Kizell Drain Downstream of 7000 Campeau Drive Geomorphological and Erosion Threshold Assessment

Kizell Drain
Kanata, Ontario

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Observations

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1 Introduction

As part of the submission package to the City of Ottawa regarding the proposed 7000 Campeau Drive development, a geomorphological and erosion threshold assessment was completed for the receiving watercourse, Kizell Drain and Watts Creek, by Matrix Solutions, on behalf of Minto Communities and Clublink Corporation, ULC. After submission, the City of Ottawa provided preliminary comments related to the erosion threshold received by the applicant on December 22, 2019, and additional comments resulting from a technical review by JTBES on June 5, 2020. GEO Morphix Ltd. was retained by Minto Communities, on behalf of ClubLink Corporation ULC to complete a technical review of the erosion threshold assessment and provide a response to comments to address the City's questions and concerns, and those presented by the technical review.This report therefore summarizes a geomorphological and erosion threshold assessment completed for the Kizell Drain, a tributary of Watts Creek, downstream of 7000 Campeau Drive in Kanata, Ontario. This exercise was completed to inform and support storm water management strategies to ensure no exacerbated rates of erosion or sedimentation occur within the receiving watercourse. To accomplish this, a detailed review of background information was completed to gain context into the channel's condition from an erosion perspective. Sensitive reaches located downstream of 7000 Campeau Drive in Kizell Drain up to Watts Creek previously identified by the work of other consultants were investigated, and an erosion threshold was calculated for the two most sensitive reaches to understand the potential impact of development on the watercourse.

The assessment included the following components:

- Desktop analysis for determining the potential zone of impact, which is the extent of the channel reaches to be assessed
- Review of relevant background materials, including existing watershed data
- Historical assessment of the receiving watercourse using aerial imagery to evaluate changes to the watercourse and its catchment area
- Field assessments to determine the overall stability of the drainage feature on a reach-by-reach basis
- Rapid assessments to quantify the stability and 'stream health' of the watercourse using the Rapid Geomorphological Assessment (RGA) and Rapid Stream Assessment Technique (RSAT)
- Review of substrate characteristics from an erosion threshold perspective for materials found within the channel bed and banks
- Two detailed geomorphological assessments, the primary objective of which is to determine the critical flow or erosion threshold for the most sensitive reaches
- Calculation of the erosion threshold based on observed field conditions, detailed survey, and analysis/modelling

2 Study Area

Assessments completed to determine erosion concerns associated with a particular development are typically limited to a section of channel within 2 to 3 reaches of the site's proposed discharge location to the receiving watercourse. This study included additional work to ensure no exacerbated issues on the sensitive watercourse, and therefore the potential zone of impact for storm water discharge originating from the proposed development at 7000 Campeau Drive was delineated as the 4.5 km of Kizell Drain extending from Beaver Pond to its confluence with Watts Creek. Here, the proposed development occupies approximately 6% of the catchment area of Kizell Drain.

We note that the City of Ottawa had requested an assessment to be completed from the discharge location through Kizell Drain and Watts Creek to its confluence with the Ottawa River. However, if erosion can be mitigated at the most sensitive sites within the proposed study area, evaluating conditions within Watts Creek would be a redundant exercise.

As one travels downstream away from a proposed development, the impacts from a given development become less apparent as the cumulative influences from other urban developments, watercourse re-alignments and local riparian conditions become more pronounced. Consequently, it becomes more difficult to distinguish the impacts of the development in question from other factors, particularly in this situation where the proposed development composes a low proportion of the overall catchment area. Specifically, the approximate proportion of the watershed occupied by the proposed development area upstream of the confluence of Kizell Drain and Watts Creek, downstream of this confluence, and at the confluence of Watts Creek and the Ottawa River, are 7%, 4% and 2.8%, respectively.

When appropriate erosion threshold and exceedances exercises inform storm water management strategies and conditions within the nearby most sensitive reaches match or nearly match existing conditions it is expected that no impacts will occur downstream. This is the appropriate approach to mitigating erosion, which is onsite control to mitigate changes in hydrology at the source. We have therefore assumed that addressing potential concerns by onsite control limiting impacts on the smaller sensitive reaches within Kizell Drain, which likely have more limited assimilation capacity, provides a target to address the potential development's impact on the larger watershed.

2.1 Geology

Channel morphodynamics are largely governed by the flow regime and the availability and type of sediments (i.e., surficial geology) within the stream corridor. 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.

The study area is located within the Ottawa Valley Clay Plain physiographic region, which occupies the majority of the Ottawa River Valley in Ontario. Specifically, the study area is characterized as a Clay Plains, composed predominantly of glaciomarine deposits of Leda Clay originating from the Champlain Sea. Local surficial geology along the tributary consists of the aforementioned glaciomarine deposits which are predominantly composed of clay and silt, with minor sand and gravel (OGS, 2010).

The sediments which compose Kizell Drain are dominated by cohesive clay materials. These materials, while small, are relatively resistant to erosion due to their cohesiveness. This creates a semi-alluvial environment in which the bed is not composed of a material which is prone to re-working based on fluvial processes, which is expected in fully alluvial systems.

3 Background Review

To gain insight into the existing conditions of Kizell Drain from an erosion perspective, the following previously completed studies were reviewed:

- Stantec & JTBES. 2011. Watts Creek Watercourse and Watershed Management Plan. Submitted to: National Capital Commission.
- AECOM & JTBES. 2015. Shirley's Brook and Watt's Creek Phase 2 Stormwater Management Study: Fluvial Geomorphologic Assessment. Submitted to: City of Ottawa
- Rennie, C.D. 2016. Linking Sediment Erodibility and Channel Stability to Utilization of Available Habitats by Fish Populations in Watts Creek. Prepared for: Binitha Chakraburtty, Sr. Municipal Engineer, National Capital Commision.
- Matrix Solutions Inc. 2019. Kizell Drain Erosion Assessment, Proposed Redevelopment of Kanata Golf and Country Club, 7000 Campeau Drive, Ottawa.
- JTBES. 2020. Memo: Peer Review of Kizell Drain Erosion Assessment authored by Matrix Solutions. Submitted to: City of Ottawa.

The fluvial geomorphology work from both the 2011 Stantec study, as well as the 2015 AECOM study were completed by JTBES. As such, the criteria provided within the 2015 study was treated as the most up to date information, and was used as a comparison with our analysis.

The most recent JTBES study completed on behalf of AECOM (2015) provided a characterization of the existing fluvial geomorphological conditions for Kizell Drain, and included detailed assessments at four reaches and rapid assessments of all reaches within the study area downstream of Beaver Pond. Matrix (2019) noted for this planning level assessment that JTBES used a critical velocity approach in calculating an erosion threshold for Leda Clay, the material which composes the channel bed. This critical velocity was determined to be 0.271 m/s, which according to the calculations by Matrix (2019), coincides with a critical discharge of 0.08 m^3/s for a typical cross section retrieved from the JTBES led study (AECOM, 2015).

In 2016, a publication from Rennie reviewed the erosion regime within Watts Creek and its main tributary, Kizell Drain. In this instance, a flume exercise was undertaken to evaluate the shear stress required to initiate transport of the Leda Clay which composes the channel bed. Specifically, the bed shear stress was recorded at the instance where any evidence of suspended or bed load transport was observed. This is considered to be a highly conservative approach, given that the flow conditions within flumes are not typically experienced in natural channels due to changes in substrate composition and the impacts of bedforms, vegetation, and sinuosity. This flume study found a critical shear stress of 3.7 N/m^2 for Leda Clay.

In 2019, Matrix Solutions completed an assessment of Kizell Drain to determine a critical erosion threshold for the purpose of informing storm water management strategies at the proposed 7000 Campeau Drive development. The study adopted a similar approach to the AECOM work, in that a sensitive reach was determined, and field data informed the identification of a critical shear stress and discharge associated with the dominant material which composes the channel bed, Leda Clay. This material was determined to have a critical shear stress of 20 N/m^2. Using the detailed assessment completed within the sensitive reach, KDG 6-2, this critical shear stress occurred at a critical discharge of 0.5 m^3/s which was selected to inform storm water management strategies.

A technical review of the work by Matrix Solutions was recently completed by JTBES (2020), which offered several questions pertaining to the methodology used to calculate the erosion threshold. Specifically, the technical review suggested that a more appropriate location for the sensitive reach is KDG-5 (KDR-4) as opposed to KDG-6-2, that more direct measurements be used as inputs to threshold calculation and interpretation and questioned the selection of sediment transport equations. As well, the memo suggested an erosion exceedance exercise to be completed for the purpose of integrating the erosion thresholds with proposed hydrological changes as a result of development.

4 Historical Assessment

A series of historical aerial photographs were reviewed to determine changes to the channel and surrounding land use. This information, in part, provides an understanding of the historical factors that have contributed to current channel conditions. For this exercise, the 1976, 1999 and 2017 photographs from the City of Ottawa online interactive mapping tool were reviewed. Cropped aerial photographs of the watercourse are provided in **Appendix A**.

In 1976, land use within Kizell Drain's watershed was predominantly agricultural, with the remainder consisting of urban areas located within Kanata to the south, and isolated forested and marshy areas to the west and north. Downstream of Beaver Pond, up to Watts Creek, the channel had mostly been straightened to facilitate agricultural activities. Fragmented sections where the channel maintained a natural planform were located between Beaver Pond and March Road, and a portion of the channel between the two current Legett Drive crossings. Between Beaver Pond and March Road, Kizell Drain had a meandering planform with low sinuosity and conveyed flows through a mixture of forest and wet meadows. Between the two Legett Drive Crossings, a short section of channel consisted of an on-line wetland. North east of this on-line wetland was another wetland area which was drained by a small tributary which formed a confluence with Kizell Drain near the downstream Legett Drive crossing, which at the time was a small dirt road.

Between 1976 and 1999, land use shifted to predominantly urban within Kizell Drain's catchment. In general the channel maintained its historic planform, with two exceptions. Immediately downstream of Beaver Pond, a section of the channel had been re-aligned to the west to facilitate development, and straightened up to a wooded area approximately 150 m from the outlet of the Pond. Several flooded sections of channel between the re-aligned section of channel and March Road suggest beaver activity was prevalent during this period. Between March Road and the downstream Legett Drive crossing, notable commercial development had occurred. This included the construction of a SWM pond which discharged into Kizell Drain at the on-line wetland area between the two Legett Drive crossings. Downstream of this location no changes were noted to the channel up to its confluence with Watts Creek.

