearing requirements for structurally sound pavement surfaces, yet still allow roots to grow under and away from pavements (Bassuk, Grabosky, Trowbridge, & Urban, 1998). The mixture is comprised of a stone matrix for strength, and soil to meet horticultural needs (Grabosky, Bassuk, & Trowbridge, 2002). In structural soil, the stone bears the load while soil particles fill the voids (see Figure 3). Structural soil is not currently used by Toronto Urban Forestry Services because it is not the best material to encourage tree growth. Despite this, there are several instances in which structural soil may be the preferred choice, given that:

- Structural soil is able to meet load bearing requirements and engineering standards to support cars (Bassuk, Grabosky, Trowbridge, & Urban, 1998)
- Structural soil is very durable and easy to integrate into complex utility systems and abnormally shaped spaces
- Structural soil can be effective at connecting continuous soil trench projects
- Structural soil is inexpensive and easy to obtain

Though Structural soil is easy to integrate into projects and meets the engineering requirements for heavy loads, there are several issues associated with it, mostly related to its effectiveness at stimulating tree growth. Issues include:

- Structural soil is 80% structure (rock) and 20% soil, which means that the technology does not provide trees with optimal soil quality for growth (Urban, , 2004).
- Due to its composition, structural soil drains quickly and consequently it is not effective for storm water management and trees can become drought stressed.

Studies on structural soil have for the most part been anecdotal, however, it has been shown that over time trees grown in structural soil show signs of stress (Urban, , n.d.).Despite these limitations, structural soil has been used by many communities and can contribute to street tree survival.

3 Challenges

The challenges associated with street tree survival initiatives relate to broad municipal planning issues associated with mainstreaming the techniques, and specific problems using the techniques for planting trees and constructing the related infrastructure in some areas.

Funding and Expense

Often technologies such as soil cells and continuous trenches can be more expensive than traditional, less effective approaches to planting trees. For example, it costs between $10,000 and $15,000 per tree to achieve the required 15 cubic metres of soil per tree using Silva Cell brand soil cells. By comparison, conventional approaches require investments in the low hundreds of dollars. The high price tag of tree survival technologies may lead developers and utility companies to oppose street tree survival strategies. Incentives such as the "one step" repair process for conducting maintenance activities can act as a selling point for survival initiatives. It is also possible to make a business case for street tree initiatives by describing both the longer survival rates and lower replacement costs, and quantifying the ecological services that street trees provide.

Currently, the City's Urban Forestry Services does not receive sustained funding for these initiatives, requiring instead that funds come out of existing budgets. Tree initiatives are therefore at constant risk of being cut, or under-funded. State-of-good-repair is a standard set for general maintenance activities related to infrastructure. This metric is biased towards built infrastructure and as a result, trees are not considered a part of the City's State-of-good-repair standard. It has been suggested that considering trees a part of the State-of-good repair would be helpful for funding street tree survival projects (Simon, 2011).

Need for Political Support and Local Champions

Political support is required to increase street tree survival through the use of sustainable tree planting tools and techniques. There are multiple mechanisms through which tree survival initiatives can be encouraged or regulated by municipal government. In addition to including trees in the State-of-good-repair standards, prescriptive tree survival targets can be included in strategic plans or written into policies. Once established within policy, long-term funding can be secured to ensure the use of sustainable planting techniques. However, especially in difficult fiscal climates, citizens rarely know to prioritize street trees. Without a strong call for action, it is unlikely that a municipal official will recommend reform of street tree plantings.

Political support is also necessary for communities to motivate street tree planting because councillors are the conduits to municipal action. Given the myriad of issues with which municipal councillors are petitioned, local champions, who establish sustainability as an important goal for their neighbourhood or municipality, can help propel sustainable street-tree planting techniques into the spotlight.

Utility Infrastructure

Public utility infrastructure includes power lines, gas mains, and drainage ways. New tree survival technologies involve anoverlap with utility infrastructure, and liaising with utilities is a necessity. Unless considered and managed, this potentially unreciprocated relationship could become a barrier to using survival technologies.

