Meander Belt Width Assessment
Pretty River

452 Raglan Street, Collingwood

Prepared for:

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October 5, 2021
PN20044a

GEO MORPHIX
Geomorphology
Earth Science
Observations

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1 Introduction

GEO Morphix Ltd. was retained to complete a meander belt width assessment for Pretty River at 452 Raglan Street in the Town of Collingwood, Ontario. It is understood that Eden Oak McNabb Inc. entered a due diligence period for the 452 Raglan Street property and required an understanding of environmental constraints and setbacks associated with Pretty River. To inform the erosion hazard (meander belt width/setback) associated with the subject property, 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
- Confirm watercourse reach delineation through a desktop assessment
- Review of recent and historical aerial photographs of the site to understand historical changes in channel form and function
- Complete rapid geomorphological assessments on a reach basis to document channel conditions and verify the desktop assessment
- Document any areas of significant erosion, collect instream measurements of bankfull channel dimensions, and characterize bed and bank material composition and structure
- Delineate limits of the meander belt width/erosion hazard on a reach basis using field observations and historical aerial photography
- Prepare a report and mapping product to characterize the watercourse, delineate the meander belt width, and summarize all findings

2 Background Review and Desktop Assessment

2.1 Background Information

The subject section of Pretty River is situated within the Nottawasaga Valley Conservation Authority (NVCA) jurisdiction, and further, the Nottawasaga Valley watershed. The Nottawasaga Valley watershed is comprised of nine subwatersheds, including the Blue Mountains subwatershed, Lower Nottawasaga subwatershed, Willow Creek subwatershed, Mad River subwatershed, Pine River subwatershed, Middle Nottawasaga River subwatershed, Boyne River subwatershed, Upper Nottawasaga subwatershed, and Innisfil Creek subwatershed (NVCA, 2018). Specifically, the subject section of Pretty River is within the Blue Mountains subwatershed. The Pretty River originates as a series of spring-fed tributaries through the Niagara Escarpment. The watercourse flows northward through Pretty River Valley Provincial Park, through rural and agricultural areas within the Town of Collingwood, and ultimately discharges to Georgian Bay through a diked flood control channel (NVCA, 2018).

Pretty River drains an area of approximately 7,700 hectares and is the second largest river in the Blue Mountains subwatershed (Blue Mountain Watershed Trust Foundation, 2018). Pretty River is characterized as a cold-water system, which sustains cold-water fish habitat and a diverse range of aquatic life. It is noted, by the Blue Mountain Watershed Trust Foundation (2018), that Pretty River is generally in good condition, with the greatest impacts stemming from development. The upper reaches of Pretty River and the Pretty River Valley are well-forested, however the portion that runs through the Town of Collingwood is primarily surrounded by agricultural and residential lands. Further, the NVCA has conducted stream bank erosion reduction projects to alleviate pressures from surrounding lands (Blue Mountain Watershed Trust Foundation, 2018).

At the subject site, the main branch of Pretty River flows south to north along the eastern extent of the property boundary. A small tributary enters the main branch of Pretty River at the southern extent of the subject property. There are two crossings over the main branch of Pretty River, which include a pedestrian bridge approximately halfway through the system, and a single-lane driveway at the northern extent of the property. Through the subject site, Pretty River is meandering with a high degree of sinuosity but enters a diked flood control channel downstream from the northern property boundary.

To identify the extent of possible erosion and delineate a natural hazard limit associated with Pretty River within the subject property, a meander belt width assessment. A study site map is provided for reference in **Appendix A**.

2.2 Geology and Physiography

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

Within the subject site, Pretty River is dominated by the Simcoe Lowlands physiographic region of Ontario (Chapman and Putnam, 2007). In terms of physiographical landforms, sand plains, shore cliff, and beaches are associated with the subject site. In terms of surficial geology, the subject lands are characterised by coarse-textured glaciolacustrine deposits (OGS, 2010). Soils within these areas include sand, gravel, minor silt and clay, and foreshore and basinal deposits (OGS, 2010). Pretty River, rather, is characterised by modern alluvial deposits (OGS, 2010). Soils within these areas include clay, silt, sand, gravel, and organic remains (OGS, 2010).

2.3 Historical Assessment

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

Various aerial photographs and satellite images from 1952 to 2018 were retrieved to complete the historical assessment and inform the 100-year erosion risk assessment. Specifically, aerial photographs from 1952, 1989, 1997 (Simcoe County Interactive Mapping Database), and satellite images from 2008 and 2018 (Google Earth Pro) were reviewed.

In 1952, the subject site and the majority of lands within the Town of Collingwood were occupied by agricultural lands. Two major road networks were constructed, including Poplar Sideroad (Highway 32) and Raglan Street. The Canadian Rail Network was also constructed and ran northwest/southeast adjacent to the western extent of the subject property. At this time, there were limited minor road networks and residential dwellings. Given the limited development in the vicinity of the property, there were no crossings over the Pretty River at the Subject Property. Based on available aerial photographs, Pretty River was characterized as a single-thread, meandering channel. Compound meanders were associated with the meander planform, which extended upstream and downstream from the Subject Property. From the Subject Property, the meandering planform extended until the Pretty River outlet to Georgian Bay. The riparian zone was occupied by mature vegetation (trees) in some locations, particularly through the southern extent of the Subject Property. On a larger scale, forested lands provided a buffer between the Subject Property and the residential dwellings located along the shoreline of Georgian Bay. A small tributary flowed beneath Raglan Street and contributed flows to the main branch of Pretty River

at the mid-point of the Subject Property. The tributary was much smaller in bankfull geometry than the main branch of Pretty River, and its planform was relatively straight.

Lands at the Subject Property, and east, south, and west of the subject property, were occupied by agricultural activities through 1989. To the north of the Subject Property, and throughout the Town of Collingwood as a whole, there were increases in residential and commercial development. Additionally, there was an increase in the number of minor road networks in the vicinity of the Subject Property. A driveway was constructed at the northern extent of the Subject Property, crossing over the main branch of the Pretty River. To accommodate development and control flows through the Town of Collingwood, Pretty River was straightened through a diked flood control structure. Specifically, the main branch of Pretty River was straightened from the Subject Property to the outlet at Georgian Bay. The riparian zone was fragmented through the watercourse, with mature tree species established at inside meander bends bordering the Subject Property. There were no changes to channel size or sinuosity associated with the small tributary contributing flows to the main branch of Pretty River. The riparian zone of the small tributary was limited, with shrubs and immature tree species.