In 2015, the primary land use change within the Kizell Drain catchment was the construction of the Marshes Golf Course. Some infilling within the business park nearby to Legett Drive and March Road had also occurred, including the construction of the buildings and associated parking lots which currently flank Site KDR-4. As part of the construction of the Marshes Golf Course, significant alterations to Kizell Drain's planform were completed. This included redirecting a portion of the flow from Kizell Drain to the north into the Marshes Golf Course, through the approximate location of the aforementioned historic tributary and its associated wetland. The two branches of Kizell Drain, the historic wetland and the channel through the golf course, form a confluence near the downstream Legett Drive crossing. Downstream of this crossing, the channel shows no change from 1976.

Through the historical record, no significant observations of lateral channel migration or planform alterations were observed, notwithstanding engineered re-alignments, and temporarily impounded areas likely due to beaver activity. Notably, any potential increases in erosion within the channel are not discernible with this resolution of study. This information suggests that Kizell Drain is relatively stable from an erosion hazard perspective in its existing condition. The channel has however been impacted by channelization for agricultural purposes, and modifications resulting from the development of the Marshes Golf Course.

5 Watercourse Characteristics

5.1 Reach Delineation

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

Reaches are typically delineated based on changes in the following:

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

In this instance our study relied on past reach delineations completed by JTBES (2015) and supported by Matrix Solutions Inc. (2019). For this report, the four detailed sites downstream of Beaver Pond within Kizell Drain, which were previously determined to be most sensitive to erosion by JTBES were reviewed. These sites are labelled KDR-X, and occur within larger reaches labeled KDG-X. A reach map is provided within **Appendix B**, field observations are available within **Appendix C**, and a photo record is available within **Appendix D**. Given the previous work completed in this watershed and that sensitive reaches have been identified and reviewed by several practitioners, this approach was deemed appropriate.

5.1.1 Reach Observations

An initial field investigation to complete rapid geomorphic assessments at the detailed assessment locations of AECOM and JTBES (2015) was completed on May 29, 2020, and included the following:

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

These observations and measurements are summarized below from upstream to downstream. 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 C**.

Detailed Assessment Site KDR-4, located within **Reach KDG-7**, is the receiving reach for flows from Beaver Pond, and the proposed 7000 Campeau Drive development. Here, a detailed survey and study was completed by JTBES in support of the AECOM subwatershed study of Watts Creek. KDR-4 extends from the outlet of Beaver Pond to a partially confined wetland area upstream of the CN Rail to the north. The channel at this location has a high degree of variability with respect to surrounding land use and riparian buffer. At the upstream extent, the channel is lined with large boulders at the outlet of Beaver Pond. A short distance downstream, the backyards of homes extend to the waters edge with significant disturbances ranging from large boulders placed along the right bank to manicured lawns. This area is also backwatered by a bedrock outcropping and what appeared to be deposited boulders and cobble. The outcrop extends approximately 90 m in length through a wooded area before entering the meadow at the downstream extent of the reach.

Where the channel is backwatered, the surficial material on the channel bed is composed of loose and unconsolidated silts and sands, which are assumed to represent transient materials that are frequently suspended during high frequency storm events. Where the underlying bed and bank materials are exposed, clay materials dominate the soil composition. Along the bed, the clay is compact whereas, along the banks, sands and silts can also be observed and felt within the clay. The section of channel through the wetland at the downstream extent of KDR-4 exhibits the most evidence of natural channel processes including a natural planform and no evidence of re-alignment. At this location, pebbles and sands can be observed along the thalweg, the location in the channel which conveys the majority of flow, overlying compact clay which is exposed in several areas and at the toe of the bank. The dense rooting structure of the tall grasses in this area stabilize the upper portion of the banks. In most locations, undercutting (averaging 20 cm in depth) was observed in the softer sandy silty clay section of the bank between the overlying root-enforced material and the underlying compact clay.

The average bankfull width exceeded 3 m upstream of the bedrock outcropping whereas the bankfull width in the natural area downstream was approximately 3 m. Average bankfull depths were approximately 0.6 m consistently through the reach. Average wetted width on the day of assessment was approximately 2.5 m upstream and 1.5 m downstream of the chute and the average wetted depth was approximately 0.15 m. Bank angles ranged from 30° to 90°.

Detailed Assessment Site KDR-3, located within **Reach KDG-5**, extends from Regional Road 49 (March Road) to Legett Drive between two large parking areas which drain directly to the riparian zone of Kizell Drain. At the time of the rapid and detailed assessments, the channel was heavily backwatered by a beaver dam over 1 m in height near the downstream extent of the reach The material composition of the channel through **KDR-3** is similar to that of **KDR-4**. The bed is mostly composed of compact clay while the banks are composed of looser clays that are more susceptible to erosion. Due in part to the backwatered condition of the site, unconsolidated sands and silts were noted along the bed of the channel. The banks were generally steep with undercutting below the root mass. There are several disturbances along this reach that create instances of larger bank failures. At these locations exposed filter cloth, failed boulder treatment and a lack of riparian vegetation suggest that alterations to the channel (straightening and localized hardening) and riparian zone (mowed lawn at the picnic table area) have exacerbated local bank erosion.

Average bankfull width and depth were approximately 3.0 m and 0.5 m, respectively. Wetted width and depth varied significantly through the study area due to the backwatering effects of the beaver dam. Bank angles ranged considerably throughout the study reach but the majority of bank slopes ranged from 60° to 90° and consisted of loamy clay.

Detailed Assessment Site KDR-2, located within **Reach KDG-4**, is located south of the Marsh Sparrow Private crossing which marks the upstream extent of the reach. This location is immediately downstream of a golf course and has a low level of sinuosity and a low longitudinal gradient. The channel was found to be mostly depositional with minor toe erosion in locations. The instream and bank vegetation was abundant with encroachment in locations. Bank and bed materials were found to be composed mostly of clay and silt.

Average bankfull width and depth were approximately 2.3 m and 0.4 m, respectively. Average wetted width and depth on the day of assessment were approximately 1.7 m and 0.20 m, respectively. Bank angles throughout the study reach were approximately 30°.

Reach KDR-1, located within **Reach KDG-1,** is located downstream of a pedestrian bridge near Burke Road. This section of Kizell Drain has a low sinuosity and is in a natural riparian area of tall grasses, similar to the wetland section of **KDR-4**. Bank toe erosion and uniform undercutting of the banks was observed throughout KDR-1. The channel bed was composed of unconsolidated sand and silt in depositional areas and highly compact clay where underlying materials are exposed. Channel banks were composed of loamy clay, with grass roots providing stability to the upper half of the banks.

Average bankfull width and depth were approximately 2.6 m and 1.0 m, respectively. Average wetted width and depth on the day of assessment were approximately 2.0 m and 0.25 m, respectively. Bank angles throughout the study reach were approximately 60-90°.

5.2 Rapid Assessments

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 <0.21), stressed/transitional (score 0.21-0.40), or adjusting (score >0.40).

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 C**. All RGA and RSAT results are summarized in **Table 1**.

Detailed Assessment Site KDR-4 was assigned an RGA score of 0.35, indicating the reach was in transition or stressed. The dominant geomorphological indicator was evidence of widening, including exposed tree roots, basal scour inside meander bends, the length of basal scour exceeded 50%, and fracture lines along the tops of banks. Secondary forms of channel adjustment included aggradation (siltation in pools, accretion on point bars, and poor longitudinal sorting of bed materials) and degradation (elevated storm sewer outfalls, scour pools, visible suspended armour layer in the bank, and channel ware into undisturbed overburden). **Reach KDR-4** was given an RSAT score of 20, or fair. The limiting factor was poor channel stability with recent bank sloughing observed.

Detailed Assessment Site KDR-3 was assigned an RGA score of 0.28, indicating the reach was in transition/stress. The dominant geomorphological indicator was evidence of widening with observation of exposed tree roots, outflanked bank treatments, and basal scour. The secondary form of adjustment was found to be aggradation with siltation in pools and poor longitudinal sorting of bed materials. **Reach KDR-3** had an RSAT score of 15, or fair. Limiting factors included low bank stability, limited variability in habitat, turbidity, and the narrow riparian area dominated by non-woody vegetation.

Detailed Assessment Site KDR-2 was assigned an RGA score of 0.16, indicating the reach was in regime. The dominant geomorphological indicator was evidence of aggradation with observations of siltation in pools, medial bars, and poor longitudinal sorting of bed materials. **Detailed Assessment Site KDR-2** had an RSAT score of 15, or fair. Limiting factors included low bank stability, limited variability in habitat, turbidity, and the narrow riparian area dominated by non-woody vegetation.

Detailed Assessment Site KDR-1 was assigned an RGA score of 0.26, indicating the reach was in transition/stressed. The dominant geomorphological indicator was evidence of widening with observations of fracture lines along the top of banks and basal scour on the inside of meander bends, on both sides of artificial riffles, and through over 50% of the channel. Secondary forms of adjustment included aggradation (siltation in pools and deposition in the overbanks) and degradation (channel worn into the undisturbed overburden). **KDR-1** had an RSAT score of 15, or fair. Limiting factors included low bank stability, limited variability in habitat, turbidity, and the narrow riparian area dominated by non-woody vegetation.

Table 1. Summary of rapid assessment results.

Reach	RGA (MOE, 2003)			RSAT (Galli, 1996)		
	Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Feature(s)
KDR-1	0.26	In Transition/Stress	Widening	20	Fair	Channel Stability
KDR-2	0.16	In Regime	Aggradation	15	Fair	Channel Stability
KDR-3	0.28	In Transition/Stress	Widening	16	Fair	Channel Stability and Channel Scour/Deposition
KDR-4	0.35	In Transition/Stress	Widening	20	Fair	Channel Stability

5.2.1 Detailed Geomorphological Assessments

Two detailed geomorphological assessments were completed by GEO Morphix Ltd. within the site identified to be most sensitive to erosion by the rapid assessments, **Site KDR-4**, and the reach determined to be most sensitive to erosion by JTBES (2020), **Site KDR-3**. The two detailed assessments were completed to determine average bankfull channel characteristics, including cross-sectional geometry and hydraulics, for the purpose of informing erosion thresholds. Representative cross sections were surveyed, and sediment samples were retrieved to characterize the bed materials. In locations where coarse material was also present, at the upstream extent of the assessed reach, Wolman Pebble Counts were also completed. A longitudinal survey of the bed was surveyed to determine slope. The channel measurements were then used to calculate bankfull flow characteristics such as discharge, average velocity, and erosion or sediment transport sensitivity. A summary of measured and computed values is presented in **Table 2**.

We note that both of these channels are appropriate for the purpose of calculating an erosion threshold as they have similar bankfull geometry and substrate composition. However, given the slightly increased gradient at **Site KDR-3**, it is expected that this site will provide a slightly more conservative estimate of the erosion threshold.

