Restoration Opportunities for the Remnant Portions of the Lost Creeks of South Etobicoke

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Disclaimer:

This report was prepared for TRCA and the City of Toronto as part of academic research and is being used to further knowledge of the impacts of urbanization on watercourses and inform watershed planning. The report is being provided to TRCA and the City of Toronto for information and consideration of possible next steps. The recommendations are the opinions of the author.

Executive Summary

Urbanization in south Etobicoke, Toronto has resulted in creeks historically viewed as a nuisance being buried, culverted or piped underground. Historic creek burial, a lack of mapping and poor understanding of the flow pathways has resulted in buried watercourse being regarded as Lost Creeks. However, creeks don't just disappear, during large rainfall or snowmelt events these buried creeks have been found to be a catalyst for flooding and reduce water quality because of reductions in storage. Stormwater run-off over impervious surfaces results in a 'flashy' hydrologic response to stormwater. These Lost Creeks have undergone significant hydrological and biogeochemical modifications leading to negative ecological and societal impacts, such as a loss of biodiversity and degraded water quality.

This project investigated restoration options for the remnant (above ground) portions of the Lost Creeks (i.e., vegetated swale or riparian enhancement) and green infrastructure (i.e., stormwater ponds or rain gardens) alternatives to stormwater management for areas contributing runoff to the Lost Creek network. The objectives of this research were to:

- Investigate potential restoration strategies for the remnant portions of the Lost Creeks
- Identify areas where implementation of green infrastructure would improve hydrologic response and reduce strain on municipal infrastructure
- Provide recommendations for potential restoration locations

The findings of this report reveal that the Lost Creeks of south Etobicoke are routed through a mix of public and private stormwater drainage infrastructure, and that the flow pathways of the Lost Creeks are not completely understood. Additionally, despite knowledge of these creeks, little has been done to preserve existing remnant portions in recent years. This has resulted in a loss of headwater and main tributary creek drainage features and missed opportunities for restoration. Upon data consultation, it was found that the information available was insufficient to accurately map the flow pathways of the Lost Creeks.

This resulted in a reconsideration of the objectives, with a focus on mapping the flow pathways of the Lost Creeks as accurately as possible with the limited information provided. This work was intended to guide the TRCA and City of Toronto's conversations and future planning for site scale restoration assessments on what should be done next based on planning, engineering, and financial considerations. The report outlines recommendations for TRCA and the City of Toronto to improve the understanding of lost creeks and potential options for restoring remnant portions.

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PROJECT OBJECTIVES

The goal of this research was to map the flow paths and identify restoration opportunities of the Lost Creeks. In response to citizen stewardship initiatives, TRCA is interested in improving ecosystem services by investigating creek restoration opportunities for remnant creeks of south Etobicoke. The specific objectives of this research were to:

1. Identify and map locations and drainage areas (where possible) of the Lost Creeks in South Etobicoke;
2. Investigate potential restoration strategies for managing stormwater at the source, thereby regulating discharge to the Lost Creek network, improving hydrologic response to precipitation events and increase capacity of the storm sewer system while reducing financial pressures on municipal infrastructure;
3. Provide recommendations to help inform future work for potential restoration locations or specific projects where benefits to aquatic or terrestrial ecosystems or municipal infrastructure would be reasonable considering the engineering, technical, and financial constraints.

STUDY AREA

The study area is bounded by Etobicoke Creek to the west and Mimico Creek to the east, Bloor Street to the north and Lake Ontario to the south. The focus is three tributaries that originally drained directly into Lake Ontario: Jackson Creek, North Creek, and Superior Creek (Figure 4). Significant urbanization in the area has resulted in modifications to the natural watercourses for all three study creeks, including stream channelization, stream straightening and stream burial.

The watercourse of Jackson Creek was originally 7.1 km long. Currently the flow path of Jackson Creek is largely defined by swales, channelized and constrained channel and municipal stormwater drainage infrastructure. The total channel length of North Creek was originally 3.8 km long. The current flow path traverses a series of channelized or constrained swales, defined natural channels, and a wetland; however, significant portions of the creek are piped underground. The total channel length of Superior Creek originally spanned 5.1.km. Currently, the entirety of Superior Creek is buried within the municipal stormwater drainage network and outlets at a stormwater outfall to Lake Ontario.

Figure 4: Study region, estimated historic Lost Creek watercourse, and current TRCA regulated watercourse, Toronto Ontario, Canada.

KEY FINDINGS

1. Based on historic aerial photos, LiDAR (Light Detection and Ranging), and site assessments, it is apparent that the municipal geospatial information is inadequate for complete mapping of the Lost Creeks in south Etobicoke. Additional inspection, or flow tracer data is needed to fully map the drainage networks of these systems.
2. Current TRCA watershed boundaries and City of Toronto Official Plan policies implemented through the development review process are not sufficient for identifying and potentially protecting and restoring watercourses that are not identified in TRCA regulatory watercourse mapping or the natural heritage system. Remaining portions could be lost without changes to TRCA and City of Toronto regulations and policies.

3. Large segments of the Lost Creeks watercourse flow through and interact with City of Toronto stormwater infrastructure. This may result in storm sewer capacity limitations during large rainfall events leading to increased likelihood of flooding.
4. The historic headwaters of the Jackson Creek watercourse likely flow to a city outfall located in the Flood Vulnerable Cluster (FVC) of Etobicoke Creek (FVC 41-1 from TRCA, Flood Risk Assessment and Ranking, 2019), potentially exacerbating localized flooding in this cluster during rainfall events when combined with contributions from the upstream portion of the watershed.
5. Localized restoration strategies for North and Jackson Creek have been identified and will likely have localized ecological and societal benefits. However, a reduction in stormwater runoff volumes are unlikely unless catchment-wide implementation of green infrastructure or catchment-scale greening occurs.

RECOMMENDATIONS

Recommendations are presented to both TRCA and the City or Toronto and have been listed in a step progression to accomplish flood management, ecosystem and water quality objectives. In some circumstances various options to the recommendations have been presented.

Recommendations for the City of Toronto and TRCA

1. Confirm location and flow pathways of the Lost Creeks and locate sewers that contain Lost Creeks

The TRCA should confirm the location and map surface flow paths of the Lost Creeks. The City of Toronto should confirm the location of stormwater infrastructure that contain Lost Creeks through the use of an inspection program and map the subsurface flow pathways of the Lost Creeks. Additionally, more detailed drainage area mapping should be completed, identifying downspout and surface connections to the storm sewer.

Option A: Flow path investigation should be done in both dry and wet weather conditions using dye tracer testing to determine the level of interaction between the Lost Creeks and municipal stormwater infrastructure.

Option B: Develop a partnership with an academic organization for investigating water residence and transit times for the Lost Creeks and conduct isotopic hydrograph separation at a stormwater outfall to determine contributing sources of water during wet weather events.

Option C: Implement a flow monitoring program at outfalls (public and private) that have evidence of dry weather flows to determine the seasonal hydrology of the Lost Creeks, and the relationship with City of Toronto stormwater drainage.

2. Undertake further analysis / study, internal discussions and discussions with the City of Toronto to determine whether to regulate remnant features. TRCA to develop a process to identify whether certain remnant features are regulated upon adoption of new Conservation Authority Regulation(s) by the Province.

Mapping of the Lost Creeks watercourse revealed that remnant (above ground) portions of the creeks still exist, despite historic and more recent creek burial in the City of Toronto's storm sewer system. To determine the best mechanism to protect these remnant portions will require further discussions. For the purposes of this research, the headwater drainage feature guideline (HDF Guideline) was used to assess the remnant features. The HDF Guideline is focused on ecological criteria. Additional criteria, such as flood risk may also be important to determine whether to regulate a remnant watercourse. Given that the *Conservation Authorities Act* is currently under review by the province and that the definition of "watercourse" could change, the development of these criteria may need to wait until after the new CA Act regulations are released to ensure alignment.

Recommendations for TRCA

3. Identify and work with private landowners and other public agencies (e.g. Humber College, City of Toronto Parks, Forest and Recreation [PF&R)) to implement feasible restoration projects on remnant portions of the Lost Creeks using funding from existing programs (e.g. Live Green Grants).

Through the use of stewardship initiatives, host a public open house discussing the benefits of the Lost Creeks, restoration project options and likely outcomes of restoration. Target private landowners where the creeks are located for beginning discussions on implementing feasible restoration projects on private property, which could include the realignment of remnant portions away from private property.

4. Incorporate the Sewersheds into TRCA hydrologic modelling and watershed planning process.

TRCA, with approval from the City of Toronto (i.e. data sharing), should consider inclusion of the sewershed catchments in hydrologic modelling and the watershed planning process. In the City of Toronto, areas by the lake are often highly urbanized and dominated by impervious cover. These areas are defined as a waterfront watershed boundary, despite sections of the sewershed falling outside of the topographically defined watershed boundary. For example, this work identified sections of these areas that are hydrologically connected to both Etobicoke Creek and Mimico Creek via sewer pipes. Additionally, previous work by the TRCA, Flood Risk Assessment and Ranking (2019), identified and ranked FVC's across the TRCA jurisdiction. One cluster located at Etobicoke Creek (41-1) corresponds to a storm sewer outfall that based on historic mapping drains Jackson Creek. The baseflow from Jackson Creek could exacerbate flooding at this location. Stormwater control measures and increased pervious surfaces (i.e., Low Impact Development features) in these areas may help to reduce downstream flooding.

