EPA
United States
Environmental Protection
Agency

Stormwater Trees

Technical Memorandum

September 2016

Great Lakes
RESTORATION

Funding for this project was provided by the Great Lakes Restoration Initiative administered by the United States Environmental Protection Agency—Great Lakes National Program Office.

This report was developed under EPA Contract No. EP-BPA-13-R5-0001 by Tetra Tech, Inc.

Trees in the urban environment can provide many benefits; however, urban tree programs face numerous challenges that can affect their success. This technical memorandum addresses planting and maintaining trees which are adjacent to roadways or sidewalks in urban areas where buildings and impervious surfaces create harsh environments. These street trees can be planted for many reasons including stormwater management or increased shade and green space.

Benefits of Trees in the Urban Environment

Mature trees provide significant stormwater quantity and rate control benefits through soil storage, interception, and evapotranspiration. A tree with a 25-foot diameter canopy and associated soil can manage the 1-inch rainfall from 2,400 square feet of impervious surface. Interception and evapotranspiration also decrease runoff volume with larger trees providing exponentially more benefit than smaller trees.

Trees have the ability to reduce stormwater that would normally flow directly into a city's storm sewer system. In addition, trees:

- Improve water quality by filtering pollutants
- Reduce effective impervious area
- Promote infiltration to the groundwater table
- Reduce urban heat island effect
- Improve air quality
- Reduce energy usage
- Increase tree canopy and tree species diversity
- Provide habitat
- Increase aesthetics city-wide

The environmental and aesthetic benefits of trees are on average over two times greater than tree care costs (USDA 2011).

- Tree canopy can reduce building air conditioning costs and energy demand
- Shady streets need to be repaved less frequently than streets with little or no shade
- Trees increase residential property values and attract shoppers to commercial districts

Trees can also provide stormwater benefits while meeting landscape requirements.

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Young trees planted in urban environment. A portion of the sidewalk is permeable pavement to allow rainwater to seep into root areas.

iTree Tools

Developed by the USDA Forest Service, this tool analyzes street tree infrastructure, functions, monetary value, and management costs

https://www.itreetools.org/

Key Issues with Urban Trees

Street trees are usually short-lived, surviving an average of 7 to 10 years and, in some areas, less than 3 years. The two main reasons for low survival rates are:

Lack of adequate soil volume. The roots of trees in the natural environment will spread out two to four times the diameter of the canopy of the tree. Roots are critical for healthy tree development as they absorb the essential nutrients, water, and oxygen the tree needs.

Solution: Provide adequate soil volume.

Preferred Soil Volumes:

- Small Tree: 600 cubic feet
- Medium Tree: 1,000 cubic feet
- Large Tree: 1,500 cubic feet
- Multiple Trees: Provide a continuous tree trench at least 8 feet wide by 3 feet deep
- Minimum Soil Volume: Per Tree: Provide at least 500 cubic feet

Lack of moisture and oxygen. Trees might not receive enough moisture or oxygen because of limited space or ground that is too compacted to absorb water.

Solution: Provide adequate moisture and access to oxygen.

Provide a loose organic soil and, where feasible, direct stormwater into tree planting zones. If oversaturation is a potential problem, provide a stone storage layer and/or a porous underdrain pipe. Provide sufficient tree opening space (preferably more than 24 square feet).

What are the Challenges?

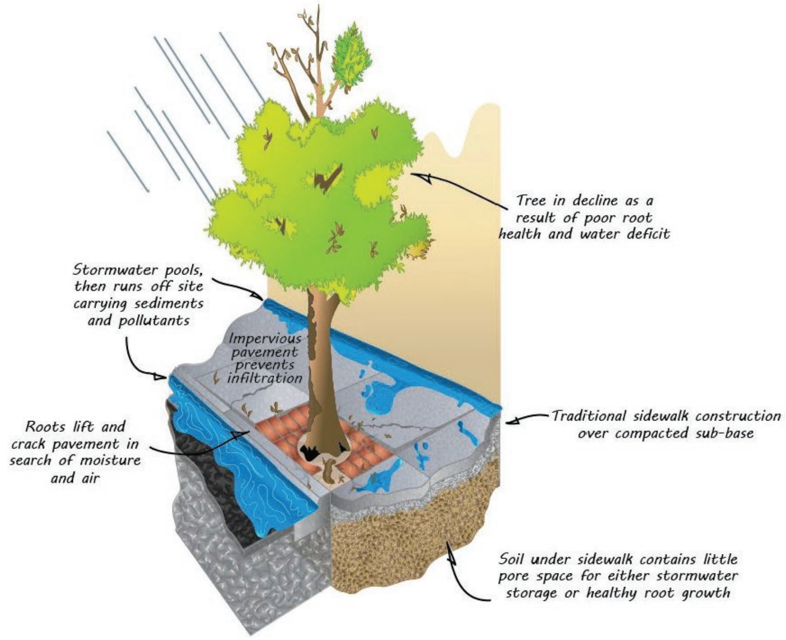
Establishing trees in an urban environment can be challenging and requires thoughtful planning and long-term programmatic support. Trees that are planted in harsh urban environments often experience difficulty becoming well established, have shorter lifespans, and are more susceptible to pests and disease. Successful urban tree programs take into consideration site constraints, design, tree selection, and maintenance needs.

What are Typical Site Constraints?

The suitability of a site to support healthy tree growth in urban areas is one of the most important aspects of planning and implementing urban tree programs. A site assessment is important to evaluate overall site suitability and potential constraints including:

- Space requirements
- Soil quality and texture
- Steep slopes
- Overhead and underground utilities
- Pavement and other impervious surfaces
- Proximity to structures

Other urban challenges can include pedestrian traffic, animal browsing, and high temperatures. In addition, trash can accumulate around tree trunks and in tree branches. Planning also needs to take into consideration Americans with Disabilities Act (ADA) requirements, traffic site lines, and visibility for businesses.



Typical street tree challenges (image from EPA 2013)

Space Requirements

Space is typically limited in urban areas, especially where high-density development occurs such as in downtown areas. Roads, sidewalks, buildings, and parking lots take up the majority of space, leaving little room for stormwater features or trees. A typical sidewalk is 8 feet wide, although width can vary from as little as 4 feet to more than 16 feet. Each planted tree should be provided with a 4-5 foot width of exposed soil at the surface (i.e., tree opening) to ensure sufficient space for the expected trunk flare of the mature tree.

Sidewalk vaults are often found in older cities and can create barriers for root growth, as can basements that extend beneath sidewalks. The planning process can include reviewing plans for nearby buildings or interviewing building owners to identify any known structures beneath the sidewalk.