Table 2 Bankfull channel parameters for the study reaches

Channel Parameter	KDR-4
Average bankfull channel width (m)	3.03
Average bankfull channel depth (m)	0.53
Average channel bed gradient (m/m)	0.0031
Average water level gradient (m/m)	0.0027
Calculated bankfull discharge (m^3/s)	0.68
Maximum Bankfull Shear Stress	10.51
Bed Material	Cohesive Clay
Bank Material	Fairly Compact Clay*
	KDR-3
Average bankfull channel width (m)	3.02
Average bankfull channel depth (m)	0.46
Average channel bed gradient (m/m)	0.004
Average water level gradient (m/m)	N/A (beaver dam)
Calculated bankfull discharge (m^3/s)	0.9
Maximum Bankfull Shear Stress	12.70
Bed Material	Cohesive Clay
Bank Material	Fairly Compact Clay*

6 Erosion Threshold Assessment

6.1 Methodology

Erosion thresholds are used to determine the magnitude of flow required to potentially entrain and transport bed and/or bank materials. As such, they may be used to inform erosion reduction strategies in channels influenced by conceptual flow management plans. The erosion threshold analysis provides a depth, velocity, or discharge at which sediment of a particular size may potentially be entrained.

The erosion threshold is the theoretical point at which entrainment of sediment would occur based on bed and bank materials. Due to the variability between bed and bank composition and structure, erosion thresholds are determined for both bed and bank materials.

Threshold targets are determined using different methods that are dependent on channel and sediment characteristics. For example, thresholds for non-cohesive sediments are commonly estimated using a shear stress approach, similar to that of Miller et al. (1977), which is based on a modified Shield's curve. A velocity approach could also be applied. For cohesive materials, a method such as that described by Komar (1987), or empirically-derived values such as those compiled by Fischenich (2001), Chow (1959) or Julien (1998), could be applied.

An erosion threshold is quantified based on the bed and bank materials and local channel geometry, in the form of a critical discharge. Theoretically, above this discharge, entrainment and transport of sediment can occur. The velocity, *U* is calculated at various depths, until the average velocity in the cross section slightly exceeds the critical velocity of the bed material. The velocity is determined using a Manning's approach, where the Manning's *n* value is visually estimated through a method described by Arcement and Schneider (1989) or calculated using Limerinos's (1970) approach. The velocity is mathematically represented as

$$U = \frac{1}{n} d^{2/3} S^{1/2} \qquad \text{[Eq. 1]}$$

where, *d* is depth of water, *S* is channel slope, and *n* is the Manning's roughness. The discharge is then calculated using the area of a typical cross section at that depth.

For the bank materials, following Chow (1959) in a simplified cross section, 75% of the bed shear stress acts on the channel banks. In a similar approach, the depth of flow is increased until the shear stress acting on the banks exceeds the resisting shear strength of the bank materials.

6.2 Results

Erosion thresholds were determined for the bank materials within **KDR-4 and KDR-3**, as they were determined to be the most sensitive reaches within the watercourse to erosion based on the field observations. Bank materials were selected for the erosion threshold given that the material was more sensitive to erosion than the predominant bed material, Leda Clay. This was evidenced throughout Kizell Drain through observations of widening being the dominant geomorphic adjustment, the lack of deep pools, and the relatively low width to depth ratio observed within the Drain (<10). The critical shear stress and velocity for the bank material were subsequently determined, and used to determine the threshold discharge, the point at which sediment entrainment begins to occur. In this instance, the bank material was determined to be consistent with a fairly compact to loose clay as described by Chow (1959), which has a range of permissible shear stresses from 5 – 10 N/m^2. This classification was determined by tests and observations completed by a Professional Geoscientist. We note that this critical shear stress is lower than that reported in other published studies for Leda Clay, such as that of Gaskin et al. (2003) which suggests a range from 6 – 20 N/m^2 for the material.

To provide an additional perspective, the material was also classified in terms of its permissible velocity as determined using the criteria of Julien (1998) for fine loamy clay, which suggests a critical velocity of between 0.45 and 0.91 m/s.

Because bank materials were selected to be the most sensitive to erosion, care was taken to observe the stratification of the channel banks in terms of where the sensitive material was located in terms of height from the channel bed. Where possible, measurements were taken at the transition from the material which constitutes the toe of the channel banks, the highly resistant to erosion Leda Clay, to the fairly compact clay. It was found that this transition occurred between 0.2 and 0.35 m above the channel bed. We note that throughout the majority of **Site KDR-3** these measurements were not feasible, as the backwater effect from the Beaver Dam rendered high water levels precluding the opportunity to make these types of observations of bank material.

The results of the erosion threshold assessment are provided in **Table 3**. Using the criteria of Chow (1959) and Julien (1998), as well as field observations of channel bank material stratification, the critical discharge to entrain materials within **KDR-4** was determined to be 0.3 m^3/s, similarly, the critical discharge within **KDR-3** was 0.3 m^3/s.

Table 3 Erosion Thresholds

Erosion Threshold Criteria	KDR-4
Average Bankfull Channel Width	3.03
Average Maximum Bankfull Depth	0.53
Energy Gradient (steepest of bankfull, channel and water level gradient, %)	0.35
Manning's 'n'	0.035
Bankfull Discharge (m^3/s)	0.68
Bankfull Velocity (m/s)	0.72
Dominant Bank Material	Fairly compact to loose clay*/Fine loamy clay**
Critical Discharge (m^3/s)	0.3
Bank Shear Stress (N/m^2)	6.78
Bed Shear Stress (N/m^2)	9.01
Average Velocity (m/s)	0.62
Critical Depth (m)	0.32
KDR-3	
Average Bankfull Channel Width	3.02
Average Maximum Bankfull Depth	0.46
Energy Gradient (steepest of bankfull, channel and water level gradient, %)	0.4
Manning's 'n'	0.0375
Bankfull Discharge (m^3/s)	0.9
Bankfull Velocity (m/s)	0.87
Dominant Bank Material	Fairly compact to loose clay*/Fine loamy clay**
Critical Discharge (m^3/s)	0.3
Bank Shear Stress (N/m^2)	8.5
Bed Shear Stress (N/m^2)	11.29
Average Velocity (m/s)	0.6
Critical Depth (m)	0.31

*Fairly compact to loose clay (Chow, Open Channel Hydraulics, 1959, pg. 174, figure 7-11)

**Fine loamy clay (Julien, Erosion and Sedimentation, 1994, Page 120)

Please note that the average bankfull channel characteristics are based on an averaged approach which assumes a rectangular cross section and consequently offers a conservative (high) estimate of discharge, velocity and shear stress.

We note that erosion thresholds were not calculated for the transient silt and sand materials within the channel, as these alluvial materials do not constitute the primary material in this semi-alluvial watercourse. We recognize the City of Ottawa's statement regarding concern over the remobilization of existing silt deposits. We suggest that these deposits are symptomatic of a location or reach which is lacking energy, and consequently aggrading. In stable natural systems such deposits are expected to be mobilized to help maintain the dynamic equilibrium which exist in such watercourses. As such, we do not believe it should be required to prevent the mobilization of these materials, as treating these materials as a critical threshold would result in a profoundly low energy system resulting in a reduced ‘stream health’ from the perspective of sediment balance. Notably, no significant silt deposits were identified within **Site KDR-4**, while those observed within **Site KDR-3** are expected to be a result of the beaver dam creating a backwater effect.

The shear stresses and critical velocities applied fall well within the range of observed values. These values and the approach applied are consistent with the identified systematic adjustments and the make-up of the bed and bank materials.

6.3 Comparison with Previously Completed Erosion Thresholds

The methods used here by GEO Morphix Ltd. differ from those recommended by the work of previous consultants. Specifically, we focused on what we determined to be the most sensitive material in the channel, the fairly compact to loose clay on the channel banks. The studies completed by JTBES on behalf of AECOM (2015), Rennie (2016) and Matrix Solutions (2019) identified the dominant bed material, Leda Clay, to be most sensitive to erosion.

Within the assessed reaches of Kizell Drain undergoing active erosion, such as **Sites KDR-4** and **KDR-3,** the dominant geomorphic adjustment is channel widening as identified by the RGA. Specifically, the most common forms of erosion observed were bank undercutting and sloughing. Notably, relatively minor scour was only observed downstream of bedrock outcroppings or storm water outlets, and at these locations widening was observed concurrently. As well, the general trend within the longitudinal profiles indicate relatively limited pool development, as riffles and transitional geomorphic units were more prevalent. Further, throughout Kizell Drain the channel has good access to its floodplain, suggesting limited degradation which would result in a higher degree of entrenchment.

All of these factors suggest that the bed material has been relatively resilient to erosion over time, and bank materials are more susceptible to erosion as a result of modification to the hydrological regime arising from such activities as urban development.

6.4 Erosion Threshold Verification

Field activities were undertaken in June 2020, to verify the proposed erosion threshold, and review the proposed criteria from the work of JTBES for Stantec (2011) and AECOM (2015), Rennie (2016) and Matrix Solutions (2019). For clarity, the erosion thresholds associated with these studies are shown within **Table 4**. We note that for the purpose of comparison with the three studies, permissible velocities and shear stresses were converted into critical discharges using a typical cross section from **KDR-4**, which was used by GEO Morphix Ltd. to calculate the apparent critical discharge.

Table 4 Erosion Thresholds from other studies

Source	Critical Velocity (m/s)	Critical Shear Stress (N/m^2)	Apparent Critical Depth (m)	Apparent Critical Discharge (m^3/s)
AECOM (2015)	0.2710		0.094	0.028
Rennie (2016)		3.7	0.095	0.029
Matrix Solutions Inc. (2019)		20	0.51	0.761
GEO Morphix Ltd. (2020)	0.6	8.47	0.31	0.3

The validation exercise involved the installation of a MantaRay continuous portable velocity flow meter from Grey Line Instruments. The tool uses the doppler shift principle to measure depth-averaged velocity, and using bankfull characteristics which are inputted into the tool converts this average velocity into a discharge at the measurement location. This instrument was installed on a platform which included an action camera programmed to take short video recordings at regular intervals to provide observations of potential sediment transport. In addition, a Helley Smith bedload sampler was installed on the platform in order to capture any potential bedload transport during the sampling period. By combining the observations from these three instruments, insights can be gained into the occurrence of sediment transport during the monitoring period.

The instrument was installed within a typical cross section, specifically a run or transitional geomorphic unit within **KDR-4**, in which bed and bank substrates were consistent with those used for the calculation of the erosion thresholds by all consultants (e.g. – bed composed of dense clay with overlaying gravels and sand, banks composed of a fairly compact to loose clay). We note that given the backwatered conditions and the consequent low velocities within site **KDR-3**, the instrument was not installed at this location.