By 1997, the Town of Collingwood was primarily occupied by residential and commercial development. There were several minor road networks constructed north of the Subject Property to connect dwellings and facilities. The Subject Property itself, as well as lands to the east, south, and west, remained occupied by agricultural activities. Unlike the downstream extent of Pretty River, the upstream extent of the channel was surrounded by agricultural lands and the planform of the watercourse was not modified. The riparian zone was occupied by mature tree species along the bank closest to the Subject Property, with limited riparian coverage along the channel bank closes to Raglan Street. The riparian zone surrounding the tributary increased in density, and the planform of the tributary remained unchanged. Downstream from the Subject Property, the channel planform through the Town of Collingwood remained straightened through the diked flood control structure.

Immediately upstream and downstream from the Subject Property, residential development was under construction in 2008. To support these developments, storm water management ponds were constructed in close proximity. This likely impacted flow characteristics through Pretty River. Land use at the Subject Property remained occupied by agricultural activities, and there were limited changes in riparian zone surrounding the watercourse. The meandering planform and high degree of sinuosity associated with Pretty River was unmodified through the Subject Property and upstream from the Subject Property.

By 2018, the Subject Property was occupied by open lands (as it is today) while the properties upstream and downstream were occupied by residential development. Immediately west of the Subject Property, residential units (including storm water management facilities) were under construction. There were no notable changes to channel planform or riparian zone characteristics. The riparian zone remained dense along the bank associated with the Subject Property, and sparser along the bank closer to Raglan Street. The small tributary flowing to the main branch of Pretty River was clearly visible through aerial photographs and displayed a slightly meandering planform. Channel width of the tributary was much smaller than that of Pretty River, and the riparian zone of the tributary was relatively spare, occupied by few shrub/tree species. The single lane crossing over the main channel was maintained, and a pedestrian bridge was constructed. Bank stabilization measures, including riprap, was visible along the outside meander bends at the Subject Property, particularly through the large, compound meander.

Despite substantial changes in land use surrounding the Subject Property, as well as channel modifications through the downstream extent of the watercourse, the planform and riparian

characteristics associated with Pretty River at the Subject Property remained relatively unchanged through time.

3 Watercourse Characteristics

3.1 Reach Delineation

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

Reaches are typically delineated based on changes in the following:

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

Reach delineation follows scientifically defensible methodology proposed by Montgomery and Buffington (1997), Richards et al. (1997), and the Toronto and Region Conservation Authority (2004) as well as others. Based on the existing channel conditions and the linear extent of the watercourse within the subject property, one (1) reach was delineated. **Reach PR-1** was delineated from approximately 50 m upstream of the southern extent of the subject lands to the driveway crossing downstream. There was also one intermittent stream identified. This stream flowed west from Raglan Street and connected with Pretty River approximately 50 m downstream of the pedestrian bridge crossing.

3.2 General Reach Observations

Field investigations were completed on May 22, 2020, and included the following:

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

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

Reach PR-1 flows south to north towards the northern limit of the subject property. Upstream from the subject reach of Pretty River**,** the watercourse flows under Poplar Sideroad and through agricultural lands with mature vegetation surrounding the channel. Moving downstream, **Reach PR-1** flows parallel to Raglan Street to the east, and a train trail to the west.

Reach PR-1 was situated within a partially confined valley setting. The channel exhibited a meandering planform and had a sinuosity that ranged from 1.31 – 3.0. The surrounding land use consisted of agricultural land and the channel was in a deposition zone. The riparian buffer zone was approximately 1-4 channel widths beyond the watercourse and had fragmented coverage. The dominant type of riparian vegetation was mature (> 30 years) tree species. There was minimal encroachment of vegetation into the channel. The reach had perennial flow with a moderate gradient and high entrenchment. Bed material was composed of clay/silt, sand and gravel. Riffle features consisted of sand, gravel, cobbles, and boulders, while pool features consisted of clay/silt, sand, and gravel. There was no aquatic vegetation through the reach and a low density of woody debris present in the channel.

Average bankfull width and depth were approximately 14.1 m and 1.45 m, respectively. Average wetted width and depth on the day of assessment were approximately 11.7 m and 0.42 m, respectively. Bank angles ranged from 60° to 90° and consisted of clay/silt and sand. Evidence of erosion was observed through 60 to 100% of the channel, with bank undercuts measuring up to 1.65 m in depth. Deposition and fresh sand deposits were observed frequently in the overbank zone.

One intermittent channel also contributed flows to **Reach PR-1.** General observations of this channel were collected, however, given its small size, the feature was excluded from the complete assessment.

There were two crossings throughout the reach, a pedestrian bridge crossing and a driveway crossing. The pedestrian bridge was approximately halfway through the reach. Bank erosion was evident at this crossing with large, exposed tree roots and undercutting along the slopes. The driveway bridge was at the downstream extent of the reach. This crossing had exposed and worn concrete footings.

3.3 Rapid Assessment

Channel instability was objectively quantified through the application of the Ontario Ministry of the Environment's (2003) Rapid Geomorphic Assessment (RGA). Observations were quantified using an index that identifies channel sensitivity based on evidence of aggradation, degradation, channel widening, and planimetric adjustment. The index produces values that indicate whether a channel is stable/in regime (score <0.20), stressed/transitional (score 0.21-0.40), or adjusting (score >0.41).

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

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

Reach PR-1 was assigned an RGA score of 0.51, indicating the reach was in adjustment. The dominant geomorphological indicator was evidence of widening by the observation of fallen/leaning trees, occurrence of large organic debris, exposed tree roots, basal scour, and fractures present along channel banks. The secondary geomorphological indicator was evidence of aggradation, based on observations of coarse materials in riffles, siltation in pools, accretion on

point bars, and deposition in the overbank zone. These characteristics influence the delineation of erosion risk in terms of overall channel stability. Overall, the channel is in adjustment, according to the RGA results. **Reach PR-1** had an RSAT score of 26, or good. There were two limiting factors, including channel stability and riparian conditions. This was due to unstable banks with frequently observed bank failures, young exposed tree roots, and large fallen trees.

