Appendix C Fluvial Geomorphic Assessment

Version 2.0
September 15, 2022 Matrix 24316-531

Sam Neale
MORRISON HERSHFIELD LIMITED
Suite 300, 125 Commerce Valley Dr. W
Markham, ON L3T 7W4

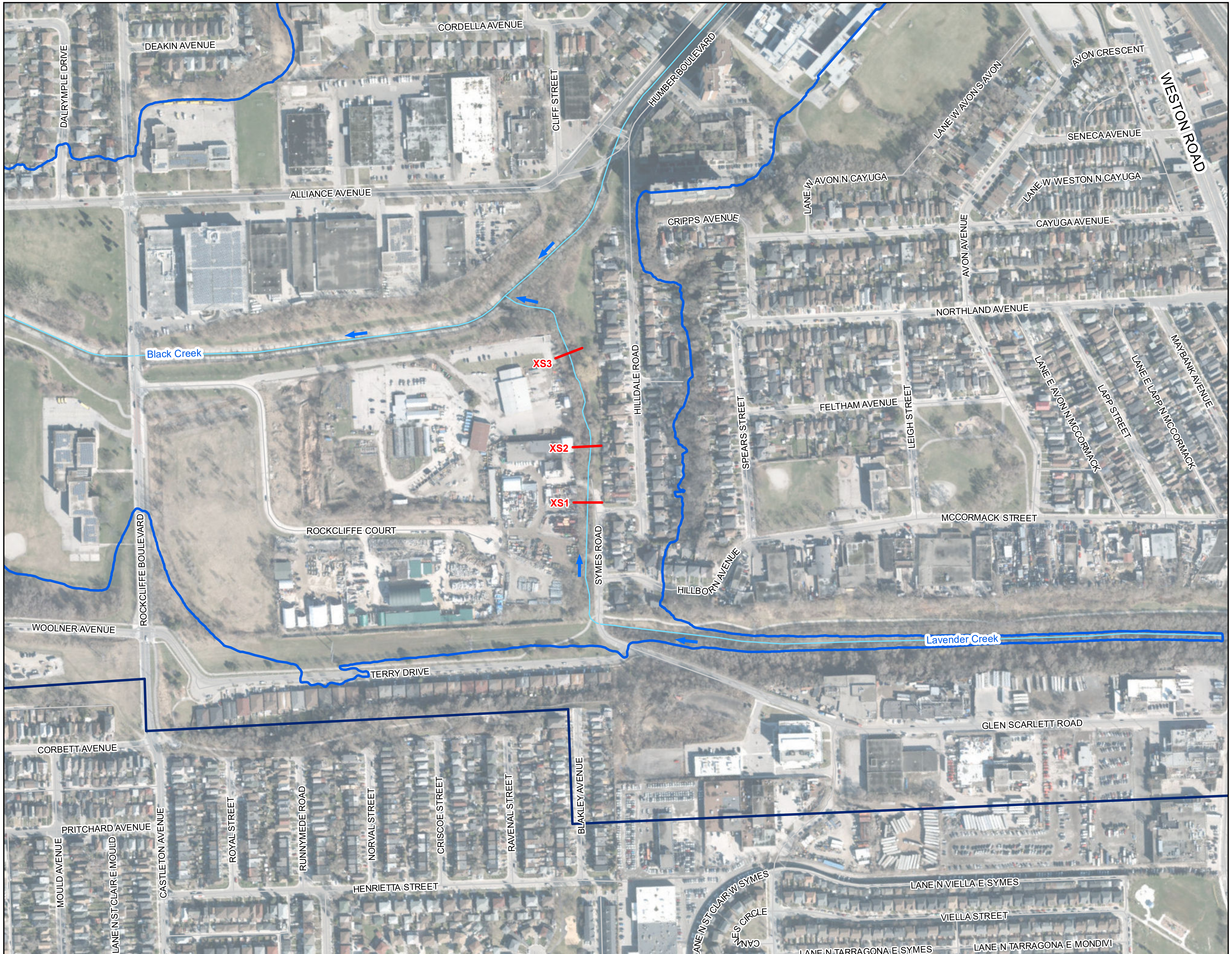
Subject: Lavender Creek Fluvial Geomorphology Assessment

Dear Sam Neale:

Two watercourses are located within the Rockcliffe Riverine Flood Mitigation Environmental Assessment study area: Black Creek and Lavender Creek. Both are within the Humber River watershed. The majority of channel within the scoped study area consists of engineered concrete channels, with the exception of Lavender Creek downstream of Symes Road. An existing conditions geomorphological assessment of Lavender Creek has been completed to identify channel characteristics, in order to evaluate future potential design alternatives that will aid in flood mitigation at Lavender Creek.