Converting a portion of a sidewalk into a tree pit (traditional or stormwater) is often accomplished as part of a road or sidewalk reconstruction project. Creative design and planning can be used to integrate trees into urban areas.

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Example of tree roots growing along the surface

Soil Quality and Texture

A lack of organic matter in the soil limits the amount of water and nutrients available to tree roots. High pH from building materials or stone that contains calcium can limit tree growth. Salinity of soils from salt application and stormwater runoff from urban areas that carry high levels of pollutants also can impact tree health. If soil quality is of particular concern (e.g., at brownfield sites), soil chemistry tests can be conducted to inform any mitigation needed. Urban soils might need to be amended to provide soil quality sufficient to promote long-term tree health.

Existing soil texture (e.g., clay-rich, loamy, sandy) also can affect a tree, so tree selection should be based in part on the type of soil at the planting site. Compacted soils can slow root growth and not allow water to seep into the soils. When trees are planted in compacted soils, the roots often grow along the surface searching for water and oxygen. Soil compaction should be evaluated to determine the need for tilling or soil amendment.

Steep Slopes

A site assessment should identify steep slopes (greater than 15 percent) because planting on slopes is logistically difficult and soils will dry out more quickly. Similarly, low-lying, flood-prone areas should be noted to inform tree species selection.

Overhead and Underground Utilities

Overhead and underground utilities can get in the way of urban trees; species selection and tree planting need to take into consideration the long-term growth of a tree and the potential for future conflict. A site assessment should note the locations of overhead wires, pavement, structures, signs, lighting, existing trees, and underground utilities. Local ordinances should be consulted for setback requirements between trees and infrastructure, and local utilities companies will provide clearance requirements for different voltage wires. Tree planting is not recommended near underground utilities unless the site is engineered to avoid utilities (e.g., provide adequate soil away from the utility).

Urban Reforestation Site Assessment

The Urban Reforestation Site Assessment is a tool to organize relevant site information and accommodate site constraints.

A site assessment typically includes the following:

General Site Information
- Location
- Property owner
- Current land use
- Site sketch

Climate
- USDA Plant Hardiness Zone
- Sunlight exposure
- Microclimate features

Topography
- Steep slopes
- Low-lying areas

Soils
- Texture
- Drainage
- Compaction
- pH
- Other (e.g., erosion, contamination)
- Soil chemistry

Vegetation
- Regional forest association
- Current vegetative cover
- Adjacent vegetative cover

Hydrology
- Site hydrology
- Stormwater runoff to planting site
- Contributing flow length
- Floodplain connection in riparian areas

Potential Planting Conflicts
- Space limitations
- Local ordinance setbacks
- Other (e.g., trash, animal impacts, heavy pedestrian traffic)

Planting and Maintenance Logistics
- Site access
- Water source
- Party responsible for maintenance

Pavement and Other Impervious Surfaces

Pavement and urban trees often come into conflict. Tree root growth under impervious surfaces (e.g., pavement, sidewalks) can cause lifting and cracking; damage to sidewalks is common in urban areas. In addition, compaction of the soils and lack of water and oxygen for tree roots can impact tree health and longevity. Alternative site layouts and construction materials can be used to minimize the risk of damage to sidewalks and maximize tree survival. Species selection and site design can reduce conflict between urban trees and pavement.

Proximity to Structures

Sufficient space is needed between trees and structures/buildings. Common problems include root damage to building foundations, damage from falling branches or the tree toppling due to one-sided root growth, and increased heat load to the trees reflected off of building surfaces. In addition, buildings and tall structures can limit light reaching trees.

When and How Do I Evaluate My Site?

All urban sites should be evaluated prior to planning for tree plantings. A site evaluation can consist of a simple visual evaluation that addresses the typical site constraints or may be more involved, depending on the visibility of the project and known constraints. Different tree species also have very different requirements for root volume, soil pH, drainage, and other factors that affect the growth and overall health of the tree. A site evaluation will allow the best trees to be selected for a given location. Gilman (2015) has published a site evaluation procedure (http://hort.ifas.ufl.edu/woody/site-evaluation.shtml) that can be used to evaluate a site based on:

- Climate and rainfall
- Ground or container planting
- Light exposure
- Soil chemistry, moisture, and texture
- Surrounding surfaces
- Exposure to salts/chemicals
- Presence of overhead wires, street lights, and structures
- Desirable tree attributes
- Preferred level of maintenance

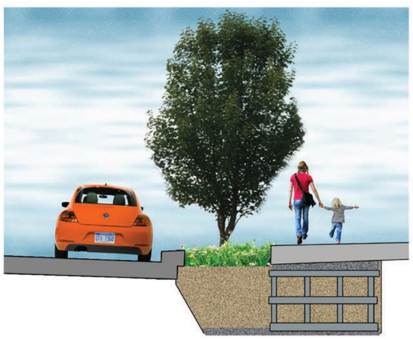
There are other site evaluation procedures available; ensure that urban site constraints are included in the evaluation method.

Design for Healthy Trees

Site design should consider the goals of the site, such as stormwater management, reduction of impervious area, or simply the integration of trees into the current space. Site design and the use of engineered best management practices can be used to enhance the effectiveness and longevity of urban trees and provide additional stormwater treatment. Various designs have been used in an effort to address the challenges presented by urban areas including structural cells, suspended sidewalks, and structural soils. In addition, various types of sidewalk configurations can be used to provide access to more water.

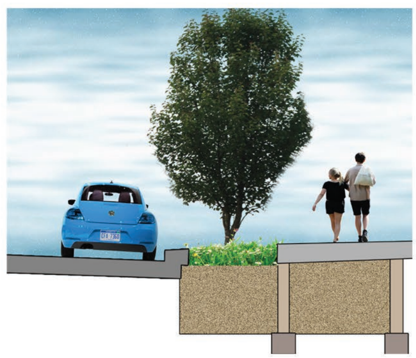
Structural Cells

Modular manufactured cells that support pavement and are filled with loose soils that encourage root growth.



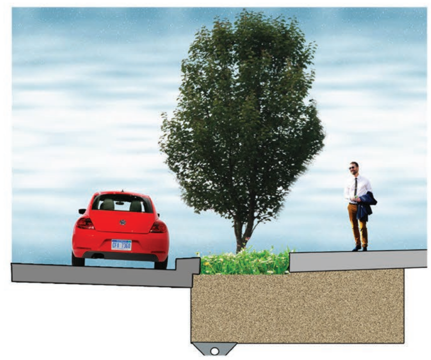
Suspended Sidewalks

Sidewalks with a supporting understructure that allows loose root-friendly soils to be continued under the walk.



Structural Soils

A blend of crushed rock and soil that is able to support pavement and can also support root growth.



