Canadian Water Network

Street Tree Clearances to Water and Wastewater Infrastructure

Approaches to avoiding, minimizing and resolving tree-utility conflicts

A comparative analysis for Toronto Water

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CONFIDENTIAL

Contents

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1.0 Introduction

Trees are an extremely valuable component of urban landscapes. Tree planting in cities results in multiple benefits: improved air quality, improved management of stormwater runoff, mitigation of heat-island effect, increased community well-being, and overall improvement of ecosystem health. The socio-economic benefits that arise from having an urban forest also vary widely and include increased tourism and recreation promotion, increased property values, reduced energy costs and generally bringing more aesthetically pleasing views in the city (Duinker et al., 2015). Overall, tree planting in urban areas results in multiple co-benefits to various city departments and other stakeholders (e.g. residents and the broader community).

To ensure that the City of Toronto's goal to increase urban forest cover to 40% can move forward sustainably, minimizing conflicts between green and grey infrastructure and identifying solutions to existing conflicts has become a priority. The Toronto Green Standard means that more trees are being planted, and there is increasing potential for conflicts to arise. As cities like Toronto contend with the planting of trees in dense urban centres with a high concentration of underground and overhead utilities and infrastructure, solutions are needed to address tree-utility conflicts proactively and effectively. When trees are planted in close proximity to water and wastewater infrastructure, potential conflicts include increased repair time and maintenance costs during emergency or planned infrastructure repairs, and tree root intrusion into sewers which can cause sewer back-ups and property damage.

This project and the resulting comparative analysis provide information which the city can use to develop and assess options by synthesizing and summarizing standards, guidance and best practices for tree planting near water/wastewater infrastructure across North America. The project also provides recommendations and preferred approaches for Toronto Water to consider when addressing conflicts between grey and green infrastructure.

1.1 Project objectives

The goal of the project was to generate insights and best practices for avoiding, minimizing, or resolving conflicts between trees and water/wastewater infrastructure. The specific objectives were:

- To provide Toronto Water with information on other municipalities' standards, guidance and practices for tree planting near water/wastewater infrastructure, which may include:
  - Clearance distances (horizontal and vertical) from the edge of water and wastewater infrastructure to:
    - Tree (root ball, trunk)
    - Soil trench
    - Soil cell or another tree planting element
  - Tree trench design elements, such as root barriers, soil cells, passive irrigation and drainage pipes

- Utility relocation practices to accommodate street tree planting
- Utility protection measures
- Exemption process/requirements for reduced clearance distances
- Infrastructure prioritization

- To generate insights and recommendations on potential best practices (where available) that Toronto Water could adopt to reduce conflicts between tree planting locations and existing water and wastewater infrastructure.

1.2 Scope, framing and approach

The insights and recommendations presented in this report are derived from a combination of CWN's review of relevant literature and the execution of a structured interview process with six municipalities/utilities across North America about their lived experiences. A comparative analysis of the approaches used by the interviewed municipalities/utilities also informed the development of the insights and recommendations.

In general, the findings from the literature review were validated using the practical experience and expertise of the municipal representatives that participated in the interview process. CWN notes that the findings and insights derived from the interview process are based on interviews conducted with one or two departments at each municipality, and as such, may not represent a comprehensive overview of standards and practices at the municipality.

CWN developed an interview questionnaire (Appendix A) to gauge the internal practices, standards, and decision-making processes for urban tree planting and the management of water/wastewater infrastructure within the interviewed municipalities/utilities. The interview questionnaire is in Appendix A. The questions were shaped using the project framing and objectives in the statement of work and were used to gain insights on the lived experiences of each municipality. The questions were structured to capture a broader understanding of both formal and informal municipal practices, as well as the internal stakeholders involved in decisions on tree-utility conflicts.

Six municipalities/utilities were engaged by CWN for interviews: City of Mississauga (Ontario), City of Montréal (Québec), City of Vancouver (British Columbia), City of Seattle (Washington), Philadelphia Water (Pennsylvania, U.S.A.) and New York City (New York, U.S.A). The municipal departments/utilities that participated in the interviews are listed below:

- City of Mississauga:
  - Community Services Department, Parks, Forestry and Environment Division
  - Planning and Building Department, Development and Design Division
- City of Montréal:
  - Integrated Stormwater Management Strategy Department, Water Services

- City of Vancouver:
    - Green Infrastructure Implementation Branch, Engineering Services
    - Integrated Strategy and Utilities Planning, Engineering Services
    - Transportation Design, Engineering Services
    - Waterworks Design Branch, Engineering Services
    - Vancouver Park Board
- City of Seattle:
    - Trees for Seattle Program, Seattle Public Utilities
    - ROW Maintenance and Urban Forestry, Seattle Department of Transportation
- Philadelphia Water:
    - Landscape Design, Green Stormwater Infrastructure Unit
- New York City:
    - Street Tree Planting, Parks and Recreation
    - Permits and Plan Review, Parks and Recreation
    - Tree Replacement and Restitution, Parks & Recreation
    - Green Infrastructure Design and Construction, Bureau of Environmental Planning and Analysis, NYC Department of Environmental Protection

After the interviews were conducted, CWN analyzed each municipality's responses and captured detailed notes for further synthesis. CWN then conducted a comparative analysis (Section 2.2) to assess the commonalities and differences among municipal approaches for managing tree-utility conflicts. CWN incorporated this analysis with the results of the literature review to synthesize insights on best practices (Section 3.0) and recommendations for Toronto Water (Section 4.0).

2.0 Managing Risks to Water/Wastewater Infrastructure from Tree Planting

2.1 Literature review

CWN conducted a literature review of research that examined urban forests and their potential impacts on other urban infrastructure. The literature was scanned for insights into common conflicts. The conflicts highlighted by most studies involved tree roots damaging sidewalks and intruding into sanitary sewers. The studies that were conducted on the impacts of tree roots on water/wastewater infrastructure focused on sewers that had been obstructed by infiltrating roots. For example, Randrup et al., (2001b) noted the increased likelihood of root infiltration in older sewer pipes made of clay and around pipe joints.

Research on the intrusion of tree roots into water/wastewater pipes can be traced back to the 1970s (Östberg et al., 2012). Since then, understanding the impacts trees have on water/wastewater assets has become an increasing interest for researchers and municipalities due to the considerable expense of repairing and replacing these assets. A common misconception is that tree roots may cause severe damage to pipes and cause them to break

(Rolf & Stål, 1994). However, trees do not cause physical damage to pipes by crushing or squeezing. More commonly, opportunistic roots will seek out already existing damage, openings or leaks and exacerbate them after infiltrating the pipe (Brennan et al., 1997; Randrup et al., 2001b; Stutter et al., 2010; Ward & Clatterbuck, 2005).

Urban growing conditions are not ideal for trees (Day et al., 2010; Stone & Kalisz, 1991). Urban soils tend to be compact and urban stormwater runoff infiltrating into soils may be saline. Tree roots grow in an opportunistic manner, and if ideal conditions are nearby, they will extend further into them to maintain their health, which often leads to conflicts with the surrounding infrastructure (Brennan et al., 1997; Randrup, 2000; Randrup et al., 2001a). Tree roots are attracted to condensation that forms on the underside of sidewalks or around watermains, which may lead to cracks in sidewalks or root infiltration into pipe joints or cracks. Sewers with existing damage, openings, cracks, or leaks are particularly at risk of root intrusion because wastewater carries nutrients in addition to water. Table 1 presents an overview of maximum and average tree root growth found in the literature, among other distances like recommended clearances.

Table 1. Relevant clearances, depth and distances for typical and maximum tree root growth (horizontal and vertical).

Type of clearance, depth or distance (horizontal growth radius, vertical growth, clearance recommendation maximum, average, etc.)	Value (m)	Species	Source
Maximum recorded, horizontal growth	20 or less	Most	(Stone & Kalisz, 1991)
Maximum recorded, vertical growth	20 or less	Most	(Stone & Kalisz, 1991)
Depth of most of the root volume (60-90%)	0.2-0.3	—	(Day et al., 2010; Randrup et al., 2001a)
Depth of most of the structural roots	0.6	—	(Randrup et al., 2001a)
Maximum recorded, vertical growth (species from urban environment grown in a natural setting)	7	*Ulmus americana* (American elm)	(Day et al., 2010)
Probable maximum horizontal distance to pipe intrusion	6	—	(Randrup, 2000)
Maximum horizontal distance to pipe intrusion	20	—	(Östberg et al., 2012)
Minimum horizontal clearance distance between tree trunk and sidewalk	1.2	—	(Hilbert et al., 2020; North et al., 2015)
Recommended horizontal clearance distance between tree trunk and sidewalk	3	—	(Randrup et al., 2001a)

Several studies have researched tree clearance distances specifically for sidewalks (Table 1). Parameters such as diameter at breast height and trunk flare diameter have been used to estimate how much room the tree will need to grow without impacting grey infrastructure (Hilbert et al., 2020; North et al., 2015; Randrup et al., 2001a). The absolute minimum distance recommended for sidewalk clearance is 1.2 m (Hilbert et al., 2020; North et al., 2015), but radial distances up to 3 m or more are recommended (Randrup et al., 2001a). These distances are important for protecting sidewalks from lateral roots that grow near the surface, but whether these distances translate into recommendations for water/wastewater infrastructure is unclear based on the reviewed literature.

Most tree species have maximum root extent radiuses and root depths of 20 m or less, both horizontally and vertically (Stone & Kalisz, 1991). Additionally, root intrusions into water/wastewater pipes are rarely attributed to trees further than 20 m away (Östberg et al., 2012). One study that surveyed 176 cities in Denmark found that most root intrusions occurred when the sewer pipe was within 6 m of a tree (Randrup, 2000). The risk of root intrusion increases with worsening pipe condition, and pipe joints or leaks along the pipe will also increase the risk of root intrusion. Over time, if there is a tree within a 20 m horizontal distance from a sewer pipe (and possibly further) (Östberg et al., 2012), the roots may have a chance of intruding into the pipe if it is in poor condition.

Although root infiltrations were discussed at length in the literature, one major tree-related conflict that the interviewed municipalities discussed was the issue of accessing water/wastewater pipes for maintenance. This conflict was mainly discussed in the literature in the context of damage caused to the tree during general construction activities (Kuser, 2000; Vogt et al., 2015). Tree roots will spread out over time, the majority of which will grow further horizontally than vertically. The bulk mass of tree root systems grows within the first 0.3 to 0.6 m of soil (Day et al., 2010; Randrup et al., 2001a). However, the tendency for tree roots to grow quite far radially may lead to conflicts when construction is required to maintain, upgrade or otherwise access water/wastewater infrastructure.

The Toronto Urban Forestry section has set guidelines in their *Tree Protection Policy and Specifications for Construction Near Trees*, which outlines the requirements for working around trees during construction (City of Toronto Urban Forestry, 2016). These guidelines require the utility to meet clearance distances from protected trees before beginning construction. If they cannot meet these distances, they must obtain a permit and assume all associated costs. For example, an arborist must be hired and brought onsite to assess the tree's status and root locations before beginning the project. The exception to these requirements is if there is an emergency, such as a watermain break, for which Urban Forestry may be contacted for assistance with tree removal. A consequence of these practices is the delay that might be caused in any situation, both emergency and non-emergency. Additionally, restitution costs for any dead or damaged trees are charged to the utility.