Lavender Creek originates west of Weston Road and extends approximately 1,200 m before discharging into Black Creek, draining an area of 5.79 km^2. Currently, Lavender Creek exhibits a very straight planform, flowing east to west from Weston Road to Symes Road in a concrete channel. The channel makes a sharp 90-degree bend at the Symes Road crossing, flowing north-westerly to Black Creek. The 400 m reach of Lavender Creek, downstream of Symes Road to the confluence at Black Creek, is currently the only alluvial channel in the study area not engineered with concrete; although, it is still highly modified and confined within a narrow riparian corridor. As it is not fully a natural channel, this section will be referred to as the alluvial reach of Lavender Creek.

A geomorphic field investigation was undertaken for the alluvial reach of Lavender Creek on December 3, 2020, to characterize channel parameters, substrate, and document indicators of instream erosion (Figure 1). Field work was limited to the segment of channel downstream of Symes Road, where the watercourse is not lined with concrete but consists of native alluvial materials, variable fill, and localized rock and concrete debris. The following geomorphic assessment includes a) a rapid field assessment (Rapid Geomorphic Assessment [RGA]/Rapid Stream Assessment Technique [RSAT]), and b) bankfull hydraulics and instream erosion threshold analyses. Lavender Creek upstream of Symes Road was not assessed as it is engineered with concrete-lined bed and banks.



Scoped EA Study Area
Geomorphic Cross-section Location
TRCA Regulatory Floodline
Watercourse
Road
Flow Direction

0 20 40 80 120 160
Meters

1:4,000

Datum: NAD 1983 UTM Zone 17N North American 1983

Sources:
Toronto and Region Conservation Authority
City of Toronto

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ENVIRONMENT & ENGINEERING

Rockcliffe Riverine Flood Mitigation
Municipal Class Environmental Assessment

Geomorphic Cross-Section Locations in Lavender Creek

Project No.: 202179500

Date: June 2022

1 RAPID FIELD ASSESSMENT

Rapid field assessments consisting of the RGA (MOE 2003) and RSAT (Galli 1996) were completed to document evidence of channel instability and to evaluate stream health. The RGA consists of a checklist of indicators of channel instability that are tabulated and quantified using an index that identifies channel sensitivity based on the presence or absence of aggradation, degradation, channel widening, and planform adjustment. Overall, the index produces values that indicate whether the channel is "Stable/In Regime", "Transitional/Stressed", or "Stressed/Adjusting". A stable score indicates that the channel morphology is within a range of variance for streams of similar characteristics. Any evidence of instability is isolated or associated with normal river meander propagation processes. A transitional score indicates that the channel morphology is within the range of variance of streams of similar hydrographic characteristics, but the evidence of instability is more frequent. An adjusting score indicates that the channel morphology is not within the range of variance, and evidence of instability is widespread. The RSAT provides a more qualitative and broader assessment of the overall health and functions of a reach. This system integrates visual estimates of channel conditions and numerical scoring of stream parameters using six categories: channel stability, erosion and deposition, instream habitat, water quality, riparian conditions, and biological indicators.

During the rapid assessments, bankfull channel dimensions are identified. In natural, stable streams, the bankfull channel area often represents the maximum capacity of the channel before flow spills into the floodplain, and the discharge at this stage is referred to as the bankfull discharge. In the case of Lavender Creek, bankfull dimensions were determined from obvious breaks or inflections in the cross-section profile and/or changes in vegetation due to the entrenched nature of the system. The study reach is described below with all references to left or right banks when looking in the downstream direction (refer to attached site photographs).