Suspended pavement and structural cells provide suspension that supports the ground structures (e.g., sidewalks) while allowing the soils to remain uncompacted. This method creates space for tree root growth and can accommodate stormwater runoff. Curb cuts are often used to route runoff from adjacent surfaces to these areas. Inlets and outlets should be used to prevent over saturation and flooding. Underground utilities can be placed around the practices and sometimes even through the suspended pavement if they are protected from water and root penetration.

Structural soils are engineered mixes used under pavements and generally consist of gravel and clay loam. The void space between the aggregate provides sufficient space to accommodate roots and stormwater runoff. Structural soils offer load bearing support and provide sufficient space for tree growth. The soil aggregate can increase infiltration rates, and trees are easily planted within the mixture. The final aggregate mixture can influence pH; species selection should consider the pH of the aggregate in addition to other site considerations. Note that the aggregate within structural soils does not count as soil, therefore a much larger volume of structural soils is needed to accommodate minimum soil requirements for trees.

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Trees planted in an urban area. Permeable pavement is used throughout to allow infiltrating runoff to reach the roots.

Stormwater tree pits or trenches are similar to traditional tree pits but have more capacity for stormwater runoff. The primary benefits of stormwater tree pits are runoff reduction; enhanced tree growth due to sufficient space, regular irrigation, and improved drainage; and bioremediation through stormwater filtration. Tree pits can be installed individually or together as part of a street redesign; stormwater benefits are maximized with adjacent stormwater tree pits connected with other stormwater management practices.

Permeable pavement can be used in conjunction with engineered BMPs such as structural soil, suspended pavement, and stormwater tree pits to increase the volume of water infiltrating into the practices and allow oxygen to get to the soil, thus maximizing tree growth. The small spaces in permeable pavement allow stormwater to pass through; a stone reservoir below the pavement temporarily stores the water until it infiltrates into the subsurface or is taken up by trees.

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Choosing the Right Tree

Choosing the right species can improve survival of the street tree. Urban environments can be harsh; proper tree selection will save money in the long run through lower maintenance and replacement costs. Native trees are generally best but, because of certain environmental factors, non-natives that are hardy and non-invasive are also appropriate. Depending on the site, factors to consider include growth rate, ornamental traits, size, canopy shape, shade potential, and benefits for wildlife. Species diversity is also important to protect against insect and disease outbreaks. A site evaluation conducted during the planning stages should provide the information needed to understand site constraints.

An additional consideration is the amount of leaf or fruit litter produced by a tree. Depending on the tree species, additional maintenance considerations may be needed such as the ability to sweep streets and keep sidewalks clean and navigable. Leaf litter may also contribute to nutrient loading, and should be a consideration in nutrient impaired watersheds. In particular, when using permeable pavement, leaf litter should be kept to a minimum.

A site evaluation conducted during the planning stages should provide the information needed to understand site constraints and inform tree selection.

Find a Tree That Fits

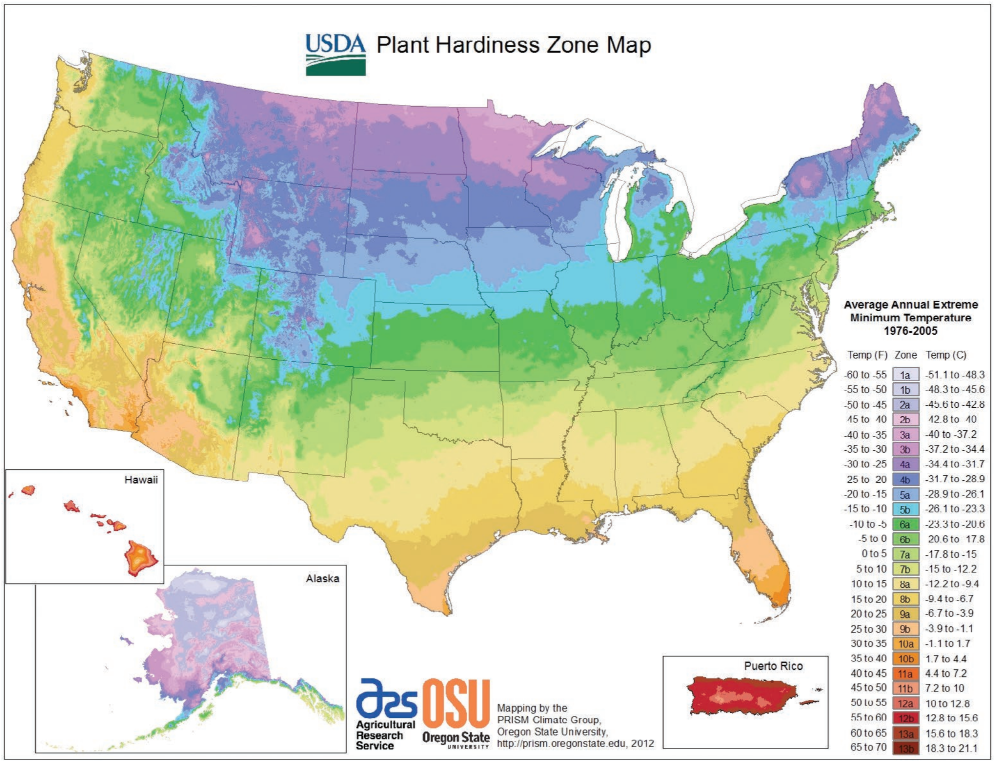
Tree reference books and the results of the site evaluation should be used to choose a tree that is appropriate for the site and meets criteria for aesthetics and maintenance.

There are trees that will fit most any condition; ensure urban tree selection takes into account the following:

- Salt and chemical exposure
- Canopy size and height
- Access to sunlight or shade
- Soil texture
- Soil volume and space limitations
- Soil moisture requirements
- Maintenance needs

If many trees are being planted, spacing of the trees should accommodate the mature canopy size.

Pay special attention to the hardiness zone; tree selection should take into account climate and low temperatures.



Examples of Tree Selection Tools and State or Region Specific Information

The Indiana Community Tree Selection Guide provides technical information to guide tree selection and a list of trees common to Indiana along with tolerance and siting information.

Illinois Extension provides a guide for tree selection that includes tree tolerance, common diseases and common pests.

Grand Rapids, Michigan, has a list of approved trees for residential planting that includes mature height, canopy spread, form/ growth habit, and tolerance to shade, soil moisture, and soil chemistry.

Minnesota provides tree selection guidance in their state stormwater manual.

The City of Chicago provides a list of typical trees planted and guidance for selecting the proper tree based on planting location and other site constraints.

Wisconsin Horticultural provides guidance on tree selection and numerous articles related to tree diseases and pests.

