Erosion Hazard and Crossing Assessment Leonard's Creek

Multi-Use Trail from Jack Crescent to Goodfellow Public School, Innisfil

Prepared for:

IBI Group
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May 11, 2020
PN20020

GEO MORPHIX
Geomorphology
Earth Science
Observations

Report Prepared by:	GEO Morphix Ltd. 36 Main Street North PO Box 205 Campbellville, ON L0P 1B0
Report Title:	Erosion Hazard and Crossing Assessment Leonard's Creek Multi-Use Trail from Jack Crescent and Goodfellow Public School, Innisfil
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Approval Date:	May 11, 2020

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1 Introduction

GEO Morphix Ltd. was retained to complete an erosion hazard assessment for a section of Leonard's Creek associated with the properties of Jack Crescent and Goodfellow Public School in the Town of Innisfil, Ontario. The subject property is bounded by 25th Sideroad to the east, Jack Crescent to the south, a wetland/woodland lot to the west, and Goodfellow Public School to the north. A stormwater management (SWM) pond is established adjacent to Leonard's Creek, which directs flow through an outfall to the main branch of Leonard's Creek.

The design and construction of a multi-use trail has been proposed for construction from Jack Crescent to Goodfellow Public School. The proposed trail is approximately 3 m wide and located entirely on Town of Innisfil lands. The trail will be at grade adjacent to the east side of the existing SWM pond and will include a raised boardwalk across the wetland area.

To determine the suitability of the proposed crossing location and provide recommendations (where possible) to reduce erosion risk, an erosion hazard assessment was completed for Leonard's Creek. Specifically, the following activities were completed:

- Review available background reports and mapping (e.g., watershed/subwatershed reporting, geology, and topography) related to channel form and function and controlling factors related to fluvial geomorphology
- Delineate watercourse reaches through a desktop assessment
- Complete rapid geomorphological assessments on a reach basis to document channel conditions and verify the desktop assessment
- Document any areas of significant erosion, collect instream measurements of bankfull channel dimensions, and characterize bed and bank material composition and structure
- Delineate limits of the meander belt width/erosion hazard on a reach basis using field observations and historical aerial photography
- Develop recommendations for the proposed crossing over the tributary to ensure that natural hazards are addressed from a fluvial geomorphological perspective
- Prepare a report and mapping product to characterize the watercourse, provide erosion protection and bank stability recommendations, and summarize all findings

2 Background Review and Desktop Assessment

2.1 Background Information

The subject section of Leonard's Creek is situated within the Innisfil Creeks subwatershed. The Innisfil Creeks subwatershed is almost entirely within the Town of Innisfil, with a small portion (3.3%) within the City of Barrie (LSRCA, 2012). The subwatershed is located to the west of the Lake Simcoe watershed. Innisfil Creeks subwatershed covers a drainage area of approximately 107 km^2 and accounts for 4% of Lake Simcoe's total watershed area (LSRCA, 2012).

The headwaters of Leonard's Creek, as well as all creeks within the subwatershed, originate in agricultural lands. From there, flows move downstream, enter urban areas (in some cases), and then outlet to Lake Simcoe. In total, the watercourse length within the Innisfil Creeks subwatershed is 150 km, which occupies 3.5% of the watercourse length within the entire watershed (LSRCA, 2012). The three most dominant land uses within the Innisfil Creeks subwatershed include agriculture (45%), natural heritage cover (33%), and urban areas (including commercial, residential, and institutional lands) (15%).

At the subject site, Leonard's Creek flows west to east between Jack Crescent and the Goodfellow Public School property. Leonard's Creek also flows adjacent to the existing SWM pond, which directs flows to the main branch of the creek. The proposed multi-use trail requires a crossing over the watercourse. Currently, the proposed crossing is located at the confluence of the SWM pond outfall and Leonard's Creek. In the comment matrix (dated January 16, 2020), the Lake Simcoe and Region Conservation Authority (LSRCA) requested that the proposed crossing location and design by examined with respect to creek morphology. Further, it was suggested that at the proposed crossing location, the creek is migrating (widening) to the north. The LSRCA requested that the erosion protection requirements for both the creek and structure be identified and that geomorphic recommendations for protection be provided.

To address the concerns of the LSRCA, and provide appropriate design considerations and protection recommendations, a fluvial geomorphological and erosion assessment will be completed at the subject reach. A study site map is provided for reference in **Appendix B**.

2.2 Geology and Physiography

Geology and physiography act as constraints to channel development and tendency. These factors determine the nature and quantity of the availability and type of sediment. Secondary variables that affect the channel include land use and riparian vegetation. These factors are explored as they not only offer insight into existing conditions, but also potential changes that could be expected in the future as they relate to a proposed activity.

The Innisfil Creeks subwatershed is dominated by the Simcoe Lowlands physiographic region of Ontario (OGS, 2003). In terms of physiographical landforms, the Sand Plains occupies the extent of Leonard's Creek within the subject site. This region is comprised of coarse-textured glaciolacustrine deposits. Soils within these areas include sand, gravel, minor silt and clay, and foreshore and basinal deposits (OGS, 2003).

2.3 Historical Assessment

A series of historical aerial photographs were reviewed to determine changes to the channel and surrounding land use and land cover. This information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics.

Various aerial photographs and satellite images from 1927 to 2015 were retrieved to complete the historical assessment and inform the erosion hazard assessment. Specifically, aerial photographs from 1927, 1946, 1965 (Natural Resources Canada), and satellite images from 2010 and 2015 (Google Earth Pro) were reviewed and are provided in **Appendix A**, for reference.

In 1927, all lands in the immediate and distant vicinity of the subject site were occupied by agriculture and woodlands. No residential areas were established and there were few dwellings on the landscape. Major road networks, including the 25th Sideroad and 9th Line were active in the Town of Innisfil. The shoreline of Goodfellow Beach (associated with Lake Simcoe), as well as a buffer surrounding the shoreline, was completely vegetated with mature tree species. Leonard's Creek was visible due to the riparian vegetation established on both banks. The planform of the creek was meandering with a low sinuosity. In some areas, the planform appeared straightened. This was likely due to ditching to accommodate agricultural activities.

There were few differences in land use surrounding the study site by 1946. Residential dwellings began occupying lands along 9th Line, as well as along the shoreline of Goodfellow Beach – particularly to the south. With an increase in minor road networks, there was greater fragmentation of agricultural areas, which remained the dominant land use. The vegetation

surrounding the shoreline of Lake Simcoe and the riparian zone of Leonard's Creek was more dense, as indicated by the contrast of the aerial photo. Given the extent of vegetation surrounding the watercourse, it is difficult to discern the planform of the channel upstream or downstream from the subject site.

