Fluvial Geomorphology Assessment: Grindstone Creek, Falcon Creek and Indian Creek

1200 King Road

City of Burlington, Ontario



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Table of Contents

1 Introduction 1
2 Existing Conditions 2
2.1 Background Review 2
2.2 Fluvial Geomorphology Assessment (Parish Geomorphic, 2014) 2
3 Physiography and Geology 2
4 Watercourse Characteristics 3
4.1 2023 Indian Creek Fieldwork 3
4.1.1 Reach Observations 3
4.1.2 Detailed Assessment 4
4.2 2026 Grindstone Creek and Falcon Creek Fieldwork 5
4.2.1 Reach Observations 5
4.2.2 Rapid Assessments 7
5 Meander Belt Width Delineation 8
6 Natural Channel Design 9
6.1 Design Objectives 9
6.2 Bankfull Channel 10
6.2.1 Fish Passage 12
6.3 Channel Planform 13
6.4 Channel Substrate Hydraulic Sizing 14
6.5 Corridor Crossing Recommendations 14
6.6 Channel Corridor 14
6.6.1 Corridor Sizing 14
6.6.2 Corridor Wetland Features 15
6.6.3 Habitat Restoration 15
6.7 Natural Erosion Control 16
7 Erosion Threshold Analysis 16
7.1 Methodology 17
7.2 Results 18
7.2.1 Indian Creek 18
7.2.2 Falcon Creek 19
7.2.3 Grindstone Creek North 20
7.2.4 Grindstone Creek South 20
8 Erosion Exceedance Analysis 22
8.1 Methods 22
8.2 Results 23
9 Design Implementation 25

9.1 Construction Timing 25
9.2 Best Management Practices 25
9.3 Post-Construction Monitoring 25
10 References 27

List of Tables

Table 1: General reach characteristics of Indian Creek 3
Table 2: Measured and calculated bankfull channel parameters according to existing conditions 5
Table 3: Meander belt width estimates for the proposed Indian Creek 15
Table 4. Results of erosion threshold analysis 21
Table 5. Results of unitary erosion threshold analysis 22
Table 6. Summary of selected erosion thresholds 22
Table 7. Results of event-based erosion exceedance analysis 24

Appendices

Appendix A: Site Map
Appendix B: Photographic Record
Appendix C: Field Observations
Appendix D: Detailed Assessment Summary
Appendix E: Erosion Exceedance Hydrographs

1 Introduction

GEO Morphix Ltd. (GEO Morphix) was retained to complete an erosion hazard assessment and corridor realignment design supporting the proposed development at 1200 King Road in the City of Burlington, herein referred to as the subject land, and verify results obtained by Parish Geomorphic (2014). The subject lands are located at 1200 King Road and bounded by Highway 403 to the north, King Road to the east, and a Canadian National (CN) Rail Line to the south. A site map is provided in **Appendix A** for reference. Previously, Parish Geomorphic (2014) completed a fluvial geomorphological assessment to delineate the meander belt width and erosion hazard for tributaries of Grindstone Creek, Falcon Creek and Indian Creek. This study serves as an update to the work completed by Parish with updated field results to ensure the recommendations presented are still applicable for the updated Draft Plan.

This report also provides recommendations for realigning and enhancing a tributary of Indian Creek, **Reach IC-T1, IC-T2,** and **IC-T3** within the City of Burlington, Ontario. A site map is provided in **Appendix A** for reference. The two tributaries of Indian Creek flow generally south from Highway 403 and confluence near the northern property boundary. From this confluence, the tributary of Indian Creek **(Reach IC-T3)** flows south towards the CN Rail Line. **Reach IC-T3** is proposed for realignment, which provides an opportunity to replace the existing degraded channel with a naturalized watercourse that significantly improves channel form and function. The existing morphologically limited channel will be replaced with a riffle and pool system, with cross-sectional dimensions closer to a natural watercourse conveying similar flows. The proposed design matches the recommendations for the previously realigned channel at the downstream extent of the property. The proposed realignment improves flow conveyance to downstream reaches, improves channel form and function, and enhances aquatic habitat by increasing substrate and morphological variability.

In developing the design, the following activities were completed:

- Background review of existing information related to the development lands, including topographical, physiographical, and geological maps of the study area, alongside the 1200 King Road Environmental Impact Assessment (EIA; Savanta Inc. et al., 2015), and the 1200 King Road Property – Fluvial Geomorphology Characterization and Recommendations (Parish Geomorphic, 2014)
- Site visit to document existing channel conditions, including a detailed survey to estimate bankfull geometry for Indian Creek
- Provide details for the channel design, including planform, cross-sections, and necessary bioengineering details
- Review/confirm the erosion hazard delineated by others in support of defining, in part, the limit of development
- Verification of the meander belt width for realigned sections of **Reach IC-T1, IC-T2**, and **IC-T3**
- Hydraulic sizing of the bankfull channel and required substrates
- Recommendations for design implementation, including construction timing and best management practices
- Determine erosion thresholds for the receiving watercourse
- Complete an erosion exceedance exercise comparing pre- and post-development hydrology provided by Urbantech Consulting (2021)
- Development of a post-construction monitoring plan

This design brief facilitates a review specifically related to the naturalized corridor design. The following report outlines the current geomorphological condition of **Reaches GC-T1, GC-T2, GC-T3, FC-6b, IC-T1, IC-T2,** and **IC-T3**, as well as design considerations for Indian Creek and technical details associated with channel sizing and habitat restoration. It also provides recommendations for the implementation and monitoring of the proposed channel.

2 Existing Conditions

2.1 Background Review

The tributary of Indian Creek is situated within the Indian Creek Watershed, with a drainage area of approximately 22.16 km^2. The headwaters originate within agricultural lands in north Burlington and flow south to Lake Ontario. The predominant land use within the watershed is historical agricultural fields and residential and commercial developments.

As part of the background review, previous field investigations were documented within the 1200 King Road Environmental Impact Assessment (EIA; Savanta Inc. et al., 2015) and were reviewed to understand watercourse characteristics. It was noted that portions of the channel had previously been realigned and straightened for agricultural activities. The channel was characterized as having an intermittent flow regime, becoming dry during the summer months. The channel had a localized area of multiple flow paths with poorly defined banks. The substrate consisted mainly of silt and sand-silt with deposits of cobble and gravel.

A review of the Fluvial Geomorphology Characterization and Recommendation prepared by Parish Geomorphic in 2014 was also undertaken. The reports recommended that the preliminary design geometries for ICT-3 be used as a guide to help support the detailed design while also proposing that a review and update of the channel geometries for ICT-2 and ICT-1 as they determined these to be potentially oversized due to the proposed flows at the time of the reports writing.

2.2 Fluvial Geomorphology Assessment (Parish Geomorphic, 2014)

Parish Geomorphic (Parish, 2014) previously completed a fluvial geomorphology study, which included a review of site history, existing conditions, and meander belt width delineation for Grindstone Creek, Falcon Creek, and Indian Creek which generally flow from north to south within the subject land. Reaches were delineated based on a desktop review and further refined from field observations. **Reaches GC-T1, GC-T2, GC-T3, ICT-1, ICT-2, ICT-3** and **FC-6b** were utilized again in the current study. A Rapid Geomorphic Assessment (RGA) and Rapid Stream Assessment Technique (RSAT) were performed on Grindstone Creek and Indian Creek in April 2014, and Falcon Creek in December 2013. Field observations were reassessed in 2023 and 2026, to ensure observations were still relevant. Given Indian Creek tributary is being realigned the meander belt widths have been updated based on the design.

Meander belt widths were delineated by Parish (2014) as the tributaries were unconfined. Given the riparian cover of Falcon Creek, and past straightening of Grindstone Creek and Indian Creek, empirical models were used to determine meander belt widths. Preliminary meander belt widths for **Reaches GC-T1**, **GC-T2**, **GC-T3**, and **FC-6b** were 9.6 m, 12 m, 10.8 m, and 42.9 m. A 10% factor of safety was applied to **Reaches GC-T1**, **GC-T2**, and **GC-T3** and a 30% factor of safety was applied to **FC-6b**, given that the reach was identified as being in transition (2010) and in adjustment (2013).

3 Physiography and Geology

Channel morphology and planform are primarily governed by the flow regime and the availability and type of sediments (i.e., surficial geology) within the stream corridor. Physiography, riparian vegetation, and land use also physically influence the channel. These factors are explored as they offer insight into what governs stream geomorphology and potential changes that could be expected in the future as they relate to a proposed activity.

The study area resides entirely within the Iroquois Plan physiographic region, representative of the Glacial Lake Iroquois shoreline (Chapman and Putnam 2007). This area is characterized as relatively flat and lies at the base of the Niagara Escarpment, consisting of glacio-lacustrine sands, silts, and gravels. In terms of surficial geology, the downstream portion of the tributary of Indian Creek is comprised of coarse-textured glaciolacustrine deposits comprised of sand, gravel, minor silt and clay. The upstream portion of the tributary of Indian Creek is characterized of Paleozoic Bedrock made up of shale. Immediately west of the upstream portion, the subject lands are comprised of clay to silt textured till that is derived from glaciolacustrine deposits and shale (OGS, 2010).

4 Watercourse Characteristics

4.1 2023 Indian Creek Fieldwork

4.1.1 Reach Observations

Reach observations and channel measurements were completed to characterize existing geomorphological conditions. Channel characterization for **Reaches IC-T1, IC-T1A, IC-T2, and IC-T3** was completed on May 10, 2023, and included the following observations:

- Reach-scale habitat sketch maps based on Newson and Newson (2000) outlining channel substrate, flow behaviour, geomorphological units, and riparian vegetation on the day
- Instream estimates of bankfull channel dimensions
- Visual observations of bed and bank material composition and structure
- Georeferenced photographs to document the location of all observed erosion

These observations and measurements are summarized below. The descriptions are supplemented and supported with representative photographs, which are included in **Appendix B**. Reach characteristics field sheets are provided in **Appendix C**. General reach characteristics are summarized below in **Table 1**.

Table 1: General reach characteristics of Indian Creek

Reach	Average Bankfull Width (m)	Average Bankfull Depth (m)	Substrate		Riparian Vegetation	Notes
			Riffle	Pool		
IC-T1	4.56	0.39	Clay and silt, gravel and cobbles		Continuous grasses	Unconfined
IC-T1A	1.81	0.51	Clay, silt, sand, gravel, cobbles, and parent material		Continuous grasses	Unconfined; irregularly meandering; heavily eroded;
IC-T2	2.52	0.58	Clay and silt		Continuous grasses	Unconfined
IC-T3	4.71	0.41	Clay and silt		Continuous grasses	Unconfined

[a] feature width (poorly defined channel)

Reach IC-T1 flowed in a north to southeast direction from Highway 403 to the confluence with **Reach IC-T3.** The reach was characterized as a historically straightened, low gradient agricultural swale situated within an unconfined floodplain. The surrounding land use was fallowed agricultural fields that have been overgrown with herbaceous vegetation and grasses that make up the riparian zone. Rooted emergent aquatic vegetation was present along the entirety of the reach. Riffle-pool bed morphology was absent from the reach, and the bed substrate was comprised of clay, silt, and minor gravel deposits. Bank angles ranged from 0° to 30°, and average feature width and depth were 4.56 m and 0.39 m, respectively. An avulsion channel had formed at the middle section of the reach and flowed south to **Reach IC-T3**. This channel was labeled as **Reach IC-T1A.**

Reach IC-T1A was initiated at the mid-section of Reach IC-T1 and flowed through the agricultural field to the mid-section of **Reach IC-T3**. This reach was characterized as a moderate to low gradient, irregularly meandering channel. The riparian zone was comprised of a continuous coverage of grasses and herbaceous vegetation. The upstream section of the channel was heavily incised and eroded with observations of undercut banks and exposed parent material. Bank angles ranged from 60° to 90°, and erosion was evident along 60 – 100% of the reach. Moving downstream, the channel gradient was reduced, and the reach had a low bed relief and was dominated by overland flow with poorly defined banks before entering **Reach IC-T3**. The average bankfull width and depth were approximately 1.81 m and 0.51 m, respectively.

Reach IC-T2 initiated at Highway 403 and flowed south to its confluence with **Reach IC-T3**. The reach was characterized as historically straightened to support adjacent agricultural practices and was situated within an unconfined floodplain. The riparian zone comprised a continuous coverage of grasses that moderately encroached on the channel. Rooted emergent vegetation, specifically phragmites, was present along the reach. The reach was dominated by runs with bed substrate comprised of clay, silt, and minor gravel deposits. The average feature width and depth were 2.52 m and 0.58 m, respectively. A tractor crossing was present within the middle of the reach, and a degraded corrugated steel pipe culvert conveyed flows within the crossing.

Reach IC-T3 originated at the confluence with **Reaches IC-T1** and **IC-T2** and flowed south to the previously realigned **Reach IC-T4** adjacent to the existing commercial developments. The reach was characterized as a historically straightened agricultural ditch within an unconfined floodplain. The reach was moderately entrenched and had a low channel bed gradient. The riparian zone was comprised of a continuous coverage of grasses that moderately encroached on the channel. Like Reaches IC-T1 and IC-T2, rooted emergent aquatic vegetation was present along the entire reach length. Riffle and pool bed morphology was absent from the channel and bed substrate was comprised of clay and silt. Bank angles ranged from 30° to 90° and average feature width and depth was approximately 4.71 m and 0.41 m, respectively. A tractor crossing was present near the downstream extent of the reach. A concrete culvert that had become separated in several locations connected the channel through the crossing. A large pool had formed on both the upstream and downstream extents of the crossing.

Based on the field observations, the existing reaches are uniform with limited morphological or sedimentological variability consistent with the observations presented by Parish Geomorphic in the 1200 King Road Property – Fluvial Geomorphology Characterization and Recommendations (2014). The proposed corridor design allows opportunities to increase diversity within the channel and floodplain by providing a single-thread channel with online and offline wetlands to support a wide range of hydroperiods. Additionally, habitat features, such as rock piles, wood piles, raptor poles etc. are proposed within the floodplain to increase terrestrial diversity. Compared to the existing conditions, the proposed design will significantly increase the quality of the system.

4.1.2 Detailed Assessment

In addition to the reach observations, a detailed assessment was completed for **Reach IC-T3** on May 10, 2023, to determine average bankfull channel characteristics, including cross-sectional geometry and hydraulics, for informing any potential restoration activities. The following activities were completed:

- Longitudinal profile along the channel bed to determine slope
- Nine representative cross-sectional surveys of the watercourse to determine average channel dimensions
- Detailed instream measurements at each cross-section, including bankfull channel geometry, riparian conditions, bank material, bank height/angle, and bank root density
- Bed materials/substrate sampling for grain size analysis

Nine representative cross-sections were surveyed, and channel measurements were then used to calculate bankfull flow characteristics such as discharge, average velocity, and erosion or sediment transport sensitivity. As part of the detailed assessment, a longitudinal survey along approximately 102 m of the bed was completed to determine the slope. A composite sample was taken to characterize bed materials. Average bankfull widths and depths at **Reach IC-T3** were 4.71 m and

0.41 m. The gradient of the bankfull channel was documented to be 0.33 %. The bankfull discharge for **Reach IC-T3** was back-calculated to be 1.42 m^3/s. A summary of the detailed assessment survey results is provided in **Table 2,** and a summary of the detailed assessment is provided in **Appendix D**.

Table 2: Measured and calculated bankfull channel parameters according to existing conditions

Channel Parameter	Reach IC-T3
Measured	
Average bankfull channel width (m)	4.71
Average bankfull channel depth (m)	0.41
Bankfull channel gradient (%)	0.63
D_{50} (mm)	<0.02
D_{84} (mm)	<0.02
Manning's n roughness coefficient	0.04
Computed	
Bankfull discharge (m^3/s)*	1.42
Average bankfull velocity (m/s)*	0.74
Unit stream power at bankfull (W/m^2)	9.74
Tractive force at bankfull (N/m^2)	13.23
Critical shear stress (N/m^2) **	15.57
Flow competency for D_{50} (m/s) ***	0.27
Flow competency for D_{84} (m/s) ***	0.27

* Based on Manning's equation

** Based on Shields diagram from Miller et al. (1977)

*** Based on Komar (1987)

4.2 2026 Grindstone Creek and Falcon Creek Fieldwork

4.2.1 Reach Observations

Field observations and channel measurements were collected from **Reaches GC-T1, GC-T2** and **FC-6b** on January 9, 2026, to support modelling, confirm design recommendations and update previous field assessments conducted by Parish Geomorphic (2014). The field data included:

- Descriptions of riparian conditions
- Estimates of bankfull channel dimensions
- Characterization of bed and bank material composition and structure
- Confirmation of valley form (i.e., unconfined, partially confined, confined)
- Observations of erosion, scour, or deposition
- Collection of photographs to document watercourses, riparian areas, adjacent land use, and channel disturbances

A photographic record documenting these descriptions is included in **Appendix B**. Field sheets for all 2026 fieldwork are provided in **Appendix C.** Summarized reach characteristics are presented below in **Table 3.**

Table 3: General reach characteristics of Grindstone and Falcon Creeks

Reach Name	Avg. Bankfull Width (m)	Avg. Bankfull Depth (m)	Bed Substrate	Bank Materials	Valley Type	Dominant Riparian Conditions	Notes
GC-T1	N/A*	N/A*	Clay/silt to sand	Clay/silt to sand	Partially confined	Trees with fragmented coverage	Channel generally lacked bank definition and consistent dominant flow path
GC-T2	2.29	0.28	Clay/silt to gravel	Clay/silt to gravel	Partially confined	Trees and herbaceous plants	Low sinuously single-thread channel with active flood chutes
FC-6b	5.54	0.61	Sand to boulders	Clay/silt to sand	Confined	Continuous forest coverage	Confined single-thread channel with valley wall contact on both banks and frequent bank erosion

*Not included due to weak bankfull indicators

Reach GC-T1, located to the north of Alayne Bryk Way and southeast of highway 403, flows from northeast to southwest within the study area. The subject reach lies parallel to the proposed road and is situated north of the crossing location. **GC-T1** diverges from **GC-T2**, however a distinct confluence was not observed at the time of assessment.

The subject reach was classified as partially confined due to the proximity of a valley wall on the right bank of the upstream extent. Riparian vegetation was primarily trees, but grasses and cattails dominated a section in the middle of the reach. Defined banks as well as a knickpoint were observed near the most downstream confluence, but these conditions did not reflect the majority of the reach. **GC-T1** was flooded at the time of assessment due to recent rain and snowmelt. A dominant flow path was observed in the downstream extent, but transitioned to multiple small flow paths with chutes. The channel planform lacked definition, and no clear bankfull indicators were observed. As such, no bankfull widths or depth measurements were included in this summary. Bank and bed materials were characterized by clay/silt and sand.

Reach GC-T2 began at a culvert under Highway 403 and ended upstream of the pond and the proposed road crossing. The single-thread, straight channel flowed from northwest to northeast and was characterized as partially confined due to the valley walls on the left and right floodplains in the upstream extent of the reach. The floodplain was active at the time of assessment due to recent snowmelt and rain. Due to the high flows at the time of assessment, chutes were observed throughout the subject reach. The riparian vegetation was a mix of trees and herbaceous plants (cattails, phragmites) which extended 10 times the average bankfull width (2.29 m). **GC-T2** had distinct pools, a range of flow conditions, and two (2) rooted knickpoints in the upstream extent. The channel then transitioned to a run-dominant feature. Bed and bank substrates ranged from clay/silt to gravel throughout the reach. A high accumulation of silt on the bed (0.40 m) was present as the channel transitioned to low-relief bed form. Bankfull was measured based on bank slope and vegetation indicators and ranged from 1.70 m - 3.60 m width and 0.22 m - 0.34 m depth.

Reach FC-6b began at a culvert under highway 403 and flowed west to east ending just before the study area boundary, slightly upstream of the proposed road crossing. It was a confined, single-thread channel, with valley wall contacts observed on both banks. The riparian zone was characterized by a continuous buffer of mature trees which extended over ten (10) times the average bankfull width (5.54 m). The morphology was a mix of riffles, runs, and deep pools (pool depths ranged from 0.35 m-0.78 m) which provided a range of flow conditions. Geomorphic units had distinct substrate types. Riffle substrate was predominantly comprised of cobbles and boulders, whereas pool substrate was primarily sand and gravel with minor siltation. Till was observed on the bed in two locations in the upstream extent. However, due to low visibility caused by turbid conditions at the time of assessment, it is possible not all instances were noted. Bank materials were comprised of silt/clay and sand. A suspended armour layer, undercuts, and exposed roots on both banks were prevalent throughout **FC-6b**. Mass bank failures, sloughs and leaning trees were also frequently observed. Bankfull width and depth measurements ranged from 3.75 m-6.90 m and 0.44 m-0.86 m, respectively. These measurements were based on bank slope, topography, vegetation and the signs of erosion listed above.

4.2.2 Rapid Assessments

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 (MOE) (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.

The field sheets detailing the RGA and RSAT scores for **Reaches GC-T1, GC-T2** and **FC-6b** are provided in **Appendix C.** A summary table of the RGA and RSAT scores are included below in **Table 4.**

Table 4: Summarized RGA and RSAT Scores for Grindstone and Falcon Creeks

Reach	RGA (MOE, 2003)			RSAT (Galli, 1996)		
	Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Feature(s)
GC-T1	0.13	In Regime	Planimetric Form Adjustment	21	Fair	Physical Instream Habitat
GC-T2	0.15	In Regime	Planimetric Form Adjustment	24	Fair	Water Quality/Physical Instream Habitat
FC-6b	0.40	In Transition	Widening	28	Good	Channel Stability/Water Quality

GC-T1 and **GC-T2** scored similar RGA and RSAT conditions. The primary factor for both RGA scores was planimetric form adjustment due to the presence of chutes, and low bed relief form observed in run-dominant **GC-T2** downstream extent and poorly defined **GC-T1** upstream extent. This differs from

the 2014 Parish assessment which noted aggradation and degradation as the primary adjustments for **GC-T1** and **GC-T2**. Degradation due to knickpoint migration was observed once in **GC-T1** but did not factor into the 2026 RGA as it was not characteristic of majority of the system. Similarly, the only consistently observed evidence of aggradation during the 2026 fieldwork was siltation in **GC-T2** pools. Woody debris was present in reaches but appeared to be caused by dead trees rather than evidence of widening. While the dominant systematic adjustment differed in the 2014 assessment, both classifications agree that these reaches are "In Regime". RSAT scores of **GC-T1** and **GC-T2** are similar between the 2014 and 2026. Both assessments determined "Fair" conditions with physical instream habitat as the limiting feature. Water quality of **GC-T2** scored low as well due to a notable grey tinge and sulfuric odour at the time of assessment.

FC-6b RGA condition was comparable to the previous assessment conducted by Parish in 2013, as both instances classified the subject reach as "In Transition". Widening was the dominant systematic adjustment in the most recent assessment as evidenced by scour on the inside of meanders and both banks of riffles. Exposed roots, leaning trees, fracture lines and frequent slumps and sloughs were also indicators. As widening impacts channel stability, it is understandable that this was a limiting feature of the **FC-6b** RSAT score. Turbid water was present at the time of assessment, commonly observed after large snowmelts and rainfalls, was also limiting feature of the RSAT score for **FC-6b**. Despite these factors, the reach still displayed "Good" stream conditions that are favourable for aquatic species.

5 Meander Belt Width Delineation

Most watercourses in southern Ontario have a natural tendency to develop and maintain a meandering planform provided 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 because of migration under existing or future hydrologic scenarios. In this type of setting, the extent of the erosion hazard is delineated by the meander belt width, which is defined as the lateral extent that a channel has historically occupied and will likely occupy in the future.

Following MNR (2002), the meander belt width can be applied, at minimum, based on 20 times the bankfull channel width. Alternatively, the meander belt width can be determined through a detailed geomorphological study that examines the largest channel meanders observed through historical and recent aerial photograph interpretation. The meander belt width can then be graphically defined using orthorectified aerial imagery by determining the channel centerline and the channel's central tendency (i.e., meander belt axis). In cases where the channel is not discernible in aerial photographs or the channel has been substantially modified, empirical models can be used to estimate the meander belt width.

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. 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. In these settings, where the channel is positioned within 15 m of a valley slope, the erosion hazard is generally defined by the toe erosion allowance, stable slope allowance, and erosion access allowance. In some instances, a meander belt width may also apply in partially confined systems (i.e., where the channel is greater than 15 m from the valley slope toe).

The empirical relations from Williams (1986) were used to determine meander belt width (m):

$$B_w = 18A^{0.65} \quad \text{[Eq. 1]}$$

$$B_w = 4.3{W_b}^{1.12} \quad \text{[Eq. 2]}$$

where B_w is meander belt width (m), A is bankfull cross-sectional area (m^2), and W_b is bankfull channel width (m). An additional factor of safety was applied to the computed belt widths to address underprediction.

The Ward et al. (2002) channel width and drainage area models were also used to determine a meander belt width (ft):

$$B_w = 6{W_b}^{1.12} \quad \text{[Eq. 3]}$$

$$B_w = 120DA^{0.43} \quad \text{[Eq. 4]}$$

where DA is the drainage area (square miles). The resulting value was then converted to the metric system (m). A 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.

A summary of the modelled meander belt widths for Grindstone Creek, and Falcon Creek are provided in **Table 5**.

Table 5: Summary of modelled meander belt widths for Grindstone Creek and Falcon Creek

Reach	Williams (1986) Area*	Williams (1986) Width*	Ward et al. (2002) Width*	Ward et al. (2002) Drainage Area*	Recommended Meander Belt Width (m)
GC-T2	13	9	13	7	12
GC-T3	10	8	11	9	10.8
FC-6b	51	38	42	36	42.9

** Includes factor of safety*

The previously delineated meander belt widths were 9.6 m, 12 m, 10.8 m, and 42.9 m, including a factor of safety (10% for Grindstone Creek and 30% for Falcon Creek) and fall within the range of meander belt widths that were calculated in this report. Given the updated field observations and modelling results, the previously recommended meander belt widths for **GC-T2**, **GC-T3**, and **FC-6b** can be carried through.

Previously, Parsh Geomorphic (2014) recommended a meander belt width of 9.6 m for **GC-T1**. Based on our observations, **Reach GC-T1** lacked well-defined geometries and likely has little erosion potential. It is our opinion that the previous meander belt width provided by Parish Geomorphic of 9.6 m can also be carried through to address the erosion hazard.

6 Natural Channel Design

6.1 Design Objectives

Given that **Reach IC-T3** and the downstream section of **Reach IC-T1** are proposed to be restored and realigned, there is an opportunity to replace the existing morphologically-limited channel with a naturalized riffle and pool system, with cross-sectional dimensions closer to that of a naturalized watercourse conveying similar flows. The following design is generally consistent with the recommendations provided in the 1200 King Road Property – Fluvial Geomorphology Characterization and Recommendations Report (Parish, 2014)

One goal of the natural channel design is to replace the existing degraded channel that past agricultural activities have previously impacted. A naturalized watercourse will significantly improve channel form and function per unit length. The channel realignment and naturalization is expected to improve riparian and aquatic conditions and provide a well-developed bankfull channel with morphological variability. Improvement in morphology and function will provide additional benefits to

sediment balance, floodplain storage, vegetation communities and terrestrial habitat features, edge impacts, water balance, fish passage and water quality.

The primary objectives of the design are to:

- Restore the physical form of the channel, including planform and in-channel characteristics
- Ensure channel stability and function during low-flow periods
- Improve the function of the channel and promote interaction with the floodplain and online wetlands
- Improve water quality by extending the detention of water through offline wetland features
- Create a low-flow channel that accommodates, at most, the 1.5-year return flow to improve the function of the channel corridor and increase interactions with the floodplain
- Create a floodplain that includes interconnected wet meadow and linear wetland features of variable depth, shape, and hydroperiod
- Provide a mix of coarse and fine sediment sources throughout the low-flow channel and floodplain
- Enhance aquatic habitat through the provision of a morphologically diverse channel with spatially varied flows
- Improve riparian habitat by installing woody plantings and dynamic floodplain features
- Mitigate potential hazards to the development as well as lands surrounding the development

Technical details are provided in subsequent sections to outline the approach used for channel sizing and habitat restoration.

6.2 Bankfull Channel

The recommended restoration design focuses on riffle-pool channel systems that will provide significant improvements to not only the channel, as they essentially mimic natural systems but also to aquatic habitat. The proposed design will provide a self-maintaining low-flow channel, allow fish passage at low-flows, and connect to the floodplain. The channel will carry a bankfull discharge, equivalent to the 1.5-year return post-development flow. When it is assessed to be an appropriate channel type, a riffle-pool system offers numerous benefits, namely:

- Channel bed relief for flow variability
- Water aeration in riffle sections
- Relatively quiescent flows in pool sections provide refuge for fish during high flows
- Instream energy dissipation
- Tortuous meanders to increase scour and pool depth, providing a potential overwintering habitat for fish species

Channel design dimensions are determined by bankfull discharge, as this represents what is generally referred to as the "*channel-forming discharge*" or the "*dominant discharge*". Several methods can be applied to select an appropriate bankfull discharge. Back calculation of discharge from a reference reach and support from hydrological modelling is usually the most appropriate. Given the significant historical channel modifications as well as changes in hydrology likely to occur because of the proposed development on site, a discharge based on hydrological modelling was determined for **Reach IC-T3** and then subsequently used to define channel bankfull geometry. The discharge used to size the bankfull channel was assumed to be equivalent to the modelled 1.5-year flow. As such, the bankfull discharge was defined as 0.71 m^3/s for Reach 1 and 2 and 1.02 m^3/s for Reach 3 and 4. Bankfull capacity for channels generally ranges from 1- to 2-year return events.

A simple Manning's approach was used to iteratively back-calculate bankfull dimensions for the proposed channel. Since pools are designed to contain ineffective space, this model over-predicts the amount of discharge they convey. As such, the modelled values for the riffles give a better prediction

of the channel's capacity. Riffle and pool geometries and anticipated bankfull conditions for the proposed channel, are provided in **Tables 6** and **7.**

The proposed channel has been subdivided into four separate design reaches based on changes in gradient and flow. **Reach 1** has a gradient of 2.60% and extends for approximately 70 m with a bankfull width and depth ranging between 1.65 m to 2.30 m and 0.21 m and 0.28 m, respectively **Reach 2** has a gradient of 1.50% and extends for approximately 84 m with a bankfull width and depth ranging between 1.75 m 10 2.40 m and 0.24 m and 0.30 m, respectively. **Reach 3** has a gradient of 0.95% and extends for approximately 267 m. The bankfull width and depth will range between 2.15 m to 2.70 m and 0.28 m and 0.34 m, respectively. **Reach 4** has a channel gradient of 0.45% and extends for approximately 105 m. The channel bankfull width and depth will range between 2.45 m to 3.10 m and 0.31 m to 0.39 m, respectively.

Table 6: Bankfull parameters for Reaches 1 and 2 of the proposed channel

Channel Parameter	Reach 1		Reach 2	
	Riffle	Pool	Riffle	Pool
Bankfull width (m)	1.65	2.30	1.75	2.40
Average bankfull depth (m)	0.21	0.28	0.24	0.30
Maximum bankfull depth (m)	0.30	0.50	0.35	0.55
Bankfull width-to-depth ratio	7.98	8.23	7.45	8.11
Channel gradient (%)	7.60	2.60	4.50	1.50
Bankfull Gradient (%)	2.60		1.50	
Radius of curvature (m)*	5		5	
Riffle-pool spacing (m)**	15		15	
Manning's roughness coefficient, *n*	0.040	0.035	0.040	0.035
Mean bankfull velocity (m/s) †	2.08	1.70	1.72	1.34
Bankfull discharge (m^3/s) †	0.71	1.09	0.71	0.95
Discharge to accommodate (m^3/s)	0.71		0.71	
Tractive force at bankfull (N/m^2)	224	128	154	81
Stream power (W/m)	528	279	313	140
Unit stream power (W/m^2)	414	199	241	100
Froude Number (unitless)	1.46	1.03	1.14	0.79
Maximum grain size entrained (m) ††	0.23	0.13	0.16	0.08
Mean grain size entrained††	0.16	0.07	0.11	0.04

* Based on Williams (1986)
** Based on Hey and Thorne (1986)
† Based on Manning's equation
†† Based on Shields equation assuming Shields parameter equals 0.06 (gravel)

Table 7: Bankfull parameters for Reaches 3 and 4 of the proposed channel

Channel Parameter	Reach 3		Reach 4	
	Riffle	Pool	Riffle	Pool
Bankfull width (m)	2.15	2.70	2.45	3.10
Average bankfull depth (m)	0.28	0.34	0.31	0.39
Maximum bankfull depth (m)	0.40	0.65	0.45	0.75
Bankfull width-to-depth ratio	7.75	8.03	7.78	8.03
Channel gradient (%)	3.50	0.95	1.80	0.45
Bankfull Gradient (%)	0.95		0.45	
Radius of curvature (m)*	6		7	
Riffle-pool spacing (m)**	18		21	
Manning's roughness coefficient, *n*	0.040	0.035	0.040	0.035
Mean bankfull velocity (m/s) †	1.71	1.16	1.33	0.88
Bankfull discharge (m^3/s) †	1.02	1.05	1.03	1.05
Discharge to accommodate (m^3/s)	1.02		1.02	
Tractive force at bankfull (N/m^2)	137	61	79	33
Stream power (W/m)	349	98	181	46
Unit stream power (W/m^2)	215	65	98	27
Froude Number (unitless)	1.04	0.64	0.76	0.45
Maximum grain size entrained (m) ††	0.14	0.06	0.08	0.03
Mean grain size entrained††	0.10	0.03	0.06	0.02

* Based on Williams (1986)
** Based on Hey and Thorne (1986)
† Based on Manning's equation
†† Based on Shields equation assuming Shields parameter equals 0.06 (gravel)

After preliminary geometries were determined, the radius of curvature and riffle-pool spacing were calculated using relations from Williams (1986) and Hey and Thorne (1986). As discussed above, once the planform parameters and bankfull geometries were determined, the channel centreline was designed, and geometries were finalized based on the final gradient.

6.2.1 Fish Passage

The near-bed velocity within the channel was modelled to determine whether fish passage is possible under the range of conditions expected for the low-flow channel. The velocity increases logarithmically with height above the bed surface in turbulent flows, through a relationship known as the von Karmen equation, or the Law of the Wall. Based on a knowledge of the bed materials, a theoretical height above the bed where velocity equals zero can be determined. The von Karmen equation is typically used to estimate the shear stress at the bed surface. However, a near-bed velocity can be back calculated using the average shear stress predicted for the low flow channel. The modelled velocity at a 0.01 m depth from the channel bed for the design reach 1 was approximately 0.19 m/s, reach 2 was approximately 0.26 m/s, reach 3 was approximately 0.25 m/s and reach 4 was approximately 0.28 m/s in the riffles at the 1.5-yr return flow.

These values are within the range of velocities tolerated by various species found within the watershed (i.e., brook stickleback, creek chub, etc.; Katopodis and Gervais, 2016). Additionally, channels with gradients less than 5.0% are possible for fish passage, and the realigned channel has gradients that are less than 5.0% (Newbury, 2013). As a result, the gradients and velocities within the realigned channel are not detrimental to fish passage for local species.

Given the impacts of agricultural land uses and limited channel form, the proposed realignment and naturalization of **Reaches IC-T1** and **IC-T3** provides a well-developed bankfull channel that will increase morphological variability and improve fish habitat and passage when compared to the existing conditions.

6.3 Channel Planform

The initial channel planform layout was created using the modelled radius of curvature value (*Rc*) as a guide. The radius of curvature (*Rc*) of meanders can be used to evaluate channel stability. For example, stable meanders typically exhibit larger *Rc* values as opposed to lower values that indicate increased channel bank erosion and avulsion. Bankful width is often an appropriate indicator for this instability. Hickin and Nanson (1983) note that channel avulsions are common when meander *Rc* is approximately 1-2 times the channel bankfull width. For larger *Rc* (e.g., >5), the upstream limb of the meander will migrate more rapidly than the downstream limb (Hooke, 1975). Based on the above bankfull widths, the radius of curvatures and feature spacing were determined.