The following paragraph presents key findings from the literature review on the lifecycle costs and considerations for tree planting. There are upfront costs in the planting of a new tree, and it takes time for the full benefits of a tree to be realized and eventually overcome the initial and maintenance costs (Vogt et al., 2015). Upfront costs include tree bed construction, digging costs and initial maintenance that ensures the survival of the tree in a harsher urban environment. The intention is for each planted tree to achieve a net benefit which can be attained over time. However, if a tree is damaged during construction leading to premature removal, a net benefit can no longer be reached and significant costs associated with the lost residual value of the tree will be incurred (Vogt et al., 2015). Ultimately, a tree removed too soon will result in sunk costs. Figure 1 presents a conceptual model of the economic benefits of tree planting with time.

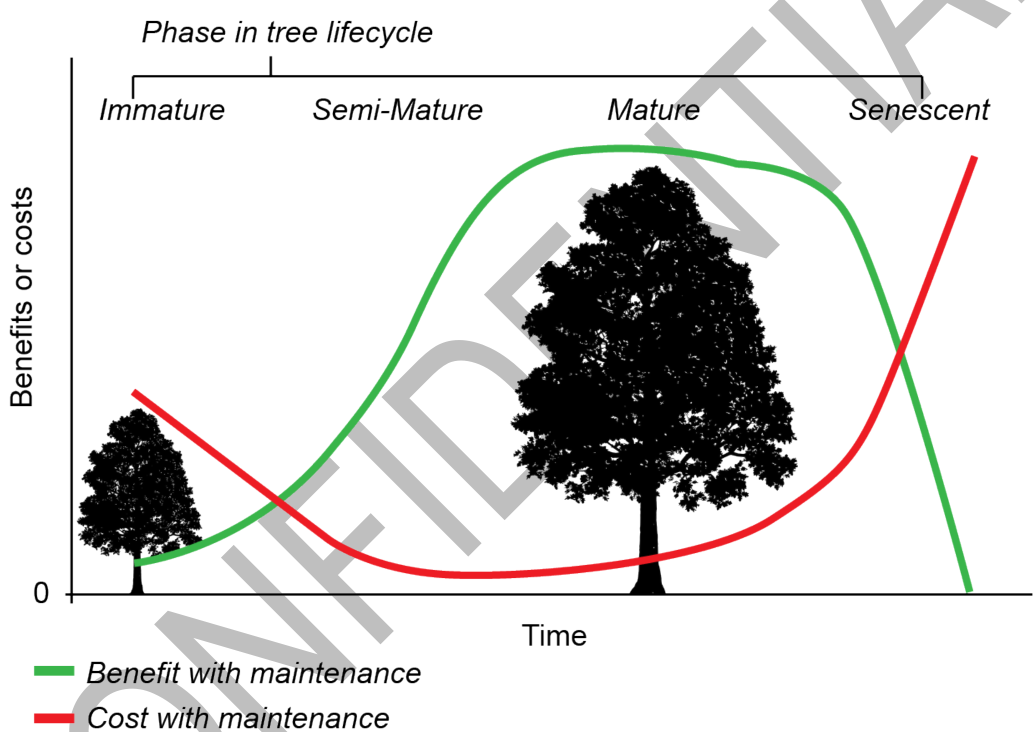

Figure 1. Conceptual model of tree economic benefits and associated costs of planting, maintenance, and tree removal. Original figure modified from Vogt et al. (2015).

Overall, the scientific literature provided a solid background on the benefits and costs of trees (Vogt et al., 2015) and some of the common conflicts with grey infrastructure but lacked a deeper understanding of the lived experience context that municipalities confront on a day-to-day basis. The non-biological elements of managing street trees such as determining appropriate planting locations were rarely addressed. As such, CWN structured the municipal interviews to yield a more holistic understanding of tree-utility conflicts and considerations for avoiding, minimizing and resolving them.

2.2 Comparison of municipal approaches to managing tree-utility conflicts

The following subsection presents a detailed comparative analysis of the approaches used by the interviewed municipalities/utilities to manage and mitigate conflicts between tree planting locations and water/wastewater infrastructure.

Figure 2 maps the locations of the interviewed municipalities in ecoregions based on designations developed by the United States Environmental Protection Agency (USEPA).

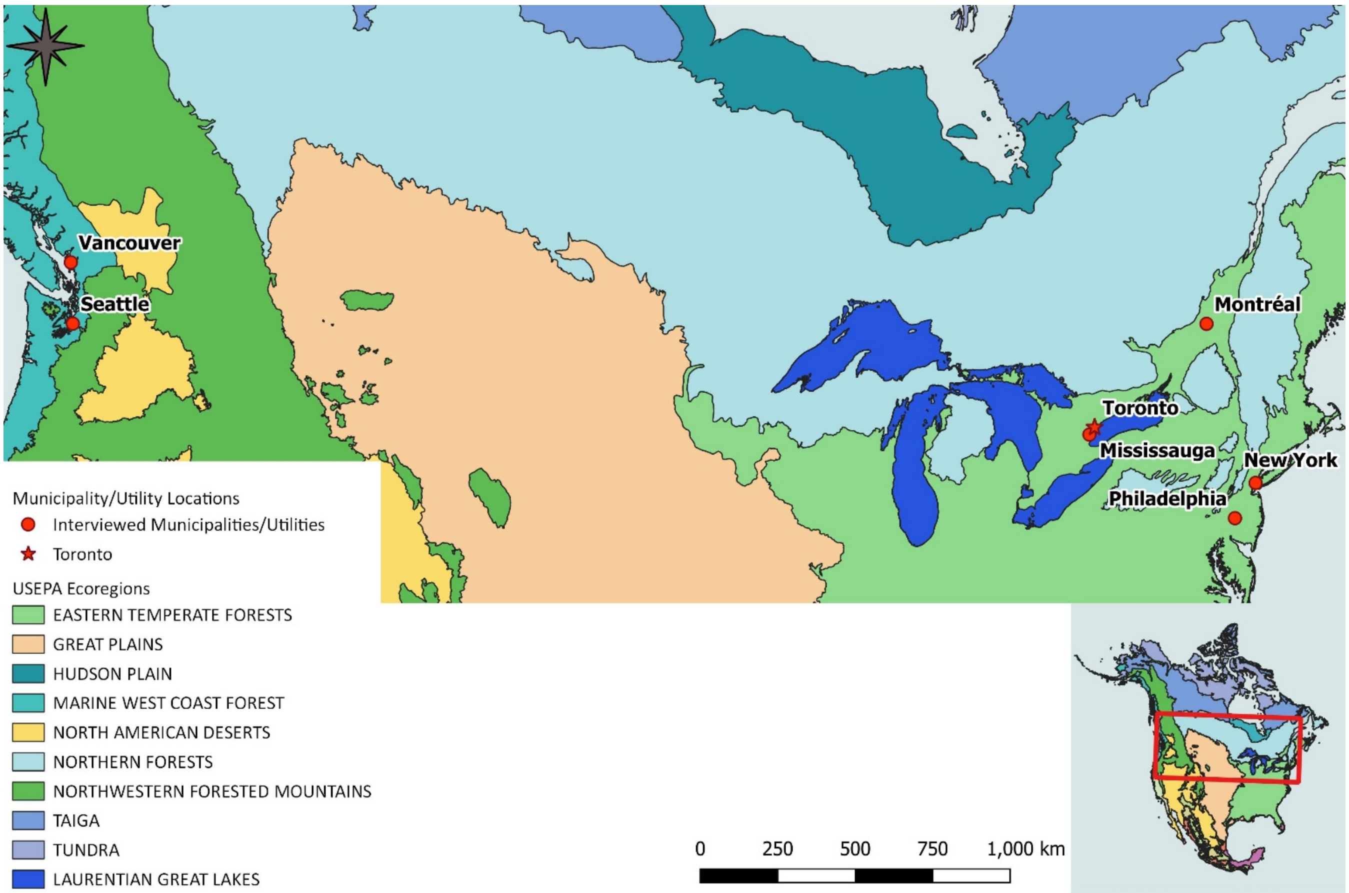

Figure 2. Locations of the interviewed municipalities/utilities and their USEPA ecoregions. Data from USEPA Level I Ecoregions of North America dataset, Natural Resources Canada Populated Places dataset, and Natural Earth Populated Places dataset. Produced December 7, 2020 by Tamara Van Staden.

Table 2 provides a snapshot of the characteristics of the municipalities/utilities that participated in the interview process. The table outlines how the cities compare with the City of Toronto's population density, average annual precipitation, temperature extremes, etc.

Table 2. Key characteristics of the municipalities that participated in CWN's interviews.

Municipality, province or state	Population	Pop. Density (per km^2)	Type of population serviced	Climate Ecoregion	Average annual precipitation (mm)	Average annual rainfall (mm)
Toronto, Ontario	2,731,571[1]	4,334.4[1]	Predominantly urban	Eastern temperate forests	831.1[2]	714.0[2]
Mississauga, Ontario	721,599[1]	2,467.6[1]	Both urban and rural	Eastern temperate forests	785.9[3]	681.6[3]
Montréal, Québec	1,704,694[1]	4,662.1[1]	Predominantly urban	Eastern temperate forests	1,000.3[4]	784.9[4]
Vancouver, British Columbia	631,486[1]	5,492.6[1]	Predominantly urban	Marine west coast forest	1,189.0[5]	1,152.8[5]
Seattle, Washington	708,823[6]	3,260[12]	Predominantly urban	Marine west coast forest	951.0[9]	955[15]
Philadelphia, Pennsylvania	1,575,522[7]	4,536[13]	Predominantly urban	Eastern temperate forests	1,054.6[10]	1,059[16]
New York City, New York	8,443,713[8]	10,772[14]	Predominantly urban	Eastern temperate forests	1,268.73[11]	1,270[17]

[1] Based on 2016 census data from Statistics Canada: https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/hlt-fst/pd-pl/Table.cfm?Lang=Eng&T=301&S=3&O=D

[2] Based on 1981 to 2010 Canadian Climate Normals data from Environment and Climate Change Canada: https://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnName&txtStationName=toronto&searchMethod=contains&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=5051&dispBack=0

[3] Based on 1981 to 2010 Canadian Climate Normals data from Environment and Climate Change Canada: https://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnProx&txtRadius=25&optProxType=city&selCity=43%7C35%7C79%7C37%7CMississauga&selPark=&txtCentralLatDeg=&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongDeg=&txtCentralLongMin=0&txtCentralLongSec=0&txtLatDecDeg=&txtLongDecDeg=&stnID=5097&dispBack=0

[4] Based on 1981 to 2010 Canadian Climate Normals data from Environment and Climate Change Canada: https://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnProx&txtRadius=25&optProxType=city&selCity=45%7C31%7C73%7C39%7CMontr%C3%A9al&selPark=&txtCentralLatDeg=&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongDeg=&txtCentralLongMin=0&txtCentralLongSec=0&txtLatDecDeg=&txtLongDecDeg=&stnID=5415&dispBack=0

[5] Based on 1981 to 2010 Canadian Climate Normals data from Environment and Climate Change Canada: https://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnProx&txtRadius=25&optProxType=city&selCity=49%7C17%7C123%7C8%7CVancouver&selPark=&txtCentralLatDeg=&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongDeg=&txtCentralLongMin=0&txtCentralLongSec=0&txtLatDecDeg=&txtLongDecDeg=&stnID=889&dispBack=0

[6] Based on 2018 population estimate from the United States Census Bureau: https://data.census.gov/cedsci/table?q=ACSDP5Y2018.DP05%20Seattle%20city,%20Washington&g=1600000US5363000&tid=ACSDP5Y2018.DP05&hidePreview=true

