Fluvial Geomorphological and Meander Belt Width Assessment

11 Main Street
Puslinch, Ontario

Prepared for:
Kayly Robbins
Weston Consulting
268 Berkeley St.
Toronto, ON

February 17th, 2023

GEO Morphix Project No. 22099

GEO MORPHIX
Geomorphology
Earth Science
Observations

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Approved by:	Paul Villard, Ph.D., P.Geo., CAN-CISEC
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1 Introduction

GEO Morphix Ltd. was retained to complete a meander belt width assessment for two unnamed tributaries of Bronte Creek to support natural constraints delineation for the proposed development at 11 Main Street in the Town of Puslinch, Ontario. The property, herein referred to as the "subject site", contains two tributaries of Bronte Creek which flow north to south. Two environmental areas have been identified within the subject site, a wetland within the western portion of the subject site and a wooded area within the eastern portion of the subject site, both staked by North-South Environmental. The two tributaries of Bronte Creek flow through these environmental areas. We understand that Conservation Halton has requested a fluvial geomorphological assessment and meander belt width delineation to identify the potential erosion hazard limits related to the watercourses within the subject site.

To address Conservation Halton's concerns related to natural hazards, and identify the meander belt width associated with the subject site, the following activities were completed:

- Review available background reports and mapping (e.g., watershed/subwatershed reporting, geology, and topography) related to channel form and function and controlling factors related to fluvial geomorphology
- Delineate watercourse reaches based on a desktop assessment (to be confirmed during field reconnaissance)
- Review recent and historical aerial photographs of the site to understand historical changes in channel form and function, and measure meander amplitude and determine the limits of the meander belt width, where possible
- Complete rapid geomorphological field assessments such as Rapid Geomorphological Assessments (RGA) and Rapid Stream Assessment Protocol (RSAT) to characterize the watercourse and confirm reach delineation results of the desktop analysis

2 Watershed Characteristics

The subject site is located within the Bronte Creek watershed, the second largest watershed within Conservation Halton's jurisdiction. Within the subject site, the two tributaries of Bronte Creek flows from north to south. The tributary located within the eastern side of the subject site flows through a natural wooded area, whereas the tributary located within the western side of the subject site flows through a wetland. Both of these tributaries flow through identified environmental areas and converge south of the subject site. The dominant land use of the watershed is agricultural and rural residential, followed by approximately 29% forested land cover as determined by using the Ontario Watershed Information Tool (OWIT, 2022). The subject site is currently used as agriculture, directly adjacent to residential housing and a local park.

2.1 Geology and Physiography

Published mapping indicates the subject site is contained within two physiographic regions, where the contact of the two regions bisects the subject site in a southwest to northeast direction. The northern half of the subject site is contained within the Horseshoe Moraines, dominated by Till Moraine landforms. The subject site to the south is contained within the Flamborough Plains, dominated by limestone plains. Drumlin landforms are mapped directly south of the subject site (Chapman and Putnam, 2007). The quaternary geology of the entire subject site is dominated by Pleistocene Wentworth Till, which consist of highly calcareous clasts in a sandy silt to silt matrix (OGS, 2010). The eastern tributary of Bronte Creek flows parallel to the contact between the two physiographic regions for approximately 400 m through subject site. Contacts between different surficial bedrocks are more easily erodible and tend to form low points in the topography, where water may tend to collect and flow. Thus, it is possible the

observed low-grade channel and online wetland system within the study site are a result of this geological contact.

3 Study Area History

A series of historical aerial photographs were reviewed to determine changes to the channel and surrounding land use and land cover. This information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics. Historical aerial photographs were obtained from the National Air Photo Library for the years 1945 (scale 1:25,000), 1965 (1:25,000), and 1972 (1:25,000), as well as recent digital imagery from Google Earth Pro (2004 through to 2018). Historical imagery is provided in **Appendix A** for reference.

In 1945, the predominant land use upstream and within the subject site is agriculture and rural residential. A small community of residential properties are adjacent to the subject site in the northwestern corner. The eastern wooded area is sparse and non-continuous, indicating possible forest clearing practices, perhaps for agricultural access or lumber. No tributary or watercourse is visible in the eastern wooded area, but any drainage feature there would be affected by the sparse riparian vegetation. Lands adjacent to the western tributary of Bronte Creek appear to be cultivated to the edges of the watercourse, with no evidence of natural woody riparian vegetation along the tributary within and upstream of the subject site. The lack of riparian vegetation for both western and eastern tributaries likely had a negative impact on channel form, water quality, and instream temperatures.

By 1965, the predominant land use within and adjacent to the subject site remains agricultural and rural residential. Construction of the baseball diamond began prior to 1965 in the northwestern section of the subject site. Riparian lands immediately adjacent to the western tributary of Bronte Creek remain cultivated to the edge of watercourse whereas the vegetation within the wooded area to the east has been permitted to grow and naturalize, enhancing the riparian vegetation along the eastern tributary.

There is little change in the land use, channel planform, or riparian vegetation of the subject site between 1965 and 1972. Between 1972 and 2004, the land use upstream of both tributaries becomes increasingly more residential, with the development of the lands north of Badenoch Street; however, agriculture is still the dominant land use in the area. The lands directly adjacent to the western tributary are no longer cultivated and grassy wetland vegetation is visible in the aerial imagery. By 1972, the wooded area appears as densely vegetated as it appears in aerial images from 2018. From 1945 to 2004, there has been no discernable change in planform of the western tributary while the eastern tributary remains non-visible in the aerial imagery.

In summary, there was limited change to land use within and upstream of the subject site over the period examined, with the exception of increasing residential development upstream of the tributaries in addition to the completion of a public park on the subject site. From a geomorphological perspective, the form and function of the Bronte Creek tributaries has been primarily impacted by agricultural practices, including riparian vegetation removal prior to 1945, but also the increased naturalization of riparian vegetation adjacent to both eastern and western tributaries post 1965. Throughout the period examined, the eastern tributaries remain non-visible in aerial imagery, while there has been no discernable change to the channel planform or size of the western tributary.

4 Reach Delineation

Reaches are homogeneous segments of channel used in geomorphological investigations. Reaches are studied semi-independently as each is expected to function in a manner that is at least slightly different from adjoining reaches. This method allows for a meaningful characterization of a watercourse as the

aggregate of reaches, or an understanding of a particular reach, for example, as it relates to a proposed activity.

Reaches are typically delineated based on changes in the following:

- Channel planform
- Channel gradient
- Physiography
- Land cover (land use or vegetation)
- Flow, due to tributary inputs
- Soil type and surficial geology
- Historical channel modifications

Reach delineation follows scientifically defensible methodology proposed by Montgomery and Buffington (1997), Richards et al. (1997), and the Toronto and Region Conservation Authority (2004) as well as others. Prior to the field assessment, four reaches were delineated for the subject site using a mapping stream layer provided by the project team. The reach delineation exercise was then confirmed in the field. Reach **TCB1** is located within the western portion of the study site and three reaches, **TCB3, TCB3a,** and **TCB2**, are located within the eastern portion of the study site. Reach breaks were determined based on changes in surficial geology and flow inputs from tributary confluences. Reach delineation is graphically defined in **Appendix B**.

5 Field Observations

Site observations of **Reaches TBC-1, TBC-2, TBC-3** and **TBC-3a** were collected on November 17th, 2022. Photographs are provided in **Appendix C** and field observations are provided in **Appendix D**.