Additionally, including these areas in analyses done as part of watershed planning will help identify priority areas for green infrastructure and restoration projects based on terrestrial, aquatic, stormwater management and hydrologic criteria.

5. Consider connectivity with the urban environment when conducting Integrated Restoration Prioritization (IRP) scoring.

Areas that are hydrologically connected to the stream via the municipal drainage network should be included as part of Integrated Restoration Prioritization Score (IRP) scoring process pending available funding. TRCA should consider data collection and development of a classification scheme for appropriate incorporation of urban streams that are heavily integrated with urban infrastructure.

Recommendations for the City of Toronto

6. Consider amending the Official Plan to encourage/support restoration of remnant features whenever a new private development or public work is undertaken.

The City of Toronto should consider the Lost Creeks when undertaking the planning and review process for developments / redevelopments, to accurately consider protection and restoration options for the Lost Creeks (including Low Impact Development [LID], green infrastructure, stormwater retrofits). The feasibility of daylighting buried portions of the Lost Creeks should be determined based on the outcomes of Recommendation 1. Watershed plans may be the appropriate process to identify remnant features to inform municipal policy.

7. Consider a stormwater rehabilitation and restoration study for this area to explore opportunities for LID infrastructure and improved stormwater management, and establish funding mechanisms.

If findings from Recommendation 1 indicate that sewer capacity is impacted by the presence of the Lost Creeks and no separation options exist, then the City should reconsider performance objectives for all developments / redevelopments occurring within the Lost Creek sewershed. The City should focus on reducing runoff volumes, erosion, improving water quality and the social benefit of green space. This would potentially reduce stress on City stormwater infrastructure and downstream FVC’s.

8. Create community awareness about existing programs for on-site stormwater management and green infrastructure.

The original watercourse of the Lost Creeks flowed through present day Ward 3 (a small portion of Jackson Creek in Ward 2). This area is now dominated by 55 % impervious cover, with remnant portions of the Creeks now only present in Ward 3. The use of on-site stormwater management techniques (e.g., green roofs, bioswales, cisterns) could be applied to properties located in the sewershed of the Lost Creeks with extensive stormwater discharge to the City’s storm sewer to increase capacity. Incentives for property owners to implement on-site stormwater management techniques and site level greening could potentially reduce downstream localized riverine flooding at a watershed scale.

9. Consider a data-driven stormwater management implementation program at stormwater outfalls located in Flood Vulnerable Clusters.

In collaboration with TRCA, the City of Toronto should consider monitoring stormwater outfalls located in FVC’s of Mimico and Etobicoke Creek to collect information on wet weather flow volumes, sources and pollutant loads. Based on monitoring data, the City of Toronto should consider enhancing stormwater management at stormwater outfalls to the watercourse. If available land is present at outfall locations, the City should consider the use of stormwater management infrastructure, applying end of pipe controls such as stormwater ponds or engineered wetlands, to intercept and treat stormwater at the outflow before being discharged to the watercourse. This could alleviate localized flooding in FVC (41-1) during extreme events and improve water quality and quantity during regular wet weather flow conditions. This recommendation builds on the Etobicoke Waterfront Stormwater Management Facilities Schedule B Municipal Class Environmental Assessment Project File Report (2012), which addresses recommendations for consolidation of Lake Ontario outfalls through the construction of an interceptor pipe and recommends various end-of-pipe treatment solutions for controlling 90% of total flow volumes. This project is oriented towards improving water quality of stormwater discharge to Lake Ontario (WWFMP, 2017).

Site Scale Recommendations for the Remnant Above Ground Portions

Site scale recommendations have been provided for the following remnant portions of the Lost Creeks (Table 1). Implementation of restoration at these sites could be done by City of Toronto (PF&R) and / or TRCA, or by developers through site plans. Benefits of Low Impact Development (LID) implementation include hydrologic, socioeconomic and environmental improvements (Kaykhosravi et al., 2019). These recommendations are targeted towards improving habitat, biodiversity and providing community value with minimal impacts towards enhancing stormwater management, due to the relatively low flow volumes moving through these sites. Recommendations are based on drainage area characteristics, current land use, and feasibility of implementation in urban areas (Martin-Mikle et al., 2015).

Table 1: List of remnant above ground Lost Creek watercourses and catchment characteristics, including proposed restoration options.

Drainage Area (DA)	***Drainage Area Size (Km^2)***	***Length of Watercourse (m)****	***Public or Private Land***	***Surficial Geology***	***Impervious Surface Coverage (% of the DA)***	***Restoration Option***
Jackson Creek						
DA 1	0.025	101.9	Public and Private	Sand	61	Restore the grass swale north of the drainage ditch located on public property.
DA 2	0.075	157.2*	Private	Silt and Sand	84	Permeable pavement, and vegetated swale with riparian buffer.
DA 3	0.093	212.9*	Private	Sand	82	Permeable pavement and vegetated swale; enhance current riparian buffer with native vegetation.
DA 4	0.031	240.0	Public	Silt and Diamicton	70	Vegetated swale or small wet/dry pond
North Creek						
DA 5	--	66.2	Public and Private	Paleozoic Bedrock and sand	--	Vegetated swale or small dry pond
DA 6	NA	465.6*	Public	Silt and Paleozoic Bedrock	30	See Etobicoke Waterfront Stormwater Management Facilities Schedule B Municipal Class Environmental Assessment Project File Report (2012), for a list of stormwater management options.

** the length of the residual (remaining above ground) watercourse is segmented by urban drainage features. The length of the watercourse reflects the length of the aboveground segments only not those pipes within the City's Stormwater Drainage.*
-- No Data.

Site Scale Recommendations for Daylighting Opportunities

Limited opportunities for daylighting the Lost Creeks currently exist. However, two opportunities have been identified in this report. In the event of future redevelopment these locations should be take into consideration for daylighting opportunities or enhanced stormwater management options (Figure 1). At this time, there are no

Official Plan policies to support daylighting. However, existing Official Plan policies provide for restoration opportunities of natural heritage features, which could be used for remnant portions.

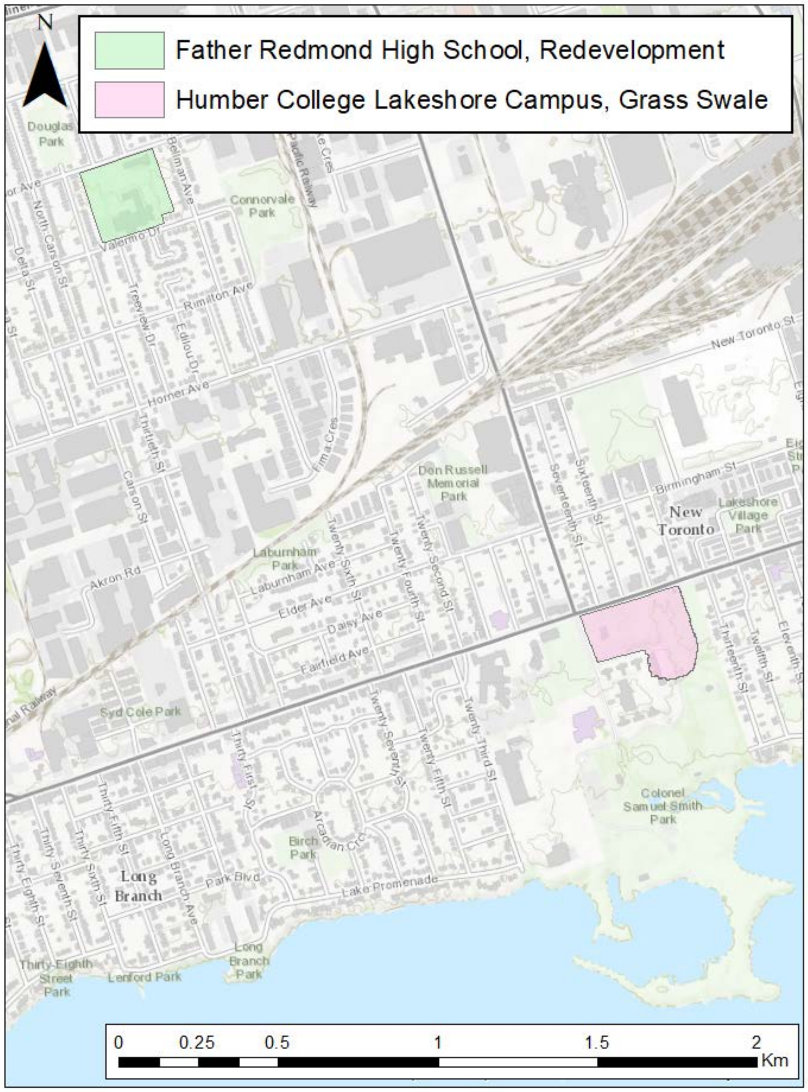

Figure 1: Opportunities for daylighting the Lost Creeks.