[7] Based on 2018 population estimate from the United States Census Bureau: https://data.census.gov/cedsci/table?q=ACSDP5Y2018.DP05%20Philadelphia%20city,%20Philadelphia%20County,%20Pennsylvania&g=0600000US4210160000&tid=ACSDP5Y2018.DP05&hidePreview=true

[8] Based on 2018 population estimate from the United States Census Bureau: https://data.census.gov/cedsci/table?q=ACSDP5Y2018.DP05%20New%20York%20city,%20New%20York&g=1600000US3651000&tid=ACSDP5Y2018.DP05&hidePreview=true

[9] Based on 1981 to 2010 precipitation normal from U.S. National Oceanic and Atmospheric Administration's National Centers for Environmental Information: https://www.ncdc.noaa.gov/cag/city/time-series/USW00024233/pcp/ann/9/1981-2010?base_prd=true&begbaseyear=1981&endbaseyear=2010

[10] Based on 1981 to 2010 precipitation normal from U.S. National Oceanic and Atmospheric Administration's National Centers for Environmental Information: https://www.ncdc.noaa.gov/cag/city/time-series/USW00013739/pcp/ann/9/1981-2010?base_prd=true&begbaseyear=1981&endbaseyear=2010

[11] Based on 1981 to 2010 precipitation normal from U.S. National Oceanic and Atmospheric Administration's National Centers for Environmental Information: https://www.ncdc.noaa.gov/cag/city/time-series/USH00305801/pcp/ann/9/1981-2010?base_prd=true&begbaseyear=1981&endbaseyear=2010

[12] Based on 2018 data from the U.S. Census American Community Survey as presented on Open Data Network: https://www.opendatanetwork.com/entity/1600000US5363000/Seattle_WA/geographic.population.density?year=2018#:~:text=The%20last%20measured%20population%20density,to%20be%209%2C204%20by%202023.

[13] Based on 2018 data from the U.S. Census American Community Survey as presented on Open Data Network: https://www.opendatanetwork.com/entity/1600000US4260000/Philadelphia_PA/geographic.population.density?year=2018

[14] Based on 2018 data from the U.S. Census American Community Survey as presented on Open Data Network: https://www.opendatanetwork.com/entity/1600000US3651000/New_York_NY/geographic.population.density?year=2018#:~:text=The%20last%20measured%20population%20density,to%20be%2028%2C159%20by%202023.

[15] Based on 1981 to 2010 average rainfall data from U.S. National Oceanic and Atmospheric Administration's National Centers for Environmental Information as presented on Weather Atlas: https://www.weather-us.com/en/washington-usa/seattle-climate#rainfall

[16] Based on 1981 to 2010 average rainfall data from U.S. National Oceanic and Atmospheric Administration's National Centers for Environmental Information as presented on Weather Atlas: https://www.weather-us.com/en/pennsylvania-usa/philadelphia-climate#rainfall

[17] Based on 1981 to 2010 average rainfall data from U.S. National Oceanic and Atmospheric Administration's National Centers for Environmental Information as presented on Weather Atlas: https://www.weather-us.com/en/new-york-usa/new-york-climate#rainfall

2.2.1 Overview of municipal tree planting programs and governance

City of Mississauga

In Mississauga, there are designated tree planting corridors along boulevards where trees are either already planted or will be planted. Projects planned by the Mississauga Forestry Branch are included as capital works and can be as large as rebuilding entire boulevards to relocate utilities to accommodate tree planting and minimize conflicts. The function of the tree corridor is to ensure that space is reserved for tree planting and prioritized when other utilities are located there, which then provides leverage for funding the relocations as part of capital works.

For independent developers, trees are often required in their designs for new projects when they submit their application to Mississauga's Public Utility Coordinating Committee (PUCC). The city has the authority to ask the developer to take on the costs of planting trees and the relocation of utilities, including water and wastewater infrastructure. City planners review the developer's design drawings and examine the planned tree planting locations. The developer can proceed with construction only once their drawings are approved. All plans for tree planting, internally or externally, are planned well in advance, making sure that those involved understand the physical and financial outcomes for all possible scenarios.

City of Montréal

Street trees are managed by two separate entities in the City of Montréal. Individual neighbourhoods (or boroughs) manage the minor streets and the trees along them. Major streets are managed by municipal services such as Service de l'eau (Water Services), Service des grands parcs (Parks Department) and Service des infrastructures du réseau routier (Transportation Services). Transportation Services are the landowners of the major streets; the Parks Department owns all parkland. The Parks Department is responsible for financing municipal tree planting and ensuring that neighbourhoods can plant as many trees as possible. The city's goal is to increase its canopy cover by 5%. Projections of 5% canopy cover loss due to the Emerald Ash Borer means that the city will need to increase canopy cover by 10% to achieve its goal.

City of Seattle

In Seattle, street trees are regulated by the Seattle Department of Transportation (SDOT) and residential tree planting is coordinated by Seattle Public Utilities (although still regulated by SDOT). The two tree planting programs, Trees for Seattle and Trees for Neighbourhoods, are supported by these departments, though SDOT has the authority to make the final call on tree planting locations. The other departments that influence tree management to lesser extents include Seattle City Light, Seattle Urban Forestry Commission, Seattle Parks, Fleet of Administrating Services, and the Office of Sustainability and Environment. Their involvement ranges from planning space for trees in new projects, informing City Council, planting trees on their own property (e.g. fire stations), and regular maintenance of trees, but in all instances, SDOT remains the point of contact for information and permitting. Seattle's tree planting programs and initiatives contribute to meeting the City of Seattle's obligations under the federal U.S. Clean Water Act.

Seattle promotes citizen stewardship with the Trees for Seattle and Trees for Neighborhoods programs. Every year, 1,000 trees are purchased by the City of Seattle and distributed to program applicants using a lottery system. Applicants are required to participate in two free courses: *Right Tree Right Place* and *Planting and Care*. These courses aid the program applicants in the process of picking the right tree species for the location they have in mind, as well as how to care for the tree during the first five years of its life and encourage healthy tree establishment. In 2020, both courses have been converted to a webinar format (Stubecki & Farmer, 2020) to address social distancing concerns during the pandemic, which has increased accessibility. The City of Seattle encourages participants to reach out with their questions and concerns at any time and they provide extensive resources and direct support from the program manager. Public and private interests in trees and residential streetscapes in these programs.

City of Vancouver

Vancouver's urban forest has undergone steady expansion over the past 10 years. In 2010, the city set a goal of planting 150,000 trees, which will be achieved by the end of November 2020. These trees are protected and managed by the City of Vancouver and the Vancouver Park Board. The Vancouver Park Board regulates publicly-owned trees such as those located on public streets and parks. The Planning, Urban Design and Sustainability Department and Engineering Department help plant and protect trees on privately-owned lands. These departments look for opportunities to collaborate on plans for tree planting and tree preservation. However, the final approval for tree planting locations — particularly if they fall slightly below designated clearance distances — is given by the Waterworks Design Branch and Vancouver Coastal Health (VCH). VCH is a publicly-funded regional health authority for the Greater Vancouver area.

New York City

New York City's Parks and Recreation Department (NYC DPR) has two forestry divisions. The Forestry, Horticulture, and Natural Resources division is referred to as the central forestry division and manages the larger tree planting program including, street tree planting, tree preservation, natural area restoration and conservation, stewardship and training programs, and creating urban forest management programs for specific parks. The Maintenance and Operations Division includes forestry offices for the five New York City boroughs and is responsible for the maintenance of parks, including the upkeep of parks and street trees.

Tree planting in New York City is funded by capital dollars, including mayoral funding and allocations from borough presidents and council members. The largest current planting initiative is the Cool Neighborhoods Program which targets areas with a high heat vulnerability index. Foresters from NYC DPR conduct a desktop-based survey to determine tree planting locations. They use a GIS tool to determine if the planting location meets clearance distance requirements for existing infrastructure, as well as infrastructure planned for the next five years. The foresters execute planning, locates and planting with assistance from the GIS and analytics team that provides data management and geospatial analysis support, including identifying areas at risk of high heat exposure. NYC DPR actively works to avoid and mitigate conflicts when planting. They have autonomy over tree planting locations, provided that they work around the agreed upon clearances, which are made possible with the support from the GIS and IT teams.

In addition to tree planting programs, the New York City Department of Environmental Protection (NYC DEP) supports a green infrastructure initiative that fulfills a combined sewer overflows consent order issued by the state (which in turn meets the state's obligations under the U.S. Clean Water Act). Green infrastructure such as raingardens and retention basins are installed across New York City, which involves decision support from the Departments of Transportation, Parks and Recreation, Design and Construction — as well as the Economic Development Corporation — that is based on each department's individual requirements for implementation. The NYC DEP is also responsible for water/wastewater infrastructure management and they formally consider green infrastructure to be a water utility unit.

Within NYC DPR there is an interagency coordination team that keeps track of all the projects and negotiations required to support the borough forestry offices, capital works, maintenance and operations, and central forestry. The interagency team represents NYC DPR's interests, share and filter information and discuss projects with different agencies to ensure that everyone who may be impacted is informed and can communicate their needs.

Philadelphia Water

When the Green Stormwater Infrastructure program was initiated in Philadelphia 10 years ago, there was a large hiring effort that brought on as many contract personnel as there were city employees. The hired contractors included engineers, planners, and landscape designers. This diversity has engendered interdisciplinary perspectives on the intersections of grey and green infrastructure. The Green Stormwater Infrastructure program contributes to the Green City, Clean Waters program, which helps meet the City of Philadelphia's obligations under the federal U.S. Clean Water Act.

In Philadelphia, trees are planted by Philadelphia Water, as well as the Parks and Recreation department. Philadelphia Water's goal is to plant as many trees as possible wherever they are managing stormwater (about 25% of trees city-wide). Their design team plans and develops new green stormwater infrastructure projects for ongoing or future capital projects which can benefit from the inclusion of green infrastructure.

Tree preservation is a priority for Philadelphia and trees are protected and preserved in as many cases as possible. They are not removed for new green stormwater infrastructure or other capital projects where possible because tree canopy protection has been prioritized, specifically because in the case of canopy cover: "loss is an event, but gain is a process" (O'Neil-Dunne, 2019).

2.2.2 Comparative analysis tables

The following tables compare the various municipal/utility approaches to avoiding, minimizing and addressing tree-utility conflicts. Table 3 highlights key characteristics of the interviewed municipalities, including common conflicts they experience and the standards, guidance and practices they use to manage tree-utility conflicts.

Table 3. Common formal and informal conflicts observed by the interviewed municipalities/utilities between green and grey infrastructure that inform prioritization approaches, as well as the standards and practices used to avoid, minimize, or manage conflicts that arise.

Municipality/Utility	Common tree-utility conflicts	Prioritization approach for addressing current conflicts or reducing future conflicts	Standards, guidance and practices for avoiding, minimizing, or managing conflicts
City of Mississauga	• Root conflicts are rare. They are typically identified by utilities that notice roots beginning to extend towards utilities during routine or emergency repair work. • Most water utilities are located beneath the middle of the road, making it easy to maintain tree-utility clearance distances • Intersections with fiber optic lines are a more common challenge	• Tree planting corridors are designated along the boulevard where trees are either already planted or reserved for trees yet to be planted • Compromises are made where trees were planted, despite knowing they will be removed when utility repair is needed. • The Public Utility Coordinating Committee (PUCC) can require a developer to include tree planting plans in their design. • Developers are sometimes asked to rebuild entire boulevards to relocate utilities and accommodate soil cells for trees. This is determined on a case-by-case basis during the Site Plan application and review process (City of Mississauga, 2013)	• A 3 m clearance is required between trees and most water assets. • Strong relationships exist between the city's utilities and forestry departments, which opens communication channels for emergency and non-emergency situations. • An extensive planning processes is in place. Applications to the Public Utility Coordinating Committee (PUCC) are reviewed by a tree preservation team. • Potential conflicts are flagged by the forestry department and discussed with utilities.