The monitoring devices were installed during two periods between June 1 and 2, and June 10 and 11, respectively. The average and maximum velocities and discharges from these events is provided within **Table 5**.

Table 5 Instream monitoring results

Date	Monitoring Duration (hrs)	Average Velocity (m/s)	Maximum velocity (m/s)	Average Discharge (m^3/s)	Maximum Discharge (m^3/s)
June 1 – 2, 2020	9.66	0.42	0.5	0.091	0.11
June 10 - 11, 2020	27.9	0.341	0.477	0.098	0.186

Results indicate that during these periods the average velocities and discharges slightly exceeded the permissible velocities and discharges proposed by AECOM and Rennie. Concurrently, negligible quantities of organic material and silt were the only materials retrieved within the Helley Smith sampler, and no evidence of bed or bank sediment transport was observed within the camera footage. This suggests that at the time of the monitoring exercises, no active erosion was ongoing within the channel, and that the erosion threshold should at minimum exceed 0.186 m^3/s.

7 Summary and Recommendations

GEO Morphix Ltd. was retained to complete a technical review of the erosion thresholds calculated by Matrix Solutions (2019), JTBES on behalf of Stantec and AECOM (2011, 2015) and the study of Rennie (2016). Our assessment entailed a detailed review of available data from these studies, rapid assessments of the 4 sensitive sites located between Beaver Pond and Kizell Drain identified by JTBES, and two detailed assessments at the two most sensitive locations as determined by field assessments and the insights of JTBES from the most recent memo (2020). GEO Morphix Ltd. determined an erosion threshold in the form of a critical discharge for **Site KDR-3 and KDR-4** as being 0.3 m^3/s based on detailed field observation, an analysis of the channel's bed and bank sediment's and its bankfull geometry. Specifically, a slightly different approach was taken which recognizes the prevalence of widening activities as opposed to channel degradation being the dominant form of erosion. Therefore, the bank materials which are composed of a fairly cohesive to loose clay were determined to be the limiting factor to erosion within the system as opposed to the cohesive Leda Clay which composes the channel bed.

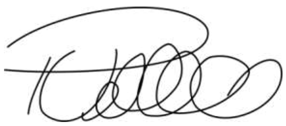
We understand an erosion exceedance exercise has been completed by JFSA (2020) which takes into account our erosion threshold in calculating the relative change between pre- and post-development scenarios in the erosion regime to identify potential impacts as a result of the proposed development of 7000 Campeau Drive. As a result of the findings of this assessment, it is our opinion that the storm water management strategy has been modified by incorporating increased storage within the ponds, lower release rates including the implementation of LID strategies.

Specifically, to address increases in erosion from changes in local hydrology, appropriate stormwater management techniques are proposed. Specifically, JFSA (2021) has incorporated an Etobicoke Exfiltration System (EES), which will capture infiltration to the 22 mm event (which accounts for 95th percentile of all annual rain events). As a result of proposed erosion mitigation associated with the stormwater management plan, there is a negligible change, or even a potential improvement, in the erosion regime between pre- and post-development scenarios, signifying that the development of 7000 Campeau Drive will not adversely impact the geomorphological condition of the Kizell Drain, and subsequently, downstream conditions within Watts Creek.

While we recognize the differences between the studies completed by the different consultants, based on field monitoring activities and a review of watercourse conditions, it is our opinion that the proposed erosion threshold based on the Leda Clay material are overly conservative. As such, we recommend that our proposed erosion threshold be used and coupled with the stormwater management strategy of the of the proposed development at 7000 Campeau Drive, we are of the opinion that these measures will ensure no exacerbated rates of erosion within the receiving watercourses.

We trust this report meets your 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

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Appendix A
Historical Imagery

Location: Kanata, Ontario
Watercourse: Kizell Drain, Upstream of March Road
Year: 1976
Source: City of Ottawa Interactive Mapping

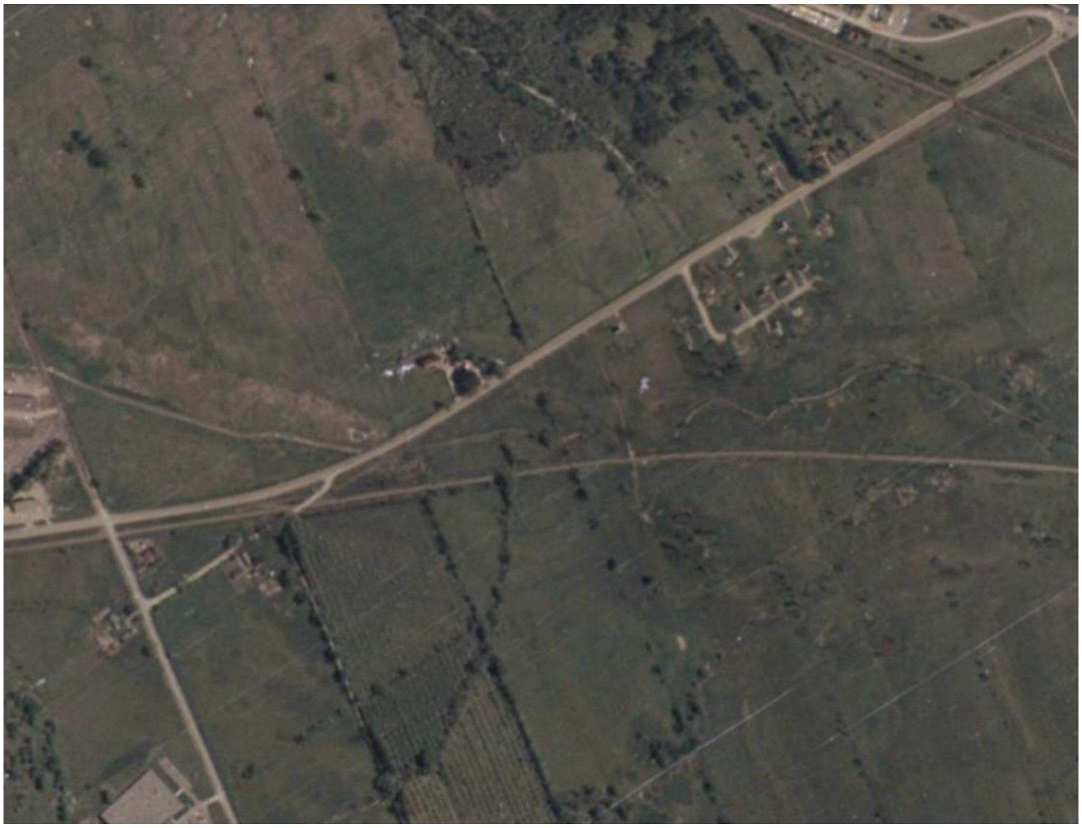
Location: Kanata, Ontario
Watercourse: Kizell Drain, Upstream of March Road
Year: 1999
Source: City of Ottawa Interactive Mapping

Location: Kanata, Ontario
Watercourse: Kizell Drain, Upstream of March Road
Year: 2015
Source: City of Ottawa Interactive Mapping

Location: Kanata, Ontario
Watercourse: Kizell Drain, between Legett Drive Crossings
Year: 1976
Source: City of Ottawa Interactive Mapping

Location: Kanata, Ontario
Watercourse: Kizell Drain, between Legett Drive Crossings
Year: 1999
Source: City of Ottawa Interactive Mapping

Location: Kanata, Ontario
Watercourse: Kizell Drain, between Legett Drive Crossings
Year: 2015
Source: City of Ottawa Interactive Mapping

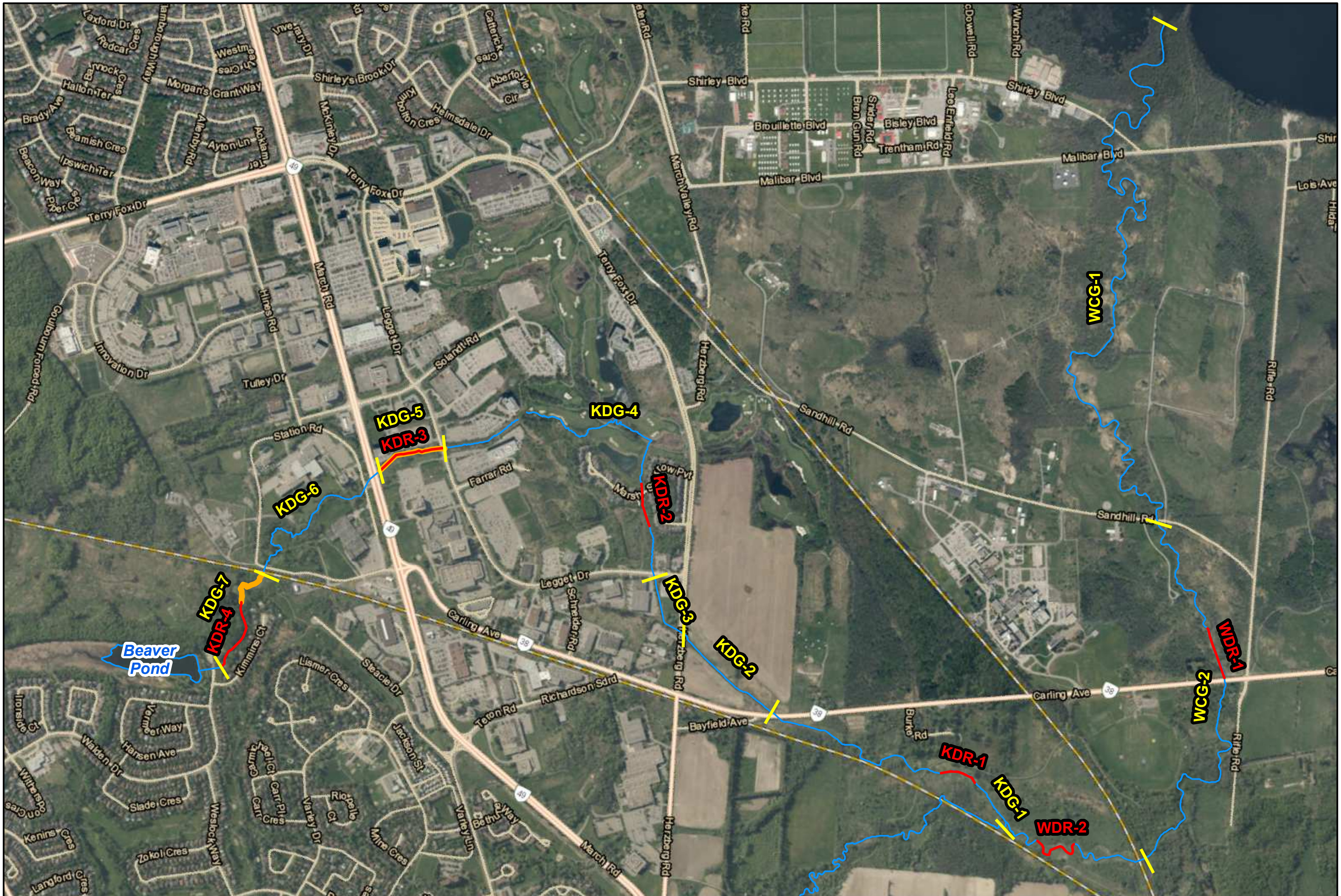


Location: Kanata, Ontario
Watercourse: Kizell Drain, from Legett Drive to Watts Creek
Year: 1976
Source: City of Ottawa Interactive Mapping