Table 1. Summary of Rapid Assessment Results

Reach	RGA (MOE, 2003)			RSAT (Galli, 1996)		
	Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Feature(s)
PR-1	0.51	In Adjustment	Widening	26	Good	Channel Stability, Riparian Conditions

4 Meander Belt Width Assessment

Most watercourses 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 meandering channel 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.

When defining the erosion hazard for a watercourse, Ministry of Natural Resources and Forestry (MNRF, 2002) guidelines 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. Given the valley wall contact observed on site, **Reach PR-1** was considered confined within the subject property.

When a meandering channel is confined (in this case, partially confined), erosion of the valley wall needs to be considered. The Ontario Ministry of Natural Resources and Forestry (MNRF) outlines an approach for establishing the erosion hazard for confined valley systems. This approach defines an appropriate erosion setback or toe erosion allowance from the channel bank where the creek is within 15 m from the toe of slope (MNRF, 2001). A toe erosion allowance can be determined in several ways: use of an average annual recession rate; use of a delineated toe erosion allowance in areas where the channel is within 15 m of the toe of slope; or use of soil information and field observations of geomorphic processes (MNRF, 2001).

The geotechnical investigation completed by Toronto Inspection Ltd. (2020) suggested a conservative 8 m erosion setback based on the MNRF approach (2001). We have provided additional support in erosion hazard delineation through review of historical aerial photographs and, specifically, a review of average annual recession rates for several channel meander bends on the property. The meander migration rates were defined using the method of Villard *et al.* (2009). This method has been used previously by GEO Morphix Ltd. and is based on scientifically defensible methodology that has been applied on projects in several jurisdictions across southern Ontario.

Meander migration rates were based on a comparison of channel planforms observed in the 1973 and 2016 aerial imagery. Several large meander bends were selected for the assessment based

on size and proximity to valley walls. Calculated meander migration rates are provided in **Table 2**.

We note that the MNRF's (2001) standard record of assessment for meander migration analysis is 25 years. This ensures that the erosion allowance is determined for a 100-year planning period. The period of record used in this analysis was 43 years. The aerial photographs used in this case were recent, reliable, and available as georeferenced images. As such, we are confident with the approach and results outlined here for the meander migration analysis. **Appendix E** includes a figure showing the various locations used to assess meander migration rates.

Table 2. Meander migration rates determined from 1973 and 2016 aerial imagery

Meander	Start Year	End Year	Migration Distance (m)	Migration Rate (m/yr)
A	1973	2016	-0.38	-0.01
B	1973	2016	-2.25	-0.05
C	1973	2016	5.43	0.13
D	1973	2016	-5.98	-0.14
E	1973	2016	3.30	0.08
F	1973	2016	-8.43	-0.20
Average Migration Rate	Average **Reach PR-1**: -0.032 m/yr			
100-Year Migration Rate	Average **Reach PR-1**: -3.22 m			

As outlined in **Table 2**, the erosion rate based on averaging the migration rates for Pretty River is -0.032 m/yr. Further, the 100-year erosion rate is -3.22 m. This suggests that migration is within the potential error of the estimates and is illustrating limited lateral migration. The negative values suggest aggradation could be a product of water levels, vegetation encroachment, or rectification errors. Based on the 100-year erosion rate, as well as observations of erosion through **Reach PR-1**, we recommend applying a 5 m erosion setback to the geotechnically long-term stable top of slope. Following MNRF's (2001) approach, the 100-year erosion setback of 5 m could be applied to address the erosion hazard where the river is within 15 of the valley toe of slope. It is understood that a preliminary setback of 8 m was proposed by Toronto Inspection Ltd. (2020); however, the 5 m erosion setback could be applied as a less conservative approach. It is important to note that the setback will need to be applied to the long-term stable top of slope for the final constraint mapping.

There is also typically an access easement, required by the respective conservation authority. NVCA may request an access easement on top of the erosion setback. We note that in other cases where a commercial or industrial development has been proposed, an access easement along an adjacent road has been provided in lieu of an access setback, as long as the road is adjacent to the stable top of bank and it can transport heavy machinery.

5 Summary and Conclusions

This section of Pretty River flows within a partially confined system through the subject lands. Through aerial photograph interpretation, it was determined that the channel planform through the system has remained relatively unchanged since the late 1950s. It is important to note that

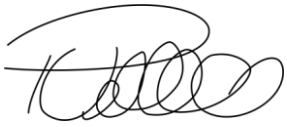
in some cases, the planform of the channels was not discernable through aerial imagery, due to the present of mature vegetation. Land use was unchanged to the east, south, and west of the subject property but was converted from primary agricultural areas to residential and commercial areas to the north of the subject property. The channel was straightened downstream of the subject lands to control flows using a dike flood control structure. The subject property is located south of Lynde Street and west of Raglan Street. The purpose of this work was to identify the 100-year erosion risk. These findings will support Eden Oak McNabb Inc.'s due diligence requirements associated with 452 Raglan Street in the Town of Collingwood.

To inform the 100-year erosion risk associated with Pretty River, a fluvial geomorphological and erosion hazard assessment was completed. A field investigation was completed on May 22, 2020 and included a rapid geomorphological assessment of **Reach PR-1.** The watercourse was identified as a defined, single-thread channel. **Reach PR-1** was identified as being in adjustment, with "good" and "fair" overall conditions, respectively. To inform the channel migration limit, an erosion hazard assessment was required.

Given the partially confined nature of **Reach PR-1** adjacent to the subject property, we completed a review of average annual recession rates for several channel meander bends on the property. Meander migration rates were based on a comparison of channel planforms observed in the 1973 and 2016 aerial imagery. The 100-year erosion rate illustrated that migration is likely within the error of measurement, and as such, systematic lateral migration is likely negligible. Therefore, based on the 100-year erosion rate, as well as observations of erosion through **Reach PR-1**, we recommend applying a 5 m erosion setback to the geotechnically long-term stable top of slope. Following MNRF's (2001) approach, the 100-year erosion setback of 5 m could be applied to address the erosion hazard where the river is within 15 of the valley toe of slope. In addition to the erosion setback, a 6 m access easement is required through NVCA. This constraint, as well as the 5 m setback on the long-term stable top of slope, should be included in final constraint mapping.

