Appleby Creek
Fluvial Geomorphology Assessment

4495 North Service Road
Burlington, ON



Prepared for:
Dream
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Submitted:
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GEO Morphix Project No. 24130

Ver.	Purpose/Change	Authored by	Approved by	Date
1.0	Report (to Client)	Andrew Forbes Matilda Oja	Paul Villard	March 11, 2025

Disclaimer

This report presents professional opinions and findings of a scientific and technical nature based on the knowledge and information available at the time of preparation. This document is prepared solely for the Client, and the data, interpretations, suggestions, recommendations, and opinions expressed in the report pertains only to the project being completed for the Client.

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1 Introduction

GEO Morphix Ltd. (GEO Morphix) was retained by Dream to complete a fluvial geomorphology assessment for a portion of Appleby Creek at 4495 North Service Road in Burlington, Ontario (herein referred to as the "subject property" and shown in (**Appendix A**). The objective of the assessment is to support the derivation of the erosion hazard limits for the subject watercourse, with a specific focus on the portion of the southern (right) bank of channel that is understood to be largely unconfined and had not been included in previously completed top-of-bank staking activities (by Conservation Halton [CH]). The results of the assessment will be used to support the planning and design of site development activities.

The following tasks were completed to address the objectives of the assessment:

- Review available study reports and data records for the site (including the results of the top-of-bank surveys by CH) to assist in the general characterization of channel and watershed conditions at the subject watercourse, as well as to guide the field studies (e.g., selection of representative channel units for the rapid geomorphic assessments), noting that this exercise will involve a review historical aerial photographs of the channel network and surrounding area to assess changes to channel patterns (natural or artificial) and land use over time.
- Complete rapid geomorphic field assessments at the subject watercourse to further characterize existing channel conditions, with a plan to use standard, industry-accepted tools such as the rapid geomorphic assessment (RGA) and rapid stream assessment technique (RSAT) to evaluate existing instream and riparian conditions (i.e., evidence of ongoing channel processes, active erosion/deposition, or potential channel/slope instability).
- Delineate the meander belt width or erosion hazard for the subject watercourse based on the results of the desktop analyses, field assessments, and, if required, empirical modelling approaches.

The purpose of this report is to outline the methods and results of the identified tasks. These details are outlined in the following sections.

2 Background Review and Desktop Assessment

2.1 Surficial Geology and Physiology

Surficial geology and physiography mapping was reviewed to assess the geologic and biophysical controls on channel morphology, recognizing that surficial geology and physiography function 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 subject property is situated within the Iroquois Plain physiographic region and the Shale Plains physiographic landform. Immediately upstream of the subject property, the physiographic region is identified as the South Slope and the physiographic landform is identified as Till Plains (drumlinized) (Chapman and Putnam, 2007). Published surficial geology mapping indicates that the subject lands are dominated by Paleozoic Shale, whereas immediately upstream of Appleby Creek, the surficial geology transitions to clay to silt-textured till derived from glaciolacustrine deposits or shale (OGS, 2010).

2.2 Site History

A series of historical aerial photographs were reviewed to determine changes to the channel and surrounding land use and land cover over time. Specifically, aerial photographs and satellite images from 1934 (1:20,000), 1962 (1:25,000), 1974 (1:25,000), and 1986 (1:25,000) were

retrieved from the National Air Photo Library (NAPL), while photos/images from 1999 (1:20,000) were retrieved from the Ministry of Natural Resources and Forestry, while satellite imagery from 2005, 2015, and 2024 were obtained from Google Earth Pro. The review and assessment of this information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics. Historical aerial photographs are provided in **Appendix B** for reference.

In 1934, the subject property and surrounding areas were primarily used for agricultural purposes. The channel within the subject property appeared to have been straightened (before 1934) to support these activities, noting that, in comparison, the section of channel upstream of the site was characterized by a natural meandering pattern. Little to no riparian vegetation was observed within, and upstream of, the subject property.

Between and 1934 and 1962, Highway 403 and North Service Road were constructed downstream of the subject property. Beyond this, channel conditions and land use remained unchanged.

From 1962 through to 2024, a series of commercial development properties and associated connecting roads were progressively established in the areas surrounding the subject property. The channel within the subject remained mostly unaltered through this same period, although grassy and herbaceous vegetation was shown to emerge in the riparian limits/corridor. Of note, the channel immediately upstream of the subject property was re-constructed between 2004 and 2005 (presumably to support the requirements or objectives of one or more of the development works in the area). This section of channel was shown to exhibit a meandering pattern with meander amplitudes of approximately 10 m.

3 Watercourse Characteristics

3.1 Reach Delineation

Reaches are homogeneous segments of channel used in geomorphological investigations. They 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.

Channel reaches are 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
- Certain types of channel modifications by humans

This follows scientifically defensible methodology proposed by Montgomery and Buffington (1997), Richards et al. (1997), and the Toronto and Region Conservation Authority (2004). Reaches are first delineated as a desktop exercise using available data and information such as aerial photography, topographic maps, geology information and physiography maps. The results are then verified in the field.

One channel reach was delineated within the subject property, described herein as **Reach AC1**. This reach extends upstream from Appleby Line within a partially confined valley setting through the northeastern portion of the subject property. It then transitions into a previously reconstructed channel immediately upstream of the subject property.

3.2 General Reach Observations

Field investigations were completed along Reach AC1 on December 20, 2024, 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 in **Table 1**. Field descriptions are supplemented and supported with representative photographs included in **Appendix C**. Field sheets, including those completed for reach characterization and rapid assessments, are provided in **Appendix D**.

Table 1. Summary of General Reach Characteristics for Reach AC1

Average Bankfull Width (m)	Average Bankfull Depth (m)	Riffle Substrate	Pool Substrate	Bank Material	Dominant Riparian Condition	Notes
3.60	0.65	Gravel to boulders and parent material	Clay/silt, sand, and cobble	Clay/silt, sand, and parent material	Continuous buffer of grasses and established trees (5-30 years)	Straight, partially confined channel adjacent to an industrial park.

In general, the channel at **Reach AC1** was shown to be relatively straight (i.e., low sinuosity with the occasional, irregular meander) and partially confined by the valley wall along the left ban. A corrugated steel pipe culvert of approximately 2.5 m was present around the mid point of the reach. Corrosion, outflanking, and failing rip rap was observed at this culvert, while immediately downstream, a failing concrete outfall headwall was identified. At the downstream extent of the reach, there was a knickpoint and large woody debris jam, creating an island upstream of the culvert that conveys flows beneath Appleby Line. The riparian vegetation along the length of the channel reach was continuous, spanning over 10 channel widths, and consisting of grasses and establishing trees (5-30 years). Instream vegetation was scarce, with a few patches of watercress along the banks' margins. The characteristic channel morphology at the reach consisted of a mix of pools, riffles, and runs with average bankfull widths and depths of 3.60 and 0.65 m, respectively. The riffles were composed of gravel to boulders, as well as exposed parent material, while the pools ranged from clay/silt to cobble. The bed materials had low embeddedness, were poorly sorted, and largely consisted of platy shale. Layers of shale parent material were also noted throughout the banks. The soil layer above this consisted of clay/silt and sand. The channel exhibited evidence of systematic widening. For example, the channel banks were commonly undercut and eroded, exposing tree roots.