Toronto's mandatory setback policies prescribe the required distance between a tree and utility infrastructure for general protection of the trees and the infrastructure. Setbacks include locations where trees could potentially be planted and even thrive, if done carefully (Simon, 2011). It has been suggested that sweeping criteria could be eliminated if there was more comprehensive communication between utility companies and street tree planters.

Beyond the necessity, communicating with utility providers demonstrates an opportunity for mutual improvements to existing infrastructure (both natural and built). Consolidating utilities into common trenches minimizes the risk to trees from utility maintenance. Consistent liaison with the utility providers would help address the risks the process may present to utility infrastructure, and minimize the risks trees could pose to the infrastructure in the future. This communication also involves the utility in the planning process, hopefully, through awareness, preventing future utility maintenance work from injuring trees or their roots. Finally, coordinating the placement of utilities, light poles, bus stops and fire hydrants can help maximize the continuity, and thus the soil volume, of continuous trenches.

Limited Range of Designs in the Toronto Streetscape Manual

As continuous trenches are relatively new technologies, there are currently a limited number of approved designs for hard surface tree planting. Furthermore, each of the approved designs is similar to the others. Because soil cells are proprietary, they also provide a limited range of options and are not included in the manual. The reality is that project conditions vary, and the current designs that have been detailed are not uniformly appropriate (City of Toronto, 2011). While a lack of appropriate technology may be a barrier to using street tree survival technologies in some locations, new technology advancements with eventually reduce this issue.

4 Lessons Learned

Lesson 1: Street tree survival requires communication between a various City departments.

In the City of Toronto many departments were involved in the development and implementation of street tree survival research and projects. Due to the number of departments involved, communication was a key component of successful projects. It is helpful to identify the relevant departments and initiate communication early and maintain it throughout. The following departments were involved with City of Toronto projects:

- Urban Forestry Services – Took the lead in planning for street tree survival in the City
- City Planning (Urban Design) – Created and incorporated street tree survival designs into the *Streetscape Manual*. The department is the first contact for any new development project
- City Planning (Environment, Policy and Research) – Developed the Green Development Standard and incorporated environmental policies that were developed by Urban Forestry Services to encourage the survival of street trees
- Transportation Services – Is responsible for road and sidewalk maintenance and consequently takes the lead in any new development project that is on behalf the city
- Engineering – Took part in approving standardized continuous trench models
- Toronto Water – Worked with Urban Forestry Services to develop the Queensway Pilot Project a project that incorporates storm water management

Lesson 2: Street tree survival initiatives can provide a great opportunity to collaborate and coordinate with storm water management.

Trees benefit stormwater management through rainfall interception, evapotranspiration, and infiltration. These mechanisms reduce and slow runoff water entering the stormwater drainage system. Urban Forestry is currently working with Toronto Water to develop a system to integrate street tree planting with storm water management. Making use of the fact that trees decrease water infiltration rates through soil, a pilot project using soil cell technology has been constructed on the Queensway in the west end of the city (DeepRoot, 2011). Water is taken up through a sewer well catchment area and delivered evenly throughout the soil using a perforated PVC pipe. Any excess overflow will be carried into the existing storm water system (DeepRoot, 2011). The system is designed to be able to manage the runoff of up to a 5 cm rain event in a 24 hour period, and will help decrease the amount of water the City's stormwater system must manage.

Lesson 3: Enforcing performance standards can be a more efficient strategy than requiring specific technical solutions.

In order to get the best results it is important that decision makers consider which technology is most appropriate in a given circumstance. For example, continuous trenches can be difficult to integrate in irregular spaces. Soil cells are much simpler to integrate with utilities and irregular spaces. A focus on performance requirements that describe the number of trees and the quantity/quality of soil required to encourage healthy growth is more likely to achieve that goal than requiring developers to use specific techniques or technologies that may be inappropriate under specific circumstances. Performance standards also allow developers to develop creative solutions in difficult situations.