Downstream of Symes Road, Lavender Creek contains a relatively straight planform, with minor sinuosity observed approximately 20 m upstream of the confluence with Black Creek. The channel is entrenched and contains bank heights between 1.0 to 2.5 m. Evidence of raised manholes and outfalls along the channel corridor suggests the channel has continued to incise for several decades. Bank erosion is extensive throughout the reach as evidenced by exposed tree roots and vertical, undercut, and overhanging banks. It is evident that high flow events frequently fill and overtop the channel corridor due to the presence of debris caught in tree branches as well as localized deposition of fine material in the overbank zone.

In general, Lavender Creek lacks a well-defined pool-riffle sequence. The majority of the reach consisted of riffles and transitional sections, with the occasional shallow pool. Transitional sections were generally characterized as extended shallow flow between riffles and poorly developed pool features. At riffles, channel substrate was dominated by gravel and small cobbles, with larger cobbles/boulders or previously placed riprap noted in several locations. Shallow pool and transitional areas contained a higher abundance of sand, silt, and small gravel. Localized well sorted gravel point bars and medial bars were observed along the corridor. Bank faces were generally not well vegetated, providing evidence of ongoing active erosion; however, vegetation on the top of bank predominantly consisted of shrubs and trees, several of which were falling/leaning.

This reach was assessed with a resulting RGA score of 0.38, indicating that it is in a Transitional or Stressed condition. Based on the indicators observed, the dominant geomorphic processes/modes of adjustment are widening and degradation. Indicators of channel widening that were observed include fallen/leaning

trees, the occurrence of large organic debris, exposed tree roots, fracture lines along top of bank, and basal scour noted on inside meander bends, both sides of channel through riffle, and along a length of >50% of the reach. It is evident that the creek banks are relatively unstable and are undergoing active erosion due to the high velocity/shear stress acting on the banks at frequent high flow events. An RSAT score of 19 was calculated for this reach, indicating that it contains low stream health. The limiting indicators for stream health were poor water quality, channel stability, and riparian conditions. RGA and RSAT field forms are attached.

1.1 Bankfull Hydraulics and Instream Erosion Threshold

To specifically assess the bankfull hydraulic capacity, detailed cross-sections were measured at three locations (riffles) along Lavender Creek using a measuring tape and metre stick to supplement the Toronto and Region Conservation Authority (TRCA) 2018 topographic survey data. At each cross-section, measurements of depth from the tape to the channel invert were recorded in 0.2 m increments and plotted. The channel substrate at each cross-section was also characterized (i.e., D_{50}, D_{84}) using a modified Wolman pebble count which utilizes the random selection and characterization of individual sediment particles from the channel bed (Wolman 1954). Cross-sections were measured to gain an understanding of the bankfull channel geometry and hydraulic capacity. Table 1 provides a summary of the selected parameters and calculated hydraulics.

TABLE 1 Summary of Bankfull Parameters from Measured Cross-sections

Parameter	XS-1	XS-2	XS-3	Average
Measured				
Average Bankfull Width (m)	7.55	6.43	6.95	6.98
Average Bankfull Depth (m)	0.81	0.72	0.75	0.76
Maximum Bankfull Depth (m)	1.07	1.08	1.09	1.08
Bankfull Width:Depth Ratio	9.30	8.97	9.21	9.16
Entrenchment Ratio (1)	1.9	3.5	3.2	2.87
Hydraulic Radius	0.75	0.67	0.62	0.68
Channel Bed Gradient (m/m) (2)	0.0065			
Bed Substrate and Bank Materials				
D_{10} (mm)	8			
D_{50} (mm)	19			
D_{90} (mm)	43			
Bank Material	Sandy loam with organic horizons and root mats; local evidence of riprap, concrete debris, artificial fill, native gravel, and clay till			
Computed (3)				
Average Bankfull Discharge (m^3/s)	11.8	8.4	9.59	9.93
Average Bankfull Velocity (m/s)	1.89	1.76	1.79	1.81
Average Bankfull Shear Stress (N/m^2)	47.4	42.6	43.6	44.5

(1) Entrenchment ratio is flood prone width divided by bankfull width, where flood prone width is taken at 2 times the bankfull depth
(2) Channel bed gradient taken from MIKE FLOOD model of Lavender Creek
(3) Manning's n assumed to be 0.035
XS - cross-section

As an approximate valuation of baseflow, the low-flow conditions on the date of the survey (December 3, 2020) were estimated to be in the range of 10 to 50 L/s. This assessment is based on the cross-section surveys and a visual approximation of the surface velocity, with average conditions of 3.1 m for wetted width, 0.05 m for averaged flow depth, and 0.1 to 0.3 m/s for the flow velocity.