1. Humber College Lakeshore Campus, Grass Swale

A large grass swale with catch basins and underdrain is located on Humber Collage Lakeshore campus (43.597534, -79.513218) (Figure 2). The creek was piped and the valley regraded about 1906 as part of improvements to the Mimico Asylum. The presence of catch basins are visible in the 1965 aerial photography and match the placement of present day infrastructure. Based on municipal stormwater data, this area does not appear to be connected to the stormwater mains. A detailed investigation of municipal stormwater connections should be conducted using dye tracer testing. Assessment of the City's GIS inventory and an analysis using LiDAR revealed that this area is dominated by localized drainage, representing an area of 0.069 Km^2. This public property (TRCA IRP Viewer: http://arcgis01.trca.on.ca/irp/) is underutilized and would be an ideal site for a LID pilot project. This area could be utilized for restoration opportunities, providing ecological (habitat), enhanced biogeochemical cycling (carbon and nitrate uptake) and community value, by improving this green space. Restoration options would need to be assessed after detailed inspection to determine the most appropriate design for end of pipe control. TRCA has included this site in its Restoration Opportunities database. This property is TRCA owned and managed by the City of Toronto.

Figure 2: Grass swale at Humber College Lakeshore Campus, 1965 georeferenced aerial photography (left) and, 2019 orthophotography (right).

2. **Father Redmond High School, Redevelopment**

A housing development (43.609962, -79.533903) was constructed in 2017, replacing the old Father Redmond High School (former Alderwood Collegiate) and resulted in a missed opportunity to daylight Jackson Creek (Figure 3). This location remains an opportunity that should be flagged for a creek daylighting assessment in the event of redevelopment, or in the open-field portion just north of the recent townhome development.

Figure 3: Jackson Creek at the former Father Redmond High School (former Alderwood Collegiate), 1939 georeferenced aerial photography, (left), 1965 georeferenced aerial photography (middle) and, 2019 orthophotography (right).

Missed Opportunities for Restoration

1. The most notable loss occurred at the old Father Redmond High School (former Alderwood Collegiate), where the recent development of townhomes in 2017 resulted in a lost opportunity to daylight Jackson Creek. The redevelopment of this area could have been used to enhance City stormwater management, promoting infiltration through the use of a vegetated swale, reducing the impact of stormwater flow volumes on the City's infrastructure. In addition to hydrologic function, this opportunity would have provided ecosystem function and improved community value.
2. In 2019, a TRCA field monitoring team noted the complete loss of a portion of the Jackson Creek headwaters located on publicly owned land adjacent to the Canadian Pacific Railway this property was identified as a Hydro Corridor, the purpose of the construction is unknown by TRCA (near East Mall and Coronet Road).
3. In 2015, the construction of the Lakeshore Grounds Interpretive Centre on the Humber College Lakeshore campus is assumed to have removed connection of North Creek to the North Creek wetland. Based on stormwater data, North Creek now flows to the outfall beside the Lakeshore Yacht Club. The remnant portion in this area is mainly localized drainage with the lake heavily influencing water levels in the North Creek wetland. Jackson Creek historically flowed into Lake Ontario at a point near present-day Rotary Peace Park. As it became integrated with municipal infrastructure, the portion upstream of Lake Shore Blvd. flows to the outfall beside the Lakeshore Yacht Club, while the downstream portion flows to Rotary Peace Park. Figure 6 demonstrates the two catchment areas of Jackson Creek. Opportunities still exist in this area to improve conditions around the North Creek wetland and the grass swale on TRCA property, which have been identified in TRCA's Restoration Opportunities database.

BACKGROUND RESEARCH

Urban watercourses, including ponds, wetlands, streams, rivers and lakes are important for flood mitigation, groundwater recharge, and for providing a range of ecosystem (e.g., habitat, pollutant uptake) and recreational services (e.g., swimming, fishing) (Steele et al., 2014; Napieralski et al., 2015). However, extensive development across cities has resulted in modifications to natural waterbodies and watercourses. Modifications to these features include draining, filling, realigning, and burying, usually to increase available land for development, reduce the likelihood of flooding, and/or reduce the transmission of waterborne illnesses (Steele et al., 2014; Everard & Moggridge 2012). These modifications have led to increases in impervious surface cover, decreases in surface stream channel density, and many natural watercourses being re-routed through a network of urban subsurface infrastructure. Subsurface flow through the urban drainage network (i.e., storm or combined sewers) complicates the flow pathways of water by decreasing the hydrologic residence time and potentially increasing pollutant transport to the downstream environment (Napieralski et al., 2015).

Creek channelization and burial results in changes in river flow regimes, reduced aquatic ecosystem services, increased flood risk (Everard & Moggridge 2012), degraded water quality (i.e., greater total suspended solids, nutrients, heavy metals and thermal loading) (Paul & Meyer, 2001), and altered creek biogeochemical cycling (e.g., nitrogen and carbon cycling) (Arango et al., 2017; Beaulieu et al., 2015; Pennino et al., 2014). Additionally, increased catchment imperviousness and connectivity with municipal stormwater drainage systems promotes a flashier hydrologic response to precipitation (Everard & Moggridge 2012; Paul & Meyer, 2001). Exploring the urban watershed continuum including storm-, sewer- and buried creek connectivity is essential for enhancing the ecological functioning of landscapes and improving watercourse resilience to extreme events (Kaushal & Belt, 2012). Transitioning from historic urban drainage system management practices toward integrated urban watershed management is possible when natural hydrologic and engineered flow paths are considered together (Kaushal & Belt, 2012).

Restoration of headwaters, daylighting Lost Creeks, strategic implementation of green infrastructure (e.g., stormwater management ponds, bioswales, raingardens and engineered wetlands) can assist in mitigating flashy hydrologic response, degraded water quality, and losses of ecosystem services in watercourses (Everard & Moggridge 2012). In many jurisdictions, daylighting and separating Lost Creeks from the combined sewer network has increased sewer capacity, reducing the likelihood of combined sewer overflows (CSOs) during wet weather flow, improving water quality, and reducing dry weather flow to wastewater treatment plants (WWTP). Thus, alleviating some municipal pumping and treatment costs (Broadhead et al., 2015). Separation of creeks from municipal infrastructure can also have ecological, societal, and recreational benefits, mainly through improvements in urban flood management and greenspace provision (Broadhead et al., 2015). Despite these potential benefits, attempts at restoring Lost Creeks that have historically been buried, culverted or diverted into municipal stormwater or combined drainage systems is complex (Everard & Moggridge 2012). For example, daylighting opportunities may not be feasible due to overlying land use, infrastructure and financial costs. An assessment of the current urban hydrologic conditions of Lost Creeks is a critical step toward identifying areas where restoration or stormwater control opportunities exist.

Municipal Drainage and Lost Creeks

Conventional designs of urban drainage are for the purpose of transporting surface water directly to streams via a network of underground stormwater pipes. Reducing hydraulic connectivity of streams to impervious surfaces has been identified as a key solution for improving water quality and quantity issues in urban watersheds (Walsh, 2005a). Research investigating the relationships between stormwater conveyance and runoff generation has recently focused on the influence of the directly connected impervious area (DCIA). DCIA represents the proportion of total impervious area that is hydraulically connected to streams via stormwater and sewage infrastructure (Ebrahimian et al., 2016; Hung et al., 2018; Kayembe & Mitchell, 2018; Meierdiercks et al., 2017; Metsäranta et al., 2005; Walsh et al., 2005a). Direct connection of impervious surfaces to urban water bodies through stormwater infrastructure pipes has been found to occur during even small rainfall events, delivering excess nutrients and contaminants to the receiving waterbodies (Walsh et al., 2005b). Promotion of interception and infiltration of event water at the watershed scale is essential for reducing negative externalities including flooding and the degradation of water quality caused by urbanization (Walsh et al., 2005b).

Buried and captured creeks are watercourses that have been piped in municipal infrastructure and are a source of groundwater (Broadhead et al., 2015). During storm events this excess water can result in sewer capacity issues. Capacity issues arise when both stream water and stormwater runoff from urban areas is transported through the municipal sewer network to a common outfall. Capacity issues are a current concern for municipalities due to an increased likelihood of flooding during extreme precipitation events. As a result of sewer capacity issues, many municipalities have invested in initiatives involving identification of groundwater inflow and infiltration through cracks in pipes primarily with a focus on wastewater infrastructure. Inflow and infiltration reduction efforts such as the City of Toronto Mandatory Downspout Disconnection Program are now being widely applied across municipalities to increase capacity during wet weather flow events (Broadhead et al., 2015). However, identification and removal of buried Lost Creeks from municipal stormwater drainage systems is often not considered (Broadhead et al., 2015) yet would likely free up considerable capacity. Inflow and infiltration initiatives will likely be insignificant in combined sewers if stream capture and burial continue. Storm sewer systems are designed for inflows (stormwater), however if significant infiltration from groundwater or buried creeks is occurring this may cause severe capacity limitations, especially if these systems were not designed to capture this excess water.

