Marlborough Creek
Meander Belt Width Delineation

6038 Ottawa Street
City of Ottawa (Richmond), Ontario

Prepared for:
David Schaeffer Engineering Ltd.
120 Iber Road, Unit 103
Stittsville, ON K2S 1E9

March 10, 2025

GEO Morphix Project No. 25011

Ver.	Purpose/Change	Authored by	Approved by	Date
1.0	Address Agency comments on February 26, 2021 Meander Belt Width Assessment Letter	Jan Franssen, Ph.D. Kat Woodrow, M.Sc.	Paul Villard, Ph.D., P.Geo	March 10, 2025

Disclaimer

Table of Contents

Appendices

1 Introduction

GEO Morphix Ltd. was retained to complete a meander belt width assessment for Marlborough Creek to support the proposed development at 6038 Ottawa Street in the City of Ottawa (Richmond), Ontario. The proposed development includes residential, commercial, and natural land uses, as well as associated road networks. The proposed development is approximately 67 hectares in area. Stormwater management facilities are proposed on site, which will direct flows to the subject watercourse. Given the proposed development is adjacent to the main branch of Marlborough Creek, a meander belt width assessment is required to delineate the erosion hazard and channel migration limit.

A preliminary Fluvial Geomorphology Report was submitted on February 26, 2021, and included a review of background reports and mapping, watercourse reach delineation, a review of recent and historical aerial photographs, and delineation of a preliminary meander belt width. The preliminary report (GEO Morphix Ltd., 2021) was based on a desktop assessment only. In April 2021, field reconnaissance was completed to confirm existing site conditions and finalize the geomorphic assessment. The field investigation verified our findings from the desktop assessment and confirmed there were no changes to the initial findings. This report provides a complete summary of the geomorphic assessment.

The following activities were completed to address the City of Ottawa’s concerns related to natural hazards, and identify the meander belt width associated with the subject property:

- 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
- Review recent and historical aerial photographs of the site to understand historical changes in channel form and function
- Delineate watercourse reaches based on a desktop assessment and confirm reach delineation through geomorphic field observations
- Conduct field reconnaissance using standard, industry-accepted tools such as the rapid geomorphic assessment (RGA) and rapid stream assessment technique (RSAT) to evaluate existing instream and riparian conditions (i.e., evidence of ongoing channel processes, active erosion/deposition, or potential channel instability)
- Delineate limits of the meander belt width/erosion hazard on a reach basis using the results of the desktop and field assessments

2 Background Review and Desktop Assessment

2.1 Background Information

The subject property is within the Rideau Valley watershed, and more specifically, the Jock River subwatershed (Richmond catchment). The Jock River-Richmond subwatershed drains an area of approximately 31 square kilometers and occupies 60 km of channel (including both Jock River and tributaries) (RVCA, 2016). According to the Rideau Valley Conservation Authority (RVCA), the majority of the Jock River (Richmond system) is in generally good condition. Further, most of the system along the Jock River main branch and Marlborough Creek has low erosion levels and an established forested riparian corridor (RVCA, 2016). Specific to riparian vegetation, Marlborough Creek has a riparian buffer of greater than 30 meters along 99% of both the right and left banks (RVCA, 2016).

2.2 Surficial Geology and Physiology

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.

Marlborough Creek within the subject property is located in the Clay Plains physiographic region of Ontario (Chapman and Putnam, 2007). The surficial geology associated with Marlborough Creek largely contributes to its planform and stability over time. The subject lands are characterized at surface as fine-textured (clay, silt) glaciomarine deposits deposited in and off-shore environment of the Champlain Sea during the Wisconsinan Glaciation (OGS, 2010). Surficial deposits and substrate within the subject property include silt and clay, minor sand, and gravel (OGS, 2010). Upstream of the subject lands, Marlborough Creek flows through lands characterized by Paleozoic bedrock and thin deposits of glacial till (OGS, 2010).

Fine-textured sediments deposited within off-shore glacio-marine or marine environments, like those observed at surface within the subject lands, may be subject to sensitivity and erosion due to high pore pressure and low shear strength when disturbed (Mayne, Cargill & Miller, 2019; Brooks, 2019). Disruptions, such as erosional slope failure, construction activities, or seismic activity, may trigger further rotational slope failures. While slope failures are well documented within Eastern Ontario and The City of Ottawa (Brooks, 2019), no such failures have been documented along Marlborough Creek or the collecting Jock River, nor were any slump scars identified during the desktop review of LiDAR data for the area. Additionally, Marlborough Creek occurs within a generally unconfined system and has limited sinuosity, further limiting the likelihood of disruptions along the outside of meander bends.

For reference, a map of local surficial geology is provided in **Appendix A.**

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 1954 to 2017 were retrieved to complete the historical assessment and inform the meander belt width delineation. Specifically, aerial photographs from 1954 (McMaster University), 1976, 1999 (City of Ottawa), and satellite imagery from 2017 (Google Earth Pro) were reviewed. All historical aerial photographs are provided in **Appendix B** for reference.

