KIZELL DRAIN EROSION ASSESSMENT
PROPOSED REDEVELOPMENT OF KANATA GOLF & COUNTRY CLUB
7000 CAMPEAU DRIVE, OTTAWA

Prepared for:
MINTO COMMUNITIES – CANADA
on behalf of **CLUBLINK CORPORATION ULC**

Prepared by:
MATRIX SOLUTIONS INC.

Version 1.0
August 2019
Ottawa, Ontario

880 Taylor Creek Drive
Orléans, ON K4A 0Z9
T 226.314.1917   F 343.548.6362
www.matrix-solutions.com

KIZELL DRAIN EROSION ASSESSMENT

Prepared for Minto Communities - Canada, August 2019

Matthew McCombs, M.A.Sc., P.Eng.
Water Resources/River Engineer

reviewed by
Ashraf Zaghal, Ph.D., P.Eng.
Senior Water Resources Engineer

VERSION CONTROL

Version	Date	Issue Type	Filename	Description
V0.1	14-May-2019	Draft	28627-531x Geomorph R 2019-05-14 draft V0.1.docx	Issued to client for review
V0.2	16-Aug-2019	Draft Revised 1	28627-531x Geomorph R 2019-08-16 draft V0.2.docx	Issued to client for review
V1.0	27-Aug-2019	Final	28627-531x Geomorph R 2019-08-27 final V1.0.docx	Issued to client

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

1 INTRODUCTION

Matrix Solutions Inc. was retained by Minto Communities – Canada on behalf of ClubLink Corporation ULC to provide a fluvial geomorphic assessment of the receiving channel of Beaver Pond and Kizell Drain to its confluence with Watts Creek. The findings of the assessment will provide input for stormwater management practices associated with the proposed development at 7000 Campeau Drive. Stormwater management considerations associated with the development at 7000 Campeau Drive to-date have suggested directing stormwater flows to Beaver Pond. Beaver Pond outlets to an urbanized watercourse on the east side of Walden Drive (MES 2019).

A fluvial geomorphic assessment has been requested by the City of Ottawa to investigate erosion sensitivity and susceptibility of the receiving channel, which may be impacted by development. Figure 1 provides the location of the proposed development, the location of Beaver Pond, and the extent of the watercourses that were investigated as part of this assessment.

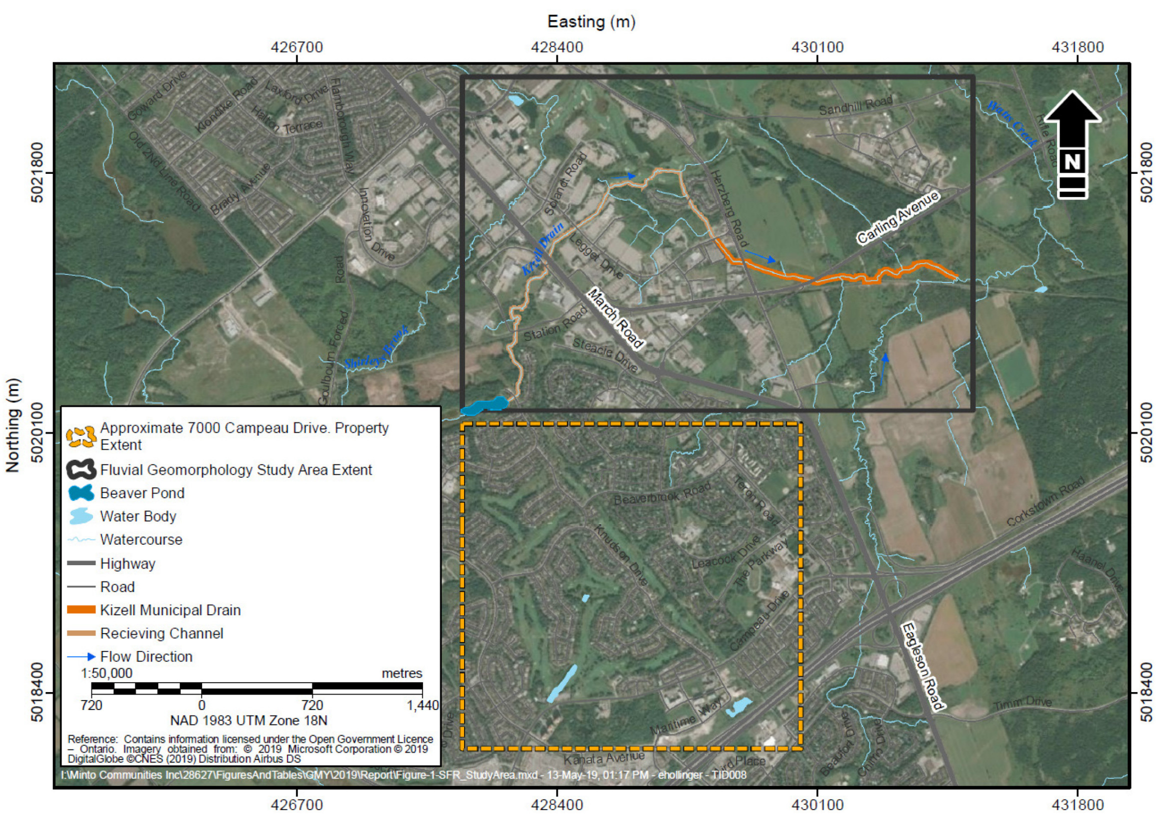


FIGURE 1 Extent of Current Study Area and Approximate Extent of Proposed Development Location (7000 Campeau Drive)

2 BACKGROUND INFORMATION

The following provides a summary of the previously completed studies and development process concerning the project area to-date:

The Marchwood Lakeside Master Drainage Plan (1984) prepared by Cumming Cockburn Ltd. (CCL) - The study proposed the diversion of surface drainage from a large area associated with the KLN development, located within the Shirley's Brook subwatershed, into the Watts Creek system via outlet to the wetland storage of the Beaver Pond stormwater management facility.

The Shirley's Brook/ Watts Creek Subwatershed Study (1999) prepared by Dillon Consulting Ltd. – The study recommends that natural drainage divides between Shirley's Brook and Kizell Drain/ Watts Creek be maintained. Planning progressed on the assumption of the diversion and the remaining phases of KNL (7, 8, and 9) have not accounted for a stormwater management block or blocks that would address stormwater management for the area of the plan naturally draining to Shirley's Brook.

Shirley's Brook and Watts Creek Phase 1 Stormwater Management Study (2011), prepared by AECOM - The study includes hydraulic model updates that indicate that increases in Beaver Pond levels and discharge to the downstream Kizell Drain under existing conditions would exceed the controlled flow value identified in the MOE Certificate of Approval of 0.96 m^3/s for the 100-year event under ultimate development conditions as well as the previously defined quantity control peak flow target of 1.2 m^3/s for the 100-year design event.

Shirley's Brook and Watts Creek Phase 2 Stormwater Management Study (Draft; 2013), prepared by AECOM - The study includes existing peak flow estimates (2-year to 100-year) at locations within the subwatershed of Watts Creek. An updated peak outflow of 1.5 m^3/s was calculated for the Beaver Pond and remains above the target value from the MOE C of A issued for the facility. The findings of the fluvial geomorphological component of the study (Appendix E; JTBES) indicate that the Shirley's Brook and Kizell Drain/Watts Creek systems are in a relatively fragile state and trying to equilibrate to changes induced by past land use changes which over time have altered the flow and sediment regimes. Under existing conditions it is anticipated that overall functioning of all systems will continue to degrade and those reaches currently identified as stable will destabilize. The study contains the identification of sensitive erosion sites and critical flow thresholds along the main branch of Shirley's Brook and Watts Creek, including along Kizell Drain downstream of the Beaver Pond stormwater management facility.