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

Respectfully submitted,



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Director, Principal Geomorphologist

Josie Mielhausen, M.Sc.
Environmental Scientist

6 References

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Appendix A
Study Site Map

WILLIAMS STREET
PEEL STREET
LYNDEN STREET
DRIVEWAY
RAGLAN STREET
TRAIL
452 Raglan Street
PR-1
Intermittent Stream
TRAIL
POPLAR SIDEROAD

Legend

- PR-1 Reach Label
- Stream
- 0.5 m Contour
- Waterbody
- Property Boundary

452 Raglan Street Meander Belt Width Assessment

Study Site

Collingwood, Ontario

GEO MORPHIX™

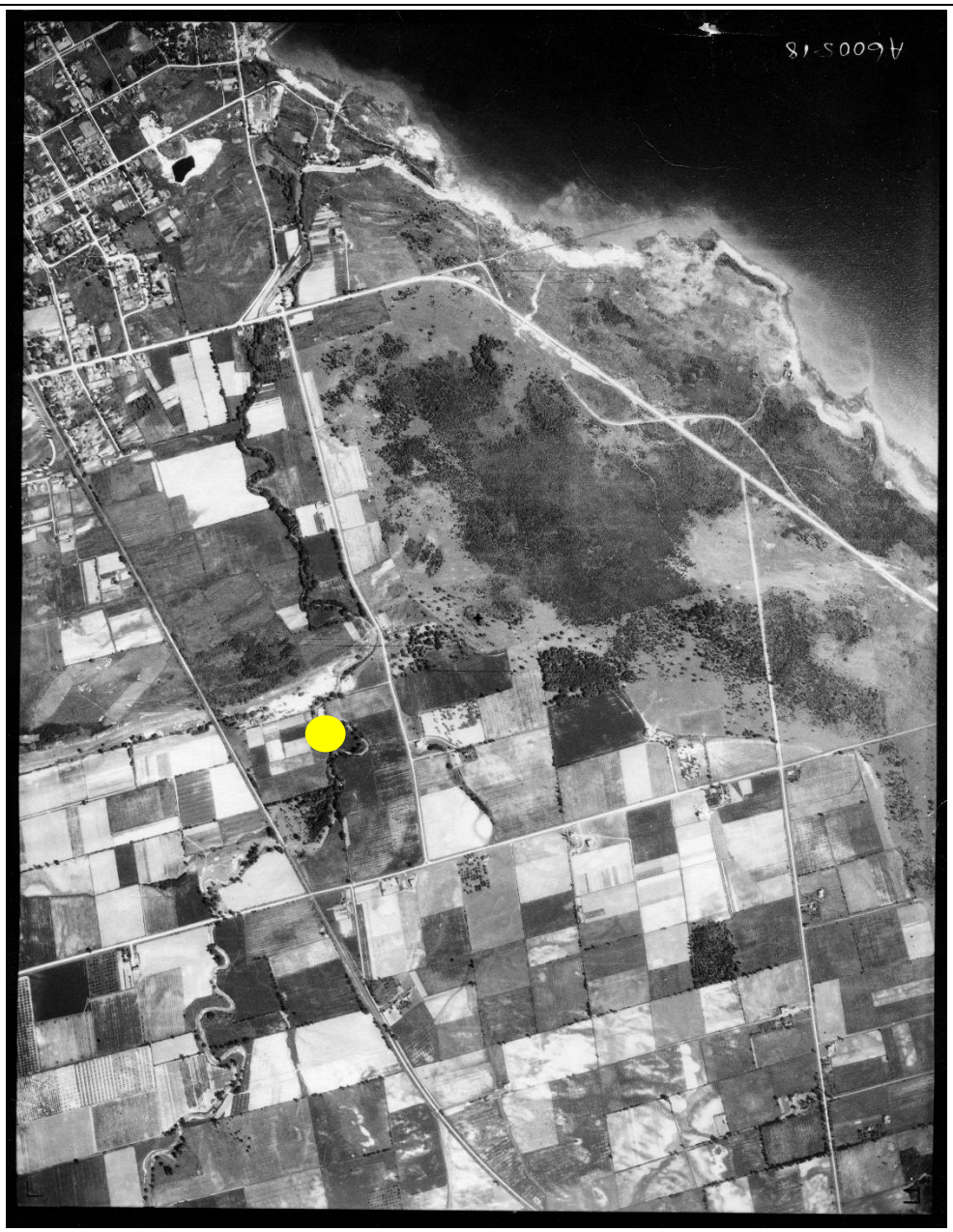
0 20 40 60 80 100

Metres

N

Imagery: Google Earth Pro, 2018.
Stream, Waterbody, Property Boundary and Unevaluated Wetland: Simcoe County, 2019.
0.5 m Contour: JoeTOPO Surveys and CADD Inc., 2020.
Printed: December 2020. PN20044. Drawn By: H.G., M.H., J.M.