On average, bankfull dimensions were approximately 6.98 m in width and 0.76 m in depth, with an average entrenchment ratio of 2.88. From these results, the bankfull channel was interpreted to be slightly entrenched on average, with moderate entrenchment measured in the upstream section (XS-1). A channel gradient of 0.65% was obtained from MIKE FLOOD modelling software as part of the hydraulic modelling component of the current project. Using a Manning's n of 0.035, bankfull parameters such as discharge, velocity, and shear stress were calculated. The resulting values are 9.93 m^3/s, 1.81 m/s, and 44.5 N/m^2, respectively. Three cross-sections corresponding to the approximate location of the field-measured cross-sections were exported from MIKE FLOOD software to display the various water levels at specific return periods (Figures 2 to 4). It is noted that the average bankfull discharge calculated using our field-measured cross-section (9.93 m/s^3) is significantly lower than the 2-year discharge (23.3 m^3/s), highlighting the urban nature of the creek's flow regime. In most cases (XS-1 and XS-2), the 10-year flow event overtops the entrenched creek valley and disperses towards the right bank. Beyond the 10-year flow event, Lavender Creek is highly influenced by backwater from Black Creek.

FIGURE 2 Cross-section 1 Showing Bankfull and MIKE FLOOD Water Levels

FIGURE 3 Cross-section 2 Showing Bankfull and MIKE FLOOD Water Levels

FIGURE 4 Cross-section 3 Showing Bankfull and MIKE FLOOD Water Levels

To assess the frequency of sediment transport processes within Lavender Creek, an erosion threshold analysis was completed to determine the hydraulic conditions, such as the critical discharge, channel depth, and average channel velocity at which bed materials of a given particle size (D_{crit}) will tend to be mobilized (Table 2). This represents the "threshold" condition at which sediment particles will start to move. A representative cross-section was selected from the field assessment to complete the erosion threshold analysis. The erosion threshold was then calculated using empirical relationships dependent on factors such as sediment size and cohesiveness. Since the median grain size (D_{50}) for Lavender Creek was within the medium gravel range (19 mm), three approaches; Komar (1987), Chow (1959), and Miller (1977) were used to derive the threshold for the reach and were averaged.

TABLE 2 Erosion Threshold Parameters for Representative Cross-section

Parameter	Komar (1987)	Chow (1959)	Miller (1977)	Average
Critical Discharge (m^3/s)	0.75	1.0	0.93	0.89
Critical Depth (m)	0.33	0.37	0.36	0.35
Critical Velocity (m/s)	0.77	0.85	0.83	0.82
Critical Shear Stress (N/m^2)	12.2	14.4	13.8	13.5
Shields Number at Channel-forming Flow	0.23			

The average critical discharge of 0.89 m^3/s indicates that the transport of the median sediment size is initiated at approximately 10% of the bankfull flow. This calculation confirms the rapid field assessment results that Lavender Creek is erosive in nature given that a flow one tenth of the bankfull event is capable of entraining the median sediment size. This interpretation is also evident in the observed channel bars of loose gravel within Lavender Creek.

As an additional reference, the Shields number was calculated at the channel-forming flow to classify Lavender Creek as either a transitional or threshold-type channel (Church 2006). For natural mixed-gravel bed channels, where the bankfull flow is assumed to be the channel forming flow, the average Shield's ratio is 0.045. The Shield's number at the channel-forming flow for Lavender Creek was calculated to be 0.23, indicating that it is a transitional-type channel and sediment transport events are more frequent than a typical bankfull, threshold-type channel.