Williams (1986) was used to derive values for the channel radius of curvature, using the following equation (Eq. 5):

$$R_C = 2.43 \times w \quad \text{[Eq. 5]}$$

where R_c is the radius of curvature and *w* is the average bankfull width.

Empirical models derived by Hey and Thorne (1986) were followed to determine riffle spacing. Hey and Thorne's (1986) modelled values are often applied in larger watercourses. As such, multiple methods (Eq. 6 – 8) were considered in order to provide a range of riffle spacing values. These are:

$$Z = 6.31 \times w \quad \text{[Eq. 6]}$$

$$Z = 9.1186 \times w^{0.8846} \quad \text{[Eq. 7]}$$

$$Z = 7.36 \times w^{0.896} \times S^{-0.03} \quad \text{[Eq. 8]}$$

where *Z* represents riffle spacing.

Stream power and unit stream power were calculated as a function of bankfull discharge and channel gradient (Eq. 9 – 10). Stream power values are important to determine the need for mitigating channel bank and bed erosion. Stream power is given by:

$$\Omega = \rho \times g \times d \times S \quad \text{[Eq. 9]}$$

where ρ is the density of water (kg/m^3), *g* is the acceleration due to gravity (m/s^2), and *Q* and *S* are discharge (m^3/s) and channel gradient, respectively.

Stream power per unit width (Eq. 6), is given by:

$$\omega = \frac{\Omega}{w} \quad \text{[Eq. 10]}$$

where as before, Ω and *w* are stream power and bankfull width, respectively.

The final channel planform is established through an iterative process. First, a cross-section with defined bankfull geometry was developed to calculate parameters for the planform (i.e., radius of curvature). The cross-section was further refined, and riffle and pool lengths were determined based on channel gradient.

6.4 Channel Substrate Hydraulic Sizing

The sizing of proposed substrate materials was guided by a review of hydraulic conditions (i.e., tractive force, flow competency) in the typical cross-sections. The channel bed substrate is derived by balancing the average shear stress acting on the bed with the critical shear stress for the material. When the critical shear stress slightly exceeds the average shear stress acting on the bed, sediment transport is initiated.

The riffle sections for all four design reaches have a mix of materials to provide a stable bed and a level of sorting. **Reach 1** to **4** have a mix of 70% granular 'B' and native material. Granular 'B' consists of a mix of stone where approximately 20% - 50% of the stone is greater than 0.005 m in diameter, but nothing larger than 0.15 m in diameter.

The granular 'B' is to be derived from pit-run material and contain no post-construction materials. This material maintains and enhances the character of the native material, while providing slightly higher stability and opportunity for sediment sorting. The gravel also provides opportunities for infiltration, filtration, and detention of water within the pore spaces to provide additional benefits by elongating the hydroperiod. The proposed mix will also improve aquatic habitat by increasing diversity between the riffle and pool substrates. These materials will always have a core of sediment that is not entrained under bankfull flow conditions. Native material is proposed for the pools given they experience lower velocities.

Immediately after construction, the outside bank of meander bends (i.e., cutbanks) may experience relatively higher erosive flows, which could lead to meander bend migration. As such, all cutbanks will be bioengineered for additional stability. For immediate erosion protection, a biodegradable erosion control blanket will be installed along the banks in riffle and pool sections. The blanket will biodegrade over time and live stakes will be installed in the immediate overbank areas to provide long-term soil stability.

6.5 Corridor Crossing Recommendations

Two future road crossings are proposed within the residential development at Street 'A' and Street 'D' that will cross the realigned **Reach IC-T3**. To support an appropriate tie-in with the channel, the dimensions for riffles and pools through the crossing are consistent with the channel upstream and downstream of the structure. Additionally, the proposed channel will remain relatively straight through he structure to limit lateral migration of meanders. To accommodate potential channel adjustments and associated erosion risk to the crossing infrastructure, the future crossing should span at least three times the bankfull channel width. Hydraulically sized stone will also be placed in the channel bed under the structure to minimize potential scour and lateral migration.

6.6 Channel Corridor

6.6.1 Corridor Sizing

The meander belt width delineation supports defining, in part, an appropriate bottom width for the valley corridor. Given the channel's low order, small scale, and vegetation control, this feature has little erosion hazard. The predicted meander belt widths for **Reach 1**, **Reach 2**, **Reach 3**, and **Reach 4** are 18 m, 19 m, 22 m, and 26 m, which all fit within the proposed valley corridor bottom widths. The proposed channel is also vegetation-controlled and will only be exposed to minor flows. The channel is anticipated to be stable once the vegetation has been established.

Regarding delineating the hazard associated with channel migration, the Ontario Ministry of Natural Resources treats confined and unconfined systems differently. Unconfined systems have poorly defined valleys or slopes outside where the channel could realistically migrate. In unconfined systems, the hazard is assumed to be from channel migration. Unconfined systems require a meander belt width. Given the channel size compared to the floodplain, this channel can be considered unconfined.

As part of the design, a meander belt width was calculated based on design bankfull dimensions to ensure that the planform has a meander belt width that falls within the existing corridor requirements. Given the watercourse scale and the system's limited migration potential, the calculated hazard limits

can be considered conservative. The meander belt width provided is based on modelled relations from Williams (1986), which were modified to include channel width and a factor of safety and applied using the bankfull channel dimensions such that:

$$B_w = (4.3{W_b}^{1.12} + W_b) \times 1.2 \quad \text{[Eq.11]}$$

Where B_w is meander belt width (m) and W_b is bankfull channel width (m). An additional 20% buffer, or factor of safety, was applied to the computed belt width value. This addresses issues of under-prediction and provides a factor of safety.The bankfull width of the proposed channel for **Reach 1**, **Reach 2**, **Reach 3**, and **Reach 4** have an average width of 1.96 m, 2.08 m, 2.43 m, and 2.78 m, respectively. A modified Williams (1986) model that includes the width of the channel and a factor of safety was applied. The resulting meander belt width estimates are provided in **Table 3**.

Table 3: Meander belt width estimates for the proposed Indian Creek

Reach	Meander Belt Width (m) (Modified Williams Width)*	Meander Belt Width (m) (Modified Ward Width)**	Proposed Corridor Bottom width (m)
Design Reach 1	14	15	20
Design Reach 2	15	16	20
Design Reach 3	17	19	25
Design Reach 4	20	22	25

*Based on modified Williams Width (1986) width method (Eq. 11)

**Based on Ward Width (2001) width method without factor of safety; included for comparison to previous report by Parish (2014)

6.6.2 Corridor Wetland Features

Online and offline wetland features are proposed within the floodplain and adjacent to the channel realignment. These features enhance terrestrial habitat by increasing diversity and providing a more natural floodplain form. They also provide functional benefits such as short-term water retention and sediment banking. They will be irregularly shaped to maximize the perimeter for a given area, which increases the potential for edge effects. Submerged and dry mounds are proposed within the offline wetlands to provide a topographically complex bottom to increase habitat heterogeneity. The short-term water retention function of these wetland types helps polish water and moderate water discharge into the channel.

The proposed offline wetlands have an average depth of 0.60 m., We have provided variability to ensure that a range of water depths and hydroperiods are provided from year to year. The depressional storage in the proposed designs will elongate the hydroperiod. Given the storage areas and the low grade on the floodplains, an area substantially more significant than just the depressional storage is anticipated to support wetland and wet meadow vegetation. Furthermore, the soils will likely have an extended hydroperiod. These features will be complemented by landscape restoration planting plans, which will be completed by others using appropriate native species.

6.6.3 Habitat Restoration

The design incorporates several habitat elements within the channel corridor to improve riparian habitat and promote wildlife biodiversity. The habitat design incorporates varying topographies and woody debris to maximize the potential for wildlife passage, forage and residency. The habitat elements proposed include brush mattresses, basking logs, brush piles, raptor poles, turtle nesting sites, rock piles and terrestrial mounds.

Brush mattress is proposed along the outside meander bend of the tortuous meanders and at the connection with the conveyance swale at the upstream extent. This treatment consists of live brush cuttings installed parallel to the banks and tied in with coir twine and stakes. The brush mattress will provide bank stability and improve aquatic habitat through shading.

Basking logs consist of a mixture of hardwood and softwood species, place in shallow areas of wetlands and anchored with a mix of stone or limestone blocks. These logs are angled in a way to promote turtle basking.

Pallet type wood piles consist of logs, snags and other wood debris, placed in a way that forms a stable interconnected mound, in the shape of a pallet. Additionally, the wood piles are planted with native fruit bearing vines, which provide forage opportunities for wildlife. Wood piles are placed at various locations along the length of the floodplain.

Raptor poles are constructed from large conifer tree trunks embedded into the ground, providing perches for larger raptors.

Turtle nesting sites are installed on south or west facing slopes away from the watercourse. These are constructed by excavating a small depression in the ground and filling it with granular 'A'/'M' material.

Rock piles consist of a mix of stone of varying sizes, piled up to create small mounds. These features provide hibernation habitat for various terrestrial species. The base of the piles is partially buried to prevent rock falls. Rock piles are installed at various locations along the length of the floodplain.

Terrestrial mounds consist of native material piled up to create small mounds with a small dimple on the top. The bottom of the mound is seeded with the specified seed mix, while the top has limited soil and seed on it to provide foraging opportunities.

The full channel corridor will be restored using native plant species. This includes appropriate species for the various seed mixes as well as woody vegetation. The plantings are intended to enhance the terrestrial habitat by providing species and habitat diversity, increasing floodplain soil stability and roughness, and increasing sedimentation. The landscaping plan has been prepared by others.

6.7 Natural Erosion Control

Newly constructed features can be vulnerable to erosion. This is particularly true before vegetation has been established along the channel banks. While low-flow events should not intensify erosion, the concern for erosion occurs when high flows or precipitation events occur during construction.

Immediately after construction, the outer banks of the meander bends (i.e., cutbanks) may experience relatively higher erosive flows, leading to meander bend migration. As such, all cutbanks are bioengineered for additional stability. A 100% biodegradable erosion control blanket and live stakes are installed along the banks in the riffle and pool sections for immediate erosion protection. Over time, the blanket will biodegrade, while the live stakes establish in the immediate overbank areas to provide long-term soil stability.

For long-term stability, implementing planting plans within each corridor is recommended. This includes deep-rooting native grasses and other herbaceous species seeded along and within channel sections, prescription of flood-tolerant native shrub and tree species, and use of seed banks within the local soil. Shrubs should be planted close to the channel margins to maximize stabilization and channel cover benefit.

Potential erosion locations (i.e., along the outside meander bends, immediately downstream of wetland features, etc.) should be anticipated and reflected in the planting plans. Live staking and shrub stock should be used adjacent to the channel bank to provide immediate benefit and long-term infilling. If appropriate live staking methods are followed, this method should provide more significant benefits than simple potted or bare root shrub planting as there is potential for higher densities with live staking. Brush mattress treatments are proposed to provide additional channel stability at the proposed pedestrian crossing.

7 Erosion Threshold Analysis

Erosion thresholds are used to determine the magnitude of flow required to potentially entrain and transport bed and/or bank material. An erosion threshold is often expressed as a critical streamflow

discharge or shear stress, at which the material within the watercourse will be mobilised. Changes in the magnitude, duration, and frequency of streamflow may alter the pattern and rates of channel erosion. Erosion thresholds are defined by assessing the morphology of the channel and the characteristics and condition of the bed and bank materials. Erosion sensitive reaches downstream of all storm water outlets were selected for analysis: **IC-T4**, **FC-6a**, **GC-T0A** and **GC-T4**. Downstream of these subject reaches the watercourses flow into engineered reaches or sewer systems, which are expected to be erosion resistant. Owing to an absence of field-based data available for all or portions of the subject reaches, some of the reach morphological data needed to define the reach erosion thresholds was obtained via desktop assessment. Additional erosion exceedance analysis was conducted using detailed assessment or remotely extracted data, with a unitary approach adopted to determine the area-weighted erosion threshold.

The erosion threshold is the theoretical point, typically expressed as a critical discharge or shear stress, at which entrainment of sediment would occur based on bed and bank materials. Due to variability between bed and bank composition and structure, erosion thresholds are determined for both bed and bank materials. The lower of the bed and bank erosion thresholds is adopted, as it provides the more conservative and limiting estimate of erosion potential.

7.1 Methodology

Erosion threshold targets are determined using different methods that are dependent on the sediment characteristics of the channel. For example, thresholds for non-cohesive sediments are commonly estimated using a shear stress approach, similar to that of Miller et al. (1977), which is based on a modified Shield's curve. A velocity approach could also be applied (Villard & Parish, 2003). For cohesive materials, a method such as that described by Komar (1987), or empirically derived values such as those compiled by Fischenich (2001), Chow (1959) or Julien (1994), could be applied. Villard and Parish (2003) emphasize the importance of selecting methods that reflect local sediment conditions and integrating them into site-specific geomorphic assessments.

An erosion threshold is quantified based on the bed and bank materials and local channel geometry, in the form of a critical discharge (Villard & Parish, 2003; TRCA 2012). Theoretically, above this discharge, entrainment and transport of sediment can occur. To determine this discharge, the velocity (U) or the shear stress (τ) is calculated at various depths for a representative cross-section until the average velocity or shear stress slightly exceeds the critical threshold of the bed material. Cross-sections and reach slopes were either surveyed in the field during detailed assessments, or extracted remotely from LiDAR DEM data. LiDAR derived cross-sections and sliopes are potentially lower resolution and have higher noise than field surveys, but are useful for determining channel conditions when field data are unavailable.

The velocity of the flow is determined using Manning's approach, where Manning's n value is visually estimated through a method described by Acrement and Schneider (1989) or calculated using the Limerino (1970) approach. The choice of Manning's n for each reach will be discussed separately below.

Velocity (U) is calculated as follows:

$$U = \frac{1}{n} d^{2/3} S^{1/2} \qquad \text{[Eq. 12]}$$

where d is the depth of water, S is the channel slope, and n is the Manning's roughness.

The shear stress is determined using the depth-slope product, which can be applied to the bed of open channels containing fluid undergoing steady flows. The shear stress is mathematically represented as:

$$\tau_0 = d\rho g S \qquad \text{[Eq.13]}$$

Where, τ_0 is shear stress, d is the water depth, ρ is water density, g is acceleration due to gravity, and S is the channel slope.

Because only 75% of bed shear stress applies to channel banks in uniform cross sections (Chow, 1959), the erosion threshold is scaled appropriately for these materials.

Where an erosion threshold is determined for a reach, the unitary erosion threshold is calculated from the drainage area as follows:

$$Q_u = Q_c / A_d$$

Where Q_u is the unitary erosion threshold in $m^3/s/ha$, Q_c is the critical discharge in m^3/s for the subject reach, and A_d is the drainage area in ha. It is assumed that is value will be consistent between adjacent reaches where hydraulic conditions such as slope, roughness, boundary materials and hydrology are comparable. This allows critical discharge to be estimated for reaches where insufficient data are available.

7.2 Results

7.2.1 Indian Creek

The erosion threshold was defined utilising detailed assessment data for **IC-T3** and remote and rapid assessment data for **IC-T4**. This allows for increased confidence in the remotely derived erosion threshold for **IC-T4** by comparing to **IC-T3** upstream.

The bed and banks of **IC-T3** were described as silt and clay during field assessments. However, the channel was densely vegetated with cattails, and the boundary materials are therefore described here as "reed plantings". The roots of the reeds provide additional cohesion to bed and bank materials, and the reed stalks increase flow resistance, both of which are likely to increase the erosion threshold and critical discharge of the reach. The critical shear stress of reed plantings was determined to be 10 Pa for both the bed and bank materials of **Reach IC-T3**, following Fischenich (2001). The bankfull slope of **Reach IC-T3** was 0.66 % and a relatively high value of 0.1 was selected for Manning's n through Reach **IC-T3**, primarily due to the dense in-channel vegetation.

These values result in erosion thresholds of **0.103 m^3/s** for the bed and **0.194 m^3/s** for the banks of **Reach IC-T3**. For a drainage area of 117.1 ha, this results in unitary erosion thresholds of 0.00092 $m^3/s/ha$ and 0.0017 $m^3/s/ha$ respectively. The conservative value of **0.00092 $m^3/s/ha$** is chosen as representative.

The bed material of **IC-T4** was coarse gravel and cobbles, reflecting the engineered erosion control on the reach. These gravels have a high critical shear stress, here conservatively estimated as 30 Pa, reflecting coarse pebbles (Julien, 1994). The banks of **IC-T4** were described as silt and clay during field assessments, densely vegetated with reeds and rushes, or with abundant tree roots. The rooted clayey soil was determined to have a very high critical shear stress, in the order of 25 Pa (Julian and Torres, 2006). The in-channel vegetation, described here as "reed plantings", has a critical shear stress of 10 Pa (Fischenich, 2001). In places, the clayey banks were observed to be eroding, lacking protection of either roots or vegetation. Therefore, the limiting bank material is taken as "fairly compact clay soil", with a critical shear stress of 7 Pa (Chow, 1959); however, this value is applicable only to short sections of the channel banks along this reach, and the majority of the reach is expected to be more erosion resistant. Bankfull slope extracted from LiDAR DEM data for **Reach IC-T4** was 0.54 % and a value of 0.1 was selected for Manning's n through **Reach IC-T4**, reflecting coarse bed material, moderate meandering and dense in-channel vegetation.

Using the above values, the erosion threshold for the channel banks of **IC-T4** is **0.132 m^3/s** (**Table 9**). Using the unitary erosion threshold of 0.00092 $m^3/s/ha$ for reach **IC-T3,** applied to a drainage area of 144.8 ha, gives an estimate erosion threshold for IC-T4 of **0.133 m^3/s** (**Table 10**). The differing approaches converging on the same value increases confidence that the calculated erosion threshold provides an accurate approximation of erosion threshold for the IC-T4.

The erosion threshold of the coarse bed material in **IC-T4** was many times bankfull discharge, nominally estimated as 4.579 m^3/s, though this value is limited by the extent of the LiDAR-derived cross sections and is likely a significant underestimation. The bed of **Reach IC-T4** is therefore expected to be stable at any reasonable predictable flows.

7.2.2 Falcon Creek

Rapid assessment field data were available for **FC-6b**, with only limited field data available for **FC-6a**. As a result, the erosion threshold for **FC-6a** was determined through a combination of remote assessment and sediment data from the upstream reach **FC-6b**.

The bed of **Reach FC-6b** was composed of gravel, with finer pebbles in pools and coarser cobbles on riffles. Without complete grainsize data, a nominal average calibre of 16 mm (medium pebbles) was used for this analysis. This material has a critical boundary shear stress of 15 Pa (Miller et al., 1977). The slope of Reach **FC-6b** was extracted from the LiDAR DEM and found to be approximately 0.55 %. A value of 0.058 was selected for Manning's n, reflecting the gravel bed, minor wood debris obstructions and in-channel vegetation, and a moderately meandering planform (Arcement and Schneider, 1989). These values result in an erosion threshold of the bed material of 0.586 m^3/s.

The observed bank material of **Reach FC-6b** was variable, with clast-supported pebble gravel, silty diamicton, sorted sands and fines, and shale bedrock all evident. The visible bedrock is consistent with mapped upper Ordovician Queenstown Formation, comprising fine grained sedimentary rocks (OGS 2011). The local surficial geology is mapped as transitional between the Halton Till and near-shore glaciolacustrine sediments (fines, sand and gravel), with a low (c. 1 m) ridge with southeast facing slope running through the study area, mapped as a palaeo-shoreline of glacial Lake Iroquois (OGS 2010). The site therefore reflects a transitional sedimentary environment, near the boundary of sorted glaciolacustrine sediment onlapping subglacial till. As a result, it is difficult to assign a single representative bank material to **Reach FC-6b**, as all observed sediment classes will have distinct erosion thresholds.

The rapid geomorphological assessments record that **Reach FC-6b** is primarily adjusting by widening, with many instances of bank slumping; this implies that the banks are more erodible than the bed. Field observations show that these small slumps primarily were occurring in sandy fines within sections of the reach expected to record littoral lacustrine sediment rather than subglacial till. These are taken as the limiting bank material, described here as "fairly compact clay soil", with a critical shear stress of 6 Pa following Chow (1959). This results in an erosion threshold of **0.179 m^3/s**. Other observed sediment within the assemblage along **Reach FC-6b** may have lower critical shear stress. However, these result in erosion thresholds well below the discharge recorded at the time of the field assessments, during which no mobilisation of bed or bank sediments was observed. The above erosion threshold therefore reflects a reasonable conservative value (i.e., lower bound estimate) for bank erosion along **Reach FC-6b**, in the absent of detailed sedimentological data for this reach.

The relatively low erosion threshold for the banks, and high threshold for the bed, is consistent with adjustment of the creek via widening as reported in the RGA. The bed through the reach is likely armoured at low-to-moderate discharges, with the bed gravel sourced partially from collapse of the gravel and till banks. This widening will likely continue untilthe channel reaches a new equilibrium state.

The conservative erosion threshold of **Reach FC-6b** is taken as the lower value established for the bank material: **0.179 m^3/s.** For a total contributing watershed area to **Reach FC-6b** of 203.5 ha, this results in a unitary erosion threshold of **0.00088 $m^3/s/ha$**.

Reach FC-6a is expected to have similar bed and bank materials to **FC-6b**, and the critical shear stresses identified above are applied (15 Pa for gravel bed material and 6 Pa for sandy fines on the banks). The value of 0.058 for Manning's n is also used, reflecting similar conditions within the reach. However, the extracted slope of **FC-6a** was determined to be 1.08 %, higher than **FC-6b**. This likely reflects flows down the slope of the shoreline landform identified and described above.

Utilising LiDAR-extracted cross-sections, the erosion threshold of **FC-6a** was determined to be 0.234 m^3/s for the bed and 0.084 m^3/s for the banks. For a drainage area of 272.3 ha, this gives a unitary threshold of 0.00086 $m^3/s/ha$ for the bed and 0.00031 $m^3/s/ha$ for the banks. These values are below comparable unitary threshold for the upstream reach **FC-6b** (0.00088 $m^3/s/ha$), which results in an erosion thresholds of 0.239 m^3/s. The lower erosion threshold determined through remote assessment better reflects the higher slope of **FC-6a** and is consistent with the expected hydraulic conditions.

Therefore, the conservative erosion threshold of **0.084 m^3/s**, with a unitary threshold of **0.00031 $m^3/s/ha$**, is chosen for this reach (**Table 9**).

7.2.3 Grindstone Creek North

Reaches GC-T1 and GC-T2 were flooded at the time of the rapid assessments, with multiple flow paths and large areas of standing water. As a result, it is difficult to rely on the field observations to define channels, boundary materials or make other observations to reliably assess the geomorphic conditions of the reaches. Downstream of **GC-T1** is a clearly defined channel leading from the flooded reach, here identified as **Reach GC-T0**; field observations of channel conditions and bondary materials were made for this reach, allowing assessment of the hydraulic conditions. This channel appears on available LiDAR DEM data (OMNRF, 2019), allowing cross-sections and channel slope to be extracted via desktop analysis. The extracted cross-sections are low-resolution and do not necessarily capture the precise channel geometry; however, they are useful for approximating conditions and setting a conservative erosion threshold for the subject reach. The extracted slope of this reach was 1.11%. A value of 0.066 was used for Manning's n based on fine boundary materials and moderate in-channel obstructions and vegetation. The depth of flow during the field survey was recorded as between 0.04 and 0.06 m without erosion observed, providing a constraint on the erosion threshold.

The channel was bounded by a friable silt-clay till with low gravel concentrations; this texture is typical of the local Halton Till and coincides with its mapped extent in this area. Clayey facies of the Halton Till have been assessed as having critical shear stress of around 9 Pa when saturated (Yeats, 2021), applicable to the bed material. The friable nature of the bank material implies weakening of the clayey structure by wet-dry or freeze-thaw cycles, which results in higher erosion sensitivity; Yeats (2021) records critical shear stress of weakened Halton Till around 1 to 1.5 Pa based on flume studies. However, the presence of abundant roots increases bank cohesion and reduces erodibility by a factor of around 5 to 19 (Julian and Torres, 2006); the value of 9 Pa, reflecting this root cohesion, is maintained for the till bank material.

Utilising the above critical shear stress and hydraulic properties of the channel, the erosion threshold for the bed is estimated as **0.023 m^3/s** (**Table 9**) for a flow depth of approximately 0.08 m. The bank material has an erosion threshold of **0.037 m^3/s** at a depth of approximately 0.11 m.

Taking the erosion threshold of the bed material as the conservative value, the unitary erosion threshold of the downstream reach of **GC-T0** was determined to be **0.00074 $m^3/s/ha$** for a drainage area of 31.1 ha. This value is lower than the adjacent watercourses and may reflect the high gradient of the remotely extracted reach or recent adjustment caused by the local flooding of the upstream reaches. Using the average unitary erosion threshold determine for FC-6b and IC-T3 of 0.00091 $m^3/s/ha$ gives an erosion threshold of 0.028 m^3/s. The similarity of this value to that determined via the remotely extracted data encourages acceptance of the latter as a similar but lower-bound estimate, giving a conservative erosion threshold for **Reach GC-T0** of **0.023 m^3/s.**

Reach GC-T0 confluences with a south-flowing tributary of Grindstone Creek, creating **Reach GC-T0A** with a combined drainage area of 87.7 ha. No data are available for this reach, and the channel undefined on LiDAR DEM data (OMNRF, 2019), preventing use of remote assessment techniques. Therefore, a unitary approach was taken. Assuming the reach slope, roughness and boundary materials are similar between **GC-T0** and **GC-T0A**, the unitary erosion threshold of 0.00074 $m^3/s/ha$ for **GC-T0** was applied, resulting in an erosion threshold for GC-T of **0.065 m^3/s** (**Table 10**).

7.2.4 Grindstone Creek South

Reach GC-T3 drains into an engineered ditch running westwards alongside the CN rail yard, eventually discharging into Grindstone Creek. Limited information is available for the boundary materials and hydraulic parameters of this ditch. A representative cross-section was extracted from LiDAR, revealing a broad, 1.10 m deep trapezoidal channel. The bed slope extracted from LiDAR DEM data was on the order of 0.001, and available photographs suggest that the bed and banks of the ditch are lined with cobble-grade riprap. This material has a high erosion resistance, with a conservative critical shear stress of 30 Pa applied here, applicable to coarse pebbles (Julien, 1994). The Manning's *n* for the drainage ditch was determined to be 0.04 (Arcement and Scheider, 1989). Using these values, the bankfull discharge was determined to be 2.417 m^3/s (**Table 9**), at which the

calculated shear stress of the bed and banks is 6.73 Pa and 5.05 Pa respectively. Therefore, the engineered channel is expected to be stable at discharges well in excess of bankfull.

Table 4. Results of erosion threshold analysis

Channel Parameter	IC-T3	IC-T4[1]	FC-6a[2]	FC-6b[1]	GC-T0[1]	GC-S[2]
Average bankfull channel width (m)	2.96	3.87	8.69	4.74	4.90	6.22
Average bankfull channel depth (m)	0.15	0.30	0.85	0.46	0.15	0.69
Channel gradient (%)	0.66	0.5	1.08	0.55	1.11	0.1
D_{50} (mm)	< 2	< 2	16	16	< 2	-
D_{84} (mm)	< 2	< 2	64	64	< 2	64
Manning's n roughness coefficient	0.1	0.1	0.058	0.058	0.066	0.04
Drainage area (ha)	112.1	144.8	272.3	203.5	31.1	0.04
Bankfull discharge (m^3/s)	0.103	1.073	10.28	1.535	0.256	2.42
Average bankfull velocity (m/s)	0.22[4]	0.93	1.47	0.71	0.39	0.58
	Bed	**Bank**	**Bank**	**Bank**	**Bed**	**Bed**
Limiting Material	Reed plantings	Fairly compact clay soil	Fairly compact clay soil	Fairly compact clay soil	Clayey till	Coarse Gravel
Reference	Fischenich (2001)	Chow (1959)	Chow (1959)	Chow (1959)	Yeats (2021)	Julien (1994)
Critical depth (m)	0.15	0.21	0.15	0.15	0.08	-
Critical shear stress (N/m^2)	10.0	10.0	8.0	8.0	9.0	30
Critical velocity (m/s)	0.22	0.27	0.35	0.35	0.25	-
Critical discharge (m^3/s)	**0.103**	**0.132**	**0.084**	**0.179**	**0.023**	**> 2.417**
Unitary erosion threshold ($m^3/s/ha$)	**0.00092**	**0.00091**	**0.00031**	**0.00088**	**0.00074**	**-**

1. Rapid assessment and remote data.
2. Remote data

Table 5. Results of unitary erosion threshold analysis

Reach	Unitary erosion threshold ($m^3/s/ha$)	Drainage area (ha)	Erosion threshold (m^3/s)
GC-T0A	0.00074	87.7	**0.065**
FC-6a	0.00088	272.3	0.239
IC-T4	0.00092	144.8	**0.133**

8 Erosion Exceedance Analysis

In support of the proposed Stormwater Management (SWM) plan, an erosion exceedance analysis was completed for reaches **GC-T, GC-T4, FC6a** and **IC-T4** which were identified as the most erosion-sensitive reaches downstream of storm water outlets. The application of erosion threshold analysis for evaluating the effectiveness of stormwater management facilities in mitigating changes in downstream erosion potential is a concept developed with support by a co-author of the present report (Villard and Parish, 2003)) and used widely across Ontario (e.g., TRCA, 2012; CVC, 2015).

Urbantech (2026) provided hydrologic simulations modelling discharge in the analysed reaches, comprising pre- and post-development projections of 2-, 5-, 10-, 25-, 50 and 100-year floods; an additional 25 mm storm event was also modelled for reach **IC-T4**. Hydrographs for reaches **GC-T**, **GC-T4** and **FC-6a** were in 5-minute timesteps, while **IC-T4** was modelled in 2-minute timesteps. The critical discharge used for each reach is summarised in **Table 11** below.

Table 6. Summary of selected erosion thresholds

Reach	Erosion threshold (m^3/s)	Source
GC-T	0.065	Unitary approach from GC-T0 (remote extraction)
GC-T4	2.417	Bankfull discharge from LiDAR data; expected to be stable
FC-6a	0.084	Remotely extracted data
IC-T4	0.132	Remotely extracted data and unitary from IC-T3

8.1 Methods

To calculate erosion indices, both velocity and shear stress were calculated at each time step. Through an iterative process, water depth and velocity were calculated for each discharge passing through a representative cross-section. The cross-section is divided into floodplain and bankfull sections. The cross-section is further broken into panels. Velocity (U) is calculated for each panel using the Manning's approach. This is a conservative approach as it allows dissipation of flood energy in the floodplain.

The total discharge, Q_T at each time step is based on the summation of the discharge of all panels, Q_i, such that:

$$Q_{T=} \sum Q_i \quad \text{[Eq. 14]}$$

Q_i is discharge through a panel (which is set at 10 percent of the cross-section). Q_i is defined as:

$$Q_i = U_i w_i d_i \quad \text{[Eq. 15]}$$

where, w_i and d_i are width and depth for each panel. The discharge for each panel was then summed to give a total discharge. This is more accurate than using average cross-sectional dimensions of a simple trapezoidal channel, as the bed is usually irregular, and a panel approach more accurately represents the true cross-sectional area.

For each event, the discharge is converted into a maximum depth and average velocity. The maximum depth is used to calculate a maximum bed shear stress, $\tau_{o_{\max}}$ based on:

$$\tau_{o_{\max}} = d_{\max} \rho g S_{\text{bed}} \quad \text{[Eq. 16]}$$

where, $d_{\max}$ is the maximum water depth, ρ is water density, g is acceleration due to gravity, and S_{bed} is the channel bed slope.

Cumulative total work, ω_{tot} is defined as:

$$\omega_{\text{tot}} = \sum \tau_{0_{\max}} . U_{\text{avg}} . \Delta t \quad \text{[Eq.17]}$$

where, U_{avg} is average velocity (Q_{tot}/A_{tot}, where A_{tot} is wetted area), while cumulative effective work index (ω_{eff}) is defined by:

$$CEWI = \sum \tau - \tau_{cr} . U . \Delta t, \omega < 0 = 0 \quad \text{[Eq. 18]}$$

where, τ_{cr} is the critical shear stress.

Time of exceedance t_{ex} defined as:

$$t_{\text{ex}} = \sum \Delta t \quad \text{for } (Q_T > Q_{\text{threshold}}) \quad \text{[Eq. 19]}$$

where, $Q_{\text{threshold}}$ is the discharge at the erosion threshold.

The cumulative effective discharge volume (CEV) is defined as:

$$\text{CEV} = \sum Q \text{ (for } Q > Q_{threshold}) \quad \text{[Eq. 20]}$$

Similarly, the cumulative effective discharge (CED) is defined as:

$$\text{CED} = \text{CEV}/t_{ex} \quad \text{[Eq. 21]}$$

8.2 Results

The summary results for all modelled reaches and storm scenarios are presented in **Table 12**.

Results of the event-based erosion exceedance modelling for **GC-T0A** show minor increases in exceedance duration (0 to 8.05 %) with minor reductions in CED (0.42 to 0.65 %). CEWI can not be estimated for GC-T0A due to the lack of reliable cross-section data. The results of this analysis demonstrate that the SWMP is effective in reducing the erosion risk within the reach by extending retention of storm water and reducing the peak flows.

Results of exceedance modelling for **GC-T4** result in no exceedance events for any of the storm scenarios. The channel is defined as stable and is expected to remain stable under post-development conditions.

The results of the exceedance modelling for **FC-6a** show minor increases in erosion metrics. Exceedance duration increases by 1 to 2 %, and CEV increases by 0.31 to 0.64 %. This results in

minor increases in CEWI of 0.39 to 0.51 %. These minor increases reflect a negligible increase in the erosion for **FC-6a** and should be interpreted as post-development matching pre-development conditions.

Exceedance modelling results for **IC-T4** show significant increases in erosion potential in all storm scenarios. Cumulative effective discharge increase by between 3 and 8 %, with exceedance duration increased by 10 to 16 %. This results in increases in CEWI of between 15.5 and 20.4 % for the 2- to 100-year return interval events, indicating a significant increase in erosion potential. The 25 mm event has a 5.8% increase in CEWI, indicating a minor increase in erosion potential for smaller storm events. Model results project that Reach **IC-T4** is likely to see increased erosion during large magnitude storm events as a result of the proposed development.

Table 7. Results of event-based erosion exceedance analysis

Return Interval Scenario		FC-6a			IC-T4			GC-T0A	
		CEV (m^3)	CEWI (N/m)	t_{ex} (hrs)	CEV (m^3)	CEWI (N/m)	t_{ex} (hrs)	CEV (m^3)	t_{ex} (hrs)
25 mm	(PRE)	N/A			6,324	7.8	4.0	N/A	
	(POST)				6,499	8.2	4.4		
	Change (%)				**2.77**	**5.84**	**10.00**		
2-year	(PRE)	29,237	258.6	29.3	14.5	48.0	16.1	7,969	6.9
	(POST)	29,425	260.4	29.7	15.4	57.8	18.6	7,934	6.9
	Change (%)	**0.64**	**0.68**	**1.42**	**6.45**	**20.39**	**15.50**	**-0.43**	**0.00**
5-year	(PRE)	61,251	479.3	30.8	16.1	69.1	18.0	11,409	7.1
	(POST)	61,508	481.8	31.3	17.0	80.8	20.9	11,335	7.2
	Change (%)	**0.42**	**0.51**	**1.63**	**5.58**	**16.89**	**15.90**	**-0.65**	**1.18**
10-year	(PRE)	83,624	617.9	31.3	17.0	81.7	19.0	13,697	7.2
	(POST)	83,944	621.0	31.8	18.2	94.8	22.0	13,607	7.3
	Change (%)	**0.38**	**0.51**	**1.60**	**7.05**	**16.14**	**15.59**	**-0.65**	**2.33**
25-year	(PRE)	112,705	791.3	32.1	18.3	97.4	20.1	16,646	7.3
	(POST)	113,086	794.8	32.7	19.5	112.7	23.0	16,554	7.8
	Change (%)	**0.34**	**0.44**	**1.82**	**6.93**	**15.68**	**14.78**	**-0.56**	**8.05**
50-year	(PRE)	134,510	916.2	32.6	19.0	109.1	20.7	18,836	7.4
	(POST)	134,942	920.1	33.1	20.4	126.2	23.6	18,743	8.0
	Change (%)	**0.32**	**0.42**	**1.53**	**7.19**	**15.69**	**14.03**	**-0.50**	**7.87**
100-year	(PRE)	156,510	1033.8	32.9	19.6	120.4	21.2	21,062	7.9
	(POST)	156,989	1037.9	33.3	21.1	139.1	24.0	20,973	8.0
	Change (%)	**0.31**	**0.39**	**1.27**	**8.01**	**15.53**	**13.03**	**-0.42**	**1.05**

The proposed stormwater management plan effectively mitigates erosion risk for receiving reaches **FC6a** and **GC-T0A**. The erosion exceedance analysis indicates that there is a post-development increase in erosion potential for **IC-T4**, which receives flows from the two proposed SWM ponds. Note that the conservatively defined erosion threshold for **IC-T4** is based on a desktop assessment and that the erosion threshold will be refined once field assessments of the subject reach are complete in Spring 2026. While the erosion exceedance analysis indicates post-development increases in CEWI for **IC-T4** which range from 15-20% we expect that the predicted increases can be adequately addressed through either optimization of the SWM plan and/or refinement of the erosion threshold following field-based assessments of the subject reach. We also note that the erosion threshold for reach IC-T4 is lowered by short sections of erodible bank material that were observed within the reach, and the gravel bed and vegetated banks of the channel are otherwise relatively erosion resistant; strengthening of the erodible sections of bank would increase the erosion threshold of the whole reach.