Municipality/Utility	Common tree-utility conflicts	Prioritization approach for addressing current conflicts or reducing future conflicts	Standards, guidance and practices for avoiding, minimizing, or managing conflicts
City of Montréal	• Water and wastewater infrastructure are typically located beneath the centreline of the road. Conflicts are not common.	• Water and wastewater infrastructure are prioritized over trees. • There are instances where trees were removed because of required repairs; there are other instances where water/wastewater pipes were relocated in accordance with state of good repair replacement to make room for trees in the future. • City services work independently from each other, which sometimes generates debates about appropriate clearance distances.	• When new trees are planted, the utility uses the opportunity to assess the health of nearby water/wastewater pipes and if pipes are in poor condition, they are relocated or lined for protection. • Water/wastewater pipes that require repair and are located below the sidewalk are typically moved into the street during the repair.
City of Seattle	• Most conflicts are caused by older and natural trees planted before standards were set, which are dealt with on a case-by-case basis. • Sewers are impacted more than watermains, typically from tree root infiltration into joints & cracks. • Trees planted without permits may be planted within clearances.	• The ultimate goal is to preserve existing trees. • Species selection is determined based on the physical characteristics of the site, such as choosing powerline-approved species for planting under transmission wires. • The decision to remove a tree or relocate pipe is examined and discussed with other departments from the perspective of the "most judicious use of the tax dollars."	• A 5-foot (1.5 m) clearance between trees & underground utility lines/pipes was established as inferred practice in the late 1990s and became standard practice in the early 2000s. • Clearance has been specifically established to protect trees during infrastructure repairs or maintenance. • Removed trees are replaced, with the intention to replace or improve the lost canopy rather than the number of trees. If there is space, as many trees are planted as possible.

Municipality/Utility	Common tree-utility conflicts	Prioritization approach for addressing current conflicts or reducing future conflicts	Standards, guidance and practices for avoiding, minimizing, or managing conflicts
City of Vancouver	• Conflicts are more common between drinking water infra-structure & trees/green infrastructure due to watermains being located beneath the side of the road (1-2 m from the curb). • Conflicts between waste-water infrastructure and trees/green infrastructure are less common due to sewers being located beneath the centreline of the road. • Vancouver Coastal Health is responsible for drinking water distribution systems in the region and does not permit stormwater infiltration within 3 m of watermains. This requirement effectively eliminates implementation of green infrastructure for one side of the right-of-way.	• Vancouver Coastal Health has the final say on green infrastructure locations near drinking water pipes; they consider & sometimes accept accommodations. • Watermains are prioritized over green infrastructure due to human health concerns related to the rare potential for stormwater to infiltrate into water pipes. • Green infrastructure is new and is therefore not typically prioritized over existing infrastructure. • In one project, trees were prioritized where they were needed aesthetically, and the water and wastewater pipes were relocated. • Trees may be prioritized in instances of public or media involvement, which can result in political interest and decision to fund the relocation of water or wastewater infrastructure.	• A 2 m minimum clearance is required between trees and watermains, hydrants and service connections. • A 3 m clearance is required between green infrastructure and drinking water infrastructure; there is currently no required clearance distance between green infrastructure and wastewater infrastructure, but the city is in the process of assessing potential clearance distance requirements. • There is some flexibility for the 3 m clearance when interacting with the utility. For example, mitigation practices may be installed to permit a smaller clearance (e.g. wrapping joints). • There is a desire to implement more soil cells and structural soil, although there are concerns about the procedures for cutting through them during utility maintenance. • The city is using high-strength and corrosion-proof pipes and wrapping joints where watermains must pass through or near green infrastructure.

Municipality/Utility	Common tree-utility conflicts	Prioritization approach for addressing current conflicts or reducing future conflicts	Standards, guidance and practices for avoiding, minimizing, or managing conflicts
New York City	• Conflicts with electric, gas & telecom utilities are more common. • Sewers are located under streets and are buried deeply, so rarely cause conflicts. • Most water infrastructure-related conflicts occur with watermains, which are located closer to the curb and occasionally approach existing or potential clearance distances for trees. Extensive coordination is required to avoid potential watermain impacts when planning tree planting in the right-of-way. • Small scale conflicts are handled on a case-by-case basis and may involve cooperation & compromises between agencies/ departments.	• The NYC PDR has autonomy on decisions regarding tree planting locations and ensure that appropriate clearances are followed. • Green infrastructure and water/ wastewater infrastructure are both handled by the NYC DEP, which makes it easier to coordinate between these two types of infrastructure. • Green infrastructure is valued equally with grey infrastructure and is considered a water utility unit. Green infrastructure is given the same autonomy as a water or sewer main. • Prioritization is a collaborative process that involves many municipal departments and can also involve borough residents through community meetings.	• A 6-foot (1.8 m) clearance is required between the tree trunk and a DEP watermain. • A 3.5-foot (1.1 m) clearance is required between green infrastructure and watermains. • A 2-foot (0.6 m) clearance is required between the tree bed and a water pipe or valve. • Watermains less than 20 inches (0.5 m) in diameter cannot be planted over. • Comprehensive departmental project information is shared internally with a GIS application to help avoid conflicts. Generalized project data are made available to the public. • An interagency branch within NYC DPR coordinates between departments and determines which teams should be involved on new projects to minimize potential conflicts. • Seasonal updates about the tree planting program are sent to community boards and elected officials.

Municipality/Utility	Common tree-utility conflicts	Prioritization approach for addressing current conflicts or reducing future conflicts	Standards, guidance and practices for avoiding, minimizing, or managing conflicts
Philadelphia Water	• Conflicts are not common due to water/wastewater pipes being located under roadways. They are dealt with on a case-by-case basis. • Emergency excavations do not usually impact trees. • Older trees occasionally cause conflicts. Addressing this is currently a work-in-progress.	• Planting trees and replacing trees is a priority, and species selection is tailored to the location to meet the physical needs of the tree. The triple bottom line needs for the municipality (social, environmental and financial) and the aesthetic benefits for the community are all considered. • As many trees as possible are planted and preserved. • Philadelphia Water's goal is to value green infrastructure equally with grey infrastructure and, where possible, limit conflicts between both types of infrastructure.	• A 5-foot (1.5 m) clearance is required between trees and most utilities, including all water assets. • If a tree and a water utility must intersect, the utility is fully protected in all cases before the tree is planted (e.g. lining of sewer pipes). • Fairly strict conservative tree clearances are required, including up to 55 feet clearances for major intersections. • Trees are tracked in GIS using unique IDs. • The utility is working towards standardizing the equal replacement of the ecological and economic value of a damaged tree's benefits as grey infrastructure is replaced.

Table 4 compares the key clearance distance criteria used by the municipalities/utilities that were interviewed. While Table 5 presents an overview of the components included in each municipality's design standards, guidance, practices and procedures that inform decisions relating to tree planting and the management or mitigation of potential tree-utility conflicts.

Table 4. Canopy goals and key clearance criteria used by the interviewed municipalities/utilities.

	City of Mississauga	City of Montréal	City of Seattle	City of Vancouver	New York City	Philadelphia Water
Current canopy coverage (%)	19%	20%	28%	18%	21%	21%
Goal canopy coverage (%)	22%	25%	30%	22%	Continuous improvement	30% (per neighbourhood)
Minimum horizontal clearance distance from the trunk to water/ wastewater pipes (m)	3.0	1.5 – 3.0*	1.52	2.0	1.83	1.52
Minimum vertical clearance distance from the tree trunk to water/ wastewater pipes (m)	N/A	N/A	N/A	1.0	N/A	0.46
Clearance distance between green infrastructure and drinking water pipes (m)	3.0	1.5 – 3.0*	1.52	3.0	1.1	1.52

* Species dependent

Table 5. Overview of each municipality/utility's design standards, guidance, practices and procedures that inform decisions on tree planting and tree-utility conflicts. If a component is part of the municipality/utility's decision making, it is indicated with a check mark. Also indicated is whether each component is formally considered or informally accounted for in the decision-making process. The term "informally considered" refers to best practices which are undertaken by the municipality/utility, but which are not formally represented in documented standards and procedures. These practices play a key role in municipal decision-making and are a critical aspect of the lived experience of the interviewed municipalities.

Municipality or utility	**Component of design standards, guidance, practices and procedures**				
	Clearance distances from water/ wastewater infrastructure to tree (or tree element)	**Tree trench design elements (e.g. root barriers, soil cells)**	**Utility relocation practices to accommodate street tree planting**	**Utility protection measures**	**Exemption process or requirements for reduced clearance distances**
City of Mississauga	✓ Formally considered	✓ Formally considered Guidance is provided on installing soil cells in new developments. Trees in sod are implemented in wider boulevards.	✓ Informally considered Case-by-case basis.	✓ **Formally considered** The streetscape cross-section design process requires that water/wastewater utilities be installed beneath the road to minimize conflicts with trees and other utilities. This is a Region of Peel requirement for easements for watermains[1] and sanitary sewers[2].	✓ Informally considered Case-by-case basis.

Municipality or utility	Component of design standards, guidance, practices and procedures				
	Clearance distances from water/ wastewater infrastructure to tree (or tree element)	**Tree trench design elements (e.g. root barriers, soil cells)**	**Utility relocation practices to accommodate street tree planting**	**Utility protection measures**	**Exemption process or requirements for reduced clearance distances**
City of Montréal	✓ Formally considered	✓ Formally considered Guidance is provided for different planting configurations. A minimum $10m^3$ of soil volume is required per tree.	✓ Informally considered Case-by-case basis.	✓ Informally considered Pipes are lined for protection.	✓ Informally considered Case-by-case basis.
City of Seattle	✓ Formally considered	✓ **Formally considered** Practice of using thin plastic root barriers; using Silva cells in new developments; only using soil cells for some newly planted trees out of the right-of-way.	✓ **Informally considered** Typically considered for full street retrofit or renovation projects. In the design phase, tree locations and utility corridors are noted and utilities are potentially relocated to maximize tree planting locations while minimizing tree-utility conflicts.	✓ **Formally considered** Standard procedure of lining sanitary sewer pipes with HDPE, particularly if they are older clay tile sewers and tree root penetration is suspected or anticipated.	✓ Informally considered Case-by-case basis.

Municipality or utility	**Component of design standards, guidance, practices and procedures**				
	Clearance distances from water/ wastewater infrastructure to tree (or tree element)	**Tree trench design elements (e.g. root barriers, soil cells)**	**Utility relocation practices to accommodate street tree planting**	**Utility protection measures**	**Exemption process or requirements for reduced clearance distances**
City of Vancouver	✓ Formally considered	✓ **Formally considered** Practice of using uncompacted, unjeopardized native soil where possible. Soil volume is matched to the tree species being planted. Soil cells are considered for new projects. The city will be considering guidance on soil cells from other municipalities.	✓ Informally considered Case-by-case basis.	✓ Formally considered Practice of using mitigation measures when tree-utility clearance distances cannot be met, such as wrapping nearby sanitary sewer or drinking water pipe joints with petrolatum tape. Blue Brute pipe is used when crossing above watermains.	✓ Formally considered For green infrastructure within the 3 m clearance, Water Design group reviews and approves or declines the exemption on a case-by-case basis. Approved exemptions require that pipe joints be wrapped. Complex exemption cases for drinking water infrastructure are reviewed by Vancouver Coastal Health.