Appendix B
Historical Aerial Photographs

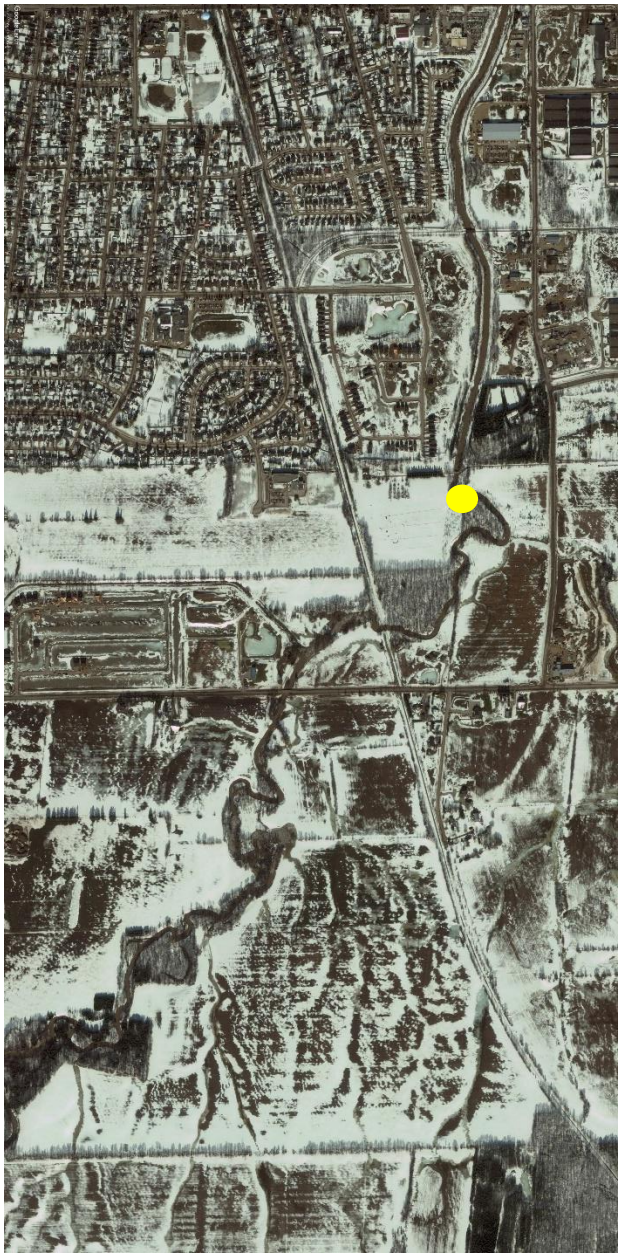


Location: Pretty River, Collingwood, ON (yellow dot)
Year: 1938
Scale: 1:20,000
Source: National Air Photo Library

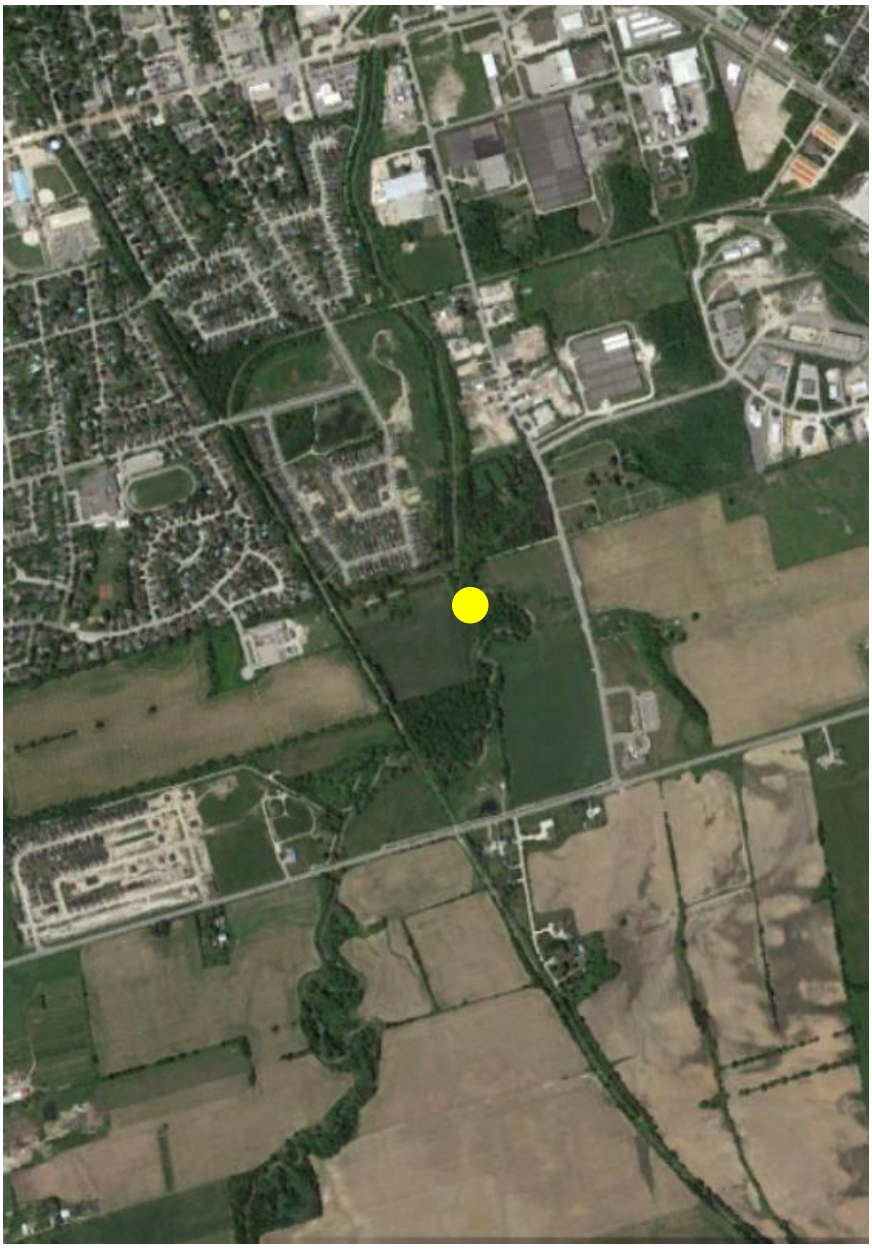
Location: Pretty River, Collingwood, ON (yellow dot)
Year: 1965
Scale: 1:35,000
Source: National Air Photo Library

Location: Pretty River, Collingwood, ON (yellow dot)
Year: 1973
Scale: 1:20,000
Source: National Air Photo Library

Location: Pretty River, Collingwood, ON (yellow dot)
Year: 1995
Scale: 1:50,000
Source: National Air Photo Library



Location: Pretty River, Collingwood, ON (yellow dot)
Year: 2011
Source: Google Earth Pro (GEP)



Location: Pretty River, Collingwood, ON (yellow dot)
Year: 2015
Source: Google Earth Pro (GEP)