9 Design Implementation

9.1 Construction Timing

Based on resident fish species and their respective life cycles, in-stream work is restricted to July 15thto March 15th unless otherwise directed by the Ministry of Natural Resources (MNR).

Vegetation removals associated with clearing, site access and staging should occur outside the key breeding bird period identified by Environment Canada for migratory birds to ensure compliance with the *Migratory Birds Convention Act, 1994* (MBCA) and *Migratory Bird Regulations*. The breeding season for migratory birds in this part of the country typically extends from as early as March 1 to as late as September 15. Should tree removals be required during critical breeding bird season, a qualified biologist should inspect those trees to ensure they do not contain nesting birds. It is understood that the MBCA is not limited to cutting woody vegetation but also applies to topsoil stripping and grubbing activities, as there are ground nesting bird species protected under the Act.

9.2 Best Management Practices

Site inspection should be performed by an inspector with experience overseeing channel works, as this type of work differs considerably from engineering projects. An experienced inspector will be able to provide quick and appropriate response to issues that may arise and ensure that construction proceeds in accordance with the approved design and contract.

The limits of construction will be delineated to prevent unanticipated impacts to natural surroundings, including trees and the existing watercourse. Flows are conveyed around the work area uninterrupted through a temporary diversion channel or with a cofferdam and pump system so the channel can be constructed fully isolated from the active flow area. This will limit downstream impacts such as sediment loading.

All isolated work areas will be dewatered to perform work under dry conditions. Water will be pumped to a sediment filtration system at least 30 m from the receiving creek and allowed to naturally flow over a well-vegetated surface and ultimately return to the channel downstream of the work area. This will allow particles to settle before reaching the watercourse.

All materials and equipment will be stored and operated in such a manner that prevents any deleterious substances from entering the water. Vehicle and equipment re-fuelling and/or maintenance will be conducted away from the watercourse, free of fluid leaks, and externally cleaned/degreased to prevent the release of deleterious substances.

9.3 Post-Construction Monitoring

A post-construction monitoring program is recommended to assess the performance of the implemented channel design. Monitoring observations can also be used to determine the need for remedial works. The following activities should be undertaken by a fluvial geomorphologist and completed on a seasonal basis (i.e., spring and fall), unless otherwise indicated, for a period of three

years following the year of construction. Biennial monitoring is recommended should the monitoring period extend beyond three years post-construction, as most potential channel adjustments would occur in the first one to two years following construction.

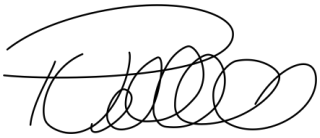
The following monitoring and reporting activities are suggested for the realigned channel:

- General observations of the channel works should be documented after construction and after the first large flooding event to identify any potential areas of erosion concern
- Monitoring should occur two times per year, after spring freshet and prior to the onset of winter conditions, and will continue for 3 years
- An initial baseline survey should be completed after the channel has been constructed; subsequent surveys should be tied into this baseline survey
- A detailed photo record of the entire channel will be required. Photos should start at the upstream end of the channel and be sufficiently spaced to allow for coverage of the entire channel. During the initial photo record, GPS locations of the photos should be recorded, and these should be the locations from where subsequent photos are taken. Alternatively, a high-resolution orthorectified aerial photo of the entire channel length can be created using an unmanned aerial vehicle (UAV) to document the channel planform. This image should be generated in the spring prior to the onset of vegetation growth
- Total station survey of the longitudinal profile and 10 cross sections following construction for the entire realignment. Channel cross-section surveys should be an equal mix of geomorphic unit types. At least two of the cross-section surveys should be monumented and georeferenced. The longitudinal profile and monumented channel cross sections would serve as the as-built reference condition for use in comparing surveys completed in subsequent years
- Re-survey of the longitudinal profile and cross sections in subsequent years after construction
- Installation of erosion pins at monumented cross sections after construction and monitoring of the erosion pins during subsequent years. Pins are to be placed on both banks, within the low flow channel. Erosion pins must be formally surveyed, including the end of the pins and their entry points into the banks, to ensure their locations and exposure are accurately recorded. Erosion pins must be resurveyed each year to ensure they have not moved due to flow, being physically hit or frost heave.
- Bed material characterization based on Wolman (1954) pebble counts or bed sample, as appropriate, annually
- General vegetation surveys completed annually after construction, for the duration of the monitoring period
- Annual reporting to summarize construction activities (i.e., design implementation), and subsequent year-end reports for the duration of the monitoring period
- A qualified fluvial geomorphologist should undertake monitoring activities

The monitoring would commence immediately after construction, and sites would be reviewed annually to identify the system's natural variability. Reporting would be provided annually prior to March 1st of the following year, with a summary report at the end of the monitoring period.

We trust this report meets your requirements. Should you have any questions please contact us.

Respectfully submitted,



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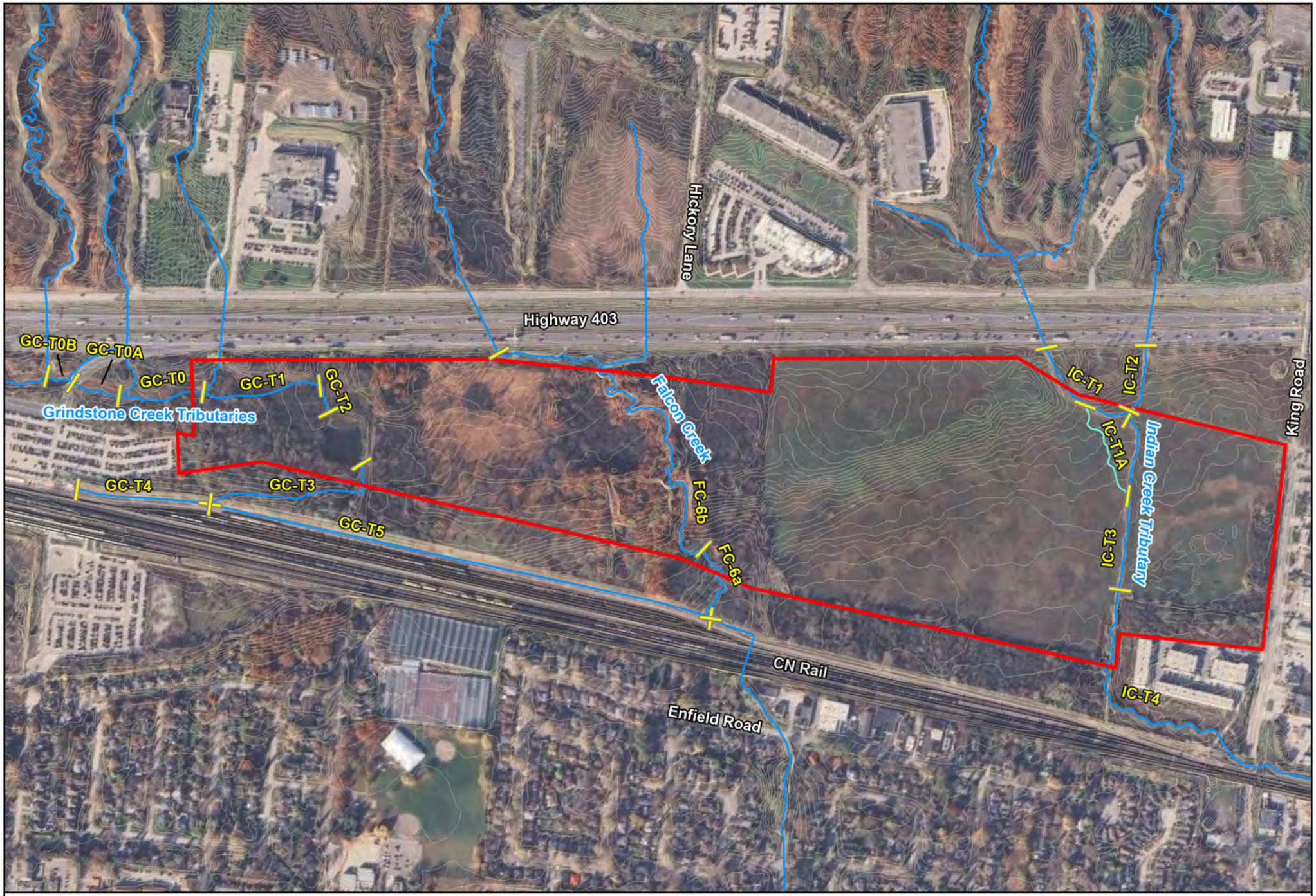
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Appendix A:
Site Map



Legend

- Reach Break and ID (ID-T1)
- Watercourse
- Avulsion Channel
- 0.5 m Contour
- Study Area

1200 King Road

Study Area and
Reach Delineation
Burlington, Ontario

GEO MORPHIX™

0 100 200
Metres

Imagery: Google Earth Pro, 2025. Watercourse: MNR, 2020. 0.5 m Contour: City of Burlington, 2024. Avulsion Channel: GEO Morphix Ltd., 2023. Study Area: Urbantech, 2024. Reach Break and ID: Parish, 2014/ GEO Morphix Ltd., 2023. Print Date: February 2026. PN23010. Drawn By: L.D., G.U.

DRAFT DRAFT

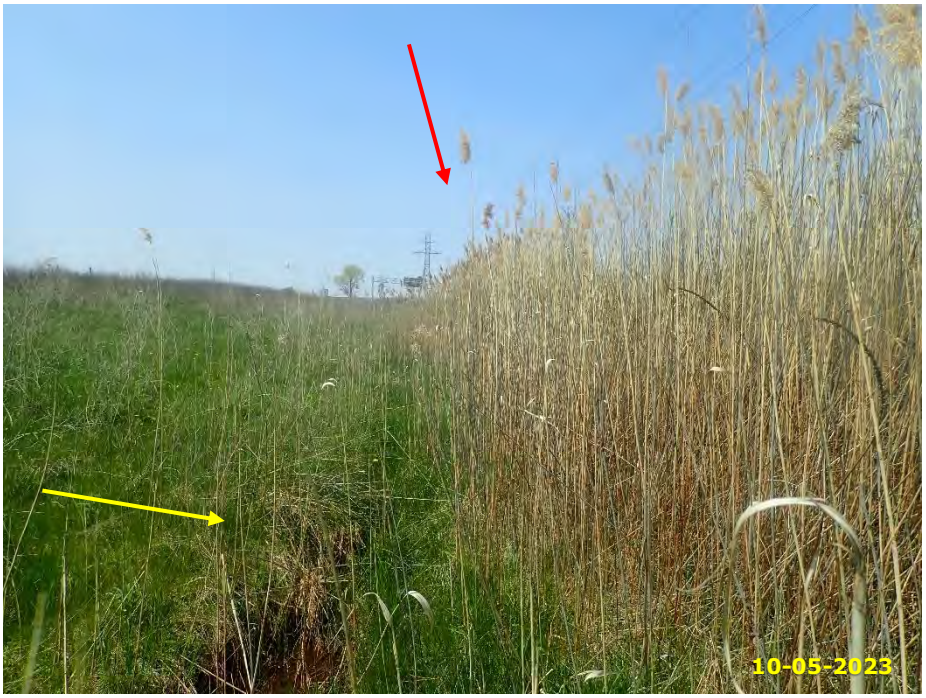
Appendix B:
Photographic Record

2023 Indian Creek Site Photographs

Photo 1 Indian Creek **Reach IC-T1**	
	The upstream extent of Reach IC-T1 just south of Hwy 403 (view of channel is obscured by dense reeds); perspective is facing upstream.
Photo 2 Indian Creek **Reach IC-T1 & Reach IC-T1A**	
	The middle extent of Reach IC-T1 where overland flow departs from the reach and connects to the avulsion channel IC-T1A (yellow arrow); perspective is facing upstream.

2023 Indian Creek Site Photographs

Photo 3
Indian Creek
Reach IC-T1 & Reach IC-T1A



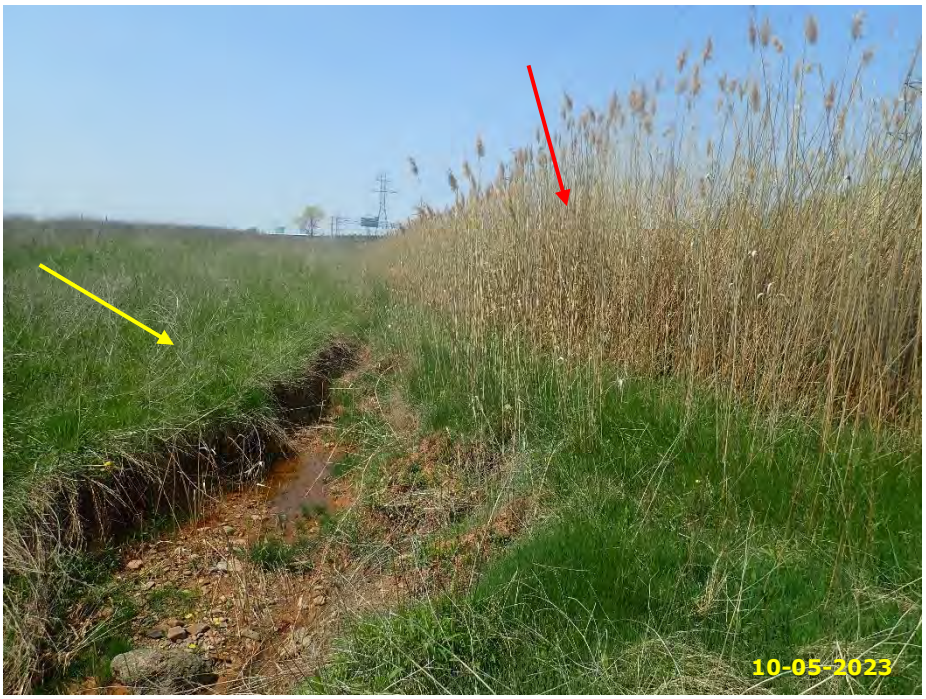
Reach IC-T1 (red arrow) where overland flow transitions to the upstream end of the avulsion channel IC-T1A (yellow arrow); perspective is facing upstream.

Photo 4
Indian Creek
Reach IC-T1



The downstream extent of Reach IC-T1; perspective is facing upstream.

2023 Indian Creek Site Photographs

Photo 5 Indian Creek **Reach IC-T1**	
	A view of the vegetation and substrate along the channel bed in Reach IC-T1.
Photo 6 Indian Creek **Reach IC-T1 & Reach IC-T1A**	
	Reach IC-T1 (red arrow) adjacent to the upstream extent of the avulsion channel IC-T1A (yellow arrow); perspective is facing upstream.

2023 Indian Creek Site Photographs

Photo 7 Indian Creek **Reach IC-T1 & Reach IC-T1A**	 Reach IC-T1 (red arrow) adjacent to the upstream extent of the avulsion channel IC-T1A (yellow arrow); perspective is facing downstream.
Photo 8 Indian Creek **Reach IC-T1A**	 Undercut right bank within the upstream extent of the avulsion channel IC-T1A, clay till is visible along the channel bed (red arrow); perspective is facing downstream.

2023 Indian Creek Site Photographs

Photo 9 Indian Creek **Reach IC-T1A**	
	Gravel and cobble sized substrate within the middle extent of IC-T1A; perspective is facing downstream.
Photo 10 Indian Creek **Reach IC-T1A**	
	Standing water, slumping along the left bank, and fracturing along the right bank within the middle extent of the avulsion channel IC-T1A; perspective is facing downstream.

2023 Indian Creek Site Photographs

Photo 11 Indian Creek **Reach IC-T1A**	
	Standing water and silt to gravel sized substrate within the middle extent of IC-T1A; perspective is facing downstream.
Photo 12 Indian Creek **Reach IC-T1A**	
	A pool of standing water and undercut right bank within the downstream extent of IC-T1A; perspective is facing downstream.

2023 Indian Creek Site Photographs

Photo 13
Indian Creek
Reach IC-T1A



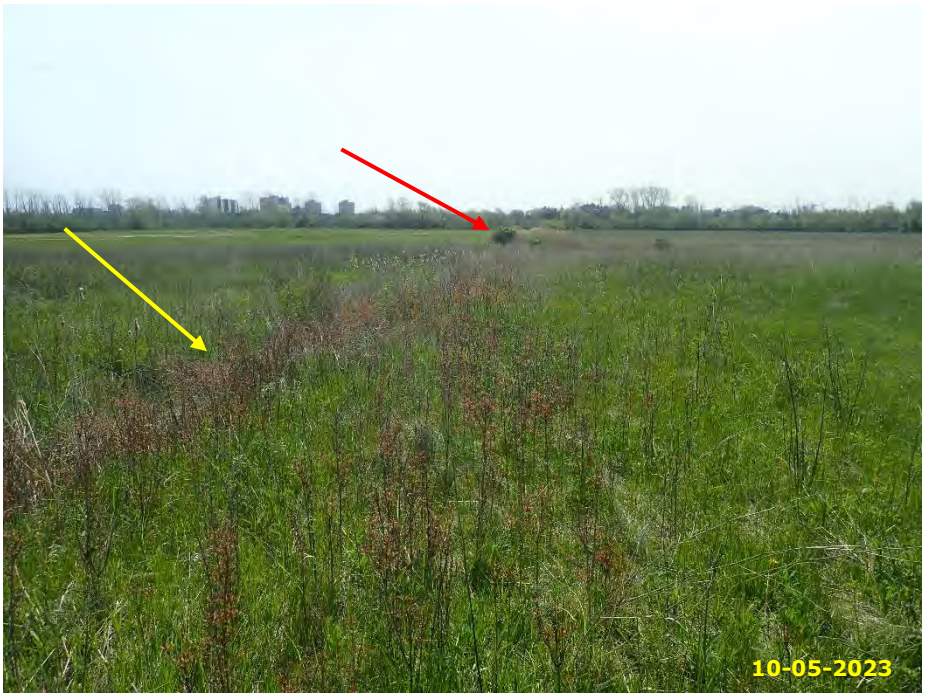
Downstream extent of IC-T1A where it transitions from a defined channel to multiple poorly-defined flow paths overland; perspective is facing downstream.

Photo 14
Indian Creek
Reach IC-T1A & Reach IC-T3



Downstream extent of IC-T1A where there are multiple poorly-defined flow paths overland (yellow arrow) that flow into IC-T3 (red arrow); perspective is facing downstream.

2023 Indian Creek Site Photographs

Photo 15 Indian Creek **Reach IC-T2**	
	Upstream extent of IC-T2 just south of Hwy 403, channel is obscured by dense reeds; perspective is facing upstream.
Photo 16 Indian Creek **Reach IC-T2**	
	Upstream extent of IC-T2 (yellow arrow) just south of Hwy 403, confluence with IC-T1 and IC-T3 is visible in the background (red arrow); perspective is facing downstream.

2023 Indian Creek Site Photographs

Photo 17 Indian Creek **Reach IC-T2**	
	View of the upstream side of a culvert beneath a crossing within the middle extent of Reach IC-T2.
Photo 18 Indian Creek **Reach IC-T2**	
	View from atop the crossing within the middle extent of IC-T2; perspective is facing upstream.

2023 Indian Creek Site Photographs

Photo 19 Indian Creek **Reach IC-T2**	
	Downstream extent of Reach IC-T2; perspective is facing upstream.
Photo 20 Indian Creek **Reach IC-T1, Reach IC-T2, & Reach IC-T3**	
	View of the confluence of IC-T1 (yellow arrow), IC-T2 (yellow arrow), and IC-T3 (blue arrow); perspective is facing upstream.

2023 Indian Creek Site Photographs

Photo 21 Indian Creek **Reach IC-T3**	
	View of substrate and vegetation along the channel bed within the upstream extent of IC-T3.
Photo 22 Indian Creek **Reach IC-T3**	
	Upstream extent of IC-T3, channel is obscured by dense reeds; perspective is facing upstream.

2023 Indian Creek Site Photographs

Photo 23 Indian Creek **Reach IC-T3**	
	Middle extent of IC-T3, channel is obscured by dense reeds; perspective is facing downstream.
Photo 24 Indian Creek **Reach IC-T3**	
	View of the right bank at XS6 within the middle extent of IC-T3; perspective is facing southwest.

2023 Indian Creek Site Photographs

Photo 25
Indian Creek
Reach IC-T3



View of the upstream side of a crossing over the channel with a disjointed concrete culvert (yellow arrow) between agricultural fields within the middle extent of IC-T3 at XS5; perspective is facing upstream.

Photo 26
Indian Creek
Reach IC-T3



A view of the substrate and vegetation surrounding the culvert on the upstream side of the crossing near XS5.

2023 Indian Creek Site Photographs

Photo 27 Indian Creek **Reach IC-T3**	
	View of downstream side of crossing with disjointed concrete culvert (yellow arrow) within the middle extent of IC-T3 at XS4, channel is obscured by dense reeds; perspective is facing west (upstream)
Photo 28 Indian Creek **Reach IC-T3**	
	Viewing XS3 (yellow arrow) within the downstream extent of IC-T3; perspective is facing north (upstream).

2023 Indian Creek Site Photographs

Photo 29 Indian Creek **Reach IC-T3**	
	Viewing XS1 within the downstream extent of IC-T3; perspective is facing downstream.
Photo 30 Indian Creek **Reach IC-T3**	
	Downstream extent of IC-T3 where a small tributary meets the channel (yellow arrow); perspective is facing north.

2023 Indian Creek Site Photographs

Photo 31 Indian Creek **Reach IC-T4**	
	Upstream end of IC-T4; perspective is facing upstream.
Photo 32 Indian Creek **Reach IC-T4**	
	A meander within the upstream extent of Reach IC-T4; perspective is facing upstream.

2023 Indian Creek Site Photographs

Photo 33 Indian Creek **Reach IC-T4**	
	A riffle within the upstream extent of Reach IC-T4; perspective is facing upstream.
Photo 34 Indian Creek **Reach IC-T4**	
	A meander within the upstream extent of IC-T4; perspective is facing upstream.

2023 Indian Creek Site Photographs

Photo 35 Indian Creek **Reach IC-T4**	
	Woody debris across the channel within the upstream extent of IC-T4; perspective is facing downstream.
Photo 36 Indian Creek **Reach IC-T4**	
	A pool and riffle sequence downstream of the woody debris within the upstream extent of IC-T4; perspective is facing upstream.

2023 Indian Creek Site Photographs

Photo 37 Indian Creek **Reach IC-T4**	
	Embedded cobble along the outside bank of a meander bend within the middle extent of IC-T4; perspective is facing upstream.
Photo 38 Indian Creek **Reach IC-T4**	
	Pool riffle sequence within the middle extent of IC-T4; perspective is facing upstream.

2023 Indian Creek Site Photographs

Photo 39 Indian Creek **Reach IC-T4**	
	Channel bed conditions within the middle extent of IC-T4; perspective is facing slightly upstream.
Photo 40 Indian Creek **Reach IC-T4**	
	A railway embankment and floodplain conditions along the right bank of IC-T4; perspective is facing south (upstream).

2023 Indian Creek Site Photographs

Photo 41 Indian Creek **Reach IC-T4**	
	Channel conditions within the downstream extent of IC-T4, dense reeds within the channel are visible (yellow arrow); perspective is facing upstream.
Photo 42 Indian Creek **Reach IC-T4**	
	An embankment and floodplain conditions along the left bank of IC-T4; perspective is facing west(upstream).

2026 Rapid Assessment Photographs

Photo 43 Grindstone Creek **Reach GC-T1**	
	Poor channel definition and heavy encroachment were characteristic of **Reach GC-T1.** A distinct flow path was observed in the downstream extent but did not continue upstream; perspective is facing upstream.
Photo 44 Grindstone Creek **Reach GC-T1**	
	The dominant vegetation types within **Reach GC-T1** were trees with some localized gaps dominated by herbaceous plants. Note woody debris is present but is the consequence of sickly vegetation rather than widening; perspective is facing east (upstream)**.**

2026 Rapid Assessment Photographs

Photo 45 Grindstone Creek **Reach GC-T1**	
	Reach GC-T1 substrates consisted of loamy fines and were covered in a thick layer of leaf litter at the time of assessment; perspective facing upstream.
Photo 46 Grindstone Creek **Reach GC-T1**	
	The confluence between **GC-T1** and **GC-T2** was not apparent at the time of assessment Flow conditions ranged from isolated pools of standing water to discontinuous slow glides over ice; perspective facing northeast.

2026 Rapid Assessment Photographs

Photo 47 Grindstone Creek **Reach GC-T2**	
	Rooted knickpoints (yellow arrow) and deep pools were characteristic of the upstream extent of **Reach GC-T2**; perspective facing upstream towards highway 403 culvert.
Photo 48 Grindstone Creek **Reach GC-T2**	
	The dominant vegetation types within **Reach GC-T2** were trees and herbaceous plants. Note the dead trees contributing to woody debris density and the flood conditions observed at the time of assessment; perspective facing north towards left floodplain.

2026 Rapid Assessment Photographs

Photo 49 Grindstone Creek **Reach GC-T2**	
	Chutes (yellow arrow) were observed throughout the reach due to the high flow conditions at the time of assessment; perspective from left bank facing south towards online pond.
Photo 50 Grindstone Creek **Reach GC-T2**	
	GC-T2 at the downstream extent where flow enters the pond; perspective facing east towards proposed road crossing location.

2026 Rapid Assessment Photographs

Photo 51 Falcon Creek **Reach FC-6b**	
	Valley wall contacts (yellow arrow) were frequently observed throughout the assessment. Leaning and undermined trees (red arrows) and basal scour were also common and noted as evidence of widening.
Photo 52 Falcon Creek **ReachFC-6b**	
	Bank substrate was comprised of silt/clay and sand. Note the suspended armor layer (red arrow), exposed roots (yellow arrow) which were common throughout **FC-6b**; perspective facing left bank.

2026 Rapid Assessment Photographs

Photo 53 Falcon Creek **ReachFC-6b**	
	Bar formations (yellow arrow) within **FC-6b** were armored with course materials and not easily reworked; perspective facing upstream.
Photo 54 Falcon Creek **ReachFC-6b**	
	Basal scour was noted in the inside of meander bends (yellow arrow); perspective facing upstream towards left bank.

2026 Rapid Assessment Photographs

Photo 55 Falcon Creek **ReachFC-6b**	
	Slumps (yellow arrow) were observed in the channel and on the banks and valley walls throughout **FC-6b**; perspective facing upstream towards left bank.
Photo 56 Falcon Creek **ReachFC-6b**	
	Sharp meander bends with valley wall contact were characteristic of **FC-6b**; perspective facing upstream towards highway 403.

Appendix C:
Field Observations

GEO MORPHIX™

General Site Characteristics

Project Number:

Date:	10-05-23	**Stream:**	INDIAN CREEK
Time:	11:30 AM	**Reach:**	IC-T1
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

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	PHRAGMITES	
	Bank stabilization	CATTAIL	
	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

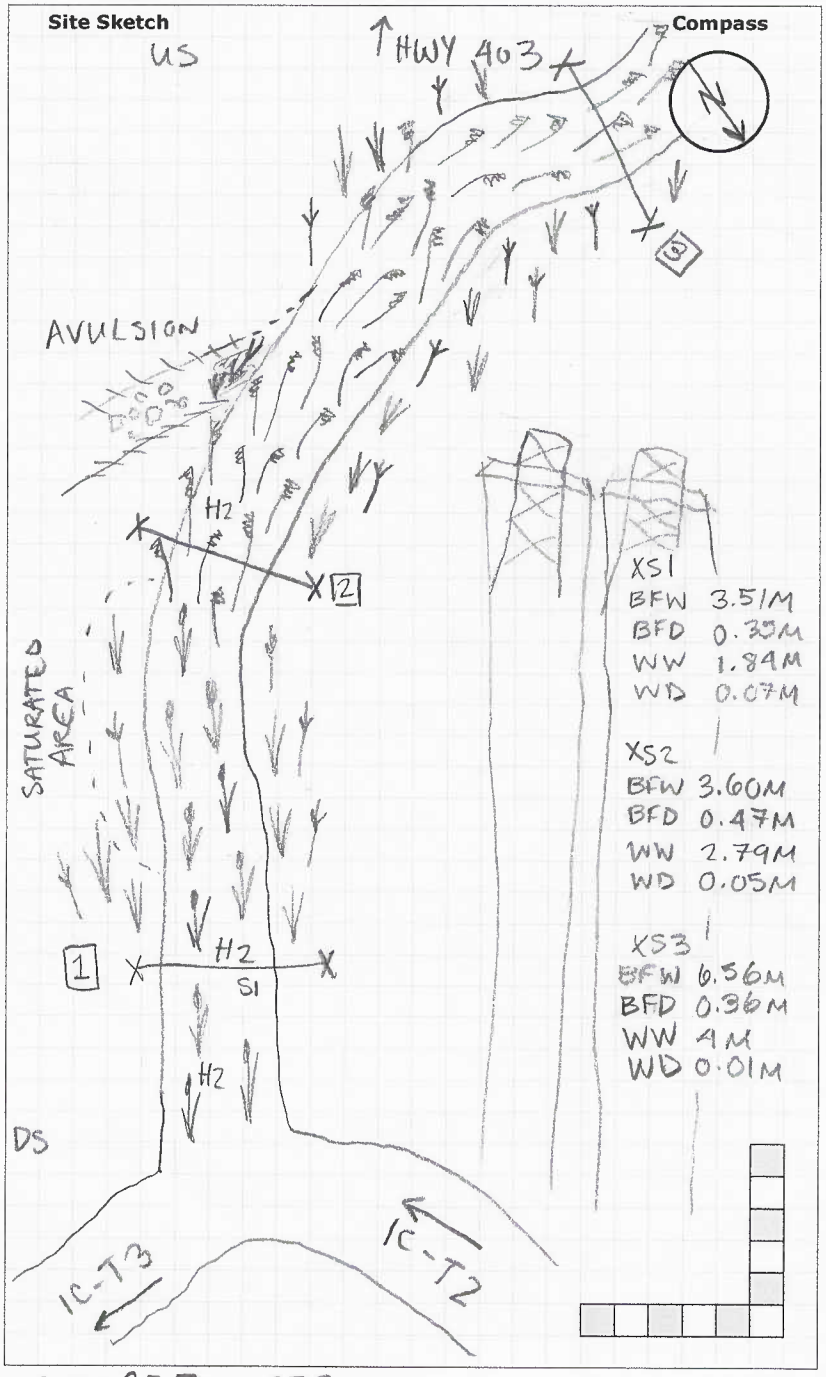
Substrate

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

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: 237 - 277

Notes: CHANNEL CHOKED W PHRAG IN U/S SECTION. AVULSION CHANNEL NOT DIRECTLY CONNECTED TO REACH, FLOW IS OVERLAND FOR ~ 5 M BEFORE DOWNCUT AVULSION CHANNEL BEGINS.

GEO MORPHIX

Reach Characteristics

Project Number: PN23010

Date:	2023-05-10	**Field Staff:**	AM ES	**Watershed/Subwatershed:**	Indian Creek
Time:	11:30	**Stream:**	Tributary of Indian C.	**UTM (Upstream):**	
Weather:	Sunny 20°C	**Reach:**	IC-TY	**UTM (Downstream):**	

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

Riparian Vegetation

Dominant Type (Table 6): 3

Encroachment (Table 7): 3

Coverage	Channel Widths	Age (yrs)
☐ None	☑ 1 - 4	☑ Immature (<5)
☐ Fragmented	☐ 4 - 10	☐ Established (5-30)
☑ Continuous	☐ > 10	☐ Mature (>30)

Aquatic & Instream Vegetation

Type (Table 8): 1

Reach Coverage %: 100

Woody Debris	WD Density
☐ In Cutbank	☑ Low
☐ In Channel	☐ Mod
☑ Not Present	☐ High

WDJ/50m: N/A

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 3

Channel Characteristics

Sinuosity Type (Table 9): 1

Gradient (Table 11): 1

Entrenchment (Table 13): 1

Down's Model (Table 15): S

Sed Sorting (Table 20): NELL

Transport Mode (Table 21): N/A

Geomorphic Units (Table 22): 8

Riffle-Pool Spacing (m): N/A

Sinuosity Degree (Table 10): 1

# of Channels (Table 12): 1

Bank Failure (Table 14): 1

Bankfull Indicators (Table 18):

Sediment Transport Observed? ☐ Yes ☑ No ☐ Not Visible

% of Bed Active: N/A

Mass Movement (Table 23): N/A N/A

% Riffles: N/A **% Pools:** N/A

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

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

Bankfull Width (m)	3.51	3.60	6.56
Bankfull Depth (m)	0.35	0.47	0.36
Undercuts (m)	N/A	N/A	N/A
Pool Depth (m)	N/A	N/A	N/A
Riffle Length (m)	N/A	N/A	N/A

(Table 19)

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

Wetted Width (m)	1.89	2.79	4.00
Wetted Depth (m)	0.07	0.05	0.01
Velocity (m/s)	STANDING		
Velocity Estimate Method	WATER		
Meander Amplitude (m)	N/A	N/A	N/A

Notes:
- historically straightened agricultural swale
- poorly defined bankfull indicators
- dominated by runs - no riffle or pool pool morphology
- minimal standing water present
- dominated by rooted emergent vegetation - phragmites & cattails.