Location: Kanata, Ontario
Watercourse: Kizell Drain, from Legett Drive to Watts Creek
Year: 1999
Source: City of Ottawa Interactive Mapping

Location: Kanata, Ontario
Watercourse: Kizell Drain, from Legett Drive to Watts Creek
Year: 2015
Source: City of Ottawa Interactive Mapping

Appendix B
Reach Map



Legend

Overview Reach
Detailed Study Reach
Detailed Assessment - May/June 2020
Watercourse

Kizell Drain

Reach Delineation and Detailed Assessment Locations

Ottawa, Ontario

GEO MORPHIX™

Imagery: City of Ottawa, 2017.
Detailed Study Reach: JTB Environmental Services, 2016.
Overview Reach: AECOM, 2015.
Detailed Sites: GEO Morphix Ltd., 2020.
Watercourse: MNRF, 2020.
Print Date: June 2020. PN20053. Drawn By: A.M.B., W.B.

Appendix C
Field Sheets

Detailed Geomorphological Assessment Summary

Reach KDR-3

Project Number:	PN20053	**Date:**	June 6, 2020
Client:	David Schaeffer Engineering Ltd.	**Length Surveyed (m):**	234.8
Location:	Kizell Drain, Kanata	**# of Cross-Sections:**	8 cross-sections

Reach Characteristics

Drainage Area:	Not measured	**Dominant Riparian Vegetation Type:**	Shrubs, trees and grasses
Geology/Soils:	Clay plains	**Extent of Riparian Cover:**	Fragmented
Surrounding Land Use:	Parking / Industrial	**Width of Riparian Cover:**	1-4 to 4-10
Valley Type:	Partially confined	**Age Class of Riparian Vegetation:**	Established (5-30 yrs)
Dominant Instream Vegetation Type:	Submergent	**Extent of Encroachment into Channel:**	Moderate
Portion of Reach with Vegetation:	40%	**Density of Woody Debris:**	Low

Hydrology

Measured Discharge (m^3/s):	Not measured	**Calculated Bankfull Discharge (m^3/s):**	3.06
Modelled 2-year Discharge (m^3/s):	Not modelled	**Calculated Bankfull Velocity (m/s):**	1.01
Modelled 2-year Velocity (m/s):	Not modelled		

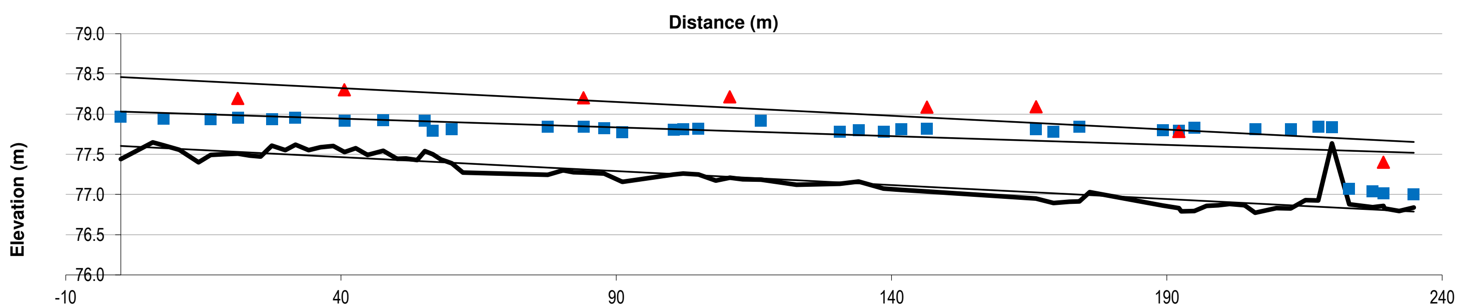
Profile Characteristics

Bankfull Gradient (%):	N/A
Channel Bed Gradient (%):	0.40
Riffle Gradient (%):	N/A
Riffle Length (m):	N/A
Riffle-Pool Spacing (m):	N/A

Planform Characteristics

Sinuosity:	1.07
Meander Belt Width (m):	Not measured
Radius of Curvature (m):	Not measured
Meander Amplitude (m):	Not measured
Meander wavelength (m):	Not measured

Longitudinal Profile



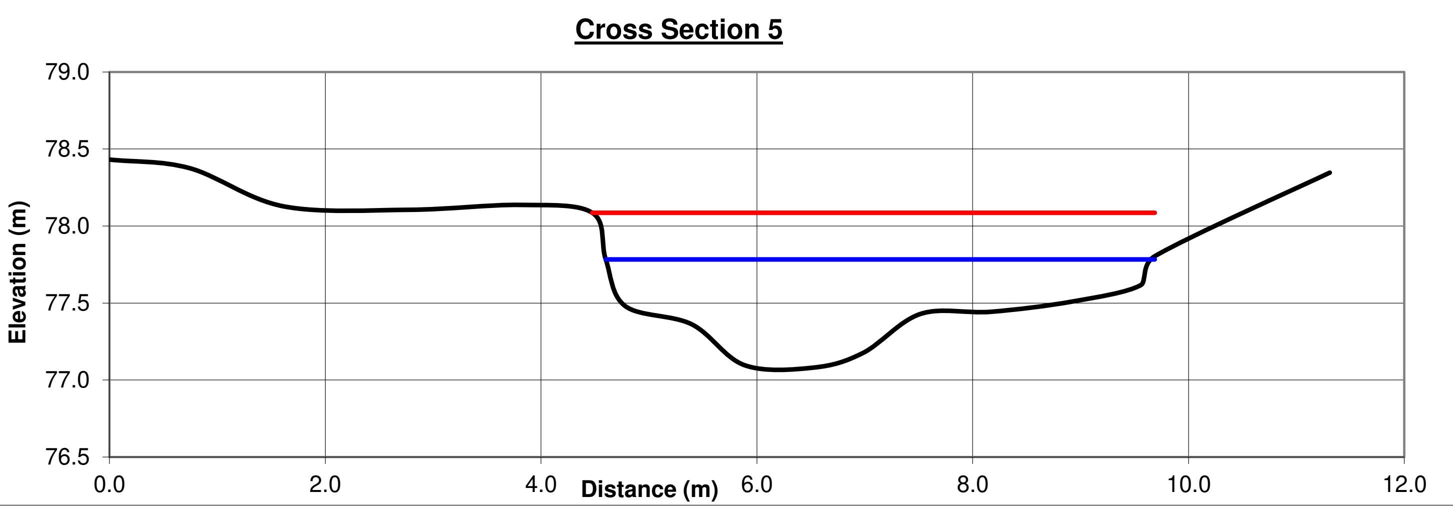
Bank Characteristics

	Minimum	Maximum	Average
Bank Height (m):	0.30	1.20	0.75
Bank Angle (deg):	15	90	54
Root Depth (m):	0.10	0.40	0.30
Root Density (%):	10	100	51
Bank Undercut (m):	0.00	0.20	0.02

	Minimum	Maximum	Average
Torvane Value (kg/cm^2):		Not measured	
Penetrometer Value (kg/cm^3):		Not measured	
Bank Material (range):		Clay, Silt and Sand	

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	3.69	7.85	5.79
Average Bankfull Depth (m):	0.29	0.69	0.52
Bankfull Width/Depth (m/m):	8	16	11
Wetted Width (m):	1.61	5.61	3.87
Average Water Depth (m):	0.11	0.53	0.33
Wetted Width/Depth (m/m):	9	16	12
Entrenchment (m):		Not measured	
Entrenchment Ratio (m/m):		Not measured	
Maximum Water Depth (m):	0.13	0.99	0.55
Manning's *n*:		0.038	



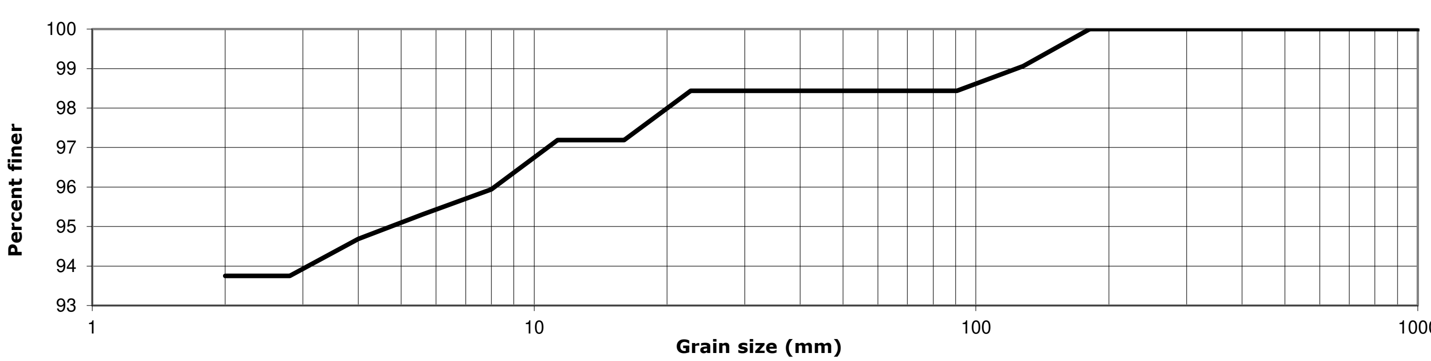
Substrate Characteristics

Particle Size (mm)

D_{10} :	<2
D_{50} :	<2
D_{84} :	<2

Subpavement:	Compact Clay
Particle shape:	Angular
Embeddedness (%):	60
Particle range (riffle):	
Particle Range (pool):	

Cumulative Particle Size Distribution



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	17.48
for D_{50}:	0.27	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	0.27	**Critical Shear Stress (D_{50}) (N/m^2):**	1.46
Unit Stream Power at Bankfull (W/m^2):	17.65		

General Field Observations

Channel Description

Detailed assessment Site KDR-3 is a channelized watercourse conveying flows through a commercial business park with large parking lots. The channel is unconfined, and at the time of the assessment was backwatered by a beaver dam which exceeded 1 m in height near Legett Drive. The channel had a fragmented, narrow riparian buffer composed of grasses and herbaceous vegetation which occasionally encroached the watercourse, with sparse shade provided from trees. The channel bed was composed of a cohesive clay material, while channel banks were composed of a loamy clay.