Reach TBC-1 is located within the western portion of the subject site, oriented in a roughly north – south direction. The reach originates at Highway 6 where the watercourse is conveyed through an oblique concrete box culvert. Upstream (west) of the Highway 6 Road Culvert is a residential yard. At the time of assessment, there was no flowing water, but isolated pools of standing water were present within the subject site except for an area directly downstream of the Highway 6 road culvert. In general, the channels are poorly defined, with soft depressions and pools of water to indicate the flow pathway in some locations. Where discernable, the bankfull width ranged from 1.0 m to 2.0 m, and depth ranged from 0.2 m to 0.3 m. In some locations, multiple soft depressions and pools of water were observed, possibly indicating a multiple channel planform. However, for the majority of its length, the reach is an unconfined channel with no defined banks and heavy vegetation encroachment of wetland grasses. The bed and banks consist of silt and clay, except in the channel directly downstream of the road culvert, where fine gravel was observed in addition to silt and clay material.

Reach TBC-2 is located within the eastern portion of the subject site, along the southern property boundary. Field observations indicate that the portion of **Reach TBC-2** within the subject site contains no defined channel and is instead a swamp consisting of pools of water intermixed with trees, grassy hummocks, and woody debris.

Reach TBC-3 is also located within the eastern woodlot on the subject site. The drainage area for this feature consists of residential land use. This reach eventually converges with **Reach TBC-2** at the downstream extent of the subject site. The reach contains no defined channel or evidence of flow, with no discernable change in the landscape to indicate previous drainage. In several locations where the reach was located via GPS, isolated wetland pockets consisting of shallow pools of water were observed.

Reach TBC-3a is a tributary of **TBC-3** which flows through the wooded area located on the eastern portion of the subject site. The drainage area for this tributary includes residential land use. Field

observations indicate this reach contains no channel definition or flow, with no discernable change observed in the landscape.

Reaches TBC-2, **TBC-3**, and **TBC-3a** are all low-order streams with limited upstream drainage areas. As such, the reaches are likely ephemeral in nature and more indicative of a headwater drainage features rather than perennial watercourses. The reaches are graphically shown in **Appendix B**, for reference.

5.1 Rapid Geomorphological Assessments

Rapid geomorphological assessments were completed to identify dominant geomorphic processes, document stream health, and to identify any areas of concern regarding erosion or instability for watercourse features identified on site (**Reach TBC-1**). Channel instability was objectively quantified through the application of the Ontario Ministry of the Environment's (2003) Rapid Geomorphic Assessment (RGA). Observations were quantified using an index that identifies channel sensitivity based on evidence of aggradation, degradation, channel widening, and planimetric adjustment. The index produces values that indicate whether a channel is stable/in regime (score <0.20), stressed/transitional (score 0.21-0.40), or adjusting (score >0.41).

Typically, the Rapid Stream Assessment Technique (RSAT) is also applied to provide a broader view of the system as it considers the ecological function of the watercourse (Galli, 1996). Observations are made of channel stability, channel scouring or sediment deposition, instream and riparian habitats, and water quality. The RSAT score ranks the channel as maintaining a poor (<13), fair (13-24), good (25-34), or excellent (35-42) degree of stream health. A summary of the results of the rapid geomorphological assessments has been provided in **Table 1**. Given the poorly defined channel and limited presence of water or flow, the RSAT could not be applied to **Reach TBC-1**.

Table 1: Rapid Geomorphological Assessment Results for Reach TBC-1

Reach	RGA (MOE, 2003)			RSAT (Galli, 1996)*		
	Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Feature(s)
TBC-1	0.14	In regime	Aggradation, planimetric adjustment	N/A	N/A	N/A

**Limited presence of water or flow in Reach TBC-1 was observed at the time of rapid field assessments. RSAT is not fully applicable.*

The RGA score for **Reach TBC-1** was 0.14, indicating that the channel was in regime. The dominant systematic adjustments were equally aggradation and planimetric adjustment, namely due to deposition in the overbank zone and formation of multiple channels through the wetland riparian zone. However, the presence of these adjustment signs was extremely minor. The overall RGA score still indicates the channel is in a stable state, which is supported by additional field observations. There are no signs of erosion, either historical or active, or other geomorphological processes which could indicate potential system adjustments. The reach is also heavily encroached by grassy vegetation in the active channel which provides an additional control to potential erosion.

6 Meander Belt Width and Erosion Hazard Assessment

Most drainage features in southern Ontario have a natural tendency to develop and maintain a meandering planform, provided there are no spatial constraints. A meander belt width or erosion hazard

assessment estimates the lateral extent that a watercourse has historically occupied and will likely occupy in the future. This assessment is therefore useful for determining the potential hazard to proposed activities in the vicinity of a watercourse.

Channel planform is affected by a number of factors such as vegetation, gradient, and stream power. In the case of the western tributary within the study site, the channel is poorly defined and highly vegetated. The gradient is low, reducing the capacity of the drainage feature to develop single defined meanders. Within the eastern portion of the study site, there is no erosion, channel definition, or indicators of previous flow, making the formation of single defined meanders unlikely. The eastern features are ephemeral in nature with no potential for erosion. As such, a meander belt width is not applicable for the eastern features.

When defining the erosion hazard for a watercourse, the Ministry of Natural Resources and Forestry treat unconfined and confined systems differently. Unconfined systems are those with poorly defined valleys or slopes well outside where the channel could realistically migrate. Confined systems are those where the watercourse is contained within a defined valley, where valley wall contact is possible. Within the study site, **Reach TBC-1** is situated within an unconfined valley system.

In unconfined systems, the meander belt width can be determined through a detailed geomorphological study that examines the largest channel meanders observed through historical and recent aerial photo interpretation, to determine the meander migration rate within 100 years. The limit of the erosion hazard and migration potential can also be delineated based on the meander amplitude. Meander amplitude is defined by Leopold et al. (1964) as the lateral distance between tangential lines drawn to the center channel of two successive meander bends. This differs from meander belt, which is measured for a reach between lines drawn tangentially to the outside bends of the laterally extreme meander bends (TRCA, 2004). The meander migration rate, meander belt width, and amplitude quantify the lateral extent of a river's occupation on the floodplain (TRCA, 2004).

Reach TBC-1 was identified as unconfined and poorly defined, with no available reference reach to provide measurable meander amplitudes. Given these conditions, the reach was not traceable through aerial photo interpretation, and the calculation of the 100-year erosion rate was not possible. Instead, empirically based meander belt widths models were reviewed for the reach on the subject lands. These models are scientifically defensible and have been verified in past projects as suitable for use in Southern Ontario. The meander belt width was calculated using a suite of empirical models, outlined below, with a summary of the results outlined in **Table 2.**

The empirical relations from Williams (1986) were modified to include channel area and width, and applied using the bankfull channel dimensions such that:

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

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

where B_w is meander belt width (m), A is bankfull cross-sectional area (m^2), and Wb is bankfull channel width (m). An additional 20% buffer, or factor of safety, was applied to the computed belt width values. This addresses issues of under prediction and provides a factor of safety. The bankfull channel dimensions observed during field reconnaissance were used to inform both the Williams Area and Width (1986) models. As noted in the field observations, the reach is poorly defined, so the geometries collected are based on several spot measurements where a defined channel could be observed. As such, the geometries used for modelling are conservative compared to average conditions where there is poor channel definition.

A meander belt width was also calculated based on TRCA's (2004) empirical model:

$$B_w = -14.827 + 8.319\ln(\rho g Q S * DA) \quad \text{[Eq. 3]}$$

where ρ is water density (1000 kg/m^3), g is acceleration due to gravity (9.8 m/s^2), Q is discharge (m^3/s), S is channel slope (m/m), and DA is drainage area (km^2). The TRCA meander belt width values were determined using a drainage area of 1.35 km^2 for **TCB-1** as well as a 2-year discharge of 1.39 m^3/s. These values were based on information provided from the Ontario Watershed Information Tool (OWIT) and GEO Morphix's own flow modelling software. A channel gradient for each reach was also determined based on available elevation/contour data and OWIT. Results of the empirical modelling exercise are outlined in **Table 2**.