2 FLUVIAL GEOMORPHIC ASSESSMENT CONCLUSIONS

Results of the fluvial geomorphic assessment for Lavender Creek confirm its impacted condition as an erosive urban channel, whereby local fill and native alluvial material that make up the channel boundary are relatively erodible as they are frequently subjected to flashy storm runoff responses from the upstream urban drainage network. The RGA and RSAT indices classify the channel stability as transitional to stressed and indicate a low stream health score. The dominant fluvial processes are widening and degradation, with a poorly developed riffle-pool morphology and irregular bars of transient bed load sediments. Mostly in a degraded state, local riprap and concrete debris provide minimal erosion control.

The above field observations and rapid assessment scores have been corroborated by analytical results for the bankfull hydraulics and an erosion threshold for the bed material. The calculated critical discharge for entrainment of the median grain sizes (0.89 m^3/s) is only 10% of the bankfull discharge capacity (9.93 m^3/s), and the bankfull discharge is less than half (43%) of the 2-year discharge. The channel is considered to be moderately to slightly entrenched, with entrenchment ratios that range from 1.9 to 3.5.

The hydraulic capacity of the floodway corridor tends to be greater than the 10-year flood discharge of 47.1 m^3/s, which is almost 5 times greater than bankfull discharge and more than 50 times greater than the critical discharge. These results are meaningful because the bankfull, 2-year, and 10-year discharges are contained within the narrow floodway corridor and are extremely competent to mobilize and transport the prevailing gravel bed material. As such, the existing channel does not function as an equilibrium threshold channel because most of the geomorphic work of erosion and sediment transport occurs well below the bankfull discharge, with multiple and frequent sediment transport events expected to occur each year. Based on the calculated Shields ratio of 0.23 for the bankfull or channel-forming discharge, the channel morphology functions in a transitional state between threshold and labile conditions (Church 2006).

The results and interpretations presented here are not unexpected for an urban channel such as Lavender Creek, with a highly modified urban runoff regime (where Q2 > QBF > Qcrit) and an alluvial channel dominated by fine gravel bed materials (D_{50} = 19 mm). The implication of this assessment on the consideration of conceptual design alternatives is that a stable and sustainable natural channel design of Lavender Creek would require creating a novel channel morphology, boundary condition, and corridor configuration commensurate with the flow frequency and hydraulics of the modified urban runoff regime. However, it is expected that the preferred solution will be engineered with a low channel roughness to address the flooding hazard, and thus application of a natural channel design approach in this case is not expected.

3 CLOSURE

We trust that this letter report suits your present requirements. If you have any questions or comments, please call either of the undersigned at 905.877.9531.

Yours truly,

MATRIX SOLUTIONS INC.

Natasha Cyples, M.Sc., P.Geo.
Fluvial Geomorphologist

Reviewed by

Roger Phillips, Ph.D., P.Geo.
Senior Geomorphologist

NC/vc
Attachments

September 15, 2022

DISCLAIMER

VERSION CONTROL

Version	Date	Issue Type	Filename	Description
V1.0	28-June-2022	Final	24316-531 Rockcliffe Geomorph Existing Conditions LR 2022-06-28 final V1.0.docx	Issued to client
V2.0	15-Sep-2022	Final revised	24316-531 Rockcliffe Geomorph Existing Conditions LR 2022-09-15 final V1.0.docx	Reissued to client

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Rapid Geomorphic Assessment and Rapid Stream Assessment Technique

RAPID GEOMORPHIC ASSESSMENT (RGA)

Matrix Solutions Inc. ENVIRONMENT & ENGINEERING

Date: Dec 3/20 ***Reach:*** Lavender Creek ***Crew:*** NC/AN/RP
Location: Toronto, ON (Rockliffe Ct.)
Weather Description: 1 degree, overcast, cold/dam ***Recorder:***