Detailed Geomorphological Assessment Summary

Reach KDR-4

Project Number:	PN20053	**Date:**	2020-06-01
Client:	DSEL Ltd.	**Length Surveyed (m):**	90.2
Location:	Ottawa	**# of Cross-Sections:**	8

Reach Characteristics

Drainage Area:	Not measured	**Dominant Riparian Vegetation Type:**	Grasses
Geology/Soils:	Clay Plain	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Residential	**Width of Riparian Cover:**	>30 m
Valley Type:	Unconfined	**Age Class of Riparian Vegetation:**	Mature
Dominant Instream Vegetation Type:	None	**Extent of Encroachment into Channel:**	None
Portion of Reach with Vegetation:	0	**Density of Woody Debris:**	low

Hydrology

Measured Discharge (m^3/s):	Not measured	**Calculated Bankfull Discharge (m^3/s):**	1.19
Modelled 2-year Discharge (m^3/s):	Not modelled	**Calculated Bankfull Velocity (m/s):**	0.90
Modelled 2-year Velocity (m/s):	Not modelled		

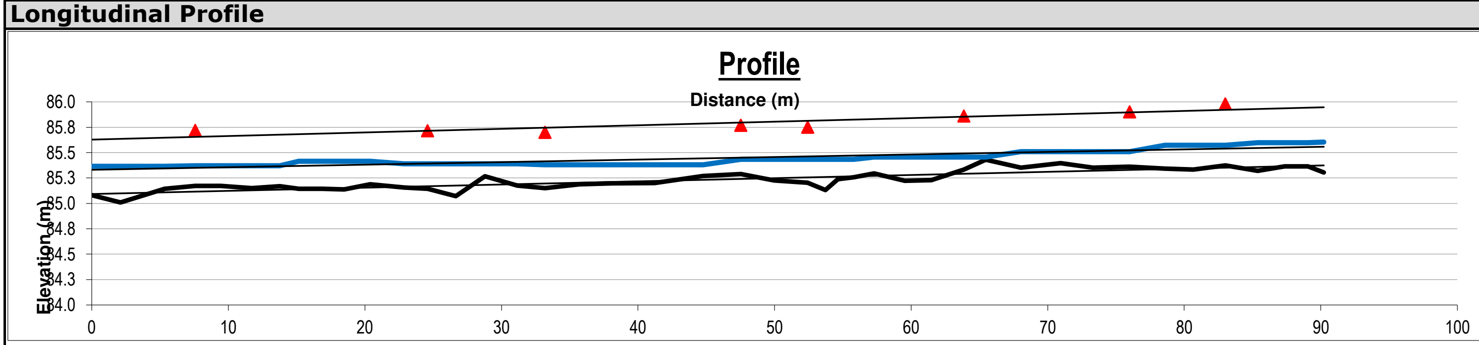
Profile Characteristics

Bankfull Gradient (%):	0.35
Channel Bed Gradient (%):	0.31
Riffle Gradient (%):	#DIV/0!
Riffle Length (m):	0.00
Riffle-Pool Spacing (m):	0.00

Planform Characteristics

Sinuosity:	1.64
Meander Belt Width (m):	Not measured
Radius of Curvature (m):	Not measured
Meander Amplitude (m):	Not measured
Meander wavelength (m):	Not measured

Longitudinal Profile



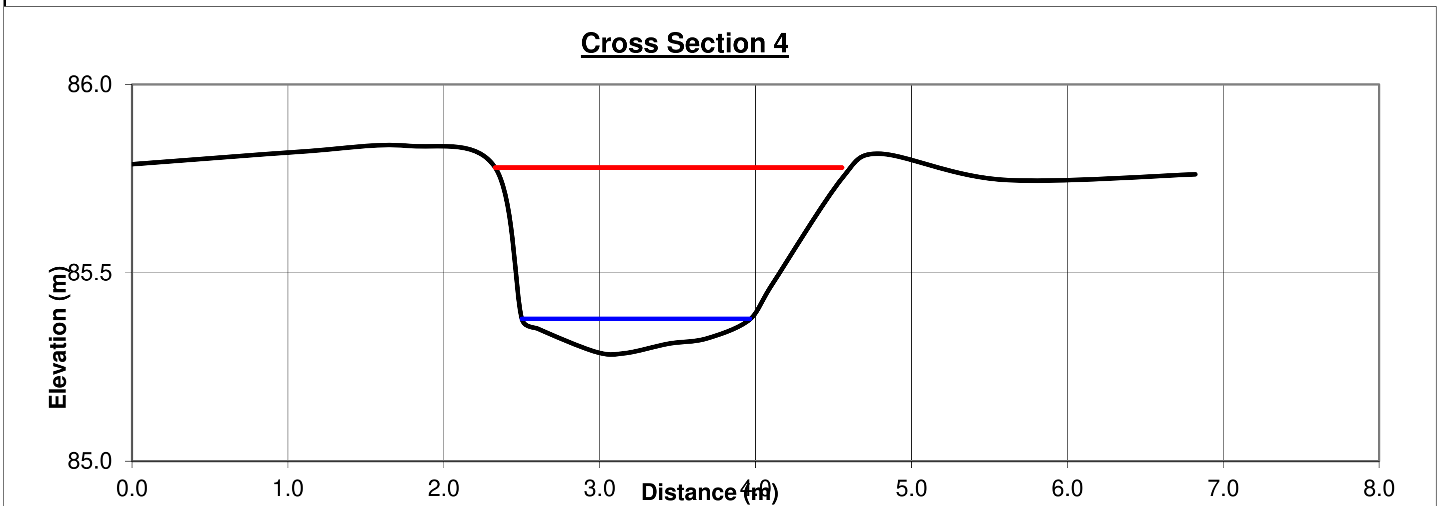
Bank Characteristics

	Minimum	Maximum	Average
Bank Height (m):	0.45	0.80	0.61
Bank Angle (deg):	30	90	72
Root Depth (m):	0.20	0.50	0.32
Root Density (%):	20	70	43
Bank Undercut (m):	0.00	0.40	0.16

	Minimum	Maximum	Average
Torvane Value (kg/cm^2):		Not measured	
Penetrometer Value (kg/cm^3):		Not measured	
Bank Material (range):		Clay to Sand	

Cross-Sectional Characteristics

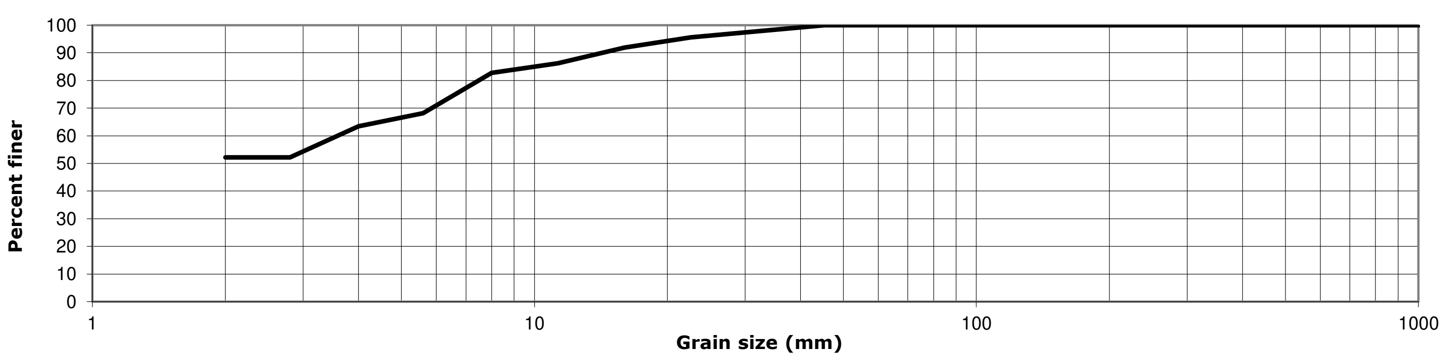
	Minimum	Maximum	Average
Bankfull Width (m):	2.23	4.82	3.38
Average Bankfull Depth (m):	0.30	0.43	0.39
Bankfull Width/Depth (m/m):	5	16	9
Wetted Width (m):	1.42	1.84	1.62
Average Water Depth (m):	0.06	0.19	0.14
Wetted Width/Depth (m/m):	9	23	13
Entrenchment (m):		Not measured	
Entrenchment Ratio (m/m):		Not measured	
Maximum Water Depth (m):	0.09	0.24	0.19
Manning's *n* :		0.035	



Substrate Characteristics

Particle Size (mm)		**Subpavement:**	Ledu Clay
D_{10} :	0.0	**Particle shape:**	Sub-Angular to Sub-Rounded
D_{50} :	0.0	**Embeddedness (%):**	0 to 40%
D_{84} :	9.0	**Particle range (riffle):**	Silt to Gravel
		Particle Range (pool):	Clay to Sand

Cumulative Particle Size Distribution



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	13.41
for D_{50}:	0.00	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	0.54	**Critical Shear Stress (D_{50}) (N/m^2):**	0.00
Unit Stream Power at Bankfull (W/m^2):	12.11		

General Field Observations

Channel Description

Detailed Assessment Site KDR-4 conveys flows through an unconfined valley, and is surrounded predominantly by residential development. The site has a continuous riparian buffer consisting of a forest in the upstream section of the site, and a meadow in the downstream section. Channel bed materials are composed of dense clay, with overlying sand, gravels and small cobbles. Banks are composed of a loamy clay. The channel has a natural sinuous planform, and the specific detailed site is delimited at the upstream extent by a bedrock outcrop and the downstream extent by a wet meadow with poor bank definition.