Lesson 4: It is important to protect trees from maintenance activities such as road, sidewalk, and utility repairs that may be harmful.
Urban Forestry Services Tree Protection Policy works to ensure that construction activities do not undermine the efforts undertaken to preserve and protect the Urban Forest. The policy document defines a "Tree Protection Zone", which is an area around a tree in which activities that may harm a tree are prohibited. Such activities include: construction; alteration of grade; storage of construction materials; disposal of liquids; movement or parking of vehicles, machinery, equipment or pedestrians (Urban Forestry Services, 2010). The policy allows for open face cuts or root pruning outside a Tree Protection Zone as long as it is done by a qualified arborist or approved tree professional, and is preceded by a dig by hand or through a low water pressure hydro vac method which is meant to prevent unnecessary root damage that occurred in the past as a result of back hoeing (Urban Forestry Services, 2010).

Lesson 5: New tree planting approaches would benefit from scientific monitoring programs.
Both in theory and practice the new technologies appear to be effective. However, a scientific monitoring program can help determine when the technologies are most effective, measure trees survival rates, when they fail and reasons for failure, as well as make recommendations on how to improve technologies and implementation plans (Urban Design, 2011).

Lesson 6: Local champions can encourage sustainable street tree planting use and integration into municipal policy.
Given that municipal attention and funding is difficult to obtain, local champions can play an important role in attracting municipal attention and propelling street tree survival into action. In the case of Roncesvalles, the local Business Improvement Association petitioned Councillor Gord Perks to help ensure that sustainable street tree planting techniques were used to replant the trees along the avenue. Councillor Perks then worked with Toronto Urban Forestry Services and the City to ensure that funding was available for this project.

Additionally, Peter Simon, with Urban Forestry Services has long worked to keep sustainable tree-planting techniques in use in the City of Toronto. Under his direction and with his encouragement, the City of Toronto has now used sustainable planting techniques in many neighbourhoods. These efforts by local champions are largely responsible for the successful use of Silva Cells and continuous soil trenches so far.

References

Akbari, H., Pomerantz, M., & Taha, H. (2001) Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. *Solar Energy , 70* (3), 295-310.

Bassuk, N., Grabosky, J., Trowbridge, P., & Urban, J. (1998) *Structural Soil: An Innovative Medium Under pavement that Improves Street Tree Vigor.* (online) Available at: http://www.hort.cornell.edu/uhi/outreach/csc/article.html [Accessed: March 18, 2011]

City of Toronto and Clean Air Partnership. (2008) *Ahead of the Storm... Preparing Toronto for Climate Change.*(online) Available at: http://www.toronto.ca/teo/pdf/ahead_of_the_storm.pdf [Accessed: February 25, 2011]

City of Toronto. (2007) *Change is in the Air: Climate Change, Clean Air, and Sustainable Energy Action Plan: Moving from Framework to Action (Phase 1).* (online) Available at: http://www.toronto.ca/changeisintheair/pdf/clean_air_action_plan.pdf [Accessed: February 25, 2011]

City of Toronto (2010b) Every Tree Counts: A portfolio of Toronto's Urban Forest.

City of Toronto. (2011 27-April). *Interview with Urban Design Department*. Interviewed by J. Auspitz [in person] Toronto, April 27, 2011

City of Toronto. (2004) *Our Common Grounds: Parks and Recreation Strategic Plan 2004.* (online) Available at: http://www.adamgiambrone.ca/downloads/Parks_commongrounds.pdf [Accessed: March 19, 2011]

City of Toronto. (2010c). *Toronto Green Standard.* (online) Available at: http://www.toronto.ca/planning/environment/greendevelopment.htm [Accessed: March 24, 2011]

City of Toronto. (2008) *Tree Symposium: Healthy Trees for a Beautiful City Proceedings*. (online) Available at: http://www.toronto.ca/planning/treesymp_march2008.htm [Accessed: March 28, 2011]

