6939 King Street, Caledon
Erosion Threshold Study

FINAL REPORT

Prepared for

Pinchin Ltd.

2470 Milltower Court
Mississauga, ON

Dec 22, 2020
Project No. P2020-469

Prepared by

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TECHNICAL MEMO

Dec 22, 2020

Mr. Rocky Yao
Regional Practice Lead, Biologist, Environmental Science
Pinchin Ltd.
2470 Milltower Court
Mississauga, ON
L5N 7W5

Re: 6939 King Street, Caledon – Erosion Threshold Study

Dear Mr. Yao,

GeoProcess Research Associates Inc. (GRA) completed an erosion threshold study for a tributary of Lindsay Creek at 6939 King Street. The results presented in this memo can be used to support land-use planning decisions or as input to other constraints mapping. If you have any questions regarding this technical memo or the methods and rationale outlined herein, please do not hesitate to contact Chris McKie at 519-221-4111 or cmckie@geoprocess.com.

Regards,

GEOPROCESS RESEARCH ASSOCIATES INC

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River Engineer

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Table of Contents

List of Figures

List of Tables

1. Introduction

GeoProcess Research Associates Inc. (GRA) was retained by Pinchin Ltd. to complete an erosion threshold study for a tributary to Lindsay Creek, which flows through a study area adjacent to 6939 King Street, in Caledon, Ontario. The objectives of this study were to characterize the existing geomorphological conditions of the watercourse and to estimate erosion thresholds to inform the stormwater management (SWM) design for a proposed development at 6939 King Street (the subject property). To address the objectives, a detailed field assessment and geomorphic survey were undertaken. The data were used to complete erosion threshold modelling to estimate critical discharges associated with potential erosion for each delineated reach of watercourse. This memo outlines the technical rationale and results of this study.

2. Study Area and Geologic Context

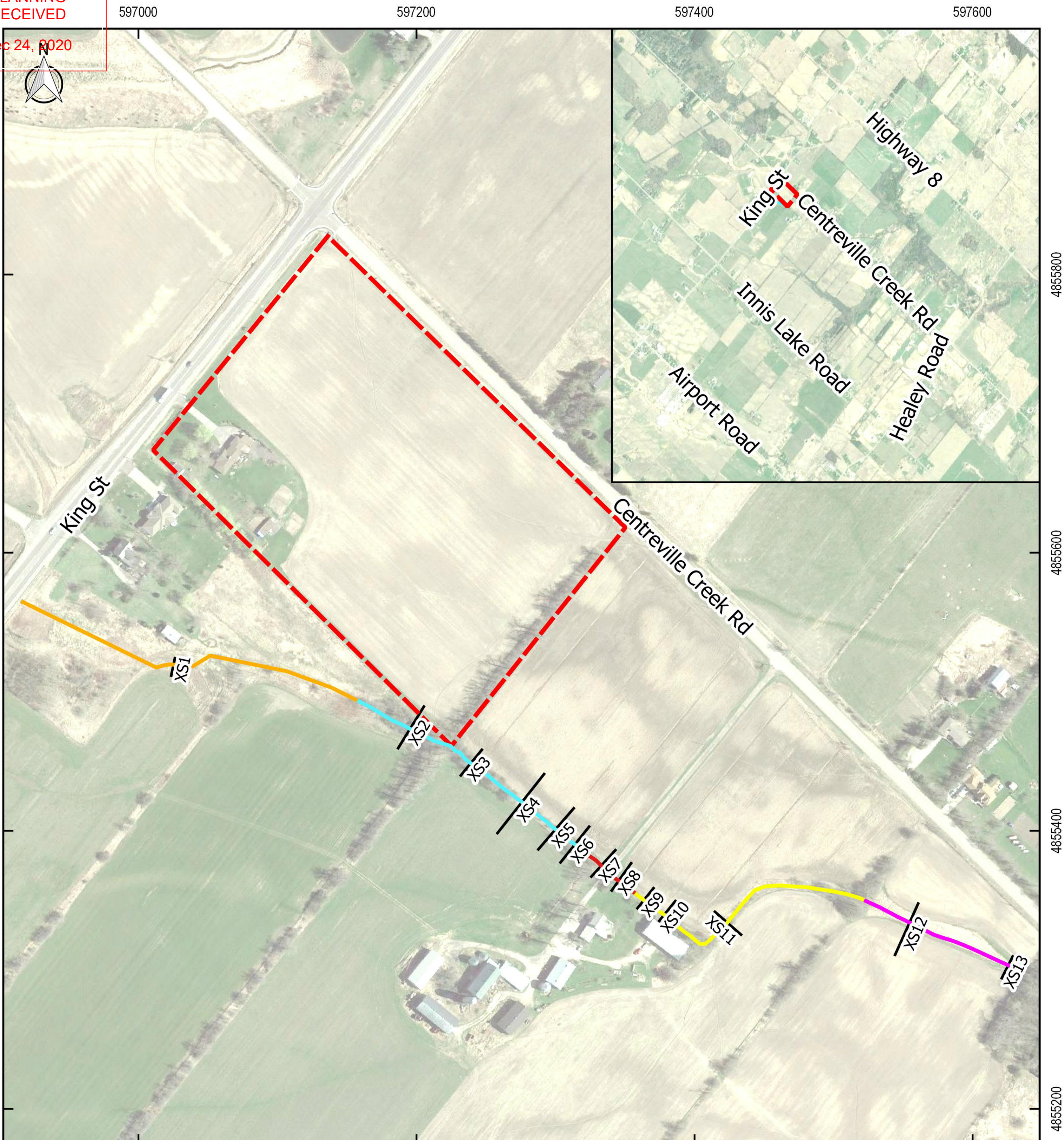
The subject property is located within the Halton Till geologic unit (Russell et al., 2005), having surficial geology primarily consisting of clay to silt-textured till derived from glaciolacustrine deposits or shale (OGS, 2010). The watercourse here is a tributary to Lindsay Creek, situated within the Humber River Watershed. The study area (Figure 1) is adjacent to King Street and Centreville Creek Road. The watercourse intersects the subject property at the southern corner of the property limits, however, approximately 815 m of the channel is contained within the expanded study area. This area captures the channel between King Street (upstream limit) and a woodlot adjacent to Centreville Creek Road (the downstream limit). In the study area, the channel flows within an unconfined valley.