3 EXISTING CONDITIONS

3.1 Surficial Geology

According to Ontario Geological Survey mapping of the Surficial Geology of Southern Ontario, there is a range of geologic materials present in the study area. This includes Precambrian bedrock, Paleozoic bedrock, fine textured glaciomarine deposits (silt and clay, minor sand and gravel), older alluvial deposits (clay, silt, sand, gravel, and organic remains), organic deposits and silty-sand to sand-textured till (OGS 2003).

3.2 Reach Delineation

Watercourse reaches are sections of channel delineated based on changes in the physical characteristics and geomorphological setting. The reach breaks as established in the AECOM (2013) report were maintained for the current study. The reaches investigated as part of the current study extend from KDG-1 to KDG-7. Sub-reaches were identified in some locations as part of the current study to provide additional details regarding lengths of channel susceptible to erosion. Figure 2 provides the location of delineated reach breaks.

3.3 Preliminary Site Investigation

An initial field investigation was completed May 3, 2019 to perform a high-level assessment of the overall condition and to record observable fluvial processes and instances of erosion occurring within the study reaches of the receiving channel and Kizell Drain. As part of the investigation, standardized rapid reach assessments were completed. Two reach assessment techniques were completed that provide a qualitative assessment of channel stability, health, and function. Appendix A provides representative photographs taken during the site investigation.

A Rapid Geomorphic Assessment (RGA; MOE 2003) documents observed indicators of channel instability. Observations made during the field investigation are 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 the channel is stable/in regime (score less than 0.20), stressed/transitional (score 0.21 to 0.40) or adjusting (score greater than 0.41).

The Rapid Stream Assessment Technique (RSAT; COG 1996) provides a broader view of the channel system by also considering the ecological function of the stream. Observations include instream habitat, water quality, riparian conditions, and biological indicators. Additionally, the RSAT approach includes semi-quantitative measures of bankfull channel dimensions, type of substrate, vegetative cover, and channel disturbance. RSAT scores rank the channel as maintaining a low (less than 20), moderate (20 to 35) or high (greater than 35) degree of stream health.

The preliminary site investigation results and observations provided in the sub-sections below are listed from the upstream extent of the study area (outlet of Beaver Pond) to the downstream extent (upstream extent of reach WCG-3, as delineated by AECOM [2013] and demonstrated in Figure 2). Observations of erosion are described in these sections with sensitive locations identified in Figure 3. A summary of channel conditions is provided in Table 1 below. In many cases we were not able to link observed channel alteration or re-alignment to existing information found in previous studies or assessments.

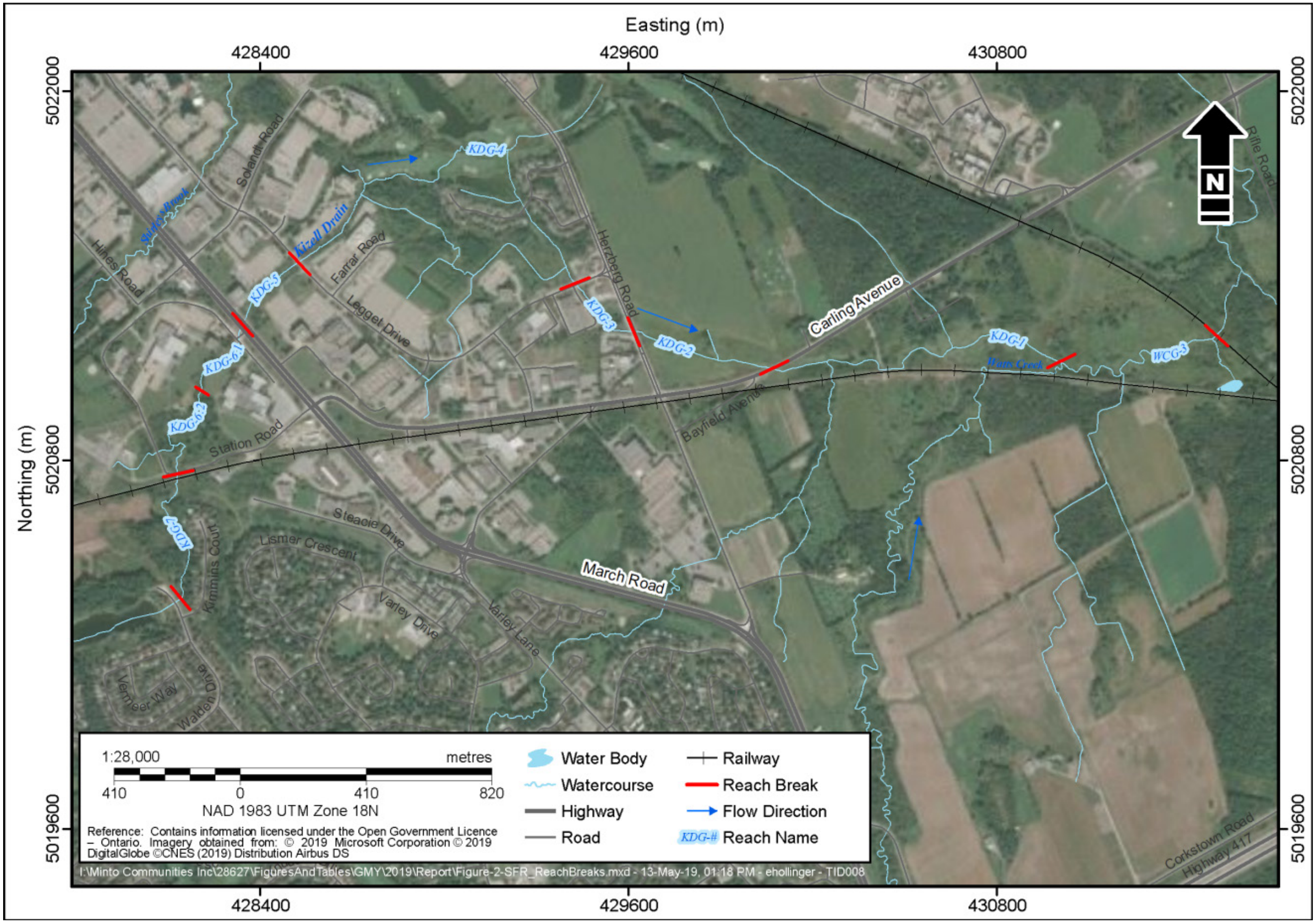


FIGURE 2 Reach Breaks through the Study Area as Delineated by AECOM (2013) with Sub-reaches Identified

3.3.1 KDG-7

Reach KDG-7 extends from the outlet of Beaver Pond on the east side of Walden Drive to the rail and Station Road crossings approximately 480 m downstream. The channel varies in form over its length with a wider stable section at the upstream extent through the backyards of homes. Through this upstream area, the channel is partially backwatered by an exposed bedrock location that is creating a cascade and scour pool downstream where the channel is more open with tall grasses. This area leads to another exposed bedrock area at a pedestrian bridge at the downstream extent. The channel received an RGA score of 0.35 indicating a transitional or stressed section of channel, with the most active process being aggradation. In a number of locations through this reach active bank and toe erosion is occurring. Evidence of planimetric form adjustment (the formation of chutes, the formation of islands and single thread to multiple thread channels) was only observed at the downstream end of the channel where local construction, an exposed bedrock highpoint, and pedestrian bridge, have created an area of excessive deposition during the recent spring freshet. The reach was assigned an RSAT score of 28 indicating moderate health. A wiffle ball and metre stick was used to approximate water velocities during the site investigation and found an approximate water velocity of 0.2 m/s, which roughly corresponds to a discharge of 0.3 m^3/s. At the time of the investigation no evidence of sediment transport was observed through this reach.