By 1965, the extent of residential areas surrounding 25th Sideroad and 9th Line increased considerably. Many additional minor road networks were constructed, and land use extending from the shoreline of Lake Simcoe to the subject site was dominated by residential dwellings. Both agricultural lands and woodlands were fragmented by the increase in residences. The riparian vegetation surrounding the downstream extent of Leonard's Creek was unchanged, however there was an increase in the number of road crossings to accommodate neighborhoods. At the study site, dense riparian vegetation isolated the channel from surrounding agricultural lands. Further upstream, woodlands dominated land use, and the watercourse planform was not discernable.

In 2010, there was a substantial increase in residential areas extending from Lake Simcoe to the subject site. Additionally, many road networks were constructed to connect the neighborhoods. Within the vicinity of the subject site, land use was dominated by residential dwellings to the east and woodlands to the west. To support the residential areas, there was also an increase in institutional and recreational lands within this section of Innisfil. At the subject site, Jack Crescent (including the roadway and associated dwellings) were well established, and SWM facilities were in place. Specifically, a SWM pond was constructed to the north of Jack Crescent, with an outfall directing flows to Leonard's Creek. Immediately north of Jack Crescent, Goodfellow Public School was constructed. Associated with Goodfellow Public School, a baseball diamond and other recreational facilities were implemented. The extent and maturity of riparian vegetation surrounding Leonard's Creek was not affected by adjacent development, and likely reduced direct impacts from construction.

Aside from the new construction of a residential development along Sandy Trail, there were no changes in land use from 2010 to 2015. The SWM facilities at the subject site were more established, with grasses and riparian vegetation surrounding the perimeter of the ponds. The density of riparian vegetation surrounding Leonard's Creek was unchanged and provided a buffer between the residences to the south and Goodfellow Public School to the north. The density of riparian vegetation decreased the capacity for identifying channel planform adjustment through time, however, the established root system associated with the watercourse likely provided a level of stability.

3 Watercourse Characteristics

3.1 Reach Delineation

Reaches are homogeneous segments of channel used in geomorphological investigations. Reaches are studied semi-independently as each is expected to function in a manner that is at least slightly different from adjoining reaches. This method allows for a meaningful characterization of a watercourse as the aggregate of reaches, or an understanding of a particular reach, for example, as it relates to a proposed activity.

Reaches are typically delineated based on changes in the following:

- Channel planform
- Channel gradient
- Physiography
- Land cover (land use or vegetation)

- Flow, due to tributary inputs
- Soil type and surficial geology
- Historical channel modifications

Reach delineation follows scientifically defensible methodology proposed by Montgomery and Buffington (1997), Richards et al. (1997), and the Toronto and Region Conservation Authority (2004) as well as others. Based on the existing channel conditions and the linear extent of the watercourse within the subject property, one (1) reach was delineated. **Reach LC-1** was delineated from approximately 50 m upstream of the existing SWM pond outfall, to 50 m downstream.

3.2 General Reach Observations

Field investigations were completed on March 9, 2020, and included the following:

- Descriptions of riparian conditions
- Estimates of bankfull channel dimensions
- Determination of bed and bank material composition and structure
- Observations of erosion, scour, or deposition
- Collection of photographs to document the watercourses, riparian areas and/or valley, surrounding land use, and channel disturbances such as crossing structures

These observations and measurements are summarized below. The descriptions are supplemented and supported with representative photographs, which are included in **Appendix C**. Field sheets, including those completed for rapid assessments, are provided in **Appendix D**.

Reach LC-1 flows west to east towards 25th Sideroad. Upstream from **Reach LC-1**, the watercourse flows from a natural area with extensive vegetation, through residential lands. Moving downstream, **Reach LC-1** flows parallel to Goodfellow Public School to the north, and an existing SWM pond to the south along Jack Crescent.

Reach LC-1 was situated within an unconfined valley setting. The channel exhibited irregular meanders and had a sinuosity greater than 1.05. The surrounding land use consisted of residential areas. The riparian buffer zone was approximately 1 to 4 channel widths and was continuous. The riparian vegetation was dominated by established (5 – 30 years) tree species. The reach had perennial flow, with a low gradient, and moderate entrenchment. Most of the reach consisted of a plain bed with riffle pool sequences observed. Bed material consisted of primarily sand, with some gravel and cobble noted. Riffle features consisted of sand, gravel, and cobble, while pool features consisted of sand and cobble. No aquatic vegetation was observed and a moderate to high density of woody debris was present in the channel.

Average bankfull width and depth were approximately 4.2 m and 0.7 m, respectively. Average wetted width and depth on the day of assessment were approximately 2.6 m and 0.5 m, respectively. Bank angles ranged from 30° to 90° and consisted of mostly silt/sand. Evidence of erosion was observed through 60 – 100% of the channel length, with bank undercuts measuring up to 0.14 m in depth. At the SWM pond outfall channel, there were concrete blocks lining the bed and banks up to the confluence.

3.3 Rapid Assessments

Channel instability was objectively quantified through the application of the Ontario Ministry of the Environment's (2003) Rapid Geomorphic Assessment (RGA). Observations were quantified using an index that identifies channel sensitivity based on evidence of aggradation, degradation,

channel widening, and planimetric adjustment. The index produces values that indicate whether a channel is stable/in regime (score <0.20), stressed/transitional (score 0.21-0.40), or adjusting (score >0.41).

The Rapid Stream Assessment Technique (RSAT) was also employed to provide a broader view of the system as it considers the ecological function of the watercourse (Galli, 1996). Observations were made of channel stability, channel scouring or sediment deposition, instream and riparian habitats, and water quality. The RSAT score ranks the channel as maintaining a poor (<13), fair (13-24), good (25-34), or excellent (35-42) degree of stream health.

These observations and measurements are summarized below. The descriptions are supplemented and supported with representative photographs, which are included in **Appendix C**. Field sheets, including those completed for RGA and RSAT assessments, are provided in **Appendix D**. All RGA and RSAT results for **Reach LC-1** are summarized in **Table 1**.