Appendix C
Photographic Record

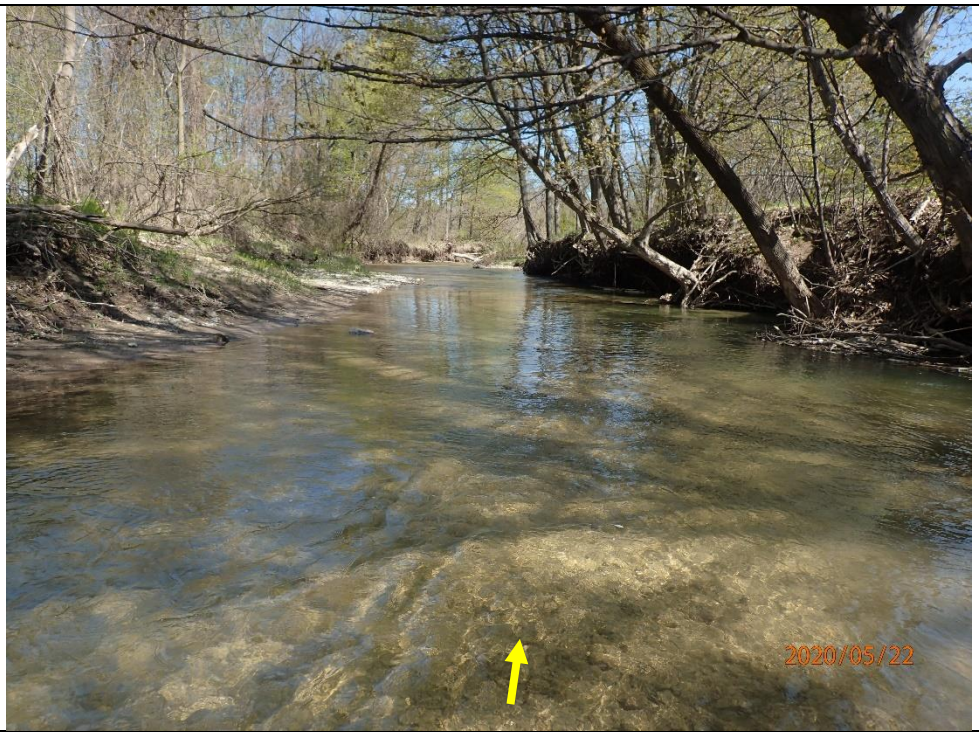
Photo 1 Reach PR-1 – Pretty River, Collingwood, Ontario	
	Photograph taken looking downstream at the upstream extent of the Reach PR-1. Pretty River flows through agricultural lands with a small riparian buffer.
Photo 2 Reach PR-1 – Pretty River, Collingwood, Ontario	
	Photograph taken of the right bank, exposed tree roots were common throughout the reach. This provides evidence of channel widening indicating the stream is in adjustment.

Photo 3 Reach PR-1 – Pretty River, Collingwood, Ontario	 Photograph taken further downstream, leaning and fallen trees were commonly identified along the reach, indicating evidence of channel widening.
Photo 4 Reach PR-1 – Pretty River, Collingwood, Ontario	 Photograph taken of a fresh large sand deposit along the top of low banks. Deposition in the overbank zones was common within the reach providing evidence of aggredation.

Photo 5 Reach PR-1 – Pretty River, Collingwood, Ontario	 The riparian zone was approximately 1 to 4 channel widths and provided fragmented coverage through the system. There was mature (>30 years) tree species within the riparian zone.
Photo 6 Reach PR-1 – Pretty River, Collingwood, Ontario	 Photograph taken looking at the left bank. Large undercuts were common (approximately 1.65 m in depth), this is an indication of erosion leading to channel widening.

Photo 7 Reach PR-1 – Pretty River, Collingwood, Ontario	 Photograph looking downstream, bank stabilization (cobbles and boulders) were present along the outside of meander bends to prevent erosion.
Photo 8 Reach PR-1 – Pretty River, Collingwood, Ontario	 Riffle/pool sequencing was good throughout the reach. Pools had an average depth of approximately 1.5 m. Siltation was identified within the pools indicating aggradation within the channel.

Photo 9 Reach PR-1 – Pretty River, Collingwood, Ontario	 Photograph taken facing downstream. Riffles were composed of coarse embedded materials such as cobbles, gravel and small boulders, providing evidence of aggradation within the channel.
Photo 10 Reach PR-1 – Pretty River, Collingwood, Ontario	 This photograph illustrates a well-vegetated, confined section of the watercourse. Erosion scarring on the base of the channel bank is indicative of widening processes.

Photo 11 Reach PR-1 – Pretty River, Collingwood, Ontario	 Photograph taken of the right bank showing exposed till. The channel was worn into undisturbed overburden / bedrock this is indicative of degradation.
Photo 12 Reach PR-1 – Pretty River, Collingwood, Ontario	 Channel bank material consisted of clay/silt and gravel. The reach was identified as being a "partially-confined" system with some sections of bank exceeding 2 m in height.

Photo 13
Reach PR-1 – Pretty River, Collingwood, Ontario

Photograph taken facing upstream. The channel had unstable slopes and bank failures were observed frequently. Suspended armour layer was visible (circled here) throughout the reach.

Photo 14
Reach PR-1 – Pretty River, Collingwood, Ontario

Bank angles ranged from 60° to 90°. Further, bank erosion was identified through 60% to 100% of the reach.

Photo 15 Reach PR-1 – Pretty River, Collingwood, Ontario	 Photograph looking downstream at the pedestrian bridge crossing. Throughout the reach there was a low density of woody debris present in the channel.
Photo 16 Reach PR-1 – Pretty River, Collingwood, Ontario	 Photograph taken looking upstream at the intermittent tributary flowing from Raglan Street into Pretty River.

Photo 17 Reach PR-1 – Pretty River, Collingwood, Ontario	 Photograph taken facing downstream. Evidence of historical bank protection was visible along the left bank.
Photo 18 Reach PR-1 – Pretty River, Collingwood, Ontario	 Photograph taken at the downstream extent of the reach where a driveway bridge crosses the watercourse. Bankfull width and depth were 11.54 m and 0.76 m, respectively.

Photo 19
Reach PR-1 – Pretty River, Collingwood, Ontario

Photograph looking at the exposed and worn concrete bridge footings associated with the driveway crossing. This provides evidence of degradation, which limits overall channel stability.