In 1954, Marlborough Creek was identified as a single-thread channel with a meandering planform and limited sinuosity. The subject lands were occupied for agricultural use with few residential dwellings established along Ottawa Street. A woodlot was present at the furthest downstream extent of the watercourse. The Canada National Railway (CNR) ran through the northwest extent of the subject property and crossed Marlborough Creek downstream from the subject property. A limited riparian buffer was observed surrounding Marlborough Creek, which consisted of sparse tree/shrub species.

By 1976, the riparian buffer associated with Marlborough Creek was more extensive, with established tree species throughout the reach and clustered around the crossings at McBean Street and Ottawa Street. Channel planform was generally unchanged; however, the development of geomorphic units was more pronounced. Channel geometry was reduced at the crossing with McBean Street but increased moving downstream into a pool feature. This pattern was repeated moving downstream through the subject property. A crossing over Marlborough Creek was constructed through private lands, which was likely large enough to facilitate small vehicles and pedestrians.

There were no changes in land use or channel planform by 1999. However, the development of geomorphic units and the fluctuation in channel geometry moving downstream became more evident. Particularly through the downstream extent of Marlborough Creek within the subject property, channel geometry was consistently widened. This may have been attributed to the time of year the photograph was taken (i.e., following snowmelt or a high rainfall event). The riparian buffer was more established through the system, with very few banks exposed with limited vegetation.

In 2017, a similar sized crossing was constructed approximately 90 m downstream from the existing bridge. There were no changes in land use or channel planform, and riparian vegetation was more established. The sequence of geomorphic units (i.e., riffles and pools) was less defined, however, this may be due to the time of year the photograph was taken (summer).

Given the limited changes in channel planform over time, the development of geomorphic units, the extent of riparian vegetation, and the underlying geology controlling the form and function of Marlborough Creek, it was determined that the system is generally stable.

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 delineated based on changes in the following:

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

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

Based on a desktop assessment, there was limited change in channel geometry, planform, or riparian cover associated with Marlborough Creek within the subject property (between McBean Street and Ottawa Street). Two (2) drainage features contributed minor flows to the system but did not impact the geomorphological or hydrological characteristics of Marlborough Creek itself. As such, one (1) singular reach was delineated as **MC1**. No additional sub-reaches within **MC1** were identified during field verification. Reach delineation is graphically defined in **Appendix C.** General Reach Observations

Field investigations were completed on April 20, 2021, 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 D**. Field sheets, including those completed for rapid assessments, are provided in **Appendix E**. The conditions observed along **Reach MC1** during the April 2021 field visit confirm the desktop reach delineation results.

Reach MC1 is located along Marlborough Creek, a tributary to the Jock River. McBean Street, the western boundary of the subject lands, marks the upstream extent of **Reach MC1**, while Ottawa Street to the north marks the downstream extent. Land use within the subject lands was diverse and included cultivated and uncultivated agricultural land, residential properties, and commercial use. A rail line runs southwest to northeast across the subject property directly north of the reach. Two private, culverted crossings were constructed about 90 metres apart midway through the reach; these likely connect the commercial property north of the reach with apparent storage on the property directly south.

Downstream of the crossings, a large pond located on the subject property was connected to the reach via two drainage features.

Reach MC1 was mostly unconfined, but several constructed berms flanking its floodplain (e.g., between the two culverted crossings on private property, upstream of the Ottawa Street crossing), create a localized area of partial confinement. Generally, there was approximately 2 meters rise between bed of the channel and the adjacent tableland, connected by moderately sloped banks and a well-connected floodplain. The channel was slightly sinuous (1.06-1.30) within a linear floodplain, with an average slope through the reach of about 0.133 percent. The definition of the channel through **Reach MC1** was variable. Where defined, the average channel width is approximately 2.5 metres and encroached upon by riparian vegetation, with occasional riffle features and vegetated bars and islands. Pool features, averaging approximately 11.5 metres width, were observed downstream of the McBean Street crossing and both upstream and downstream of the two private crossings located mid-reach. Bed substrate was moderately well sorted, with riffles consisting of gravel and cobble sized clasts, and pool substrate composed of clay, silt, sand, and gravel-sized clasts; larger cobble and boulder clasts occurred along the floodplain but appeared to have been placed through human activity (i.e., removing stones to prepare land for cultivation). Banks were entirely covered by established and stable riparian vegetation.

Wetland submergent and emergent vegetation occurred continuously along the floodplain of the reach, occasionally spanning the channel and causing it to become undefined. Water quality was observed as low levels of turbidity and limited colour and odour. Beyond the wetland-occupied floodplain, riparian vegetation become less continuous as they transition to established trees (5-30 years) and grass species.

3.2 Rapid Geomorphological Assessment Tools

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 D**. Field sheets, including those completed for RGA and RSAT assessments, are provided in **Appendix E**.