The proposed stormwater management (SWM) facility will outlet to the channel at the southern corner of the subject property. The channel at this location has an upstream drainage area of 31 ha (estimated using the Ontario Flow Assessment Tool), with the SWM facility having a drainage area of 6 ha (provided by Crozier Consulting Engineers).

3. Methods

3.1. Reach Delineation

5 discrete watercourse reaches were delineated in the study area for the assessment. Reaches are a means of separating watercourse segments that transition between different morphologies or constraints, for example due to changes in geology, slope, valley confinement, sediment sources, anthropogenic influences, or discharge. A reach can range in length, depending on the size and characteristics of the watercourse but should be long enough that average hydraulic and morphologic characteristics can be confidently estimated. In this assessment, reaches were delineated based on dominant changes in channel morphology and by culverts at the upstream and downstream limits of the study site. Reach delineations are shown on Figure 1.



Project No. P2020-469
Dec 22, 2020

0 50 100 150 200 metres

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[Drawing by: CWM]

LEGEND

Property Line
Cross-section

Reach ID

LCT-1
LCT-2
LCT-3
LCT-4
LCT-5

GeoProcess RESEARCH ASSOCIATES

Figure 1: Study Area Map

6939 King Street, Caledon, Ontario

3.2. Field Methods

A detailed geomorphic survey of the study area was completed by GRA on November 17, 2020, using survey-grade global navigation satellite system (GNSS) receivers with enabled real-time kinematic (RTK) corrections (+/- 0.04 m error). The survey consisted of a longitudinal profile, where significant breaks in slope were measured. Cross-sections were surveyed to characterize the dominant cross-sectional morphology. Channel substrate was visually characterized and photographed. A detailed georeferenced photo record was compiled.

4. Existing Conditions

4.1. Reach Delineation

The subject watercourse was delineated into five distinct reaches based on channel characteristics including width, slope and vegetation cover. The following sections describe the features of each reach in detail. Locations of delineated reaches are shown in Figure 1.