Photos:

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX

General Site Characteristics

Project Number: 23010

Date:	10-05-23	**Stream:**	INDIAN CREEK
Time:	12:00 PM	**Reach:**	IC-T1A
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

Features

- Reach break
- Station location
- Cross-section
- Flow direction
- Riffle
- Pool
- Sediment bar
- Eroded bank/slope
- Undercut bank
- Bank stabilization
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Beaver dam
- Vegetated island

Monitoring

- Long-profile
- Monumented XS
- Monumented photo
- Monumented photo direction
- Sediment sampling
- Erosion pins
- Scour chains

Additional Symbols

- CATTAIL
- PHRAGMITES

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

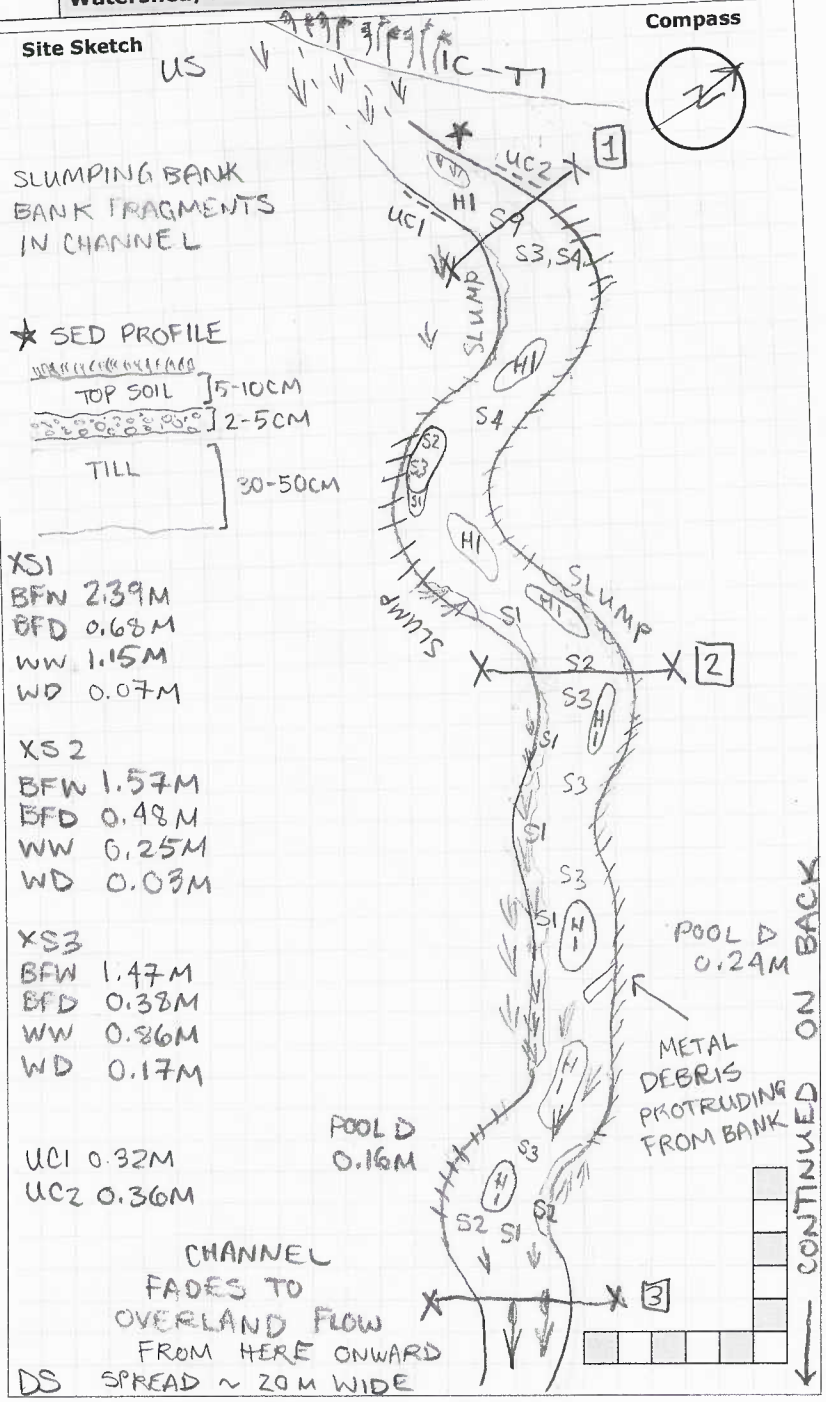
Substrate

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

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: 278 - 400

Notes: SUSPENDED ARMOUR IN BANK, TILL STARTS ~5CM BELOW AT W/S END. NO TILL OBSV CLOSER TO D/S END

GEO MORPHIX

General Site Characteristics

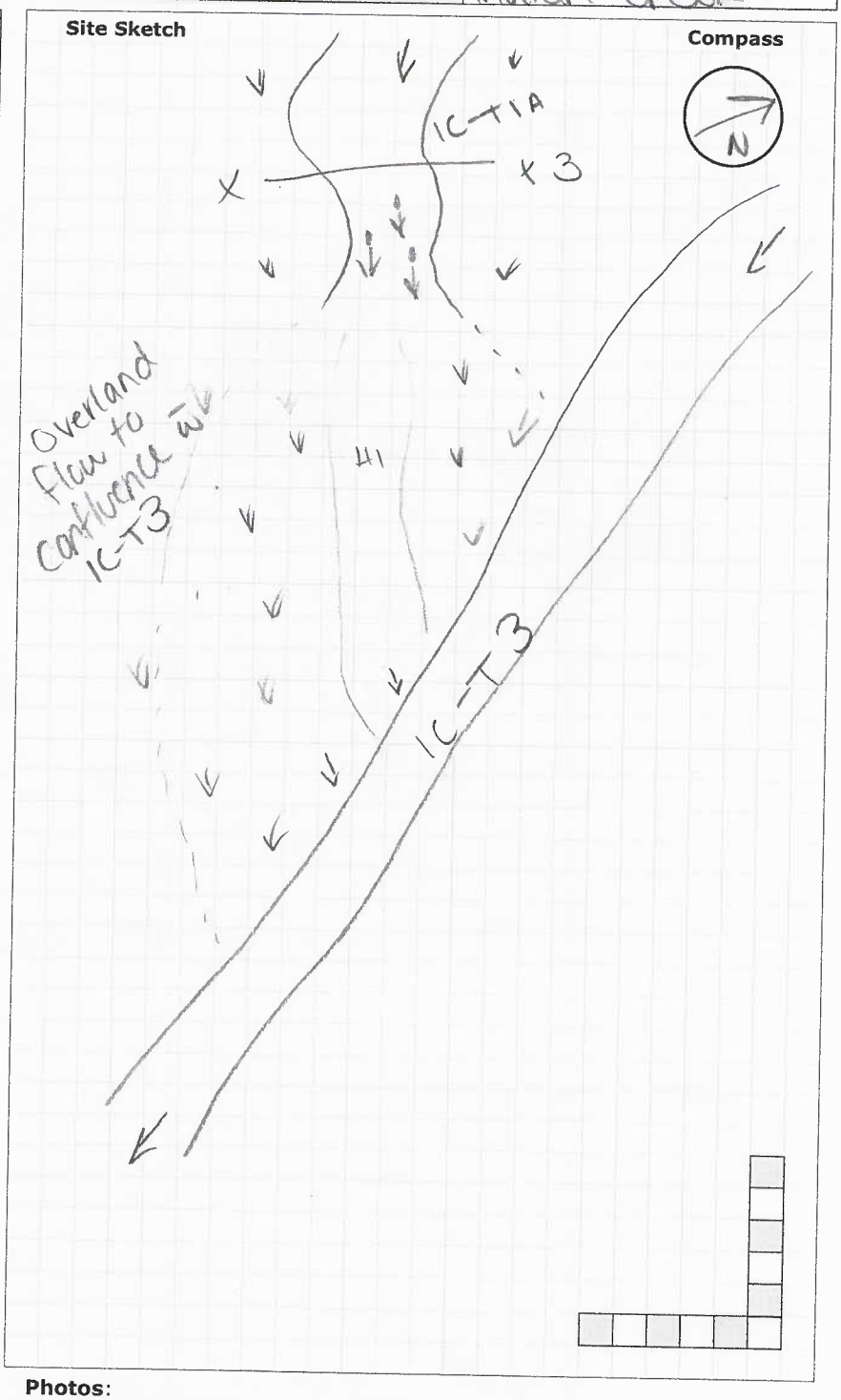
Project Number: PN23010

Date:	2023-05-10	**Stream:**	Trib of Indian Ck.
Time:	12:00 pm	**Reach:**	IC-T1A
Weather:	Sunny 20°C	**Location:**	1200 King Rd, Burlington
Field Staff:	AA YS	**Watershed/Subwatershed:**	Indian Creek

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	
Undercut bank	
Bank stabilization	
Leaning tree	
Fence	
Culvert/outfall	
Swamp/wetland	
Grasses	
Tree	
Instream log/tree	
Woody debris	
Beaver dam	
Vegetated island	

Additional Symbols

Site Sketch



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		

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

Photos:

Notes:

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX

Reach Characteristics Project Number: 23010

Date:	10-05-23	**Field Staff:**	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK
Time:	12:00 PM	**Stream:**	INDIAN CREEK	**UTM (Upstream):**	
Weather:	SUNNY 20°C	**Reach:**	IC-T1A	**UTM (Downstream):**	

Land Use (Table 1): 3 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): 9 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 2 | ☐ Evidence of Groundwater Location: NA Photo: \

Riparian Vegetation

Dominant Type (Table 6): 3, 4
Encroachment (Table 7): 3

Coverage: ☐ None; ☐ Fragmented; ☒ Continuous
Channel Widths: ☐ 1 - 4; ☐ 4 - 10; ☒ > 10
Age (yrs): ☐ Immature (<5); ☒ Established (5-30); ☐ Mature (>30)

Aquatic & Instream Vegetation

Type (Table 8): 5
Reach Coverage %: 40

Woody Debris: ☐ In Cutbank; ☐ In Channel; ☒ Not Present
WD Density: ☐ Low; ☐ Mod; ☐ High
WDJ/50m: NA

Water Quality

Odour (Table 16): 1
Turbidity (Table 17): 2

Channel Characteristics

Sinuosity Type (Table 9): 2
Gradient (Table 11): 1
Entrenchment (Table 13): 1
Down's Model (Table 15): E, e
Sed Sorting (Table 20): PS
Transport Mode (Table 21): NA
Geomorphic Units (Table 22): 9
Riffle-Pool Spacing (m): NA

Sinuosity Degree (Table 10): 2
# of Channels (Table 12): 1
Bank Failure (Table 14): 2, 3
Bankfull Indicators (Table 18): 1, 3
Sediment Transport Observed?: ☐ Yes ☒ No ☐ Not Visible
% of Bed Active: NA
Mass Movement (Table 23): 1, 3
% Riffles: \
% Pools: \

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	☒	☐	☒	☐	☐	☒	☐
Riffle	☐	☐	☐	☐	☐	☐	☐
Pool	☐	☐	☐	☐	☐	☐	☐
Bed (if no riffle-pool morphology)	☒	☒	☒	☒	☐	☒	☐

				Wetted Width (m)			
Bankfull Width (m)	2.39	1.57	1.47		1.15	0.25	0.86
Bankfull Depth (m)	0.68	0.49	0.38	Wetted Depth (m)	0.09	0.03	0.17
Undercuts (m)	0.32	0.36		Velocity (m/s)	\	\	\
Pool Depth (m)	0.24	0.16		Velocity Estimate Method	\	\	\
Riffle Length (m)	\	\	\	Meander Amplitude (m)	11	9	6

Notes: IC-T1A IS AN AVULSION CHANNEL THAT CONNECTS IC-T1 AND IC-T3, BYPASSING THE D/S SECTION OF IC-T1 WHERE IT MEETS IC-T2 NORTHEAST OF THE POWERLINE PYLONS. THE U/S SECTION OF THE IC-T1A WHERE IT BRANCHES FROM IC-T1 IS A ~5-10M SECTION OF OVERLAND FLOW THAT IS DEGRADING THE TOPSOIL W SEVERAL SMALL RILLS; THE GROUND WAS SATURATED AT THIS LOCATION. THE CHANNEL IS DOWNCUT INTO THE TOPSOIL AND TILL BEYOND THIS. UNDERCUTTING WAS OBSERVED IN THIS U/S AREA ALONG W A SUSPENDED ARMOUR LAYER IN THE VERTICAL BANK. THE CHANNEL MEANDERS IN AN IRREGULAR PATTERN W HIGHER AMPLITUDE MEANDERS W/IN THE U/S SECTION. BANKS ON BOTH SIDES ARE ERODING W FRACTURES, TOPPLES, AND SLUMPING. MEANDER AMPLITUDE AND BANKFULL DEPTH DECREASE W DISTANCE D/S. THE CHANNEL EVENTUALLY FADES TO MULTIPLE POORLY DEFINED OVERLAND FLOW PATHS ~30M EAST OF IC-T3.

Photos: 278-400

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Rapid Geomorphic Assessment

Project Number: 23010

Date:	10-05-23	**Stream:**	INDIAN CREEK
Time:	12:00 PM	**Reach:**	IC-TIA
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

Process	No.	Geomorphological Indicator: Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		X	5/7
	2	Coarse materials in riffles embedded	X		
	3	Siltation in pools	X		
	4	Medial bars	X		
	5	Accretion on point bars	X		
	6	Poor longitudinal sorting of bed materials	X		
	7	Deposition in the overbank zone		X	
		Sum of indices =	5	2	0.71
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	NA	NA	2/10
	2	Exposed sanitary / storm sewer / pipeline / etc.	NA	NA	
	3	Elevated storm sewer outfall(s)	NA	NA	
	4	Undermined gabion baskets / concrete aprons / etc.	NA	NA	
	5	Scour pools downstream of culverts / storm sewer outlets	NA	NA	
	6	Cut face on bar forms		X	
	7	Head cutting due to knickpoint migration		X	
	8	Terrace cut through older bar material		X	
	9	Suspended armour layer visible in bank	X		
	10	Channel worn into undisturbed overburden / bedrock	X		
		Sum of indices =	2	3	0.2
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	NA	NA	4/10
	2	Occurrence of large organic debris		X	
	3	Exposed tree roots	NA	NA	
	4	Basal scour on inside meander bends	X		
	5	Basal scour on both sides of channel through riffle	X		
	6	Outflanked gabion baskets / concrete walls / etc.	NA	NA	
	7	Length of basal scour >50% through subject reach	X		
	8	Exposed length of previously buried pipe / cable / etc.		X	
	9	Fracture lines along top of bank	X		
	10	Exposed building foundation	NA	NA	
		Sum of indices =	4	2	0.4
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		X	1/7
	2	Single thread channel to multiple channel		X	
	3	Evolution of pool-riffle form to low bed relief form		X	
	4	Cut-off channel(s)		X	
	5	Formation of island(s)		X	
	6	Thalweg alignment out of phase with meander form	NA	NA	
	7	Bar forms poorly formed / reworked / removed	X		
		Sum of indices =	1	5	0.14

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.36

In Regime	In Transition/Stress	In Adjustment
☐ 0.00 - 0.20	☒ 0.21 - 0.40	☐ 0.41

Version #3
Last edited: 10/02/2023

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

GEO MORPHIX™

Rapid Stream Assessment Technique Project Number: 23010

Date:	10-05-23	**Stream:**	INDIAN CREEK
Time:	12:00 PM	**Reach:**	IC-TIA
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

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

NA

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX

Date:	10-05-23	PN:	23010	Location:	IC-T1A

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) NA
	• 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 NA
	• 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
	• 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 NA
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) = 12	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: KS

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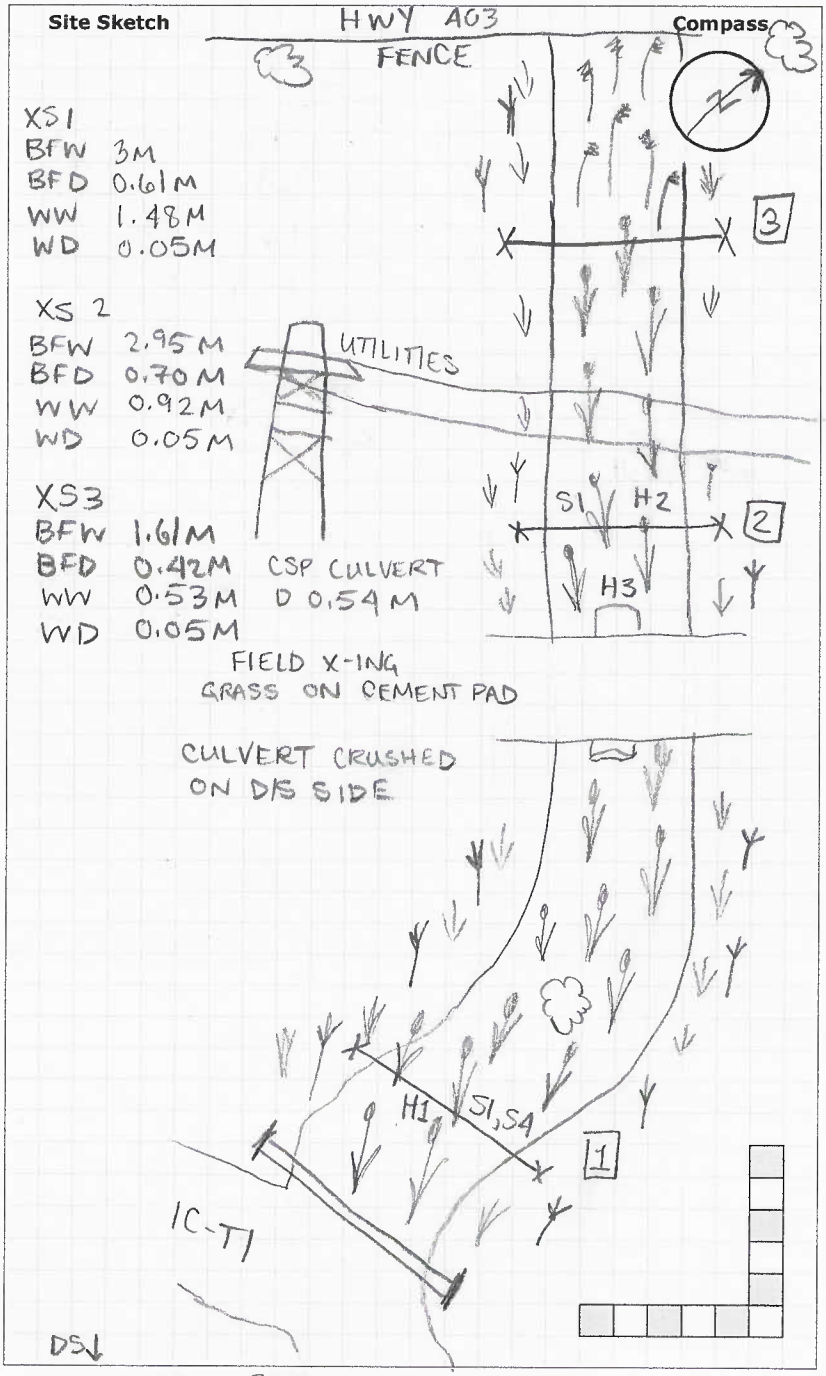
General Site Characteristics

Project Number: 23010

Date:	10-05-23	**Stream:**	INDIAN CREEK
Time:	11:00 AM	**Reach:**	IC-T2
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

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	HERBACEOUS VEG
Bank stabilization	CATTAIL
Leaning tree	PHRAGMITES
Fence	
Culvert/outfall	
Swamp/wetland	
Grasses	
Tree	
Instream log/tree	
Woody debris	
Beaver dam	
Vegetated island	

Site Sketch



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		

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

Photos: 195 ~ 236

Notes: STRAIGHTENED AG SWALE RGA RSAT NA HEAVY VEG MOSTLY CATTAILS, PHRAG NEAR US EXTENT AT 403. JUVENILE WILLOWS IN SOME LOCATIONS ALONG BANK

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX

Reach Characteristics

Project Number: PN23010

Date:	2023-05-10	**Field Staff:**	AA ES	**Watershed/Subwatershed:**	Indian Creek
Time:	11:00	**Stream:**	Trib of Indian Ck.	**UTM (Upstream):**	
Weather:	Sunny 20°C	**Reach:**	IC-T2	**UTM (Downstream):**	

Land Use (Table 1): 3 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): 12 | **Channel Zone** (Table 4): 1 | **Flow Type** (Table 5): 2 | ☐ Evidence of Groundwater Location: N/A Photo: N/A

Riparian Vegetation

Dominant Type (Table 6): 3

Encroachment (Table 7): 3

Coverage
- ☐ None
- ☐ Fragmented
- ☑ Continuous

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

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

Aquatic & Instream Vegetation

Type (Table 8): 1

Reach Coverage %: 100

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

WD Density
- ☑ Low
- ☐ Mod
- ☐ High

WDJ/50m: N/A

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 3

Channel Characteristics

Sinuosity Type (Table 9): 1

Gradient (Table 11): 1

Entrenchment (Table 13): 1

Down's Model (Table 15): S

Sed Sorting (Table 20): WELL

Transport Mode (Table 21): N/A

Geomorphic Units (Table 22): 8

Riffle-Pool Spacing (m): N/A

Sinuosity Degree (Table 10): 1

# of Channels (Table 12): 1

Bank Failure (Table 14): 1

Bankfull Indicators (Table 18): 3/5

Sediment Transport Observed? ☐ Yes ☑ No ☐ Not Visible

% of Bed Active: N/A

Mass Movement (Table 23): N/A

% Riffles: N/A **% Pools:** N/A

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

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

Bankfull Width (m)	3.00	2.95	1.61
Bankfull Depth (m)	0.61	0.70	0.42
Undercuts (m)	N/A	N/A	N/A
Pool Depth (m)	N/A	N/A	N/A
Riffle Length (m)	N/A	N/A	N/A

(Table 19)

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

Wetted Width (m)	1.48	0.92	0.53
Wetted Depth (m)	0.05	0.05	0.05
Velocity (m/s)	STANDING WATER		
Velocity Estimate Method	N/A	N/A	N/A
Meander Amplitude (m)	N/A	N/A	N/A

Notes:
- historically straightened agricultural swale
- tractor crossing present - corrugated steel pipe (CSP) culvert @ crossing
- riffle-pool sequencing absent - dominated by runs
- dominated by chara & rooted aquatic veg - phrag & cattails

Photos:

Version #4
Last edited: 04/04/2023

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

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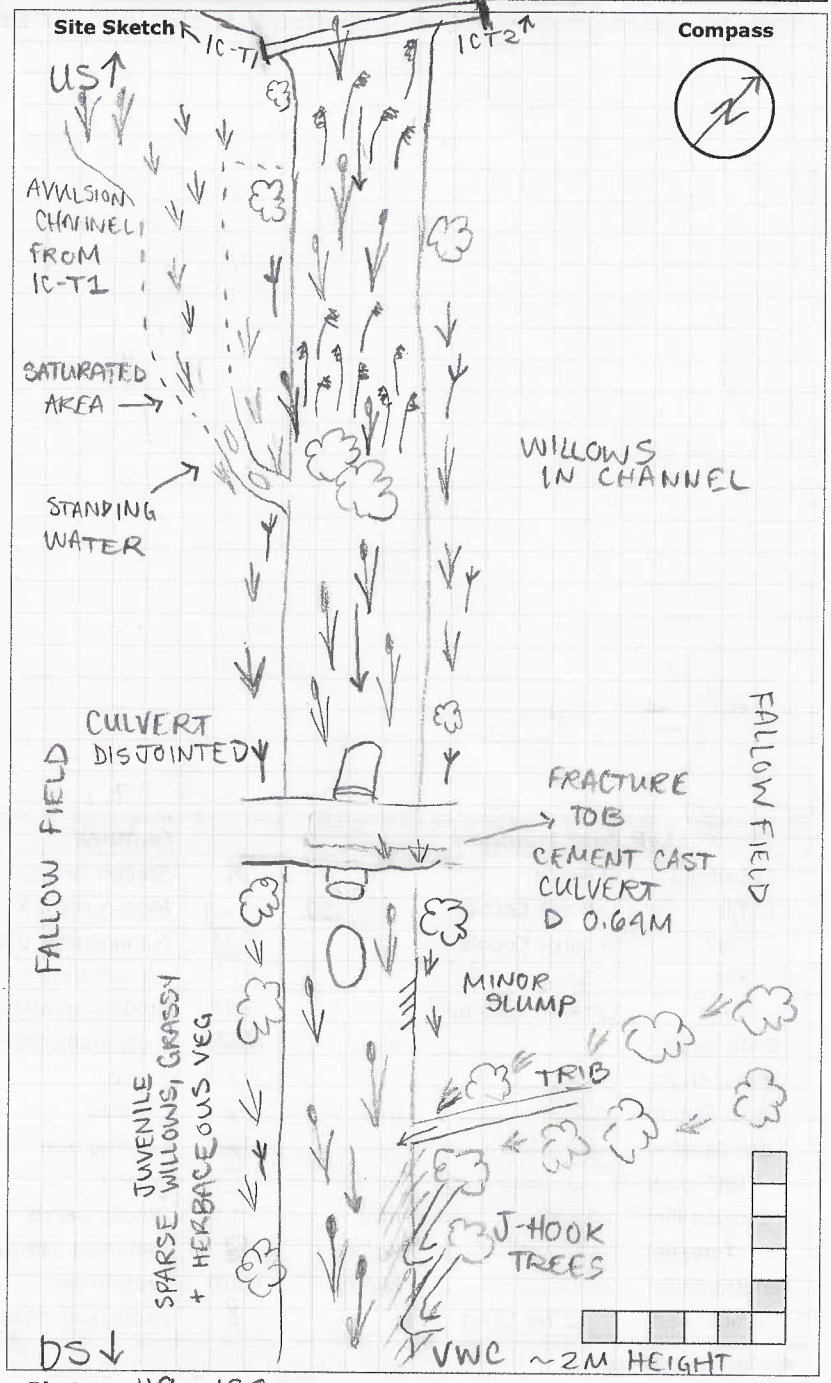
General Site Characteristics

Project Number: 23010

Date:	10-05-23	**Stream:**	INDIAN CREEK
Time:	10:15 AM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

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	HERBACEOUS VEG
Bank stabilization	PHRAGMITES
Leaning tree	CATTAIL
Fence	
Culvert/outfall	
Swamp/wetland	
Grasses	
Tree	
Instream log/tree	
Woody debris	
Beaver dam	
Vegetated island	

Site Sketch



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		

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

Photos: 119 - 198

Notes: STRAIGHTENED AG SWALE. EXTREME IN CHANNEL VEG ALTERNATES BTW PHRAG + CATTAIL W SOME WILLOW. DEGRADED FARM X-ING W SEPERATED CEMENT CULVERT SEGMENTS STILL CONDUITS FLOW RGA RSAT NOT APPLICABLE

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX

Reach Characteristics

Project Number: PN7301C

Date:	2023-05-10	**Field Staff:**	AA KS	**Watershed/Subwatershed:**	Indian Creek
Time:	10:15	**Stream:**	Tributary Indian Ck.	**UTM (Upstream):**	
Weather:	Sunny 20°C	**Reach:**	IC-T3	**UTM (Downstream):**	

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

Riparian Vegetation

Dominant Type (Table 6): 3

Encroachment (Table 7): 3

Coverage	Channel Widths	Age (yrs)
☐ None	☑ 1 - 4	☑ Immature (<5)
☐ Fragmented	☐ 4 - 10	☐ Established (5-30)
☑ Continuous	☐ > 10	☐ Mature (>30)

Aquatic & Instream Vegetation

Type (Table 8): 1

Reach Coverage %: 90

Woody Debris	WD Density
☐ In Cutbank	☑ Low
☐ In Channel	☐ Mod
☑ Not Present	☐ High

WDJ/50m: N/A

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 3

Channel Characteristics

Sinuosity Type (Table 9): 1

Gradient (Table 11): 1

Entrenchment (Table 13): 1

Down's Model (Table 15): S

Sed Sorting (Table 20): WELL

Transport Mode (Table 21): N/A

Geomorphic Units (Table 22): 8

Riffle-Pool Spacing (m): N/A

Sinuosity Degree (Table 10): 1

# of Channels (Table 12): 1

Bank Failure (Table 14): 1

Bankfull Indicators (Table 18): 3/5

Sediment Transport Observed? ☐ Yes ☑ No ☐ Not Visible

% of Bed Active: N/A

Mass Movement (Table 23): N/A

% Riffles: N/A **% Pools:** N/A

Bank Angle	Bank Erosion
☐ 0 – 30	☐ < 5%
☑ 30 – 60	☑ 5 – 30%
☐ 60 – 90	☐ 30 – 60%
☐ Undercut	☐ 60 – 100%

(Table 19)

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

Bankfull Width (m)	*	*	*	**Wetted Width (m)**	*	*	*
Bankfull Depth (m)	*	*	*	**Wetted Depth (m)**	*	*	*
Undercuts (m)	N/A	N/A	N/A	**Velocity (m/s)**	STAGNANT		
Pool Depth (m)	N/A	N/A	N/A	**Velocity Estimate Method**	WATER		
Riffle Length (m)	N/A	N/A	N/A	**Meander Amplitude (m)**	N/A	N/A	N/A

Notes: * Refer to detailed assessment summary and field sheets.

Photos:

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX™

Detailed Assessment Long Profile (Total Station)

Project Code: PN23010

Date:	10-05-23	**Reach:**	IC-T3
Time:	10:15	**Location:**	Burlington
Weather:	Sunny 20°C	**Watershed/Subwatershed:**	Indian Creek
Field Staff:	AA KS	**Rain in last 24 hours:**	☑ None ☐ Yes: Amount ____ mm

Point No.		Code	Notes
		RTK	

Survey Direction

☐ Upstream to Downstream
☑ Downstream to Upstream

Cross-sections

No. of Cross-sections Surveyed: 9
Monitoring Cross-sections: ☑ No ☐ Yes
XS ID: ____ / ____ / ____
Erosion Pin Installed: ☑ No ☐ Yes
XS ID: ____ / ____ / ____

Velocity & Sediment Transport

☐ Velocity ________ m/s **Method:**
☐ Discharge ________ m^3/s ________
Sed. Transport (Table 21): ☐ Suspended
☐ Saltation ☐ Sliding ☐ Rolling
Percentage of Bed Active: ______ %

Valley Type

☐ Confined ☐ Partially ☑ Unconfined

Channel Zone

☐ Headwater ☑ Transfer ☐ Deposition

Land Use

Agricultural

Vegetation

Aquatic Vegetation: Rooted emergent
Coverage of Reach: 90 %
☑ In Stream ☑ Margins ☑ On Bank
Riparian Vegetation: ☐ No ☑ Yes
Extent of Riparian Cover:
☐ Fragment ☐ None ☑ Continuous
Riparian Cover (channel widths):
☑ 1-4 ☐ 4-10 ☐ >10
Age Class of Riparian Vegetation:
Immature Established Mature
☑ (<5 yrs) ☐ (5-30 yrs) ☐ (>30 yrs)
Extent of Encroachment:
☐ None ☐ Minimal ☑ Moderate
☐ Heavy ☐ Extreme
Density of Woody Debris:
☑ Low ☐ Moderate ☐ High
Blockage(s) in Channel:
☐ Infrastructure ☐ Dam ☐ LWD

Version #3
Last edited: 21/02/2023

Senior staff sign-off (if required): ________ Checked by: ________ Completed by: AA

Detailed Cross-Section Characteristics

Project Number: 23010

GEO MORPHIX™

Date:	10-05-23	**Cross-section:**	XS1
Time:	12:30PM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

					Notes
RTK					

Cross-sectional Morphology (Table 22)

☐ Riffle ☐ Pool ☐ Run ☒ Other

Substrate Sample: LB

☐ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

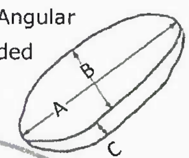
Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
SILT			SILT			SILT			SILT		

Particle Shape: ☐ Platy ☐ Very Angular ☐ Sub-angular ☐ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded

Embededness: ________ %

Subpavement: ____________________



[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☐ Not Obsv ☒ Not Visible - Reason: CATTAILS

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: NA %

Velocity

☐ Measured ________m/s Method: ____________

☐ Estimated ________m/s XS ID: ____________

Distance ________m Time ________s V ________m/s

Distance ________m Time ________s V ________m/s

Distance ________m Time ________s V ________m/s

Discharge

☐ Estimated ________m^3/s Method: ____________

☐ Measured ________m^3/s XS ID: ____________

Depth ________m Width ________m V_{60} ________m/s

Depth ________m Width ________m V_{60} ________m/s

Depth ________m Width ________m V_{60} ________m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

Senior staff sign-off (if required): ________ Checked by: ________ Completed by: KS

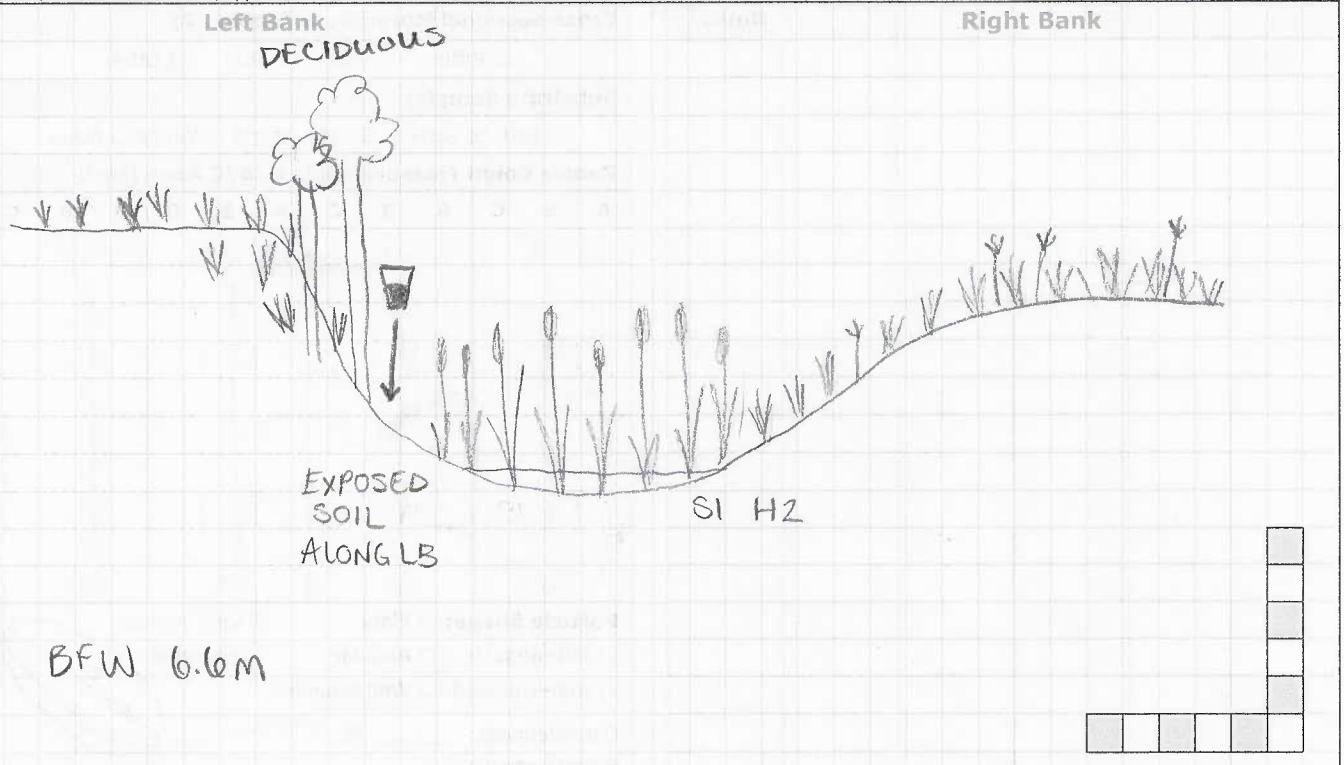
GEO MORPHIX

Bank Characteristics

Project Number: 23010

Date:	10-05-23	**Cross-section:**	XS 1
Time:	12:30 PM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	INDIAN CREEK, BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials			Features		Right Bank Materials		
☐ Bedrock	☐ Gravel			Station location	☐ Bedrock	☐ Gravel	
☐ Till	☐ Small Cobble			Monumented XS	☐ Till	☐ Small Cobble	
☐ Clay	☐ Large Cobble			Monumented photo	☐ Clay	☐ Large Cobble	
☒ Silt	☐ Small Boulder			Undercut bank	☒ Silt	☐ Small Boulder	
☐ Sand	☐ Large Boulder			Eroded bank/slope	☐ Sand	☐ Large Boulder	
Bank Height:	1.35	m		Bank stabilization	Bank Height:	0.95	m
Bank Angle:	70	°		Fence	Bank Angle:	45	°
Root Depth:	0.3	m		Grasses	Root Depth:	0.50	m
Root Density:	20	%		Leaning tree	Root Density:	60	%
Undercut:	NA	m		Tree	Undercut:	NA	m
Erosion Pin:	NA	m		Woody Debris	Erosion Pin:	NA	m
Torvane:	NA	kg/cm²		Sediment sample	Torvane:	NA	kg/cm²
Penetrometer:	NA	kg/cm²		Erosion pin	Penetrometer:	NA	kg/cm²
Foot Used:	☐ Yes ☐ No			Scour/bed chain	Foot Used:	☐ Yes ☐ No	

Additional Notes

XS HEAVILY VEGETATED W CATTAIL, BED NOT VISIBLE

Photos: LB: 401 DS: 402 US: 403 RB: 404

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX

Detailed Cross-Section Characteristics

Project Number: Z3010

Date:	10-05-23	**Cross-section:**	XS 2
Time:	12:45	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