Table 2: Meander Belt Width Modelling Results for Reach TBC-1

Reach	Meander Belt Width (m)			Recommended Meander Belt Width (m)
	TRCA* (2004)	Modified Williams – Area** (1986)	Modified Williams – Width** (1986)	
TCB-1	38	10	9	38

**One standard deviation is included as a factor of safety in the TRCA meander belt width value*
***A 20% factor of safety has been included in the modified Williams (area and width) meander belt width value*

The Williams Area and Width models resulted in meander belt widths of 10 m and 9 m. Note that these models are based on bankfull channel geometries collected during field reconnaissance. The average bankfull channel geometries were collected in localized area where a defined channel could be discerned. However, this is not representative of average conditions along the reach given that the channel is generally poorly defined.

For **Reach TCB-1,** we recommend applying a meander belt width of 38 m, following the Toronto Region Conservation Agency (TRCA) model. The TRCA model considers contributing drainage area, flows, and local gradients rather than relying on bankfull channel geometry alone. The 38 m meander belt width is conservative in nature given that there is limited channel definition and very limited erosion potential along this reach. The recommended meander belt width also falls within the current staked wetland boundary and is therefore not a limiting constraint for the proposed development. A map of the meander belt width delineation is provided in **Appendix E**.

7 Summary and Recommendations

Two tributaries of Bronte Creek flow through the western and eastern portion of the subject site at 11 Main Street in Puslinch, Ontario. A desktop assessment was completed which included a review of existing watershed data and historical and recent aerial photographs. Field reconnaissance was also completed to document existing conditions, confirm results of the desktop assessment, and support erosion hazard delineation. This information, in part, will be used in the overall constraint plan to define the limit of development for proposed activities on site.

It was found that the drainage features to the east of the subject site are low-order streams that contain isolated and interspersed wetland pockets within a natural wooded area. No continuous defined stream could be located along each reach within the eastern staked wooded area. As such, there is no potential for erosion and a meander belt width is not applicable.

For **Reach TCB-1,** the watercourse flowing through the western portion of the subject site, a meander belt width of 38 m is recommended. The meander belt width was determined through an empirical modelling exercise. The final meander belt width is conservative given that the channel is small, poorly

defined, and shows limited evidence of erosion or adjustment. It should be noted that the meander belt width also sits within an existing staked wetland boundary and is not a limiting constraint on the proposed development.

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

Respectfully submitted,

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Director, Principal Geomorphologist

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Manager of Watershed Studies

Lucy Lu, M.Sc., G.I.T.
River Scientist

8 References

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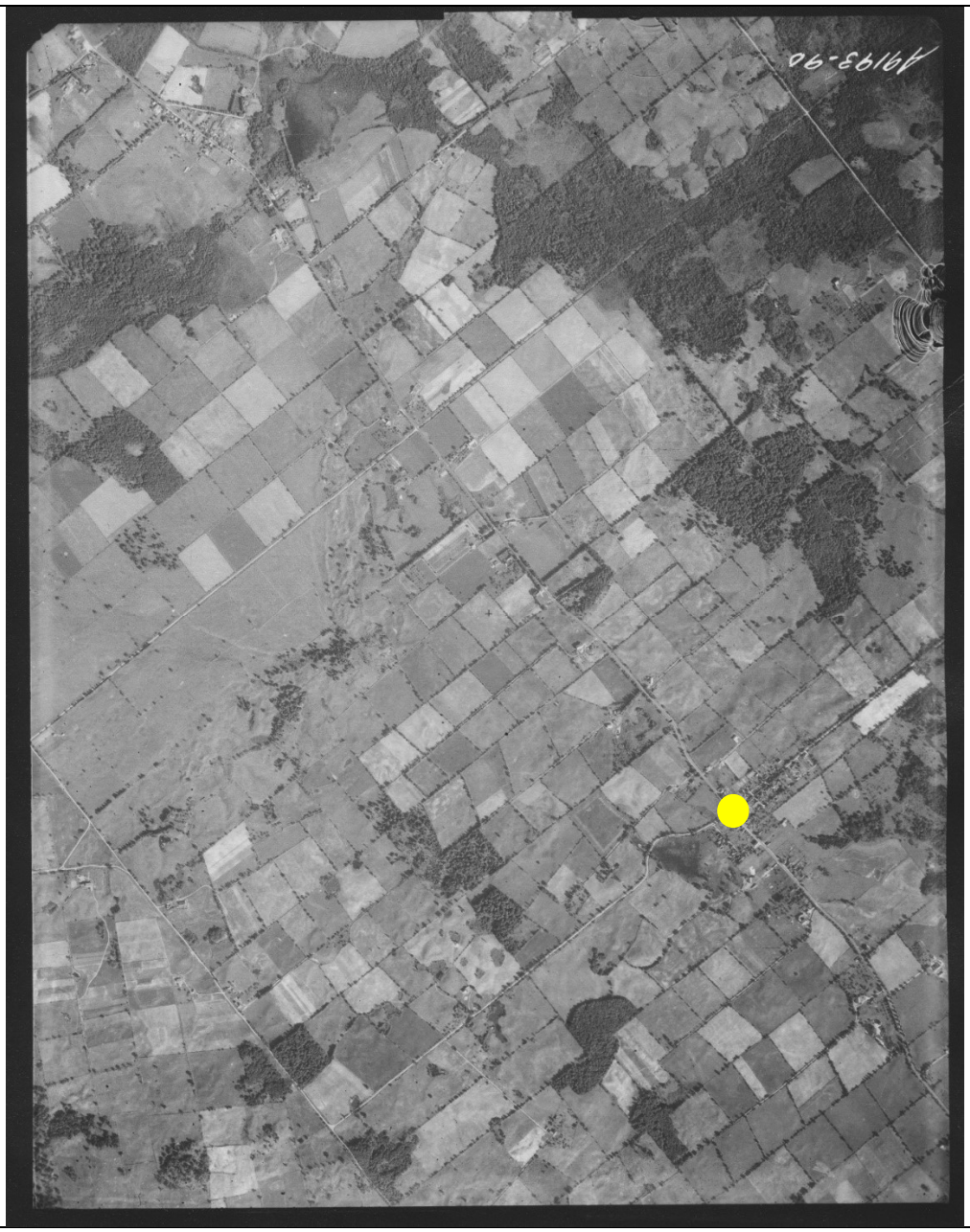
Appendix A
Historical Aerial Photographs