3.3.2 KDG-6

Reach KDG-6 was divided into two sub-reaches due to a distinctive change in channel form and riparian quality. Reach 6.2, upstream, is set in a clearly defined floodplain composed mainly of tall grasses and shrubs and transitions into a thicket and wooded area downstream. The sub-reach extends from Station Road to edge of the forested area approximately 330 m downstream. The channel received an RGA score of 0.46, indicating a channel in adjustment. Widening was found to be the most active process. Through the open grassed area some valley wall contacts were noted where the channel has migrated to the edge of the floodplain to the toe of the valley slope. Widening was most prominent through the wooded area where rooting coverage is not as dense as upstream. Observations of aggradation and degradation were also recorded throughout the reach. The reach was assigned an RSAT score of 27 indicating moderate health.

Reach 6.1 extends approximately 240 m to March Road. The reach was assessed separately as it appears heavily altered and the riparian habitat has been removed and replaced with young planted trees and shrubs. The channel showed little evidence of natural channel adjustment and was mostly aggradational with some signs of widening (toe erosion and slumping in select locations). The channel received an RGA score of 0.17, indicating the channel is in regime, and an RSAT score of 24, indicating moderate channel health.

3.3.3 KDG-5

KDG-5 runs between the culvert at March Road to twin culverts at Legget Drive and appears altered and straightened with tall grasses, manicured lawns and parking lots through the riparian zone. Due to the altered nature of the watercourse there are few geomorphic features present. In a number of locations, active lateral channel migration was observed in the form of significant bank erosion and bank failures, often exposing underlying geotextile cloth likely used in recent construction activities as part of channel re-alignment. The upstream end of the reach was also incised to underlying compact clay along the bed of the channel, while the downstream end is a more depositional environment with soft deposits of clay and silt. The RGA score for the reach was 0.24 (transitional) with aggradation observed as the dominating process in the downstream area and degradation dominating upstream. The RSAT score was 20, indicating low to moderate health.

3.3.4 KDG-4

Reach KDG-4 extends from Legget Drive, through the golf course and back to Legget Drive, for a total length of approximately 1.3 km. This length showed few signs of active channel erosion except for the sharp bend just upstream of a pedestrian bridge culvert. The channel appears straightened and the riparian corridor is heavily limited through the golf course. Aggradation was the dominant process with a soft, unconsolidated bed throughout and other evidence of deposition throughout. The reach received an RGA score of 0.30, indicating a transitional section, and an RSAT score of 21 indicating a low to moderate health.

3.3.5 KDG-3

KDG-3 is approximately 250 m in length between Legget Drive and Herzberg Road. The channel is oversized and straight and has been maintained as a municipal drain through this, and downstream reaches of the subject watercourse. The channel is confined between two parking lots and provides little evidence of natural channel evolution given its maintenance, atypical slope, materials and large cross-section. The channel is steep and fast moving water prevents aggradation through this reach. Energy through this section of the channel is not well dissipated as there is little in terms of roughness. Typically this approach to municipal drain maintenance results in significant erosion downstream as un-dissipated energy is transferred to downstream, more susceptible channel reaches. The reach received an RGA ranking of 0.13, suggesting the channel is stable, and a RSAT ranking of 14, or low health.

3.3.6 KDG-2

KDG-2 is approximately 450 m in length between Herzberg Road and Carling Avenue. The channel at this location is also oversized and straight, through agricultural lands. The channel through this section has a more moderate gradient but has been widened significantly. Few geomorphic features were observed through this reach. The channel was mostly aggradational with an RGA ranking of 0.11, suggesting the channel is stable, with an RSAT ranking of 18, indicating low channel health.

3.3.7 KDG-1

The final reach of the Kizell Drain is located between Carling Avenue and the of confluence of the channel with Watts Creek. The channel through this reach also appears straightened and realigned in some sections to accommodate local infrastructure (rail and access crossings). The riparian corridor is slightly improved and the channel is able to migrate more actively through its floodplain. Active erosion was observed at sharp bends where energy is focused to the outer bank. In general the reach was found to be transitional with an RGA ranking of 0.28 and RSAT score of 23, indicating moderate channel health.

TABLE 1 Summary of Preliminary Channel Assessments

Reach	Average Bankfull Width (m)	Average Bankfull Depth (m)	RSAT Stability Ranking (Health)	RGA Stability Index	Most Active Process
KDG-7	2.8	0.6	28 (Moderate)	0.35 (Transitional)	Aggradation
KDG-6.2	2.1	0.6	27 (Moderate)	0.46 (In Adjustment)	Widening
KDG-6.1	3.0	0.7	24 (Moderate)	0.17 (In Regime)	Aggradation
KDG-5	3.5	1.3	20 (Moderate)	0.24 (Transitional)	Aggradation
KDG-4	4.0	1.1	21 (Moderate)	0.30 (Transitional)	Aggradation
KDG-3	4.0	0.8	14 (Low)	0.13 (In Regime)	Degradation
KDG-2	7.0	0.4	18 (Low)	0.11 (In Regime)	Aggradation
KDG-1	3.4	1.0	23 (Moderate)	0.28 (Transitional)	Widening

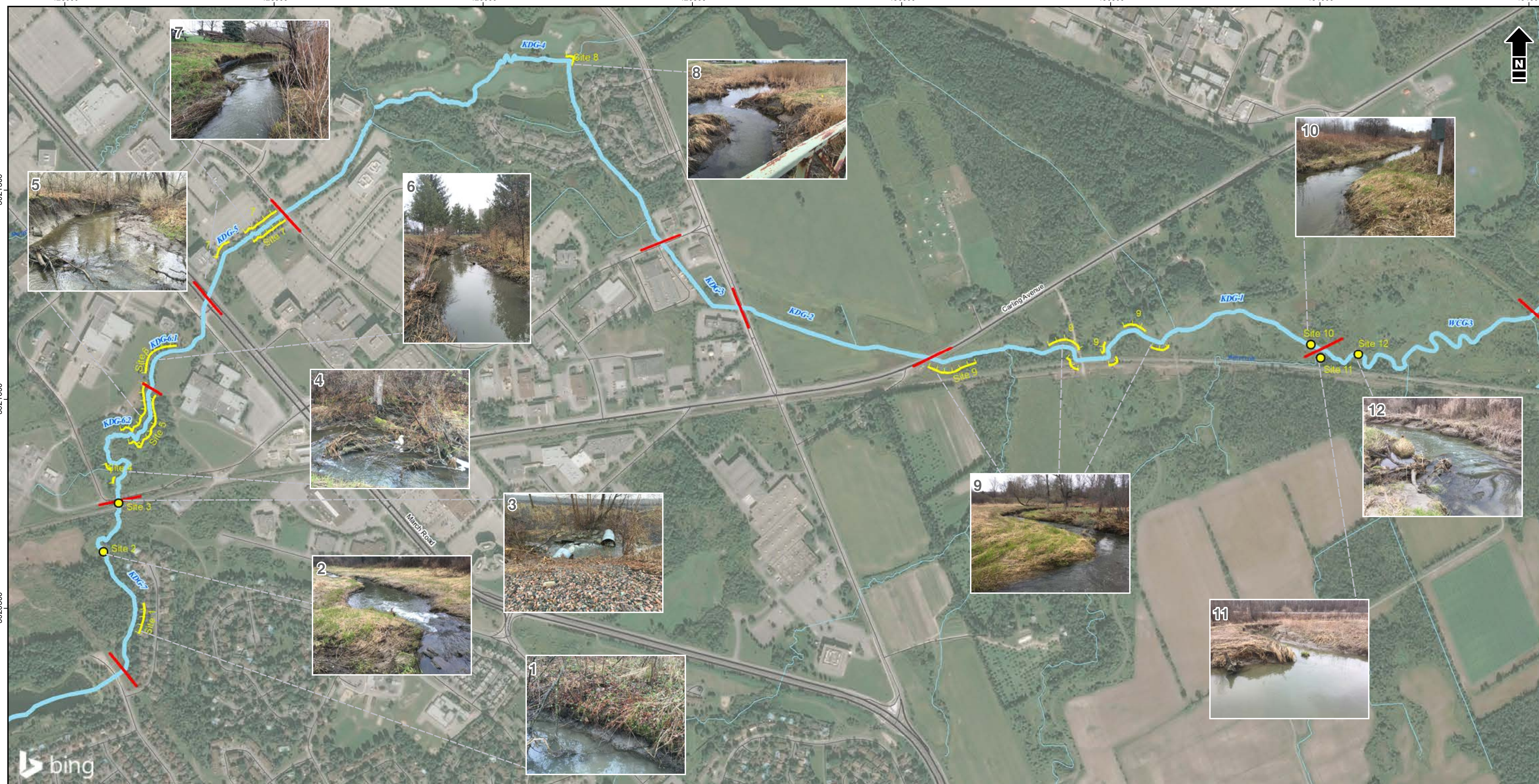
3.3.8 Watts Creek and Downstream Conditions