3.3 Rapid Geomorphological Assessment Tools

Rapid assessments were completed to identify dominant geomorphic processes, document stream health, and to identify any areas of concern regarding erosion or instability. 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) can also by employed to provide a broader view of the system as it considers the ecological function of the watercourse (Galli, 1996). Observations are 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.

Reaches were also classified according to a modified Downs (1995) Channel Evolution Model. The Downs (1995) model describes successional stages of a channel because of perturbation, namely hydromodification. Understanding the current stage of the system is beneficial as this allows one to predict how the channel will continue to evolve or respond to an alteration to the system.

The results of these assessments are summarized below.

Table 2. Summary of Rapid Assessment Results for Reach AC1

RGA (MOE, 2003)			RSAT (Galli, 1996)			Downs Channel Evolution Model (1995)	River Styles Framework*
Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Feature(s)		
0.24	In transition	Evidence of widening	25	Good	Channel stability and riparian habitat conditions	U - Undercutting	Mixed load, straight

A Rapid Geomorphic Assessment score of 0.24 was determined, indicating the reach is in transition, with widening identified as the dominant process of adjustment. This is evidenced by basal scouring for over 50% of the reach and exposed tree roots with undermining of over 1.0 m. The RSAT score was 25, indicating that the reach was in good overall health. Undercut banks with young, exposed tree roots and major localized gaps in the wooded vegetation made channel stability and riparian habitat conditions the limiting factors for this reach. **Reach AC1** was classified as undercutting based on Downs (1995) classification and a straight mixed load channel based on the River Styles Framework (Brierley and Fryirs, 2005).

4 Erosion Hazard Delineation

Most watercourses in southern Ontario have a natural tendency to develop and maintain a meandering planform, provided that there are no topographical or spatial constraints. When defining the limits of an erosion hazard for a watercourse, unconfined and confined systems are assessed differently (TRCA, 2004 and MNR, 2002).

Unconfined systems are those with streams in open areas (i.e., valley not apparent) or with valley walls that are positioned at a sufficient distance where the channel cannot reasonably be expected to contact as a result of migration. In this type of setting, a meander belt width assessment is used to estimate the lateral extent that a channel has historically occupied and will likely occupy in the future. This assessment is therefore useful for determining the potential erosion hazard to a feature or proposed activity in vicinity of a watercourse. Confined systems, in contrast, are those where a watercourse is contained within a defined valley where meander bend migration may be constrained by valley walls. In this setting, a 100-year migration rate or a toe erosion allowance is provided, in conjunction to a slope stability assessment provided by a geotechnical engineer, to estimate the lateral extent a channel could occupy in the future. This type of erosion hazard application is only applied to where the channel is positioned within 15 m of the valley slope toe. The erosion hazard is defined by the toe erosion allowance, stable slope allowance, and erosion access allowance. Partially confined systems are those where meander bends are adjacent to only one valley wall, and the watercourse is therefore restricted in migration and floodplain

occupation on one side of the valley system. Where the channel is positioned within 15 m of the valley slope toe, the erosion hazard is defined by the toe erosion allowance, stable slope allowance, and erosion access allowance. Where the channel is positioned greater than 15 m of the valley slope toe, the erosion hazard can be defined by the meander belt width, as well as the stable slope allowance and erosion access allowance.

Within the subject property, the channel at **Reach AC1** was characterized as partially confined. This considers that the channel bank on the left/north side was shown to directly abut the northern valley wall for the full extent of the reach, while the southern channel bank was shown to include valley contact for the upstream-most 40 m of the reach.

Areas identified as confined along **Reach AC1** require a toe erosion allowance to delineate the erosion hazard, whereas areas identified as unconfined require a meander belt width for the same purposes. Each of these components are outlined in the sub-sections below, noting that, as detailed further on, the toe erosion estimates identified herein should be validated by the results of a geotechnical slope stability assessment.

4.1 Toe Erosion Allowance Delineation

Due to a lack of reliable georeferencing control points for the subject property, the minimum toe erosion allowance for the confined portions of **Reach AC1** was defined based on guidance from MNR (2002), noting that the reach-scale observations of soil conditions and erosion activity were used to help inform the selection. This considers that the rate of toe erosion recession could not be reliability quantified using the MNR-based overlay analysis (given the absence of georeferenced photos/images or equivalent data over a minimum 25-year period).

Based on the above, a toe erosion allowance of 5 - 8 m was deemed appropriate for the confined portions of **Reach AC1**, with a focus on the lower end of the identified range. This accounted for the following field observations at the channel:

- Well vegetated valley walls and riparian zones, composed of grasses and established trees.
- Minor to moderate bank erosion, including exposed tree roots and undercutting.
- Presence of fine-grained bank materials, such as clay, silt, sand, and parent material (shale)

Of note, the overall erosion hazard limit in confined systems, as outlined in the MNR (2002) guidelines, is based on a combination of the toe erosion allowance, a stable slope allowance, and an erosion access allowance. The combined setbacks are additive and result in a final long-term erosion hazard limited. In this context, the toe erosion allowance recommendations provided here should be reviewed in tandem, and validated by, the results of a geotechnical slope stability assessment for the subject reach.

4.2 Meander Belt Width Delineation

In partially confined systems where the channel is greater than 15 m from the toe of valley slope, or valley walls are > 2 m high, the extent of the watercourse-based erosion hazard can be defined by the meander belt width. The conventional method to estimate a meander belt width relies on a series of georeferenced or orthorectified aerial imagery. The channel's meander belt axis is initially determined on a reach-by-reach basis, and the lateral limits of the meander belt, as defined by the channel's maximum meander amplitude and an appropriate factor of safety, is then used to delineate the meander belt.

As identified in **Section 4.1**, the absence of suitable georeferencing controls prevented the completion of a reliable overlay analysis. In a similar way, it prevented the use of conventional methods to estimate the meander belt width (via the use of a series of georeferenced or orthorectified aerial imagery). Based on this and to supplement conventional methods, a suite of empirical equations were used to calculate the meander belt width for the unconfined portion of the subject reach. These models are scientifically defensible and have been verified in past

projects as suitable for use in southern Ontario. Average bankfull channel dimensions measured during field reconnaissance were used to inform both the Williams (1986) and Ward et al. (2002) channel width models.