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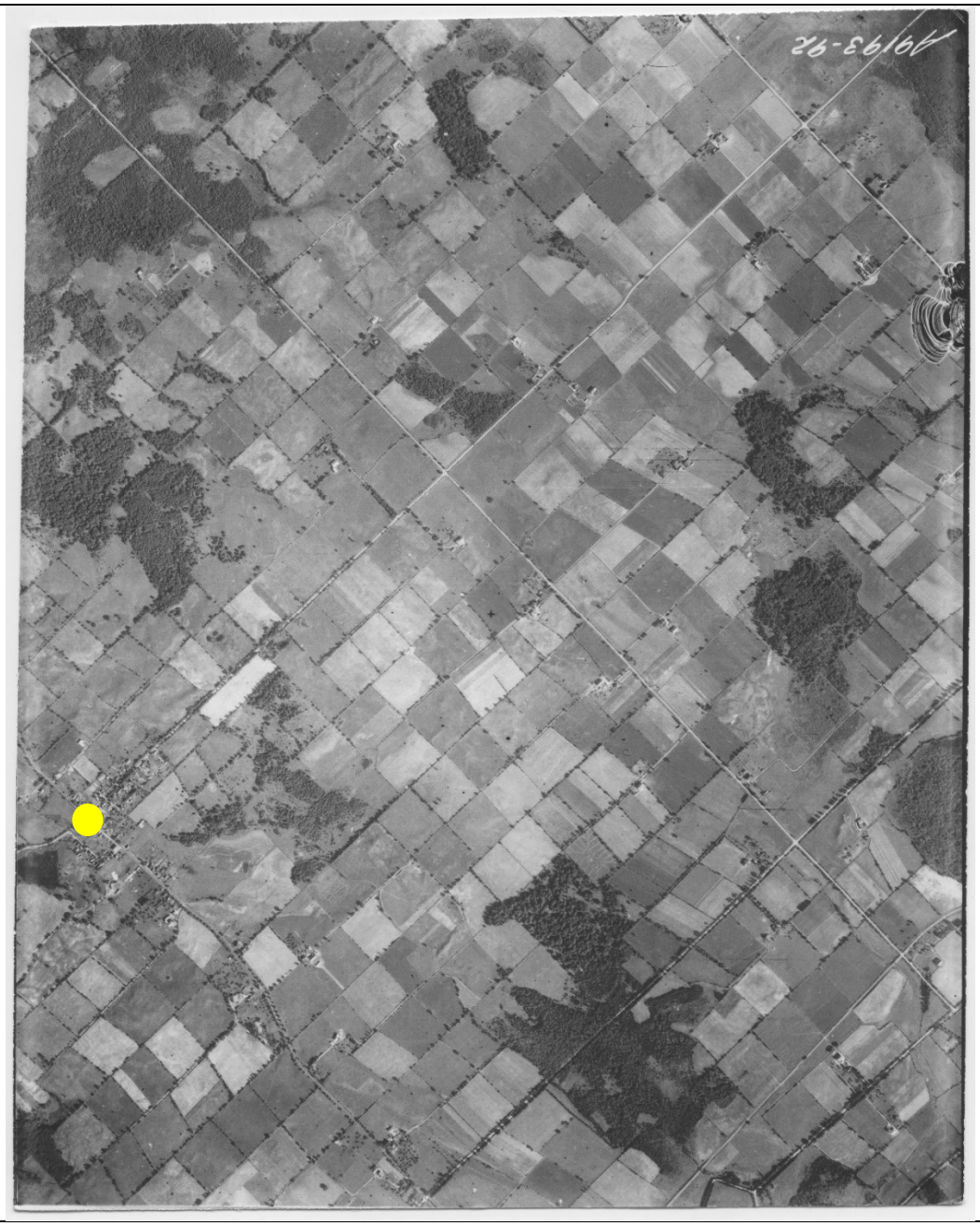
Year: 1945
Scale: 1:20,000
Source: National Air Photo Library



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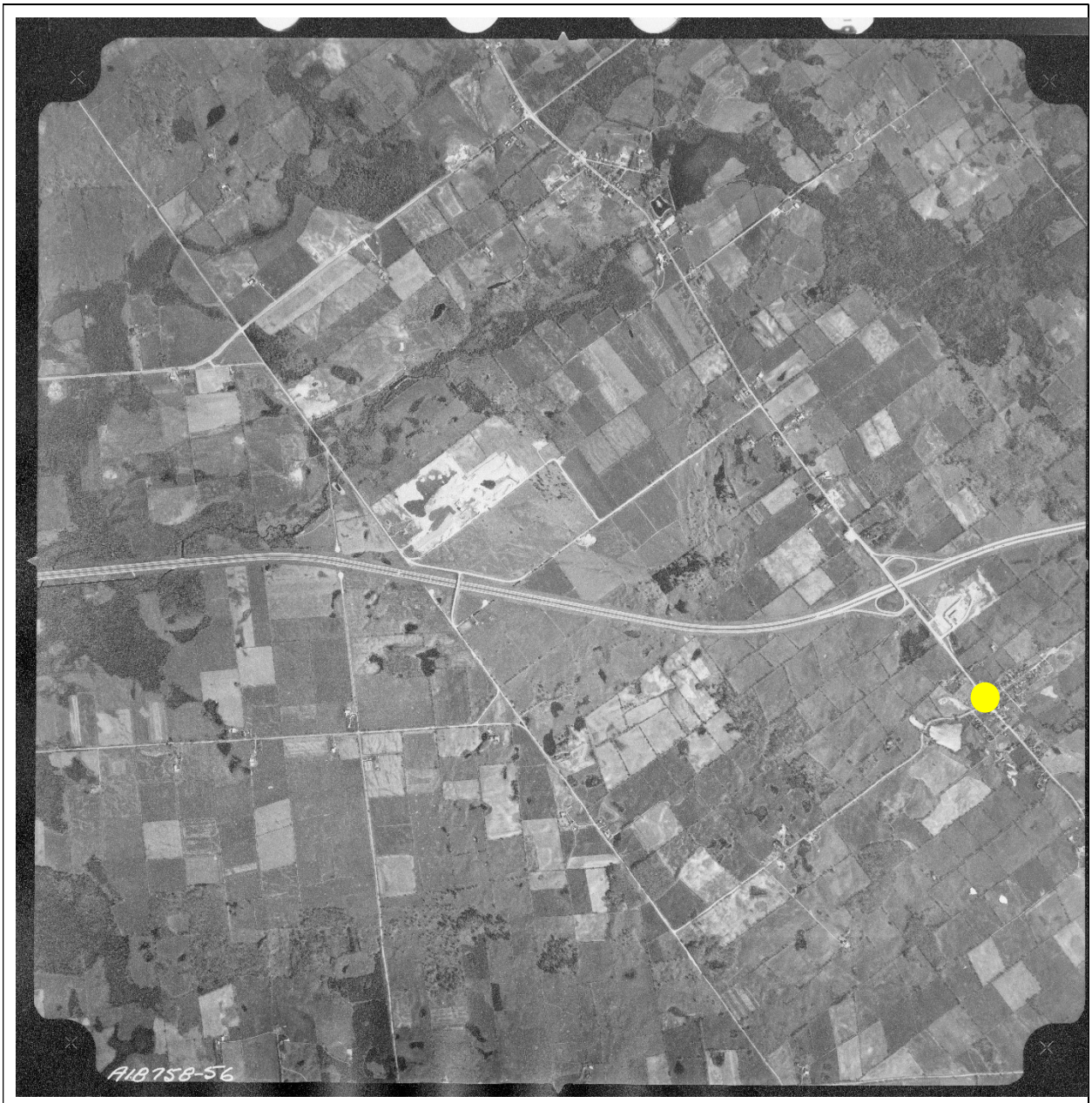
Source: National Air Photo Library