FORM / PROCESS	*GEOMORPHIC INDICATOR* Num	Description	*PRESENT? (√)* No	Yes	*FACTOR VALUE*	
Evidence of Aggradation (AI)	1	Lobate Bar	☑	☐		
	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 Indicies:	5	2	0.28571	7
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	☑	☐		
	2	Exposed sanitary / storm sewer / pipeline / etc.	☑	☐		
	3	Elevated sorm sewer oufalls	☐	☑		
	4	Undermined gabion baskets / concrete aprons / etc.	☐	☑		
	5	Scour pools d/s of culverts / storm sewer outlets	☑	☐		
	6	Cut face on bar forms	☑	☐		
	7	Head cutting due to knick point migration	☑	☐		
	8	Terrace cut through older bar material	☑	☐		
	9	Suspended armour alyer visible in bank	☑	☐		
	10	Channel worn into undisturbed overburden / bedrock	☐	☑		
		Sum of Indicies:	7	3	0.3	#
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	☐	☑		
	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	Gabion baskets / concrete walls / etc. out flanked	☑	☐		
	7	Length of basal scour >50% through subject reach	☐	☑		
	8	Exposed length of previously buried pipe / cable / etc.	☑	☐		
	9	Fracture lines along top of bank	☐	☑		
	10	Exposed building foundation	☐	☐	NA	
		Sum of Indicies:	2	7	0.77778	9
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	☑	☐		
	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 meander form	☐	☑		
	7	Bar forms poorly formed / reworked / removed	☑	☐		
		Sum of Indicies:	6	1	0.14286	7

COMMENTS: medial bar in one location, not a strong indicator
however provides some evidence of aggradation
localized evidence of sorting across bars
ill-defined pool-riffle sequence, lack of deep pools
channel likely artificially entrenched, banks could be fill, not a natural corridor

STABILITY INDEX: 0.37659

Condition: Transitional

~ Factor Value = # YES / Total #
~ STABILITY INDEX (SI) = (AI+DI+WI+PI)/4
SI ≤ 0.20 = In Regime
SI 0.21 - 0.40 = Transitional or Stressed
SI ≥ 0.41 = In Adjustment

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

RAPID STREAM ASSESSMENT (RSAT)

Date: Dec 3/20 ***Reach:*** Lavender Creek ***Crew:*** NC/AN/RP
Location: Toronto, ON (Rockliffe Ct.)
Weather Description: 1 degree, overcast, cold/dan ***Recorder:*** NC

	Excellent	***Good***	***Fair***	***Poor***	***Points***
Channel Stability	9 - 11	6 - 8	3 - 5	0 - 2	2
Scour / Deposition	7 - 8	5 - 6	3 - 4	0 - 2	4
Instream Habitat	7 - 8	5 - 6	3 - 4	0 - 2	4
Water Quality	7 - 8	5 - 6	3 - 4	0 - 2	2
Riparian Conditions	6 - 7	4 - 5	2 - 3	0 - 2	3
Biological Indicators	7 - 8	5 - 6	3 - 4	0 - 2	4
				Total:	19

Stability Rankings: *<20 = LOW* ☑ *20 - 35 = MODERATE* ☐ *>35 = HIGH* ☐

Site Photographs

Matrix Solutions Inc.
December 3, 2020

1. Lavender Creek downstream of Symes Road crossing; debris jam immediately downstream of culvert and channel bed is heavily armoured with riprap.

Matrix Solutions Inc.
December 3, 2020

2. View downstream of Symes Road; left bank is actively eroding as evidenced by exposed tree roots, leaning trees, bank undercutting, and leaning fence atop the bank.

Matrix Solutions Inc.
December 3, 2020

3. View downstream; channel follows a relatively straight planform; most banks are undercut and contain exposed tree roots and leaning trees.

Matrix Solutions Inc.
December 3, 2020

4. Elevated storm sewer outfall on left bank; concrete pad along bank at been undermined and is failing.

Matrix Solutions Inc.
December 3, 2020

5. View upstream towards bridge crossing; large, well-sorted gravel medial bar with dominant flow path towards left bank.

Matrix Solutions Inc.
December 3, 2020

6. View upstream; right bank actively eroding, bank contains exposed parent material.

Matrix Solutions Inc.
December 3, 2020

7. View towards downstream extent of Lavender Creek; on inner bank, note exposed parent material at toe of bank and bank slumping.

Matrix Solutions Inc.
December 3, 2020

8. Exposed manhole on right bank; bank is near vertical and continues to erode.

Matrix Solutions Inc.
December 3, 2020

9. View downstream towards confluence with Black Creek; channel bed and banks become concrete-lined as approaching Black Creek.

Matrix Solutions Inc.
December 3, 2020

10. Confluence with Black Creek; note large vertical drop ~1m in height in concrete where Lavender Creek discharges into Black Creek.