Identifying potential restoration opportunities is complicated when urban streams have been culverted or buried in urban stormwater or combined drainage systems. Geographic and hydrologic characterization of buried creeks is limited, and as a result, it can be challenging for municipalities to make informed decisions regarding water resources management (Aguilar et al., 2019). Identification of Lost Creeks is challenging as modern municipal geospatial inventories rarely include culverts and ditches, high resolution topographic maps (1:500) are often not available or are expensive, and historic maps often lack detail on spatial and temporal transitions of creeks from surface waters to subsurface infrastructure (Broadhead et al., 2015). Additionally, infrastructure that originates on or crosses private land (in absence of an easement) is often not mapped by municipalities, as they generally do not have ownership of this infrastructure. Management of buried creeks is often overlooked in the regulatory policy framework because the pipe system may involve a mixture of groundwater, stormwater and potential illicit sanitary connections (Aguilar et al., 2019; Doyle & Bernhardt, 2011). Understanding hydraulic connectivity of streams and stormwater conveyance is essential for adequate watershed management (Doyle & Bernhardt, 2011; Walsh, 2005b).

Stream Restoration

Ecological restoration focuses on restoring ecosystem function to impaired natural systems to maximize ecosystem services such as water quality and quantity control, improving sustainability and resilience (Cascade model, 2015). Restoration outcomes not only provide environmental benefits, but have also been found to provide economic and societal benefits including increased infrastructure protection and access to green space

(Kenney et al., 2012; Wild et al., 2011). Initial identification of the main factors contributing to the degradation of urban waterbodies is essential for consideration of plausible and effective restoration opportunities. Stream restoration of urbanized watercourses has often occurred through enhancement of stream reach or riparian zones; however, these attempts often fail as the rate of degradation can be extremely high in urban areas (Neale & Moffett, 2016; Walsh et al., 2005b). Objectives for urban design should aim towards meeting a balance between evapotranspiration and recharge, with the latter important for maintaining baseflow (Walsh et al., 2005b). Various alternatives to stream restoration have been employed to reduce water quantity and quality issues and can include the acquisition of green space, implementation of LID technology, stream reach or riparian scale restorations (re-establishing the riparian buffer, improving vegetative and bank stability, developing erosion and sediment controls) or development or programs including public education and outreach (Moran, 2007).

Above-Ground Stream Restoration

Restoration of stream reaches flowing on the surface can include reach scale efforts such as channel or floodplain reconfiguration, channel reconstruction, re-establishing the riparian buffer, and slowing water down through the use of site-scale green infrastructure (e.g., raingardens, green roofs, bioswales, permeable pavers)(Moran, 2007; Bernhardt et al., 2005).

Stream channel restoration involves a series of management strategies for improving the physical and ecological conditions of degraded streams. A range of restoration strategies have been implemented in urban streams and can include stormwater management, stream channel reconfiguration and planting of riparian buffers (Bernhardt et al., 2007). Restoration opportunities of heavily urbanized streams is often complicated by property ownership, underground urban infrastructure, and land use (Bernhardt et al., 2007). However, research has identified that catchment scale stormwater drainage is a constraining factor for stream restoration and that restoration efforts should focus on controlling stormwater at the source (Walsh et al., 2005b) and limiting storm-, sewer- and buried creek connectivity.

Implementation of LIDs can be non-structural or structural (Screening LID options: LID SWM Planning and Design Guide, 2018). Non-structural site design, preserving permeable surfaces and natural heritage is often more economically and operationally efficient than structural site design, and source, conveyance and end of pipe stormwater management controls, and should be considered first compared to large site scale changes (Screening LID options: LID SWM Planning and Design Guide, 2018). However, in heavily urbanized areas with little remnants of natural heritage, site design changes including LIDs and storm sewer modifications may be required. Prior to consideration of LIDs, a detailed site description of land use, land cover, ownership, soil type, topography, slope, significant habitat, and natural and municipal drainage is required (Better site design: LID SWM Planning and Design Guide, 2019). Implementation of LIDs and design criteria should be focused on preserving or improving groundwater or baseflow characteristics, preventing undesirable geomorphic or watercourse changes, preventing flooding, and maintaining ecosystem diversity (Better site design: LID SWM Planning and Design Guide, 2019). LIDs can be an effective way to diverting or retain stormwater in heavily urban areas, where more traditional restoration options are constrained by limited space.

Buried Stream Daylighting

Restoration of buried stream reaches includes separation of the creeks from the sewer system and daylighting (i.e., engineering the stream to flow on the surface). Opportunities where stream daylighting exists should be strongly considered, as positive outcomes such as enhanced flood control, increased stormwater management, and revitalization of communities through the provision of green space (Moran, 2007), as well as habitat development and wetland generation (Wild et al., 2011) have been documented. While stream reach scale responses to daylighting are often positive, for example, the development of benthic and fish communities upstream, Wild et al., (2011) suggest that these benefits should be considered at a catchment scale, as that is where ecological benefits should be observed. Economic benefits have also been marginally reported and include increased property values and greater support for local businesses due to increased traffic (Pinkham, 2000). Daylighting has also resulted in negative externalities including limited public access and perceived loss of wildlife and habitat during construction and development phases (Wild et al., 2011). Challenges of stream daylighting include excavation and displacement of local infrastructure to make space for the floodplain, land acquisition, financial constraints, and creation of easements. However, with careful coordination, design, planning and outreach, successful daylighting projects are possible.

PROJECT METHODOLOGY

This section outlines the methodologies used in this project including: historic data consultation, sewershed delineation, field data collection, and drainage area mapping.

Historic Data Consultation

Historic aerial photos, present day orthophotography, LiDAR and the report titled *Toward the Ecological Restoration of South Etobicoke Final Report* (1997)[1] were used to map temporal changes in flow paths and creek burial since 1939. These efforts are required to better understand current flowpaths and the extent of the contributing drainage area of the Lost Creeks when geospatial and CCTV data is limited.

Sewershed Delineation

Delineation of the sewersheds of the Lost Creeks was performed using active sewer outfalls to Lake Ontario, Mimico Creek and Etobicoke Creek which were selected as watershed outlets (pour points) for catchment delineation of each of the study creeks. Delineation of the sewershed was done by segmenting the urban drainage area controlled by the municipal drainage network including curb cuts, storm catch basins, storm pipes, and outfalls.

Stormwater in the study area is controlled and conveyed by a network of storm sewers. Available urban drainage infrastructure obtained in GIS format directly from the City of Toronto (including trunk sewers, catch basins, maintenance holes, outfalls, and culverts/ditches) were used to delineate the sewershed for each creek. The findings presented in this report are based off the current City of Toronto municipal geospatial inventories for water systems infrastructure and do not include infrastructure located on private property. Based on historic aerial photos, LiDAR, and site assessments, it is apparent that the municipal geospatial information is inadequate for complete mapping of the Lost Creeks. Future project initiatives involving Lost Creek restoration, deculverting, daylighting or LID implementation should include stormwater tunnel surveys or manual entry to map the flow paths of the Lost Creeks, identify any illicit sanitary system connections, and involve monitoring a range of pipe flow conditions though the use of semi-permanent monitoring equipment to inform water balance calculations and hydraulic modeling efforts (Aguilar et al., 2019).

[1] TRCA and the City of Toronto appreciate the research and commitment of M.J Harrison to the lost creeks of South Etobicoke which has helped inform this report.

Field Data Collection

A Headwater Drainage Feature Assessment (HDF) was conducted in 2019 by TRCA. A total of 39 locations were identified and visited three times from March to September to assess flow condition and riparian function with changes in seasonality (Evaluation, Classification and Management of Headwater Drainage Features Guidelines, 2014). A limited HDF analysis was conducted including only a hydrology and riparian assessment, resulting in a selection of the sites receiving a status result. The results of a complete HDF analysis indicate a range of options including ‘No Management Required’, ‘Maintain/ Replicate Terrestrial Linkage’ or ‘Maintain Recharge’, ‘Conservation’ and ‘Protection’.

Drainage Area Mapping

Localized site scale drainage area mapping of the above ground watercourse was performed using LiDAR data and ArcHydro. Topographic drainage areas were determined using TRCA Elevation, a LiDAR DEM product clipped to the extent of the study area with a 5 km^2 buffer. Using the modified LiDAR product, ArcHydro was used to determine the localized flow direction grid and for generation of the stream network raster. If available, active City of Toronto catch basins were selected as the catchment outlets (pour points) for topographic catchment delineation. If active City of Toronto catch basins were not available in the City GIS inventory, the nearest (unmapped or private) catch basin was used. The catchments were then merged to create a delineated drainage area with the catch basin reflecting the outlet. This methodology is limited to microtopography at the site scale and does not incorporate drainage from roofs. Detailed site servicing plans (including roof drainage maps and downspout connections) would be required for accurate site scale and LID modeling of rainfall-runoff scenarios.