GEO | MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code: PN20053

Date:	May 29, 2020	**Stream/Reach:**	KDR-1
Weather:	Cloudy, 28 degrees C	**Location:**	Kizell Drain, U/S of Watts Confluence
Field Staff:	MM	**Watershed/Subwatershed:**	Watts Creek Tributary
UTM (Upstream)		**UTM (Downstream)**	

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

Riparian Vegetation

Dominant Type: (Table 6) 3

Species: ____________

Coverage: ☐ None ☐ Fragmented ☒ Continuous

Channel widths: ☒ 1-4 ☐ 4-10 ☐ > 10

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

Encroachment: (Table 7) 1

Aquatic/Instream Vegetation

Type (Table8): 2 | Coverage of Reach (%): 30

Woody Debris: ☐ Present in Cutbank ☐ Present in Channel ☒ Not Present

Density of WD: ☒ Low ☐ Moderate ☐ High

WDJ/50m: 0

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

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

Entrenchment (Table 13): 1 | **Type of Bank Failure** (Table 14): 2/5 | **Downs's Classification** (Table 15): d/e

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

Bankfull Width (m)	2.7	2.6	2.6	**Wetted Width (m)**	2.2	1.8	2.0
Bankfull Depth (m)	1.0	0.9	1.0	**Wetted Depth (m)**	0.28	0.28	0.20

Riffle/Pool Spacing (m): N/A | **% Riffles:** 5 | **% Pools:** N/A | **Meander Amplitude:** N/A

Pool Depth (m): N/A | **Riffle Length (m):** 15 | **Undercuts (m):** 0.15 | **Comments:**

Velocity (m/s): - | - | - | **Wiffle ball / ADV / Estimated** Did not measure

Bank Angle: ☐ 0 – 30 ☐ 30 – 60 ☒ 60 – 90 ☐ Undercut

Bank Erosion: ☐ < 5% ☐ 5 – 30% ☐ 30 – 60% ☒ 60 – 100%

Notes:

Channel bottom:
~ 0.1 m
Sandy/silt
Loose, unconsolidated materials

Bank:
Loose, compact clay/silt

Underlying materials:
Compact clay

Completed by: MM   Checked by: PV

GEO | MORPHIX

Rapid Geomorphic Assessment   Project Code: PN20053

Date:	May 29, 2020	Stream/Reach:	KDR-1
Weather:	Cloudy, 28 degrees C	Watershed/Subwatershed:	Kizell Drain/Watts Creek Tributary
Field Staff:	MM	Location:	Kizell Drain U/S Watts Creek confluence

Process	Geomorphological Indicator		Present?		Factor Value
	No.	Description	Yes	No	
Evidence of Aggradation (AI)	1	Lobate bar		x	2/7
	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 =	2	5	0.29
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		x	1/6
	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	N/A		
	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 =	1	5	0.17
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		x	4/7
	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 =	4	3	0.57
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		x	0/7
	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 =	0	7	0

Additional notes:	Stability Index (SI) = (AI+DI+WI+PI)/4 =			0.26
	Condition	In Regime	In Transition/Stress	In Adjustment
	SI score =	☐ 0.00 - 0.20	☒ 0.21 - 0.40	☐ 0.41

Completed by: MM   Checked by: PV

Reach Characteristics **Project Code:** PN20053

GEO MORPHIX — Geomorphology Earth Science Observations

Date:	May 29, 2020	Stream/Reach:	KDR-2
Weather:	Sunny, 27 degrees C	Location:	Kizell Drain at Herzberg
Field Staff:	MM	Watershed/Subwatershed:	Watt's Creek Tributary
UTM (Upstream)		UTM (Downstream)	

Land Use (Table 1): 7 | **Valley Type** (Table 2): 3 | **Channel Type** (Table 3): 11/12 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: ____________

Riparian Vegetation

Dominant Type: (Table 6): 2/3

Species: ____________

Coverage: ☐ None ☐ Fragmented ☒ Continuous

Channel widths: ☒ 1-4 ☐ 4-10 ☐ > 10

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

Encroachment: (Table 7): 1

Aquatic/Instream Vegetation

Type (Table8): 2 | Coverage of Reach (%): 80

Woody Debris: ☐ Present in Cutbank ☐ Present in Channel ☒ Not Present

Density of WD: ☒ Low ☐ Moderate ☐ High

WDJ/50m: 0

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

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

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

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

Bankfull Width (m)	2.3	2.3	2.4
Wetted Width (m)	1.4	1.7	2.1
Bankfull Depth (m)	0.35	0.5	0.4
Wetted Depth (m)	0.15	0.20	0.24

Riffle/Pool Spacing (m): Irregular | **% Riffles:** 20 | **% Pools:** 20 | **Meander Amplitude:** N/A

Pool Depth (m): 0.4 | **Riffle Length (m):** 7 | **Undercuts (m):** 0.2

Velocity (m/s): - | - | - (Wiffle ball / ADV / Estimated)

Not measured

Comments: Mostly depositional, some minor toe erosion, vegetation-heavy

Bank Angle: ☒ 0 – 30 ☐ 30 – 60 ☐ 60 – 90 ☐ Undercut

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

Notes:

Completed by: MM Checked by: PV

GEO | MORPHIX

Rapid Geomorphic Assessment

Project Code: PN20053

Date:	May 29, 2020	Stream/Reach:	KDR-2
Weather:	Cloudy, 27 degrees C	Watershed/Subwatershed:	Watt's Creek Tributary
Field Staff:	MM	Location:	Kizell Drain at Herzberg

Process	Geomorphological Indicator		Present?		Factor Value
	No.	Description	Yes	No	
Evidence of Aggradation (AI)	1	Lobate bar		x	3/6
	2	Coarse materials in riffles embedded		x	
	3	Siltation in pools	x		
	4	Medial bars	x		
	5	Accretion on point bars	N/A		
	6	Poor longitudinal sorting of bed materials	x		
	7	Deposition in the overbank zone		x	
		Sum of indices =	3	3	0.5
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	N/A		1/8
	2	Exposed sanitary / storm sewer / pipeline / etc.		x	
	3	Elevated storm sewer outfall(s)		x	
	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 =	1	7	0.12
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		x	0/6
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots		x	
	4	Basal scour on inside meander bends	N/A		
	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 =	0	6	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		x	0/7
	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 =	0	7	0

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 =			0.16
Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☒ 0.00 - 0.20	☐ 0.21 - 0.40	☐ 0.41

Completed by: MM   Checked by: PV

Reach Characteristics

Project Code: PN20053

GEO MORPHIX
Geomorphology Earth Science Observations

Date:	May 29, 2020	**Stream/Reach:**	KDR-3
Weather:	Cloudy, 26 degrees C	**Location:**	Kizell Drain
Field Staff:	MM	**Watershed/Subwatershed:**	Watt's Creek Tributary
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 4 | **Valley Type** (Table 2): 3 | **Channel Type** (Table 3): 11/12 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: ____________

Riparian Vegetation

Dominant Type: (Table 6) 2/3

Species: ____________

Coverage:
- ☐ None
- ☒ Fragmented
- ☐ Continuous

Channel widths
- ☒ 1-4
- ☐ 4-10
- ☐ > 10

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

Encroachment: (Table 7) 2

Aquatic/Instream Vegetation

Type (Table8): 2/3 | Coverage of Reach (%): 70

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

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

WDJ/50m: 0

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

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

Entrenchment (Table 13): 1 | **Type of Bank Failure** (Table 14): 2 | **Downs's Classification** (Table 15): U

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

Bankfull Width (m)	2.3	3.2	2.1	**Wetted Width (m)**	1.8	3.0	1.4
Bankfull Depth (m)	0.5	0.5	0.4	**Wetted Depth (m)**	0.26	0.46	0.15

Riffle/Pool Spacing (m): Irregular | **% Riffles:** 10 | **% Pools:** 10 | **Meander Amplitude:** -

Pool Depth (m): 0.45 | **Riffle Length (m)**: 10 | **Undercuts (m)**: 0.2 | **Comments:**

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

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

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

Notes:

Completed by: MM   Checked by: PV

GEO | MORPHIX

Rapid Geomorphic Assessment   Project Code: PN20053

Date:	May 29, 2020	Stream/Reach:	KDR-3
Weather:	Cloudy, 26 degrees C	Watershed/Subwatershed:	Watt's Creek Tributary
Field Staff:	MM	Location:	Kizell Drain

Process	Geomorphological Indicator		Present?		Factor Value
	No.	Description	Yes	No	
Evidence of Aggradation (AI)	1	Lobate bar		x	
	2	Coarse materials in riffles embedded		x	
	3	Siltation in pools	x		
	4	Medial bars		x	2/7
	5	Accretion on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Deposition in the overbank zone		x	
		Sum of indices =	2	5	0.29
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	N/A		
	2	Exposed sanitary / storm sewer / pipeline / etc.	N/A		
	3	Elevated storm sewer outfall(s)		x	
	4	Undermined gabion baskets / concrete aprons / etc.		x	
	5	Scour pools downstream of culverts / storm sewer outlets		x	2/8
	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 =	2	6	0.25
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		x	
	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	4//9
	6	Outflanked gabion baskets / concrete walls / etc.	x		
	7	Length of basal scour >50% through subject reach	x		
	8	Exposed length of previously buried pipe / cable / etc.	x		
	9	Fracture lines along top of bank		x	
	10	Exposed building foundation	N/A		
		Sum of indices =	4	5	0.44
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		x	
	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	1/7
	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 =			0.28
	Condition	In Regime	In Transition/Stress	In Adjustment
	SI score =	☐ 0.00 - 0.20	☒ 0.21 - 0.40	☐ 0.41

Completed by: MM   Checked by: PV

Reach Characteristics

Project Code: PN20053

GEO MORPHIX — Geomorphology Earth Science Observations

Date:	May 29, 2020	**Stream/Reach:**	KDR-4
Weather:	Cloudy, 21 degrees C	**Location:**	Kizell Drain, Kanata
Field Staff:	MM	**Watershed/Subwatershed:**	Watt's Creek Tributary
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 1/2/7 | **Valley Type** (Table 2): 3 | **Channel Type** (Table 3): 12 | **Channel Zone** (Table 4): 2 (3 u/s) | **Flow Type** (Table 5): 1 | ☒ Groundwater | Evidence: Iron staining

Riparian Vegetation

Dominant Type: (Table 6) 1/3

Species: ____________

Coverage: ☐ None ☒ Fragmented ☐ Continuous

Channel widths: ☒ 1-4 ☐ 4-10 ☐ > 10

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

Encroachment: (Table 7) 2-5

Aquatic/Instream Vegetation

Type (Table8) 1-2 — Coverage of Reach (%) 70

Woody Debris: ☐ Present in Cutbank ☒ Present in Channel ☐ Not Present

Density of WD: ☒ Low ☐ Moderate ☐ High

WDJ/50m: 2

Water Quality

Odour (Table 16): 1 — D/S smell phosphorus

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): 1-2

Sinuosity (Degree) (Table 10): 1-2

Gradient (Table 11): 1-3

Number of Channels (Table 12): 1

Entrenchment (Table 13): 2-3

Type of Bank Failure (Table 14): 2

Downs's Classification (Table 15):