Watts Creek meets the Kizell Drain downstream of KDG-1. The channel Kizell Drain was investigated as part of this study up to this confluence as the impact of the proposed development would likely be more pronounced in the two to three reaches downstream of the Beaver Pond outlet at Walden Drive.

Watts Creek upstream and downstream of the confluence with the Kizell Drain is dominated by widening and degradation processes, including channel incision into undisturbed overburden, basal scour on the inside of meander bends, steep bank angles, basal scour through both sides of the channel, fracture lines along the top of bank and significant slumping.

Easting (m)

Northing (m)



Water Body
Watercourse
Watts Creek
Highway
Road
Reach Break
Erosion Sites
Erosion Points of Interest

Site	Erosion Characteristics
1	Minor Toe Erosion
2	Scour Pool Downstream of Cascade
3	Poor Culvert Alignment
4	Valley Toe Erosion
5	Erosion Through Wooded Area
6	Minor Toe Erosion and Slumping
7	Bank Erosion/Failures
8	Erosion at 90 degree Bend
9	Erosion at Bends
10	Kizell Drain Upstream of Confluence
11	Watts Creek Upstream of Confluence
12	Watts Creek Downstream of Confluence

1:9,500 metres
100 0 100 200
NAD 1983 UTM Zone 18N

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

Minto Communities Inc.
7000 Campeau Drive

Erosion Inventory Overview

Date:	Project:	Submitter:	Reviewer:
May 2019	28627	M. McCombs	A. Zaghal

Disclaimer: The information contained herein may be compiled from numerous third party materials that are subject to periodic change without prior notification. While every effort has been made by Matrix Solutions Inc. to ensure the accuracy of the information presented at the time of publication, Matrix Solutions Inc. assumes no liability for any errors, omissions, or inaccuracies in the third party material.

Figure 3

Reference: Contains information licensed under the Open Government Licence – Ontario. Imagery obtained from: © 2019 Microsoft Corporation © 2019 DigitalGlobe ©CNES (2019) Distribution Airbus DS

I:\Minto Communities Inc\28627\FiguresAndTables\GMY-2019\Report\Figure-3-Erosion_Inventory_Overview.mxd - Tabloid_L - 14-May-19, 02:52 PM - eholinger - TID004

4 EROSION THRESHOLD ANALYSIS

The erosion threshold analysis was based on reach KDG-6.2. This reach was found to be the most sensitive reach of the Kizell Drain, exhibiting of widening including basal scour through the majority of the reach and on the inside of meander bends, steep bank angles, exposed tree roots, the occurrence of large organic debris in areas and fallen/leaning trees. There were also signs of degradation (channel incision into undisturbed overburden/bedrock, elevated root fan above channel bed, and bank height increases) and aggradation (lateral bars, siltation in pools, deposition on point bars and deposition in the overbank).The survey was collected in the upstream portion of the sub-reach where any existing erosion and incision has not exaggerated the channel cross-section as is the case in cross-sections through the wooded area downstream. Erosion threshold analyses of areas with larger cross-sections as a result of increased widening and degradation and where underlying more compact clay material is exposed through the bed and banks can result in un-representative results.

4.1 Detailed Field Data Collection and Analysis

A total of eight cross-sections and a longitudinal profile were investigated for approximately 240 m of the Kizell Drain through reach KDG-6.2 (the location of the survey and information extracted from representative cross-sections is presented in Appendix B). The surveyed section contained a range of materials along the bed (various coarse and fine material) and bank conditions (tall grasses, shrubs, and sandy clayey silts) typical of the subject watercourse through most of its reaches. The vicinity of the surveyed reach to Beaver Pond is also appropriate as additional inputs to the channel are fewer than sections of greater capacity further downstream.

Three of the cross-sections (XS-1 to XS-3) were surveyed in an area where the bed of the channel was composed of coarse sands and gravels. These materials indicate that these cross-sections were collected in a depositional area. In this case, these deposits were caused by a number of debris jams and bedrock exposures which have created backwatered environments upstream of their location. Sands are highly susceptible to erosion due to their small grain size and lack of cohesion between particles.

Two cross-sections (XS-5 and XS-6) were collected in areas where larger gravels, cobbles, and boulders were observed. The material appeared to match the colour and hardness of local bedrock outcrops and may be natural but may have been placed at a crossing and displaced during larger flow events.

Finally, three cross-sections (XS-4, XS-7, and XS-8) were collected where underlying compact clay was observed. These locations are believed to be the most representative as the effects of backwatering from bedrock exposures were limited. Compact clay was observed as the sub-pavement through the majority of the reach. A summary of the bankfull characteristics of each cross-section is provided in Table 2. Mean diameters of channel bed materials were collected using the method described by Wolman (1954).

Bank materials were entirely composed of sandy and/or clayey silt with a consistently deep (30 cm +) tall grass and shrub rooting structure and high coverage rooting density. Bank angles were steep and undercut but kept intact by the rooting density of the grasses or through contact with underlying compact clays. More notable areas of bank erosion are located at valley wall contacts where the vegetation is dominated by trees, which provide stability to the valley wall. Although the sandy and clayey silts of the banks are erosive materials with low cohesion, the current vegetation and associated rooting provides good shear resistance to existing shear stresses. Native grass lined channels have a permissible shear stress of 57-81 N/m^2 and permissible velocities ranging 1.22-1.83 m/s (Fischenich, 2001), which exceed the critical shear stress and critical velocity ranges of Leda Clay (6-20 N/m^2 and 1.1-1.6 m/s, respectively; Gaskin et al., 2003). Further incision into the channel bottom could cause further instabilities of the banks via increased undercutting which can, in turn, result in slumping of the bank and overbank into the channel. As such, the erosion of the bed material is considered to be the most appropriate in considering erosion thresholds as bank failures are directly related to increased erosion, scour, and incision of the channel bed.