Municipality or utility	Component of design standards, guidance, practices and procedures				
	Clearance distances from water/ wastewater infrastructure to tree (or tree element)	**Tree trench design elements (e.g. root barriers, soil cells)**	**Utility relocation practices to accommodate street tree planting**	**Utility protection measures**	**Exemption process or requirements for reduced clearance distances**
New York City	✓ Formally considered	✓ Formally considered Guidance on tree planting bed size, depth and composition: 5x10 ft. planting bed where possible; 18- to 24-inch planting bed depth; composition of sandy loam topsoil, layered with compost and biochar, capped with mulch.	✓ Informally considered Case-by-case basis.	✓ **Formally considered** Standard of noting potential conflicts in the design stage. Design plan notes are used to indicate when utility protection measures are needed prior to proceeding with construction and design elements will account for the necessary utility protection (e.g. pipe lining). Practice of encasing sanitary sewer pipes in concrete as a protection measure if they are installed at a depth shallower than 4 ft. Requirement for easements for	✓ Informally considered Case-by-case basis.

Municipality or utility	Component of design standards, guidance, practices and procedures				
	Clearance distances from water/ wastewater infrastructure to tree (or tree element)	**Tree trench design elements (e.g. root barriers, soil cells)**	**Utility relocation practices to accommodate street tree planting**	**Utility protection measures**	**Exemption process or requirements for reduced clearance distances**
				watermains and sanitary sewers crossing land parcels (e.g. parks) not within the right-of-way.	
Philadelphia Water	✓ Formally considered	✓ Informally considered For green infrastructure measures that include trees (e.g. tree trenches), the utility may specify a break in the tree trench where it crosses near or above a utility to allow access to the utility in the future and minimize costs associated with replacing the planting bed.	✓ Informally considered Case-by-case basis.	✓ Formally considered Typically avoid installing green infrastructure directly above wet utilities. Practice of lining the utility when green infrastructure must be installed above or near it. Design guidelines[3] provide guidance on how to 'cross' utilities safely and protect them.	✓ Formally considered Water utilities must be fully protected if they are going to intersect with green infrastructure. Encroachment standards that note permissible asset encroachments within the right-of-way.

[1] Region of Peel Public Works: Design, Specifications and Procedures Manual – Linear Infrastructure – Watermain Design Criteria (June 2010): https://www.peelregion.ca/public-works/design-standards/pdf/water-design.pdf

[2] Region of Peel Public Works: Design, Specifications and Procedures Manual – Linear Infrastructure – Sanitary Sewer Design Criteria (March 2017): https://www.peelregion.ca/public-works/design-standards/pdf/sanitary-sewer-design-criteria.pdf

[3] City of Philadelphia Green Stormwater Infrastructure Planning and Design Manual (April 2018): http://documents.philadelphiawater.org/gsi/GSI_Planning_and_Design_Manual.pdf

2.2.3 Assessment of municipal standards, guidance and practices

Across municipalities/utilities, the degree to which tree-utility conflicts occur varies significantly. In addition, the number and types of departments involved in making decisions on managing tree-utility conflicts varies from one municipality to the next. No two municipalities/utilities in this study were exactly alike in their overarching management of street trees and the urban forest. However, there were some trends in their standards and general approach to managing green and grey infrastructure conflicts. Common approaches included designated clearance distances, water/wastewater infrastructure protection measures if clearances cannot be met, planting smaller trees if clearances cannot be met, tree restitution practices, and placing or relocating water/wastewater pipes beneath the centreline of the road.

Most municipalities/utilities found that specific clearance distances have been helpful for avoiding or minimizing tree-utility conflicts. For example, the City of Seattle has clear planting guidelines and clearance distances for new trees and infrastructure, which were established by Seattle's Department of Transportation nearly 20 years ago. Trees are required to be a minimum distance of 1.5 m away from all underground utilities. These clearances were established to protect trees from damage in instances where underground infrastructure repairs or maintenance would be needed. The most common utility conflicts that come up in Seattle are from trees planted before the guidelines were set. Similarly, New York City has found that their distinct standards for clearances, combined with their comprehensive GIS infrastructure dataset and field applications, have made conflicts less common.

Meeting clearance distances can be difficult in a dense right-of-way, and compromises may need to be made between departments. In cases where clearance distances cannot be met, some municipalities/utilities noted additional measures that they use to protect utilities, such as lining pipes (Philadelphia Water and City of Montréal, respectively) and wrapping joints (City of Vancouver). Notably, root barriers were not discussed at length by any municipality, though they were mentioned by the City of Seattle as being unnecessary if appropriate clearance distances are met. This insight is supported by the literature, which suggests that root barriers may be ineffective in compacted soils, which are common in urban settings (Mullaney et al., 2015).

All municipalities/utilities discussed instances where trees needed to be removed, though most had different approaches for tree replacement and restitution. Philadelphia Water is working towards valuing green infrastructure at the same level as grey infrastructure. When grey infrastructure is damaged during construction, it is replaced and possibly upgraded; and these ideas are transferable to green infrastructure as well. Philadelphia Water suggested that when a tree needs to be removed and replaced, a value that is equivalent to the removed tree's benefits should also be replaced (e.g. replacing the total tree diameter in multiple locations). A more specific example is the NYC Tree Valuation Method (NYC Parks, 2012) which quantifies the economic benefit of the tree, which is then used to estimate an appropriate replacement if that tree is damaged or removed. New York has a Tree Replacement and Restitution branch that manages tree valuation for this purpose.

The municipalities/utilities interviewed indicated that the removal of trees was sometimes necessary to resolve tree-utility conflicts. Most emphasized that this is the last possible option considered, because trees provide the most benefit when fully grown and healthy. Losing a tree before it reaches maturity may result in sunk costs (i.e. the benefits do not outweigh the initial costs of planting) (Vogt et al., 2015). Planting above or near water/wastewater infrastructure immediately introduces the risk of sunk costs associated with emergency or routine maintenance activities. New trees should be planted with careful consideration of the surrounding infrastructure (both buried and above-ground) to avoid or minimize these situations. For example, if a tree needs to be planted over water/wastewater pipes, the increased potential of that tree being removed in the future could be accounted for by planting smaller and less expensive trees to minimize sunk costs. The City of Mississauga has employed this practice in some instances. Consulting with the forestry department on the species of tree to plant will aid selecting the right tree for the location and situation.

There are trade-offs that exist for every tree-utility conflict, particularly when a given location in the right-of-way would benefit from both water assets *and* the planting of a tree (or several trees). For example, there may be significant future costs associated with planting trees above or near water/wastewater infrastructure, such as sunk costs of prematurely removed trees and restitution costs for the utility. However, the interim value of the planted trees may be worth exploring in some cases. In Mississauga, a proposed tree alignment went directly between a playground and a soccer field along a property line. Trees were planted within a water asset easement with the understanding that if repairs were required, those trees would be removed. The functional value of those trees as a sound barrier, in addition to their ecological benefits, were deemed worthwhile despite the potential costs. Alternatively, water/wastewater pipes may instead be placed beneath the centreline of the road to avoid conflicts with trees, but this may result in added costs to the utility associated with pipe access during emergency or routine maintenance activities.

Several municipalities have defaulted the location of some of their water/wastewater pipes to be beneath the centreline of the road, including the City of Mississauga, City of Montréal, and New York City. The City of Vancouver also locates their wastewater pipes beneath the centreline of the road, but watermains are typically located 1-2 m from the curb or edge of the roadway which decreases the number of potential green infrastructure implementation locations in boulevards. In Montréal, water/wastewater pipes have been relocated in some instances from the boulevard to beneath the road centreline to make way for trees. Most municipalities/utilities that discussed moving water/wastewater infrastructure for trees only did so if the road was already undergoing major construction or retrofits, or if there was a significant social driver (e.g. public demand). There are many factors to consider regarding the trade-offs of removing and replacing trees in the future and relocating water/wastewater infrastructure so that it is beneath the road, including consideration for the loss of the residual value of water/wastewater pipes in the event that they are prematurely relocated.

When asked, most municipalities/utilities suggested that effective internal communication is critical to improving the management of tree-utility conflicts. Many departments influence, or are influenced by, tree planting and tree growth; effective communication between these departments and water/wastewater utilities can help avoid conflicts before any construction begins. Deciding on municipality-wide standards and practices for managing conflicts is not a simple task and requires consultation with multiple departments about approvals, revisions and compromises. Communication on clearance distance needs and the risks of sunk costs is necessary to develop a working plan for future planting and to actualize the co-benefits that a healthy urban forest can yield.

3.0 Insights and Best Practices for Minimizing and Resolving Conflicts

The following subsections highlight key insights and best practices that emerged from the municipal interview process. The subsections also identify concrete examples from the interviewed municipalities/utilities that support each of the identified insights and best practices.

3.1 Clearance distances are important in preventing most conflicts but do not eliminate conflicts

Clearly defined clearance distances that specify the minimum distance between new trees and existing water/wastewater infrastructure are an important first step in minimizing potential conflicts. However, most of the municipalities/utilities that were interviewed indicated that clearance distances alone do not guarantee the elimination of conflicts.

New York City's clearance distances are informed by specific learnings from past conflicts. In general, their clearance distances are determined using a collaborative multi-department approach. The Department of Transportation leads the development of clearance distances within the right-of-way but seeks input from multiple departments when developing or updating existing clearance distances. Any changes to clearance distances are reflected in the Department of Transportation's periodic design manual updates.

The City of Mississauga's streetscape cross-section design process plays a key role in minimizing potential tree-utility conflicts and is undertaken in the planning stage for new infrastructure/development. The process ensures that there is a designated location for each element within the streetscape and that clearance distances between elements are accounted for and assigned as part of the design process. Water, wastewater and stormwater pipes are typically located beneath the centreline of the road; other utilities are placed in the boulevard along a dedicated utility trench; trees are placed in tree planting corridors along the boulevard. The design process ensures that wet utilities only cross tree corridors laterally. In general, the occurrence of tree-utility conflicts is limited if the construction of the designed cross-sections is sequenced correctly. Streetscape cross-sections are developed by the Transportation and Works Department.

Philadelphia Water and the City of Seattle's Department of Transportation both practice proactive avoidance by limiting the planting of trees and other green infrastructure above buried water/wastewater infrastructure. The locations of buried water/wastewater pipes are identified in the planning and design stages for green infrastructure and trees (through GIS mapping analysis), and planting directly above water/wastewater infrastructure is avoided where possible. In cases where the implementation of new water/wastewater infrastructure is being planned, the placement of pipes beneath existing trees is discouraged. In addition to both cities' established clearance distances, these proactive avoidance practices provide an added measure of protection for both water/wastewater infrastructure and green infrastructure.

Several municipalities/utilities also reported that in certain cases, clearance distances are reassessed to balance the protection of water/wastewater infrastructure against tree planting targets. In such cases, a smaller clearance may be allowed if the tree planting initiative guarantees that water/wastewater infrastructure is fully protected before planting takes place. Infrastructure protection measures mentioned by the interviewed municipalities/utilities include lining sanitary sewer pipes and replacing older sewer pipes with airtight HDPE pipes.

In general, the way that clearance distances are determined vary across the interviewed municipalities/utilities. For example, some municipalities/utilities measure clearances horizontally from the trunk of the tree to the water/wastewater asset, while others have identified vertical clearances in addition to horizontal clearances or have specified general clearance distances from all underground utilities.