					Notes
RTK					

Cross-sectional Morphology (Table 22)

☐ Riffle ☐ Pool ☐ Run ☒ Other

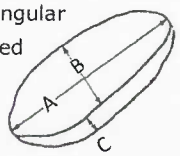
Substrate Sample:

☐ Bed ☐ Bank ☐ Subpavement ☐ Water ☒ None

Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
SILT			SILT			SILT			SILT		

Particle Shape: ☐ Platy ☐ Very Angular ☐ Sub-angular ☐ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded



[Pebble ABC axis guide]

Embededness: _____ %

Subpavement: _____

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☐ Not Obsv ☒ Not Visible - Reason: CATTAILS

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: _____ %

Velocity

☐ Measured _____ m/s Method: _____

☐ Estimated _____ m/s XS ID: _____

Distance _____ m Time _____ s V _____ m/s

Distance _____ m Time _____ s V _____ m/s

Distance _____ m Time _____ s V _____ m/s

Discharge

☐ Estimated _____ m^3/s Method: _____

☐ Measured _____ m^3/s XS ID: _____

Depth _____ m Width _____ m V_{60} _____ m/s

Depth _____ m Width _____ m V_{60} _____ m/s

Depth _____ m Width _____ m V_{60} _____ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

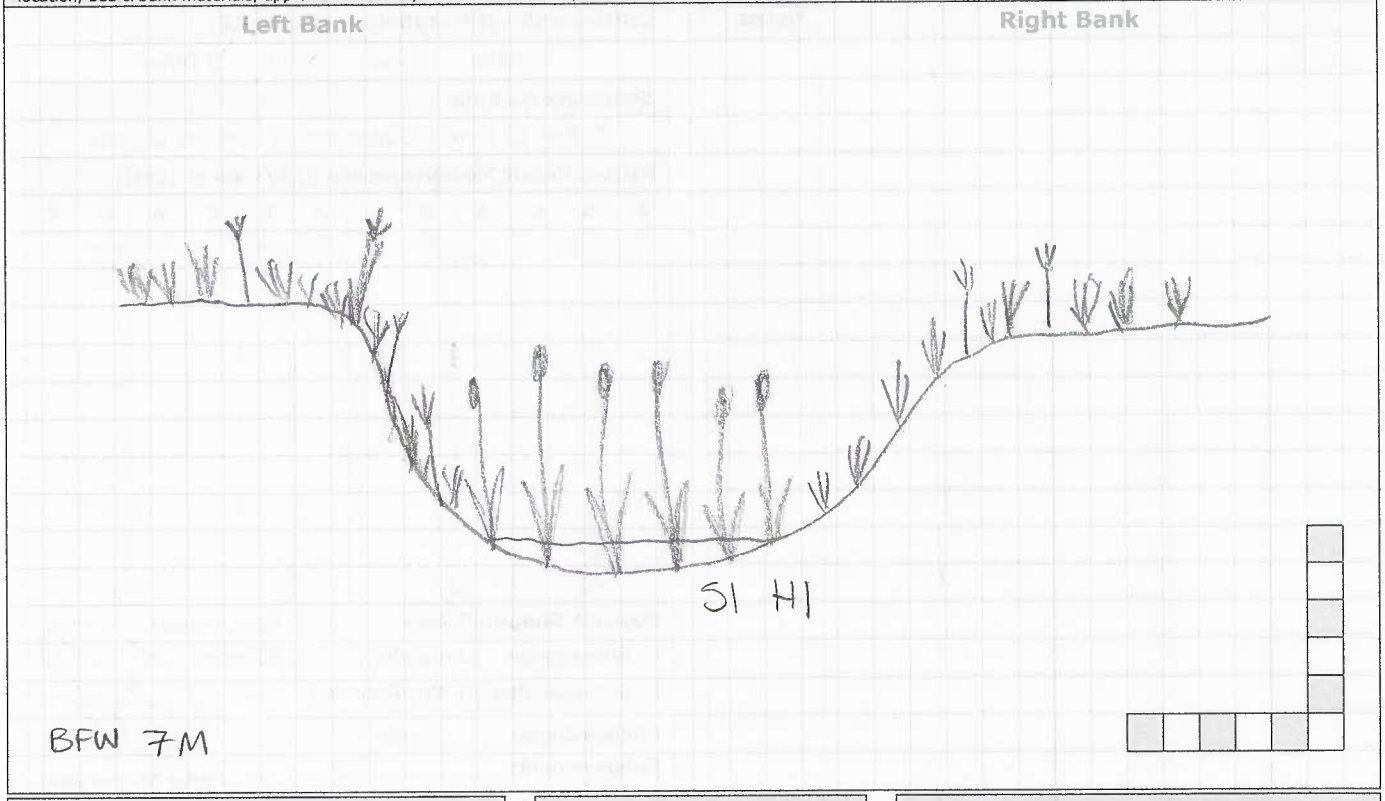
GEO MORPHIX™

Bank Characteristics

Project Number: 23010

Date:	10-05-23	**Cross-section:**	XS 2
Time:	12:45 PM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials			Features		Right Bank Materials		
☐ Bedrock	☐ Gravel			Station location	☐ Bedrock	☐ Gravel	
☐ Till	☐ Small Cobble			Monumented XS	☐ Till	☐ Small Cobble	
☐ Clay	☐ Large Cobble			Monumented photo	☐ Clay	☐ Large Cobble	
☒ Silt	☐ Small Boulder			Undercut bank	☒ Silt	☐ Small Boulder	
☐ Sand	☐ Large Boulder			Eroded bank/slope	☐ Sand	☐ Large Boulder	
Bank Height:	1.5	m		Bank stabilization	Bank Height:	1.0	m
Bank Angle:	60	°		Fence	Bank Angle:	50	°
Root Depth:	0.5	m		Grasses	Root Depth:	0.6	m
Root Density:	50	%		Leaning tree	Root Density:	70	%
Undercut:	NA	m		Tree	Undercut:	NA	m
Erosion Pin:	NA	m		Woody Debris	Erosion Pin:	NA	m
Torvane:	NA	kg/cm²		Sediment sample	Torvane:	NA	kg/cm²
Penetrometer:	NA	kg/cm²		Erosion pin	Penetrometer:	NA	kg/cm²
Foot Used:	☐ Yes ☐ No			Scour/bed chain	Foot Used:	☐ Yes ☐ No	

Additional Notes

HIGH DENSITY CATTAILS IN CHANNEL

Photos: LB: A05 DS: A06 US: A07 RB: A08

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX

Detailed Cross-Section Characteristics

Project Number: 23010

Date:	10-05-23	**Cross-section:**	XS 3
Time:	1:10 PM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

					Notes
RTK					

Cross-sectional Morphology (Table 22)

☐ Riffle ☐ Pool ☐ Run ☒ Other

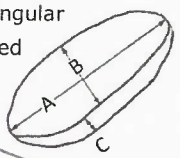
Substrate Sample:

☐ Bed ☐ Bank ☐ Subpavement ☐ Water ☒ None

Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
SILT			SILT			SILT			SILT		

Particle Shape: ☐ Platy ☐ Very Angular ☐ Sub-angular ☐ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded



[Pebble ABC axis guide]

Embededness: _____ %

Subpavement: _____

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: _____

If Observed (Table 21):

☒ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: >10 %

Velocity

☐ Measured _____ m/s Method: _____

☐ Estimated _____ m/s XS ID: _____

Distance _____ m Time _____ s V _____ m/s

Distance _____ m Time _____ s V _____ m/s

Distance _____ m Time _____ s V _____ m/s

Discharge

☐ Estimated _____ m^3/s Method: _____

☐ Measured _____ m^3/s XS ID: _____

Depth _____ m Width _____ m V_{60} _____ m/s

Depth _____ m Width _____ m V_{60} _____ m/s

Depth _____ m Width _____ m V_{60} _____ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

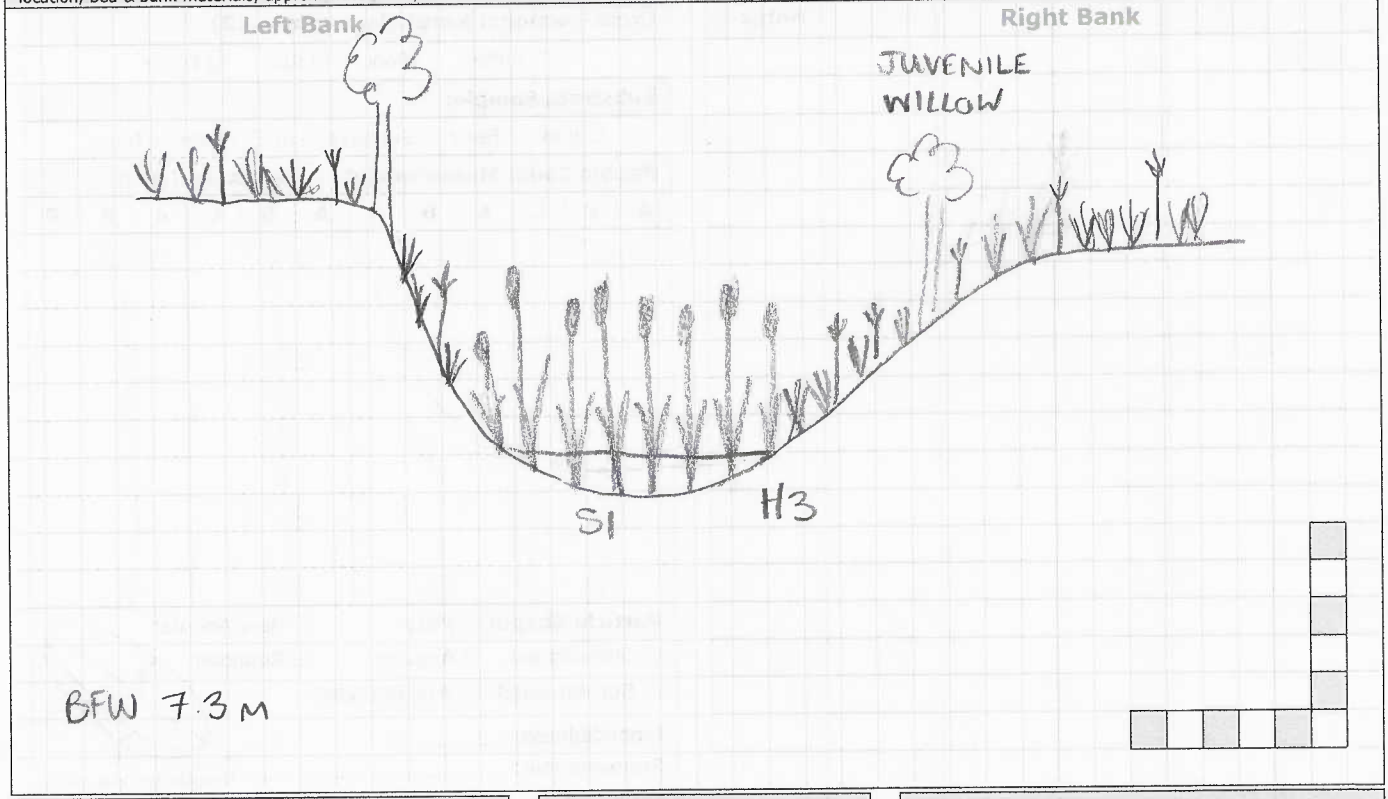
GEO MORPHIX

Bank Characteristics

Project Number: 23010

Date:	10-05-23	**Cross-section:**	XS3
Time:	1:10 PM	**Reach:**	IC-T3
Weather:	SUNNY 20 °C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials			Features		Right Bank Materials		
☐ Bedrock	☐ Gravel			Station location	☐ Bedrock	☐ Gravel	
☐ Till	☐ Small Cobble			Monumented XS	☐ Till	☐ Small Cobble	
☐ Clay	☐ Large Cobble			Monumented photo	☐ Clay	☐ Large Cobble	
☒ Silt	☐ Small Boulder			Undercut bank	☒ Silt	☐ Small Boulder	
☐ Sand	☐ Large Boulder			Eroded bank/slope	☐ Sand	☐ Large Boulder	
Bank Height:	1.3	m		Bank stabilization	Bank Height:	1.05	m
Bank Angle:	70	°		Fence	Bank Angle:	40	°
Root Depth:	0.50	m		Grasses	Root Depth:	0.50	m
Root Density:	60	%		Leaning tree	Root Density:	60	%
Undercut:	NA	m		Tree	Undercut:	NA	m
Erosion Pin:	NA	m		Woody Debris	Erosion Pin:	NA	m
Torvane:	NA	kg/cm²		Sediment sample	Torvane:	NA	kg/cm²
Penetrometer:	NA	kg/cm²		Erosion pin	Penetrometer:	NA	kg/cm²
Foot Used:	☐ Yes ☐ No			Scour/bed chain	Foot Used:	☐ Yes ☐ No	

Additional Notes

Photos: RB: A09 DS: A10 LB: A11 US. A12

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics

Project Number: 23010

Date:	10-05-23	**Cross-section:**	XS 4
Time:	1:30 PM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

					Notes
RTK					

Cross-sectional Morphology (Table 22)

☐ Riffle ☐ Pool ☐ Run ☒ Other

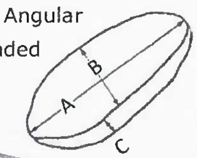
Substrate Sample: RB

☐ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
SILT			SILT			SILT			SILT		
	2			12			22			32	
	3			13			23			33	
4	4	4	14	14	14	24	24	24	34	34	34
	5			15			25			35	
	6			16			26			36	
	7			17			27			37	
8	8	8	18	18	18	28	28	28	38	38	38
	9			19			29			39	
	10			20			30			40	

Particle Shape: ☐ Platy ☐ Very Angular
☐ Sub-angular ☐ Angular ☐ Rounded
☐ Sub-Rounded ☐ Well Rounded



Embededness: ________ %

Subpavement: ____________________

[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ____________

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ____________ %

Velocity

☐ Measured ________ m/s Method: ____________

☐ Estimated ________ m/s XS ID: ____________

Distance ________ m Time ________ s V ________ m/s

Distance ________ m Time ________ s V ________ m/s

Distance ________ m Time ________ s V ________ m/s

Discharge

☐ Estimated ________ m^3/s Method: ____________

☐ Measured ________ m^3/s XS ID: ____________

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

Senior staff sign-off (if required): ________ Checked by: ________ Completed by: KS

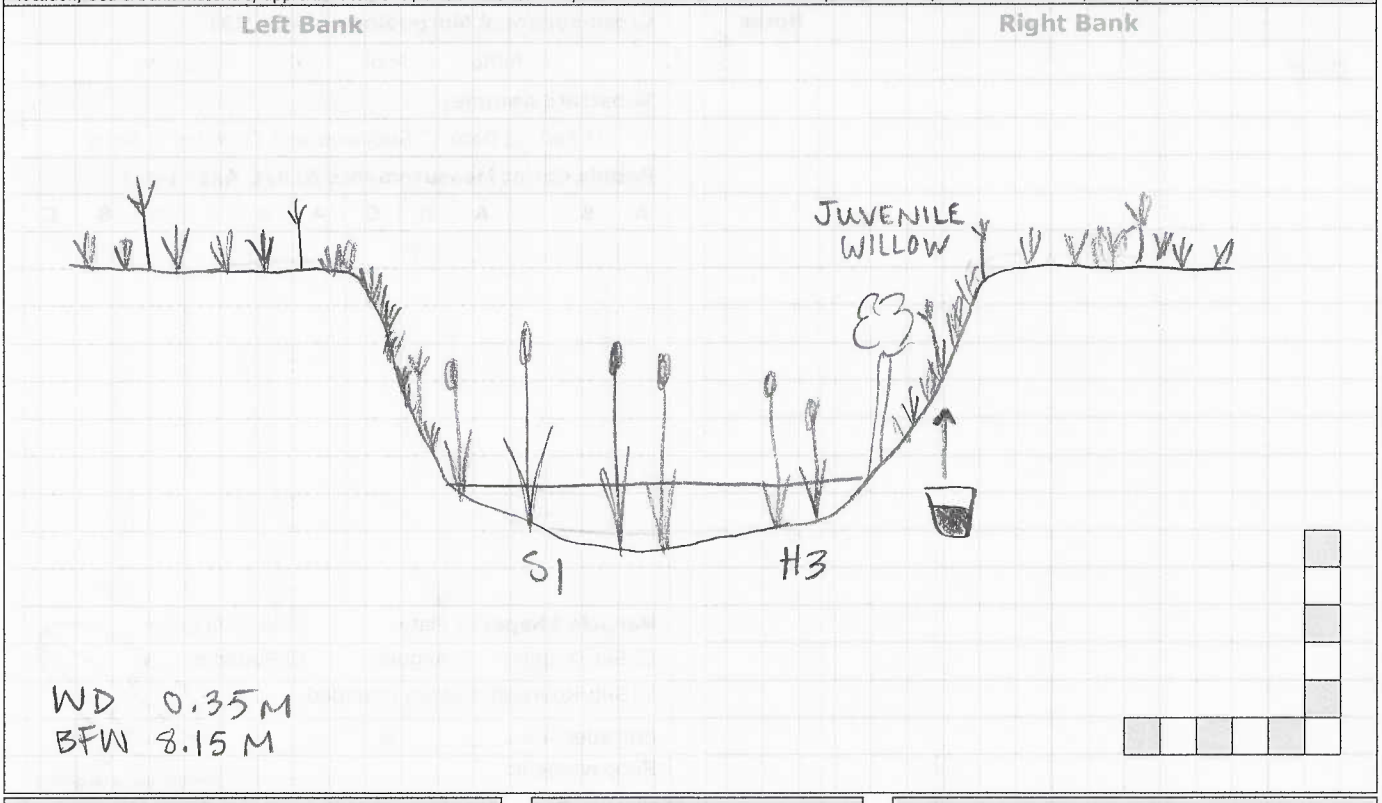
GEO MORPHIX™

Bank Characteristics

Project Number: 23010

Date:	10-05-23	**Cross-section:**	XS4
Time:	1:30 PM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials			Features		Right Bank Materials		
☐ Bedrock	☐ Gravel			Station location	☐ Bedrock	☐ Gravel	
☐ Till	☐ Small Cobble			Monumented XS	☐ Till	☐ Small Cobble	
☐ Clay	☐ Large Cobble			Monumented photo	☐ Clay	☐ Large Cobble	
☒ Silt	☐ Small Boulder		------	Undercut bank	☒ Silt	☐ Small Boulder	
☐ Sand	☐ Large Boulder		#####	Eroded bank/slope	☐ Sand	☐ Large Boulder	
Bank Height:	1.45	m		Bank stabilization	Bank Height:	1.40	m
Bank Angle:	80	°	x-x-x	Fence	Bank Angle:	70	°
Root Depth:	0.60	m		Grasses	Root Depth:	0.50	m
Root Density:	80	%		Leaning tree	Root Density:	70	%
Undercut:	NA	m		Tree	Undercut:	NA	m
Erosion Pin:	NA	m		Woody Debris	Erosion Pin:	NA	m
Torvane:	NA	kg/cm²		Sediment sample	Torvane:	NA	kg/cm²
Penetrometer:	NA	kg/cm²		Erosion pin	Penetrometer:	NA	kg/cm²
Foot Used:	☐ Yes ☐ No			Scour/bed chain	Foot Used:	☐ Yes ☐ No	

Additional Notes

DISJOINTED CULVERT IMMEDIATELY U/S

Photos: DS: 413 LB: 414 US: 415 RB: 416

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics

Project Number: 23010

Date:	10-05-23	**Cross-section:**	XS5
Time:	1:50 PM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

					Notes
RTK					

Cross-sectional Morphology (Table 22)

☐ Riffle ☒ Pool ☐ Run ☐ Other

Substrate Sample:

☐ Bed ☐ Bank ☐ Subpavement ☐ Water ☐ None

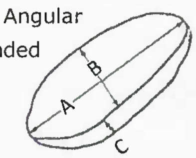
Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
SILT			SILT			SILT			SILT		

Particle Shape: ☐ Platy ☐ Very Angular ☐ Sub-angular ☐ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded

Embededness: ______ %

Subpavement: ______



[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ______

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ______ %

Velocity

☐ Measured ______ m/s Method: ______

☐ Estimated ______ m/s XS ID: ______

Distance ______ m Time ______ s V ______ m/s

Distance ______ m Time ______ s V ______ m/s

Distance ______ m Time ______ s V ______ m/s

Discharge

☐ Estimated ______ m^3/s Method: ______

☐ Measured ______ m^3/s XS ID: ______

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

Senior staff sign-off (if required): ______ Checked by: ______ Completed by: KS

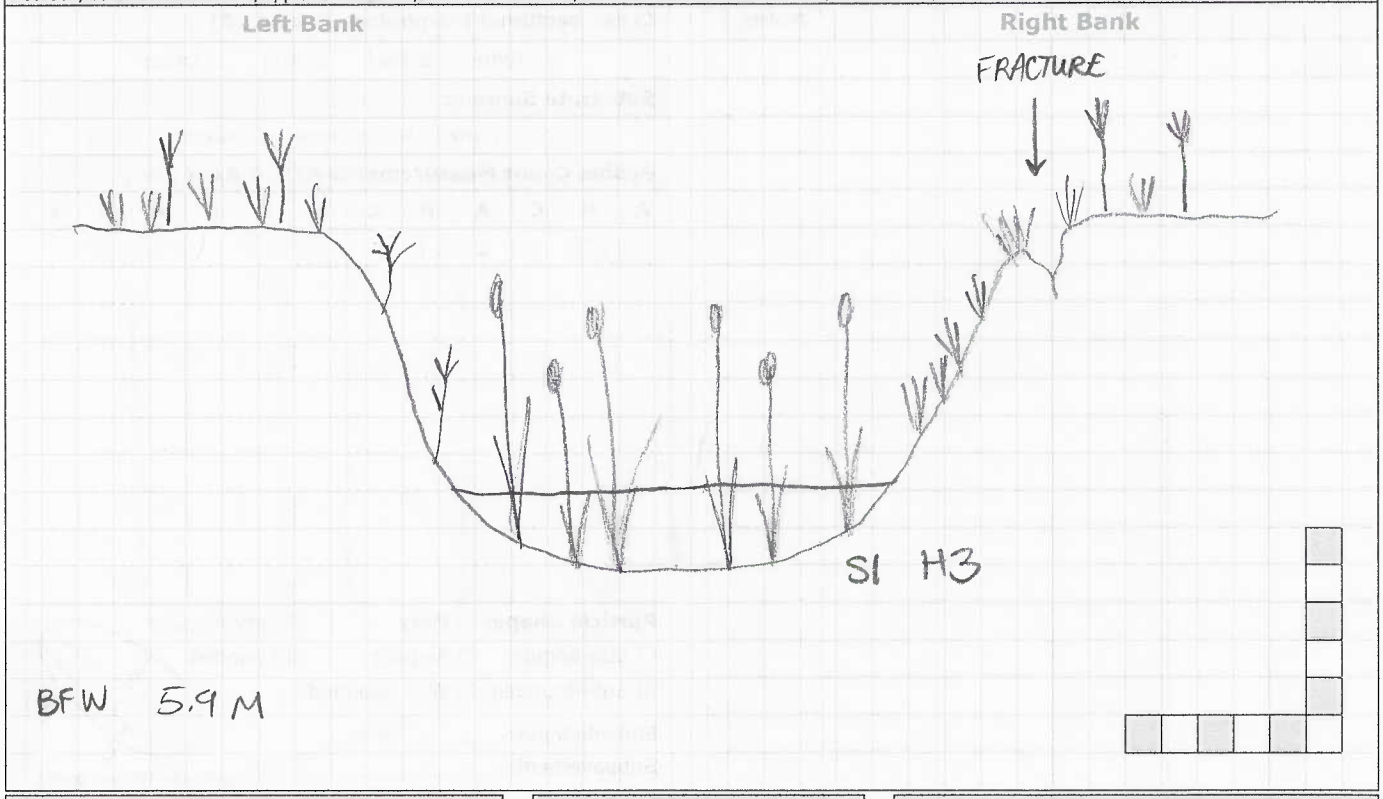
GEO MORPHIX

Bank Characteristics

Project Number: 23010

Date:	10-05-23	**Cross-section:**	XS5
Time:	1:50 PM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials			Features		Right Bank Materials		
☐ Bedrock	☐ Gravel			Station location	☐ Bedrock	☐ Gravel	
☐ Till	☐ Small Cobble			Monumented XS	☐ Till	☐ Small Cobble	
☐ Clay	☐ Large Cobble			Monumented photo	☐ Clay	☐ Large Cobble	
☒ Silt	☐ Small Boulder		------	Undercut bank	☒ Silt	☐ Small Boulder	
☐ Sand	☐ Large Boulder		#####	Eroded bank/slope	☐ Sand	☐ Large Boulder	
Bank Height:	1.4	m		Bank stabilization	Bank Height:	1.4	m
Bank Angle:	80	°	x-x-x	Fence	Bank Angle:	70	°
Root Depth:	0.36	m		Grasses	Root Depth:	0.60	m
Root Density:	36	%		Leaning tree	Root Density:	70	%
Undercut:	NA	m		Tree	Undercut:	NA	m
Erosion Pin:	NA	m		Woody Debris	Erosion Pin:	NA	m
Torvane:	NA	kg/cm²		Sediment sample	Torvane:	NA	kg/cm²
Penetrometer:	NA	kg/cm²		Erosion pin	Penetrometer:	NA	kg/cm²
Foot Used:	☐ Yes ☐ No			Scour/bed chain	Foot Used:	☐ Yes ☐ No	

Additional Notes

FRACTURES ALONG TOP OF RB
DISJOINTED CULVERT IMMEDIATELY DOWNSTREAM
WATER OPAQUE GREY-BROWN

Photos: RB: A16 DS: A17 US: A18 LB: A19

Version #4
Last edited: 21/02/2023

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

Detailed Cross-Section Characteristics **Project Number:** 23010

GEO MORPHIX™

Date:	10-05-23	**Cross-section:**	XS 6
Time:	2:30 PM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

					Notes
RTK					

Cross-sectional Morphology (Table 22)

☐ Riffle ☐ Pool ☐ Run ☒ Other

Substrate Sample:

☐ Bed ☐ Bank ☐ Subpavement ☐ Water ☒ None

Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
SILT			SILT			SILT			SILT		

Particle Shape: ☐ Platy ☐ Very Angular ☐ Sub-angular ☐ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded

Embededness: ________ %

Subpavement: ________

[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ________

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ________ %

Velocity

☐ Measured ________ m/s Method: ________

☐ Estimated ________ m/s XS ID: ________

Distance ________ m Time ________ s V ________ m/s

Distance ________ m Time ________ s V ________ m/s

Distance ________ m Time ________ s V ________ m/s

Discharge

☐ Estimated ________ m^3/s Method: ________

☐ Measured ________ m^3/s XS ID: ________

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

Senior staff sign-off (if required): ________ Checked by: ________ Completed by: KS

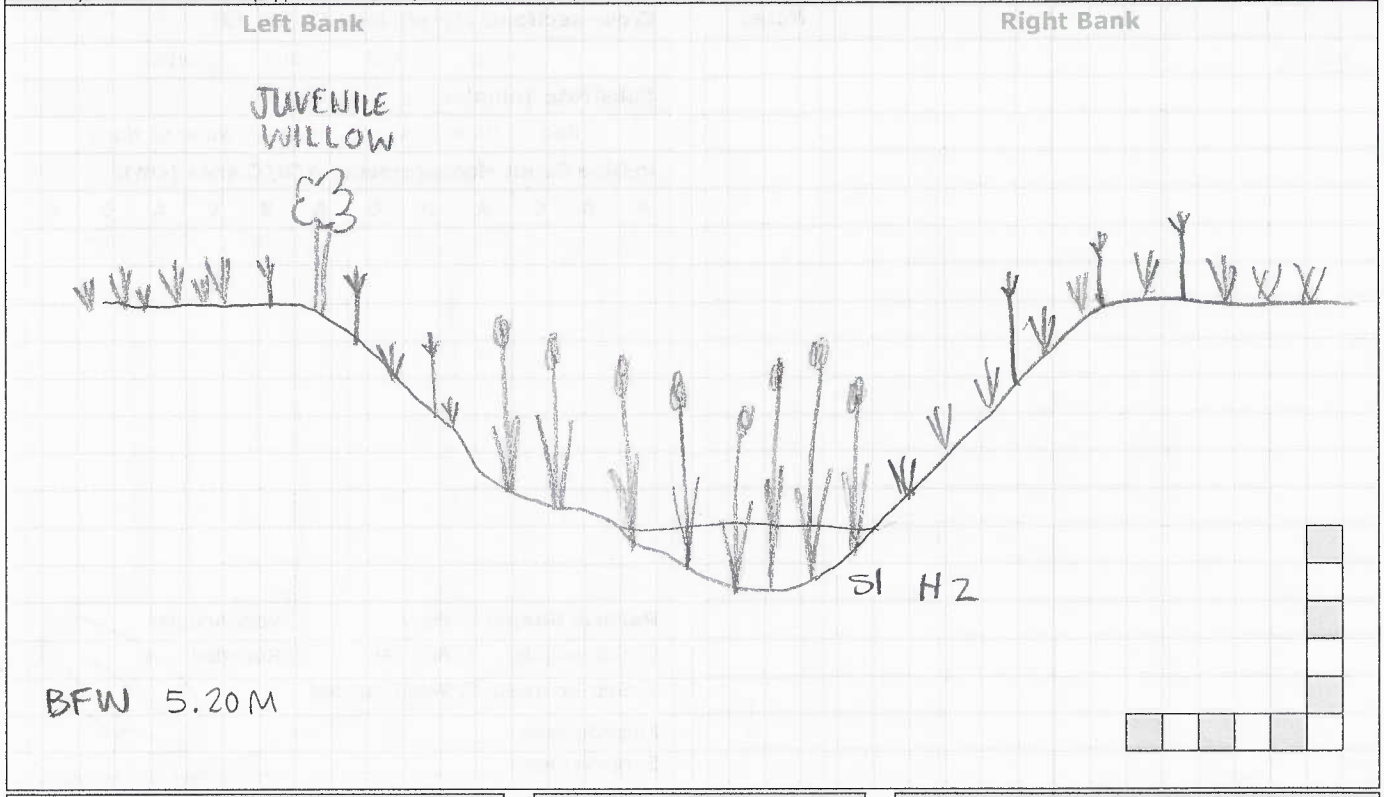
GEO MORPHIX

Bank Characteristics

Project Number: 23010

Date:	10-05-23	**Cross-section:**	XS 6
Time:	2:30 PM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials			Features		Right Bank Materials		
☐ Bedrock	☐ Gravel			Station location	☐ Bedrock	☐ Gravel	
☐ Till	☐ Small Cobble			Monumented XS	☐ Till	☐ Small Cobble	
☐ Clay	☐ Large Cobble			Monumented photo	☐ Clay	☐ Large Cobble	
☒ Silt	☐ Small Boulder			Undercut bank	☒ Silt	☐ Small Boulder	
☐ Sand	☐ Large Boulder			Eroded bank/slope	☐ Sand	☐ Large Boulder	
Bank Height:	1.15	m		Bank stabilization	Bank Height:	1.10	m
Bank Angle:	60	°		Fence	Bank Angle:	60	°
Root Depth:	0.50	m		Grasses	Root Depth:	0.5	m
Root Density:	80	%		Leaning tree	Root Density:	80	%
Undercut:	NA	m		Tree	Undercut:	NA	m
Erosion Pin:	NA	m		Woody Debris	Erosion Pin:	NA	m
Torvane:	NA	kg/cm²		Sediment sample	Torvane:	NA	kg/cm²
Penetrometer:	NA	kg/cm²		Erosion pin	Penetrometer:	NA	kg/cm²
Foot Used:	☐ Yes ☐ No			Scour/bed chain	Foot Used:	☐ Yes ☐ No	

Additional Notes

Photos: RB: 426 LB: 427 DS: 428 US: 429

Version #4
Last edited: 21/02/2023

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

GEO
MORPHIX

Detailed Cross-Section Characteristics   Project Number: 23010

Date:	10-05-23	**Cross-section:**	XS 7
Time:	2:10 PM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

					Notes
RTK					

Cross-sectional Morphology (Table 22)

☐ Riffle ☐ Pool ☐ Run ☒ Other

Substrate Sample:

☐ Bed ☐ Bank ☐ Subpavement ☐ Water ☒ None

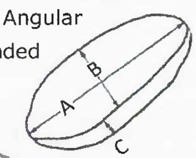
Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
SILT			SILT			SILT			SILT		

Particle Shape: ☐ Platy ☐ Very Angular ☐ Sub-angular ☐ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded

Embededness: ________ %

Subpavement: ____________________



[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason:____________

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ______________ %

Velocity

☐ Measured ________m/s Method: ______________

☐ Estimated ________m/s XS ID: ______________

Distance __________m Time __________s V ________m/s

Distance __________m Time __________s V ________m/s

Distance __________m Time __________s V ________m/s

Discharge

☐ Estimated ________m^3/s Method: ______________

☐ Measured ________m^3/s XS ID: ______________

Depth _________m Width _________m V_{60} _________m/s

Depth _________m Width _________m V_{60} _________m/s

Depth _________m Width _________m V_{60} _________m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

Senior staff sign-off (if required): ________ Checked by: ________ Completed by: KS

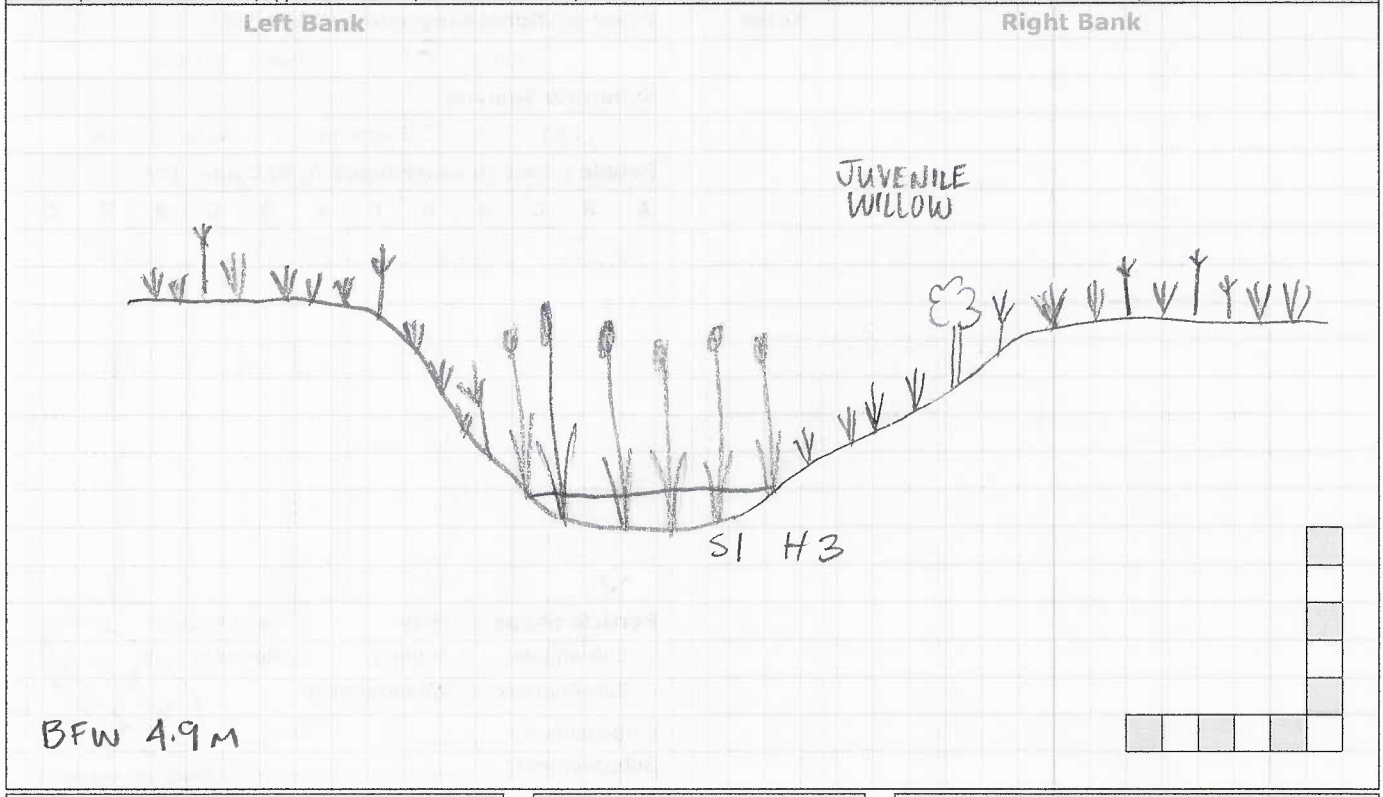
GEO MORPHIX™

Bank Characteristics

Project Number: 23010

Date:	10-05-23	**Cross-section:**	XS 7
Time:	2:10 PM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials			Features	Right Bank Materials		
☐ Bedrock	☐ Gravel		Station location	☐ Bedrock	☐ Gravel	
☐ Till	☐ Small Cobble		Monumented XS	☐ Till	☐ Small Cobble	
☐ Clay	☐ Large Cobble		Monumented photo	☐ Clay	☐ Large Cobble	
☒ Silt	☐ Small Boulder		Undercut bank	☒ Silt	☐ Small Boulder	
☐ Sand	☐ Large Boulder		Eroded bank/slope	☐ Sand	☐ Large Boulder	
Bank Height:	1.3	m	Bank stabilization	Bank Height:	1.05	m
Bank Angle:	70	°	Fence	Bank Angle:	35	°
Root Depth:	0.50	m	Grasses	Root Depth:	0.50	m
Root Density:	80	%	Leaning tree	Root Density:	80	%
Undercut:	NA	m	Tree	Undercut:	NA	m
Erosion Pin:	NA	m	Woody Debris	Erosion Pin:	NA	m
Torvane:	NA	kg/cm²	Sediment sample	Torvane:	NA	kg/cm²
Penetrometer:	NA	kg/cm²	Erosion pin	Penetrometer:	NA	kg/cm²
Foot Used:	☐ Yes ☐ No		Scour/bed chain	Foot Used:	☐ Yes ☐ No	