TABLE 2 Summary of Surveyed Cross-Sectional Data

Cross-Section	Bankfull Width (m)	Maximum Bankfull Depth (m)	Approximate Bankfull Discharge (m^3/s)	Mean Bed Material Diameter (mm)
XS-1	2.36	0.29	0.6	5
XS-2	2.78	0.64	2.0	3
XS-3	2.28	0.44	0.9	3
XS-4	2.36	0.29	0.6	29
XS-5	2.19	0.46	1.0	26
XS-6	2.48	0.59	1.4	Compact clay/silt
XS-7	2.87	0.75	2.5	Compact clay
XS-8	2.33	0.74	2.1	Compact clay

In Table 2 above, the approximation of bankfull discharge was calculated using cross-sectional area, the bankfull slope of the channel, a Manning's n of 0.035, and Manning's equation.

4.2 Method

The general procedure for determining erosion thresholds is to evaluate a critical shear stress, or permissible velocity at which the material composing the bed of the channel will begin to mobilize. Once a representative value is established, a model is used which increases the volume of the channel incrementally to the point where the relationship between depth and slope of the channel produces values of shear stress or velocities equal to the critical shear stress or permissible velocities. Matrix uses a number of established entrainment relationships to calculate erosion thresholds in order to consider a range of results. The model results are examined for convergence and compatibility with field observations. Selection of appropriate thresholds is based on an understanding of site conditions and of the assumptions and range of conditions under which the entrainment equations are applicable.

1. Due to the varying slopes and substrates within reach KDG-6.2, two approaches were taken to determine the erosion thresholds of the various materials observed at each cross-section. Cross-sections 1, 2, and 3 were collected in depositional environments created by bedrock highs and woody debris. The bottom materials in these cross-sections were composed of sands and pebbles. Typically finer overlying materials provide a constant sediment source to the channel. The transport of this material is not indicative of an increased rate of erosion in the channel. However the transport of underlying material and coarser materials found in riffles is an indication of the sediment transport or natural erosion processes of the channel. The bed substrates in cross-sections 5 and 6 were largely made up of gravels with a median grain size (D_{50}) of 29 and 26 mm, respectively. Therefore, thresholds were derived from Neil (1967). This method was developed for uniform particles ranging from 6 to 30 mm in size (gravel) and relates competent mean velocity to grain size, specific gravity, and depth of flow to predict when bed material will first be displaced. The equation is as follows:

$$\frac{\rho V_{mc}^2}{Y_s' D_g} = 2.50 \left(\frac{D_g}{d}\right)^{-0.20}$$

Where:

- ρ is specific weight of water
- V_{mc} is competent mean velocity
- Y_s' is specific weight of sediment
- D_g is effective grain size and d is depth of flow

2. In the case of cohesive sediment (compact clay), the analysis must rely on relationships developed through literature that have been applied to determine the maximum permissible shear stresses for samples of cohesive sediment. The second method by Chow (1959) provides estimates of critical shear stress based on the void ratio (or level of compactness) of various cohesive materials (Figure 4). Values in the range of fairly compact to compact clays in Figure 4, as found onsite, are comparable to erosion tests of Leda Clay, typical of the Ottawa area. The study by Gaskin et al. (2003) determined critical shear thresholds of Leda Clay ranging between 6 to 20 N/m^2 and critical velocities to range between 1.1 to 1.6 m/s.

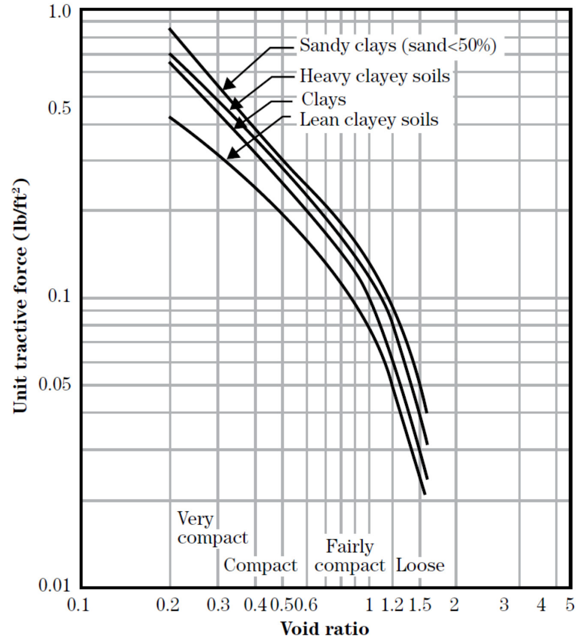


FIGURE 4 Allowable Shear Stress in Cohesive Material (Chow 1959; Figure 7-11, p.174)

Once the critical shear stress is determined based on the studies described above, thresholds are subsequently calculated for each cross-section using the iterative process described at the beginning of this section.

4.3 Results

Table 3 presents the findings of the erosion threshold; two sets of results are presented as part of this study. The first set, using the method by Neil (1967) presents the erosion threshold findings of the riffle cross-sections composed of coarse, non-cohesive material. The second set, using the method by Chow (1959), presents the results of the cross-sections where cohesive sediment dominates. In these tables, the critical shear stress is a value that represents the force required to shear a given particle from its surface. Critical discharge, depth, and velocity are evaluated from an iterative model and values correspond to the flow at which sediment particles become suspended into the water column. Cross-section and longitudinal profile data used in the model was extracted from the GPS based survey of the channel collected on May 6, 2019.

TABLE 3 Averaged Erosion Threshold Results

Method	Parameter	Average Results
Neil (1967) – For coarse material (gravels) found at riffle locations – XS-5 and XS-6.	Permissible velocity (m/s)	1.33
	Critical discharge (m^3/s)	**0.88**
	Maximum cross-section depth (m)	0.39
	Maximum cross-section velocity (m/s)	1.38
Chow (1959) – For exposed cohesive compact clays through runs – XS-4, XS-7, and XS-8.	Critical Shear Stress (N/m^2)	20
	Critical discharge (m^3/s)	**0.50**
	Maximum depth (m)	0.34
	Maximum velocity (m/s)	1.21

The results presented in Table 3 were based on a 0.78% bankfull slope and the observed composition of channel bed materials. The results suggest that the median grain size of the material found in the riffles would be transported at a critical discharge of 0.88 m^3/s based on the method by Neil (1967).

The results from Chow suggest a range of possible results based on the compactness of the bed material which was composed predominantly of compact clay. Using a critical shear stress at the upper range of Leda Clay of 20 N/m^2 (Gaskin et al. 2003), a maximum cross-sectional velocity of 1.21 m/s was calculated. The assumption that the upper range of critical shear stresses is representative of the in-situ material is appropriate given that the range of permissible velocities for Leda Clay of 1.1 to 1.6 m/s. As such, a critical discharge of 0.50 m^3/s is assumed to be representative of this material.

4.4 Comparison with AECOM (2013) Results

JTBES in the AECOM report (2013) indicated that the critical velocity for reach KDR-4 was 0.271 m/s. If the flow is back-calculated based on the bankfull cross-section dimensions reported by JTBES, the critical discharge would be approximately 0.08 m^3/s. The JTBES report acknowledged that a discrepancy existed because, based on these results the sediment of the bed should be in transport even under low flow conditions, however there was little or no evidence of sediment entrainment at the time of their investigation. JTBES attributed this to the presence of the silt and clay fraction comprising the bed for which additional factors were not considered in their analysis (i.e. cohesiveness of the material). In comparison, the analysis carried out in this report has paid special attention to the complexity of streambed structure and framework and therefore resulted in critical discharge values that are more reasonable and representative of river mechanics along the study area.

5 RECOMMENDATIONS

During the site investigation, there were no indications of major concerns of erosion affecting critical infrastructure downstream of Beaver Pond within the study reaches examined as part of this study. The location of greatest risk appears to be through reach KDG-5 where active channel erosion has resulted in bank failures. The most intense failures occur in locations where there is no riparian vegetation along the banks and manicured lawns do not provide the erosion resistance observed in other reaches. These locations are exposed to future erosion. This reach is far enough downstream that the impacts of the proposed development would be immeasurable if existing stormwater management practices at the Beaver Pond and contributing areas are maintained. Further, there are numerous contributions from tributaries and stormwater management outlets in the interim distance between KDG-5 and the reaches downstream of the outlet, which will attenuate potential impacts of increased flows as a result of the development.