The Center for Watershed Protection (see Appendix B of the Urban Tree Planting Guide) provides a list of common trees and their associated tolerance levels to various environmental conditions (e.g., drought, compaction, salt tolerance, etc.).

Amend the Soil

Urban soils often need to be amended to support healthy street trees. Compost is often used to increase soil organic matter, decrease bulk density, improve drainage, provide nutrients, and increase water and nutrient holding capacity. Peat amendments can also increase organic matter and water and nutrient holding capacity, in addition to increasing acidity. Other amendments include gypsum, which can be added to urban soils to decrease soil salinity; limestone, which is used to decrease soil acidity; and sulfur, which increases soil acidity.

Soil compaction, pH, and drainage should be evaluated at the planting site to determine the need for soil amendments. More detailed tests such as organic matter content, nutrient availability, and salt content can also be performed (see table below).

Recommended corrective actions for urban soils (CWP 2006)

Soil Characteristic	Moderately Impacted Threshold	Severely Impacted Threshold	Corrective Measure
Percent sand	>75	>90	Add compost or peat
Percent kaolinitic clay	>50	>65	Add compost or peat
Percent expandable clay	Any	>10	Add gypsum
Percent clay and silt	>50	>75	Add compost or peat
Bulk density of clay (mg/m^3)	<1.4	>1.5	Add compost or peat
Bulk density of loam (mg/m^3)	>1.5	>1.7	Add compost or peat
Aeration porosity (percent large pore volume)	<2	<1	Add compost or peat
Infiltration, percolation, and permeability rates (in/hr)	<0.25	<0.20	Add compost or peat
Depth to bedrock (ft)	<4	<2	Add topsoil
Depth to impermeable layer (ft)	<6	<4	Mix soils
Acidic soils (pH)	<6	<4	Add lime
Alkaline soils (pH)	>7.5	>8.5	Add compost or peat, add sulfur
Cation exchange capacity (meq/100g)	>5	<3	Add compost and/or peat
Potassium (lbs/acre)	<124		Add compost
Phosphorus (lbs/acre)	<44		Add compost
Magnesium	Varies		Add dolomitic limestone or compost if deficient
Calcium	Varies		Add calcareous limestone, gypsum, or compost if deficient
Percent organic matter	<1		Add compost or peat
Soluble salt (ppm)	>600	>1,000	Add gypsum or sulfur, add compost or peat

Select the Type of Planting

Bare root plants are small and easy to plant. It is best to plant bare roots in the spring when the plants are dormant. Bare root plants are the most cost effective but can be small and therefore not very visible. Container trees can be 4 to 5 feet tall and are heavier than bare root plants, but they are still easy to plant in any season. Balled and burlapped trees are typically larger and may require additional equipment for planting. All plants should be grown locally so they are already adapted to local climate variability.

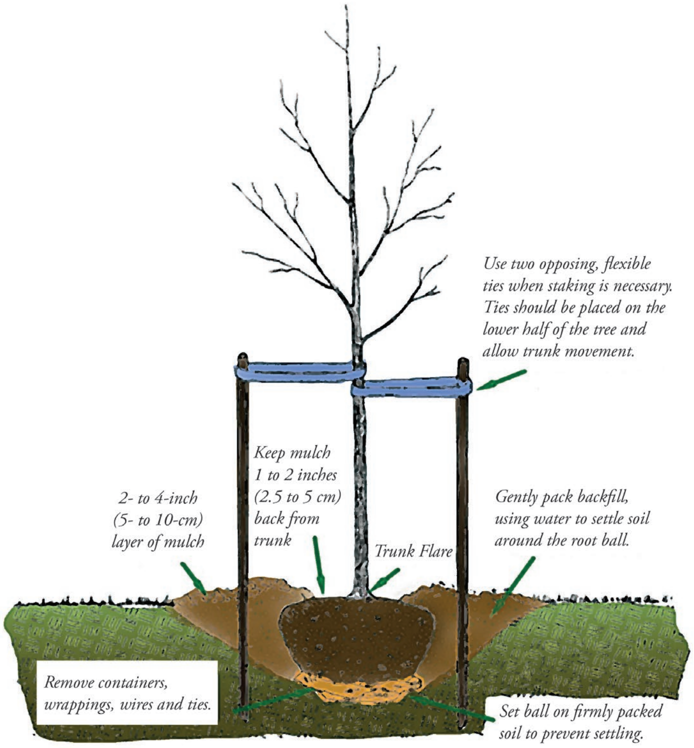
Advantages and disadvantages of various plant materials (CWP 2006)

Type of Plant Material	Size Range	Advantages	Disadvantages
Bare root	Seedlings up to 2-inch caliper	• Inexpensive • Easy to plant and transport • Condition of roots is easy to evaluate • Soil interface problems are not an issue	• Limited planting window • Not appropriate for all species • Requires special storage/handling • More subject to accidental damage by mowers
Container grown	Seedlings up to 2-inch caliper	• Longer planting window • Readily available • Visible to maintenance crews	• Moderate to high cost • Roots may be pot-bound • May require more watering after planting
Balled and burlapped	1- to 4-inch caliper	• Longer planting window than bare root • Larger size makes plants more resistant to damage • Heights are generally above most competing plants	• Most expensive • Difficult to plant without machinery • Cannot see condition of roots

Tree Planting Guidelines

Ideally trees should be planted during the dormant season after the leaves have dropped and before buds open. Transplanting stresses the tree and results in slower growth and reduced vitality, but proper planting can minimize this shock. Follow these planting steps (see figure) to help ensure successful growth (International Society of Arboriculture 2011):

1. Dig a planting hole that is 2–3 times wider than the root ball and as deep as the root ball. Make sure the trunk flare—the place where trunk expands at the base of the tree—will be partially visible above the soil surface.
2. Remove containers or cut away the wire basket if present, and straighten, cut, or remove circling roots. Cut wrappings and ties around the trunk.
3. Place the tree at the proper height to ensure new roots have enough oxygen to develop.
4. Straighten the tree in the hole.
5. Fill the hole gently but firmly to stabilize the root ball and remove air pockets.
6. Stake the tree, if necessary, such as in windy spots or if planting bare root stock. Remove support staking and ties after the first year of growth.
7. Cover the base of the tree with a 2- to 4-inch layer of mulch, leaving 1 to 2 inches of mulch-free area surrounding the trunk.
8. Keep the soil moist but not waterlogged.



Source: International Society of Arboriculture 2011

Tree planting guidelines

Inspection and Maintenance

Simple inspection procedures can help identify maintenance needs and unhealthy trees. Inspections for initial plantings focus on successful tree establishment, and follow-up inspections focus on long term survival. The initial inspection ensures proper planting, staking, mulching, flagging, and other characteristics (see table below). The long term inspections assess the overall tree health and determine maintenance needs (see table below). After the initial planting, trees should be inspected every few months for the first three years, after which an annual inspection is typically adequate.