Reach LC-1 was assigned an RGA score of 0.32, indicating the reach was in transition/stress. The dominant geomorphological indicator was evidence of widening by the observation of fallen/leaning trees, occurrence of large organic debris, exposed tree roots, basal scour on inside meander bends and the length of basal scour through the reach. These characteristics influence the delineation of an erosion hazard in terms of overall channel stability. The secondary geomorphological indicator was evidence of aggradation, by the observation of siltation in pools, accretion on point bars, and deposition in the overbank zone. Overall, the channel is in transition/stress, according to the RGA results. **Reach LC-1** had an RSAT score of 25, or good. There were two limiting factors, including channel stability and channel scouring/sediment deposition. This was due to recent large tree falls, pool substrate composition, and large sand deposits in the overbank zone.

Table 1. Summary of Rapid Assessment Results

Reach	RGA (MOE, 2003)			RSAT (Galli, 1996)		
	Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Feature(s)
LC-1	0.32	In Transition/Stress	Widening	25	Good	Channel Stability, Channel Scouring/Sediment Deposition

4 Erosion Hazard Assessment

During the field investigation, observations were collected to understand the extent of erosion at the subject site and inform overall channel stability as it relates to the proposed multi-use trail. Specifically, meander amplitudes were measured, and evidence of erosion at the outlet associated with the SWM pond outfall was assessed.

Meander amplitudes ranged from 8.6 m to 13 m. A 20% factor of safety was applied to the largest meander amplitude (13 m) to account for changes in creek morphology over time. Crossing footings should be placed beyond the delineated hazard limit (including the 20% factor of safety) to ensure footing stability over time. With a 20% factor of safety, the hazard limit is approximately 16 m. At both upstream and downstream meanders, there was limited evidence of erosion.

Further, there was no evidence of erosion associated with the confluence between the SWM pond outfall and the main branch of Leonard's Creek.

It is understood that the proposed multi-use trail crossing is a boardwalk structure. As such, it is unlikely that the crossing will have a substantive impact on the channel. The erosion hazard limit is identified as 16 m, but if required, a slightly reduced footing placement (while still accounting for the meander amplitude of 13 m) would be acceptable.

5 Recommendations for Multi-Use Trail Crossing

Crossings can have significant impacts on valley and stream corridors. Rivers and streams are also dynamic systems and can easily migrate across their floodplains over time impacting crossing infrastructure. Therefore, it is important to recognize and account for natural hazards in association with watercourse crossings. The assessment outlined herein is based on the guidance and recommendations outlined by the Toronto Region Conservation Authority (TRCA) Crossings Guideline for Valley and Stream Corridors (2015) and the Credit Valley Conservation (CVC) Authority Fish and Wildlife Crossing Guidelines (2017). These are standard and accepted approaches for crossing design and implementation.

From a fluvial geomorphological perspective, watercourse crossings should be designed to minimize the probability of channel contact with the crossing infrastructure while accounting for natural channel adjustment (i.e., migration, erosion, scour) (TRCA, 2015; CVC, 2017). In general, it is recommended that any proposed crossings address the following fluvial geomorphological considerations, where appropriate:

- Potential channel erosion and/or migration
- Account for any local or upstream meanders
- Cross the watercourse at a reasonably straight and stable section of channel
- Cross the watercourse at a perpendicular angle
- Maintain sediment transport processes
- Maintain velocity differentials for frequent storm events

Generally, the current crossing location meets the recommended criteria described above. It is important to note that the proposed crossing location is in close proximity to the confluence between the SWM pond and the main branch of Leonard's Creek. Given the limited evidence of erosion in this location, the current position is acceptable. However, to optimize the crossing location from a geomorphological perspective, a minor realignment downstream from the confluence would be preferred. It is understood that there are constraints associated with realigning the crossing downstream. These constraints include existing tie-ins for the crossing and reducing disturbance to vegetation. Given the constraints, the current crossing location is acceptable.

Given the limited geomorphological indicators of erosion, additional bioengineering is not required for bank protection. Rather, materials for bank protection may include the trees harvested on site to accommodate construction.

6 Summary and Conclusions

This section of Leonard's Creek flows within an unconfined system through the subject lands. Through aerial photograph interpretation, it was determined that the channel planform through the system has remained relatively unchanged since the late 1920s. It is important to note that

the planform of the subject section of Leonard's Creek was not visible through aerial imagery, due to the presence of mature vegetation. Land use was converted from primarily agricultural areas, to residential and recreational areas. The subject property is located between Jack Crescent (to the south) and Goodfellow Public School (to the north). The purpose of this work was to assess the erosion hazard associated with the subject reach to inform crossing recommendations for a multi-use trail.

To inform crossing recommendations for the multi-use trail to connect Jack Crescent and Goodfellow Public School, an erosion hazard assessment was completed. A field investigation was conducted on March 9, 2020 and included a rapid geomorphological assessment for **Reach LC-1**. **Reach LC-1** was identified as a defined, single-thread channel. Further, it was identified as being in transition/stress (widening being the limiting factor), with "good" overall conditions. Within the study site, a SWM pond directs flow to the main branch of Leonard's Creek. Currently, the multi-use trail crossing is proposed at the confluence between the SWM pond outfall and the main branch of Leonard's Creek.

To identify erosion issues and recommendations for the proposed crossing design, meander amplitudes were measured, and evidence of erosion was assessed. The largest meander amplitude was measured as 13 m. With a 20% factor of safety, the erosion hazard limit for **Reach LC-1** was identified as 16 m. Although the RGA results indicate evidence of widening, there was limited evidence of erosion at the proposed crossing location. It is unlikely that the crossing will have a substantive impact on the channel, and as such, a slightly reduced footing placing (while still accounting for the meander amplitude of 13 m) would be acceptable.

Overall, crossing siting and design should aim to avoid damage to infrastructure and minimize channel contact with the crossing infrastructure to reduce erosion hazards. As such, the proposed crossing should consider potential future channel erosion and/or migration, be aligned perpendicular to the channel, maintain sediment transport processes and velocity differentials, and be positioned within a relatively straight or stable section of channel. Generally, the current crossing location meets the recommended design criteria. To optimize the crossing location from a geomorphological perspective, a minor realignment downstream from the confluence would be preferred. However, given existing constraints to realigning the crossing downstream (tie-ins and reducing disturbance to vegetation), the current crossing location is considered acceptable.

We trust this report meets your current requirements. Should you have any questions or concerns, please contact the undersigned.

Respectfully submitted,

Paul Villard, Ph.D., P.Geo., CAN-CISEC, EP, CERP
Director, Principal Geomorphologist

Josie Mielhausen, M.Sc.
Junior Environmental Scientist

7 References

Credit Valley Conservation (CVC). 2017. Fish and Wildlife Crossing Guidelines.