Appendix D
Field Assessment Sheets

GEO MORPHIX
Geomorphology Earth Science Observations

General Site Characteristics

Project Code: PN20044

Date:	2020-05-22	**Stream/Reach:**	PR-1
Weather:	SUNNY 22°C	**Location:**	RAGLAN STREET, COLLINGWOOD
Field Staff:	BB AS	**Watershed/Subwatershed:**	PRETTY RIVER

Features

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

Flow Type

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

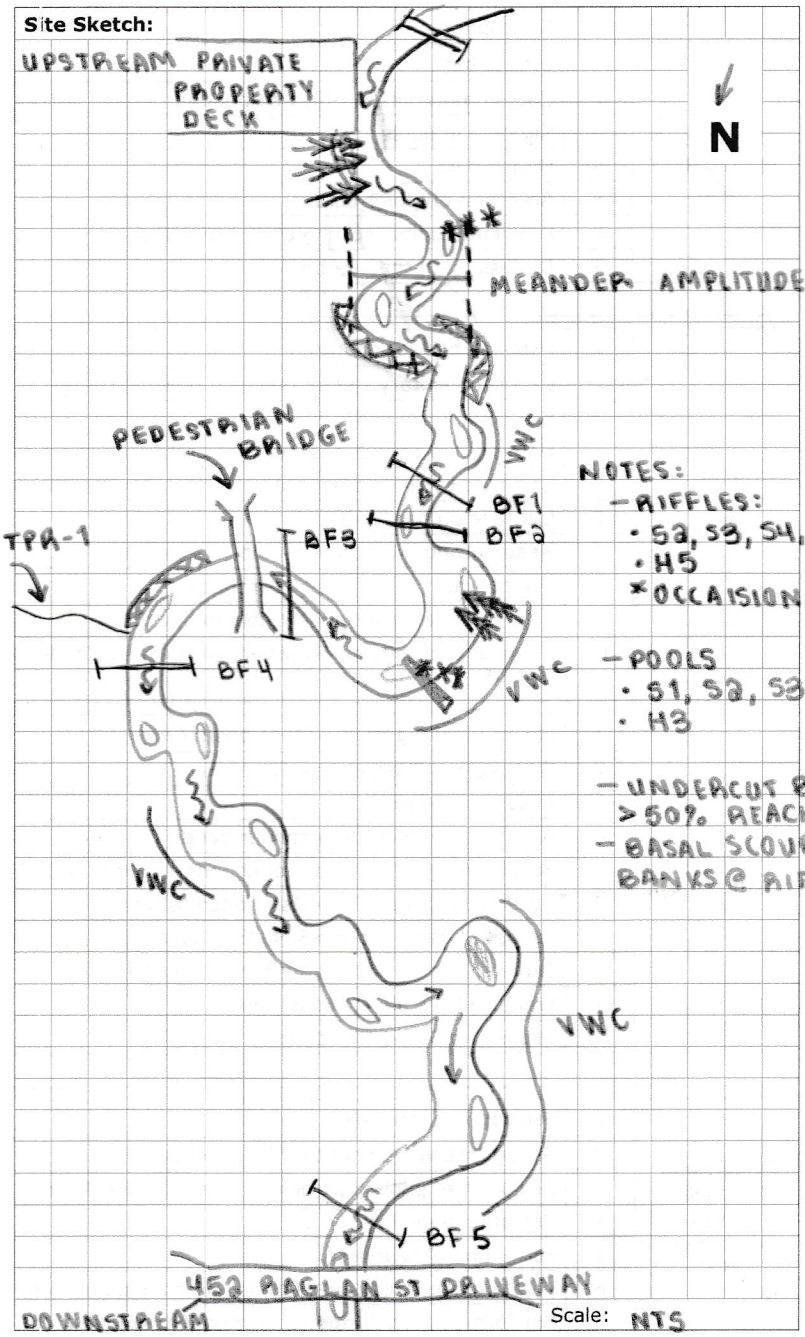
Substrate

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

Other

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

Site Sketch:



Scale: NTS

Additional Notes:

Completed by: BB Checked by: PV + JM

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Rapid Geomorphic Assessment

Project Code: PN30044

Date:	2020-05-22	**Stream/Reach:**	PR-1
Weather:	Sunny 22°C	**Location:**	RAGLAN ST, COLLINGWOOD
Field Staff:	BB AS	**Watershed/Subwatershed:**	PRETTY RIVER

Process	No.	Geomorphic Indicator: Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	4/7
	2	Coarse materials in riffles embedded	✓		
	3	Siltation in pools	✓		
	4	Medial bars		✓	
	5	Accretion on point bars	✓		
	6	Poor longitudinal sorting of bed materials		✓	
	7	Deposition in the overbank zone	✓		
		Sum of indices =	4	3	0.57
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	✓		3/7
	2	Exposed sanitary / storm sewer / pipeline / etc.	N/A		
	3	Elevated storm sewer outfall(s)	N/A		
	4	Undermined gabion baskets / concrete aprons / etc.		✓	
	5	Scour pools downstream of culverts / storm sewer outlets	N/A		
	6	Cut face on bar forms		✓	
	7	Head cutting due to knick point migration		✓	
	8	Terrace cut through older bar material		✓	
	9	Suspended armour layer visible in bank	✓		
	10	Channel worn into undisturbed overburden / bedrock	✓		
		Sum of indices =	3	4	0.43
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	✓		7/8
	2	Occurrence of large organic debris	✓		
	3	Exposed tree roots	✓		
	4	Basal scour on inside meander bends	✓		
	5	Basal scour on both sides of channel through riffle	✓		
	6	Outflanked gabion baskets / concrete walls / etc.		✓	
	7	Length of basal scour >50% through subject reach	✓		
	8	Exposed length of previously buried pipe / cable / etc.	N/A		
	9	Fracture lines along top of bank	✓		
	10	Exposed building foundation	N/A		
		Sum of indices =	7	1	0.88
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	1/7
	2	Single thread channel to multiple channel		✓	
	3	Evolution of pool-riffle form to low bed relief form		✓	
	4	Cut-off channel(s)		✓	
	5	Formation of island(s)		✓	
	6	Thalweg alignment out of phase with meander form	✓		
	7	Bar forms poorly formed / reworked / removed		✓	
		Sum of indices =	1	6	0.14