From an overall channel health perspective, there are two culverts that are of concern, but do not create an immediate risk to infrastructure. The culverts between the rail and Station Road lack a smooth transition between them. This location is identified in Figure 3 with a picture of the misalignment. There is also a culvert at the reach break between KDG-6.2 and KDG-6.1. The crossing is wider than bankfull but the obvert was only approximately 30 cm above the water level at the time of the field investigation. It is believed that the backwater effect of this culvert contributes to some portion of widening upstream through KDG-6.2.

Under existing conditions, the straightened and enlarged cross-sections of the length of watercourse maintained as a municipal drain are effective at displacing water quickly but can be damaging to downstream reaches. Channels generally migrate and meander. A natural channel form is effective at reducing channel energy in the form of roughness and through a dynamic equilibrium between erosion and deposition. Municipal drains, while effective at conveying water, do not provide a great deal of energy dissipation which often results in excessive erosion in downstream, more natural reaches, such as Watts Creek.

6 CONCLUSION

A fluvial geomorphic assessment was completed for the receiving channel of Beaver Pond and Kizell Drain to its confluence with Watts Creek to provide input for stormwater management practices associated with the proposed development at 7000 Campeau Drive.

As part of the assessment, a preliminary assessment of the study reach was completed using RGAs and by identifying erosion sensitive locations. Following an analysis of the preliminary findings, a representative reach suitable for erosion threshold analysis associated with inputs from Beaver Pond was completed and found that a critical discharge of 0.50 m^3/s was representative.

7 REFERENCES

AECOM. 2013. Shirley's Brook and Watts Creek Phase 2 Stormwater Management Study. Draft Report. Prepared for: City of Ottawa, March 2013.

Chow, V.T., 1959. Open-Channel Hydraulics. McGraw-Hill, New York, 584 pp.

Dillon Consulting Limited. 1999.Shirley's Brook and Watts Creek Subwatershed Study, Main Report. Submitted to: City of Kanata and Region of Ottawa-Carleton.

Fischenich, 2001. Stability Thresholds for Stream Restoration Materials. EMRRP Technical Notes

Collection (ERDC TN-EMRRP-SR-29), U.S. Army Engineer Research and Development Center,

Vicksburg, M.S. www.wes.army.mil/e/emrrp.

Galli, J. 1996. Rapid stream assessment technique, field methods. Metropolitan Washington Council of Governments. 36pp.

Gaskin, S.J., Pieterse, J., Al Shafie, A., Lepage, S. 2003. Erosion of undisturbed clay samples from the banks of the St. Lawrence River. Canadian Journal of Civil Engineering, 30: 585-595.

JTB Environmental Systems Inc. 2013. Fluvial Geomorphology Draft Existing Conditions Report. Contained in Appendix E of Shirley's Brook and Kizell Drain/Watts Creek Phase 2 Stormwater Management Study (Draft), AECOM, March 2013. Prepared for: City of Ottawa.

Komar, P.D., 1987. Selective gravel entrainment and the empirical evaluation of flow competence. Sedimentology, 34: 1165-1176.

McKinley Environmental Solutions (MES). 2019. *Combined Environmental Impact Statememtn and Tree Conservation Report – Kanata Golf and Country Club Redevelopment.*

Ministry of the Environment. 2003. Stormwater Management Planning and Design Manual, Ontario Ministry of Environment, March 2003.

Neill, C.R., 1967. Mean Velocity Criterion for Scour of Coarse Uniform Bed Material. Proc. 12th Cong. Int. Assoc. Hydraulic Research, Fort Collins, Colorado, 46-54.

Ontario Geological Survey. 2003. Surficial Geology of Southern Ontario.

Wolman, M.G. 1954. A method of sampling coarse bed material. Transactions of the American Geophysical Union, 35(6): 951-956.