Lake Simcoe Region Conservation Authority (LSRCA). 2012. Innisfil Creeks Subwatershed Plan.

Ministry of Natural Resources and Forestry (MNRF). 2002. Technical Guide – River and Stream Systems: Erosion Hazard Limit.

Montgomery, D.R. and J.M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin, 109 (5): 596-611.

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Richards, C., Haro, R.J., Johnson, L.B. and Host, G.E. 1997. Catchment and reach-scale properties as indicators of macroinvertebrate species traits. Freshwater Biology, 37: 219-230.

Toronto and Region Conservation Authority. 2004. Belt Width Delineation Procedures.

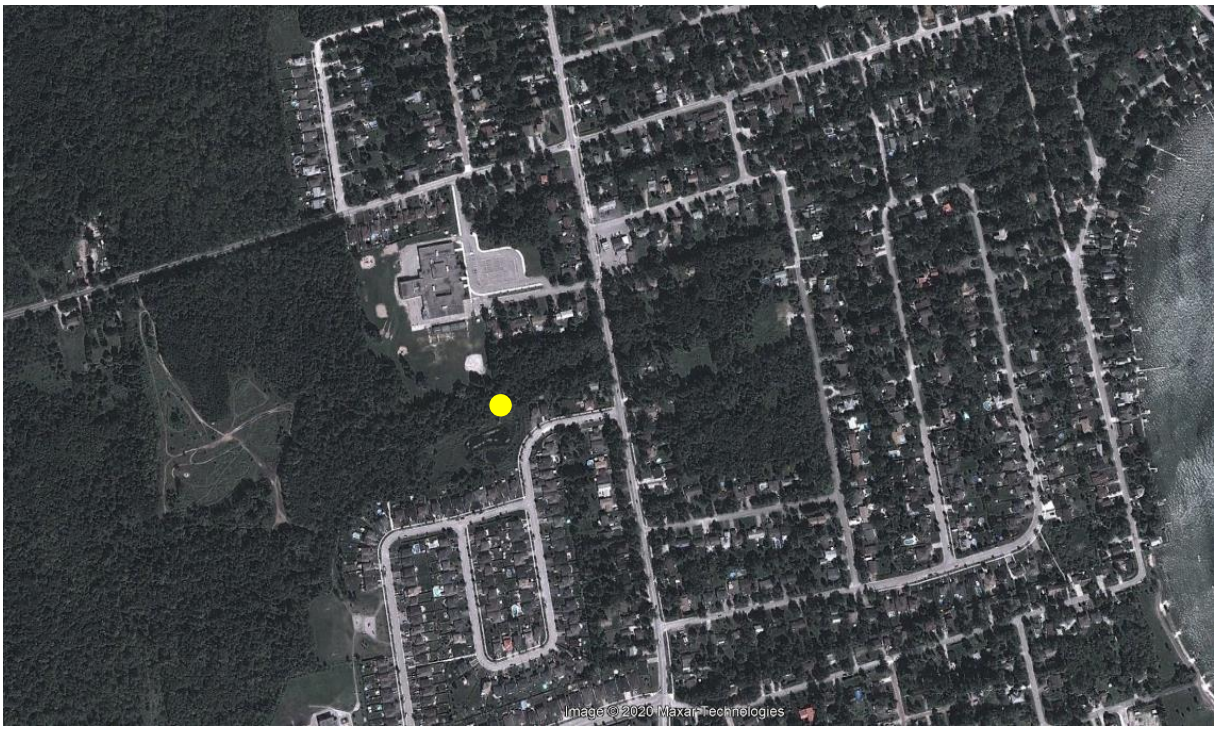
Toronto and Region Conservation Authority. 2015. Crossings Guidelines for Valley and Stream Corridors.

Appendix A
Historical Aerial Photographs

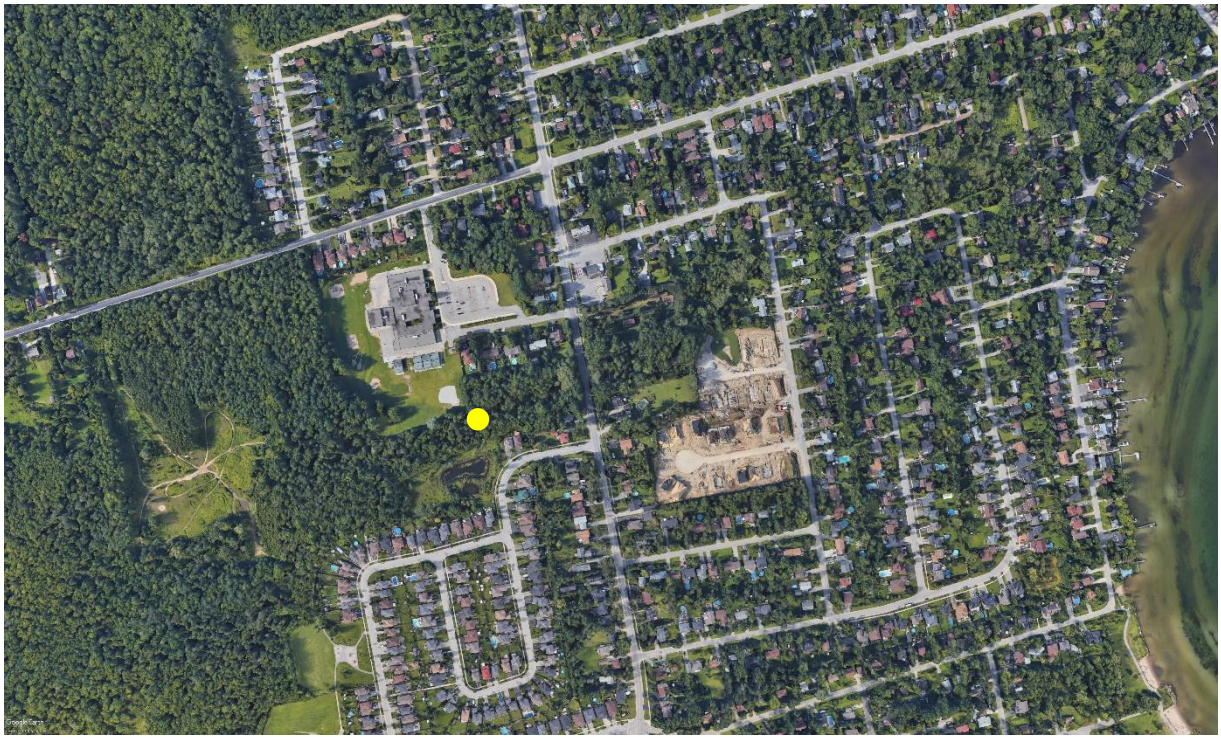
Location: Leonard's Creek, Innisfil, Ontario (yellow dot)
Year: 1927
Scale: 1:15,000
Source: National Air Photo Library