Reach MC1 was assigned an RGA score of 0.14, indicating the reach was in regime. The dominant geomorphological indicator was evidence of widening due to the observations of fallen and leaning trees and occurrence of large organic debris. However, it is important to note that falling and leaning trees were likely attributed to human modification adjacent to the watercourse rather than from active channel processes. **Reach MC1** had an RSAT score of 30, or "good". There was one limiting factor, riparian habitat conditions, that was attributed to the narrow riparian area outside of the well-connected flood plain, which was with predominantly wooded vegetation (i.e., trees)and fragmented in some areas.

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.

When a meandering channel is 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).

In unconfined systems, the limit of the erosion hazard and migration potential can 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). Both the meander belt width and amplitude quantify the lateral extent of a river's occupation on the floodplain (TRCA, 2004).

Given that Marlborough Creek is a naturally unconfined system, recent aerial photographs from Google Earth Pro were reviewed and the amplitude of two meander bends were measured. This measurement was used to delineate the meander belt width extent. Meander amplitudes were measured from the largest extent of the historical to most recent meanders. As such, the meander amplitude measurement accounts for both potential migration over the historical record (i.e., 63 years) and the largest apparent expression of the channel. Meander amplitudes ranged from 39.2 m to 60.5 m. Further, a 10% factor of safety was applied to the largest meander amplitude (60.5 m) to account for changes in creek morphology over time. With a 10% factor of safety, the calculated meander belt width is 67 m. The meander belt width delineation is graphically presented in **Appendix F.**

5 Summary and Recommendations

Marlborough Creek flows through a generally unconfined valley system within the northwestern extent of the subject property. One (1) reach was delineated as part of the fluvial geomorphological assessment and meander belt width analysis. A meander belt width assessment was completed via desktop analysis, and a technical memo summarizing the preliminary findings was submitted on February 26, 2021.

The desktop analysis utilized, in part, historical aerial photographs to determine that land use, channel planform, and riparian vegetation had not undergone substantial changes between 1954 and 2017. During the time period between 1954 and 2017, geomorphic units (i.e., riffles, pools) were developed and the riparian buffer zone became more established. Given the surficial geology and the little change to land use in the area, it is anticipated that the watercourse is largely controlled by the underlying bedrock. The desktop analysis suggests that Marlborough Creek is generally stable and will not likely experience significant changes in channel form or function in the future.

A rapid geomorphological assessment was conducted during a field investigation on April 20, 2021. **Reach MC-1** was confirmed as a single-thread channel with an established riffle-pool sequence. Channel substrate was characterized by clay/silt and sand along the banks, with the addition of gravel and cobble sized clasts along the bed (riffles) and sporadic boulder sized clasts throughout the reach. Additional boulder sized clasts were also observed in the floodplain of the reach. A fragmented riparian buffer of established tree and grass species occurs about 1 to 4 times the channel width on either side of the channel throughout the reach. Emergent aquatic vegetation also contributes to high encroachment (~80%) along **Reach MC-1**. **Reach MC-1** was therefore classified as stable with limited evidence of channel adjustment.

To determine the meander belt width (i.e., erosion hazard) extent for the creek, the amplitude of two (2) meander bends were measured along Marlborough Creek. Meander amplitudes ranged between 39.2 and 60.5 metres. A 10% safety factor was applied to the largest meander amplitude (60.5 m) to account for changes to creek morphology over time. With this 10% factor of safety, the calculated meander belt width is 67 m.

Given the results of the rapid assessment, including no evidence of erosion, cohesive substrate characteristics along channel banks and bedrock outcrops contributing to the overall stability of the watercourse, a meander belt width of 67 metres is appropriate and conservative in nature. A map presenting the final meander belt width delineation is provided in **Appendix F.**

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

Respectfully submitted,

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

Kat Woodrow, M.Sc.
Manager of Watershed Studies

6 References

Brooks, G.R. 2019. Sensitive clay landslide inventory map and database for Ottawa, Ontario; Geological Survey of Canada, Open File No. 8600.

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

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

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

Leopold, L.B., Wolman, M.G., and J.P. Miller. 1964. Fluvial Processes in Geomorphology. New York: Dover Publications Inc. 522 pp.

Mayne, P. W., Cargill, E., & Miller, B. 2019. Geotechnical characteristics of sensitive Leda clay at Canada test site in Glouchester, Ontario. AIMS Geosciences, 5(3), 390–114.