4.1.1. Reach LCT-1

Reach LCT-1 extends approximately 260 m downstream of the King Street culvert crossing and is upstream of the proposed stormwater management outlet. It is characterized as a wide valley that is dominated by well-established vegetation (including tall grasses, cattails and phragmites) and does not contain a clearly defined channel. Reach LCT-1 largely consists of topographic depressions that convey runoff from adjacent agricultural lands and outflow from the stormwater management (SWM) pond located immediately north of King Street. Vegetation appears to play a dominant role in maintaining channel stability. Several manicured segments of channel (short cut grass) were observed in the downstream half of the reach (Photo 4). Reach LCT-1 has a moderate slope of 0.63% and terminates at a treeline located west of the south corner of the subject property. Reach LCT-1 is shown in Photos 1 to 4.

Photo 1: Poorly defined flow path in Reach LCT-1

Photo 2: Overland flow path from adjacent agricultural field in Reach LCT-1

Photo 3: Pooling water in local depression along Reach LCT-1

Photo 4: Maintained path along Reach LCT-1

4.1.2. Reach LCT-2

Reach LCT-2 is approximately 200 m long and flows along a treeline located downstream of the LCT-1 reach break. Reach LCT-2 consists of a shallow unconfined channel that is well connected to the floodplain and is characterized by a slightly steeper slope of 0.8% (steeper than LCT-1). Channel substrate primarily consists of fine sediment and organic material. The stability of the reach is heavily influenced by the presence of trees, large woody debris and thick underbrush vegetation. These features play a dominant role in channel stability and dissipating erosive energy in the overbank zone. A concentrated flow path intersects the main channel at a confluence near the south corner of the subject property, conveying runoff from the agricultural field west of the reach (Photo 8).

Photo 5: Shallow, unconfined channel with well connected floodplain in Reach LCT-2

Photo 6: Typical view of Reach LCT-2

Photo 7: Large woody debris in Reach LCT-2

Photo 8: Flow path (left) from adjacent field joins LCT-2 main channel (right) at confluence

4.1.3. Reach LCT-3

Reach LCT-3 is approximately 40 m long and begins at the clearing of the Reach LCT-2 treeline. Historic channelization is evident along this reach as the channel becomes wider and straighter. Flow is conveyed under a private laneway through a corrugated steel pipe (CSP) culvert. The channel slope continues at 0.8% from the previous reach and then transitions into a steeper gradient of 1.2% downstream of the CSP culvert. The channel bed and banks are largely vegetated with short grasses and weeds that appears to be maintained by the private property owner. Channel substrate primarily consists of fine sediment and organic material. Tile drain flow inputs were noted along the reach.

Photo 9: Reach LCT-3, facing upstream

Photo 10: Reach LCT-3, facing downstream

4.1.4. Reach LCT-4

Reach LCT-4 is approximately 195 m long and flows from the LCT-3 reach break into a wetland area. LCT-4 is channelized, having a slope of 0.26% and is well connected to the floodplain. Channel substrate primarily consists of fine sediment and organic material. The channel bed and banks are largely vegetated with tall grasses that provide significant erosion protection along the reach and play a dominant role in stabilization. Tile drain flow inputs were noted along the reach.

Photo 11: Reach LCT-4, facing downstream

Photo 12: Reach LCT-4, facing upstream

Photo 13: Reach LCT-4, facing upstream

Photo 14: Reach LCT-4, facing downstream

4.1.5. Reach LCT-5

Reach LCT-5 is along a wetland area that was highly disturbed at the time of survey. In its current state, Reach LCT-5 is characterized by a moderate slope of 0.7% and extends approximately 120 m towards a woodlot adjacent to Centreville Creek Rd. where the reach terminates. The reach was found to be stripped of vegetation and ploughed with a narrow, shallow dug-out channel conveying flow. The channel bed substrate consists of loose fine material. Satellite imagery reveals that vegetation was previously well established along the reach, which would be expected to contribute to channel stability. While this reach is included in the analysis, it was deemed not suitable for use in determining the erosion threshold for the study area due to the high level of anthropogenic disturbance and it not being representative of the system-wide morphologic characteristics.