Location: Leonard's Creek, Innisfil, Ontario (yellow dot)
Year: 1946
Scale: 1:20,000
Source: National Air Photo Library

Location: Leonard's Creek, Innisfil, Ontario (yellow dot)
Year: 1965
Scale: 1:25,000
Source: National Air Photo Library

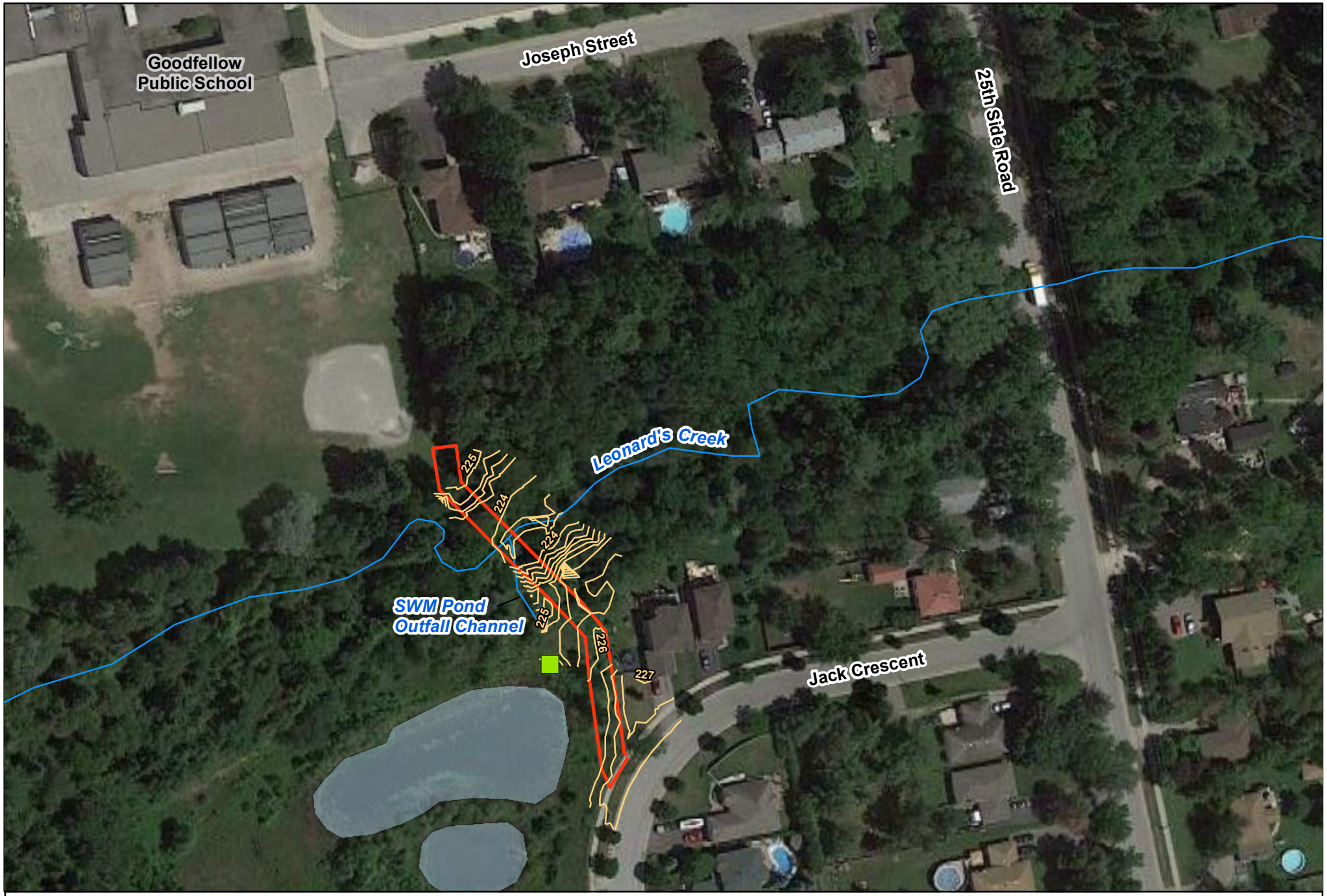


Location: Leonard's Creek, Innisfil, Ontario (yellow dot)
Year: 2010
Source: Google Earth Pro (GEP)



Location: Leonard's Creek, Innisfil, Ontario (yellow dot)
Year: 2015
Source: Google Earth Pro (GEP)

Appendix B
Study Site Map



Legend

- Headwall
- Proposed Multi-Use Trail
- Contour (0.25 m)
- Watercourse
- Waterbody

Goodfellow Public School to Jack Crescent

Proposed Multi-Use Trail

Innisfil, Ontario

N

0 10 20

Metres

GEO MORPHIX™

Imagery: Google Earth: June 2015.
Proposed Multi-Use Trail, Headwall,
Contours: IBI, 2019 and GEO Morphix Ltd., 2020.
Watercourse: MNRF, 2020.
Waterbody: MNRF and GEO Morphix Ltd., 2020.
Print Date: April 2020. PN20020. Drawn By: W.B., J.M.

Appendix C
Photographic Record

Photo 1 Reach LC-1 – Leonard' s Creek, Innisfil, ON	 Photograph taken from the downstream extent of Reach LC-1. Both banks were covered with snow and ice throughout the reach. Water levels were high due to recent snowmelt.
Photo 2 Reach LC-1 – Leonard' s Creek, Innisfil, ON	 Photograph taken from the south bank. Exposed tree roots were observed along the entire reach and undercuts up to 0.14 m were measured.

Photo 3 Reach LC-1 – Leonard' s Creek, Innisfil, ON	
	Photograph looking upstream. An uprooted tree was noted on the outside of this meander bend (left bank) which provides evidence of channel widening.
Photo 4 Reach LC-1 – Leonard' s Creek, Innisfil, ON	
	Photograph looking upstream. Leaning trees and instream logs were decelerating flows as they entered the meander bend.