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

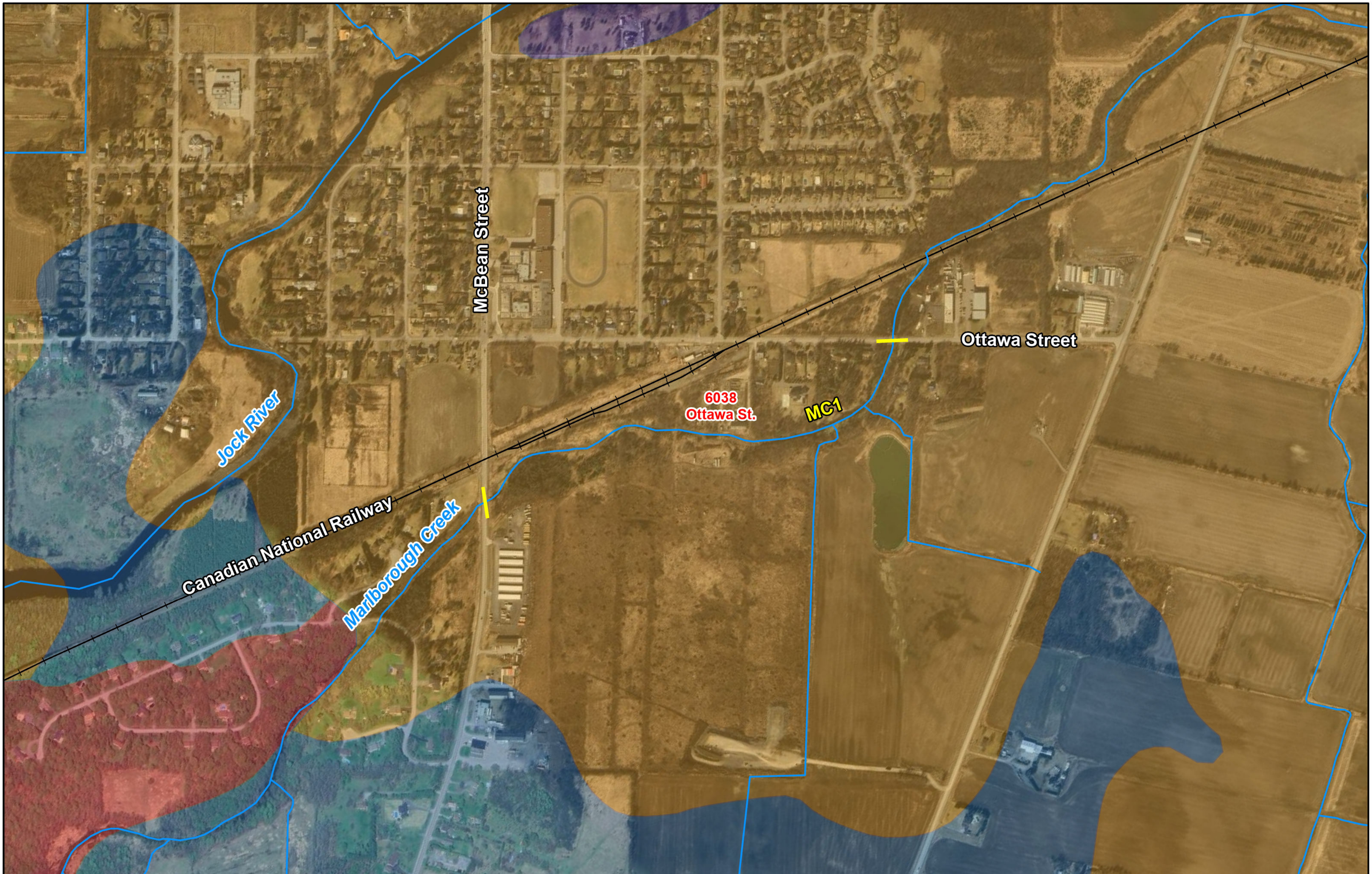
Montgomery, D.R. and J.M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin, 109 (5): 596-611.

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

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

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

Appendix A:
Surficial Geology Mapping



Legend

Reach Break and ID
Railway
Watercourse

Surficial Geology

10a,Offshore marine deposits (clay, silt)
19,Alluvial deposits (clay,silt,sand)
3,Bedrock (limestone, dolomite)
5b,Till (sandy silt diamicton)