Inspection checklists (adapted from CWP 2006)

Initial Inspection	Long-Term Inspection
☐ Is the tree planted at the correct height? ☐ Has a tree shelter been installed properly (if needed)? ☐ Are stakes installed properly (if needed)? ☐ Has mulch been properly applied around trees? ☐ Has the tree been well watered?	☐ Assess tree vigor and overall health ☐ Count the number of living trees and record species to determine survival rate ☐ Evaluate cause of dead trees and recommend supplemental planting if appropriate ☐ Determine if pruning is needed ☐ Inspect trees for signs of insect damage and disease ☐ Determine if stakes need to be adjusted or removed ☐ Determine if tree shelters need to be adjusted or replaced ☐ Evaluate if weed control is needed

The Minnesota Pollution Control Agency provides a summary of different visual indicators, potential causes, and suggested next steps for many common tree issues (see table below).

Visual indicators, potential causes, and recommended next steps (MPCA 2016)

If you see	Potential cause	You should
A flat-sided trunk at the base of the tree	Encircling root restricting the flow of water and nutrients between the roots and rest of the tree	Excavate to check for encircling root
An elm tree with bright yellow leaves on one or two branches	Dutch elm disease	Immediately call the university* or an arborist
An elm tree with liquid oozing from the trunk	Slime flux or wetwood	Not worry about health
Bark damage near the bottom of the tree	Rodent or string trimmer	Apply mulch/trunk guard to protect from further damage
Black clumps on branches of a cherry tree	Black knot	Call for advice*
BRANCHES		
Bumps on leaves	Many	Not worry about health
Hole in trunk or branches	Many	Call for advice*
Holes in leaves	Insect feeding	Not worry about health
LEAVES		
Leaves sticky and covered with a black velvety coating (like soot)	Piercing, sucking insect and sooty mold	Hose down leaves to get rid of sap
Leaves wilted	Many	Call for advice*
Many branch tips snipped off and laying on the ground	Squirrel damage	Not worry about health
Small leaves	Many	Call for advice*
Sparse leaves	Many	Call for advice*
Spots on leaves	Many	Call for advice*
TRUNK		
Very little growth	Many	Call for advice*
Webs in the branches or webs covering the tips of branches	Fall webworm or Eastern tent caterpillar	Not worry about health
Yellow or brown leaves	Many	Call for advice*

* Call an arborist or other qualified professional

The establishment period after a tree is planted is a critical time for the long-term health of the tree. Regular maintenance will help ensure establishment and success of urban trees. To increase the lifespan and effectiveness of planting, mulch, stakes, tree shelters, and signage can be used to protect the new plantings. Mulch protects the plants from temperature extremes, maintains soil moisture, prevents erosion, and adds organic matter. Stakes provide trees the support for a stronger trunk and root system. Signage can also provide multiple benefits, from prevention of trampling to educating the public on the new site.

An example 5-year maintenance schedule is provided below.

Example inspection and maintenance schedule (CWP 2006)

Inspection and Maintenance Activity	Year 1	Year 2	Year 3	Year 4	Year 5
Regularly inspect tree health and survival	x	x	x	x	x
Water trees	x	x	x		
Remove tree shelters			x	x	x
Remove stakes and wires		x			
Implement invasive species and noxious weed control methods as needed	x	x	x	x	x
Prune damaged, dead, or diseased branches		x	x	x	x
Implement integrated pest management methods as needed	x	x	x	x	x
Install supplemental plantings if desired		x	x	x	x

Watering

Watering is the most essential thing that can be done for a new tree. The soil should be saturated with at least 15 gallons of water (or three 5-gallon buckets) one to three times per week for 3 years, depending on site conditions. Ensure that compacted soils will allow water to percolate to the tree's root system. Water slowly to prevent runoff. A watering truck may be needed in urban areas where access to water is limited.

Tetra Tech

Tree watering bag

How to know if trees are being watered enough but not too much?

- The soil should be moist but not soaked; if the soil below the surface feels dry, it's time to water
- Too much water causes leaves to yellow and fall
- If it has rained an inch or more during the week, watering is not needed; water is most essential in the warmer months (May through October)
- A tree watering bag or 5-gallon bucket with holes in the bottom can be used to measure the amount of water

Weeding

Weeds compete with trees for water and nutrients, which can stress trees and reduce their growth, especially street trees that already have limited resources.

How to effectively keep weeds under control?

- Use mulch to suppress grass and weeds
- Use a weeding tool to remove the entire root system
- If additional weed control is needed, weed mat or landscaping fabric could be added under mulch

Other Tree Planting and Maintenance Resources

http://www.arborday.org/trees/tips/

http://www.treesaregood.com/treecare/tree_planting.aspx

http://www.tree-planting.com/

Mulching

Mulch, particularly shredded bark or composted wood chips, can be applied at the base of the tree to hold moisture, maintain soil temperature, and suppress grass and weeds.

What is the best way to apply mulch?

- Make sure the ground is not compacted by cultivating the first 2 to 3 inches of soil so water and air can reach the roots
- Apply a 2- to 4-inch layer of mulch around the base of the tree, leaving a 1- to 2-inch mulch-free area around the trunk to prevent the bark from rotting
- Do not apply more than 4 inches of mulch or any additional soil; this will ensure that water and oxygen can penetrate to the roots

Pruning and Trimming

Pruning is generally not necessary for new plantings, but as trees, grow dead or diseased branches should be removed as needed. If a tree is surrounded by sidewalks, powerlines, buildings, or curbs, it is important to maintain clearance from these structures as the tree grows.

Pests and Diseases

Pest and disease management are also critical components of successful tree establishment. Be on the lookout for common pests and diseases that can damage trees. Local information on tree pests and disease can be found on University Extension websites and other local guides. If pests or disease are found during an inspection, immediate action should be taken.

Emerald Ash Borer

Gypsy Moth

Asian Long-horned Beetle

Oak Wilt

Human Impacts

Signage, fencing, tree shelters, and mulching can all help notify public of a tree planting. Trash and pet waste can also accumulate around urban street trees. Signage or education programs can be used to inform the public; waste receptacles and pet waste pick-up bags can also be provided in areas where pet walking is common. In addition, lights added to trees can potentially harm a tree and may require a permit.

References

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Maplewood Mall Stormwater Retrofits

Case Study Contacts: Tina Carstens, Administrator, Ramsey-Washington Metro Watershed District, Minnesota, Erin Wenz, PE, Barr Engineering Company

Ramsey Washington Metro Watershed District (RWMWD) protects and improves the water resources in the eastern portion of the Twin Cities metropolitan area in Minnesota, covering approximately 65 square miles in the Mississippi River watershed. RWMWD is a special purpose governmental unit that includes all of part of 12 cities in two counties and is governed by a five-member board of managers.