Photo 5 Reach LC-1 – Leonard' s Creek, Innisfil, ON	 Photograph looking upstream at Reach LC-1. Outflow from the SWM pond outlet enters Leonard's Creek from the left. A woody debris jam was causing ice build-up directly upstream of the confluence.
Photo 6 Reach LC-1 – Leonard' s Creek, Innisfil, ON	 Photograph of the SWM pond outflow channel, looking upstream. The bed and banks were lined with concrete blocks.

Photo 7 Reach LC-1 – Leonard' s Creek, Innisfil, ON	 Photograph looking upstream at Reach LC-1. The channel slightly widened at the right bank (left of photo) prior to reaching the confluence.
Photo 8 Reach LC-1 – Leonard' s Creek, Innisfil, ON	 Photograph looking upstream towards a meander bend. The channel exhibited irregular meanders.

Photo 9 Reach LC-1 – Leonard' s Creek, Innisfil, ON	 Photograph looking upstream from the south bank. Channel bank angles ranged from 30° to 90° and consisted of primarily silt/sand and rootlets.
Photo 10 Reach LC-1 – Leonard' s Creek, Innisfil, ON	 Photograph taken looking upstream. Average bankfull width and depth were 4.2 m and 0.7 m, respectively.

Photo 11 Reach LC-1 – Leonard' s Creek, Innisfil, ON	 Photograph taken from the south bank towards Goodfellow Public School's fence line. A stormwater outfall was visible with flows entering Leonard's Creek.
Photo 12 Reach LC-1 – Leonard' s Creek, Innisfil, ON	 Photograph taken looking at bank materials upstream of the SWM pond confluence. Fresh deposits of sand were observed in the overbank zone in several locations along the reach, providing evidence of aggradation.

Photo 13 Reach LC-1 – Leonard' s Creek, Innisfil, ON	 Photograph looking upstream at Reach LC-1. Riffle-pool sequences were present throughout the reach. Bed materials ranged from silt/sand to small cobble.
Photo 14 Reach LC-1 – Leonard' s Creek, Innisfil, ON	 Photograph taken at the upstream extent of Reach LC-1. Leaning and fallen trees were observed along the entire reach.

Appendix D
Field Assessment Sheets

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Geomorphology Earth Science Observations

General Site Characteristics

Project Code: 20020

Date:	2020-03-09	**Stream/Reach:**	LEONARD'S CREEK
Weather:	OVERCAST 9°C	**Location:**	JACK CRES, INNISFIL
Field Staff:	BB + TR	**Watershed/Subwatershed:**	LEONARDS CREEK, LAKE SIMCOE

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Medial bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization/gabion
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Station location
- Vegetated island

Flow Type

H1	Standing water
H2	Scarcely perceptible flow
H3	Smooth surface flow
H4	Upwelling
H5	Rippled
H6	Unbroken standing wave
H7	Broken standing wave
H8	Chute
H9	Free fall

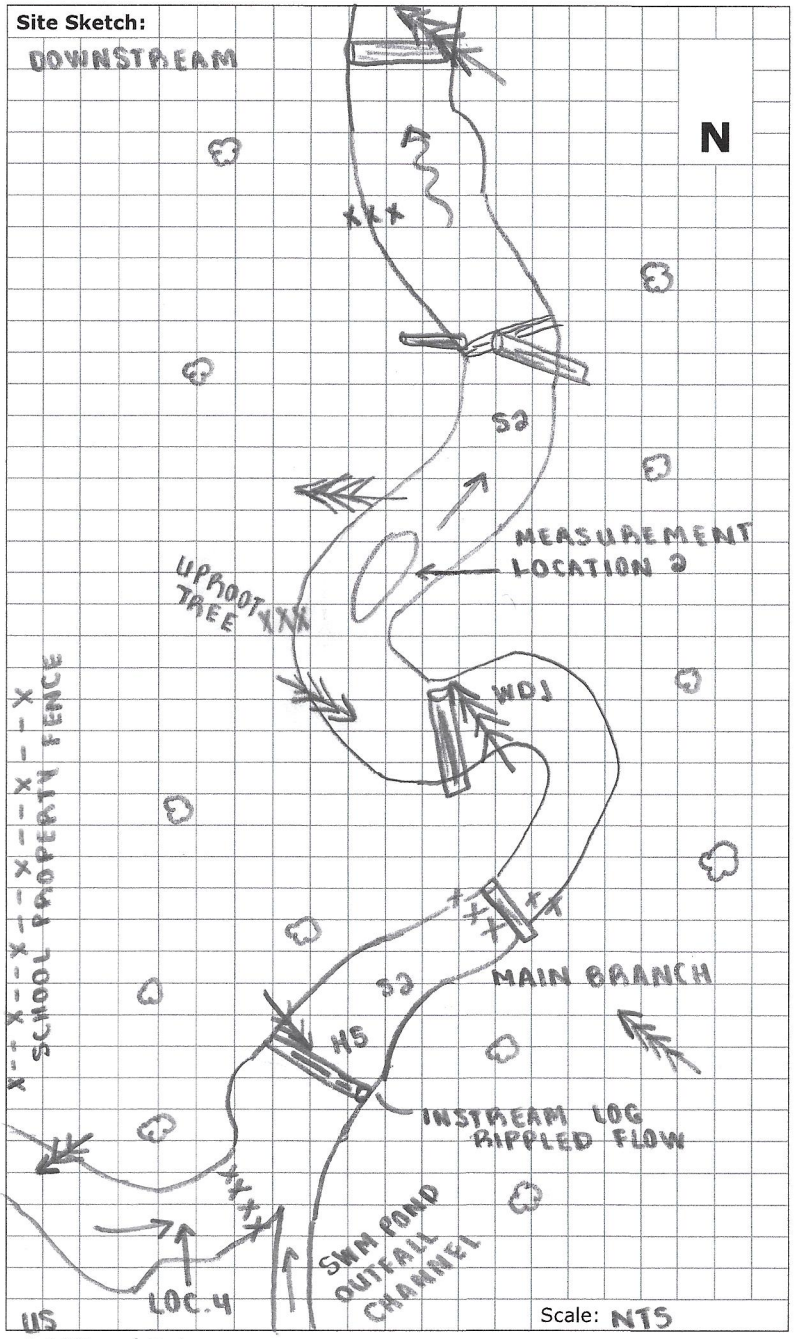
Substrate

S1	Silt	**S6**	Small boulder
S2	Sand	**S7**	Large boulder
S3	Gravel	**S8**	Bimodal
S4	Small cobble	**S9**	Bedrock/till
S5	Large cobble		