The relevant empirical equations/models are summarized below, noting that a summary of the results is provided in **Table 3.**

- The empirical relations from Williams (1986) are described as follows and were modified to include channel width:
  - $B_w = 18A^{0.65} + W_b$ [Eq. 1]
  - $B_w = 4.3W_b{}^{1.12} + W_b$ [Eq. 2]

  where *Bw* is meander belt width (m), *A* is bankfull cross-sectional area (m^2), and *Wb* is bankfull channel width (m), with the understanding that a 20% buffer, or factor of safety, was applied to the computed belt widths to address issues of under prediction.

- The Ward et al. (2002) channel width and drainage area models are outlined as:
  - $B_w = 6W_b{}^{1.12}$ [Eq. 3]
  - $B_w = 120DA^{0.43}$ [Eq. 4]

  where DA is the drainage area (square miles). The resulting value was then converted to the metric system (m). A 20% factor of safety was not applied to the Ward et al. (2002) channel width value due to the approach used in the modelling (i.e., hazard envelope rather than a linear relationship). A 20% factor of safety is included in the Ward et al. (2002) drainage area equation.

- The TRCA (2004) empirical model is described as follows:
  - $B_w = -14.827 + 8.319\ln(\rho gQS * DA)$ [Eq. 5]

  where ρ is water density (1000 kg/m^3), g is acceleration due to gravity (9.8 m/s^2), Q is discharge (m^3/s), S is channel slope (m/m), and DA is drainage area (km^2), noting that:

  - The TRCA meander belt width values were determined using a drainage area of 2.10 km^2 provided by the Ontario Watershed Information Tool.
  - A 2-year discharge of 1.89 m^3/s was calculated using the Index Flood Method (Moin & Shaw, 1985) as documented in the User Guide for the Ontario Flow Assessment Tool (OFAT) (MNR, 2020).
  - The channel slope was calculated to be 0.006 based on topographic data interpolated from the City of Burlington 2017 contour dataset.
  - One standard error was added to the calculated belt width following TRCA (2004) guidelines, where no change in hydrologic regime is anticipated.

Table 3. Summary of Meander Belt Width Estimates for Reach AC1

Meander Belt Width (m)					
Williams (1986) Channel Area*	**Williams (1986) Channel Width***	**Ward et al. (2002) Channel Width**	**Ward et al. (2002) Drainage Area**	**TRCA (2004)****	**Recommended MBW**
52	32	36	33	39	33

** Includes a 20% factor of safety*
***Includes 1 standard error (8.63), no change in hydrologic regime anticipated*

Based on the results from the empirical modeling exercise and as displayed in **Appendix E**, a meander belt width estimate of 33 m (relating to the modelled calculations from Ward et al. [2002]) was recommended for the unconfined portion of the subject reach. This considers that the meander belt estimate using the Ward et al. (2002) drainage area model is suitable, as the channel has undergone historical modifications.

5 Summary

GEO Morphix was retained by Dream to complete a fluvial geomorphology assessment for a portion of Appleby Creek at 4495 North Service Road in Burlington, Ontario. The objective of the assessment was to support the derivation of the erosion hazard limits for the subject watercourse/channel, with a specific focus on the portion of the southern (right) bank of channel that is understood to be largely unconfined and had not been included in previously completed top-of-bank staking activities (by Conservation Halton [CH]). The results of the assessment will be ultimately used to support the planning and design of site development activities.

The key results of the assessment at the subject channel (delineated in the study as **Reach AC1**) are summarized as follows:

- The results of the desktop assessment showed that **Reach AC1** was historically modified/straightened (prior to 1934) and has since remained relatively stable.

- The results of the field assessment confirmed the following channel characteristics:
    - The channel planform at **Reach AC1** was identified as partially confined, noting that the channel bank on the left/north side was shown to directly abut the northern valley wall for the full extent of the reach, while the southern channel bank was shown to include valley contact for the upstream-most 40 m of the reach.
    - The banks of the channel were comprised of mostly fine-grained sediment (clay, silt, and sand) and parent material (shale) and supported well-vegetated conditions.
    - Erosion-sedimentation patterns at the channel included instances of minor to moderate bank erosion (reflected by exposed tree roots and undercutting).

- The results of the erosion hazard delineation showed that:
    - Based on guidance from MNR (2002), coupled with the reach-scale observations of channel conditions, a toe erosion allowance of 5 - 8 m was deemed appropriate for the confined portions of **Reach AC1**.
    - Based on the results from the empirical modeling exercise, a meander belt width estimate of 33 m (relating to the modelled calculations from Ward et al. [2002]) was recommended for the unconfined portion of **Reach AC1**.

Of note, the overall erosion hazard limit in confined systems, as outlined in the MNR (2002) guidelines, is based on a combination of the toe erosion allowance, a stable slope allowance, and an erosion access allowance. The combined setbacks are additive and result in a final long-term erosion hazard limited. In this context, the toe erosion allowance recommendations provided here should be reviewed in tandem, and validated by, the results of a geotechnical slope stability assessment for the subject reach.

6 Closure

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

Respectfully submitted,



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Associate Director, Technical Lead



Matilda Oja, M.Sc., EPt
Geomatics / Remote Sensing Technician

7 References

Chapman, L.J. and Putnam, D.F. 2007. Physiography of southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 228.

Downs, P.W. 1995. Estimating the probability of river channel adjustment. Earth Surface Processes and Landforms, 20: 687-705.

Galli, J. 1996. Rapid Stream Assessment Technique, Field Methods. Metropolitan Washington Council of Governments.

Ministry of the Environment (MOE). 2003. Ontario Ministry of the Environment. Stormwater Management Guidelines.

Ministry of Natural Resources (MNR). 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.

Ontario Geological Survey (OGS). 2010. Surficial geology of Southern Ontario. Ontario Geological Survey. Miscellaneous Release – Data 128-REV.