APPENDIX A

Site Photographs

Matrix Solutions Inc.
May 2, 2019

1. KDG-7 between outlet from pond and crest of cascade looking upstream.

Matrix Solutions Inc.
May 2, 2019

2. KDG-7 bedrock/large boulder cascade looking downstream.

Matrix Solutions Inc.
May 2, 2019

3. KDG-7 downstream of cascade looking downstream toward area under construction (left/west).

Matrix Solutions Inc.
May 2, 2019

4. KDG-7, downstream extent where exposed bedrock and breached beaver dam have created a depositional area.

Matrix Solutions Inc.
May 2, 2019

5. KDG-6.2, part of detailed survey location upstream of thicket looking downstream.

Matrix Solutions Inc.
May 2, 2019

6. KDG-6.2/6.1 reach break at location of culvert.

Matrix Solutions Inc.
May 2, 2019

7. KDG-6.1, typical section looking downsteam from reach break with KDG-6.2.

Matrix Solutions Inc.
May 2, 2019

8. KDG-5 typical section looking downstream.

Matrix Solutions Inc.
May 2, 2019

9. KDG-4 upstream of golf course looking downstream from pedestrian crossing.

Matrix Solutions Inc.
May 2, 2019

10. KSF-4 typical section.

Matrix Solutions Inc.
May 2, 2019

11. KDG-3, looking downstream from Legget Drive.

Matrix Solutions Inc.
May 2, 2019

12. KDG-2 looking downstream from culvert at Herzberg Road.

Matrix Solutions Inc.
May 2, 2019

13. KDG-1 looking downstream from Carling Avenue.

Matrix Solutions Inc.
May 2, 2019

14. KDG-1 looking upstream of confluence with Watts Creek.

Matrix Solutions Inc.
May 2, 2019

15. Watts Creek upstream of confluence with the Kizell Drain.

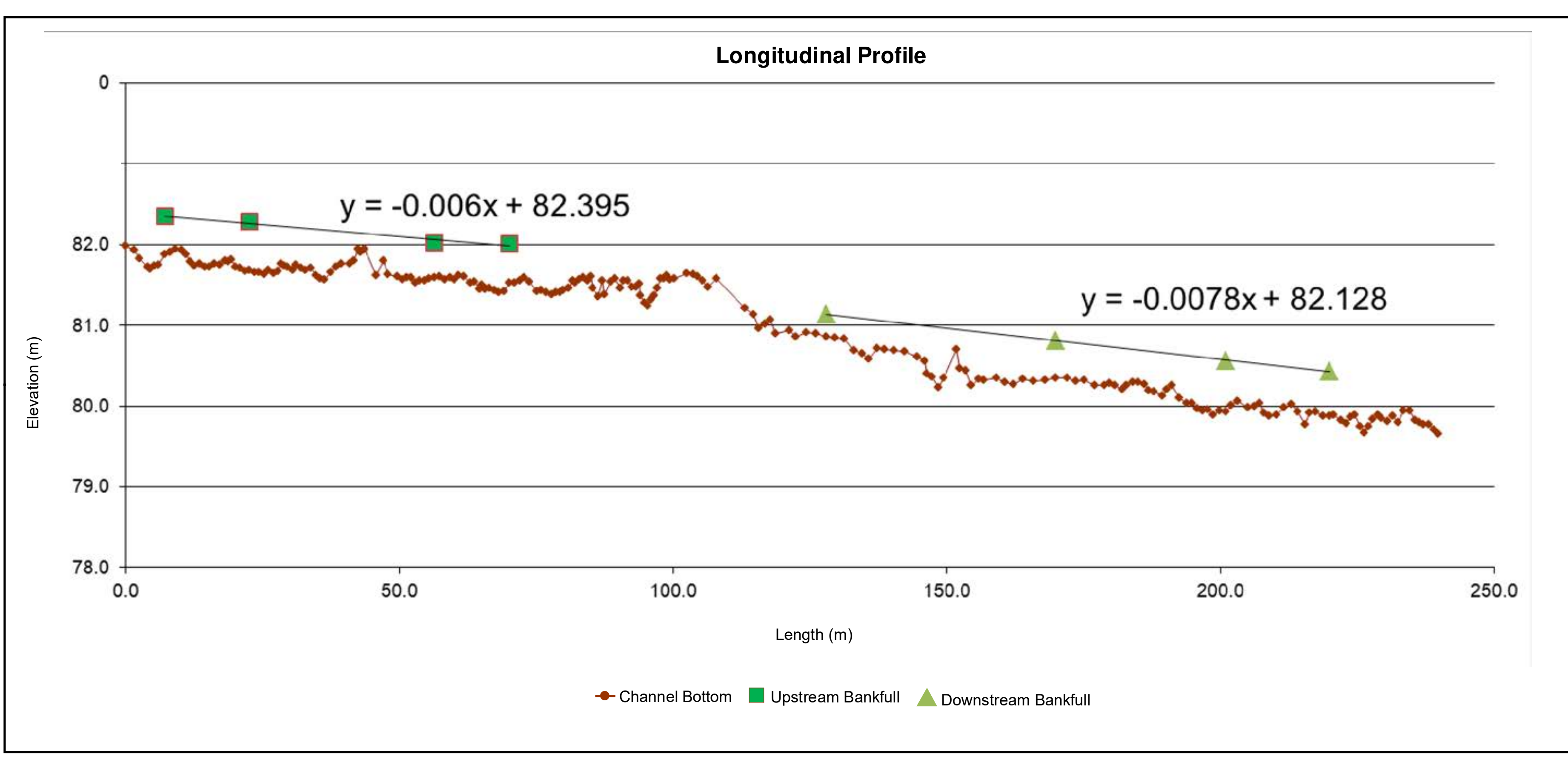
Matrix Solutions Inc.
May 2, 2019

16. WCG-3 downstream of confluence with the Kizell Drain.

APPENDIX B

Detailed Survey

I:\Minto Communities Inc\28627\FiguresAndTables\GMY\2019\Report\Appendix-B-Detailed_Survey.mxd - Tabloid_P - 14-May-19, 03:04 PM - ehollinger - TID003



Road
Watercourse
Surveyed Channel
Cross-section

1:20,000 metres
210 0 210 420
NAD 1983 UTM Zone 18N

Reference: Contains information licensed under the Open Government Licence – Ontario. Imagery obtained from: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

Minto Communities Inc.
7000 Campeau Drive

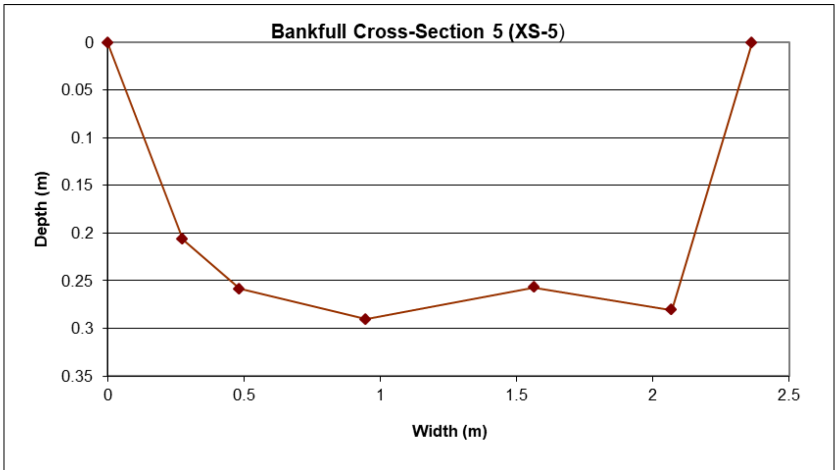
Detailed Survey

Date:	Project:	Submitter:	Reviewer:
May 2019	28627	M. McCombs	A. Zaghal

Appendix
B

Riffle Cross-sections

Cross-Section 5 (XS-5):



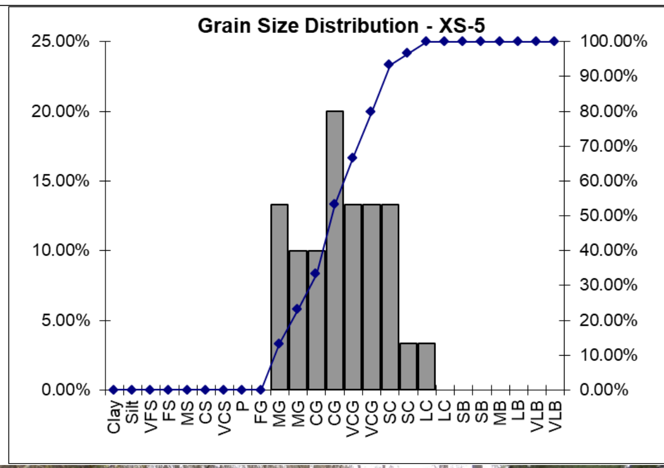
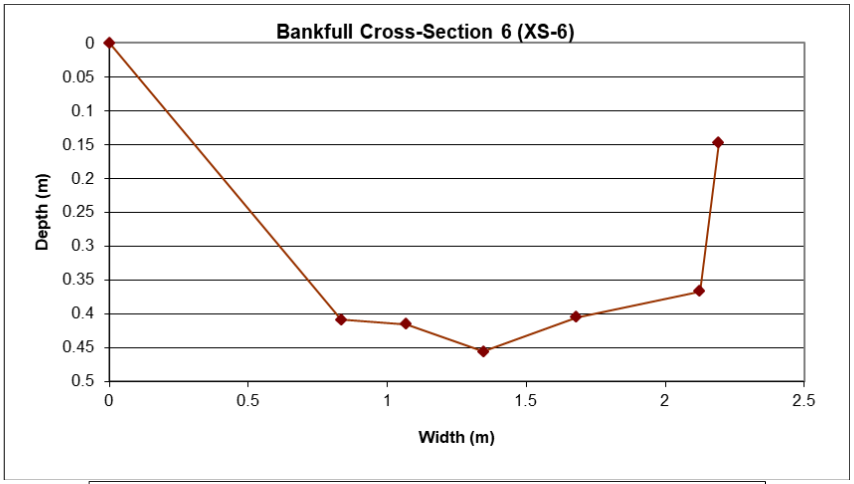


FIGURE B1 XS-5 looking downstream

Cross-Section 6 (XS-6):