Other

BM	Benchmark	**EP**	Erosion pin
BS	Backsight	**RB**	Rebar
DS	Downstream	**US**	Upstream
WDJ	Woody debris jam	**TR**	Terrace
VWC	Valley wall contact	**FC**	Flood chute
BOS	Bottom of slope	**FP**	Flood plain
TOS	Top of slope	**KP**	Knick point

Site Sketch:



Additional Notes: SKETCH CONTINUED ON PAGE 2

Completed by: BB Checked by: _____

GEO MORPHIX
Geomorphology Earth Science Observations

General Site Characteristics

Project Code: 20030

Date:	2020-03-09	**Stream/Reach:**	LEONARD'S CREEK
Weather:	OVERCAST 9°C	**Location:**	JACK CRES, INNISFIL
Field Staff:	BB TR	**Watershed/Subwatershed:**	LEONARDS CREEK, LAKE SIMCOE

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Medial bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization/gabion
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Station location
- Vegetated island

Flow Type

H1	Standing water
H2	Scarcely perceptible flow
H3	Smooth surface flow
H4	Upwelling
H5	Rippled
H6	Unbroken standing wave
H7	Broken standing wave
H8	Chute
H9	Free fall

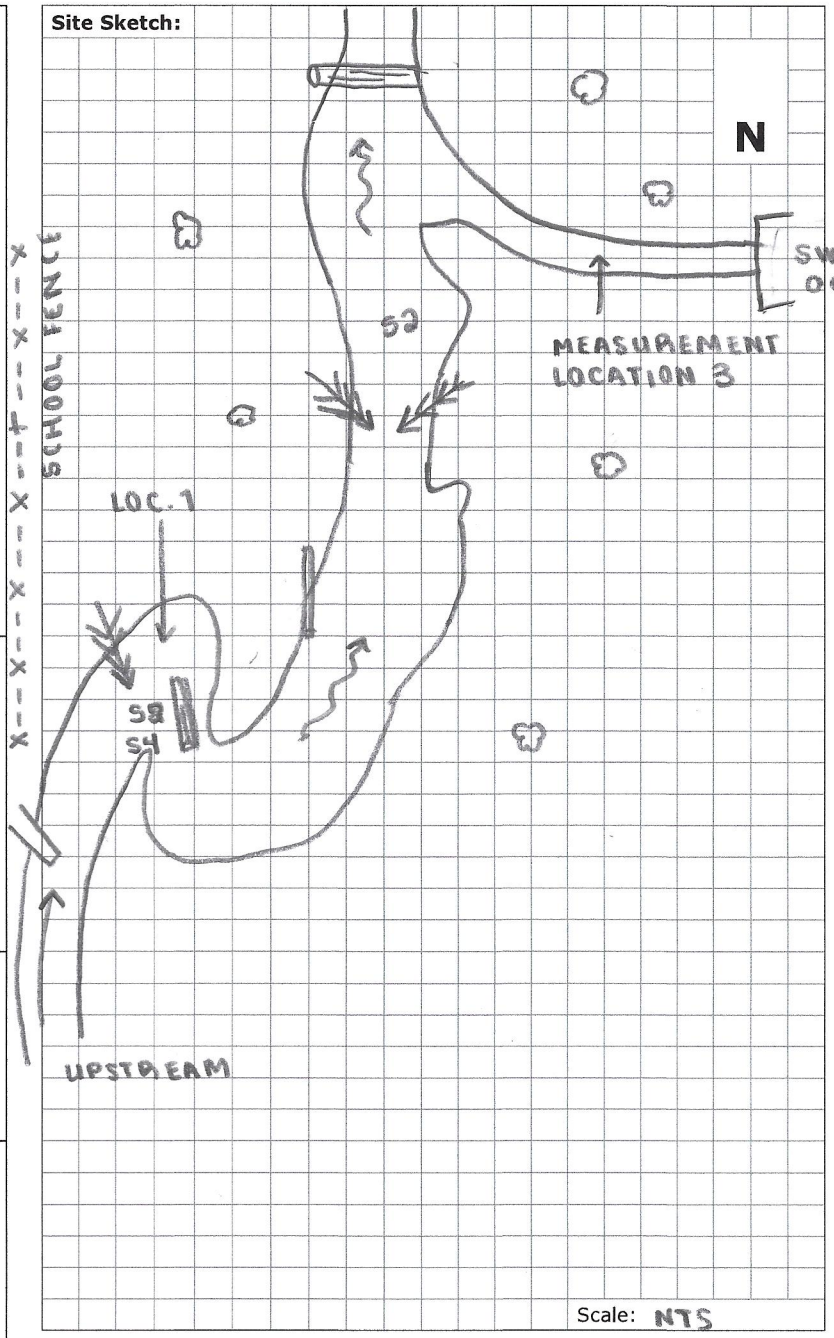
Substrate

S1	Silt	**S6**	Small boulder
S2	Sand	**S7**	Large boulder
S3	Gravel	**S8**	Bimodal
S4	Small cobble	**S9**	Bedrock/till
S5	Large cobble		

Other

BM	Benchmark	**EP**	Erosion pin
BS	Backsight	**RB**	Rebar
DS	Downstream	**US**	Upstream
WDJ	Woody debris jam	**TR**	Terrace
VWC	Valley wall contact	**FC**	Flood chute
BOS	Bottom of slope	**FP**	Flood plain
TOS	Top of slope	**KP**	Knick point

Site Sketch:



Scale: NTS

Additional Notes:

Completed by: BB Checked by: _____

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Rapid Geomorphic Assessment

Project Code: 20020

Date:	2020-03-09	**Stream/Reach:**	LEONARDS CREEK
Weather:	OVERCAST 9°C	**Watershed/Subwatershed:**	LAKE SIMCOE
Field Staff:	BB + TR	**Location:**	JACK CRES, INNISFIL