3.2 Formal prioritization approaches play a limited role in conflict resolution

None of the interviewed municipalities/utilities had a formal or codified approach to prioritizing trees versus water/wastewater infrastructure, particularly when tree-utility conflicts occurred. In general, the municipalities/utilities identified and resolved conflicts between tree planting locations and water/wastewater infrastructure on a case-by-case basis, both for existing conflicts and conflicts that arise in the planning stages. When conflicts do arise, the general approach used by most municipalities is to assess the conflict, communicate with the department(s) involved and identify potential resolution measures.

When used in combination with clear guidance on clearance distances between trees and water/wastewater infrastructure, most municipalities have found that that the case-by-case approach to addressing conflicts has generally led to effective conflict resolution.

Seattle Public Utilities have found that most tree-utility conflicts occur in locations where trees had been planted before the Department of Transportation's clearance distance standards were put into effect. Seattle Public Utilities have found each of these tree-utility conflicts to be unique and therefore address each conflict on a case-by-case basis.

NYC DEP does not have a formal procedure for prioritization in the event of a tree-utility conflict. Conflicts are typically assessed and addressed on a case-by-case basis. When a tree-utility conflict does occur, NYC DEP's approach is to identify and coordinate with the necessary department(s) then collaborate to identify potential solutions.

The City of Vancouver's planning process is intended to minimize the potential for tree-utility conflicts. However, when conflicts do occur, they are addressed on a project-by-project basis by collaborating across departments. Conflicts are typically flagged by specific project managers, who then coordinate a discussion with the various departments involved to assess and identify solutions. Council priorities are also considered during these cross-department discussions.

Some municipalities/utilities informally prioritize water/wastewater infrastructure to minimize potential tree-utility conflicts.

- Generally, the City of Montréal informally prioritizes grey infrastructure over trees and other green infrastructure.
- In Vancouver, decisions made by the City's Water Design Department and the regional health authority (Vancouver Coastal Health) are prioritized because water is designated as critical for public safety. As such, decisions on clearance distances and the placement of trees and other green infrastructure often place priority on the protection of drinking water infrastructure.
- In New York City, the high density of above- and under-ground infrastructure requires that city departments practice active conflict avoidance (where possible) when it comes to planting new trees. Although there is no formal prioritization process, when it comes to implementing new infrastructure or planting new green infrastructure or trees, municipal departments informally prioritize the protection of existing infrastructure where possible. Active conflict avoidance and mitigation is a typical NYC DPR practice when assessing tree planting locations. This sometimes means eliminating potential planting locations to avoid potential utility conflicts. They use a strict locates process to identify nearby utilities prior to planting and tree planting beds are designed to avoid potential future conflicts with nearby utilities (e.g., designing shallow planting beds and using smaller tree species).
- The City of Mississauga's streetscape cross-section design process is another example of the application of active conflict avoidance that can be applied in the planning stages for new infrastructure/development. By designating specific locations for all types of infrastructure, the potential for tree-utility conflicts is minimized. In cases where water/wastewater pipes laterally cross the tree corridor, the city informally prioritizes the pipe infrastructure by ensuring that tree planting does not occur directly above pipes. If tree-utility conflicts do occur, particularly when emergency watermain or sanitary sewer repairs could potentially impact trees, a Forestry Department representative is notified

to assess the conflict onsite and discuss potential solutions with the utility or departments as needed. A forester is typically on-call for any urgently needed tree-utility conflict assessments.

For some municipalities/utilities, easements for linear water/wastewater infrastructure provide a means of indirectly prioritizing grey infrastructure and ensuring pipe access for repairs and maintenance. This approach ensures that tree planting does not occur directly above watermains or sanitary sewer pipes. In the City of Mississauga, their upper-tier municipality (Region of Peel) has easement requirements for watermains and sanitary sewer pipes to ensure this infrastructure remains accessible. As such, trees cannot be planted directly above water/wastewater pipes. In New York City, new installations of water/wastewater infrastructure require the creation of an easement, particularly if installations occur in parkland. The NYC DPR are aware of these easements and avoid planting trees directly above this infrastructure because of the high potential for future conflicts.

For many municipalities/utilities, a case-by-case approach to resolving existing conflicts is essential because it triggers cross-department collaboration. In many cases, how infrastructure and other assets are valued is specific to a municipality/utility's culture and is difficult to fully codify and formally prioritize. A case-by-case approach to addressing tree-utility conflicts allows for a necessary degree of professional judgement when it comes to assessing solutions, making decisions and informing actions and investments. Ultimately, overall success relies on internal culture and collaboration.

When trees have been planted within the designated clearance distances of water/wastewater pipes, case-by-case prioritization may be informed by some of the scenarios listed below. Note that none of these scenarios directly prioritize pipe infrastructure over trees (or vice versa). Rather, they represent potential considerations for weighing whether to prioritize pipe infrastructure or trees depending on the overall condition of either one or both.

- Exposed pipe joints
- Aged pipes that may be scheduled for replacement
- Out of date pipe materials (e.g. clay, brick, etc.)
- Damaged pipes
- Pipes smaller than 20 inches (NYC) or 40 cm (Rolf & Stål, 1994)
- Sick, dead or damaged trees
- Pest-infected trees at risk of death
- Invasive tree species
- Trees that do not have enough soil volume for their roots
- A large project is scheduled within the right-of-way

3.3 Collaboration and coordination are key in anticipating and addressing conflicts

CWN interviewed representatives from water and wastewater utilities, as well as urban design, planning, forestry, transportation, stormwater and green infrastructure departments. Foresters, landscape designers, engineers, ecologists, and water resources specialists were interviewed, among others. The respondents all agreed that cross-departmental and cross-disciplinary collaboration and coordination are critical to anticipating, reducing and addressing tree-utility conflicts. Figure 3, which was adapted from Philadelphia's *Complete Streets Design Handbook* portrays the cross-departmental nature of decisions within the right-of-way. Mandates for tree planting within the right-of-way may fall within the realm of different departments, depending on the municipality/utility. For example, Philadelphia's Department of Parks and Recreation is in charge of decisions on street tree planting, while in Seattle, these decisions are undertaken by the Department of Transportation.

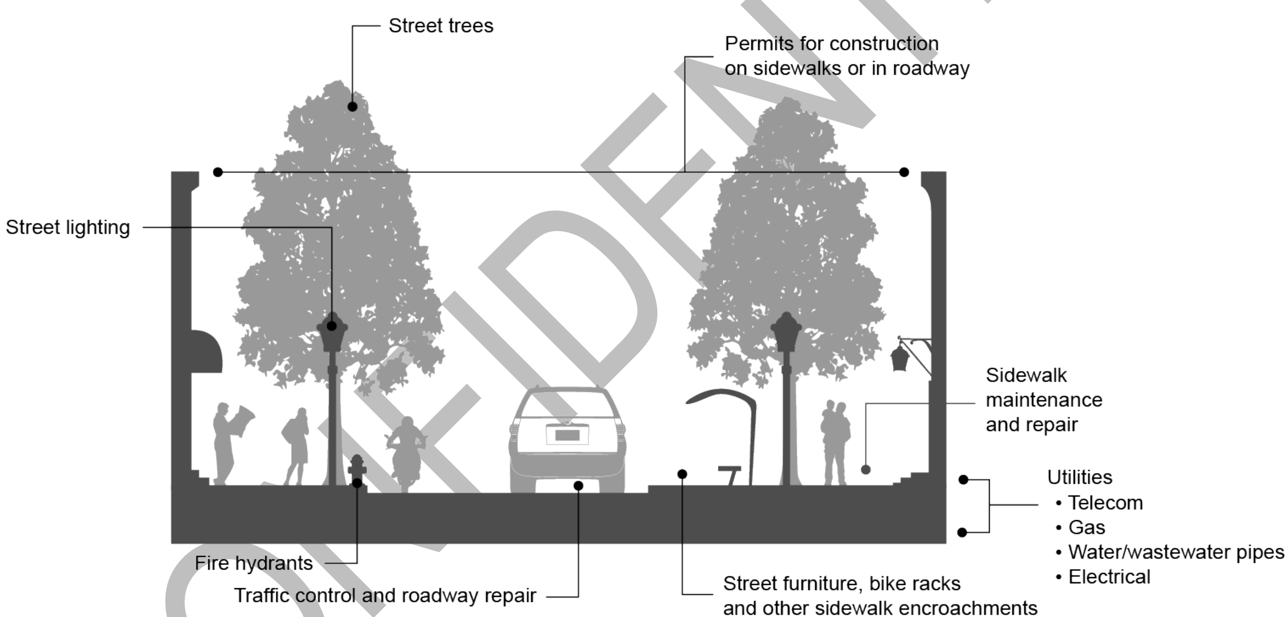

Figure 3. Illustration of the various types of infrastructure in the right-of-way, each requiring decision-making by different municipal departments and agencies such as water/wastewater utilities, urban planning departments, transportation departments and parks/forestry departments (Adapted from the City of Philadelphia, 2017)

Municipalities/utilities indicated during the interview process that they use either active or passive collaboration and coordination, or a mixture of both. The dissemination of knowledge and expertise across departments is an important part of why collaboration and coordination are so essential to anticipating, reducing and addressing tree-utility conflicts. Collaboration ultimately benefits the municipality as a whole, particularly when approaches to conflict resolution effectively engage and draw on the expertise of multiple departments.

The City of Mississauga's Site Plan Approval Process requires that a Public Utilities Coordination Committee (PUCC) circulate all development applications where potential conflicts with existing utilities are anticipated within the right-of-way (City of Mississauga, 2013). Any departments that may be impacted by conflicts are asked to review and approve the applications and associated design drawings. Cross-department discussions are a critical aspect of the conflict resolution process; the departments involved discuss the conflict with a goal of reaching an agreement on the preferred course of action. In some cases, the course of action may be to relocate the existing utility, while in others it may be to remove existing tree(s) and charge for tree removal and replacement. The PUCC process is critical for ensuring that new developments will not introduce tree-utility conflicts and that external stakeholders (e.g. developers) are aware of these conflicts and the requirements for addressing them.

In the City of Seattle, decisions on trees and tree planting could involve up to nine municipal departments, including Public Utilities, City Light (electric utility), Parks, Transportation and the Office of Sustainability and Environment. Within the right-of-way, decisions are made by the Department of Transportation, but they actively collaborate and coordinate with the other departments to ensure potential tree-utility conflicts are anticipated and addressed.

When tree planting is proposed in the City of Vancouver, it is a trigger for multi-department collaboration. Urban Forestry, Street Design, Transportation Design and Green Infrastructure Branches may be involved, and they communicate and collaborate to assess potential infrastructure impacts.

In New York City, cross-department collaboration and coordination is standard practice for any planned infrastructure projects. The department 'owning' the planned infrastructure project typically identifies nearby utilities and other infrastructure and notifies any departments that may be impacted. They also conduct a tree inventory and notify the NYC DPR or the Department of Transportation if any trees may be impacted and provide an opportunity for these departments to comment on preliminary designs. The NYC DPR's Interagency Coordination Team (ICT), which falls under the Maintenance and Operations Division, may also get involved on behalf of the central and borough forestry branches to communicate their needs and interests to other departments. If impacts to trees are anticipated for a particular project, the ICT steps in to coordinate among the departments and assesses a collective path forward for protecting the trees, or as a last resort, removing and replacing the trees. Although the ICT acts on behalf of the NYC DPR, they are a neutral mediator for cross-department discussions, looping in the necessary departments and ensuring that conflicts are addressed collaboratively.