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Year: 1965
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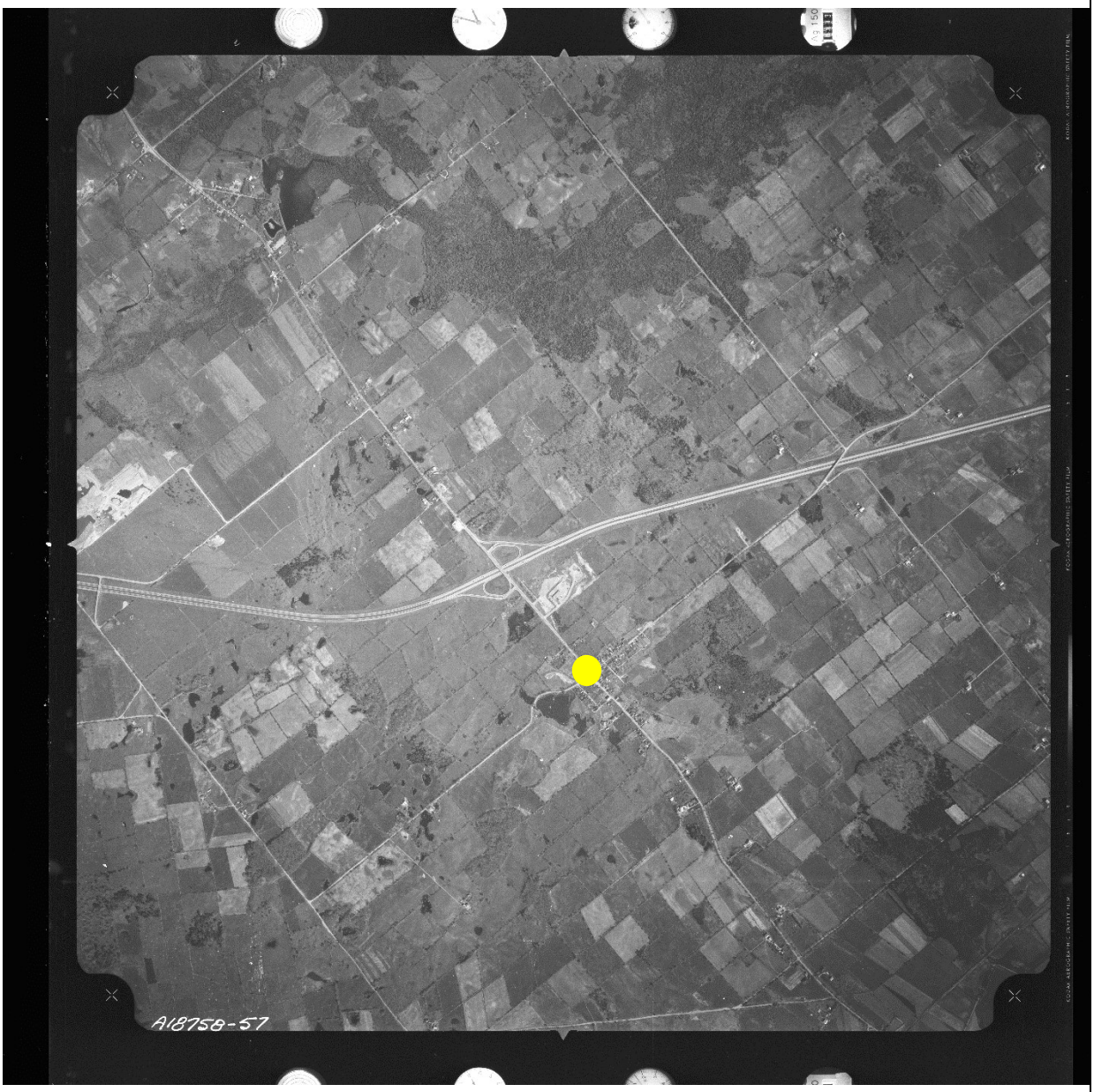
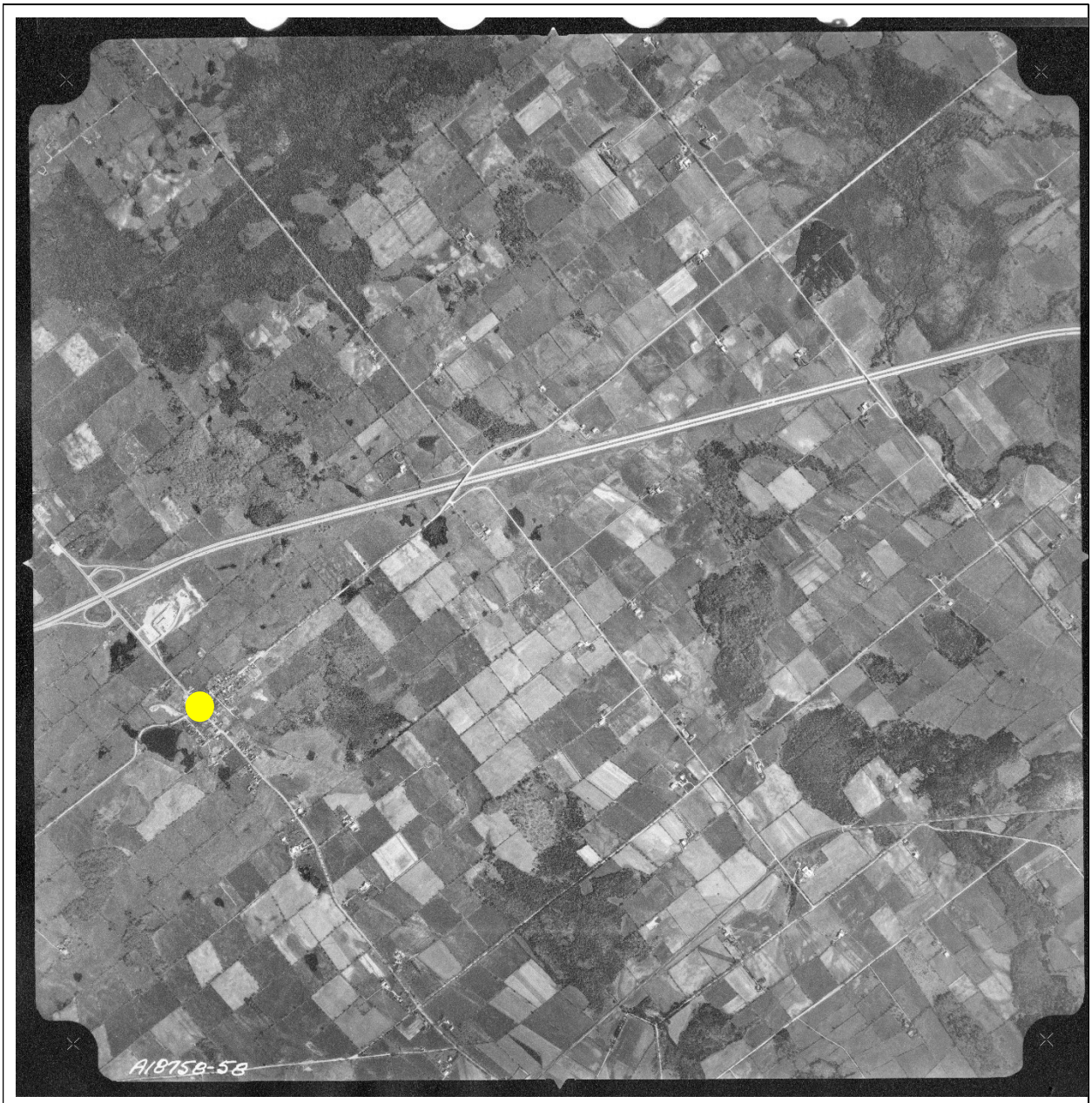
Source: National Air Photo Library



Location: Queen Street and Calfass Road, Town of Puslinch Yellow Dot)
Year: 1965
Scale: 1:25,000
Source: National Air Photo Library



Location: Queen Street and Calfass Road, Town of Puslinch (Yellow Dot)
Year: 1965
Scale: 1:25,000
Source: National Air Photo Library

Location: Queen Street and Calfass Road, Town of Puslinch (Yellow Dot)
Year: 1972
Scale: 1:25,000
Source: National Air Photo Library

Appendix B
Reach Mapping

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Study Area

Bronte Creek

Puslinch, Ontario

Legend

- Reach Breaks and ID
- Watercourse
- Channel observed in field as ephemeral drainage features
- 0.25 m Contour
- Staked Wetland
- Staked Woodland
- Study Boundary

0 75 150

Metres

Imagery: Google Earth, 2018.
Watercourse and Study Boundary: Weston Consulting, 2022. 0.25 m Contour: J.D. Barnes, 2022. Staked Wetland, Staked Woodland: Colville Consulting Inc., 2022. PN22099. Print Date: December 2022.Drawn By: L.L., M.O.