Photo 15: Reach LCT-5, facing downstream

Photo 16: Reach LCT-5, facing upstream

4.2. Channel Morphology

The geomorphic survey data were used to complete an at-a-stage hydraulic analysis for each surveyed cross-section. Bankfull geometry and corresponding hydraulic parameter estimates for each cross-section are summarized in Table 1.

Table 1: Summary of bankfull channel geometry and estimated hydraulic parameters.

Reach	XS ID	Area (m^2)	Width (m)	Mean Depth (m)	Wetted Perimeter (m)	Hydraulic Radius (m)	W:D Ratio	Roughness Coefficient (n value)	Discharge (m^3/s)
LCT-1	XS1	0.21	3.32	0.06	3.42	0.06	52.4	0.05	0.05
LCT-2	XS2	0.63	6.77	0.09	6.84	0.09	72.7	0.04	0.29
LCT-2	XS3	0.59	3.94	0.15	4.27	0.14	26.1	0.04	0.36
LCT-2	XS4	2.01	6.64	0.30	6.93	0.29	21.9	0.04	1.97
LCT-2	XS5	1.64	5.26	0.31	5.45	0.30	16.8	0.04	1.65
LCT-2	XS6	1.26	3.65	0.35	3.89	0.32	10.5	0.04	1.34
LCT-3	XS7	1.21	4.98	0.24	5.11	0.24	20.5	0.022	1.88
LCT-3	XS8	1.58	3.98	0.40	4.29	0.37	10.0	0.022	4.04
LCT-4	XS9	1.02	3.38	0.30	3.63	0.28	11.2	0.05	0.45
LCT-4	XS10	1.02	3.49	0.29	3.71	0.28	11.9	0.05	0.44
LCT-4	XS11	2.96	5.86	0.51	6.22	0.48	11.6	0.05	1.84
LCT-5	XS12	0.33	1.63	0.20	1.94	0.17	8.0	0.016	0.54
LCT-5	XS13	0.33	1.58	0.21	1.79	0.19	7.5	0.016	0.57

5. Erosion Threshold Assessment

If properly managed, additional flow inputs (post stormwater management facilities) should not generate excess erosion relative to the existing flow regime, ideally beyond a condition representative of the stable channel morphology. The channel bed material is consistent with a depositional morphology, having loosely consolidated alluvium or organic material overlying clay. Frequent "flushing flows" likely mobilize this surficial layer of silt, with eroded sediment being replaced by material transported from upstream. In depositional areas, this sediment will accrete in increasingly deeper and wider alluvial deposits. In erosional areas, this material will erode down to the underlying parent material (the clay). The erodible nature of the surficial alluvium is such that even minor flows are likely to transport this material. Channel stability is, therefore, not governed by the surficial, silty alluvium but by both the underlying cohesive substrate, and roots and vegetation cover that are prevalent within the channel and overbank regions throughout much of the study area.

Characteristics pertaining to the erodibility of cohesive material (e.g. the critical shear stress) are known to have considerable variability, even at the local scale, sometimes spanning multiple orders of magnitude (Hanson and Simon, 2001; Shugar et al., 2007). This project used field-verified surficial geology mapping to identify the soil type governing channel erosion. A literature-based approach was then used to determine a range of erosion thresholds that have been empirically derived for the identified soil type and vegetation boundary materials from field and laboratory testing. These literature-based estimates are widely used for estimating erosion thresholds in cohesive material. Finally, hydraulic modelling of surveyed cross-sections was performed to identify the critical discharge at which erosion of the material is likely to occur.

The duration of erosion exceedance is an important factor to consider, as it has been shown that erosion thresholds for cohesive soil decrease with increasing duration of competent flows (Figure 2). Accordingly, erosion thresholds in areas of the study site where roots and vegetation do not provide significant erosion protection can range between 2.0 m/s and approximately 0.6 m/s. For this analysis, a conservative approach was used; one that estimated erosion thresholds assuming a longer competent flow duration (>50 hours), corresponding to the point when thresholds begin to reach a constant rate of approximately 0.6 m/s for bare clay (Fischenich, 2001).