As much as possible in New York City, collaboration and cross-department coordination is conducted in the early stages of project planning and implementation. For emergency water/wastewater infrastructure repairs that may impact trees, a tree work permit must be issued by the Permits and Plan Review as well as the Tree Restitution teams. The tree work permit will include an assessment of the measures that need to be taken to avoid damaging the tree(s) (e.g. hand digging, trenching or tunneling near tree roots). The Permits and Plan Review and Tree

Restitution teams work collaboratively with the department conducting water/wastewater infrastructure repairs (typically NYC DEP) to determine an effective course of action.

Some municipalities noted that the direct engagement of external stakeholders (e.g. developers, community members) is another important factor in reducing conflicts and increasing awareness of the important functions served by trees and green infrastructure. Community outreach is an essential component of minimizing tree-utility conflicts in New York City. The NYC DPR Tree Work Hub provides an accessible means of communicating with the broader community about tree planting initiatives (New York City, 2020a). Seasonal notification packages are sent to community boards and council members to provide periodic updates regarding the tree planting program. In the past, council members and community members have flagged potential tree-utility conflicts to the NYC DPR, typically in locations where upcoming capital projects would be taking place in the near-term. As such, community outreach plays an important role in anticipating potential conflicts posed by tree planting initiatives.

Some examples of how municipalities have used passive collaboration techniques to anticipate and address potential tree-utility conflicts are described below:

The City of Mississauga's Forestry Department is in the process of developing a real-time GIS record of the location of existing trees throughout the city. In addition to tree location, the GIS record would include details about each tree's planting medium (i.e. whether the tree is planted in sod, soil cells or structural soil). By making this record available to all departments involved in right-of-way design and construction, the Forestry Department's intent is to better inform decision-making within the right-of-way.

Another example of passive collaboration and coordination is New York City's broadly accessible projects map (New York City, 2020b). Created by the Department of Information Technology and Telecommunications, the map provides a means of tracking the location of all current capital projects across the city. For each project, the map includes a brief project description and identifies the managing agency/department. During field reconnaissance of potential tree planting locations, the NYC DPR uses the projects map and their in-house forestry survey tool to identify and avoid potential utility conflicts.

Similarly, Philadelphia Water's planning group uses a combination of GIS tools to select green infrastructure project locations. The tools consider topography, potential conflicts with other city initiatives and projects, and potential impacts to city departments, external partners and other stakeholders. Following this assessment, the planning group proposes the type of stormwater management practice and green infrastructure that is most appropriate given the potential impacts or conflicts highlighted by the GIS tools. All trees within the City of Philadelphia are tracked in GIS by unique numbers which indicate specific locations and tree characteristics, which further supports the planning group and other departments in anticipating and avoiding potential tree-utility conflicts.

Seattle's Department of Transportation also tracks street trees via a GIS inventory (City of Seattle, 2020). Their inventory includes information on scientific and common names, tree diameter, location/address and the party responsible for the tree's maintenance. This inventory informs a passive coordination and collaboration process across the City of Seattle's departments.

The permitting process can also play an important role in ensuring passive collaboration and coordination. In New York City, all departments are tied to the permitting process. When permits are granted, they stipulate specific protection measures for any infrastructure that may be impacted. The NYC DEP is in the process of adding green infrastructure to the list of official city infrastructure, which means that green infrastructure (e.g. rain gardens, permeable pavement) will ultimately be flagged by the permitting process if they need to be protected during construction work. The permit approvals process essentially ensures that the party conducting construction work implements necessary protection measures with the department that 'owns' the infrastructure being impacted. In general, permitting has the potential to be a powerful coordination tool for both planned and emergency water/wastewater infrastructure repairs.

In New York City, a combination of active and passive collaboration and coordination is used to align departments and foster consistency in decision-making within the right-of-way to limit the potential for tree-utility conflicts. The MYC DPR has a dedicated GIS analytics team that undertakes geospatial analysis to assess planting targets and potential tree planting locations. GIS analysis, active collaboration with the NYC DEP and the Department of Design and Construction, as well as field reconnaissance of planting locations are all used to inform Parks decisions on tree planting.

3.4 Trends in tree planting programs that cross the public-private divide

In areas where there is high competition for assets within the right-of-way, tree planting programs that cross the public-private divide can provide a targeted means of increasing tree canopy to fully realize tree planting benefits without relying entirely on limited planting locations within the right-of-way and minimizing conflicts with other assets.

The City of Seattle's Trees for Seattle and Trees for Neighborhoods programs are comprehensive city-wide programs that promote, support and assist with tree planting initiatives on private property. The programs are coordinated by Seattle Public Utilities and the Department of Transportation. Each year, 1,000 trees are purchased by the city; private property owners can then apply to receive up to 4 trees in a given year. The city works with the program participants to ensure that buried services are located to accurately assess where trees can be planted on the property. The Department of Transportation also evaluates the planting location selected to ensure that the location complies with the city's requirements for tree-utility clearance distances. Seattle Public Utilities also hosts a free class to engage and educate participants in the tree selection process and to avoid future tree-utility conflicts. Although the City assumes the initial cost of the trees, private property owners are responsible for ongoing maintenance of the trees.

Philadelphia Water is increasingly assessing the potential for 'off-street' implementation of green infrastructure, given the limited implementation space within the right-of-way. The utility is developing agreements with schools and privately-owned vacant lots to expand green infrastructure implementation. Similarly, the City of Montréal is currently funding an initiative to plant trees on private lots and will assume the initial cost of the trees and their planting.

The City of Mississauga's development application process provides the city with the authority to ask developers to assume the costs associated with tree planting. The city can ask developers to provide and plant street trees in 2-metre-wide soil cell trenches within the boulevard (i.e. public right-of-way). Developers are given a choice of planting trees within the boulevard and relocating buried utilities as needed or planting the trees within a 3-metre unencumbered setback on private land. Similarly, NYC DPR requires that developers plant a certain percentage of trees based on the length of the frontage of their development.

Ultimately, the success of these programs provides a strong case for coordinating and implementing tree planting initiatives that cross the public-private divide, thus maximizing tree planting locations and fully realizing tree planting benefits without completely relying on limited and high-competition planting locations within the right-of-way.

The City of Toronto's Parks, Forestry and Recreation Department has a number of urban forestry grants and incentives for tree planting on private property (e.g. Neighbourhood Tree Giveaway Program) (City of Toronto, 2020). It may be beneficial for the city to review the scope and budget of these grants and incentives to assess whether their expansion would effectively contribute to meeting tree canopy targets while limiting future planting within crowded city rights-of-way.

3.5 Proactive water and wastewater infrastructure renewal to minimize future tree-utility conflicts

Capitalizing on efficiencies across municipal departments could provide an effective means of proactively protecting water/wastewater infrastructure in the right-of-way. This approach relies heavily on cross-department coordination and collaboration that enables water/wastewater utilities to take advantage of parallel work being conducted in an area that has historically experienced (or is currently experiencing) tree-utility conflicts. Undertaking preventative lining of sewer pipes in locations where other construction work is happening (by the utility or other departments) could provide a means of targeting specific conflict zones while minimizing the cost of excavation and infilling.

In general, proactive actions that directly protect water and wastewater pipes (e.g. wrapping joints or lining pipes) located near or directly below street trees have stronger potential for minimizing potential tree root intrusion than actions that focus on confining tree roots (e.g. root barriers) (Mullaney et al., 2015; Ward & Clatterbuck, 2005). To be cost- and resource-effective, it is important to focus opportunistic lining initiatives on pipes which are in known conflict zones or that may be prone to future conflicts. One example is sanitary sewer pipes or joints, which may experience leakage or inflow/infiltration that encourages root intrusion. 'Bursting' or lining sanitary sewer pipes located near or below trees in the right-of-way is an effective means of protecting against root intrusion through pipe cracks or joints.

When tree planting is being planned in the right-of-way, the City of Montréal's Water Services proactively assesses the condition of water or wastewater pipes that exist near the planting location and determines an appropriate course of action. The city will line the pipe(s) assessed to be in bad condition and relocate pipe(s) assessed to be in good condition that are at risk of experiencing tree-utility conflicts in the future. Whether lining or relocating nearby pipes, the cost is shared between the Water Services and the department implementing the tree planting initiative (typically the Parks Department). This practice of opportunistic renewal, and active avoidance in some cases, plays a key role in minimizing future tree-utility conflicts.

Seattle Public Utilities has found that gradually and opportunistically upgrading portions of their sanitary sewer system has reduced the occurrence of root intrusion into sewer pipes. They frequently employ pipe 'bursting' techniques by pulling new HDPE pipes through older clay tile sewer pipes, which has resulted in airtight sewer pipes and minimized the potential for root intrusion.

For conflict zones which are known and of immediate concern, less invasive approaches such as trenchless lining of sewer pipes could be an effective complement to opportunistic renewal strategies in terms of minimizing disruption to other infrastructure in the right-of-way, including potential damage to planted trees. Ultimately, effectively undertaking opportunistic renewal to protect water/wastewater pipes requires a degree of anticipating work by, and coordinating with, other municipal departments.

3.6 Assessment of co-benefits promotes a balance of grey and green infrastructure and provides strong foundation for conflict resolution

The assessment of co-benefits could provide a strong foundation for understanding different, as well as commonly-held goals and targets for various departments within a municipality. This can provide a strong starting point for developing and implementing a conflict resolution approach that is tailored to a municipality's unique governance structure and culture.

Philadelphia Water evaluates information from multiple sources and aims to achieve triple bottom line benefits from trees in their green infrastructure program. The utility has found that in certain cases, an effective approach for exploring exemptions to clearance distance requirements is to present evidence-based case studies (from scientific literature or other cities' experiences) to municipal departments with assets in the right-of-way. Sharing knowledge has enabled the utility to explain their perspective to other departments, engage these departments and reach a mutual understanding in terms of balancing the needs for both green and grey infrastructure. Although Philadelphia Water does not specifically assess co-benefits, their experience with cross-departmental knowledge sharing is an important first step in building a collaborative approach to conflict resolution.

Several municipalities interviewed discussed the wide-ranging benefits of trees and other green infrastructure. They noted that quantifying benefits is important for communicating the value of investing in these assets. Seattle's Department of Transportation conducts an annual quantification of benefits of their tree inventory using the U.S. Department of Agriculture's i-Tree application (USDA, 2020). Street trees in Seattle are currently estimated to yield over $100 million USD in benefits like improved stormwater management (which supports their federal obligations under the U.S. Clean Water Act) and air quality.

The City of Montréal has created a committee to assess the co-benefits associated with city tree planting and to weigh those co-benefits against the costs of tree planting. As part of this assessment, the city is investigating the stormwater management potential of trees and tree trenches in collaboration with researchers at the Institut de recherche en biologie végétale (Plant Biology Research Institute) at the University of Montréal.

In general, most of the municipalities interviewed are not formally conducting co-benefits assessments to address tree-utility conflicts. Although many address conflicts on a case-by-case basis and use a collaborative approach to resolving these conflicts, none have created a formal framework for addressing existing tree-utility conflicts. However, the assessment and/or quantification of tree planting benefits is an important step in laying the groundwork for a co-benefits approach to addressing and resolving tree-utility conflicts. The development of a formal framework, although not an immediate necessity for successful conflict resolution, can add a degree of consistency and robustness to the practice of anticipating and addressing potential conflicts. The assessment of cross-departmental co-benefits is a foundational element in the development of a formal framework for conflict resolution that works for, and is adopted by, the entire municipality.