Appendix C
Field Sheets

GEO MORPHIX
Geomorphology Earth Science Observations

General Site Characteristics

Project Code: 22099

Date:	OCT 17th, 2022	**Stream/Reach:**	TBC-1
Weather:	overcast.	**Location:**	PUSLINCH
Field Staff:	MK, LL	**Watershed/Subwatershed:**	BRONTE CREEK

Features

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

oblique Box Culvert
n: 0.6m
W. 2.7 m
U/S wetland, private development, box culvert
oily sheen, iron bacteria

Flow Type

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

pooling adjacent to LHV trail
organic. bkf measured to full width

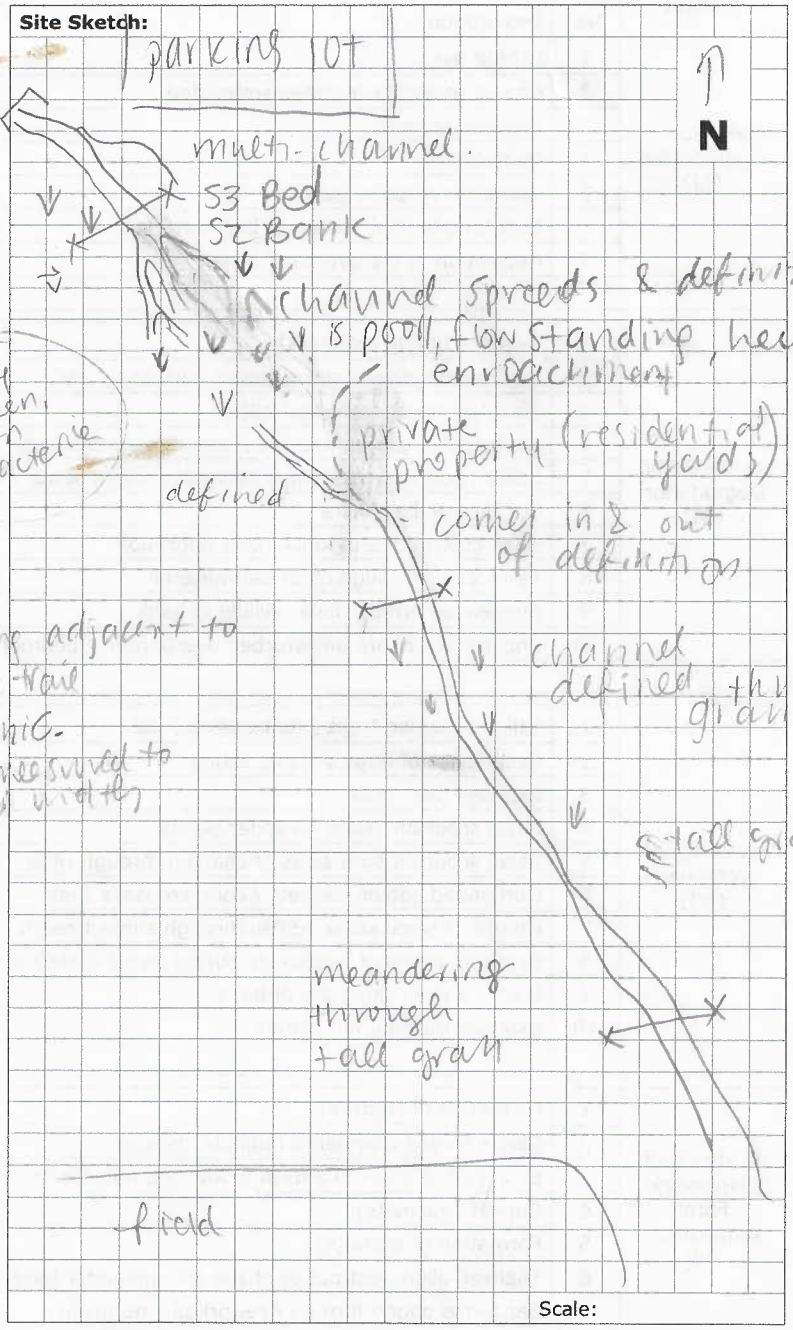
Substrate

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

Other

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

Site Sketch:



Scale:

Additional Notes:

Completed by: LL Checked by: _____

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Rapid Geomorphic Assessment **Project Code:** PN22099

Date:	2022-10-17	**Stream/Reach:**	TCB-1
Weather:	OVERCAST	**Location:**	Puslinch
Field Staff:	MK LL	**Watershed/Subwatershed:**	Bronte

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

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.14

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

Completed by: LL Checked by: _____

GEO | MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code/Phase: PN22099

Date:	2022-10-17	**Stream/Reach:**	TCB-1
Weather:	OVERCAST	**Location:**	PUSLINCH
Field staff:	MK LL	**Watershed/Subwatershed:**	BRONTE
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 7 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): 12 | **Channel Zone** (Table 4): 1 | **Flow Type** (Table 5): 1 | ☐ Groundwater* | Evidence: _____

Riparian Vegetation

Dominant Type: (Table 6): 3/4
Species: _____ _____

Coverage: ☐ None ☐ Fragmented ☒ Continuous

Channel widths: ☐ 1-4 ☐ 4-10 ☒ >10

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

Encroachment: (Table 7): 3-4

Aquatic/Instream Vegetation

Type (Table8): 1 | **Coverage of Reach (%):** 20

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

Density of WD: N/A ☐ Low ☐ Moderate ☐ High | WDJ/50m: 0

Water Quality

Odour (Table 16): G organic

Turbidity (Table 17): 3/5

Channel Characteristics

Sinuosity (Type) (Table 9): 2 | **Sinuosity (Degree)** (Table 10): 1 | **Gradient** (Table 11): 1 | **Number of Channels** (Table 12): 2

Entrenchment (Table 13): 1 | **Type of Bank Failure** (Table 14): 1/N/A | **Downs's Classification** (Table 15): D

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

		★POOL			★POOL	
Bankfull Width (m)	1.0	2.00	1.00	**Wetted Width (m)**	0.62	0.75	0.48
Bankfull Depth (m)	0.30	0.20	0.20	**Wetted Depth (m)**	0.105	0.15	0.15

Riffle/Pool Spacing (m): poor RIP structure | **% Riffles:** | **% Pools:** | **Meander Amplitude:** 0

Pool Depth (m): 0.10 | **Riffle Length (m):** N/A | **Undercuts (m):** Ø

Velocity (m/s): 0.013 | Ø standing water | 0.1 | **Wiffle ball / ADV / Estimated**

Bank Angle: ☒ 0 – 30 ☐ 30 – 60 ☐ 60 – 90 ☐ Undercut

Bank Erosion: ☒ < 5% ☐ 5 – 30% ☐ 30 – 60% ☐ 60 – 100%

Comments:

Notes: WETLAND channel, goes in & out of definition, residential on one side, ~~of~~ park on other