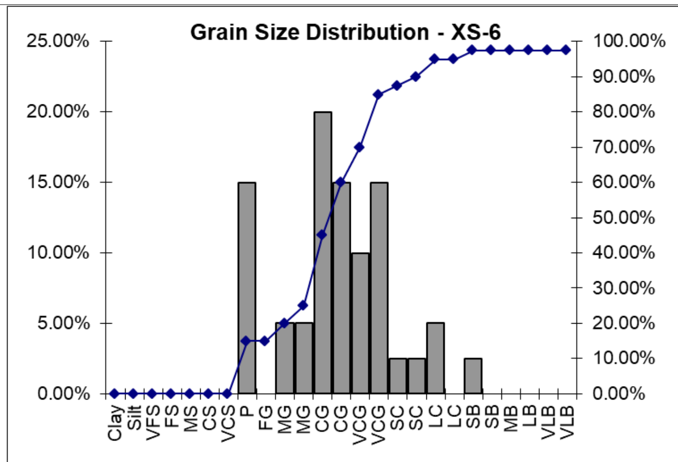
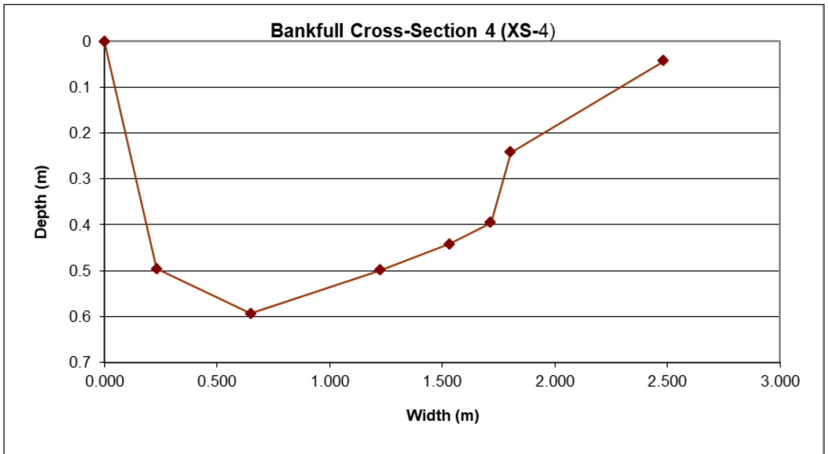


FIGURE B2 XS-6 Looking Downstream

Compact Clay Dominated Run Cross-Sections

Cross-Section 4 (XS-4):



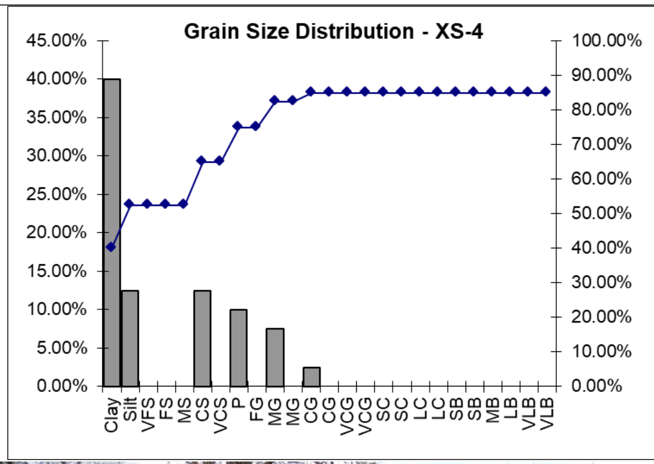
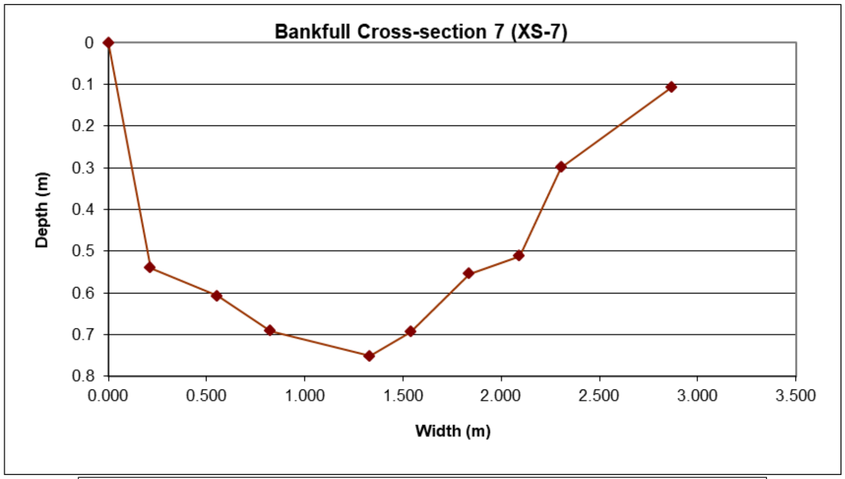


FIGURE B3 XS-4 Looking Downstream

Cross-Section 7 (XS-7):



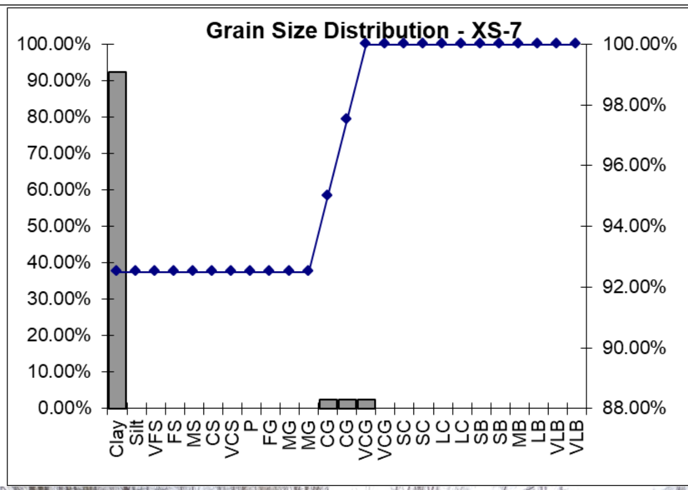
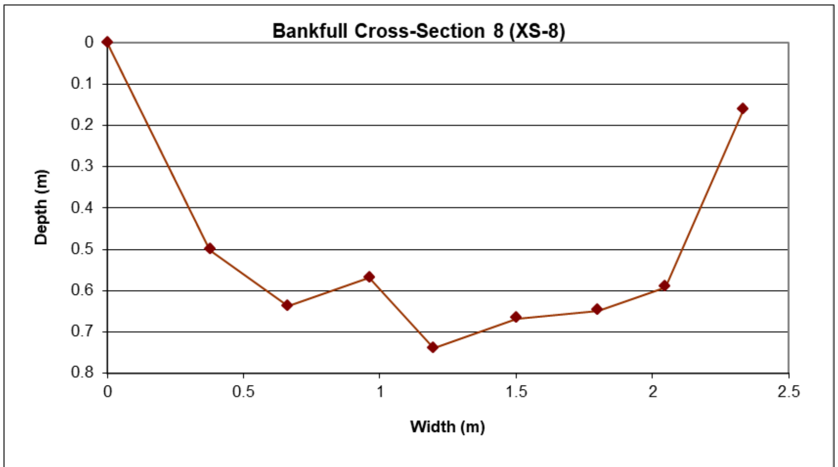


FIGURE B4 XS-7 Looking Downstream

Cross-Section 8 (XS-8):



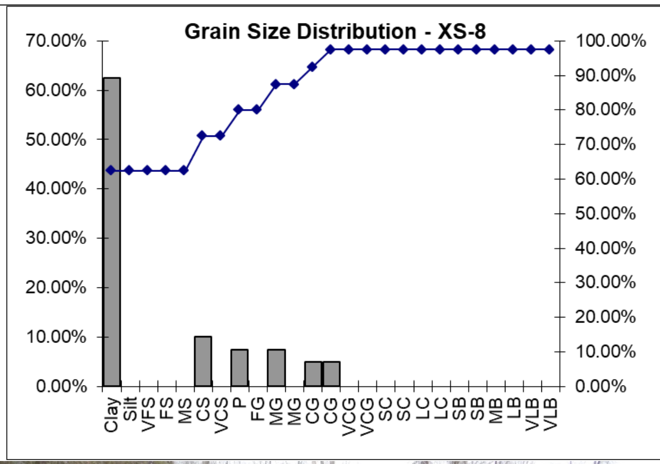


FIGURE B5 XS-8 Looking Downstream