DETAILED RESULTS

This section outlines the results of historic data consultation, sewershed delineation, field data collection, and drainage area mapping. The results were then used to support the findings and recommendations.

Temporal Mapping of Creek Burial: 1954-2019

The estimated historic watercourse of the Lost Creeks was compared to georeferenced aerial imagery available from 1954-2019 to determine changes in the above ground watercourse (Figure 5). Aerial imagery revealed large segments of Jackson Creek flowing above ground in the 1950s, while burial and integration of Superior and North Creek into the City’s sewer network likely occurred before the 1950s. Additionally, more recent changes in the extent of Jackson Creek have been observed between 2011 and 2019 indicating that recent creek loss has occurred as a result of development in the area.

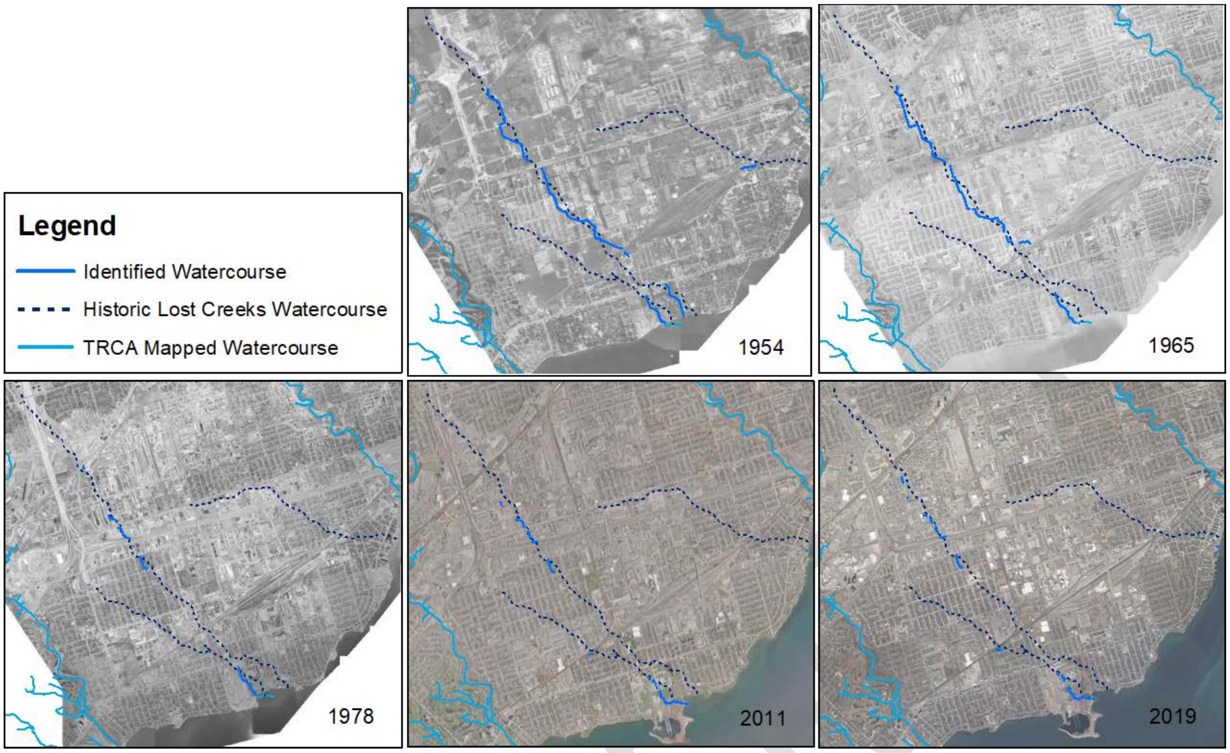

Figure 5: Temporal progression of creek loss from 1954-2019 for South Etobicoke.

Stormwater Drainage, Sewershed Delineation and Flood Vulnerability

Results from sewershed delineation supports that large portions of the three study creeks flow through City of Toronto stormwater infrastructure (Figure 6). Presence of these creeks in the storm sewer could reduce storm sewer capacity during large rainfall events leading to increased likelihood of flooding.

Sewershed delineation reveals that the drainage area of Jackson Creek is segmented by municipal stormwater drainage pipes, where the upstream portion of the creek above the Gardiner Expressway diverts flow from its original outlet at Lake Ontario to four outfalls at Etobicoke Creek. The southern end of the creek system enters Lake Ontario via a stormwater outfall. The creek has a total sewershed of 7.9 km^2, of which 71% is impervious cover.

Similarly, the majority of North Creek is buried, flowing through the City's storm sewer with some above ground portions still present, most notably the terminal end which flows through a wetland in Colonel Samuel Smith Park. The current sewershed encompasses a drainage area of 5.3 km^2, of which 66% of the area is covered by impervious surfaces.

The entirety of Superior Creek is piped within the municipal stormwater drainage network and outlets to Lake Ontario at a stormwater outfall. Superior Creek has a sewershed drainage area of 7.7 km^2 with 66% impervious cover. The current drainage area of Superior Creek is segmented, the northern portion above the Gardiner Expressway drains to Mimico Creek through a stormwater outfall, and the southern portion of the Creek drains to Lake Ontario at a stormwater outfall.

Areas not currently within TRCA's watershed boundaries (i.e. South Etobicoke waterfront area) are contributing stormwater from these areas to outfalls within a managed watershed boundary. One outfall is located in FVC 41-

1, within the provincially designated Etobicoke Creek Special Policy Area located at the confluence of Etobicoke Creek and Renforth Creek. This area has a vulnerability cluster ranking of 35, with annual damages attributed to flooding amounting to $140,720, where 90% of average annual damage is non-residential. Buildings in this area are vulnerable to flooding at the 100-year storm and some buildings closer to the southern valley wall could become vulnerable at the 25-year storm. FVC rankings were accessed based on the amount of financial damage to property determined by flood depth/damage curves. The drainage area and assumed flow directionally of the study creeks was mapped using City of Toronto GIS inventory only. Additional private stormwater infrastructure or inspection data is required to provide a complete picture of the underground flowpaths and create a more comprehensive map of the stormwater drainage areas.

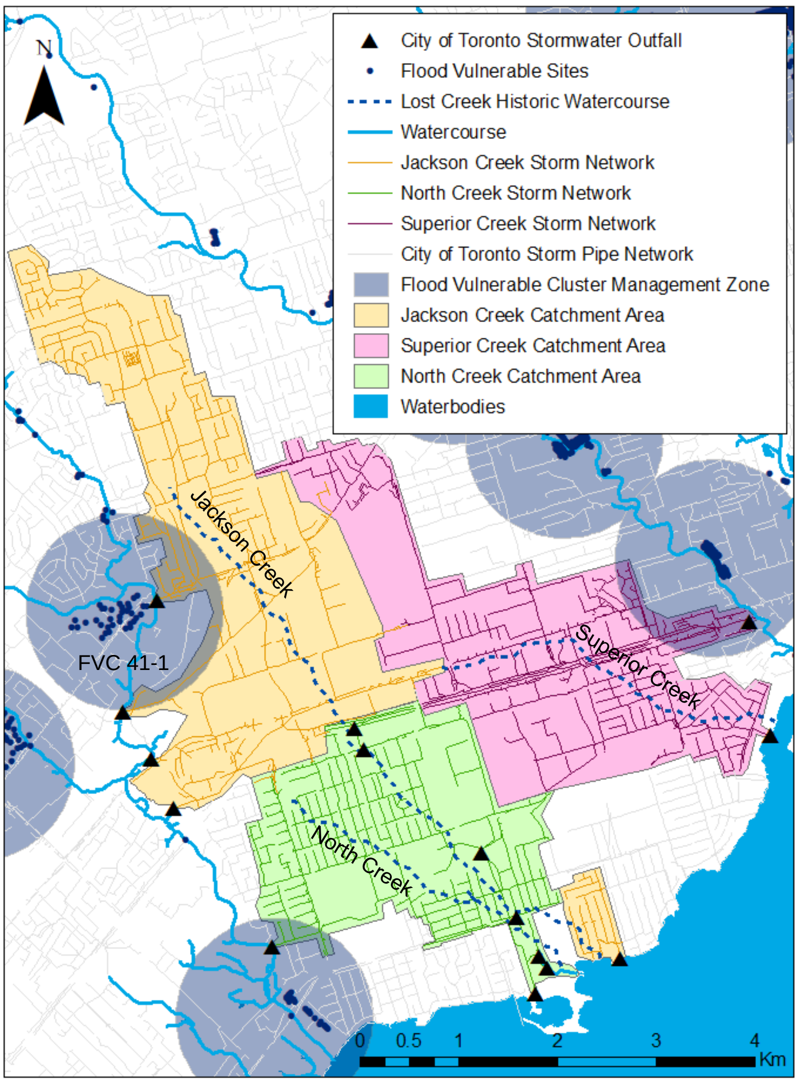

Figure 6: Sewersheds and stormwater networks draining Jackson, Superior and North Creek. FVC's. Estimated historic creek watercourse included as a reference.