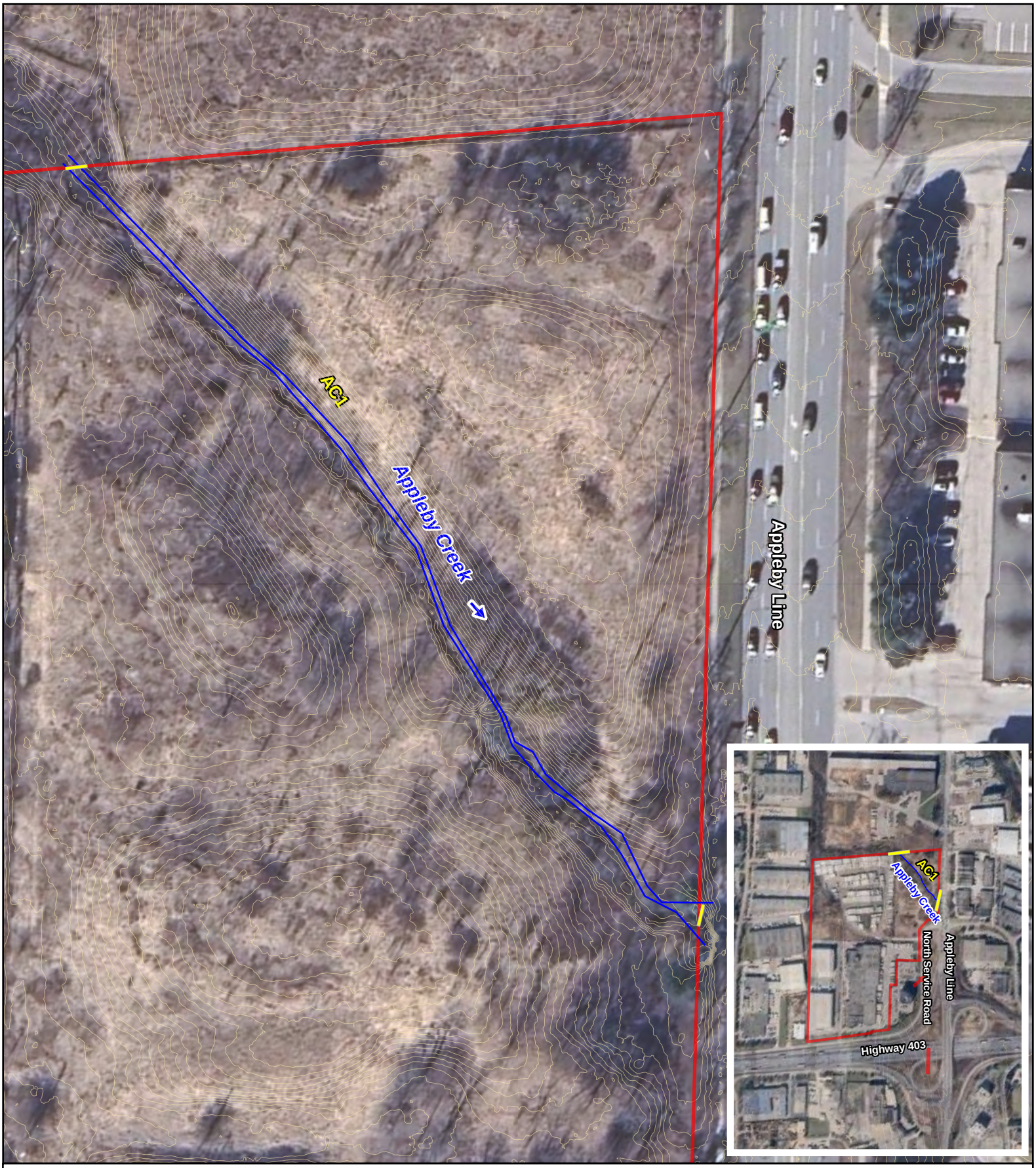
Richards, C., Haro, R.J., Johnson, L.B. and Host, G.E. 1997. Catchment and reach-scale properties as indicators of macroinvertebrate species traits. Freshwater Biology, 37: 219-230.

Toronto and Region Conservation Authority (TRCA). 2004. Belt Width Delineation Procedures.

Ward, A., Mecklenberg, D., Mathews, J. and Farver, D. 2002. Sizing Stream Setbacks to Help Maintain Stream Stability. Paper Number: 022239. 2002 ASAE Annual International Meeting. Chicago, IL, USA. July 28- July 31, 2002.

Williams, G.P. 1986. River meanders and channel size. Journal of Hydrology, 88 (1-2): 147-164.