City of Toronto Planning. (2010a) *About the Streetscape Manual*. (online) Available at: http://www.toronto.ca/planning/urbdesign/streetscapemanual.htm [Accessed: March 25, 2011]

CityGreen. (2011) *Leading the way in advanced Structural Soil Cells.* (online) Available at: http://www.citygreensystems.com/pdfs/Citygreen%20StrataCell%20Booklet.pdf [Accessed: March 26, 2011]

Citygreen Urban Landscape Systems. (2011) *Trees in Cities - Solutions*. (online) Available at: http://www.citygreensystems.com/html/solutions.html [Accessed: March 25, 2011]

DeepRoot. (2011) *Silva Cell Brochure (DeepRoot Silva Cells: Restoring Ecosystem Services to the Urban Environment)*. (online) Available at: http://www.deeproot.com/silvapdfs/resources/supporting/silva_cell_brochure.pdf [Accessed: March 28, 2011]

DeepRoot. (2011) *Silva Cell Urban Storm Water Management and Soil Cells.* (online) Available at: http://www.deeproot.com/products/silva-cell/applications.html [Accessed: March 18, 2011]

Girling, C., Galdon, M., Davis, L., and Kellett, R. (2008) *Green Infrastructure in Calgary's Mobility Corridors.* Vancouver BC: UBC Design Centre for Sustainability, School of Architecture and Landscape Architecture, University of British Columbia.

Grabosky, J., Bassuk, N., & Trowbridge, P. (2002) Structural Soils: a new medium to allow urban trees to grow in pavement. *LATIS* , 1-23.

Johnston, M. (2004) Impacts and adaptation for climate change in urban forests. *Proceedings of the 6th Canadian Urban Forest Conference,* Kelowna, BC.

Neely, A., Gregory, M., & Platts, K. (1995) Performance measurement system design : a literature review and research agenda. *International Journal of Operations & Production Management , 15* (4), 80-116.

Richardson, G. (2010) *Adapting to Climate Change: An Introduction for Canadian Municipalities.* Ottawa, Ontario: Natural Resources Canada.

Rosenzweig, C., Solecki, W. D., & Slosberg, R. B. (2006) *Mitigating New York City's heat island with urban forestry, living roofs, and light surfaces.* (online) Available at: http://www.urbanforestrysouth.org/resources/library/mitigating-new-york-city2019s-heat-island-with-urban-forestry-living-roofs-and-light-surfaces [Accessed: March 19, 2011]

Simon, P. (2011) *Interview: Street tree survival initiatives*. Interviewed by J. Auspitz [in person] Toronto, April 26, 2011

Thompson, J. W., & Sorvig, K. (2008) *Sustainable Landscape Construction: A Guide to Green Building Outdoors* (2nd ed.). Washington, DC: Island Press.

Urban Forestry Services. (2008) *Every Tree Counts: A portfolio of Toronto's Urban Forest.* (online) Available at: http://www.toronto.ca/trees/pdfs/Every_Tree_Counts.pdf [Accessed: March 28, 2011]

Urban Forestry Services. (2010, July) *Tree Protection Policy and Specifications for Construction Near Trees.* (online) Available at: http://www.toronto.ca/trees/pdfs/TreeProtSpecs.pdf [Accessed: March 27, 2011]

Urban, J. *Comparing Silva Cells and Structural Soil.* (online) Available at: http://www.deeproot.com/silvapdfs/resources/articles/Comparing_Silva_Cells_and_Structural_Soil.pdf [Accessed: March 28, 2011]

Urban, J. (2004) *Growing the Urban Forests.* (online) Available at: http://www.toronto.ca/planning/treesymp_march2008.htm [Accessed: March 28, 2011]

Weiditz, I., & Penney, J. (2007) *Climate Change Adaptation Option's for Toronto's Urban Forests.* (online) Available at: http://www.cleanairpartnership.org/reports_climate_change_adaptation [Accessed: March 19, 2011]