Additional Notes

Photos: LB: 422 US: 423 DS: 424 RB: 425

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics   Project Number: 23010

Date:	10-05-23	**Cross-section:**	XS 8
Time:	2:45 PM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

					Notes
RTK					

Cross-sectional Morphology (Table 22)

☐ Riffle ☐ Pool ☐ Run ☒ Other

Substrate Sample: RB

☐ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

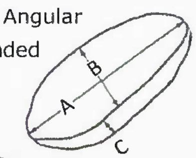
Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
SILT			SILT			SILT			SILT		
↓			↓			↓			↓		

Particle Shape: ☐ Platy ☐ Very Angular
☐ Sub-angular ☐ Angular ☐ Rounded
☐ Sub-Rounded ☐ Well Rounded

Embededness: ________ %

Subpavement: ____________________



[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ________

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ________________ %

Velocity

☐ Measured ________m/s Method: ______________

☐ Estimated ________m/s XS ID: ______________

Distance ________m Time ________s V ________m/s

Distance ________m Time ________s V ________m/s

Distance ________m Time ________s V ________m/s

Discharge

☐ Estimated ________m^3/s Method: ______________

☐ Measured ________m^3/s XS ID: ______________

Depth ________m Width ________m V_{60} ________m/s

Depth ________m Width ________m V_{60} ________m/s

Depth ________m Width ________m V_{60} ________m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

Senior staff sign-off (if required): ________ Checked by: ________ Completed by: KS

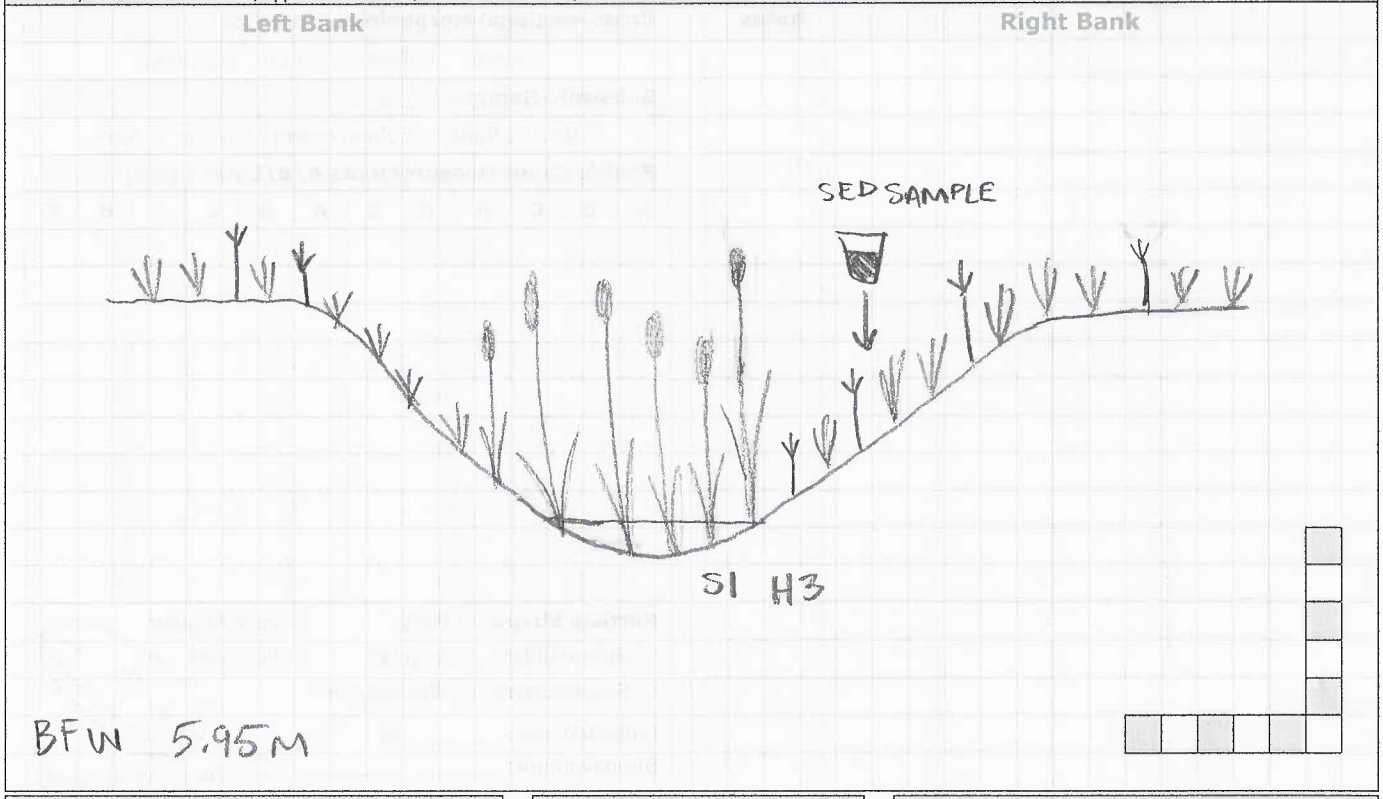
GEO MORPHIX

Bank Characteristics

Project Number: 23018

Date:	10-05-23	**Cross-section:**	XS 8
Time:	2:45 PM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials			Features		Right Bank Materials		
☐ Bedrock	☐ Gravel			Station location	☐ Bedrock	☐ Gravel	
☐ Till	☐ Small Cobble			Monumented XS	☐ Till	☐ Small Cobble	
☐ Clay	☐ Large Cobble			Monumented photo	☐ Clay	☐ Large Cobble	
☒ Silt	☐ Small Boulder			Undercut bank	☒ Silt	☐ Small Boulder	
☐ Sand	☐ Large Boulder			Eroded bank/slope	☐ Sand	☐ Large Boulder	
Bank Height:	1.15	m		Bank stabilization	Bank Height:	1.0	m
Bank Angle:	56	°		Fence	Bank Angle:	45	°
Root Depth:	0.50	m		Grasses	Root Depth:	0.50	m
Root Density:	80	%		Leaning tree	Root Density:	70	%
Undercut:	NA	m		Tree	Undercut:	NA	m
Erosion Pin:	NA	m		Woody Debris	Erosion Pin:	NA	m
Torvane:	NA	kg/cm²		Sediment sample	Torvane:	NA	kg/cm²
Penetrometer:	NA	kg/cm²		Erosion pin	Penetrometer:	NA	kg/cm²
Foot Used:	☐ Yes ☐ No			Scour/bed chain	Foot Used:	☐ Yes ☐ No	

Additional Notes

Photos: RB: 430 LB: 431 DS: 432 US: 433

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics   Project Number: 23010

Date:	10-05-23	**Cross-section:**	XS9
Time:	3:00 PM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

					Notes
RTK					

Cross-sectional Morphology (Table 22)

☐ Riffle ☐ Pool ☐ Run ☒ Other

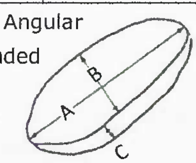
Substrate Sample:

☐ Bed ☐ Bank ☐ Subpavement ☐ Water ☒ None

Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
SILT			SILT			SILT			SILT		
↓			↓			↓			↓		

Particle Shape: ☐ Platy ☐ Very Angular ☐ Sub-angular ☐ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded



Embededness: ________ %

Subpavement: ________________

[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason:____________

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ________________ %

Velocity

☐ Measured ________m/s Method: ____________

☐ Estimated ________m/s XS ID: ____________

Distance ________m Time ________s V ________m/s

Distance ________m Time ________s V ________m/s

Distance ________m Time ________s V ________m/s

Discharge

☐ Estimated ________m^3/s Method: ____________

☐ Measured ________m^3/s XS ID: ____________

Depth ________m Width ________m V_{60} ________m/s

Depth ________m Width ________m V_{60} ________m/s

Depth ________m Width ________m V_{60} ________m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

Senior staff sign-off (if required): ________ Checked by: ________ Completed by: KS

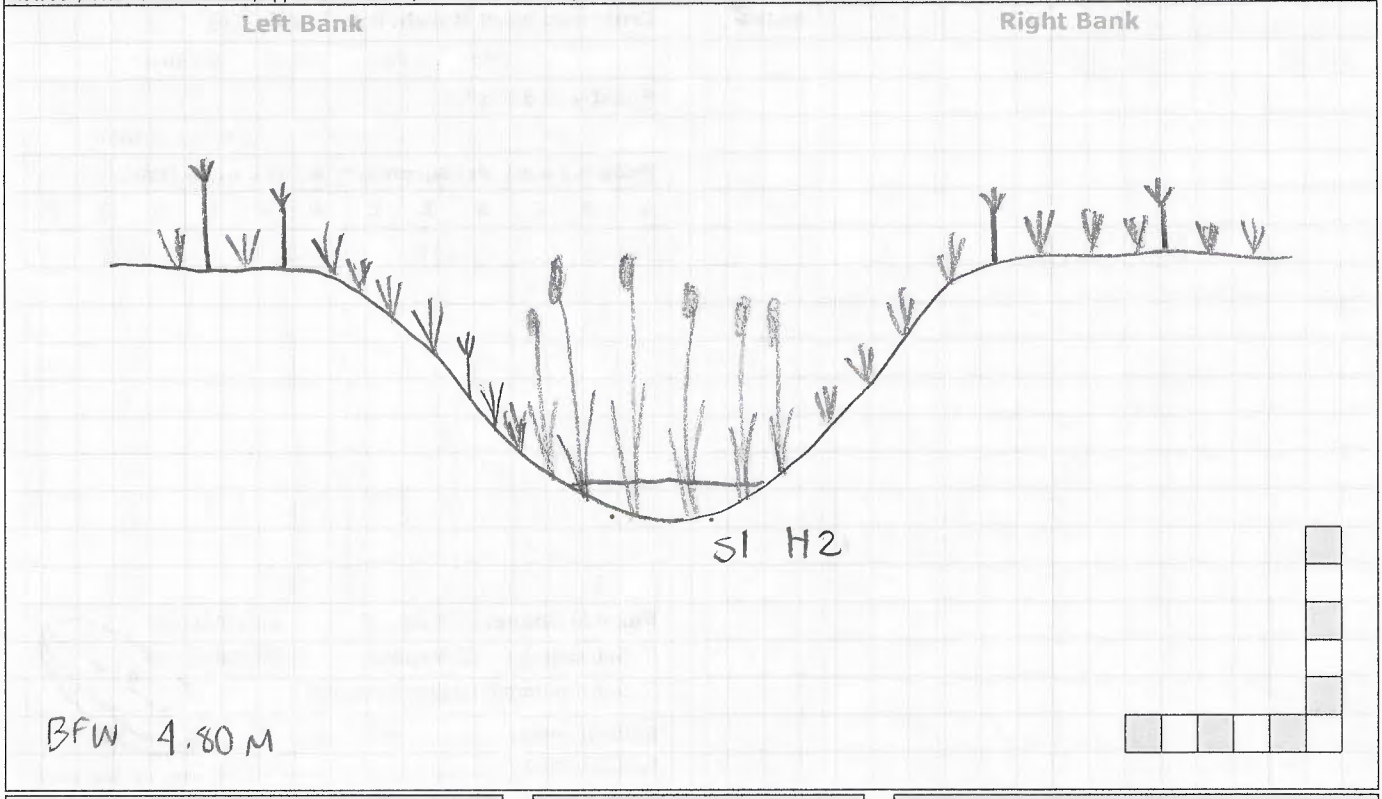
GEO MORPHIX

Bank Characteristics

Project Number: 23010

Date:	10-05-23	**Cross-section:**	XS 9
Time:	3:00PM	**Reach:**	IC-T3
Weather:	SUNNY 20°C	**Location:**	BURLINGTON
Field Staff:	AA KS	**Watershed/Subwatershed:**	INDIAN CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials			Features		Right Bank Materials		
☐ Bedrock	☐ Gravel			Station location	☐ Bedrock	☐ Gravel	
☐ Till	☐ Small Cobble			Monumented XS	☐ Till	☐ Small Cobble	
☐ Clay	☐ Large Cobble			Monumented photo	☐ Clay	☐ Large Cobble	
☒ Silt	☐ Small Boulder			Undercut bank	☒ Silt	☐ Small Boulder	
☐ Sand	☐ Large Boulder			Eroded bank/slope	☐ Sand	☐ Large Boulder	
Bank Height:	1	m		Bank stabilization	Bank Height:	0.8	m
Bank Angle:	45	°		Fence	Bank Angle:	45	°
Root Depth:	0.50	m		Grasses	Root Depth:	0.50	m
Root Density:	80	%		Leaning tree	Root Density:	70	%
Undercut:	NA	m		Tree	Undercut:	NA	m
Erosion Pin:	NA	m		Woody Debris	Erosion Pin:	NA	m
Torvane:	NA	kg/cm²		Sediment sample	Torvane:	NA	kg/cm²
Penetrometer:	NA	kg/cm²		Erosion pin	Penetrometer:	NA	kg/cm²
Foot Used:	☐ Yes ☐ No			Scour/bed chain	Foot Used:	☐ Yes ☐ No	

Additional Notes

Photos: LB: A34 DS: A35 US: A36 RB: A37

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX

General Site Characteristics

Project Number: 23D10

Date:	2026-01-09	**Stream:**	Grindstone Creek
Time:	9:30	**Reach:**	GC-T1
Weather:	Mixed Sun, -20	**Location:**	Aldershot GO, Burlington
Field Staff:	JA CM	**Watershed/Subwatershed:**	16 Mile Creek Credit River

Features

- Reach break
- Station location
- Cross-section
- Flow direction
- Riffle
- Pool
- Sediment bar
- Eroded bank/slope
- Undercut bank
- Bank stabilization
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Beaver dam
- Vegetated island

Monitoring

- Long-profile
- Monumented XS
- Monumented photo
- Monumented photo direction
- Sediment sampling
- Erosion pins
- Scour chains

Additional Symbols

- survey flag tape
- // Cattails
- F Phrag
- Reach break
- S1 ice/flooded area

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

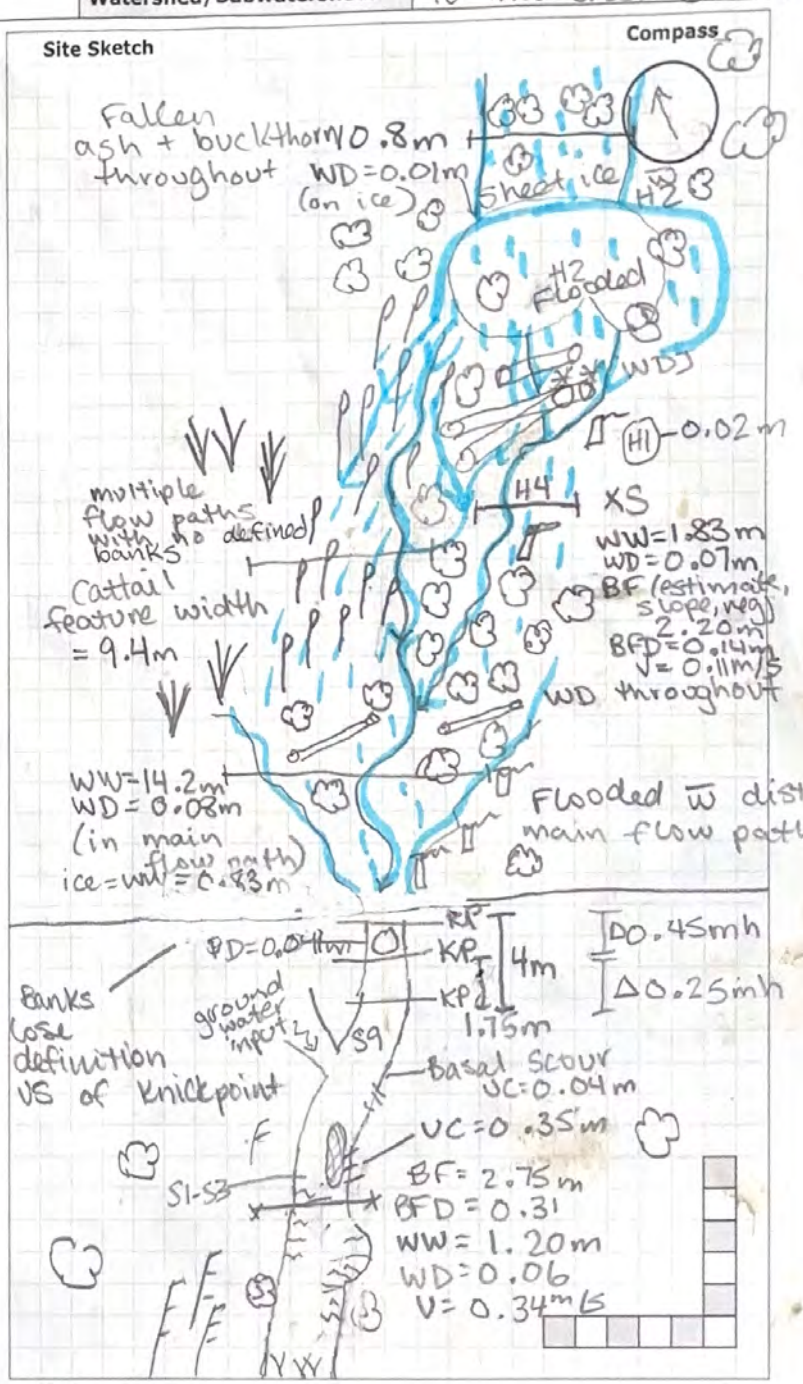
Substrate

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

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: DS of GC-T1 reach break clearly defined. GC-T1 was flooded and only had distinct main flow path in the DS extent No clear bank definition. Flooded and frozen S1/S2/clay substrate throughout

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: 23010

Date:	2026-01-09	**Stream:**	Grindstone Creek
Time:	9:30	**Reach:**	GC-T1
Weather:	Mixed Sun, -2°	**Location:**	Aldershot GO
Field Staff:	CM JA	**Watershed/Subwatershed:**	1k Mile Creek Credit River

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		

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

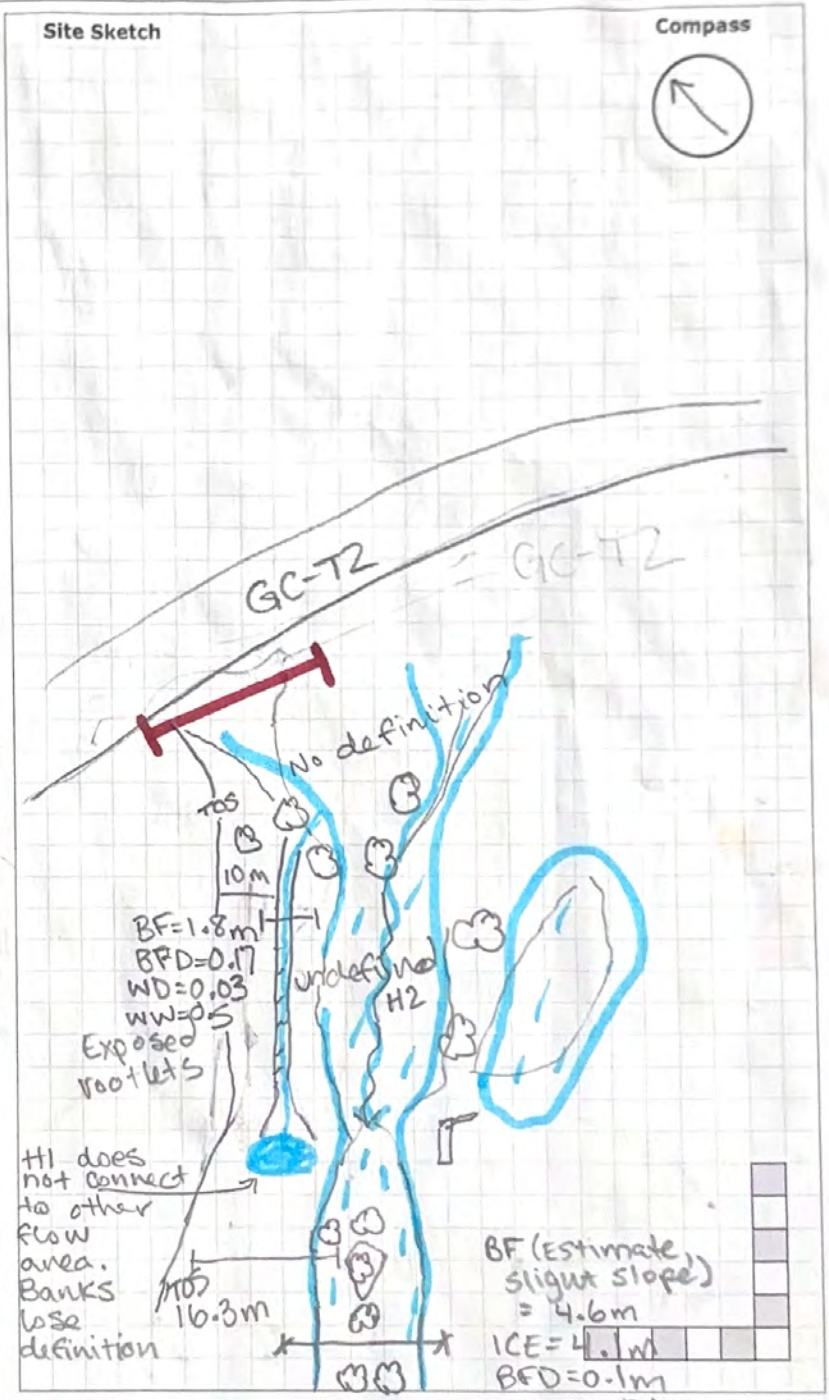
Substrate

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

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

Rapid Geomorphic Assessment

Project Number: 23010

Date:	2026-01-09	**Stream:**	Grindstone Creek
Time:	9:30	**Reach:**	GC-T1
Weather:	Sun, -2°	**Location:**	Aldershot GO, Burlington
Field Staff:	CM JA	**Watershed/Subwatershed:**	16 mile Crk, Credit River

Process	No.	Geomorphological Indicator	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		X	0/7
	2	Coarse materials in riffles embedded		X	
	3	Siltation in pools		X	
	4	Medial bars		X	
	5	Accretion on point bars		X	
	6	Poor longitudinal sorting of bed materials		X	
	7	Deposition in the overbank zone		X	
		Sum of indices =	0	7	0
Evidence of Degradation (DI)	1	Exposed bridge footing(s) N/A	—	—	1/5
	2	Exposed sanitary / storm sewer / pipeline / etc.		X	
	3	Elevated storm sewer outfall(s) N/A	—	—	
	4	Undermined gabion baskets / concrete aprons / etc. N/A	—	—	
	5	Scour pools downstream of culverts / storm sewer outlets N/A	—	—	
	6	Cut face on bar forms N/A	—	—	
	7	Head cutting due to knickpoint migration	1		
	8	Terrace cut through older bar material		X	
	9	Suspended armour layer visible in bank		X	
	10	Channel worn into undisturbed overburden / bedrock		X	
		Sum of indices =	1	4	0.2
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc. - Primarily decaying/dead trees.		X	0/8
	2	Occurrence of large organic debris - Same note as above		X	
	3	Exposed tree roots		X	
	4	Basal scour on inside meander bends		X	
	5	Basal scour on both sides of channel through riffle		X	
	6	Outflanked gabion baskets / concrete walls / etc. N/A	—	—	
	7	Length of basal scour >50% through subject reach		X	
	8	Exposed length of previously buried pipe / cable / etc.		X	
	9	Fracture lines along top of bank		X	
	10	Exposed building foundation N/A	—	—	
		Sum of indices =	0	8	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s) - multiple flood chutes	X		2/6
	2	Single thread channel to multiple channel - Channel banks not defined	—	NA	
	3	Evolution of pool-riffle form to low bed relief form Not within GC-T1 but from GC-T1 to	X		
	4	Cut-off channel(s)		X	
	5	Formation of island(s)		X	
	6	Thalweg alignment out of phase with meander form		X	
	7	Bar forms poorly formed / reworked / removed		V	
		Sum of indices =	2	4	0.33

Notes: → Reach flooded with multiple flow paths and poorly defined geomorphic units + banks
→ Heavy encroachment from trees/shrubs

Stability Index (SI) = (AI+DI+WI+PI)/4 =			0.13
In Regime	**In Transition/Stress**	**In Adjustment**	
☒ **0.00 - 0.20**	☐ **0.21 - 0.40**	☐ **0.41**	

Version #3
Last edited: 10/02/2023

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

→ Knick point + scour at DS extent but does not reflect majority of system

GEO MORPHIX

Rapid Stream Assessment Technique Project Number: 23010

Date:	2026-01-09	**Stream:**	Grindstone Crk
Time:	9:30	**Reach:**	GC-T1
Weather:	Sun, -2°	**Location:**	Aldershot GO, Burlington
Field Staff:	CM YA	**Watershed/Subwatershed:**	16 Mile Creek Credit River

Category	Poor	Fair	Good	Excellent
Channel Stability N/A No/minimal definition of banks	• < 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 Tree falls not due to widening	• 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) No large substrates. Mainly fines
	• 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

no bar forms

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX

Date:	2026-01-09	PN:	23010	Location:	Aldershot GO, Burlington

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
	• 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) = 21	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

GEO MORPHIX

Reach Characteristics

Project Number: 23010

Date:	2026-01-09	**Field Staff:**	CM JA	**Watershed/Subwatershed:**	16 Mile Creek Credit River
Time:	9:30	**Stream:**	Grindstone Creek	**UTM (Upstream):**	
Weather:	mixed Sun, -2°	**Reach:**	GC-T1	**UTM (Downstream):**	

Land Use (Table 1): 4 | **Valley Type** (Table 2): ☆ 1 | **Channel Type** (Table 3): 14 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 3 | ~~Evidence of Groundwater Location~~ ~~Photo:~~

Riparian Vegetation

Dominant Type (Table 6): 1+2 | **Encroachment** (Table 7): 4

Coverage	Channel Widths	Age (yrs)
☐ None	☐ 1 - 4	☐ Immature (<5)
☒ Fragmented	☐ 4 - 10	☑ Established (5-30)
☐ Continuous	☒ > 10	☐ Mature (>30)

Aquatic & Instream Vegetation

Type (Table 8): N/A | **Reach Coverage %**: N/A

Woody Debris	WD Density
☐ In Cutbank	☐ Low
☐ In Channel	☐ Mod
☐ Not Present	☑ High

WDJ/50m: 2

Water Quality

Odour (Table 16): 1 | **Turbidity** (Table 17): 1

Channel Characteristics

Sinuosity Type (Table 9): ☆3 | **Gradient** (Table 11): 1 | **Entrenchment** (Table 13): 1 | **Down's Model** (Table 15): S | **Sed Sorting** (Table 20): well | **Transport Mode** (Table 21): 3 | **Geomorphic Units** (Table 22): N/A | **Riffle-Pool Spacing (m)**: N/A

Sinuosity Degree (Table 10): 2 | **# of Channels** (Table 12): 5 | **Bank Failure** (Table 14): N/A | **Bankfull Indicators** (Table 18): ☆ | **Sediment Transport Observed?** ☐ Yes ☒ No ☐ Not Visible | **% of Bed Active**: 0 | **Mass Movement** (Table 23): N/A | **% Riffles**: N/A | **% Pools**: N/A

Bank Angle	Bank Erosion
☑ 0 - 30	☑ < 5%
☐ 30 - 60	☐ 5 - 30%
☐ 60 - 90	☐ 30 - 60%
☐ Undercut	☐ 60 - 100%

(Table 19)	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Bank	☑	☑	☐	☐	☐	☐	☐
Riffle	☐	☐	☐	☐	☐	☐	☐
Pool	☐	☐	☐	☐	☐	☐	☐
Bed (if no riffle-pool morphology)	☑	☑	☐	☐	☐	☐	☐

☆ **Bankfull Width (m)**	☆	☆	☆	**Wetted Width (m)**	1.83	14.2	0.83
☆ **Bankfull Depth (m)**	☆	☆	☆	**Wetted Depth (m)**	0.07	0.08	0.02
Undercuts (m)				**Velocity (m/s)**	0.11	0.01	0
Pool Depth (m)				**Velocity Estimate Method**	WB	WB	WB
Riffle Length (m)				**Meander Amplitude (m)**	N/A		→

Notes:

Reach was flooded at time of assessment. Multiple flow paths present. Absent/Poor channel definition
☆ Valley wall present on RB side of reach in the most US extent. Otherwise unconfined
☆ Bankfull widths/depths were measured during site walk, but BF indicators were weak and should not be considered hard definitions
High volume of woody debris from diseased trees
When dominant flow path was noted, sinuosity was low
→ Riparian veg had some gaps that were primarily grasses or cattails

Photos:

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX

General Site Characteristics

Project Number: 23010

Date:	2026-01-09	**Stream:**	Grindstone Creek
Time:	10:30	**Reach:**	GC-T2
Weather:	Rain, -2°	**Location:**	Aldershot GO, Burlington
Field Staff:	CM JA	**Watershed/Subwatershed:**	16 Mile Creek Credit River

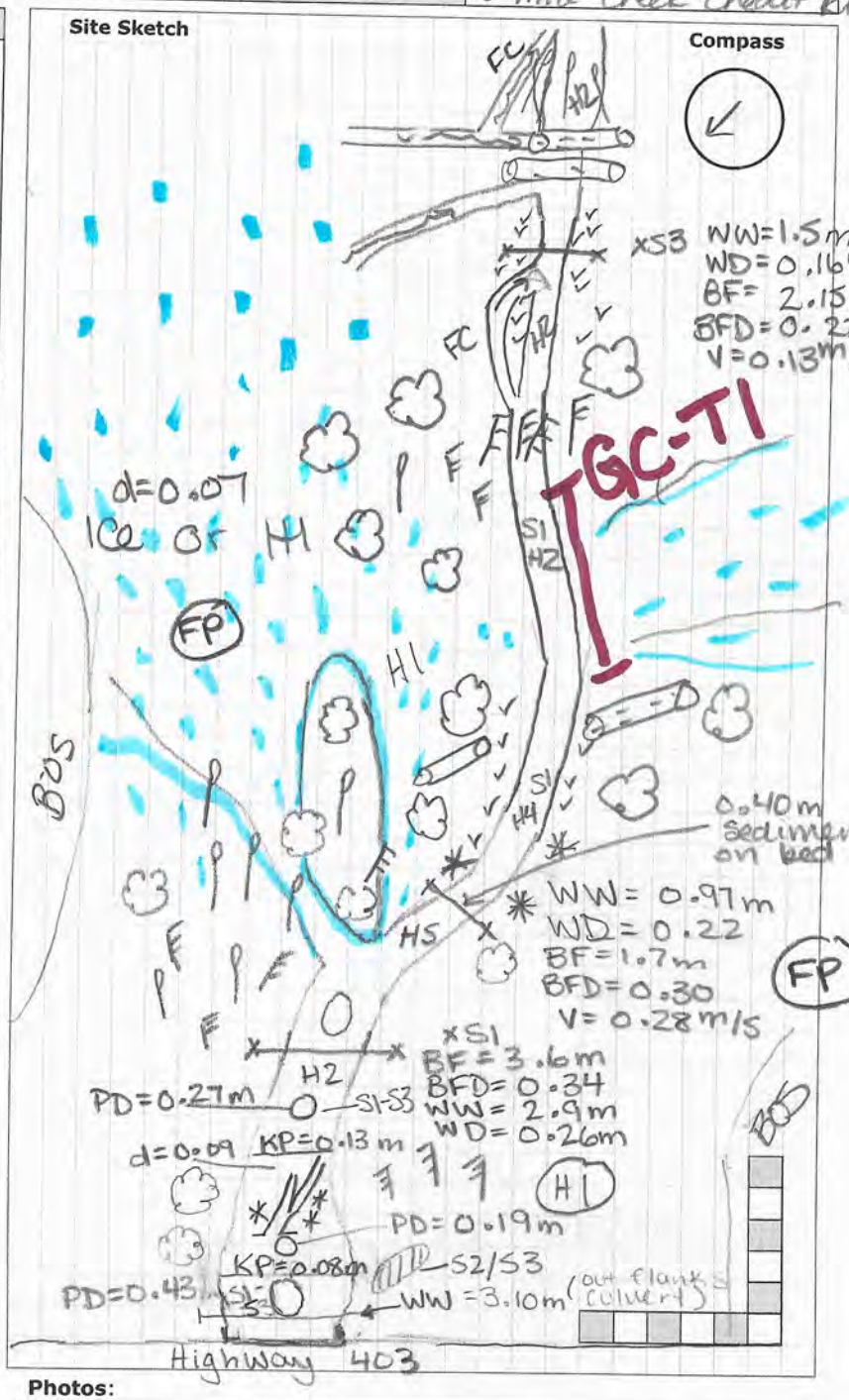
Features		Monitoring	
	Reach break		Long-profile
	Station location		Monumented XS
	Cross-section		Monumented photo
	Flow direction		Monumented photo direction
	Riffle		Sediment sampling
	Pool		Erosion pins
	Sediment bar		Scour chains
	Eroded bank/slope	**Additional Symbols**	
	Undercut bank	FFF	Phragmites
	Bank stabilization		Culvert
	Leaning tree		Deposition on bank
	Fence	S1 S3	Flooded area
	Culvert/outfall		Reach break
	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		

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:

Clay, Silt, Sand, gravel bed + banks consistent throughout reach. Minor basal scour near online pond

Grey tinge + sulfuric odour to water

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: 23010

Date:	2026-01-09	**Stream:**	Grindstone Creek
Time:	10:30	**Reach:**	GC-T2
Weather:	Rain/Sun, -2°	**Location:**	Aldershot GO, Burlington
Field Staff:	CM JA	**Watershed/Subwatershed:**	16 MC Credit River

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	Tree with J trunk
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