Critical velocity, while traditionally used for erosion threshold estimations, does not consider channel geometry. For example, two cross-sections with the same average velocity may have different shear stress distributions if one is wider and shallower than the other. As such, critical shear stress was also assessed. Critical hydraulic shear stress for cohesive sediments can vary considerably, with reported values in literature also ranging multiple orders of magnitude (Briaud, 2008) (Figure 3). For high plasticity clay, Briaud (2008) gives a range between approximately 10- >100 N/m^2 (Figure 3). Fischenich (2001) reports a value for stiff clay of 12.4 N/m^2 which was selected here because it is within the overall range reported by Briaud (2008) and provides a conservative estimate to account for the inherent uncertainty of erosion threshold estimation in cohesive sediment.

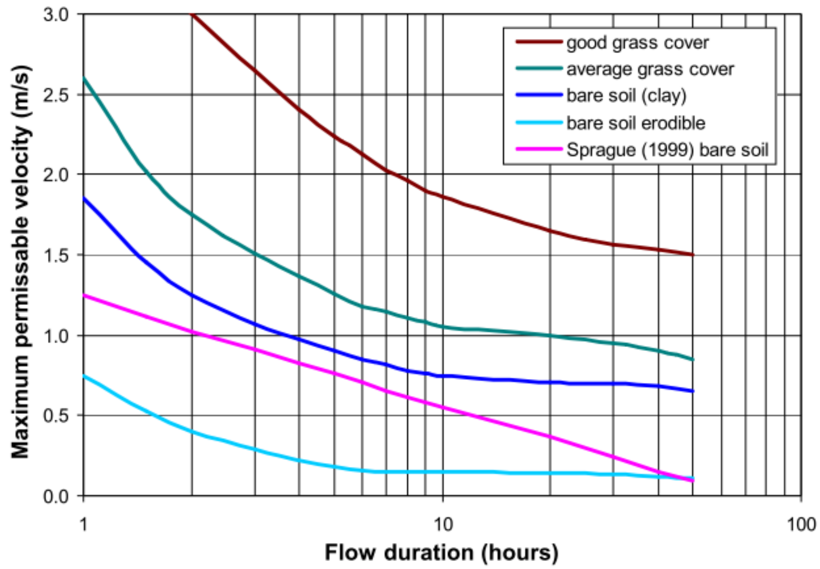

Figure 2: Flow duration curve. Source: Fluvial Systems Pty Ltd. (Adapted from Fischenich (2001)

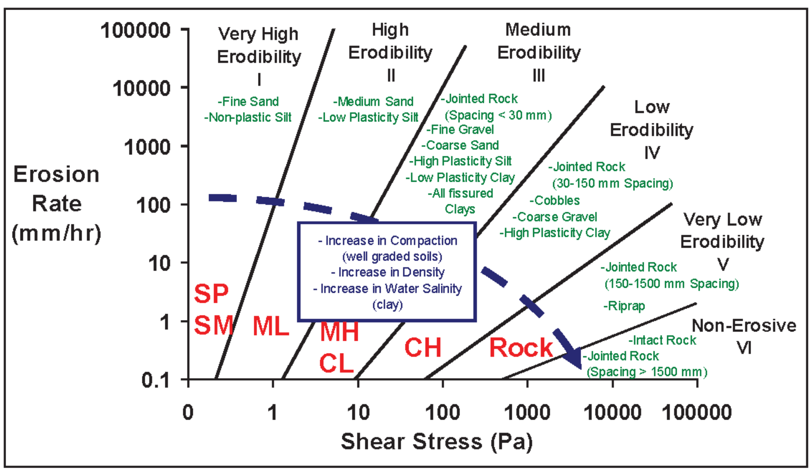

Figure 3: Critical shear stress for various materials (Briaud, 2008)

Channel stability is heavily influenced by roots and vegetation cover for a large portion of the study area. Consequently, appropriate critical velocity and shear stress thresholds pertaining to the primary vegetation boundary material were selected for each cross-section where applicable. For long native grasses, Fischenich (2001) reports a permissible shear stress range of 57.5 – 81.4 N/m^2 and a permissible velocity range of 1.2 – 1.8 m/s. For short native and bunch grasses, Fischenich (2001) reports a permissible shear stress range of 33.5 – 45.5 N/m^2 and a permissible velocity range of 0.9 – 1.2 m/s. A conservative approach was undertaken such that the lowest reported permissible shear stress and velocity values were assumed for the erosion thresholds for each vegetation type. Critical shear stresses and velocities for the surveyed cross-sections are presented in Table 2.