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

Bankfull Width (m)	3.8	3.2	2.3
Wetted Width (m)	2.5	2.7	1.5
Bankfull Depth (m)	0.6	0.4	0.65
Wetted Depth (m)	0.16	0.10	0.19

Riffle/Pool Spacing (m) Irregular | **% Riffles:** 10 | **% Pools:** 10 | **Meander Amplitude:** 5-10

Pool Depth (m) 0.35-0.45 | **Riffle Length (m)** 10-20 | **Undercuts (m)** 0.20

Velocity (m/s) - | - | - — Wiffle ball / ADV / Estimated

Not measured

Comments: Through enrenched area: Bankfull width 2.5 m, bankfull depth 0.4 m wetted width 1.7 m, and wetted depth 0.2 m

Bank Angle: ☐ 0 – 30 ☒ 30 – 60 ☒ 60 – 90 ☐ Undercut

Bank Erosion: ☐ < 5% ☐ 5 – 30% ☒ 30 – 60% ☐ 60 – 100%

Notes:

Completed by: MM   Checked by: PV

Rapid Geomorphic Assessment

Project Code: PN20053

Date:	May 29, 2020	Stream/Reach:	KDR-4
Weather:	Cloudy, 25 degrees C	Watershed/Subwatershed:	Watt's Creek Tributary
Field Staff:	MM	Location:	Kizell Drain, Kanata

Process	Geomorphological Indicator		Present?		Factor Value
	No.	Description	Yes	No	
Evidence of Aggradation (AI)	1	Lobate bar		x	3/4
	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 =	3	4	0.43
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		x	4/10
	2	Exposed sanitary / storm sewer / pipeline / etc.		x	
	3	Elevated storm sewer outfall(s)	x		
	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 =	4	5	0.4
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		x	2/10
	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.		x	
	9	Fracture lines along top of bank		x	
	10	Exposed building foundation		x	
		Sum of indices =	2	7	0.20
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		x	0/7
	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 =	0	7	0

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 =			0.26
Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☐ 0.00 - 0.20	☒ 0.21 - 0.40	☐ 0.41

Completed by: MM Checked by: PV

Appendix D
Photo Record

Photo 1
Kizell Drain, KDR-4 – Kanata, Ontario

Looking downstream at the furthest upstream extent of Site KDR-4, immediately downstream of the Beaver Pond outlet. Both banks are armoured and vegetated.

Photo 2
Kizell Drain, KDR-4 – Kanata, Ontario

Downstream of the armoured section near the pedestrian bridge, exposed compact clay was observed. This material was consistently observed as the underlying material throughout Kizell Drain.

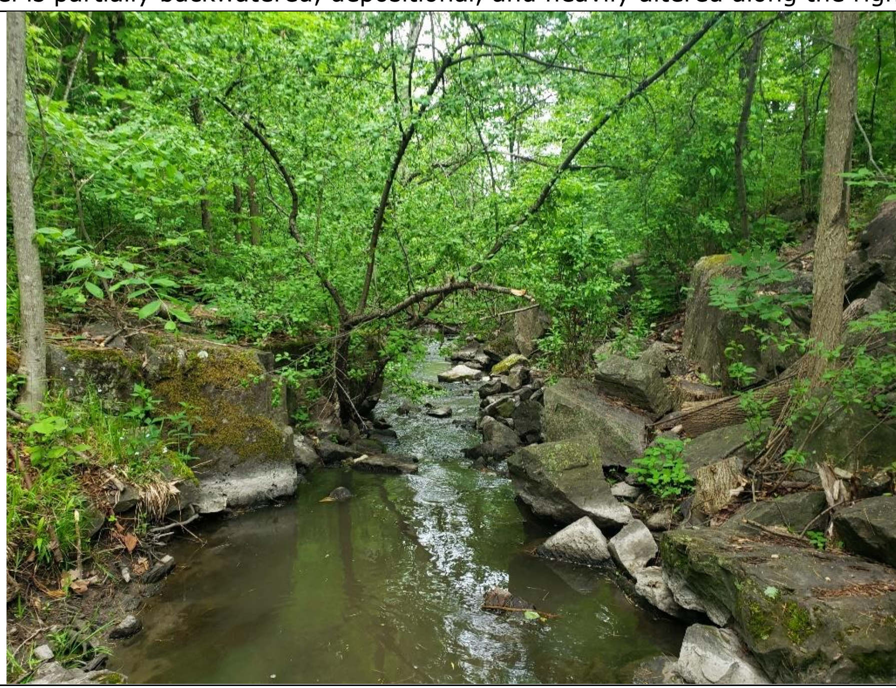
Photo 3 Kizell Drain, KDR-4 – Kanata, Ontario		
	Between the pedestrian bridge (upstream) and the bedrock outcrop (downstream), the channel is partially backwatered, depositional, and heavily altered along the right bank.	
Photo 4 Kizell Drain, KDR-4 – Kanata, Ontario		
	Upstream extent of an approximately 90 m bedrock outcropping which appeared to be composed of native bedrock and deposited boulders	

Photo 5 Kizell Drain, KDR-4 – Kanata, Ontario	 The downstream extent of the bedrock outcrop is a shallow waterfall or knickpoint, and a wide and relatively shallow scour pool. Downstream of the scour pool, the channel conveys flows through a grassy meadow.
Photo 6 Kizell Drain, KDR-4 – Kanata, Ontario	 In this section of KDR-4 where the riparian area has been subjected to less disturbance than adjacent reaches of the Kizell Drain, the banks are generally steep and composed of a loamy clay.

Photo 7 Kizell Drain, KDR-4 – Kanata, Ontario		
	At the downstream extent of the natural riparian area, the channel is backwatered by exposed bedrock creating a depositional area with a soft, unconsolidated sandy silt overlying cohesive clay on the channel bed.	
Photo 8 Kizell Drain, KDR-4 – Kanata, Ontario		
	Exposed compact grey clay was frequently observed along the bed of the channel.	

Photo 9
Kizell Drain, KDR-4 – Kanata, Ontario

Below the dense grass rooting structure, both banks through the natural riparian area of KDR-4 are composed of a loamy clay.

Photo 10
Kizell Drain, KDR-3 – Kanata, Ontario

Culvert marking the upstream extent of AECOM detailed reach, KDR-3. This reach was also partially backwatered in May, 2020 at the time of the rapid assessment when these photographs were taken.

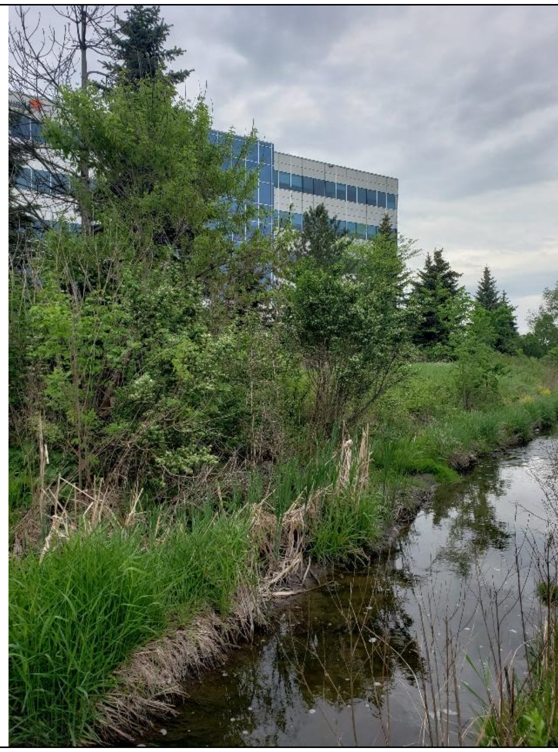
Photo 11 Kizell Drain, KDR-3 – Kanata, Ontario	
	View looking downstream at left bank riparian habitat. The channel is confined by parking lots for large office buildings on either side. The parking lots appear to drain towards the channel.
Photo 12 Kizell Drain, KDR-3 – Kanata, Ontario	
	Similar to KDR-4, the banks were steep with undercutting below the rooting system.

Photo 13 Kizell Drain, KDR-3 – Kanata, Ontario		
	Exposed filter cloth and bank erosion adjacent to exposed bedrock along the right bank. At this location, it is assumed that the presence of bedrock increases channel energy to the left bank.	
Photo 14 Kizell Drain, KDR-3 – Kanata, Ontario		
	In this instance of bank erosion, the riparian vegetation has been cut and maintained. The lack of riparian vegetation and rooting structure is assumed to have resulted in the increased erosion.	

Photo 15
Kizell Drain, KDR-3 – Kanata, Ontario

Downstream of channel disturbances, the channel is significantly backwatered by a beaver dam, limiting the ability to make observations of erosion. The channel was mostly depositional in this backwatered area.

Photo 16
Kizell Drain, KDR-3 – Kanata, Ontario

Example of direct parking lot drainage into the riparian zone/channel.

Photo 17 Kizell Drain, KDR-3 – Kanata, Ontario	
	Beaver dam located near the downstream extent of KDR-3.
Photo 18 Kizell Drain, KDR-3 – Kanata, Ontario	
	View downstream of beaver dam where the exposed silt and clay toe of bank can be observed

Photo 19 Kizell Drain, KDR-2 – Kanata, Ontario		
	Upstream extent of KDR-2 looking downstream. The channel is mostly depositional with loose unconsolidated sandy silt bed.	
Photo 20 Kizell Drain, KDR-2 – Kanata, Ontario		
	Submergent and emergent aquatic vegetation were observed throughout the reach, suggesting that here the system has low energy.	

Photo 21 Kizell Drain, KDR-1 – Kanata, Ontario		
	Pedestrian bridge marking the upstream extent of KDR-1. Here, there is an approximately 15 m long riffle	
Photo 22 Kizell Drain, KDR-1 – Kanata, Ontario		
	KDR-1 is relatively straight and represents a section of the furthest downstream reach of the Kizell Drain before its confluence with Watts Creek. The channel in this location is incised into the compact clay at its bed with undercutting observed along the banks.	

Photo 23 Kizell Drain, KDR-1 – Kanata, Ontario	
	Through KDR-1, there is evidence of lateral migration. In this photograph (looking downstream), deposition of sandy silts were observed along the left bank and slumping was observed along the right bank.
Photo 24 Kizell Drain, KDR-1 – Kanata, Ontario	
	Through the majority of the reach, the bed was composed of highly compact grey clay which could only be disturbed by scratching at the bed.