The Kohlman Creek Subwatershed Infiltration Study identified Maplewood Mall and its 35-acre parking lot as a potential site for reduction of phosphorus loads and runoff volumes to Kohlman Lake, a nutrient-impaired water body. The watershed district worked closely with the mall owners, Simon Property Group, to redesign the parking lot; other project partners included the City of Maplewood and Ramsey County. The project was designed and implemented over a period of 6 years (2008–2013). The primary stormwater components of the parking lot redesign include 55 rain gardens and 375 trees.

Barr Engineering

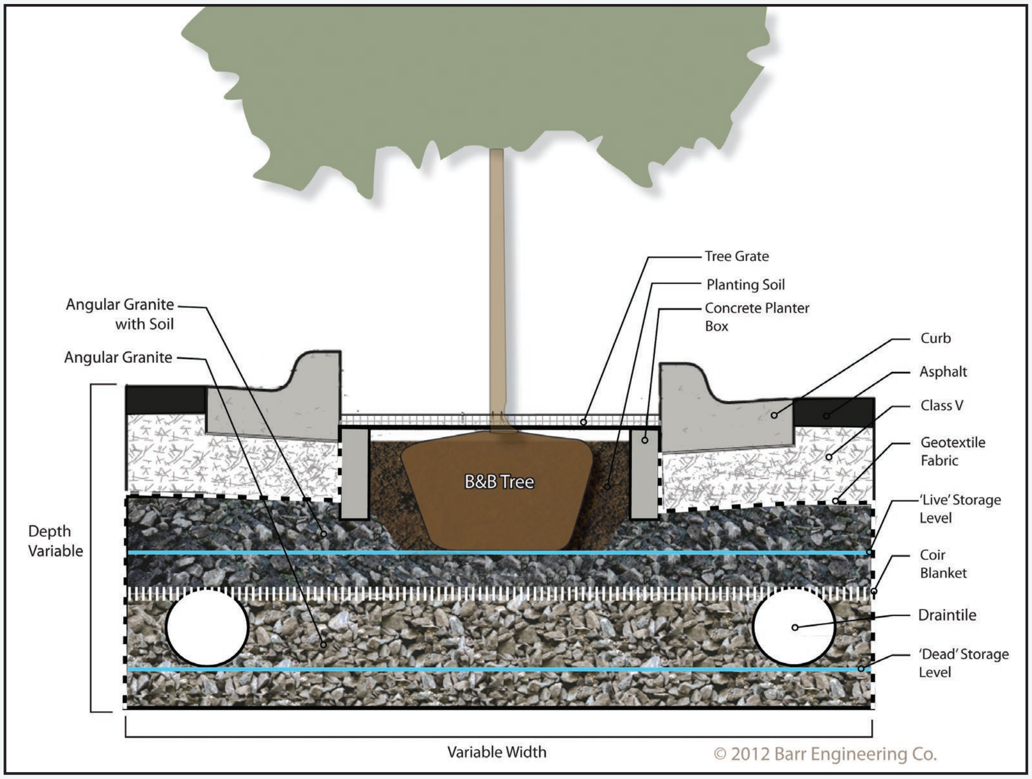
The trees are planted primarily in tree trenches within the parking lot itself, although many trees are also planted at higher elevations in the large rain gardens. The tree trenches extend approximately one mile in length (cumulatively) throughout the mall parking lots, and stormwater enters the trenches at points adjacent to the trees. Stormwater from the parking lot is pretreated by sump catch basins, with over 100 inlet sumps located throughout the tree trench and rain garden system. Stormwater enters the tree trenches either directly through the grate that surrounds each tree or through strips that allow movement of water from the parking lot to the trenches (see tree trench design graphic on the next page). Curbs and tree guards (see photo on the next page) protect trees from car damage. The tree trenches are designed and installed using angular, load-bearing granite that supports the pavement and traffic and allows the soil in the void spaces to remain non-compacted. The soil and remaining void space serve as a growing medium for the trees and allow exchange of gases to and from the roots. On average, approximately 820 cubic feet

Costs and benefits

- *The site is estimated to reduce phosphorus loading by 60 percent and sediment loading by 90 percent through capturing and either infiltrating or filtering the first inch of rainfall.*
- *Total project costs were approximately $6 million, funded through a combination of grants, loans, and watershed district levies.*

Maplewood Mall Stormwater Retrofits

of granite is supplied per tree. Five different tree species were planted (Discovery Elm (*Ulmus davidiana*), Skyline Honey Locust (*Gleditsia tricanthos var. inermis*), Espresso Kentucky Coffeetree (*Gymnocladus dioicus*), Common Hackberry (*Celtis occidentalis*), and Swamp White Oak (*Quercus bicolor*)). These species were selected to be colorful, easy to maintain, and tolerant of the local environmental conditions.



Tree trench design used at Maplewood Mall, MN. Image by Barr Engineering

The project targets dissolved phosphorus removal in addition to particulate removal through the use of iron-enhanced sand filters included as part of the rain garden designs. This project site is regularly inspected by RWMWD staff and has been monitored since pre-construction. Monitoring being conducted in 2016 will further refine load reduction estimates.

The design challenges included compacted soils and the existence of numerous utilities, some of which were not well-marked. Simon Property Group's concerns included the aesthetics of the stormwater features, maintenance, business disruption during construction, and the loss of parking spaces. These concerns were addressed primarily through the project's design. For example, ease of maintenance design components included designing for passage of vehicles between trees, designing for tree protection between parking spaces, and choosing low maintenance options for plants and materials.

Supplemental watering was provided using 15-gallon capacity gator bags for the first two years after planting, after which trees receive water only from precipitation—directly from above and indirectly from the runoff water in the trench. Modifications recommended by the designer (Erin Wenz, Barr Engineering) include larger capacity gator bags to facilitate watering and twice yearly fertilization for the first two years of growth. Tree loss on this project site has not been significant and has been similar to tree loss in general in the Twin Cities metropolitan area.

Tetra Tech

Tree planted in tree trench; note the curb and tree cage used to protect trees from car damage.

Maplewood Mall Project Flyer

MAPLEWOOD MALL
Rainwater Runoff Retrofit Project

Project Summary

Designed to improve the water quality in Kohlman Lake (and ultimately the Mississippi River), the Maplewood Mall Rainwater Runoff Retrofit Project reduces and filters rainwater runoff before it leaves the mall's 35-acre parking lot. The project includes several features: a cistern that captures roof runoff, rainwater gardens, rainwater tree groves, and permeable pavers.