Surficial Geology

Marlborough Creek

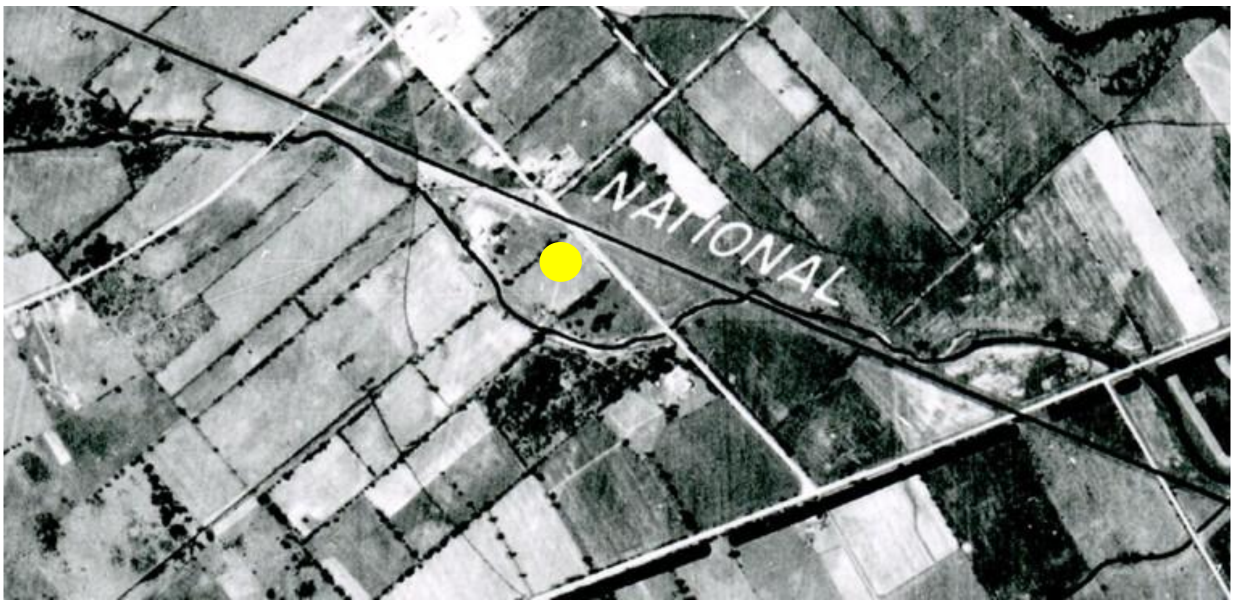
6038 Ottawa Street
Richmond, Ontario

GEO MORPHIX™

0 55 110 220
Metres

Hillshade: MNRF, 2020.
Reach Break and ID: GEO Morphix Ltd., 2021.
0.5 m Contour: DSEL, 2021. Surficial Geology,
Watercourse and Railway: MNRF, 2024/2021. PN25011
Printed: March 2025. . Drawn by: K.W., L.D., G.U.

Appendix B:
Historical Aerial Imagery



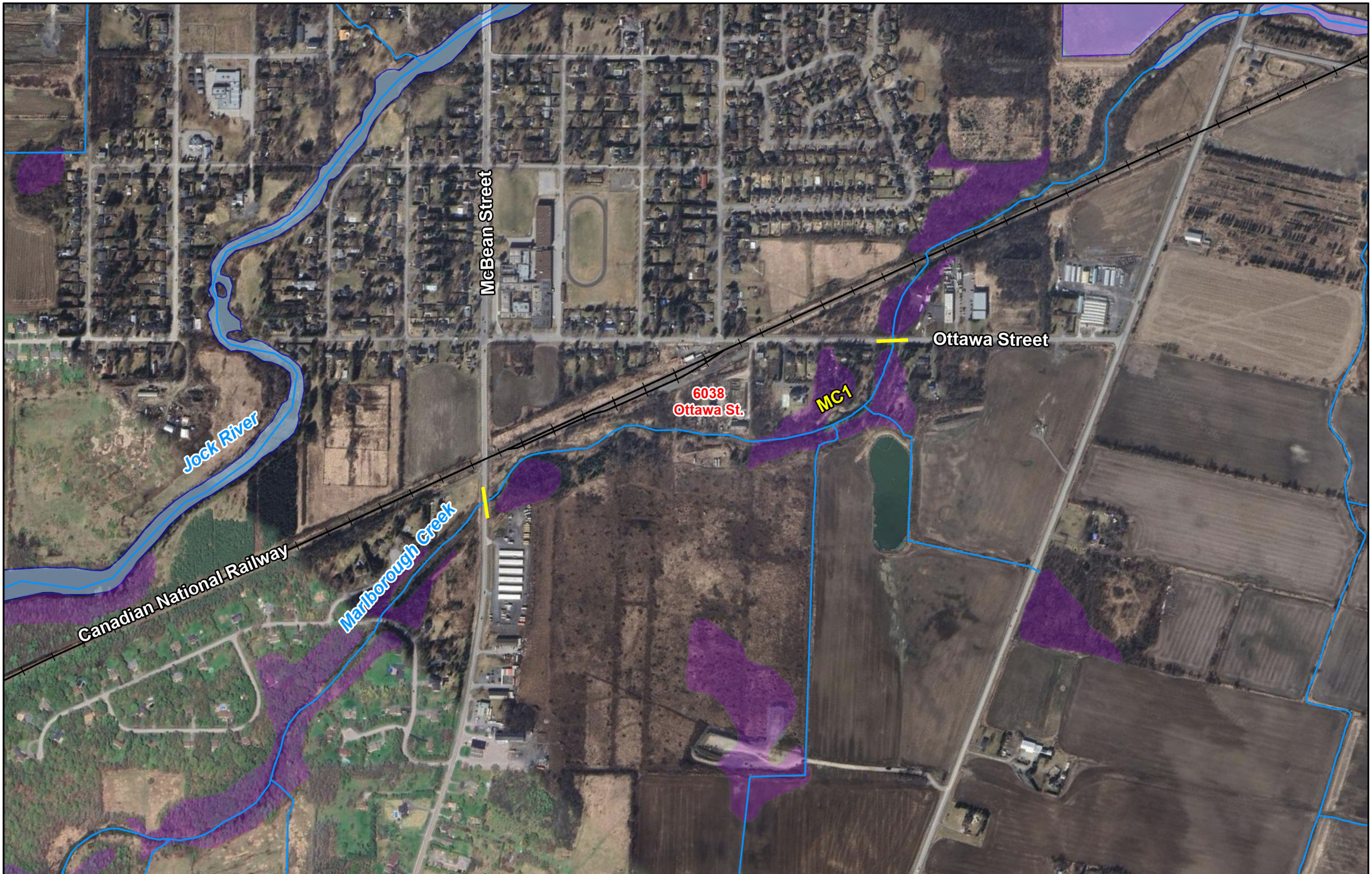
Location: 6038 Ottawa Street, Ottawa (Richmond), ON (yellow circle)
Year: 1954
Scale: 63,360
Source: McMaster University (Ontario Department of Lands and Forests)