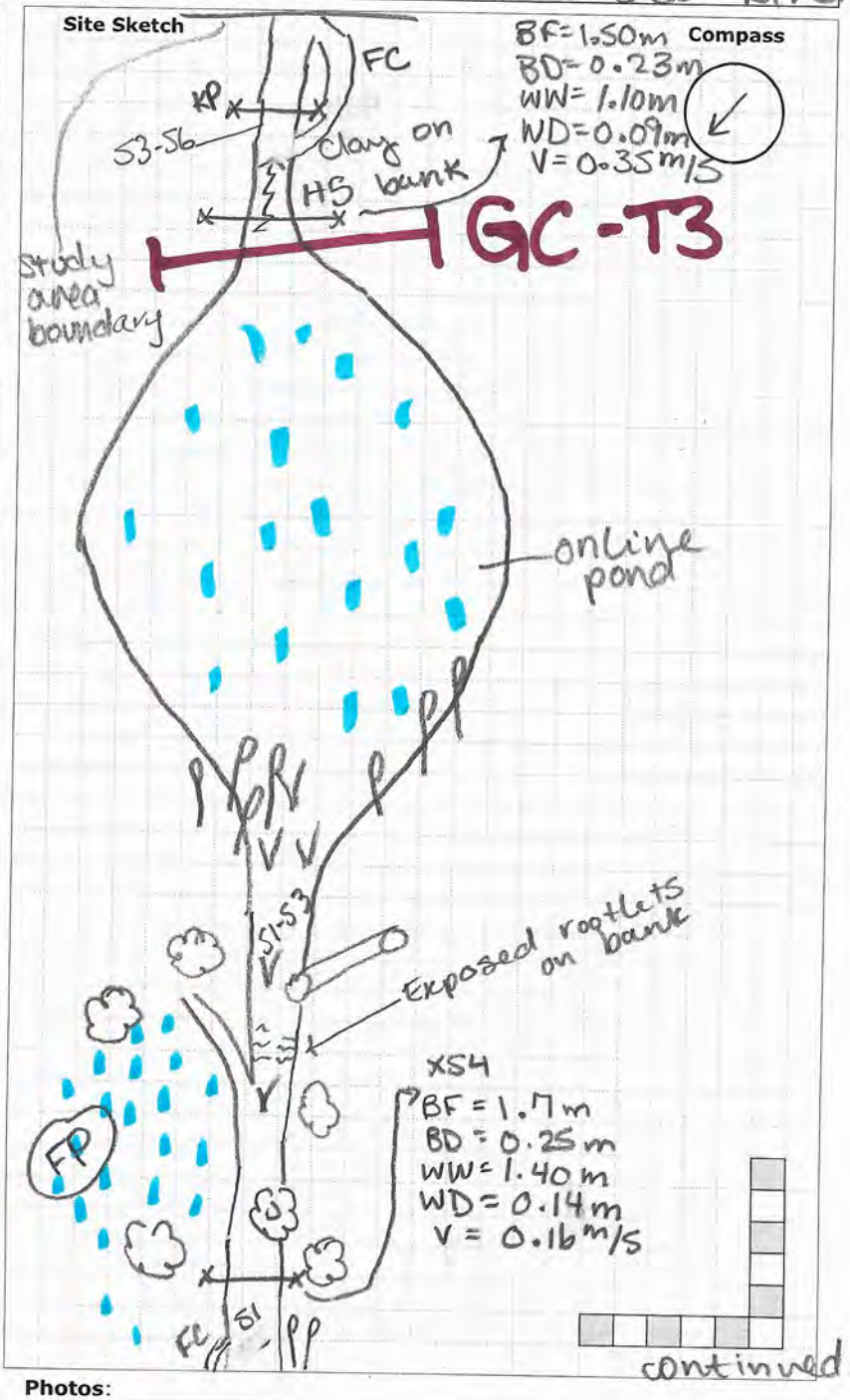
Substrate

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

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

Rapid Geomorphic Assessment **Project Number:** 23010

Date:	2026-01-09	**Stream:**	Grindstone Creek
Time:	10:30	**Reach:**	GC-T2
Weather:	mixed sun/rain, -2°	**Location:**	Aldershot GO, Burlington
Field Staff:	CM YA	**Watershed/Subwatershed:**	16MC, Credit River

Process	No.	Geomorphological Indicator	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		X	1/5
	2	Coarse materials in riffles embedded N/A	—	—	
	3	Siltation in pools	X		
	4	Medial bars		X	
	5	Accretion on point bars		X	
	6	Poor longitudinal sorting of bed materials N/A	—	—	
	7	Deposition in the overbank zone * near culvert only		X	
		Sum of indices =	1	4	0.20
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		X	0/9
	2	Exposed sanitary / storm sewer / pipeline / etc.		X	
	3	Elevated storm sewer outfall(s)		X	
	4	Undermined gabion baskets / concrete aprons / etc. ↗ Right culvert wing slightly eroded at toe.		X	
	5	Scour pools downstream of culverts / storm sewer outlets		X	
	6	Cut face on bar forms N/A	—	—	
	7	Head cutting due to knickpoint migration		X	
	8	Terrace cut through older bar material		X	
	9	Suspended armour layer visible in bank		X	
	10	Channel worn into undisturbed overburden / bedrock		X	
		Sum of indices =	0	9	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc. - From dying trees		X	1/9
	2	Occurrence of large organic debris		X	
	3	Exposed tree roots → DS extent	X		
	4	Basal scour on inside meander bends		X	
	5	Basal scour on both sides of channel through riffle		X	
	6	Outflanked gabion baskets / concrete walls / etc.		X	
	7	Length of basal scour >50% through subject reach		X	
	8	Exposed length of previously buried pipe / cable / etc.		X	
	9	Fracture lines along top of bank		X	
	10	Exposed building foundation N/A	—	—	
		Sum of indices =	1	8	0.11
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s) * flood shoots throughout	X		2/7
	2	Single thread channel to multiple channel		X	
	3	Evolution of pool-riffle form to low bed relief form - RP with pools to runs	X		
	4	Cut-off channel(s)		X	
	5	Formation of island(s)		X	
	6	Thalweg alignment out of phase with meander form		X	
	7	Bar forms poorly formed / reworked / removed		X	
		Sum of indices =	2	5	0.29

Notes: →Siltation in pools →deposition on banks primarily US at 403
→Knickpoints from roots
→Woody debris does not match widening, but from dying trees
→Flood went to valley wall

Stability Index (SI) = (AI+DI+WI+PI)/4 =		0.15
In Regime	**In Transition/Stress**	**In Adjustment**
☒ **0.00 - 0.20**	☐ **0.21 - 0.40**	☐ **0.41**

Version #3
Last edited: 10/02/2023

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

GEO MORPHIX

Date:	2026-01-09	PN:	23010	Location:	Burlington, On

Category	Poor	Fair	Good	Excellent
Flooded. Typical wetted perimeter unknown	• 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)
Physical Instream Habitat	• 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
No riffle-pool space except near 403	• 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
	• 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) = 24	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/JA

GEO MORPHIX

Rapid Stream Assessment Technique Project Number: 23010

Date:	2026-01-09	**Stream:**	Grindstone Creek
Time:	10:30	**Reach:**	OC-T2
Weather:	Mixed rain+sun, -2°	**Location:**	Aldershot GO, Burlington
Field Staff:	CM JA	**Watershed/Subwatershed:**	16Mile Credit River

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

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX

Reach Characteristics Project Number: 23010

Date:	2026-01-09	**Field Staff:**	CM JA	**Watershed/Subwatershed:**	16MC, Credit River
Time:	10:30	**Stream:**	Grindstone Creek	**UTM (Upstream):**	
Weather:	Rain/Sun, -2°	**Reach:**	GC-T2	**UTM (Downstream):**	

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

Riparian Vegetation

Dominant Type (Table 6): 1/

Encroachment (Table 7): 3

Coverage	Channel Widths	Age (yrs)
☐ None	☐ 1 - 4	☐ Immature (<5)
☐ Fragmented	☐ 4 - 10	☐ Established (5-30)
☒ Continuous	☒ > 10	☐ Mature (>30)

Aquatic & Instream Vegetation

Type (Table 8): 1

Reach Coverage %: 35

Woody Debris	WD Density
☐ In Cutbank	☐ Low
☒ In Channel	☒ Mod
☐ Not Present	☐ High

WDJ/50m: 1

Water Quality

Odour (Table 16): 6

Turbidity (Table 17): 3

Channel Characteristics

Sinuosity Type (Table 9): 1

Gradient (Table 11): 1

Entrenchment (Table 13): 1

Down's Model (Table 15): D

Sed Sorting (Table 20): Well

Transport Mode (Table 21): 2

Geomorphic Units (Table 22): 8

Riffle-Pool Spacing (m):

Sinuosity Degree (Table 10): 1

# of Channels (Table 12): 1

Bank Failure (Table 14): 1

Bankfull Indicators (Table 18): 1, 3, 5

Sediment Transport Observed? ☐ Yes ☒ No ☐ Not Visible

% of Bed Active: 0

Mass Movement (Table 23): N/A

% Riffles: **% Pools:**

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	☒	☒	☒	☐	☐	☐	☐
Riffle	☐	☐	☐	☐	☐	☐	☐
Pool	☐	☐	☐	☐	☐	☐	☐
Bed (if no riffle-pool morphology)	☒	☒	☒	☐	☐	☐	☐

Bankfull Width (m)	1.7	2.15	1.70	**Wetted Width (m)**	0.97	1.50	1.40
Bankfull Depth (m)	0.30	0.22	0.25	**Wetted Depth (m)**	0.22	0.16	0.14
Undercuts (m)	0	0	0	**Velocity (m/s)**	0.28	0.13	0.16
Pool Depth (m)	0.43	0.27	0.26	**Velocity Estimate Method**	WB	WB	WB
Riffle Length (m)				**Meander Amplitude (m)**			

Notes:

→ Grey, turbid water with sulfuric odor at US extent near 403
→ Sediment deposition on bank was concentrated to US extent, 403 likely contributor
→ Reach was flooded at time of assessment and extended to VW.
→ Encroachment + flooding made main channel difficult to discern, especially in US + mid reach extent
→ Woody debris appears to be from dying trees rather than widening
→ Many active flood chutes at time of assessment
→ Partially confined due to valley wall in US, but open in mid/US extent

Photos: → No prominent meanders observed/measured
→ High accumulation of sediment on bed in US/mid extent (0.4m)

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX

General Site Characteristics

Project Number: 23010

Date:	2026-01-09	**Stream:**	Falcon Creek
Time:	12:15	**Reach:**	FC-6b
Weather:	Sun/Cloud, -2°	**Location:**	Aldershot GO
Field Staff:		**Watershed/Subwatershed:**	16 Mile Creek Credit River

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	SAL = suspended armour layer	
	Bank stabilization	UT undermined tree	
	Leaning tree	33 J shaped tree trunk	
	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

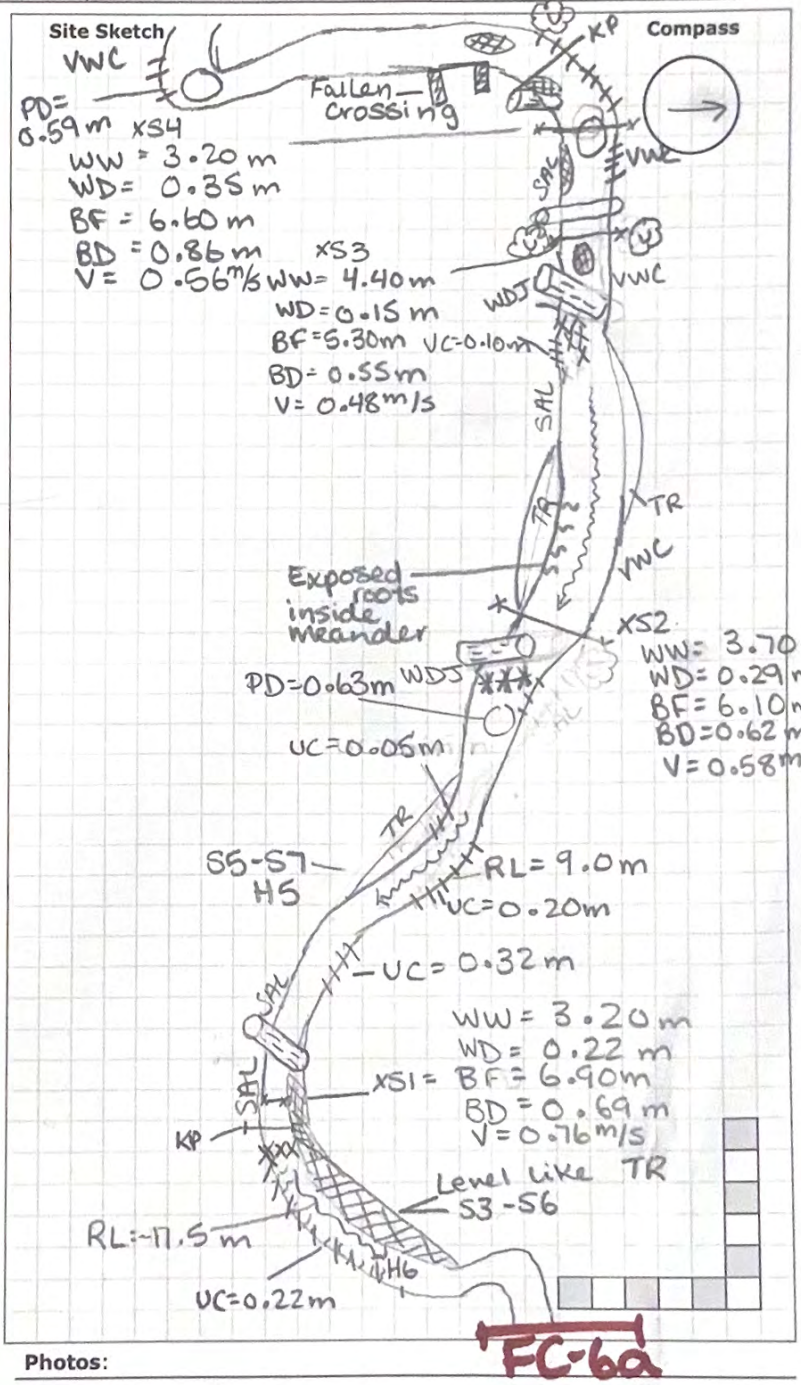
Substrate

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

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:

water brown with turbidity

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: 23010

Date:	2026-01-09	**Stream:**	Falcon Creek
Time:	12:15	**Reach:**	FC-66
Weather:	Rain/Sun, -2°	**Location:**	Aldershot GO, Burlington
Field Staff:	CM JA	**Watershed/Subwatershed:**	16 Mile Creek Credit River

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		

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

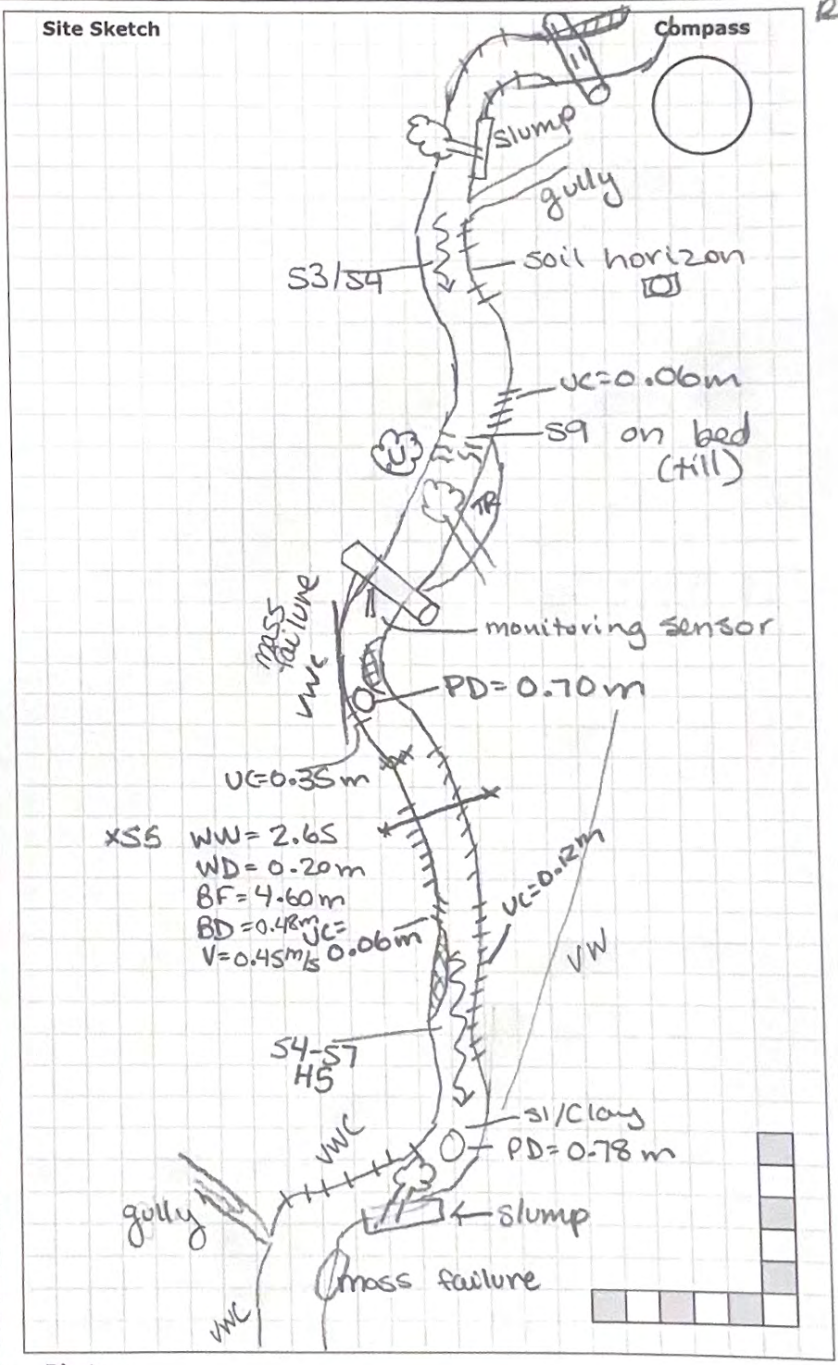
Substrate

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

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:

GEO MORPHIX

General Site Characteristics

Project Number: 23010

Date:	2026-01-09	**Stream:**	Falcon Creek
Time:	12:15	**Reach:**	FC-6b
Weather:	Sun/Cloud, -2°	**Location:**	Aldershot GO
Field Staff:	CM JA	**Watershed/Subwatershed:**	16 MC Credit River

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		

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

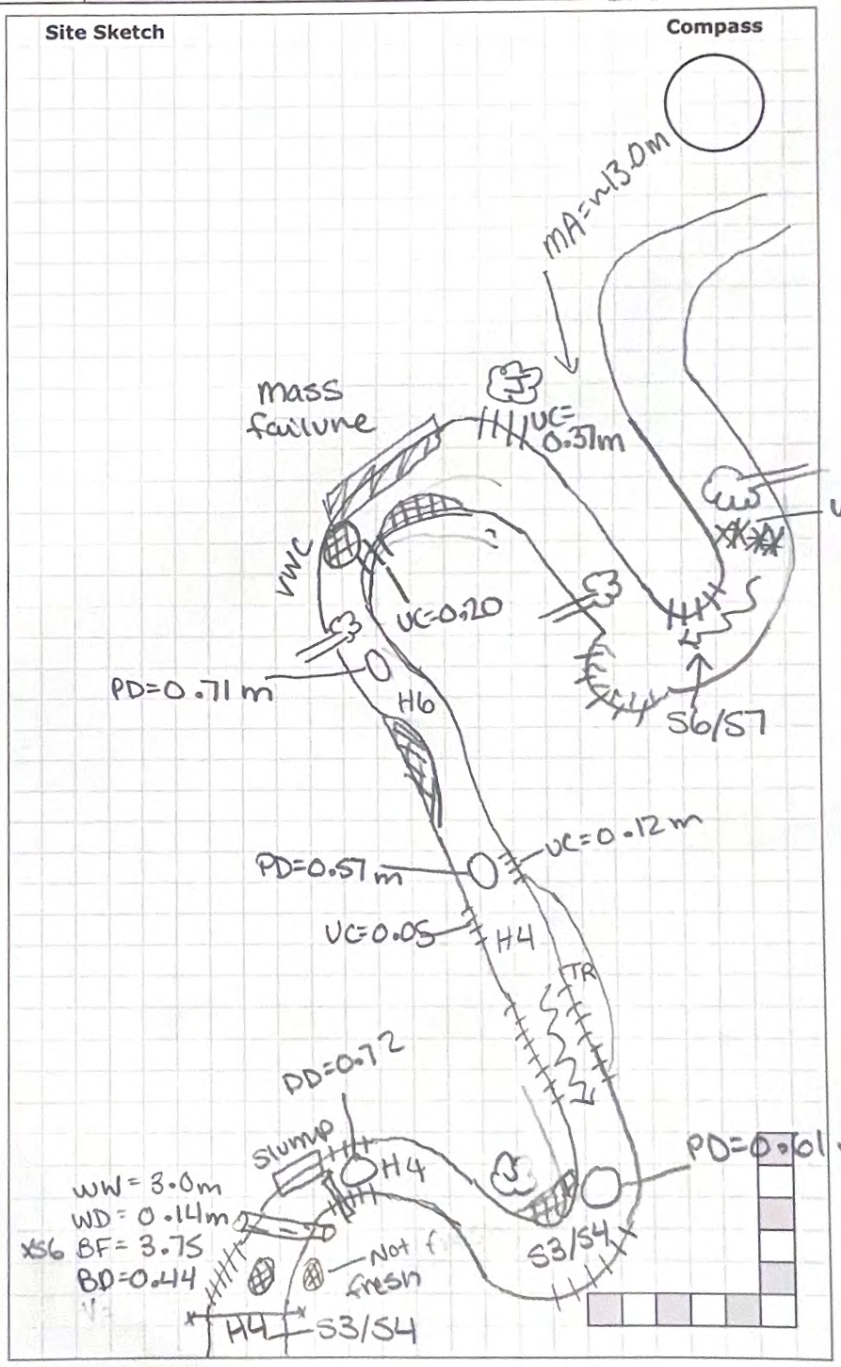
Substrate

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

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

Rapid Geomorphic Assessment **Project Number:** 23010

Date:	2026-01-09	**Stream:**	Falcon Creek
Time:	14:00	**Reach:**	FC-6b
Weather:	Cloudy / Rain, -2°	**Location:**	Aldershot GO, Burlington
Field Staff:	CM, JA	**Watershed/Subwatershed:**	16 MC, Credit River

Process	No.	Geomorphological Indicator	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		X	3/7
	2	Coarse materials in riffles embedded		X	
	3	Siltation in pools	X		
	4	Medial bars	X		
	5	Accretion on point bars	X		
	6	Poor longitudinal sorting of bed materials		X	
	7	Deposition in the overbank zone		X	
		Sum of indices =	3	4	0.43
Evidence of Degradation (DI)	1	Exposed bridge footing(s) 1 collapsed historic crossing due to widening	X	X	2/7
	2	Exposed sanitary / storm sewer / pipeline / etc.		X	
	3	Elevated storm sewer outfall(s) N/A	—	—	
	4	Undermined gabion baskets / concrete aprons / etc. N/A	—	—	
	5	Scour pools downstream of culverts / storm sewer outlets N/A	—	—	
	6	Cut face on bar forms		X	
	7	Head cutting due to knickpoint migration		X	
	8	Terrace cut through older bar material	X		
	9	Suspended armour layer visible in bank	X		
	10	Channel worn into undisturbed overburden / bedrock — 1 area in US extent		X	
		Sum of indices =	2	5	0.29
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	X		7/8
	2	Occurrence of large organic debris	X		
	3	Exposed tree roots	X		
	4	Basal scour on inside meander bends	X		
	5	Basal scour on both sides of channel through riffle	X		
	6	Outflanked gabion baskets / concrete walls / etc. NA	—	—	
	7	Length of basal scour >50% through subject reach	X		
	8	Exposed length of previously buried pipe / cable / etc.		X	
	9	Fracture lines along top of bank	X		
	10	Exposed building foundation N/A	—	—	
		Sum of indices =	7	1	0.88
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		X	0/7
	2	Single thread channel to multiple channel		X	
	3	Evolution of pool-riffle form to low bed relief form		X	
	4	Cut-off channel(s)		X	
	5	Formation of island(s)		X	
	6	Thalweg alignment out of phase with meander form		X	
	7	Bar forms poorly formed / reworked / removed		X	
		Sum of indices =	0	7	0

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.40

In Regime	In Transition/Stress	In Adjustment
☐ 0.00 - 0.20	☒ 0.21 - 0.40	☐ 0.41

Version #3
Last edited: 10/02/2023

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

GEO MORPHIX

Rapid Stream Assessment Technique Project Number: 23010

Date:	2026-01-09	**Stream:**	Falcon Creek
Time:	14:00	**Reach:**	FC-6b
Weather:	Cloud/Rain, -2°	**Location:**	Aldershot GO, Burlington
Field Staff:	CM JA	**Watershed/Subwatershed:**	16MC, Credit River

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 → Armor stone exposed, but primarily clay/silt/sand	• 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

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX

Date:	2026-01-09	PN:	23010	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
	• 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 (Turbid at time of assessment)	• 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) = 28	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

GEO MORPHIX

Reach Characteristics Project Number: 23010

Date:	2026-01-09	**Field Staff:**	CM JA	**Watershed/Subwatershed:**	16 MC Credit River
Time:	14:00	**Stream:**	Falcon Creek	**UTM (Upstream):**	
Weather:	Cloud / Rain, -2°	**Reach:**	FG6b	**UTM (Downstream):**	

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

Riparian Vegetation

Dominant Type (Table 6): 1
Encroachment (Table 7): 1

Coverage	Channel Widths	Age (yrs)
☐ None	☐ 1 - 4	☐ Immature (<5)
☐ Fragmented	☐ 4 - 10	☐ Established (5-30)
☒ Continuous	☒ > 10	☒ Mature (>30)

Aquatic & Instream Vegetation

Type (Table 8): NA
Reach Coverage %: /

Woody Debris	WD Density
☑ In Cutbank	☐ Low
☑ In Channel	☐ Mod
☐ Not Present	☐ High

WDJ/50m: 1

Water Quality

Odour (Table 16): 1
Turbidity (Table 17): 3

Channel Characteristics

Sinuosity Type (Table 9): 2
Gradient (Table 11): 1
Entrenchment (Table 13): 3
Down's Model (Table 15): C
Sed Sorting (Table 20): Mod
Transport Mode (Table 21): 1
Geomorphic Units (Table 22): 5-8
Riffle-Pool Spacing (m): ~30m

Sinuosity Degree (Table 10): 5
# of Channels (Table 12): 1
Bank Failure (Table 14): 1, 2, 6
Bankfull Indicators (Table 18): see notes
Sediment Transport Observed? ☒ Yes ☐ No ☐ Not Visible
% of Bed Active:
Mass Movement (Table 23): 4/1
% Riffles:
% Pools:

Suspension causing turbid water

NOT visible

Bank Angle	Bank Erosion
☐ 0 - 30	☐ < 5%
☐ 30 - 60	☐ 5 - 30%
☑ 60 - 90	☐ 30 - 60%
☐ Undercut	☐ 60 - 100%

(Table 19)

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

Bankfull Width (m)	6.9	5.3	6.1	**Wetted Width (m)**	3.2	4.4	3.7
Bankfull Depth (m)	0.69	0.53	0.62	**Wetted Depth (m)**	0.22	0.15	0.29
Undercuts (m)	0.32	0.35	0.12	**Velocity (m/s)**	0.76	0.48	0.58
Pool Depth (m)	0.63	0.70	0.72	**Velocity Estimate Method**	WB	WB	WB
Riffle Length (m)	17.5	28.0	9.0	**Meander Amplitude (m)**	15	13	

Notes:

→ Meander amplitudes approximations due to irregular shapes + difficult terrain to measure
→ Turbid water at time of assessment made sediment transport difficult to observe
→ Bankfull indicators included topo, slope, sed deposits, exposed roots, veg, bar forms
→ High volume of fallen or undermined trees
→ Mass failures of valley wall and banks present on both banks
→ Valleywall contact on both banks
→ Bars form at bends, around WDJ and in center of channel
→ Undercutting + less extensive toe erosion on inside of meanders and on both banks of riffles

Photos:

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

Version #4
Last edited: 04/04/2023

Appendix D:
Detailed Assessment Summary

Detailed Geomorphological Assessment Summary

Reach IC-T3

Project Number:	PN23010	**Date:**	10-05-23
Client:	Alinea Group Holdings Inc.	**Length Surveyed (m):**	102.1
Location:	Indian Creek, Burlington	**# of Cross-Sections:**	9

Reach Characteristics

Drainage Area:	1.17 km2	**Dominant Riparian Vegetation Type:**	Grasses and herbaceous
Geology/Soils:	Clay till; fine to coarse sand and gravel	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Agricultural	**Width of Riparian Cover:**	> 10 channel widths
Valley Type:	Unconfined	**Age Class of Riparian Vegetation:**	Immature
Dominant Instream Vegetation Type:	Rooted emergent	**Extent of Encroachment into Channel:**	Moderate
Portion of Reach with Vegetation:	100%	**Density of Woody Debris:**	Low

Hydrology

Measured Discharge (m^3/s):	Not modelled	**Calculated Bankfull Discharge (m^3/s):**	1.42
Modelled 2-year Discharge (m^3/s):	Not modelled	**Calculated Bankfull Velocity (m/s):**	0.74
Modelled 2-year Velocity (m/s):	Not modelled		

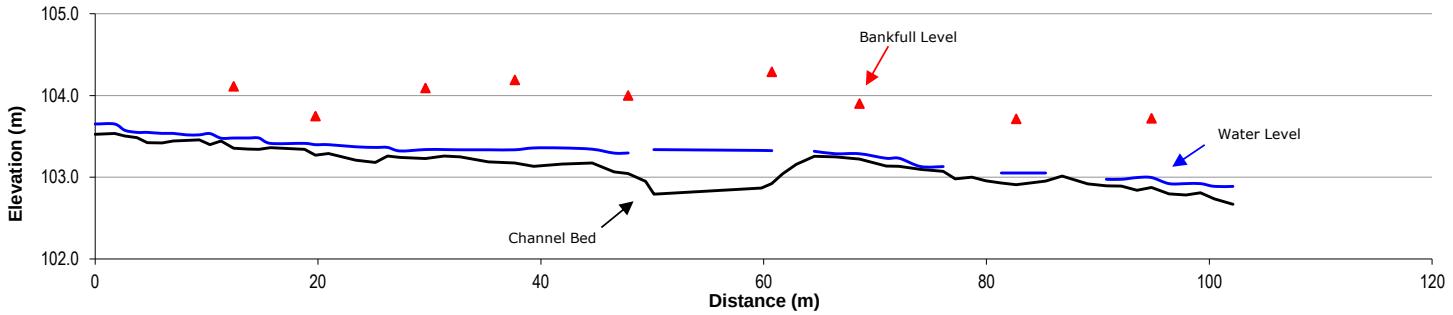
Profile Characteristics

Bankfull Gradient (%):	0.33
Channel Bed Gradient (%):	0.63
Riffle Gradient (%):	No riffles present
Riffle Length (m):	No riffles present
Riffle-Pool Spacing (m):	No riffles present

Planform Characteristics

Sinuosity:	1.03
Meander Belt Width (m):	Not measured
Radius of Curvature (m):	Not measured
Meander Amplitude (m):	Not measured
Meander wavelength (m):	Not measured

Longitudinal Profile



Bank Characteristics

	Minimum	Maximum	Average
Bank Height (m):	0.80	1.50	1.19
Bank Angle (deg):	35	80	58
Root Depth (m):	0.30	0.60	0.49
Root Density (%):	20	80	66
Bank Undercut (m):	0.00	0.00	0.00

	Minimum	Maximum	Average
Torvane Value (kg/cm^2):		Not measured	
Penetrometer Value (kg/cm^3):		Not measured	
Bank Material (range):		Clay and silt	

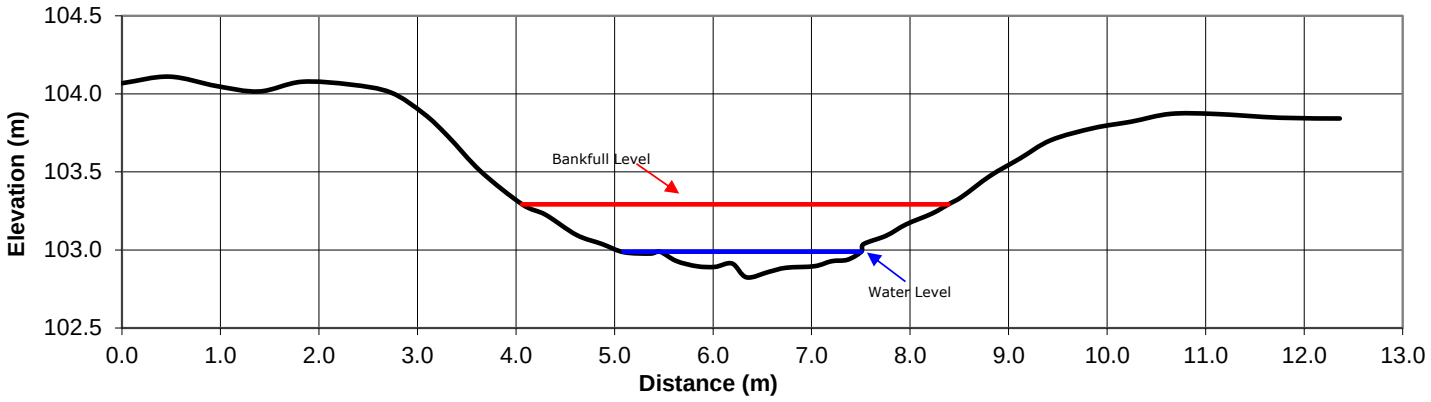
Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	3.44	6.17	4.71
Average Bankfull Depth (m):	0.28	0.58	0.41
Bankfull Width/Depth (m/m):	9	20	12
Wetted Width (m):	0.80	3.49	2.08
Average Water Depth (m):	0.03	0.16	0.07
Wetted Width/Depth (m/m):	12	111	35
Entrenchment (m):		No entrechment	
Entrenchment Ratio (m/m):		No entrechment	
Maximum Water Depth (m):	0.10	0.39	0.19
Manning's *n* :		0.043	



Photograph at cross section 1 (looking upstream)

Representative Cross-Section 1



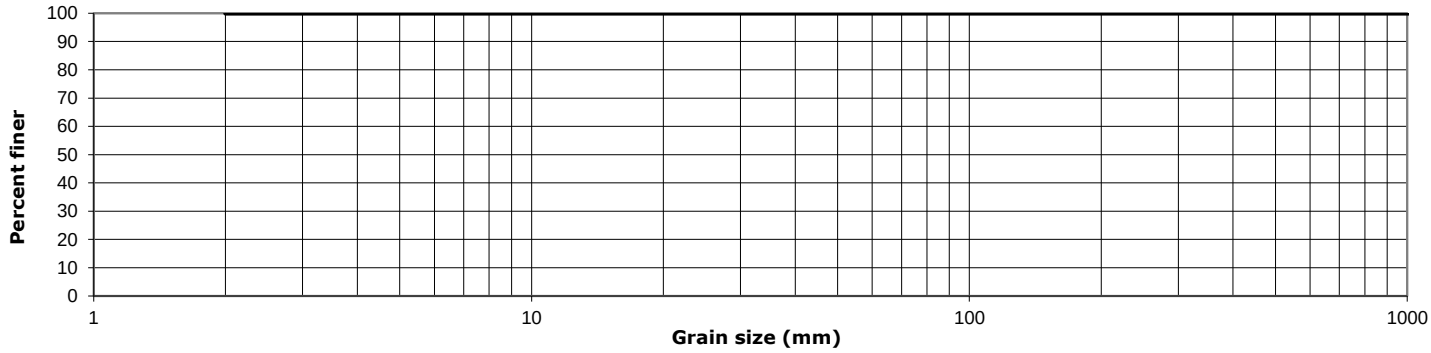
Substrate Characteristics

Particle Size (mm)

D_{10} :	0.02
D_{50} :	0.02
D_{84} :	0.02

Subpavement:	Clay till; fine to coarse sand and gravel
Particle shape:	Rounded
Embeddedness (%):	Not applicable
Particle range (riffle):	Not applicable
Particle Range (pool):	Not applicable

Cumulative Particle Size Distribution



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	13.23
for D_{50}:	0.00	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	0.00	**Critical Shear Stress (D_{50}) (N/m^2):**	0.00
Unit Stream Power at Bankfull (W/m^2):	9.74		