Appendix A
Study Area and Reach Delineation



Legend

- Reach Break and ID
- Water Edge
- 0. 25 m Contour
- Subject Property

Study Area

Appleby Creek

Burlington, Ontario

GEO MORPHIX™

0 20 40

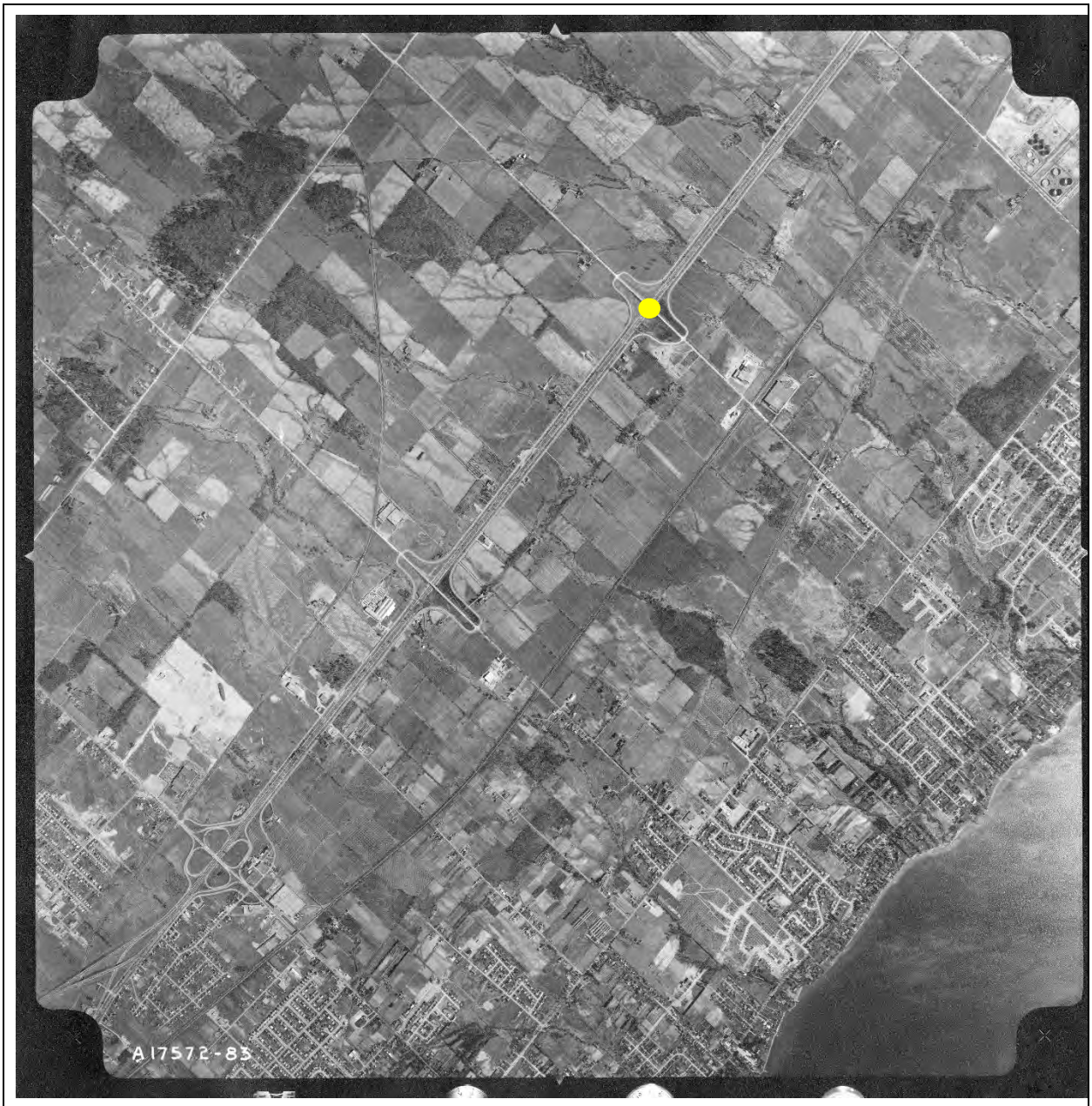
Metres

Imagery: Google Earth Pro, 2023. 0.25 m Contour: MNRF, 2018. Water Edge, Property Line, : R. Avis Surveying Inc., 2024. Reach Break and ID: GEO Morphix Ltd., 2024
Print Date: March 2025. PN24130. Drawn By: A.F., M.O., G.U.

Appendix B
Historical Aerial Photographs



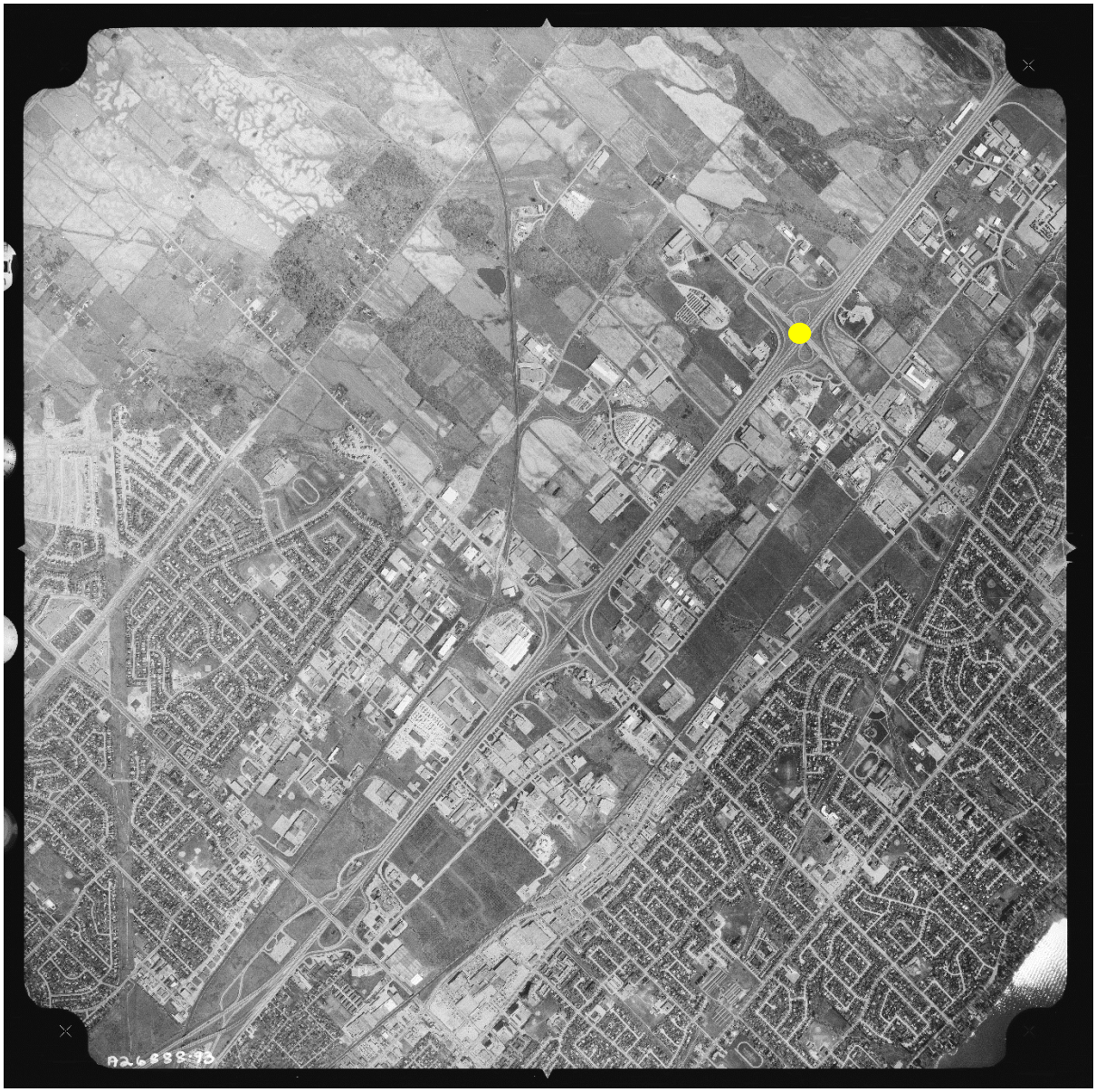
Location: Burlington, ON
Yellow Point: Approximate Location of Appleby Line and Highway 403
Year: 1934
Scale: 1:20,000
Source: National Air Photo Library



Location: Burlington, ON
Yellow Point: Intersection of Appleby Line and Highway 403
Year: 1962
Scale: 1:25,000
Source: National Air Photo Library



Location: Burlington, ON
Yellow Point: Intersection of Appleby Line and Highway 403
Year: 1974
Scale: 1:25,000
Source: National Air Photo Library



Location: Burlington, ON
Yellow Point: Intersection of Appleby Line and Highway 403
Year: 1986
Scale: 1:25,000
Source: National Air Photo Library



Location: Burlington, ON
Yellow Point: Intersection of Appleby Line and Highway 403
Year: 1999
Scale: 1:20,000
Source: MNR (LIO), 1999



Location: Burlington, ON
Yellow Point: Intersection of Appleby Line and Highway 403
Year: 2005
Scale: Digital Orthoimagery
Source: Google Earth Pro



Location: Burlington, ON
Yellow Point: Intersection of Appleby Line and Highway 403
Year: 2015
Scale: Digital Orthoimagery
Source: Google Earth Pro



Location: Burlington, ON
Yellow Point: Intersection of Appleby Line and Highway 403
Year: 2024
Scale: Digital Orthoimagery
Source: Google Earth Pro

Appendix C
Photographic Record

Photo 1
Appleby Creek – Reach AC1
Burlington, Ontario



Reach AC1 consisted of a mix of pools, riffles, and runs.