Completed by: LL + MK Checked by: _____

GEO MORPHIX
Geomorphology Earth Science Observations

General Site Characteristics

Project Code: PN2100

Date:	2022-10-17	**Stream/Reach:**	TBC-2
Weather:	OVERCAST	**Location:**	PUSLINCH
Field Staff:	MK LL	**Watershed/Subwatershed:**	BRONTE

Features

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

Flow Type

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

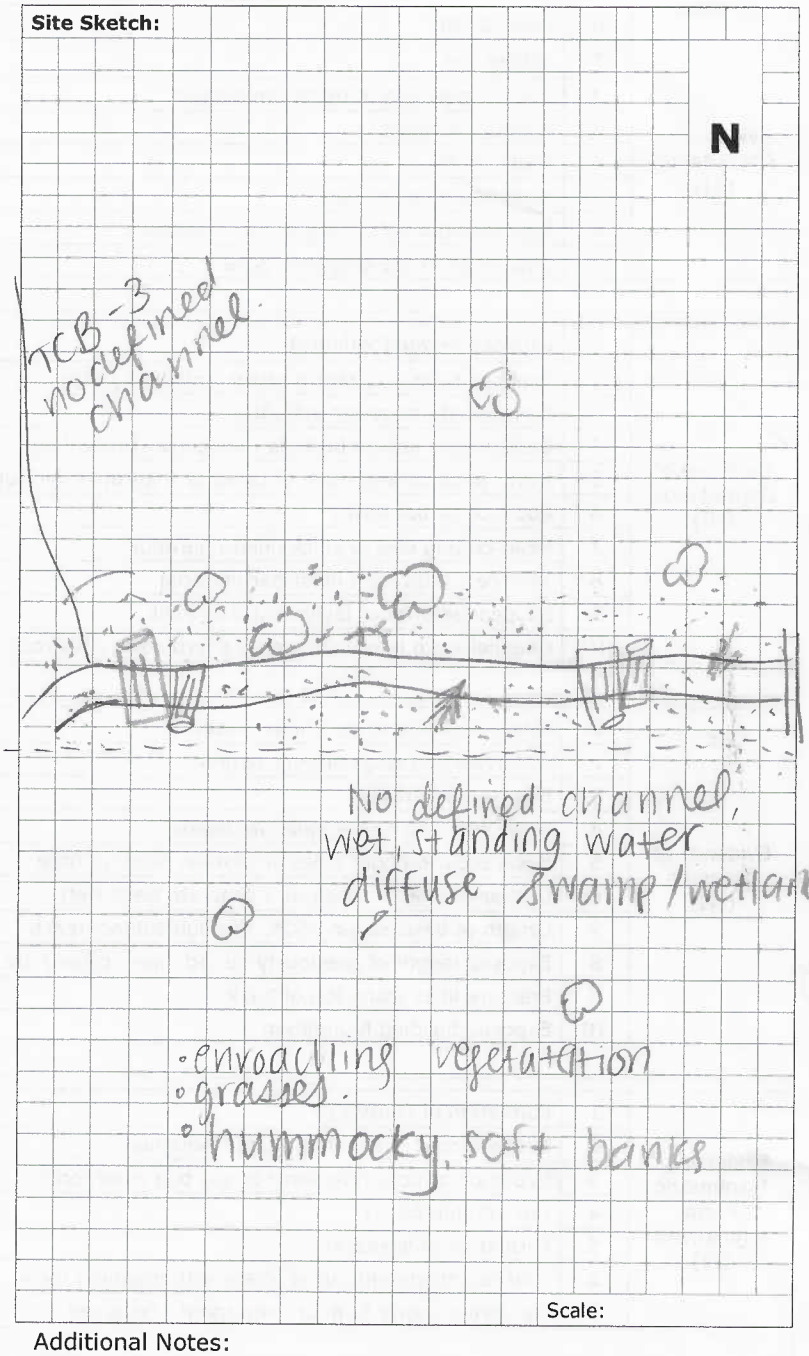
Substrate

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

Other

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

Site Sketch:



Additional Notes:

Completed by: LL Checked by: _____

GEO MORPHIX
Geomorphology Earth Science Observations

General Site Characteristics

Project Code: PN22099

Date:	2022-10-17	**Stream/Reach:**	TBC-3
Weather:	OVERCAST	**Location:**	PUSLINCH
Field Staff:	MK LL	**Watershed/Subwatershed:**	BRONTE

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

Flow Type

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

Substrate

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

Other

BM	Benchmark	**EP**	Erosion pin
BS	Backsight	**RB**	Rebar
DS	Downstream	**US**	Upstream
WDJ	Woody debris jam	**TR**	Terrace
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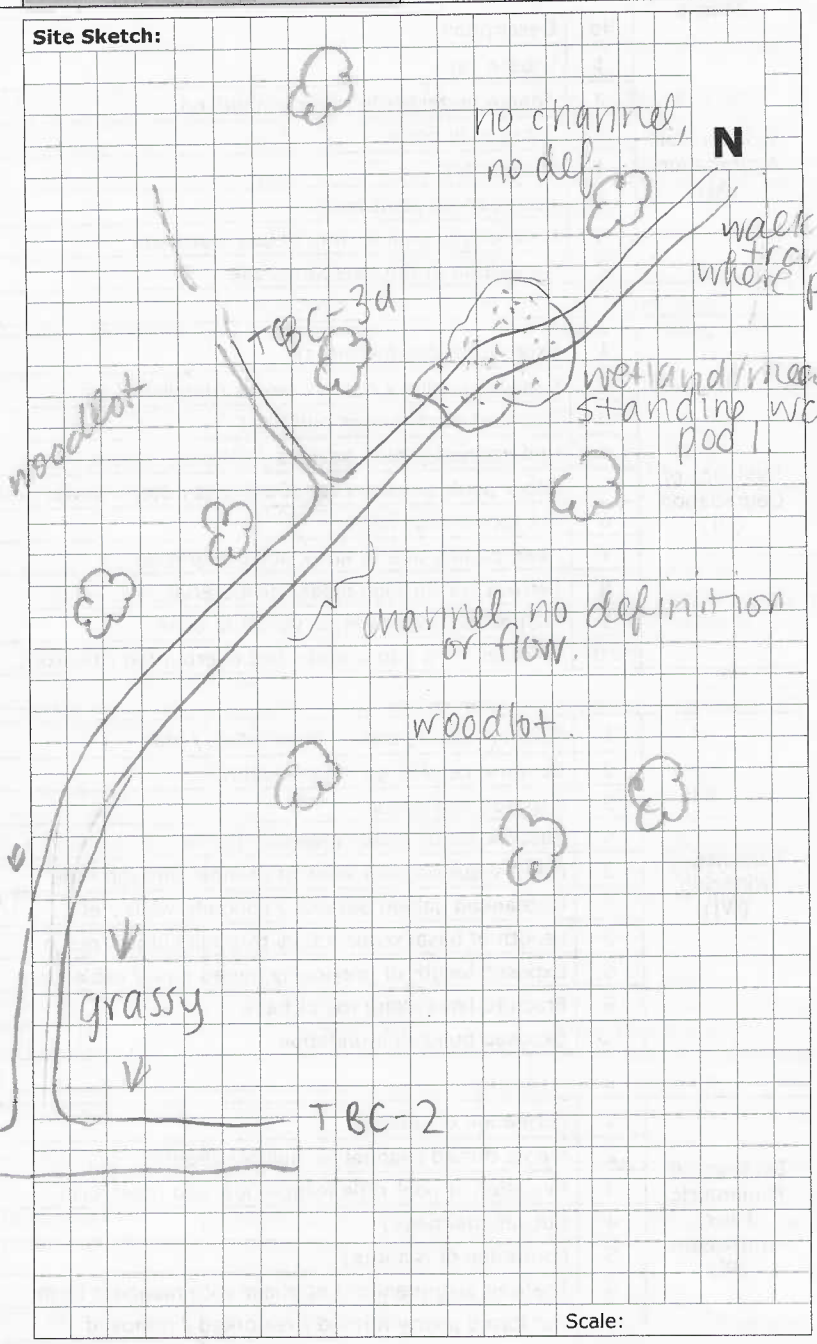
Site Sketch:



Scale:

Additional Notes:

Completed by: LL Checked by: _____

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Geomorphology Earth Science Observations

General Site Characteristics

Project Code: PN22099

Date:	OCT 17th	**Stream/Reach:**	TBC-3a
Weather:	OVERCAST	**Location:**	PUSLINCH
Field Staff:	MK LL	**Watershed/Subwatershed:**	BRONTC

Features

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

Flow Type

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

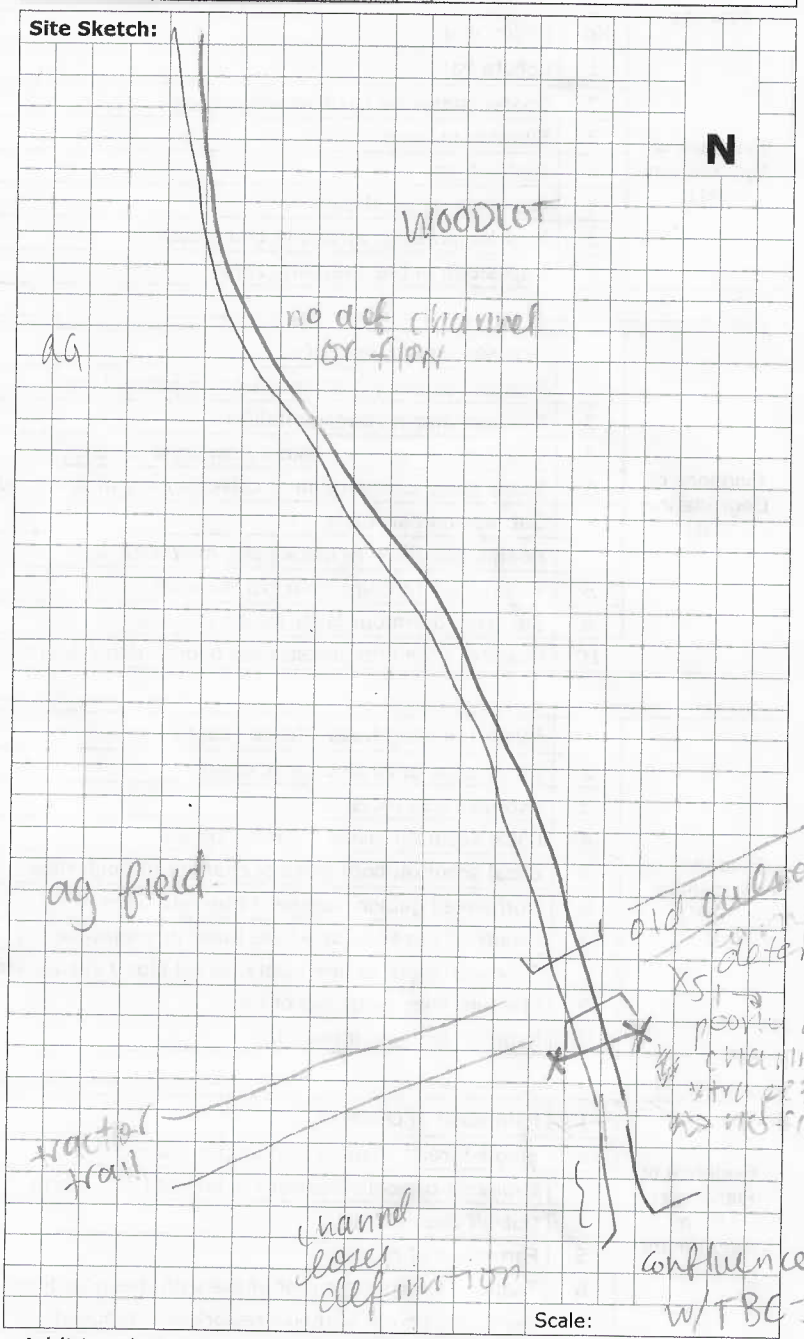
Substrate

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

Other

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

Site Sketch:



Additional Notes:

Completed by: LL Checked by: _____

Appendix D
Photo Observations

Tributary of Bronte Creek
Reach TBC-1
Photo 1

Highway 6 Concrete box culvert at the upstream extent of TBC-1

Tributary of Bronte Creek
Reach TBC-1
Photo 2

Defined bankfull conditions downstream of culvert. Metre stick for scale.

Tributary of Bronte Creek
Reach TBC-1
Photo 3

The riparian area consisted mainly of tall grasses with sparse herbaceous shrubs and trees. Bankfull channel was poorly defined throughout.

Tributary of Bronte Creek
Reach TBC-1
Photo 4

Downstream of reach as it continues to flow off property boundaries. Outside of pictured grassy riparian area is agricultural field.

Tributary of Bronte Creek
Reach TBC-2
Photo 5

Hummocky areas with instream grasses and pooled, standing water is typical condition along Reach TBC-2

Tributary of Bronte Creek
Reach TBC-2
Photo 6

Grassy hummocks and trees throughout pools of water. No defined bankfull channel present along Reach TBC-2

Tributary of Bronte Creek
Reach TBC-3
Photo 7

The riparian zone of Reach TBC-3 contained wooded area. No bankfull channel or flow paths observed in the upstream sections.

Tributary of Bronte Creek
Reach TBC-3
Photo 8

A minor flow path was observed in the very downstream extent of the study site, presumed to be associated with mapped stream Reach TBC-3.

Tributary of Bronte Creek
Reach TBC-3a
Photo 9

The riparian area consisted of wooded area. No defined flow path observed in association with mapped stream Reach TBC-3a

Appendix E
Meander Belt Width Delineation

GEO MORPHIX™

Meander Belt Width Delineation

Bronte Creek

Puslinch, Ontario

Legend

- Reach Break and ID
- Watercourse
- Channel observed in field as ephemeral drainage features
- 0.25 m Contour
- Meander Belt Width
- Meander Belt Width (Off Property - Field Verification Required)
- Staked Wetland
- Staked Woodland
- Study Boundary

0 75 150

Metres

Imagery: Google Earth, 2018. Study Boundary, Watercourse: Weston Consulting, 2022. 0.25 m Contour: J.D. Barnes, 2022. Staked Wetland, Staked Woodland: Colville Consulting Inc., 2022. Meander Belt Width: GEO Morphix Ltd., 2022. Print Date: February 2023. PN22099. Drawn By: L.L., M.O.

GEO MORPHIX™

Meander Belt Width Delineation

Bronte Creek

Puslinch, Ontario

Legend

- Reach Break and ID
- Watercourse
- 0.25 m Contour
- Meander Belt Width
- Meander Belt Width (Off Property - Field Verification Required)
- Staked Wetland
- Staked Woodland
- Study Boundary

N

0 10 20

Metres

Imagery: Google Earth, 2018. Study Boundary, Watercourse: Weston Consulting, 2022. 0.25 m Contour: J.D. Barnes, 2022. Staked Wetland, Staked Woodland: Colville Consulting Inc., 2022. Meander Belt Width: GEO Morphix Ltd., 2022. Print Date: December 2022. PN22099. Drawn By: L.L., M.O.