Summary of Headwater Drainage Feature Assessment Report (2019)

Results of the HDF report revealed that the remnant portions of Jackson Creek and North Creek provide important hydraulic and riparian functioning as per the HDF Guidelines and a majority of the remnant portions classified for Conservation or Protection (Figure 7). Ontario Surficial Geology was used to determine importance of localized recharge for riparian buffers (0-30m) on either side of the remnant portions. Drainage areas classified by sandy soils are assumed to be important for maintaining recharge and therefore are classified as 'Maintain Recharge' according to the HDF. Locations where hydrologic or riparian functioning is negligible would be classified as 'No Management Required' or 'Maintain/ Replicate Terrestrial Linkage'. However, due to the limited size of the drainage areas, it is unlikely that these areas would be important for terrestrial functioning and therefore would likely be classified as 'No Management Required'.

Complete burial of Superior Creek in municipal stormwater infrastructure resulted in the tributary not being adequately accessed by the HDF guidelines, with the exception of the outfall at Lake Ontario. Findings of the HDF support that the remnant portions of the creeks do provide ecosystem and hydrologic services and therefore could be considered and regulated under the TRCAs regulation mapping. The status of the HDF results have been included for the corresponding drainage areas (Table 2). Please consult Lost Creeks of Etobicoke Creek Watershed: A Headwater Drainage Feature Assessment Report (2019) for more detailed information.

As noted in the recommendations, HDF assessment is one set of criteria to help determine how to treat remnant watercourses in heavily urbanized areas. For example, additional criteria that could be applied on whether to regulate a feature include:

- Size of the upstream drainage area contributing to the feature (drainage areas were assessed as part of this research, but size was not factored into the recommendations)
- Proportion of the remnant portion relative to the total feature (i.e. proportion above ground compared to underground infrastructure)
- Extent of the characteristics of the remnant feature (defined watercourse, defined or undefined valley, natural or channelized) (partially covered through the HDF assessment report)
- Significance of its contribution to regulatory tests (control of flooding, erosion, pollution and conservation of lands)

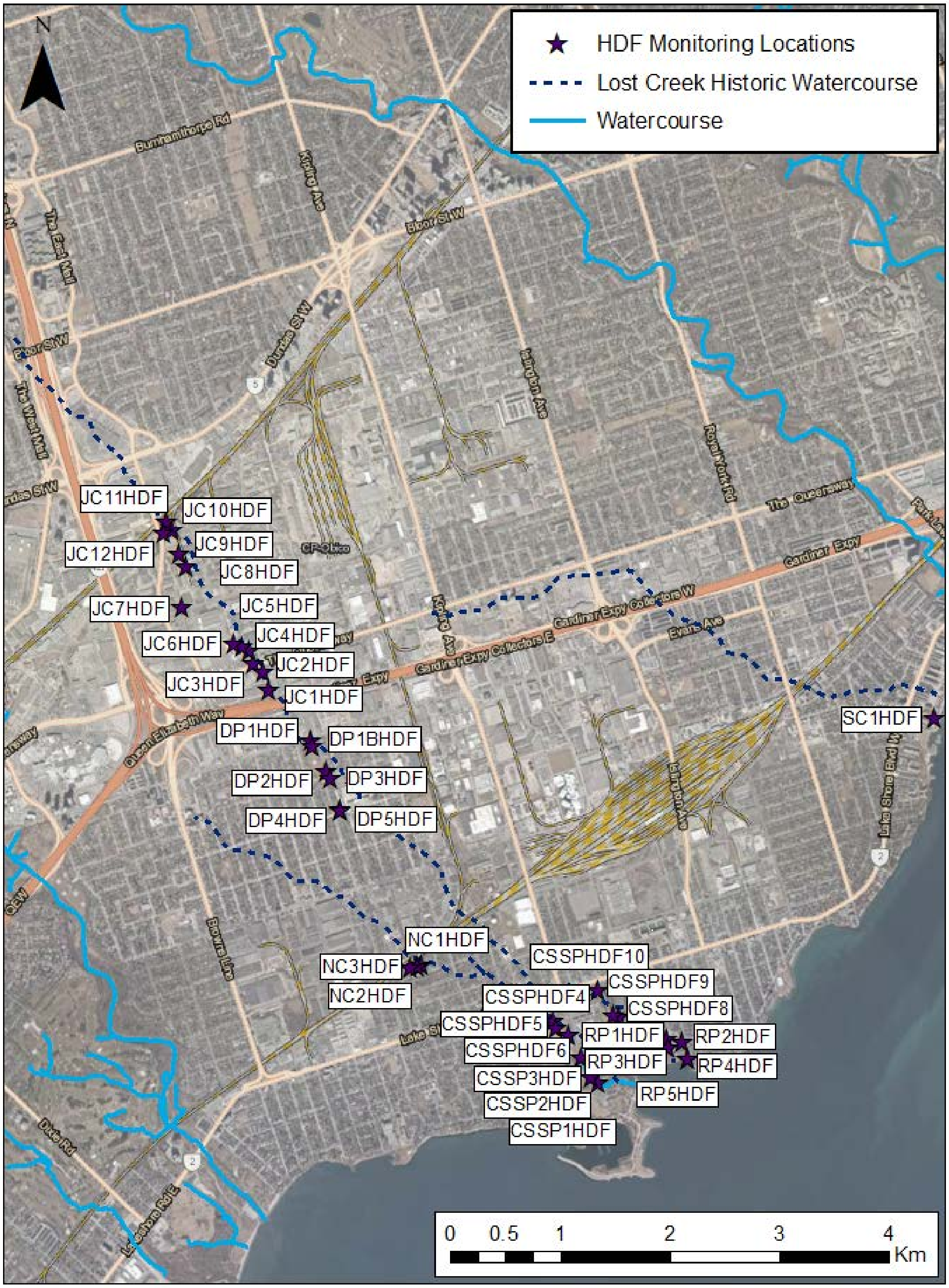

Figure 7: Map of the Headwater Drainage Feature Assessment (HDF) monitoring locations.

Table 2: Status of the Headwater Drainage Feature Assessment Report for the mapped drainage areas.

Monitoring Site	***Drainage Area***	***Feature Type***	***Hydrology Classification***	***Riparian Classification***	***Status of HDF***
CSSPHDF10	--	No defined feature	Limited or Recharge	Contributing	No Management Required
CPSSHDF9	--	Tiled Feature	Important	Contributing	Protection
CSSPHDF8	--	Swale	Limited or Recharge	Important	No Management Required
CSSP1HDF	DA6	Wetland	Important	Important	Protection
CSSP2HDF	DA6	Defined natural channel	Important	Important	Protection
CSSP3HDF	DA6	Defined natural channel	Important	Important	Protection
CSSPHDF4	DA6	Defined natural channel	Limited or Recharge	Important	No Management Required
CSSPHDF5	DA6	Defined natural channel	Limited or Recharge	Important	No Management Required
CSSPHDF6	--	Defined natural channel	Limited or Recharge	Important	No Management Required
DP1BHDF	DA4	Swale	Valued or contributing	Contributing	Mitigation
DP1HDF	DA4	Swale	Limited or Recharge	Important	No Management Required
DP2HDF	DA4	Swale	Valued or contributing	Contributing	Mitigation
DP3HDF	--	Swale	Limited or Recharge	Contributing	No Management Required
DP4HDF	--	Swale	Limited or Recharge	Contributing	No Management Required
DP5HDF	--	Tiled Feature	Valued or contributing	Contributing	Mitigation
JC01HDF	DA3	Channelized/constrained	Important	Contributing	Protection
JC02HDF	DA3	Channelized/constrained	Valued or contributing	Contributing	Mitigation
JC03HDF	DA2	Channelized/constrained	Important	Important	Protection
JC04HDF	DA2	Channelized/constrained	Important	Important	Protection
JC05HDF	DA2	Swale	Important	Contributing	Protection
JC06HDF	DA2	Swale	Important	Important	Protection
JC10HDF	--	Channelized/constrained	Limited or Recharge	Important	Maintain Recharge
JC11HDF	DA1	Swale	Limited or Recharge	Important	Maintain Recharge
JC12HDF	DA1	Swale	Limited or Recharge	Contributing	Maintain Recharge
JC8HDF	--	Channelized/constrained	Valued or contributing	Important	Conservation
JC9HDF	DA1	Channelized/constrained	Limited or Recharge	Important	Maintain Recharge
NC1HDF	DA5	Channelized/constrained	Valued or contributing	Important	Conservation
NC2HDF	--	Swale	Valued or contributing	Important	Conservation
NC3HDF	DA5	Swale	Valued or contributing	Important	Conservation
RP1HDF	--	Tiled Feature	Limited or Recharge	Contributing	No Management Required
RP2HDF	--	Swale	Important	Contributing	Protection
RP3HDF	--	Tiled Feature	Limited or Recharge	Contributing	No Management Required
RP4HDF	--	Tiled Feature	Limited or Recharge	Contributing	No Management Required

Monitoring Site	Drainage Area	Feature Type	Hydrology Classification	Riparian Classification	Status of HDF
RP5HDF	--	Tiled Feature	Limited or Recharge	None	--
SC1HDF	--	Channelized/constrained	Important	Contributing	Protection*

A limited HDF analysis was conducted including only a hydrology and riparian assessment, the results of the analysis indicate a range of statuses.
Features of valued or contributing hydrology classification and important riparian classification achieve a conservation HDF status.
Features with a limited or recharge hydrology classification achieve a maintain / recharge HDF status if surficial geology indicates hydrologic recharge (i.e. sandy or gravel soils). If surficial geology does not support recharge hydrology (i.e. clay or silty soils) have a no management required HDF status.
JC07aHDF and JC07HDF originally included in Lost Creeks of Etobicoke Creek Watershed: A Headwater Drainage Feature Assessment Report (2019) were monitored in the incorrect location and have been removed from this report.
-- Monitoring sites which fall outside of the drainage area determined by Drainage Area Mapping.
**SC1HDF is a sewer outfall and should not classify for protection.*
A CSSPHDF7 was not mapped by the field team, accounting for the change from site CSSPHDF6 to CSSPHDF8.