Photo 2
Appleby Creek – Reach AC1
Burlington, Ontario



Bed materials at the riffles consisted primarily of platy shale ranging in size from gravel to large cobble.

Photo 3 Appleby Creek – Reach AC1 Burlington, Ontario	
	The substrate was poorly sorted throughout the reach.
Photo 4 Appleby Creek – Reach AC1 Burlington, Ontario	
	The channel was generally straight with low sinuosity and irregular meanders.

Photo 5
Appleby Creek – Reach AC1
Burlington, Ontario



Bank materials consisted of a layer of soil composed of clay/silt and sand, with layers of shale below.

Photo 6
Appleby Creek – Reach AC1
Burlington, Ontario



A riparian buffer of grasses and established trees (5-30 years) spanned over 10 channel widths on either side.

Photo 7
Appleby Creek – Reach AC1
Burlington, Ontario



Eroded, undercut banks and exposed roots of young trees were common along the banks.

Photo 8
Appleby Creek – Reach AC1
Burlington, Ontario



A utility pole was observed along the margin of the channel in the downstream section of the reach.

Photo 9
Appleby Creek – Reach AC1
Burlington, Ontario



Photograph of corrugated steel pipe culvert and outfall. Outflanking, corrosion, and a failing rip rap revetment and concrete headwall were noted in the area.

Photo 10
Appleby Creek – Reach AC1
Burlington, Ontario



The channel was partially confined by a valley on the left bank. Valley wall contact can be seen in the photo above.

Photo 11
Appleby Creek – Reach AC1
Burlington, Ontario



Photograph of a large woody debris jam at the downstream extent. A 0.74 m tall knickpoint was also measured.

Appendix D
Field Observations

GEO MORPHIX

General Site Characteristics

Project Number: 24130

Date:	2024-12-20	**Stream:**	Appleby Creek
Time:	10:00	**Reach:**	
Weather:	Snowy, -4°	**Location:**	Burlington, On
Field Staff:	CM SC	**Watershed/Subwatershed:**	W Lake Ontario Shoreline

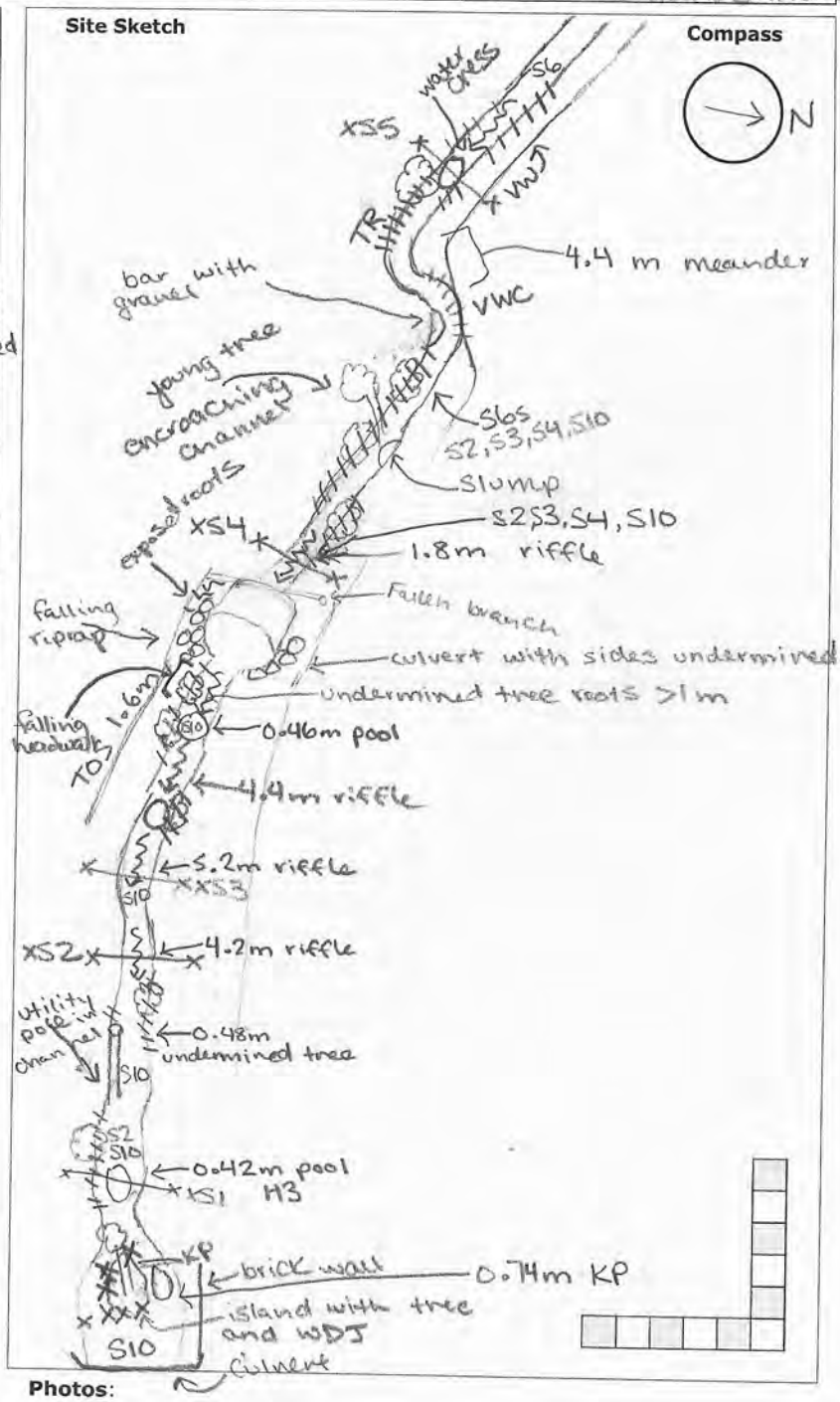
Features		Monitoring	
	Reach break		Long-profile
	Station location		Monumented XS
	Cross-section		Monumented photo
	Flow direction		Monumented photo direction
	Riffle		Sediment sampling
	Pool		Erosion pins
	Sediment bar		Scour chains
	Eroded bank/slope	**Additional Symbols**	
	Undercut bank		Undermined tree
	Bank stabilization		
	Leaning tree		
	Fence		
	Culvert/outfall		
	Swamp/wetland		
	Grasses		
	Tree		
	Instream log/tree		
	Woody debris		
	Beaver dam		
	Vegetated island		