Table 2: Critical velocity and shear stress for surveyed cross-sections.

Reach ID	XS ID	Primary Bed Composition	Critical Velocity (m/s)	Critical Shear Stress (Pa)
LCT-1	XS1	Vegetation (tall grasses, weeds)	1.2	57.5
LCT-2	XS2	Mixed alluvium & vegetation (grasses, weeds, brush, roots)	1.2	57.5
LCT-2	XS3	Mixed alluvium & vegetation (grasses, weeds, brush, roots)	1.2	57.5
LCT-2	XS4	Mixed alluvium & vegetation (grasses, weeds, brush, roots)	1.2	57.5
LCT-2	XS5	Mixed alluvium & vegetation (grasses, weeds, brush, roots)	1.2	57.5
LCT-2	XS6	Mixed alluvium & vegetation (grasses, weeds, brush, roots)	1.2	57.5
LCT-3	XS7	Vegetation (maintained short grass)	0.9	33.5
LCT-3	XS8	Vegetation (maintained short grass)	0.9	33.5
LCT-4	XS9	Vegetation (tall grasses, weeds)	1.2	57.5
LCT-4	XS10	Vegetation (tall grasses, weeds)	1.2	57.5
LCT-4	XS11	Vegetation (tall grasses, weeds)	1.2	57.5
LCT-5	XS12	Bare soil (clay) [1]	0.6	12.4
LCT-5	XS13	Bare soil (clay) [1]	0.6	12.4

[1] Previously vegetated (channel disturbed by agricultural equipment, considered a temporary condition).

Critical discharge is the discharge rate (m^3/s) corresponding to a velocity or shear stress that equals the specified erosion threshold. Based on the principles discussed above, the critical discharge for each surveyed cross-section was estimated for a variety of thresholds derived from the empirical, literature-based estimates for the channel materials (referenced above).

Table 3 reports the corresponding critical discharges for each cross-section. Because of the range of critical velocities and shear stresses, a range of critical discharges applies to each cross-section. The critical discharges reported in Table 3 represent those estimated using the more conservative erosion thresholds, meaning that material strength and resistance to erosion were assumed based on the lower end of published literature.

Table 3: Critical discharges corresponding to erosion thresholds for measured cross-sections (m^3/s).

Reach ID	XS ID	Velocity Threshold	Bed Shear Threshold	Minimum Threshold
LCT-1	XS1	0.05 [1]	0.05 [1]	0.05 [1]
LCT-2	XS2	0.29 [1]	0.29 [1]	0.29 [1]
LCT-2	XS3	0.36 [1]	0.36 [1]	0.36 [1]
LCT-2	XS4	1.97 [1]	1.97 [1]	1.97 [1]
LCT-2	XS5	1.65 [1]	1.65 [1]	1.65 [1]
LCT-2	XS6	1.34 [1]	1.34 [1]	1.34 [1]
LCT-3	XS7	0.21	1.88 [1]	0.21
LCT-3	XS8	0.20	2.37	0.20
LCT-4	XS9	0.45 [1]	0.45 [1]	0.45 [1]
LCT-4	XS10	0.44 [1]	0.44 [1]	0.44 [1]
LCT-4	XS11	1.84 [1]	1.84 [1]	1.84 [1]
LCT-5 [2]	XS12	0.021	0.54 [1]	0.021
LCT-5 [2]	XS13	0.019	0.54	0.019

[1] Critical discharge not attained within bankfull channel. Value corresponds to bankfull discharge.
[2] Reach disturbed by agricultural equipment (resulting critical discharge unrepresentative).

The results indicate that Reach LCT-5 is the most sensitive reach, with erosion thresholds being exceeded at lower discharges than in other reaches. However, as previously mentioned, Reach LCT-5 is heavily anthropogenically disturbed (recently tilled) and is not representative of the system-wide morphology in the area, and should not govern the erosion threshold analysis.

The subsequent lowest critical discharge is reported for Reach LCT-1; however, Reach LCT-1 is upstream of the proposed SWM outlet location, and while it provides an upstream reference point, it is not incorporated into the final erosion threshold result because it won't be receiving stormwater discharge from the site.