Project Cost and Funding Sources

Phase I	
District CIB Levy	$600,000
Phase II	
District CIB Levy	$700,000
Clean Water Fund Grant	$500,000
Phase III	
District CIB Levy	$700,000
MPCA 319 Grant	$500,000
Phase IV	
Clean Water Fund Grant	$625,000
TMDL Implementation Grant	$1,250,000
PFA CWRF Loan	$1,177,217
PFA CWRF Grant	$392,406

Project Partners

- Simon Property Group
- City of Maplewood
- Ramsey County

MAPLEWOOD MALL

Location of features within the 35-acre footprint

Features & Benefits

55 RAINWATER GARDENS — *They filter 9 million gallons of runoff**

6,733 SQ FT. OF PERMEABLE PAVERS — *They infiltrate 260,000 gallons of runoff**

1 CISTERN — *It holds 5,700 gallons of roof runoff*

375 TREES — *11.2 million gallons of runoff brought into the tree trenches**

*** *in a typical year*

Understanding the Impact

67% of water from the parking lot is now captured or infiltrated at the mall, up from 3% prior to project implementation.

Learn more at www.rwmwd.org

CLEAN WATER LAND & LEGACY AMENDMENT

Ramsey-Washington Metro Watershed District

Great Lakes RESTORATION

Funding for this project was provided by the Great Lakes Restoration Initiative administered by the United States Environmental Protection Agency—Great Lakes National Program Office.

This report was developed under EPA Contract No. EP-BPA-13-R5-0001 by Tetra Tech, Inc.

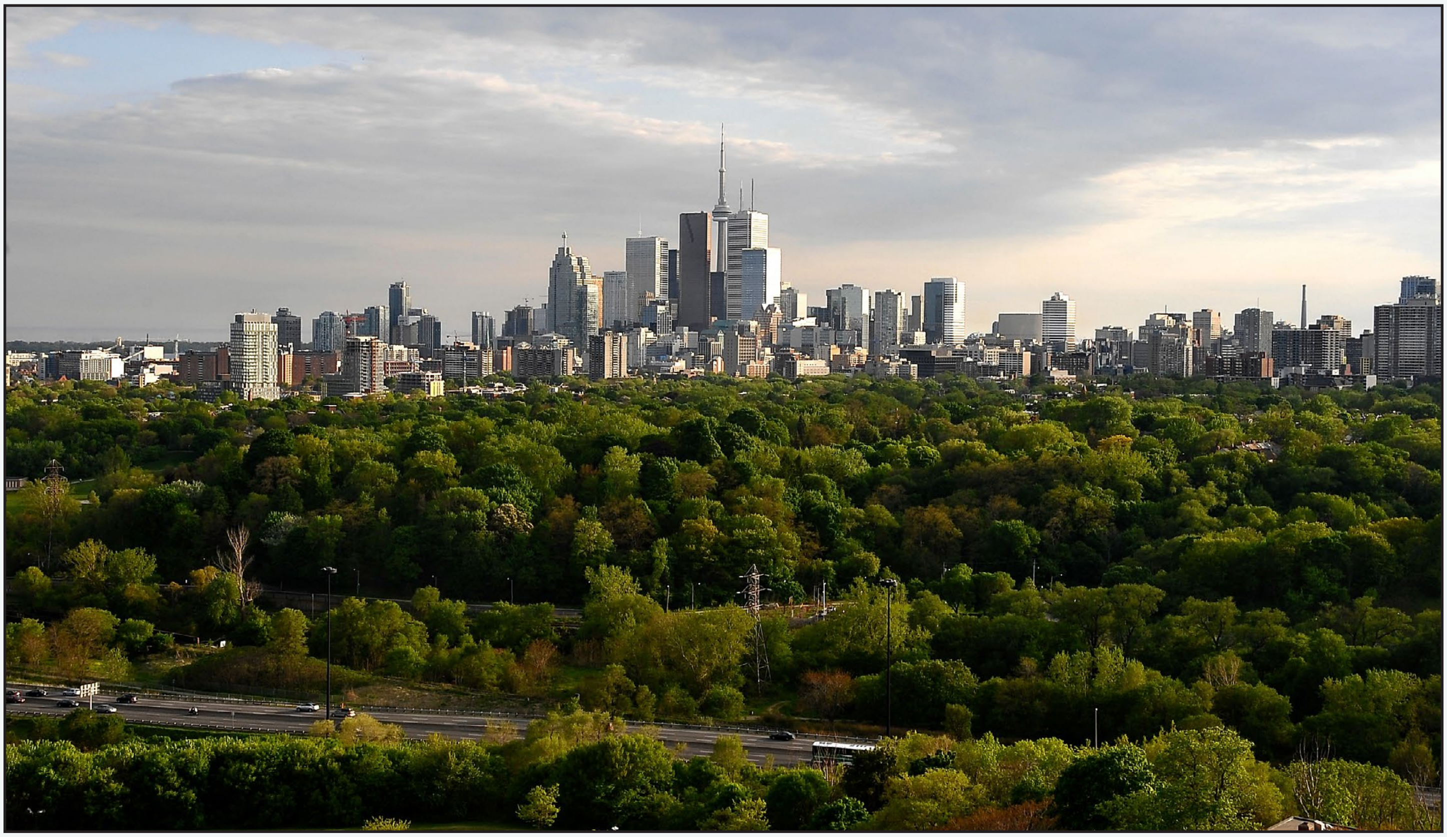
Sustaining and Expanding the Urban Forest: Toronto's Strategic Forest Management Plan

Case Study Contacts: Jason Doyle, Director, Urban Forestry, City of Toronto, Dean Hart, Manager, Forestry Operations, City of Toronto

According to an Ipsos Reid poll, conducted in fall 2015:

- *Overall, residents believe the city is doing a good job maintaining trees across all areas, particularly in city parks (81% satisfied).*
- *Most residents agree that ravines and other natural park areas are important to their quality of life (75%).*

The City of Toronto recognizes the value of the urban forest and is committed to maximizing the potential ecological, social, and economic benefits from urban trees. Toronto is a Canadian city of almost 2.8 million people located along the northern shore of Lake Ontario. Its humid continental climate leads to warm, humid summers and cold, dry winters, similar to many of the cities in the Midwestern United States. The city's Urban Forestry branch of the Parks, Forestry & Recreation division maintains over four million trees on public property and works with local groups and residents to expand and improve the urban forest throughout the city. The city's urban forestry goal is to increase tree canopy cover across the city to 40 percent. As of 2013, urban forest canopy cover in Toronto was approximately 27 percent, which included over ten million trees (see table on the next page). Sixty percent of the trees are on private lands, 34 percent are in city parks and natural areas, and six percent are along city-owned streets. The city has been planting approximately 100,000 trees on public lands (parks, streets, ravines) per year, with hopes to increase that rate to 300,000 trees per year through new private-public partnerships with landowners on privately owned land.