Flow Type			
H1	Standing water	**H1A**	Back 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	**H9A**	Dissipates below 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	**S10**	UNCONSOLIDATED SHALE

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



Photos:

Notes:

Version #4
Last edited: 21/02/2023

Senior staff sign-off (if required): _____ Checked by: _____ Completed by: CM

GEO MORPHIX

General Site Characteristics

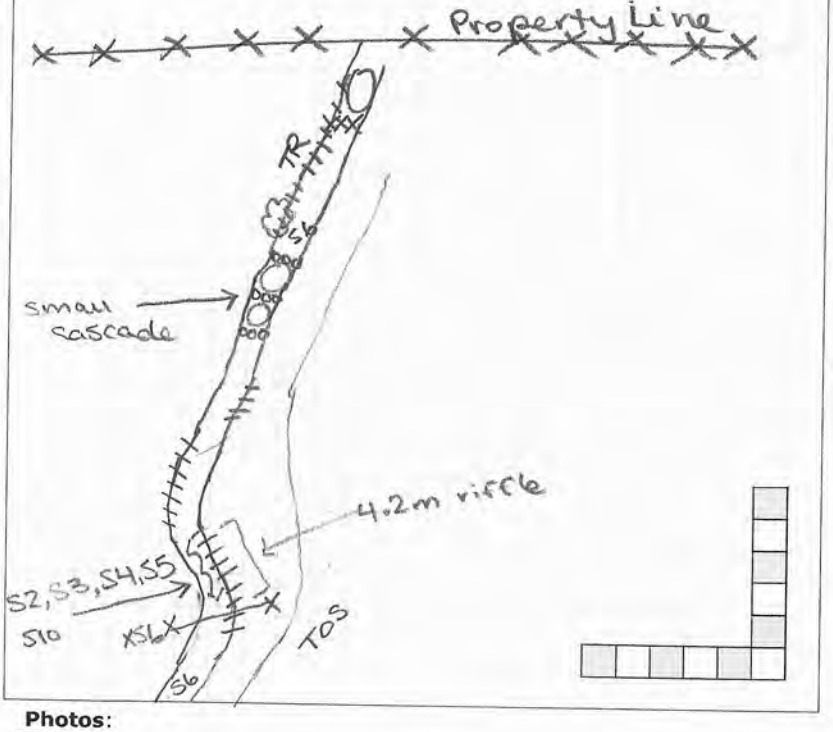
Project Number: 24130

Date:	2024-12-20	**Stream:**	Appleby Creek
Time:	10:00	**Reach:**	
Weather:	Snowy, -4°	**Location:**	Burlington, On
Field Staff:	SC CM	**Watershed/Subwatershed:**	W Lake Ontario Shoreline

Features		Monitoring	
	Reach break		Long-profile
	Station location		Monumented XS
	Cross-section		Monumented photo
	Flow direction		Monumented photo direction
	Riffle		Sediment sampling
	Pool		Erosion pins
	Sediment bar		Scour chains
	Eroded bank/slope	**Additional Symbols**	
	Undercut bank		
	Bank stabilization		
	Leaning tree		
	Fence		
	Culvert/outfall		
	Swamp/wetland		
	Grasses		
	Tree		
	Instream log/tree		
	Woody debris		
	Beaver dam		
	Vegetated island		

Site Sketch

Compass: N



Photos:

Notes:

Flow Type			
H1	Standing water	**H1A**	Back 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	**H9A**	Dissipates below free fall

Substrate			
S1	Silt	**S6**	Small boulder
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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

Reach Characteristics Project Number: 2H130

GEO MORPHIX

Date:	2024-12-20	**Field Staff:**	CM SC	**Watershed/Subwatershed:**	W Lake Ontario Shoreline
Time:	10:00	**Stream:**	Appleby Crk	**UTM (Upstream):**	Zone 17, 599103 E, 4804146 N
Weather:	Snow -4°	**Reach:**		**UTM (Downstream):**	Zone 17, 598911 E, 4804150 N

Land Use (Table 1): A | **Valley Type** (Table 2): 3 | **Channel Type** (Table 3): 11 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Evidence of Groundwater Location: watercress Photo: _____

Riparian Vegetation

Dominant Type (Table 6): 1/3

Coverage: ☐ None ☐ Fragmented ☑ Continuous

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

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

Encroachment (Table 7): 2

Aquatic & Instream Vegetation

Type (Table 8): 2

Reach Coverage %: 2

Woody Debris: ☐ In Cutbank ☒ In Channel ☐ Not Present

WD Density: ☒ Low ☐ Mod ☐ High

WDJ/50m: 0.5

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 2

Channel Characteristics

Sinuosity Type (Table 9): 1

Gradient (Table 11): 1

Entrenchment (Table 13): 1

Down's Model (Table 15): V

Sed Sorting (Table 20): Poor

Transport Mode (Table 21): 2|3

Geomorphic Units (Table 22): 5-8

Riffle-Pool Spacing (m): 7.7

Sinuosity Degree (Table 10): 1

# of Channels (Table 12): 1

Bank Failure (Table 14): 2

Bankfull Indicators (Table 18): 3|7

Sediment Transport Observed?: ☐ Yes ☒ No ☐ Not Visible

% of Bed Active: ☒

Mass Movement (Table 23): 1

% Riffles: 40

% Pools: 40

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

Bank Erosion: ☐ < 5% ☐ 5 - 30% ☑ 30 - 60% ☐ 60 - 100%

(Table 19)

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Bank	☑	☑	☐	☐	☐	☑ Shale	☐
Riffle	☐	☐	☑	☑	☑	☑ Shale	☐
Pool	☑	☑	☐	☑	☐	☐	☐
Bed (if no riffle-pool morphology)	☐	☐	☐	☐	☐	☐	☐

	XS1	XS2	XS3
Bankfull Width (m)	2.4	6.05	4.7
Bankfull Depth (m)	0.74	0.86	0.65
Undercuts (m)	0.08	0.20	0
Pool Depth (m)	0.42	0.36	0.46
Riffle Length (m)	5.2	4.2	4.4

	XS1	XS2	XS3
Wetted Width (m)	2.0	3.4	1.0
Wetted Depth (m)	0.42	0.36	0.05
Velocity (m/s)	0.07	0	0.292
Velocity Estimate Method	WB	WB	WB
Meander Amplitude (m)	3.7	3.1	2.4

Notes:

XS4 - Riffle
Riffle Length = 1.8 m
BF Width = 2.75
BF Depth = 0.52
Wetted Depth = 0.04
velocity = 0.459 m/s
undercut = 0.08 m
MA = 3.1 m

XS5 - Pool
BF Width = 2.75 m
Wetted Width = 2.15 m
Pool Depth = 0.2 m
Undercut = 0.21 m
Velocity = 0.07 m/s

XS6 - Riffle
MA - 3.7
WBW - 1.9
BFW - 3m
WD - 0.045
WBF - 0.5
V - 0.474 m/s
UC - 0.49
Riffle length - 4.2 m

Tree roots significantly undermined on both banks throughout reach. Only 2 WDJ, however @ US and DS extent.