Location: 6038 Ottawa Street, Ottawa (Richmond), ON (yellow circle)
Year: 1976
Source: City of Ottawa

Location: 6038 Ottawa Street, Ottawa (Richmond), ON (yellow circle)
Year: 1999
Source: City of Ottawa

Location: 6038 Ottawa Street, Ottawa (Richmond), ON (yellow circle)
Year: 2017
Source: Google Earth Pro

Appendix C:
Study Area and Reach Delineation Mapping



Legend

- Reach Break and ID (MC1)
- Railway
- Watercourse
- Waterbody
- Evaluated Wetland
- Not Evaluated Wetland

Study Area

Marlborough Creek

6038 Ottawa Street
Richmond, Ontario

GEO MORPHIX™

0 55 110 220
Metres

Imagery: Google Earth Pro, 2024.
Reach Break and ID: GEO Morphix Ltd., 2021.
0.5 m Contour: DSEL, 2021. Wetland, Waterbody,
Watercourse and Railway: MNRF, 2024/2021.
Printed: March 2025. PN25011. Drawn by: K.W., L.D., G.U.

Appendix D:
Field Photographs

Photo 1
Marlborough Creek (MC1) – Richmond, Ontario

Photograph looking downstream towards the Ottawa Street bridge crossing (the furthest upstream extent of MC1). The riparian corridor was less than four times bankfull width and consisted of grasses and trees.

Photo 2
Marlborough Creek (MC1) – Richmond, Ontario

Photograph looking upstream towards Marlborough Creek. Channel banks were occupied by grasses and aquatic plant species.

Photo 3 Marlborough Creek (MC1) – Richmond, Ontario	 Photograph looking towards the downstream extent of MC1. Emergent aquatic plant species occupied greater than 80% of the channel.
Photo 4 Marlborough Creek (MC1) – Richmond, Ontario	 Photograph looking towards the right bank (facing downstream). Bank materials consisted of clay, silt, with minor sand. Channel banks were occupied by vegetation and there was no evidence of erosion.

Photo 5 Marlborough Creek (MC1) – Richmond, Ontario		
	The channel bed was occupied by gravel, small cobble, and large cobble. Further, bed substrates were underlain by bedrock in some locations.	
Photo 6 Marlborough Creek (MC1) – Richmond, Ontario		
	Photograph looking downstream at a riffle. Riffle substrate consisted of small and large boulders. The reach was occupied by 75% large pools and 25% riffles.	

Photo 7 Marlborough Creek (MC1) – Richmond, Ontario		
	Photograph looking upstream. There was heavy encroachment of vegetation into the channel, as well as leaning trees along the channel banks.	
Photo 8 Marlborough Creek (MC1) – Richmond, Ontario		
	A large berm was constructed along the right bank (facing downstream) of MC1. The watercourse was unconfined in all areas besides the location of the berm.	

Photo	
Photo 9 Marlborough Creek (MC1) – Richmond, Ontario	 Photograph looking downstream towards a single-lane crossing. Four large corrugated steep pipe culverts conveyed flows beneath the crossing.
Photo 10 Marlborough Creek (MC1) – Richmond, Ontario	 Geomorphic units were established through the reach and consisted of large, deep pools, and riffles. There was good connectivity between the watercourse and the floodplain.

Photo 11 Marlborough Creek (MC1) – Richmond, Ontario	 Clusters of large boulders and exposed bedrock were present along channel banks and within the floodplain.
Photo 12 Marlborough Creek (MC1) – Richmond, Ontario	 Photograph looking upstream towards the McBean Street bridge. A large pool with emergent aquatic species occupied the channel in this location, with good connectivity to the floodplain.