Every Tree Counts, City of Toronto

Sustaining and Expanding the Urban Forest: Toronto's Strategic Forest Management Plan

Summary of Toronto's Urban Forest (from *Sustaining and Expanding the Urban Forest: Toronto's Strategic Forest Management Plan, 2012–2022*)

Measure	Results
Number of trees in Toronto	Approximately 10.2 million
Canopy cover	26.6% to 28%[a]
Canopy cover target	40%
Number of trees on public lands	Approximately 4.1 million (40%)
Number of trees on private lands	Approximately 6.1 million (60%)
Characteristics of the trees that make up the urban forest	• 68% are less than 15.2 cm diameter • 18% are between 15.2 cm and 30.6 cm diameter • 14% are greater than 30.6 cm diameter • Predominance of native species (64%)
Structural value of the urban forest	Approximately $7 billion
Ecological services[b] provided by the urban forest	Valued at $28.2 million annually
Carbon storage	Valued at $25 million

a. Canopy cover estimates for the city have been generated using different methods and results have varied from 19.9% to 28%, but the most current assessment indicates the range is between 26.6% and 28%.

b. This valuation only includes an estimate for air pollution removal, energy savings, avoided carbon related to energy conserved and carbon sequestration.

Matt Forsythe

City of Toronto

Sustaining & Expanding the Urban Forest: Toronto's Strategic Forest Management Plan was adopted in 2013 and describes the city's vision, strategic goals, and challenges to sustaining and expanding the city's urban forest. The city intends to achieve the plan's goals through maintenance of the urban forest, protection of the urban forest and natural heritage, planting to expand the urban forest, and planning to ensure strategic advancement of forest management objectives. The major challenges to sustaining and expanding the urban forest include threats to forest health, tree maintenance, urbanization impacts, climate change impacts, recreational pressures, and public awareness (see table on the next page).

Sustaining and Expanding the Urban Forest: Toronto's Strategic Forest Management Plan

Challenges to sustaining and expanding Toronto's urban forest with highlights of associated actions

Challenge	Current and Future Actions by Toronto's Urban Forestry Branch
Forest health threats	• Identify and manage forest health through integrated pest management, including monitoring and treatment; see Toronto's emerald ash borer experience here • Develop a Forest Health Threats Strategy which will classify threats and address best practices, including partnerships and communication
Tree maintenance requirements and expectations	• Continue to expand a proactive maintenance cycle to maintain street and park trees on a seven-year cycle • Manage forested areas with practices such as prescribed burns and invasive species control • Support success of newly planted trees through structural pruning, watering, and mulching
Balancing urbanization impacts and sustaining the urban forest	• Protect the existing canopy through by-laws and take steps to measure their efficacy • Identify canopy expansion areas and collaborate with local partners to target tree planting in expansion areas • Maintain or restore healthy soils and other site conditions (e.g., sufficient volume of uncompacted soil, easy access to utilities, approaches to sidewalk repair that don't compact soils) to support urban trees
Climate change impacts	• Increase urban forest's resilience to stressors such as pests and drought through tree species diversity (e.g., Tree Seed Diversity Project) • Monitor species composition and survival; adapt tree species mix based on results • Promote tree planting standards that accommodate soil volume needs, moisture retention, space for mature tree growth, and required utility access
Recreational pressures	• Restrict inappropriate land uses and prevent habitat fragmentation through policy development • Minimize user impacts through design solutions (e.g., boardwalk with railings in Glen Stewart Ravine) • Map environmentally significant areas to evaluate threat level and prioritize natural area management
Increasing public awareness of the value and sensitivity of the urban forest	• Educate public on natural area management and appropriate trail user activities (e.g., Trees Across Toronto, the city's native tree and shrub planting program; and Community Stewardship Program, which involves volunteers that provide ongoing maintenance, monitoring, and restoration activities) • Look for opportunities to create private funds for land stewardship of private sites adjacent to public property

Other examples of Toronto's Urban Forestry activities include trail improvements in city parks and ash tree management.

Matt Forsythe

Sustaining and Expanding the Urban Forest: Toronto's Strategic Forest Management Plan

The strategic plan lays out the city's approach to monitor progress and measure success. Every ten years the city conducts a canopy study to describe the current composition, structure, and distribution of the urban forest. To help evaluate the health of the forest, Urban Forestry annually measures the percent of street trees replaced within three years of planting and the percent of trees that survive five years.

City of Toronto

Existing tree planting programs include the city's street tree planting program and Trees Across Toronto, both of which are city efforts to plant trees on public lands (see table below). Additionally, the non-profit organization Local Enhancement & Appreciation of Forests (LEAF) runs the Backyard Tree Planting Program to enhance the urban forest on private property. The city is working with stakeholders to develop a tree planting strategy, which will identify existing planting programs on public lands and opportunities on private lands. The strategy will also include recommendations for formal monitoring programs.

Toronto's Tree Planting Solutions in Hard Boulevard Surfaces Best Practices Manual (2013) provides structural details and construction specifications to help inform future tree planting solutions.

Tree planting programs and incentives

Program	Service
City of Toronto's Street Tree Planting Program	Urban Forestry plants trees on city owned land in front of residential, industrial, and commercial properties for free. The city proactively looks for tree planting opportunities and contacts property owners. Additionally, property owners can request a tree at no cost.
City of Toronto's Trees Across Toronto	The city's native tree and shrub planting program solicits volunteers and coordinates public tree planting events. With the success of tree planting in larger sites, the program's current focus is on smaller park and ravine sites to further expand the urban forest and maintain existing trees.
LEAF's Backyard Tree Planting Program	Local Enhancement & Appreciation of Forests (LEAF) is a non-profit organization dedicated to the protection and enhancement of the urban forest. Among their many services, LEAF offers Toronto homeowners full service and do-it-yourself backyard tree planting services at a subsidized cost.

Dean Hart, Manager, Forestry Operations, reports that having political support has been crucial for funding and implementation of the *Strategic Forest Management Plan*. Recent funding has enabled Urban Forestry to increase tree maintenance, and the stability of funding supports the city's planting initiatives; there have been no significant budget cuts in the last ten years. Additionally, the *Strategic Forest Management Plan* allows the city to prepare for future threats to their urban forest. For example, with the knowledge that the emerald ash borer would likely reach Toronto's urban forest, the city was able to put funding in place in advance of the ash borer's arrival. Implementation of the strategic plan will require support and cooperation among multiple city divisions and partners in the public and private sectors.

Great Lakes RESTORATION

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