Thus, Reach LCT-3 is considered the most sensitive reach across the study area to receive new stormwater form the proposed development. The erosion threshold here corresponds to a critical discharge of 0.20 m^3/s. This discharge value correlates to the velocity threshold of 0.9 m/s, and is considered a conservative estimate for determining critical discharge due to the following:

- The velocity threshold of 0.9 m/s is the most conservative value for permissible velocities in short and native bunch grasses (Fischenich, 2001).
- While the velocity threshold results in a critical discharge of 0.20 m^3/s, the bed shear threshold results in a critical discharge of 2.37 m^3/s in XS8 where the bed shear threshold is met. The bed shear threshold indicates a discharge a full order of magnitude higher than the velocity threshold, indicating the conservatism in the velocity threshold method.

The proposed SWM design has discharge targets presented in Table 4. While a 25 mm storm event is generally used in erosion mitigation studies, the 2-year storm event provides a target that is generally more conservative than the 25 mm event. The 2-year target release rate is approximately 14% of the total erosion threshold discharge.

Table 4: SWM Target Release Rates from Humber River Watershed Unit Flow for Equation F Sub-Basin 36 (Provided by Crozier Consulting Engineers)

Storm	Target Release Rate (m3/s)
2-year	0.028
5-year	0.043
10-year	0.052
25-year	0.066
50-year	0.077
100-year	0.087

Therefore, it is expected that additional flow inputs from the proposed SWM design will not generate excess erosion relative to the existing flow regime. This recommendation is made on the following considerations and limitations:

- The 2-year storm event target release rate is 14% of the total erosion threshold discharge. The 100-year storm event target release rate is only 44% of the erosion threshold discharge, which is still a relatively low proportion.
- The methods of evaluating the erosion thresholds were conservative. Specifically, selecting the minimum discharge determined either using the velocity threshold or the bed shear threshold produces a conservative value, and the values selected for the thresholds were on the lower (conservative) limit of the ranges presented in literature.
- While the evaluation of upstream hydrology is not within the scope of this study, the upstream contributions can be characterized. The main contributor to the channel upstream channel is another SWM facility (updated in 2015) that should contain similar erosion mitigation controls, thus limiting additional erosion potential from upstream flow inputs. Additionally, the proposed SWM facility drainage area (6 ha) accounts for 16% of the total catchment area (37 ha) at the outlet location, yet the proposed SWM flows only account for 14% of the total erosion threshold discharge during the 2-year event.
- Due to the inherent differences in hydrologic response between the various land-uses and SWM controls in the basin, peak flows from upstream sources within the basin would likely not occur at the same time as peak flow from the proposed SWM design.
- Reach LCT-5 is not included in the erosion threshold determination. This is due to the heavy anthropogenic disturbance and to it being unrepresentative of the rest of the natural channel system being assessed.

6. Conclusions

A fluvial geomorphology and erosion threshold study was conducted on a tributary of Lindsay Creek in the upper portion of the watershed. The objectives of the study were to a) characterize the existing geomorphological conditions of the watercourse, and b) to estimate erosion thresholds to inform the SWM design. Key conclusions of the study are as follows:

- The watercourse stability is predominantly controlled by vegetation, with reaches controlled by trees, large woody debris and underbrush vegetation to reaches controlled by short manicured grass.
- Most reaches evaluated in the study do not reach velocity or bed shear thresholds prior to bankfull discharge, indicating frequent floodplain access maintains channel stability.
- The reach within the manicured grass (LCT-3) is the most sensitive to erosion due to its increased level of incision, relatively high slope (1.2%) and limited vegetation growth. Flows greater than 0.20 m^3/s may cause erosion in this reach.
- The proposed SWM design target release rates, specifically the 2-year storm event (0.028 m^3/s), do not indicate that excess erosion will be generated relative to the existing flow regime. This is supported by the heavily controlled nature and differences in hydrologic response times within the upstream basin.
- Reach LCT-5 is not included in the erosion threshold determination. This is due to the heavy anthropogenic disturbance and to it being unrepresentative of the rest of the natural channel system being assessed.

7. References

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Prepared for Pinchin Ltd.

Dec 22, 2020

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