Appendix E:
Field Observations

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics **Project Code:** PN21012

Date:	April 20, 2021	**Stream/Reach:**	Marlborough Creek/MC-1
Weather:	Overcast, 8 degrees C	**Location:**	Richmond, Ontario
Field Staff:	JM	**Watershed/Subwatershed:**	Jock River
UTM (Upstream)	435209.70 m E, 5003650.78 m N	**UTM (Downstream)**	435599.88 m E, 5004339.76 m N

Land Use (Table 1): 2/7 | **Valley Type** (Table 2): 3 | **Channel Type** (Table 3): 12 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | [ ] Groundwater | Evidence: N/A

Riparian Vegetation

Dominant Type: (Table 6) 1/3
Species: Cattails

Coverage: [ ] None [x] Fragmented [ ] Continuous

Channel widths: [x] 1-4 [ ] 4-10 [ ] > 10

Age Class (yrs): [ ] Immature (<5) [x] Established (5-30) [ ] Mature (>30)

Encroachment: (Table 7) 4

Aquatic/Instream Vegetation

Type (Table8) 1 | Coverage of Reach (%) 80

Woody Debris: [x] Present in Cutbank [ ] Present in Channel [ ] Not Present

Density of WD: [x] Low [ ] Moderate [ ] High

WDJ/50m: 1

Water Quality

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

Channel Characteristics

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

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

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	[ ]	[ ]	[x]	[x]	[ ]	[ ]	[ ]
Pool Substrate	[x]	[x]	[x]	[ ]	[ ]	[ ]	[ ]
Bank Material	[x]	[x]	[ ]	[ ]	[x]	[ ]	[ ]

Bankfull Width (m) 10.75 | 7.53 | 4.0 — **Wetted Width (m)** - | - | -
Estimated using laser distance measurer
Bankfull Depth (m) - | - | - — **Wetted Depth (m)** - | - | -

Riffle/Pool Spacing (m) 20 | **% Riffles:** 25 | **% Pools:** 75 | **Meander Amplitude:** Not measured in field

Pool Depth (m) - | **Riffle Length (m)** 1-2 | **Undercuts (m)** N/A | **Comments:**

Velocity (m/s) Not measured | **Wiffle ball / ADV / Estimated**

Bank Angle: [x] 0 – 30 [x] 30 – 60 [ ] 60 – 90 [ ] Undercut

Bank Erosion: [x] < 5% [ ] 5 – 30% [ ] 30 – 60% [ ] 60 – 100%

Notes: No evidence of erosion
Large boulders within floodplain

Additional bankfull width measurements:
7.5 m
10 m
2.3 m
> 10 m

Completed by: JM   Checked by: KW

GEO | MORPHIX
Geomorphology Earth Science Observations

General Site Characteristics **Project Code:** PN21012

Date:	April 20, 2021	**Stream/Reach:**	Marlborough Creek (MC1)
Weather:	Overcast, 8°C	**Location:**	Richmond, Ontario
Field Staff:	JM	**Watershed/Subwatershed:**	Jock 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: N/A

Additional Notes: → [V] = Stand of dormant wild parsnip/hogweed
→ Several large boulders within channel, along banks, and within the floodplain
→ Good connectivity between channel + floodplain

Completed by: JM Checked by: KW

GEO | MORPHIX

Rapid Geomorphic Assessment — Project Code: PN21012

Date:	April 20, 2021	Stream/Reach:	Marlborough Creek/MC-1
Weather:	Overcast, 8 degrees C	Watershed/Subwatershed:	Jock River
Field Staff:	JM	Location:	Richmond, Ontario

Process	Geomorphological Indicator No.	Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		X	1/7
	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 =	1	6	0.14
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		X	0/7
	2	Exposed sanitary / storm sewer / pipeline / etc.	N/A		
	3	Elevated storm sewer outfall(s)	N/A		
	4	Undermined gabion baskets / concrete aprons / etc.	N/A		
	5	Scour pools downstream of culverts / storm sewer outlets		X	
	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 =	0	7	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	X		2/7
	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.	N/A		
	7	Length of basal scour >50% through subject reach		X	
	8	Exposed length of previously buried pipe / cable / etc.	N/A		
	9	Fracture lines along top of bank		X	
	10	Exposed building foundation	N/A		
		Sum of indices =	2	5	0.28
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		X	
	7	Bar forms poorly formed / reworked / removed		X	
		Sum of indices =	1	6	0.14

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: JM Checked by: KW

Rapid Stream Assessment Technique **Project Code:** PN21012

Date:	April 20, 2021	**Stream/Reach:**	Marlborough Creek/MC-1
Weather:	Overcast, 8 degrees C	**Location:**	Richmond, Ontario
Field Staff:	JM	**Watershed/Subwatershed:**	Jock 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**

Evaluation Category	**Poor**	**Fair**	**Good**	**Excellent**
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**