General Field Observations

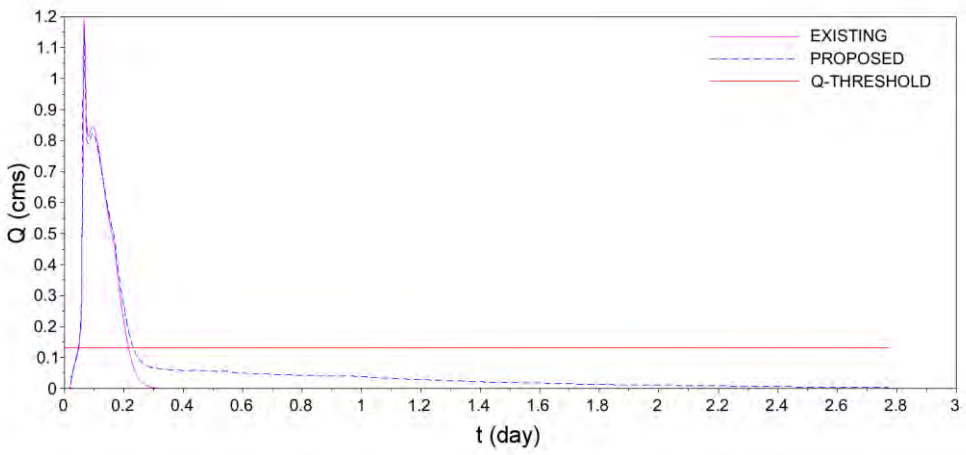
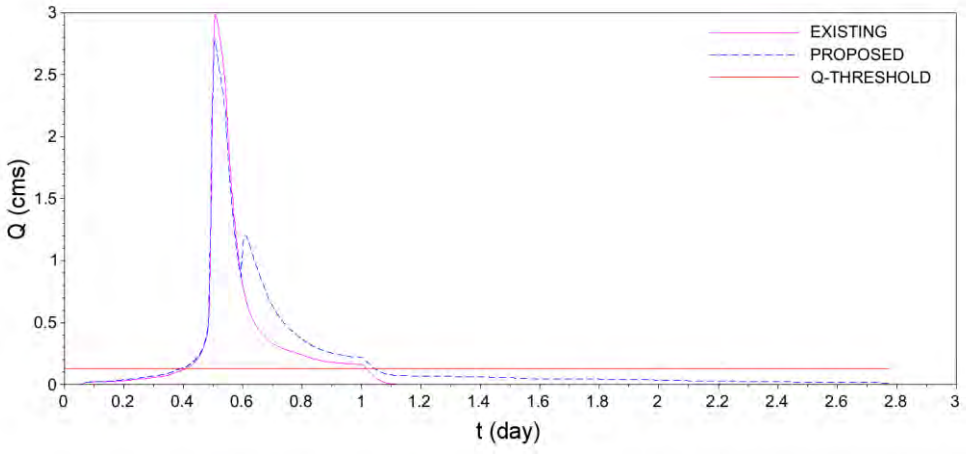
Channel Description

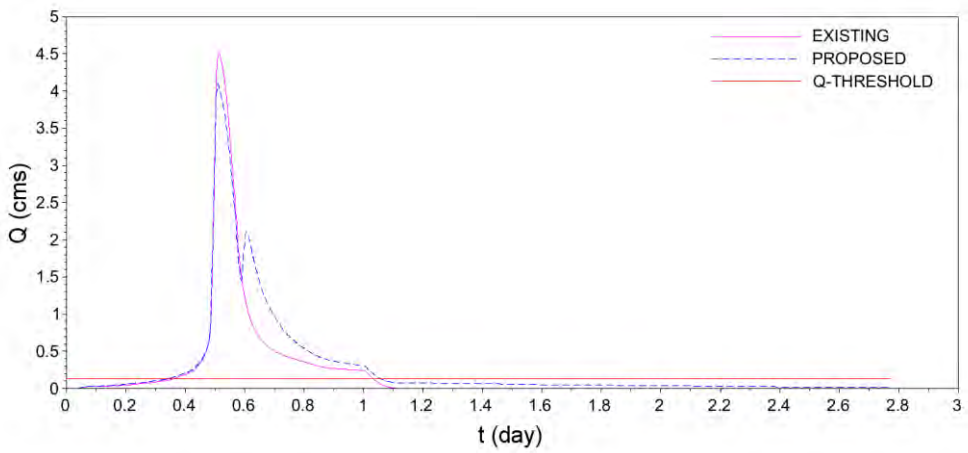
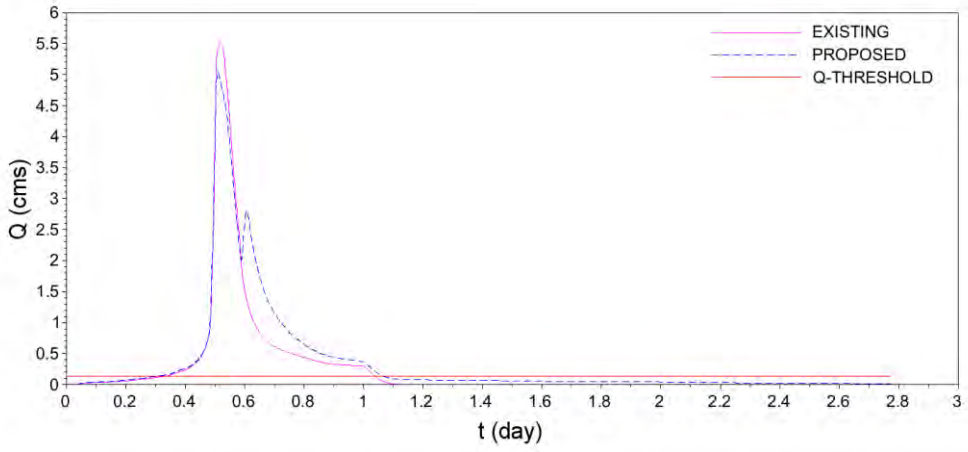
Reach IC-T3 is a historically straightened agricultural swale situated in an unconfined floodplain. The riparain zone was comprised of a continuous coverage of grasses. Rooted emergent aquatic vegetation was present along the entirety of the reach. Riffle and pool sequencing was absent from the channel and bed and bank substrate was primarily clay and silt. Bank angles ranged from 35° to 80° and minor bank erosion was observed near the downstream extent in the form of slumping and scour. A tractor crossing was present within the reach with a cement culvert in a degraded condition. The culvert was disjointed and large scour pools had formed on the upstream and downstream side of the crossing.

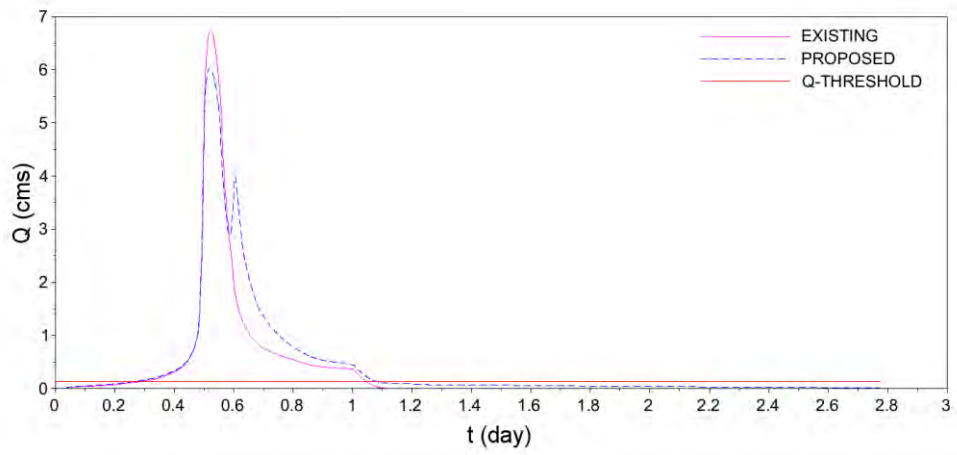
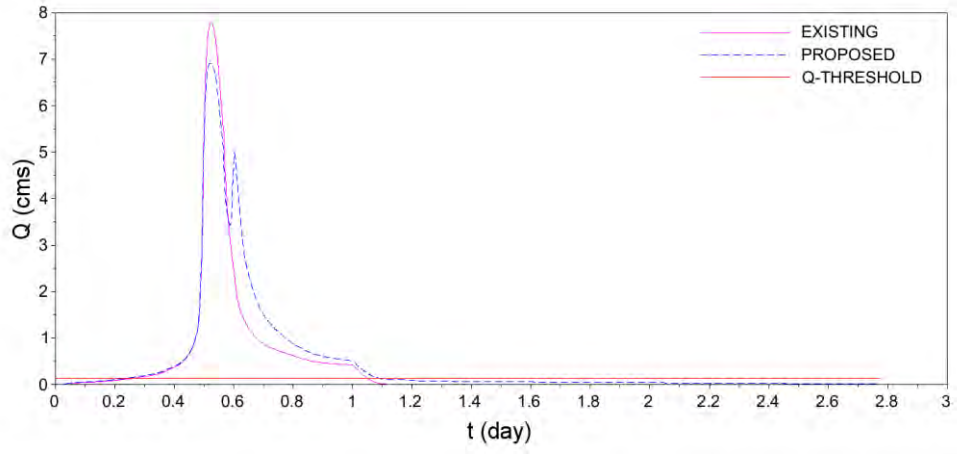
Cross Section 2 - Facing Downstream

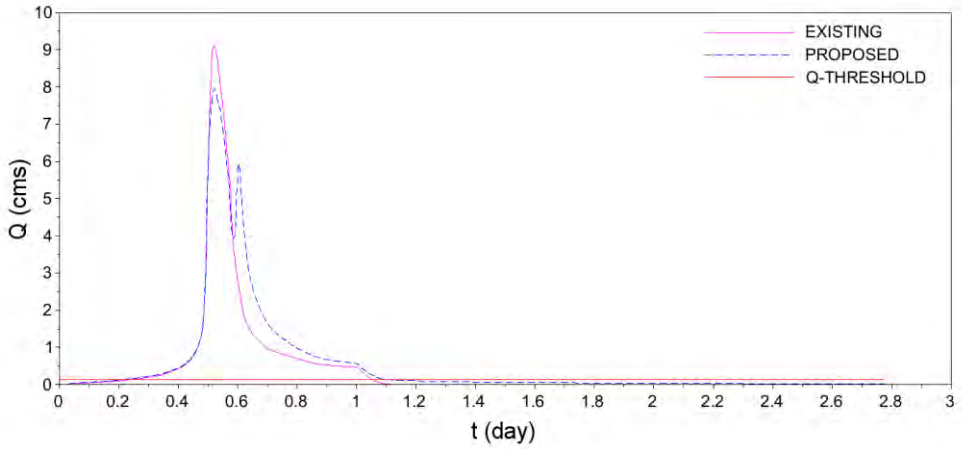
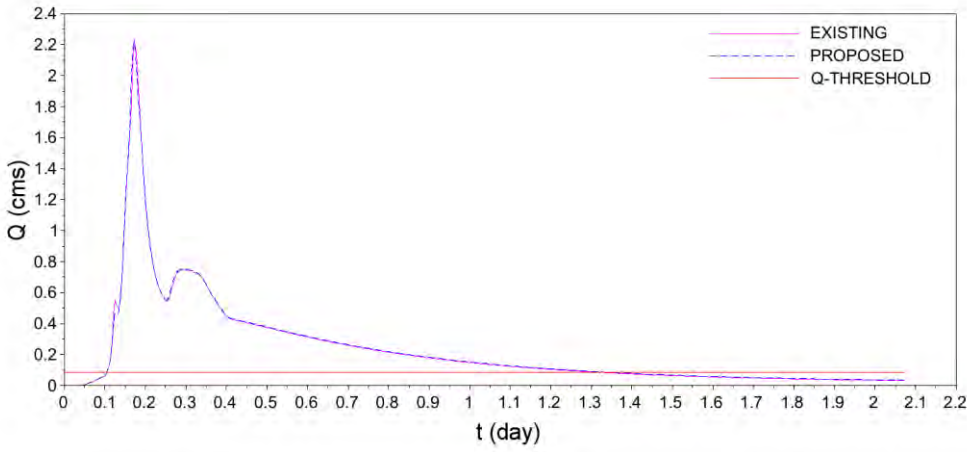


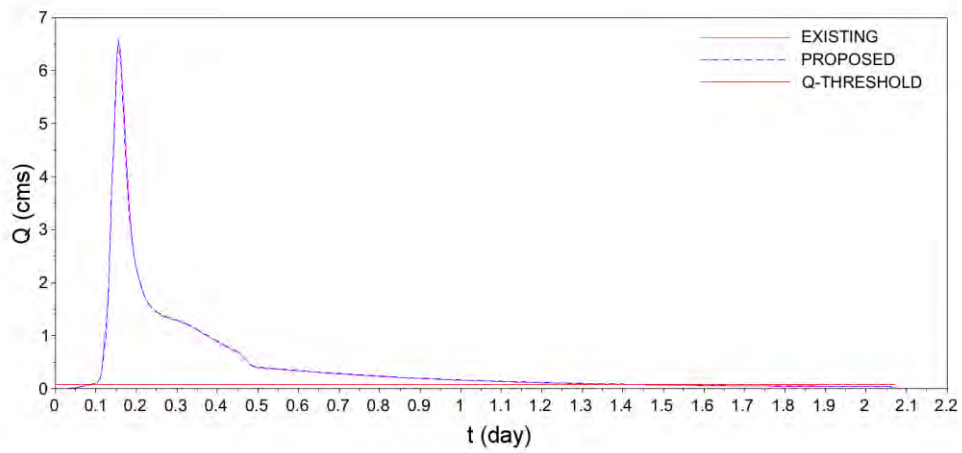
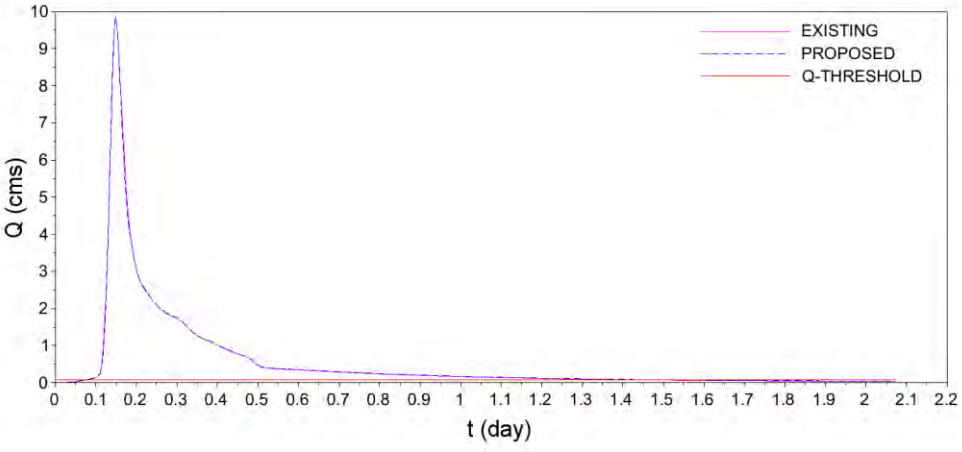
Appendix E:
Erosion Exceedance Hydrographs

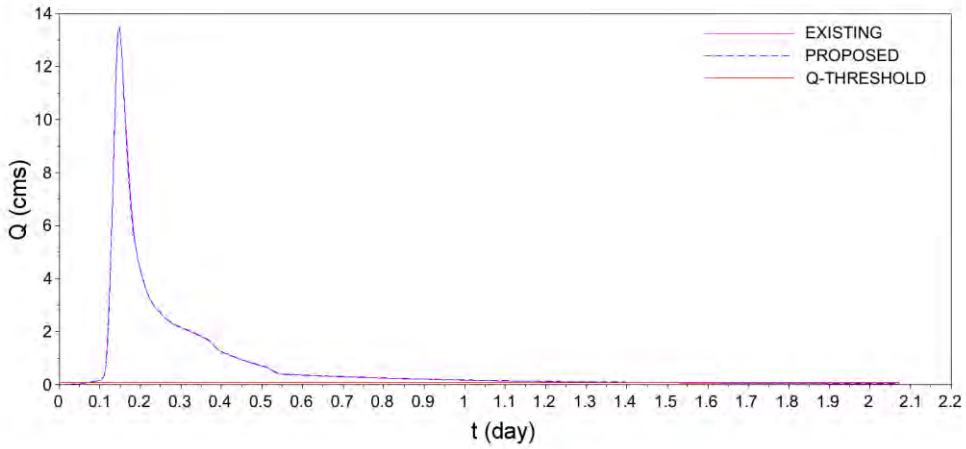
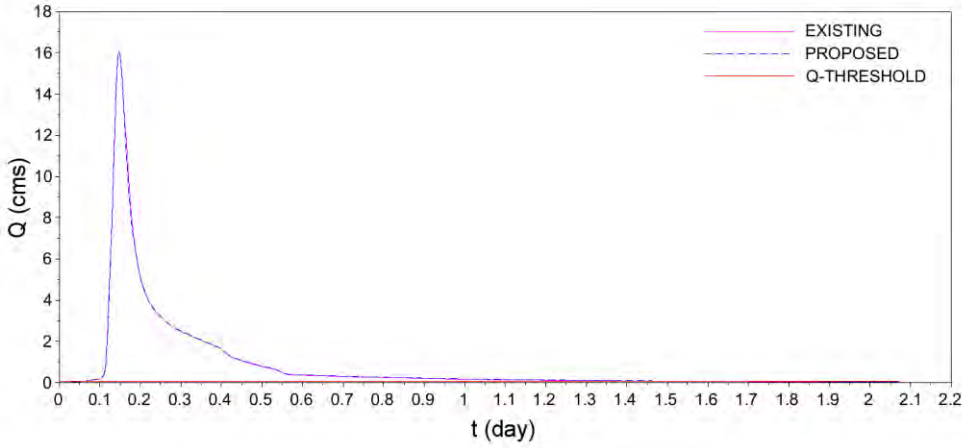
Reach **IC-T4** 25 mm	
Reach **IC-T4** 2-year	

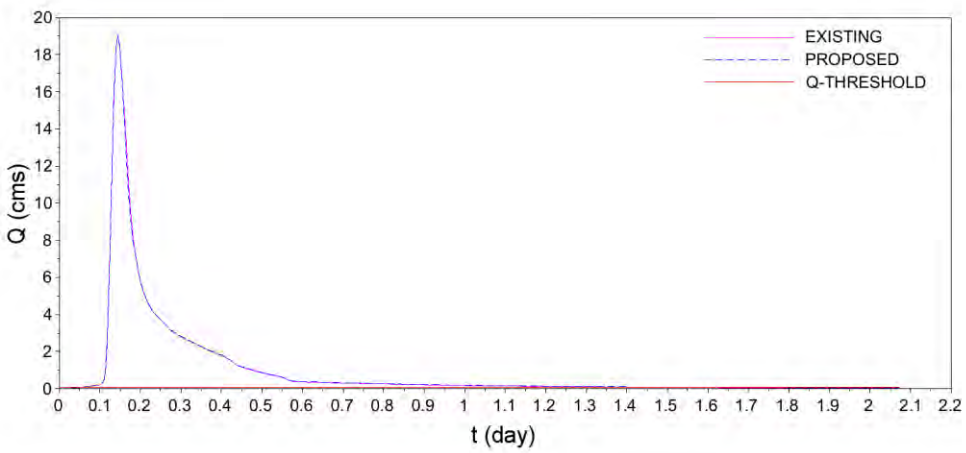
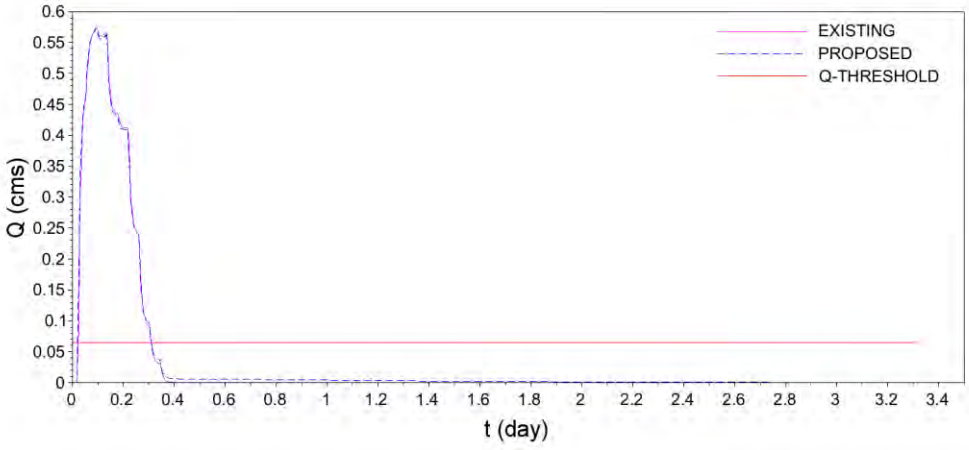
Reach **IC-T4** 5-year	
Reach **IC-T4** 10-year	

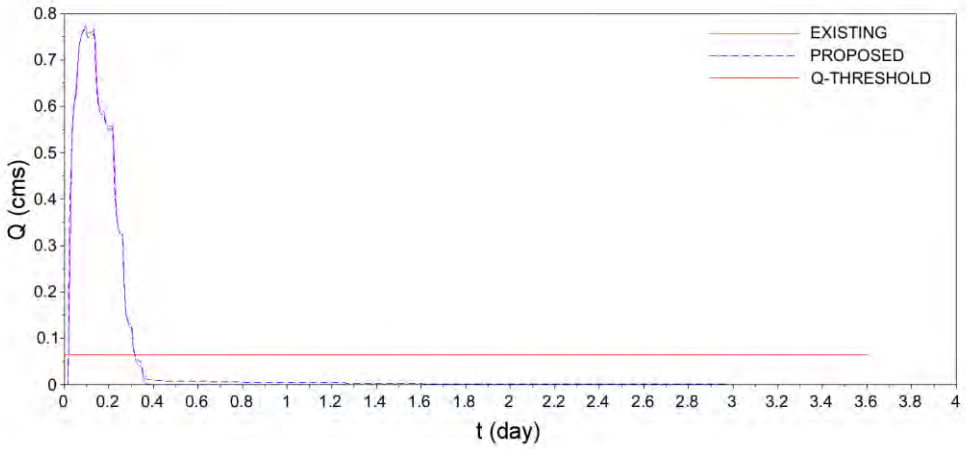
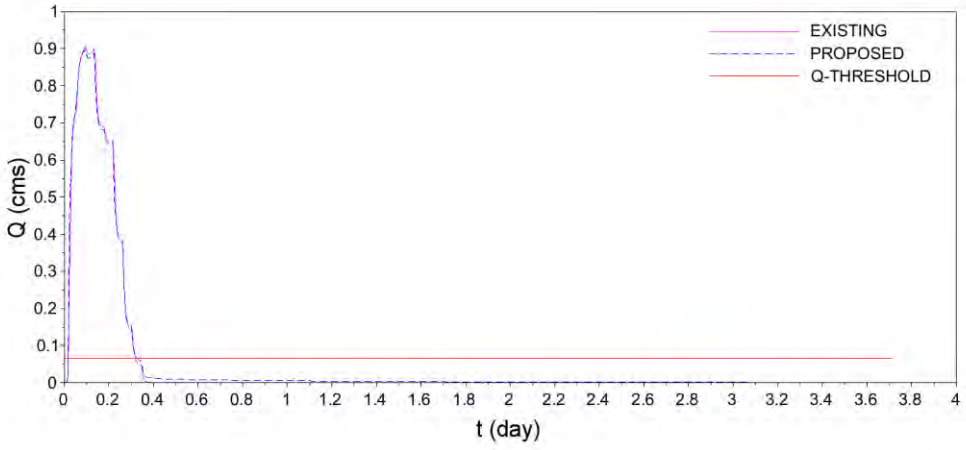
Reach **IC-T4** 25-year	
Reach **IC-T4** 50-year	

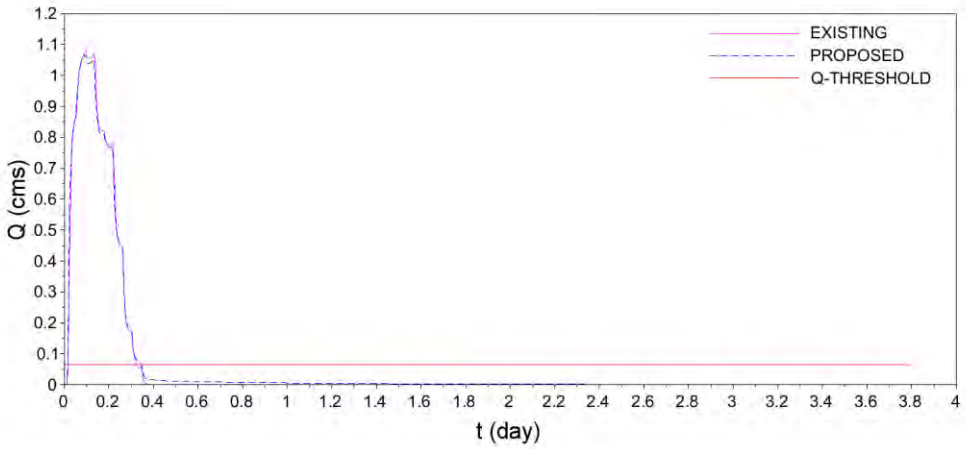
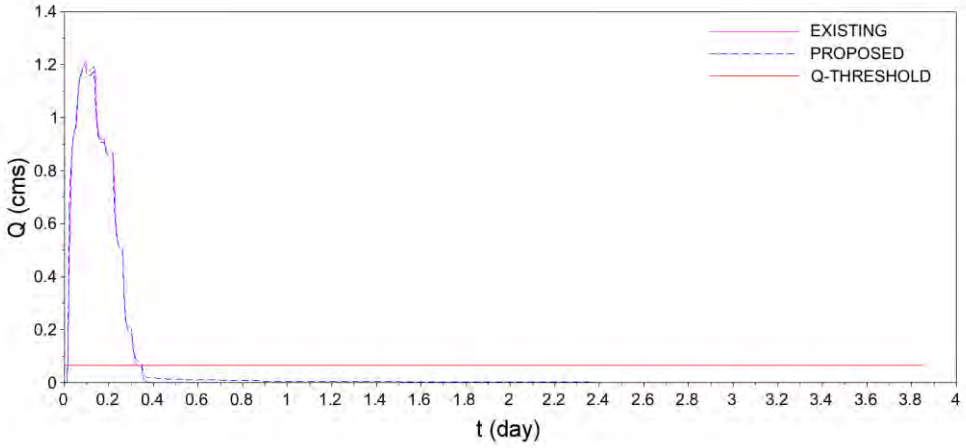
Reach **IC-T4** 100-year	
Reach **FC-6a** 2-year	

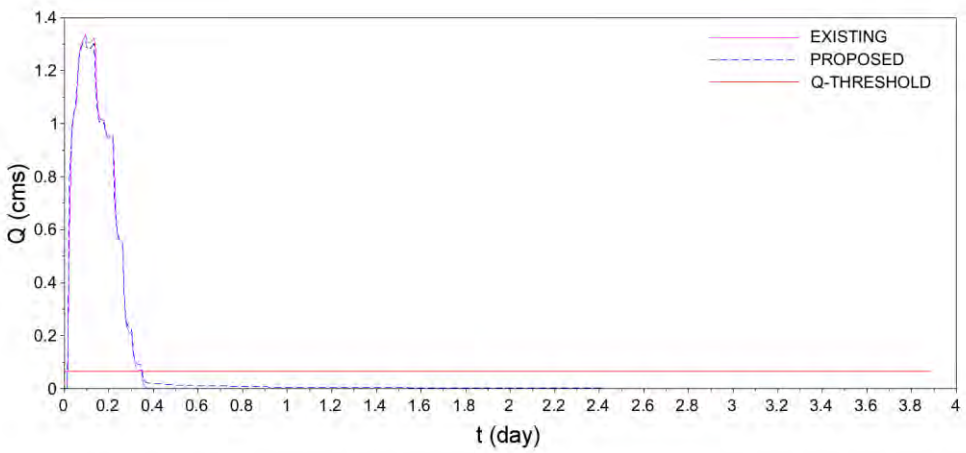
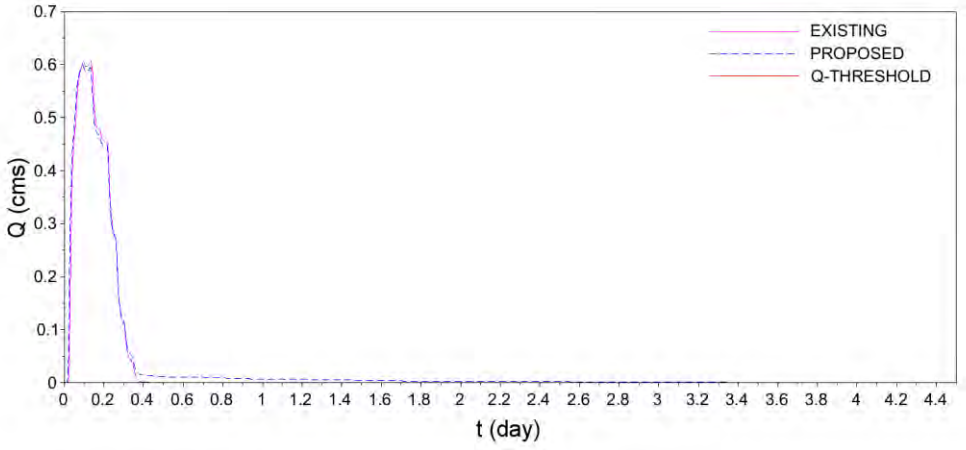
Reach **FC-6a** 5-year	
Reach **FC-6a** 10-year	

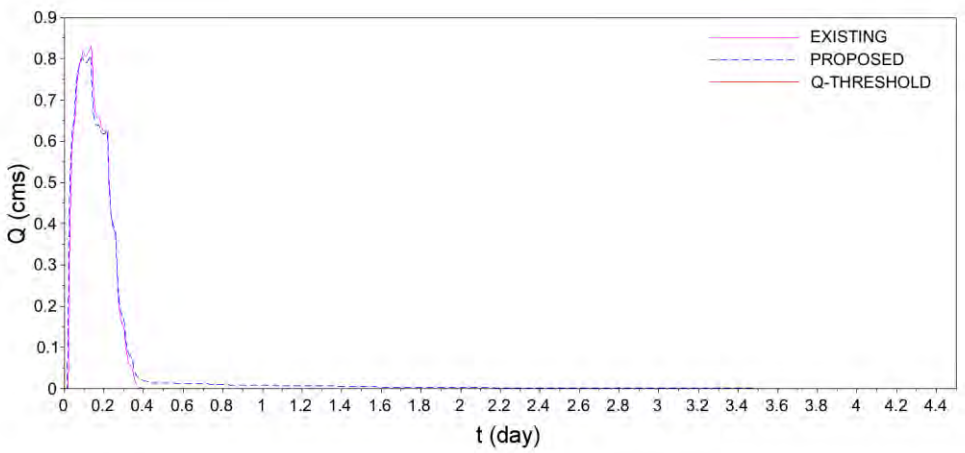
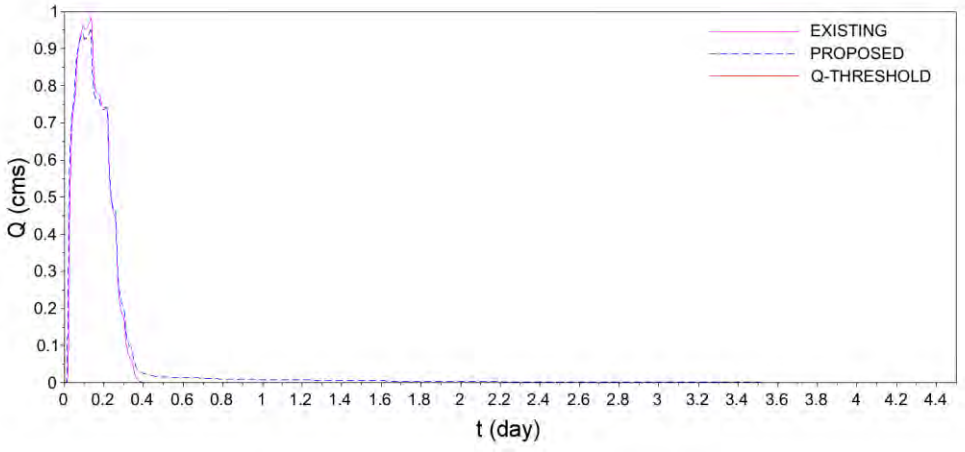
Reach **FC-6a** 25-year	
Reach **FC-6a** 50-year	

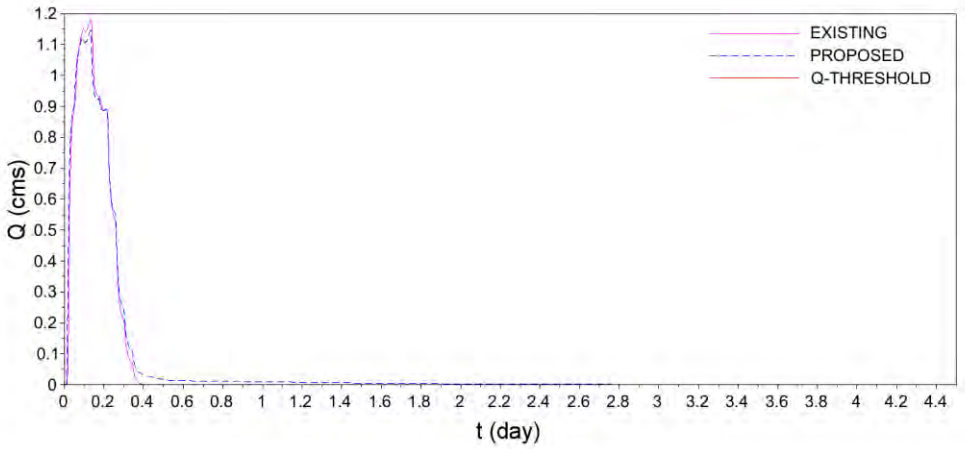
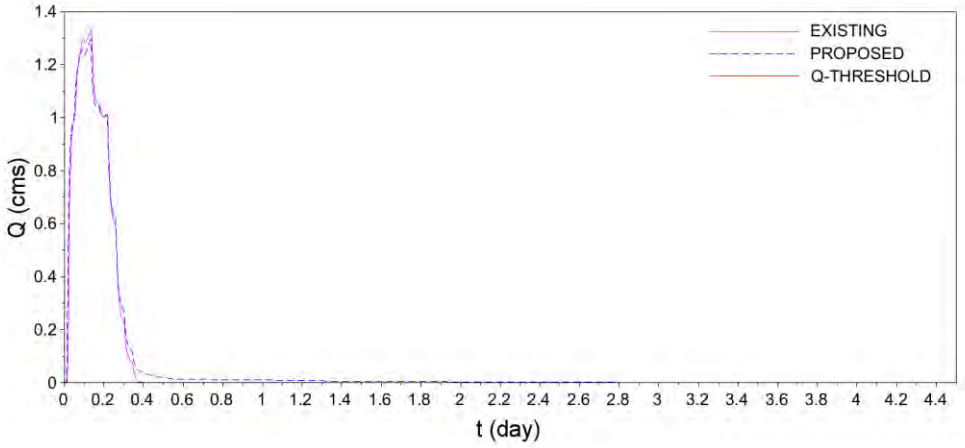
Reach **FC-6a** 100-year	
Reach **CT-T0A** 2-Year	

Reach **CT-T0A** 5-Year	
Reach **CT-T0A** 10-Year	

Reach **CT-T0A** 25-Year	
Reach **CT-T0A** 50-Year	

Reach **CT-T0A** 100-Year	
Reach **GC-T4** 2-Year	

Reach **GC-T4** 5-Year	
Reach **GC-T4** 10-Year	

Reach **GC-T4** 25-Year	
Reach **GC-T4** 50-Year	

Reach **GC-T4** 100-Year	