Current Status of the Lost Creeks Watercourses

Topographic drainage areas (total surface area upstream of a specific terminal point) of the remnant portions of the Lost Creeks were determined (Figure 7) in attempts to better understand the surface and subsurface flow pathways of the Lost Creeks. The drainage areas exclude direct contributions from downspouts and roof drainage and is based only on surface topography. More detailed drainage area mapping (identifying downspout connections to the storm sewer) should be done prior to implementation of restoration initiatives.

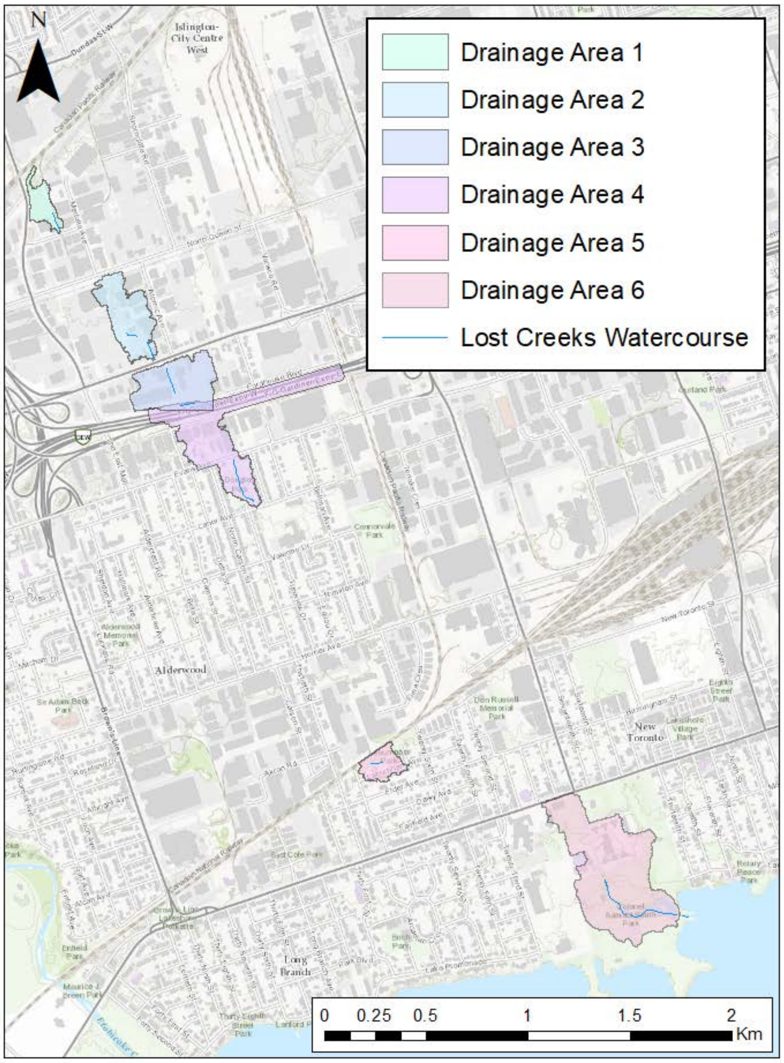

Figure 8: Drainage areas and watercourse for the remnant portions of the Lost Creeks.

Jackson Creek

Drainage Area 1

The remaining headwaters of Jackson Creek represent 0.025 km^2 of localized surface drainage on public and private land (Figure 9). The area drains to a private twin inlet catch basin that connects to the City's storm sewer through a stormwater pipe (Figure 10). The land use in the area is industrial (83%), institutional (<1%) and successional forest (16%), where 61% of the surface is impermeable. Based on the City's GIS inventory for stormwater assets, this water eventually flows to an outfall in Etobicoke Creek. According to the *Lost Creeks of Etobicoke Creek Watershed: A Headwater Drainage Feature Assessment Report* (2019) the headwater sites are located on public land (TRCA IRP Viewer: http://arcgis01.trca.on.ca/irp/) and underwent construction in 2019 which resulted in complete loss of the upstream headwater drainage features, however the stormwater ditch on private land remains.

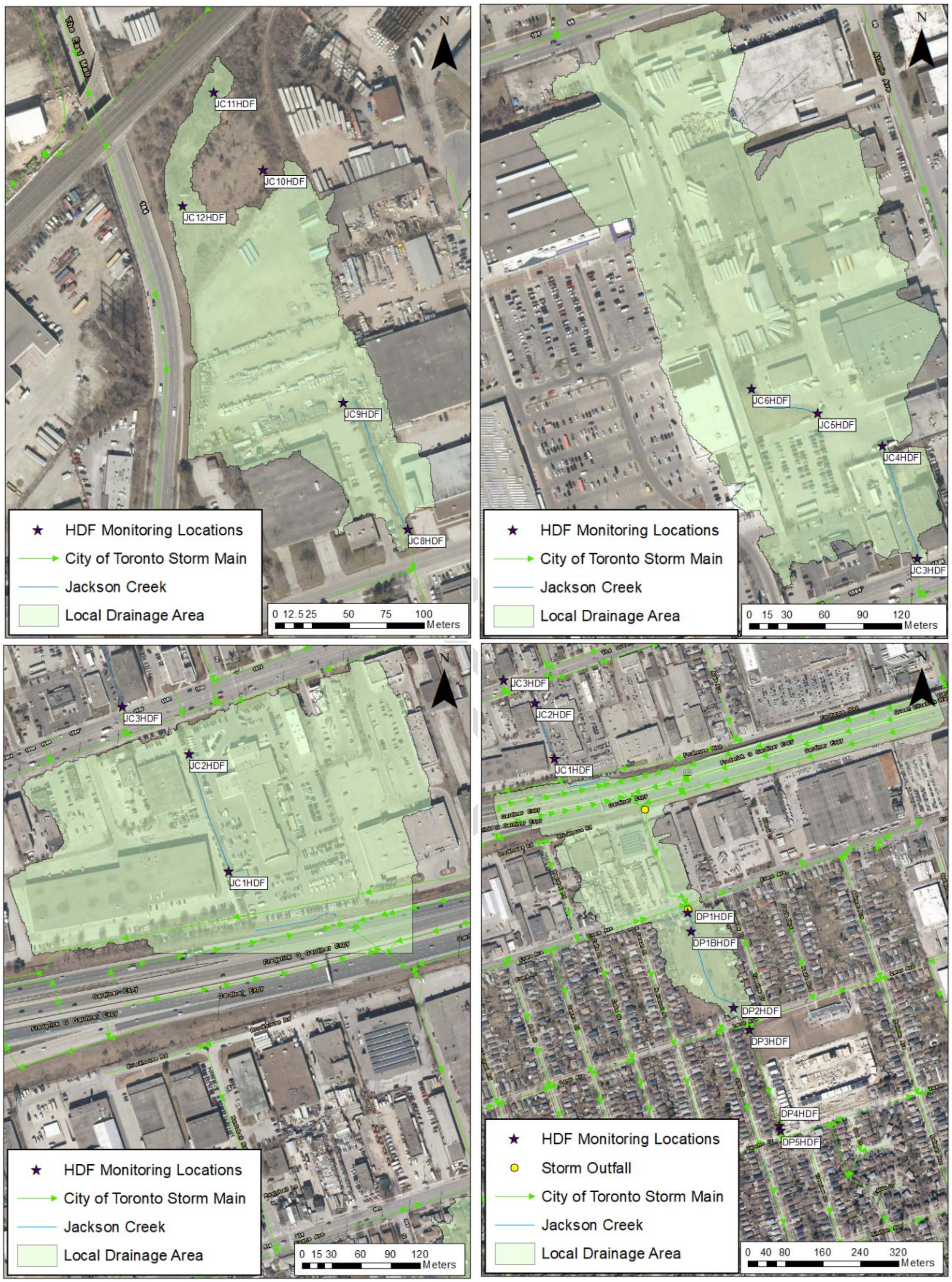

Figure 9: Remnant Jackson Creek watercourse, potential sites for above ground restoration. Headwater (DA 1) (top left), drainage north of the Queensway and south of North Queen Street (top right) (DA 2) drainage north of the Gardiner Expressway (top right) (DA 3), and drainage south of the Gardiner Expressway, Douglas Park (bottom left) (DA4).