Date:	April 20, 2021	**Reach:**	MC-1	**Project Code:**	PN21012

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

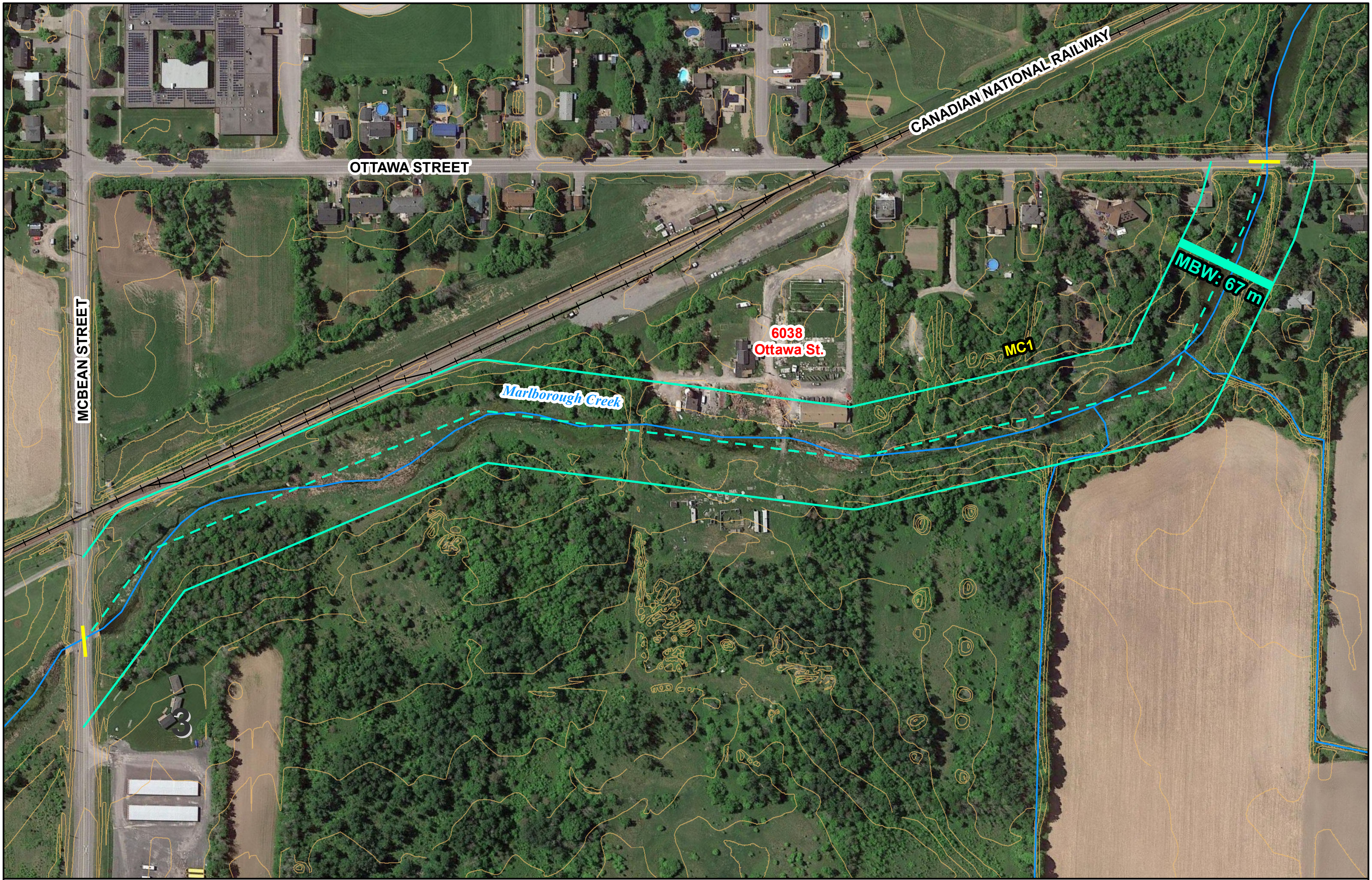
Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 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) = 30	**Poor (<13)**	**Fair (13-24)**	**Good (25-34)** X	**Excellent (>35)**

Completed by: JM Checked by: KW

Appendix F:
Meander Belt Width Delineation Mapping



Legend

- MC1 Reach Break and Label
- Watercourse Central Tendency
- Meander Belt Width
- Watercourse
- Railway
- 0.5 m Contour

Meander Belt Width

Marlborough Creek

6038 Ottawa Street
Richmond, Ontario

GEO MORPHIX™

0 25 50 100
Metres

Imagery: Google Earth Pro, 2018.
Reach Break and Label, MBW, and Central Tendency: GEO Morphix Ltd., 2021.
0.5 m Contour: DSEL, 2021.
Watercourse and Railway: MNRF, 2021.
Printed: February 2021. PN21012. Drawn by: M.H., J.M., P.V.