4.0 Conclusions and Recommendations for Toronto Water

Although many of the municipalities/utilities interviewed are working on addressing tree-utility conflicts to varying degrees, the task of effectively balancing grey and green infrastructure is an ongoing effort. Effectively addressing tree-utility conflicts continues to be a challenge for all the interviewed municipalities. However, each municipality has developed their own approach (or suite of approaches) to both reduce the occurrence of tree-utility conflicts and better address these conflicts when they do occur.

After considering the literature and interview responses, CWN determined that a robust conflict resolution process should consider the following elements:

- **Clearance distances are most effective when informed by cross-departmental experiences of conflict**. Although most of the interviewed municipalities/utilities stated that clearance distances alone do not guarantee the elimination of tree-utility conflicts, they identified clearly defined clearance distances as an important first step in minimizing potential conflicts. To be effective, clearance distances should be informed by past experiences of conflicts across departments.
- **Case-by-case conflict resolution can be used as a trigger for collaboration**. In the absence of a codified or formal approach to prioritization, a case-by-case approach to conflict resolution can provide a strong foundation for collaboration and coordination across departments (both for existing conflicts and conflicts that arise in the planning stages). For this approach to be successful, communication channels must be put in place in advance to support individuals and departments with determining who to collaborate with and when.
- **A combination of active and passive collaboration methods is key for anticipating and addressing tree-utility conflicts**. The dissemination of knowledge and expertise across departments is an important part of why collaboration and coordination are so essential to anticipating, reducing and addressing tree-utility conflicts. A combination of active collaboration (i.e. direct cross-departmental outreach) and passive collaboration (such as project/infrastructure maps and GIS inventories of grey and green infrastructure) is key to a robust conflict resolution process. Collaboration ultimately benefits the entire municipality when approaches to conflict resolution effectively engage and draw on the expertise of multiple departments.
- **Prioritization and the assessment of trade-offs are informed by a municipality's culture and values, and a cross-departmental assessment of co-benefits could provide a strong foundation for identifying how to bridge differing values that inform prioritization and trade-offs.** Formally implementing prioritization or trade-off assessment techniques requires a broader understanding of how to holistically integrate potentially intangible elements such as departmental culture and corporate values. An assessment of co-benefits across departments can be a starting point to understanding how prioritization and trade-offs can be implemented or identified in a way that considers goals and targets in different departments.

Based on the information and insights highlighted in this report, CWN recommends that Toronto Water consider the following actions and best practices to inform and improve tree-utility conflicts now and in the future.

4.1 Immediate or short-term actions

- Organize and facilitate cross-departmental discussion on clearance distances to assess whether current clearances are working for those who own assets within the right-of-way. Discussions could consider the potential adoption of proactive avoidance practices that prevent tree planting directly above water and wastewater pipes. Setting and reviewing clearance distances is an iterative and collaborative process; consider implementing periodic cross-departmental discussions that assess the effectiveness of clearance distances.
  - **Stakeholders:** Toronto Water; Parks, Forestry and Recreation; Transportation Services; others with assets in the right-of-way
- Assess and determine the actual and sunk costs of tree-utility conflicts to Toronto Water. This includes sunk costs incurred from the premature relocation and premature deterioration of water/wastewater pipes. The assessment can help identify where to focus investments/actions that minimize tree-utility conflicts in the near-term. It can also provide a starting point for future prioritization efforts.
  - **Stakeholder:** Toronto Water
- For locations within the right-of-way that are (or are becoming) crowded with assets, consider implementing street planters or green infrastructure measures instead of trees. Cross-departmental discussions could inform the identification of potential tree planting conflicts and whether green infrastructure measures would be more suitable.
  - **Stakeholders:** Toronto Water; Parks, Forestry and Recreation; Transportation Services
- Initiate discussions with Parks, Forestry and Recreation to investigate the potential for expanding tree planting programs that cross the public-private divide. Encouraging stewardship-driven tree planting on private property could be a means of realizing tree canopy targets and benefits while reducing the city's reliance on tree planting within the right-of-way, particularly in locations where there is high competition for asset space.
  - **Stakeholders:** Toronto Water; Parks, Forestry and Recreation

4.2 Intermediate-term actions

- Assess the potential for opportunistic renewal of water/wastewater infrastructure that capitalizes on timing and location of other construction activities across the City. This approach relies heavily on cross-departmental coordination and collaboration to take advantage of parallel work being conducted in an area that has historically experienced (or is currently experiencing) tree-utility conflicts. Planning water/wastewater infrastructure upgrades or renewal in conjunction with other construction activities could provide a means of targeting specific conflict zones while minimizing construction costs for Toronto Water.

  - **Stakeholders:** Toronto Water; departments that undertake construction activities

- Undertake a proactive pipe protection/lining initiative that focuses on water/wastewater infrastructure in poor condition, thereby increasing the service standard for these pipes. Use a risk-based approach to prioritize locations and select and sequence pipe protection work. Start with the most compromised cracked or leaking pipes in locations that have experienced (or might experience) conflicts with tree roots. Collaborate with Parks, Forestry and Recreation who can help flag locations where tree root growth can become problematic (e.g. locations with low soil volumes for trees).
  - **Stakeholders:** Toronto Water; Parks, Forestry and Recreation
- Implement and employ GIS tools and other applications that help city foresters/arborists avoid or accommodate current water/wastewater infrastructure when determining potential tree planting locations. In the early stages, these tools could focus on depicting the locations of current (and possibly planned) Toronto Water infrastructure. Later stages could focus on including more detailed information about the infrastructure, required clearances, etc.
  - **Stakeholders:** Toronto Water; Parks, Forestry and Recreation

4.3 Longer-term actions

- Undertake a co-benefits assessment to better balance service levels for grey and green infrastructure. When determining service level targets, it is important to account for and balance targets for both grey and green infrastructure. The assessment of co-benefits can help inform reasonable service level targets that: 1) holistically consider the City of Toronto's priorities and 2) aim to extend the service life of all assets. Ultimately, balancing — and also extending — the service life for grey and green infrastructure benefits the municipality as a whole.
  - **Stakeholders:** Toronto Water; Parks, Forestry and Recreation; Engineering and Construction Services; potentially other departments
- Increase or improve the integration and sharing of expertise across departments to better anticipate and address tree-utility conflicts. In addition, hiring practices that consider the multi-disciplinary nature of tree-utility conflicts (and other current or emerging municipal utility challenges) will improve problem solving and approaches to conflict resolution. Teams with diverse sets of competencies will be best suited to tackle the challenges of a continually evolving utility workplace.
  - **Stakeholder:** Toronto Water

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Appendix A: Interview questionnaire

Project on Street Tree Clearances to Water and Wastewater Infrastructure

Introduction

Canadian Water Network (CWN) is undertaking a project for Toronto Water. The project involves conducting a comparative analysis of standards, guidance and practices for tree planting near water/ wastewater infrastructure to reduce or minimize conflicts between tree planting locations and existing infrastructure. A key project task involves engaging select municipalities and water/wastewater utilities in North America to discuss their tree planting programs and tree-utility conflicts that they are experiencing or have experienced, including design standards, practices and operating procedures that they have used to resolve or minimize potential conflicts. This is intended to enable Toronto Water to either select an approach to supplement their current conflict resolution practices or an alternative to existing practices (see *Project Description* below for more information).

Canadian Water Network is a trusted broker of insights for the water sector. Our unique approach begins with an in-depth understanding of the problem and identifying where progress can be made. We talk to the experts and consult the knowledge base to frame the knowns and unknowns. From there, we communicate relevant insights to practice and policy leaders, moving the conversation forward.

Project Description

Toronto Water is interested in determining ways to improve tree planting procedures and design standards in a way that minimizes conflicts between tree planting locations and water/wastewater infrastructure. The City of Toronto's current tree planting practices and design standards provide guidance on appropriate clearances, but do not provide guidance on how to resolve conflicts and how to address concerns for access and maintenance of infrastructure below or near trees.

The City of Toronto's 2013 Strategic Forest Management Plan includes a 10-year vision to "protect, maintain and expand the urban forest to achieve a healthy, sustainable forest with a canopy cover of 40%". The increase of the urban forest canopy includes utilizing boulevard space for street trees. As boulevard space becomes more congested, utility conflicts with tree plantings are increasing in streetscape designs, resulting in proposals for trees to be planted over or in near proximity to Toronto Water infrastructure, such as watermains and sewers. City tree planting practices and design standards provide for required clearances, however there is an increasing need to find ways to resolve conflicts and mitigate or address concerns for access and maintenance of utilities below or near trees.

Toronto Water is exploring ways to improve existing tree planting procedures and design standards to help reduce conflicts between tree planting locations and existing Toronto Water Infrastructure. For this project, CWN is conducting a comparative analysis to determine current approaches undertaken in other jurisdictions across North America to identify and minimize conflicts between tree planting locations and water/wastewater infrastructure. The recommendations from this project will help to inform next steps for Toronto Water, which may involve changes to design review processes (conflict resolution and coordination), design guidelines, operational changes, and internal inter-divisional agreements.

Thank you for agreeing to participate in an interview for the project. In preparation for this conversation, we kindly ask that you review the following interview questions in advance.

Interview Questions

1. Please provide an overview of your municipality/utility's tree planting program and include a description of the departments involved in the decision-making process.

2. Has your municipality/utility experienced (or is it currently experiencing) conflicts between tree planting locations and existing water or wastewater infrastructure? If so, how has your municipality/utility responded to these conflicts?
    - Responses may include approaches to reduce conflicts, mitigate damage to infrastructure, minimize damage to trees while accessing infrastructure for maintenance, and/or reduce life cycle costs resulting from trees in close proximity to infrastructure.

3. How does your municipality/utility manage utility conflicts, tree planting priorities, and public relations? Please indicate whether you use any prioritization approaches to assess and balance needs.

4. Does your municipality/utility currently have any standards, guidance, practices, or operating procedures for tree planting near water and wastewater infrastructure? Relevant infrastructure may include watermains, sewers, service connections, hydrants, and reservoirs. Potential standards, guidance, practices, or procedures may include the following elements:
    - Clearance distances (horizontal and vertical) from edge of water/wastewater infrastructure to the tree (root ball or trunk) or soil trench or soil cell;
    - Guidance to ensure trees are protected while accessing water/wastewater infrastructure for maintenance (e.g. guidance on safely removing the soil cell);
    - Tree trench design elements, such as root barriers, soil cells, passive irrigation, drainage pipes;
    - Utility relocation practices to accommodate street tree planting;
    - Utility protection measures;

- Exemption process/requirements for reduced clearance distances;
- Infrastructure prioritization;
- Guidance or requirements from local health authorities on offset distances, particularly offsets between green infrastructure and drinking water pipes.

5. In your opinion, how effective are the above standards/guidance/practices/procedures in terms of accounting for future access and restoration, compensation, budget or funding, operation, and maintenance of the water/wastewater infrastructure?

6. What have been the key challenges in the development and implementation of the aforementioned standards/guidance/practices/procedures? Please share any lessons learned or opportunities for improvement.

7. CWN will be using the following table to compare the state of the urban forest and related setback distances across the municipalities and utilities we are interviewing. If possible, **please complete this table and return to Dalia Al-Ali (dalali@cwn-rce.ca).**

What is your municipality's or utility's:	Value
Current canopy coverage (%)	
Goal canopy coverage (%)	
Minimum horizontal setback distance from the base of a tree trunk to grey infrastructure (m)	
Minimum vertical setback distance from the base of a tree trunk to grey infrastructure (m)	
Infiltration offset between green infrastructure and drinking water pipes (m)	