VWC in 1 section of reach on LB (see sketch map)

Photos:

Version #4
Last edited: 04/04/2023

Senior staff sign-off (if required): _____ Checked by: _____ Completed by: CM SC

GEO MORPHIX

Rapid Stream Assessment Technique Project Number: 24130

Date:	2024-12-20	**Stream:**	Appleby Creek
Time:	10:00	**Reach:**	
Weather:	Snowy, On	**Location:**	Burlington, On
Field Staff:	CM SC	**Watershed/Subwatershed:**	W Lake Ontario Shoreline

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	• 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

SNOW COVERED - COULDN'T SEE OVERBANK

Version #2
Last edited: 10/02/2023

Senior staff sign-off (if required): _____ Checked by: _____ Completed by: CM SC

GEO MORPHIX

Date:	2024-12-20	PN:	24130	Location:	Burlington, ON

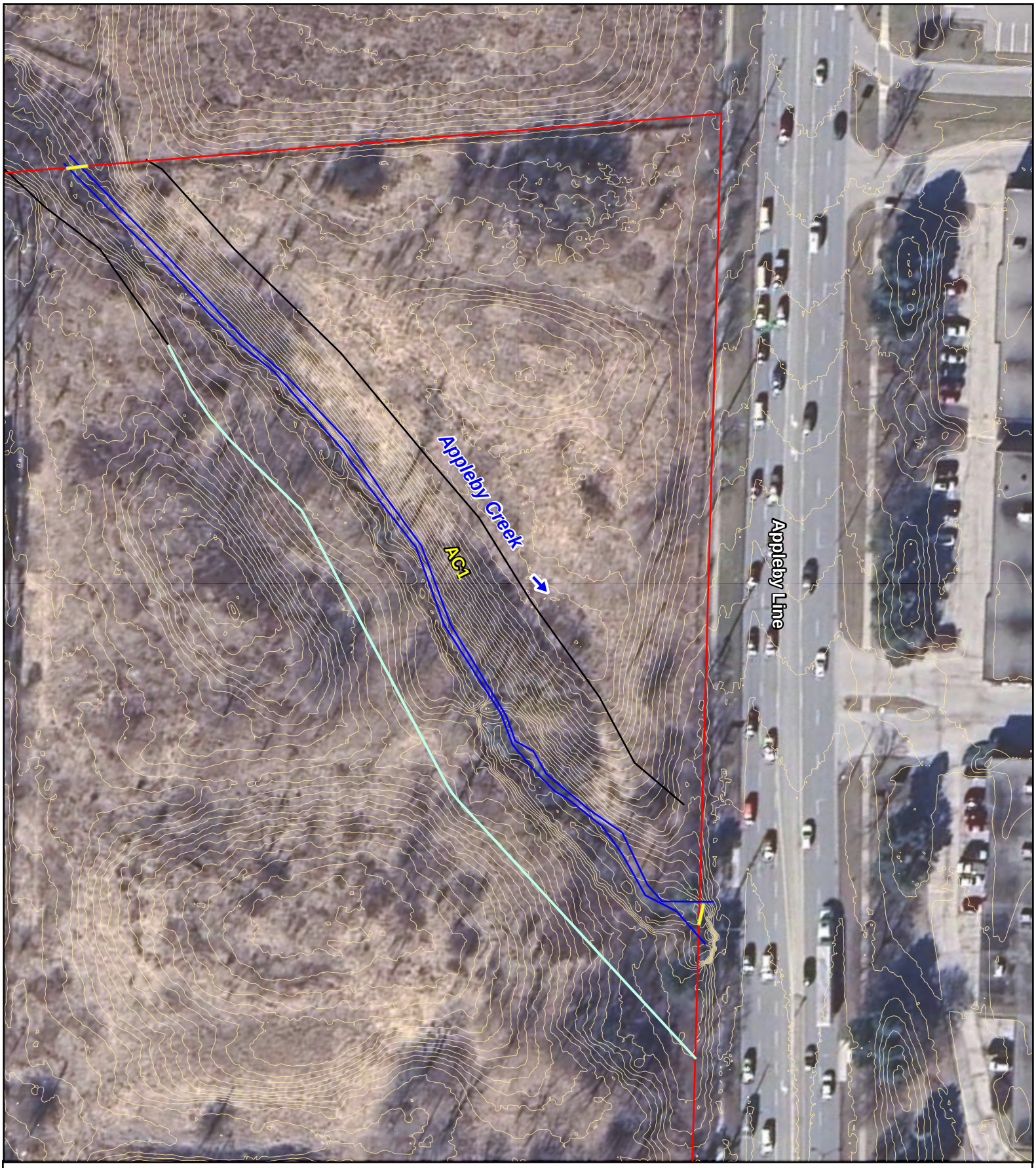
Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem 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	• Riffle/Pool ratio 0.9-1.1:1
NA	• 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	Point range: ☐ 3 ☐ 4	Point range: ☒ 5 ☐ 6	Point range: ☐ 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	Point range: ☐ 3 ☐ 4	Point range: ☐ 5 ☐ 6	Point range: ☒ 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	Point range: ☐ 2 ☒ 3	Point range: ☐ 4 ☐ 5	Point range: ☐ 6 ☐ 7

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

Version #2
Last edited: 10/02/2023

Senior staff sign-off (if required): _____ Checked by: _____ Completed by: CM

Appendix E
Meander Belt Width Delineation



Legend

- Reach Break and ID
- Water Edge
- 0. 25 m Contour
- Subject Property
- Staked Top of Bank
- Meander Belt Width (33m)

Meander Belt Width

Appleby Creek

Burlington, Ontario

GEO | MORPHIX™

0 20 40

Metres

Imagery: Google Earth Pro, 2023. 0.25 m Contour: MNRF, 2018 (interpolated from LiDAR). Subject Property, Staked Top of Bank Water Edge: R. Avis Surveying Inc., ,2024. MBW, Reach Break and ID: GEO Morphix Ltd., 2024. Drawn By: A.F., M.O., G.U. Print Date: March 2025. PN24130.