Process	Geomorphological Indicator		Present?		Factor Value
	No.	Description	Yes	No	
Evidence of Aggradation (AI)	1	Lobate bar		✓	3/7
	2	Coarse materials in riffles embedded		✓	
	3	Siltation in pools	✓		
	4	Medial bars		✓	
	5	Accretion on point bars	✓		
	6	Poor longitudinal sorting of bed materials		✓	
	7	Deposition in the overbank zone	✓		
		Sum of indices =	3	4	0.43
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	N/A		0/6
	2	Exposed sanitary / storm sewer / pipeline / etc.	N/A		
	3	Elevated storm sewer outfall(s)		✓	
	4	Undermined gabion baskets / concrete aprons / etc.	N/A		
	5	Scour pools downstream of culverts / storm sewer outlets		✓	
	6	Cut face on bar forms		✓	
	7	Head cutting due to knickpoint migration	N/A		
	8	Terrace cut through older bar material		✓	
	9	Suspended armour layer visible in bank		✓	
	10	Channel worn into undisturbed overburden / bedrock		✓	
		Sum of indices =	0	6	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	✓		5/7
	2	Occurrence of large organic debris	✓		
	3	Exposed tree roots	✓		
	4	Basal scour on inside meander bends	✓		
	5	Basal scour on both sides of channel through riffle		✓	
	6	Outflanked gabion baskets / concrete walls / etc.	N/A		
	7	Length of basal scour >50% through subject reach	✓		
	8	Exposed length of previously buried pipe / cable / etc.	N/A		
	9	Fracture lines along top of bank		✓	
	10	Exposed building foundation	N/A		
		Sum of indices =	5	2	0.71
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	1/7
	2	Single thread channel to multiple channel		✓	
	3	Evolution of pool-riffle form to low bed relief form		✓	
	4	Cut-off channel(s)		✓	
	5	Formation of island(s)		✓	
	6	Thalweg alignment out of phase with meander form		✓	
	7	Bar forms poorly formed / reworked / removed	✓		
		Sum of indices =	1	6	0.14

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.32

Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☐ 0.00 - 0.20	☑ 0.21 - 0.40	☐ 0.41

Completed by: BB Checked by: _____

Rapid Stream Assessment Technique

Project Code: 20030

Date:	2020-03-09	**Stream/Reach:**	LEONARDS CREEK
Weather:	OVERCAST 9°C	**Location:**	JACK CRES, INNISFIL
Field Staff:	BB + TR	**Watershed/Subwatershed:**	LAKE SIMCOE

Evaluation Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☑ 6 ☐ 7 ☐ 8	☐ 9 ☐ 10 ☐ 11

Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition >81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition <30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon N/A	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☑ 4	☐ 5 ☐ 6	☐ 7 ☐ 8

Date:	2020-03-09	Reach:	LEONARDS CREEK	Project Code:	20020

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. • Velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high amount of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ; ≥1.51:1	• Riffle/Pool ratio 0.5-0.69:1 ; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1 ; 1.11-1.3:1 N/A HIGH WATER LEVELS	• Riffle/Pool ratio 0.9-1.1:1
	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☑ 5 ☐ 6	☐ 7 ☐ 8

Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15m below surface	• Objects visible to depth 0.15-0.5m below surface	• Objects visible to depth 0.5-1.0m below surface	• Objects visible to depth > 1.0m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☑ 6	☐ 7 ☐ 8

Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: <50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: >80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☐ 1	☐ 2 ☐ 3	☑ 4 ☐ 5	☐ 6 ☐ 7

Total overall score (0–42) = 25	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Completed by: BB Checked by: _____

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code: 20020

Date:	2020-03-09	**Stream/Reach:**	LEONARD'S CREEK
Weather:	OVERCAST 9°C	**Location:**	JACK CRES, INNISFIL
Field Staff:	BB + TR	**Watershed/Subwatershed:**	LAKE SIMCOE
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 7 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): 8 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: _____

Riparian Vegetation

Dominant Type: (Table 6): 7
Species: _____

Coverage:
- ☐ None
- ☐ Fragmented
- ☑ Continuous

Channel widths:
- ☑ 1-4
- ☐ 4-10
- ☐ > 10

Age Class (yrs):
- ☐ Immature (<5)
- ☑ Established (5-30)
- ☐ Mature (>30)

Encroachment: (Table 7): 3

Aquatic/Instream Vegetation

Type (Table8): N/A | **Coverage of Reach (%):** 0

Woody Debris
- ☐ Present in Cutbank
- ☑ Present in Channel
- ☐ Not Present

Density of WD:
- ☐ Low
- ☑ Moderate
- ☐ High

WDJ/50m: _____

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): 2
Sinuosity (Degree) (Table 10): 3
Gradient (Table 11): 1
Number of Channels (Table 12): 1
Entrenchment (Table 13): 8
Type of Bank Failure (Table 14): 2/6
Downs's Classification (Table 15): E

• SWM POND OUTFALL EXCLUDED

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☐	☑	☑	☑	☐	☐	☐
Pool Substrate	☐	☑	☐	☑	☐	☐	☐
Bank Material	☐	☑	☐	☐	☐	☐	☐

LOCATION	1	2	3
Bankfull Width (m)	5.78	3.8	3.55
Bankfull Depth (m)	0.64	0.87	0.3
Wetted Width (m)	3.3	2.85	1.65
Wetted Depth (m)	0.51	0.57	0.15

Riffle/Pool Spacing (m): N/A | **% Riffles:** 40 (ESTIMATE) | **% Pools:** 60 | **Meander Amplitude:**

Pool Depth (m): N/A | **Riffle Length (m):** N/A | **Undercuts (m):** 0.14

Velocity (m/s): LOCATION: 2: 0.48 | 3: 0.09 | 4: 0.38 — Wiffle ball / ADV / Estimated

Bank Angle
- ☐ 0 – 30
- ☑ 30 – 60
- ☑ 60 – 90
- ☑ Undercut

Bank Erosion
- ☐ < 5%
- ☐ 5 – 30%
- ☐ 30 – 60%
- ☐ 60 – 100%

Comments: REFER TO SITE MAP FOR BANKFULL MEASUREMENT LOCATIONS

Notes:
- BANKFULL WIDTHS & DEPTHS MAY VARY DUE TO ICE COVER UP TO 0.8 m
- BANK & RIPARIAN ZONE THICK ICE/SNOW COVER
- BANKFULL LOCATION #4
  width (m) = 3.7
  Depth (m) = 0.94
  W. Width (m) = 3.3
  W. Depth (m) = 0.69
- UNDERCUT MEASURED @ LOCATION 2 OUTSIDE MEANDER RBANK
- RIFFLES & POOLS PRESENT IN MAIN CHANNEL BUT WATER DEPTH & CLARITY RESTRICTED MEASUREMENT
- WATER LEVELS DEEP DUE TO SNOWMELT
- BANKFULL INDICATORS COVERED BY SNOW/ICE

Completed by: BB | Checked by: _____