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.51

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

Completed by: BB Checked by: PV + JM

Rapid Stream Assessment Technique

Project Code: PN30044

Date:	2020-05-22	**Stream/Reach:**	PR-1
Weather:	SUNNY 22°C	**Location:**	RAGLAN ST, COLLINGWOOD
Field Staff:	BB AS	**Watershed/Subwatershed:**	PRETTY RIVER

Evaluation Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☑ 4 ☐ 5	☐ 6 ☐ 7 ☐ 8	☐ 9 ☐ 10 ☐ 11
Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition >81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition <30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• 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

GEO | MORPHIX

Date:	2020-05-22	Reach:	PR-1	Project Code:	PN20044

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. • Velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high amount of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
SEASONAL TEMP. NOT MEASURED	• 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 N/A	• 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) = 26	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Completed by: BB Checked by: PV + JM

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code: PN20044

Date:	2020-05-22	**Stream/Reach:**	PRETTY RIVER / PR-1
Weather:	SUNNY 22°C	**Location:**	RAGLAN ST, COLLINGWOOD
Field Staff:	BB AS	**Watershed/Subwatershed:**	PRETTY RIVER
UTM (Upstream)		**UTM (Downstream)**	

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

Riparian Vegetation

Dominant Type: (Table 6): 1
Species: Trees + Shrubs

Coverage:
- ☐ None
- ☑ Fragmented
- ☐ Continuous

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

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

Encroachment: (Table 7): 2

Aquatic/Instream Vegetation

Type (Table8): 6 | **Coverage of Reach (%):** < 5

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

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

WDJ/50m: 1

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): 3 | **Sinuosity (Degree)** (Table 10): 3 | **Gradient** (Table 11): 2 | **Number of Channels** (Table 12): 1

Entrenchment (Table 13): 3 | **Type of Bank Failure** (Table 14): 2 | **Downs's Classification** (Table 15): E

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

	①	②	③		①	②	③
Bankfull Width (m)	15.95	14.9	11.43	**Wetted Width (m)**	14.65	11.7	8.8
Bankfull Depth (m)	1.72	1.45	1.18	**Wetted Depth (m)**	0.41	0.31	0.47

Riffle/Pool Spacing (m): 18.26 | **% Riffles:** 40 | **% Pools:** 30 | **Meander Amplitude:** 22m *

Pool Depth (m): 1.5-2.0 | **Riffle Length (m):** 12.5 | **Undercuts (m):** 1.65

Velocity (m/s): 0.50 | 0.23 | 0.20 — Wiffle ball / ADV / Estimated

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

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

Comments: SUBPAVEMENT IS SILTY TILL → VARVING OBSERVED

Notes: * MEANDER AMPLITUDE MEASUREMENT FOR ONE SMALLER MEANDER US (SEE SKETCH) NOT ENTIRE REACH

① RIFFLE
- UNDERCUT RB W/ LEANING TREES
- YOUNG & OLD EXPOSED TREE ROOTS
- BAR ON LB - VEGETATED BEGINS

② RIFFLE
- BASAL SCOUR BOTH BANKS
- EXPOSED YOUNG TREE ROOTS
- VWC ON LB
- END OF VEGETATED BAR LB

Completed by: BB | Checked by: PV + JM

③ PEDESTRIAN BRIDGE RUN
- BASAL SCOUR BOTH BANKS

TOB W = 14.40 m
D = 3.00 m

④ DS-MID M.BEND
BFW = 10.70 m
D = 0.88 m
WW = 10.08 m
D = 0.67 m

GENERAL OBSERVATIONS

- COARSE MATERIALS IN RIFFLES EMBEDDED
- POINT BAR MATERIALS MODERATE LONGITUDINAL SORTING
- BASAL SCOUR BOTH BANKS THROUGH RIFFLE
- LEANING TREES
- EXPOSED TREE ROOTS
- THALWEG NOT IN PHASE WITH MEANDER BENDS
- BANANA SEDIMENT STREAM BEND MARKS ABSENT → RIPPLES
- BAR ON OUTSIDE OF MEANDER BEND
  FOLLOWED BY DEEP POOL ~ 1.5 - 2.0 m ESTIMATED
- BANK HEIGHTS INCREASING DOWNSTREAM

* PEDESTRIAN BRIDGE

- CROSSING @ RUN RIGHT BEFORE (US) LARGEST MEANDER
- RB UNDERCUT @ TOP OF SLOPE / BANK
- BASAL SCOUR BOTH BANKS
- BRIDGE CONSTRUCTION - WOOD FOOTINGS
  METAL BAR 100% MATERIALS
  ~ 1.00 m WIDTH
- FOOTINGS ~ 2.00 m OUT FROM BANKS

* SMALL TRIBUTARY DS RAGLAN ST

- INTERMITTENT
- RIFFLE POOL DEVELOPMENT
- RIFFLES SMALL COBBLE
- POOLS SAND
- HIGH GRADIENT
- LARGE BOULDERS US @ BEND
- WIDENS DS TOWARDS CONFLUENCE

→ SEE PICTURES

DOWNSTREAM HALF OF REACH

- 'I' TRUNKED W/ LEANING TREES
  MID LARGE MEANDER
- LARGER BED MATERIAL @ DS
  HALF OF REACH
  ↳ ATTACHED ALGAE
- VWS COMMON AROUND BENDS
- BANK HEIGHTS DOUBLE
- CRIB WALL STRUCTURE / EROSION
  CONTROL

BANKFULL (5)

- US DRIVEWAY BRIDGE
- BF W = 11.54 m
  D = 0.76 m
  WW = 9.07 m
  D = 0.38 m

  V = 0.38 m/s

Appendix E
Meander Migration Analysis

Migration Measurement Locations

Pretty River

452 Raglan Street, Collingwood

GEO MORPHIX™

DRIVEWAY

A

B

C

D

E

F

452 Raglan Street

Pretty River

Legend

A — Location of migration measurements*

* direction of arrow indicates (+) direction of erosion

Watercourse in:

- 2016
- 2012
- 2008
- 2002
- 1973

Contour (50 cm)

Property boundary

Imagery: Simcoe County, 2016. Watercourse: GEO Morphix Ltd., 2020.
Contour: JoeTOPO Surveys and CADD Inc., 2017 and 2020.
Property boundary: Zubek, Emo, Patten & Thomsen Limited, 2020.