Figure 10: Drainage ditch on private property (Left), drains to privately owned pipe.

Drainage Area 2

Drainage Area 2 (DA2) is 0.075 km^2. This area is represented by 84% impervious surface and is dominated by a mix of commercial (33%), industrial (67%) with some road (<1%) surface drainage. The inlet location for DA2 downstream of the Jackson Creek headwaters is unknown. This area could include drainage from an outflow not recorded in the City's GIS inventory and regional private localized drainage determined by drainage area mapping (0.075 Km^2) (Figure 9). This area drains to a City owned catch basin, inlet with headwall (Figure 11).

Based on the City's GIS inventory it is possible that drainage from this region is also segmented and flows to an outfall on Etobicoke Creek. However, a continuous flow pathway is also possible based on the presence of a large private outfall slightly downstream. A possible flow path into the City's storm sewers would need to be confirmed by inspection.

Figure 11: Drainage ditch on private property (Left), drains to a City of Toronto culvert with headwall (Right).

Drainage Area 3

Drainage Area 3 (DA3) is 0.093km^2, where 82% of the surface is impervious. The land use in this area is represented by commercial (66%), industrial (23%), roads (7%), and recreation/open space (4%). The outfall for DA3 is not mapped in the City's GIS inventory and the upstream connections to DA2 are unclear. It is likely that a direct connection between the DA2 and DA3 exist, with the presence of an unmapped pipe, however further investigation is required to confirm this assumption. This area represents the second largest drainage area where portions of Jackson Creek remain above ground (0.093 Km^2) (Figure 9). This remnant portion flows between two properties, to a double beehive catch basin (Figure 12). Two possible flow pathways are likely, the first is that a private pipe intersects laterally with a City owned storm water pipe and is transported to Etobicoke Creek. This is a suggested possibility due to GIS data indicating a pipe diameter increase from 1050mm to 1200mm without the presence of surface contributions along this stretch (no catch basins observed in GIS database). An alternative to this flow path is that the water flows downstream and enters a catch basin, which represents a ditch inlet for highway drainage. Site visits were unable to confirm if the drainage is daylighted before entering the highway ditch, as safety limitations prevented this investigation. The flow path of this drainage should also be confirmed through further investigation.

Figure 12: Private outfall (Left), drainage to downstream double beehive catch basin on private property.

Drainage Area 4

This flow path of Jackson Creek through Drainage Area 4 (DA4) is the best understood, with the creek flowing through a publicly owned drainage ditch in Douglas Park (TRCA IRP Viewer: http://arcgis01.trca.on.ca/irp/). The north end of the park has an active outfall without headwall (Figure 9). A conservative drainage area was determined to be 0.031 km^2, excluding drainage from upstream DA1, DA2 and DA3, as the upstream flow path is unclear (Figure 13). This drainage area includes highway drainage and localized drainage from the nearby parkland. This area is dominated by 70% impervious surface with the majority of drainage attributed to the highway drainage. Roads (39%), industrial (30%), medium density recreation/open space (20%), residential (10%) and commercial (<1%), represent the land use. This area drains downstream to a double beehive catch basin in Douglas Park that is not mapped in the City's GIS inventory. It is assumed that a pipe connects with a downstream stormwater pipe and flows through the City's storm sewer to an outfall at Lake Ontario.

Figure 13: City of Toronto Outfall in Douglas Park (Left), drainage to downstream double beehive catch basin in Douglas Park (Right).

North Creek

Drainage Area 5

The headwaters of North Creek include an outfall in Laburnham Park, City owned public land (TRCA IRP Viewer: http://arcgis01.trca.on.ca/irp/) that likely drains the upstream Canadian Pacific (CP) Rail property. The exact drainage area was unable to be mapped using LiDAR due to limited slope variability in the region (Figure 14). This area flows through the park incorporating localized park drainage (Figure 15). The ditch flows into the backyard of a private residence where the connection to the City's storm sewer network is unclear, but likely intersects one of two possible City's storm pipes downstream. This area likely drains to the same outfall at Lake Ontario as the DA4 and potentially DA3 sections of Jackson Creek.

Figure 14: Remnant North Creek watercourse, potential sites for above ground restoration projects. Headwater (left) (DA5) and terminal wetland in Colonel Samuel Smith Park (right) (DA6).

Figure 15: Outflow downstream of Canadian Pacific (CP) rail property (Left), drainage to private property, back yard (Right).

Drainage Area 6

The terminal outlet of North Creek was originally Lake Ontario, however due to historic lake filling the North Creek wetland was constructed. This drainage area reflects localized drainage from the Humber Collage Lakeshore Campus and adjacent City park property - Colonel Samuel Smith Park (Figure 16). It is estimated that flow to an outfall at Lake Ontario is more recent, and that prior to 2015, the upstream drainage of both North and Jackson Creek originally discharged aboveground on Humber College property, where the water meandered through the property and eventually drained to the North Creek Wetland through a currently abandoned pipe and outfall (Figure 14). The upstream drainage areas of North and Jackson Creek likely drain directly to Lake Ontario via an outfall and no longer drain through the North Creek wetland. The construction of a campus building between 2015 and 2016 likely resulted in the rerouting of this stormwater drainage, preventing flow through this pipe and outfall.

Figure 16: Left to right, Outfall to North Creek at Humber Collage, Outfall to North Creek Wetland, 2019, orthophotography of North Creek Wetland.

Superior Creek

As previously discussed, the entirety of Superior Creek is buried in the City's stormwater drainage features, so presently no clear opportunities for restoration exist. The drainage of the creek is segmented, where the upstream portion drains to Mimico Creek through a stormwater outfall with headwall. The southern portion of the Creek, south of the Gardiner Expressway, drains via an outfall with headwall in Superior Park, a storm and sanitary sewer overflow. Based on this information, this area has limited opportunities for restoration (Figure 17).

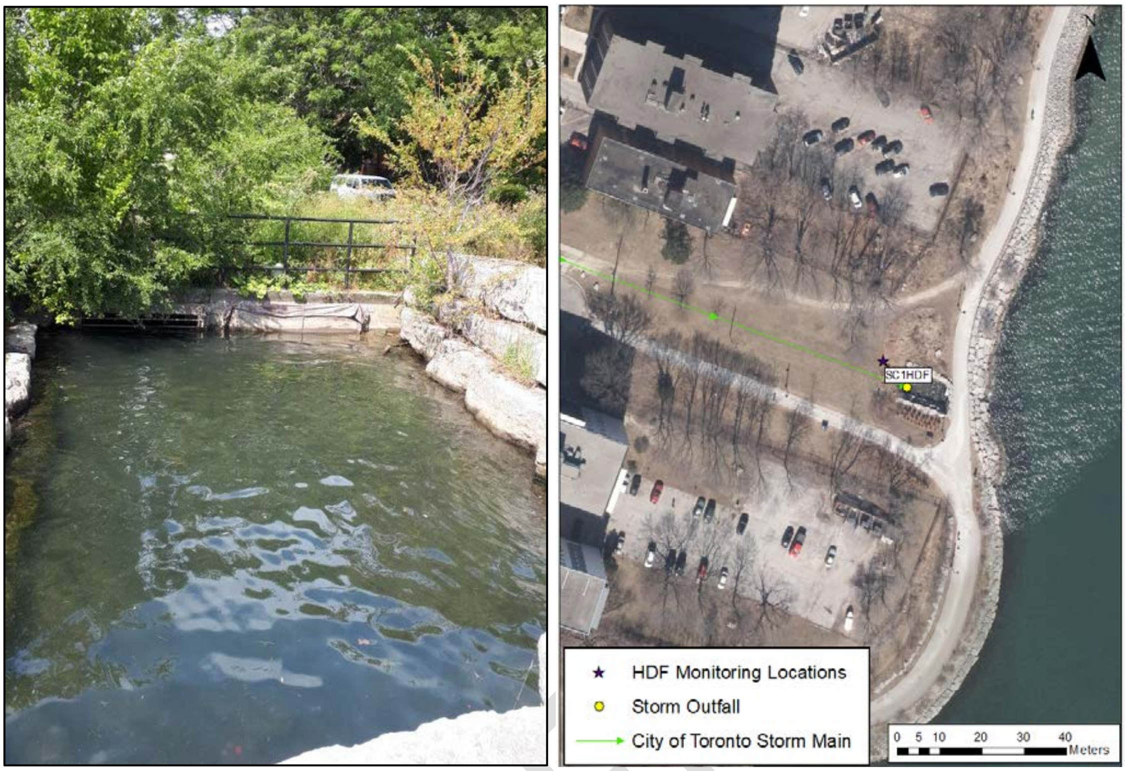

Figure 17: Stormwater Outfall and Sanitary Sewer Overflow location at Lake Ontario.

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