Geomorphological Report, Tributary of Spring Creek

Municipal Class Environmental Study for Clark Boulevard Extension and Eastern Avenue Improvements from Rutherford Road to Kennedy Road

City of Brampton

Prepared for:
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December 17, 2021
Project No. PN19055

GEO MORPHIX
Geomorphology
Earth Science
Observations

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Appendices

1 Introduction

An Environmental Assessment (EA) is being completed in support of the Clark Boulevard extension from Rutherford Road to Hansen Road, and the Eastern Avenue widening from Hansen Road to Kennedy Road, in the City of Brampton. GEO Morphix Ltd. was retained to fulfill the geomorphological requirements associated with the EA.

The extension of Clark Boulevard will require to cross a minor Tributary of Spring Creek, which runs diagonally across the study limits. Geomorphological services were required to assess the erosion hazard associated with the watercourse, inform future crossing requirements (e.g., crossing size and configuration), and evaluate the need for erosion protection and channel realignment in the vicinity of the Clark Boulevard extension.

This report outlines the activities completed in fulfillment of the geomorphological requirements. Specifically, this includes:

- A review of available background materials, including floodline mapping and HEC-RAS flood modelling
- A review of watershed characteristics that directly influence the local geomorphology
- A review of historical aerial imagery to determine past landuse changes and assess channel migration patterns
- Geomorphic assessment of the study site to characterize the watercourse
- Assessment of the erosion hazard through a desktop review and verification through a modelling exercise
- Identification of potential erosion hazards, and restoration opportunities within the channel

An overview of the EA study limits and associated watercourses are provided in **Appendix A**, for reference.

2 Background Review

2.1 Subwatershed Characteristics

Channel morphology and planform are largely governed by the flow regime and the availability and type of sediments (e.g., surficial geology) within the stream corridor. Physiography, riparian vegetation and land use also physically influence the channel. 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.

Physiographically, the project site is located on a *Bevelled Till Plain* consisting of the Halton Till, which is a clayey to silty till (OGS, 2003). However, extensive land development in the subwatershed have altered geological characteristics. For instance, the subject reach of channel has been realigned within an engineered valley and the upstream reaches are fully piped. This has contributed to significant changes in natural channel functioning, including rapid flow conveyance following rainfall and sediment exhaustion due to limited upstream sources, which generally result in channel instability.

2.2 Reach Delineation

Reaches are homogeneous segments of channel used in geomorphological investigations delineated based on changes in the channel's existing condition (e.g., channel planform, gradient, physiography, land cover, flow contributions, anthropogenic channel modifications, etc.). Reaches are studied semi-independently as each is expected to function in a manner that is at least slightly different from adjoining reaches. This 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. This follows a scientifically defensible methodology proposed by Montgomery and Buffington (1997).

Reaches are first delineated as a desktop exercise using available data and information such as aerial photography, topographic maps, geology information and physiography maps. The results are then verified in the field. Within the study area, a lone reach of the Tributary of Spring Creek was identified between Hansen Road and Rutherford Road. The reach upstream of Hansen Road was not assessed as it is piped. The noted channel reaches are depicted in **Appendix A**.

2.3 Study Area History

A series of historical aerial images were reviewed to determine changes to the channel and surrounding land use/cover. This information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics and may continue to impact them in the future. Aerial photographs from 1960, 1969, 1974, 1981, and satellite imagery from 2004 to 2018 (Google Earth Pro) were reviewed to complete the historical assessment.

In 1960, the subject site and surrounding lands were predominantly agricultural in nature. Farm fields extended to the subject channel reach creek with no visible riparian buffer. The channel and valley alignment were similar to present day observations. For instance, the planimetric form was generally linear with a sharp bend midway through the reach. The channel was likely realigned in this manner to maximize the area available for crops. Notably, multiple swales fed into the creek beyond the bend, stemming from adjacent fields.

By 1969, there was a notable increase in land development along Rutherford Road and Hansen Road. The downstream extent of the study reach was confined on both sides by industrial or commercial complexes. The upstream extent of the study reach flowed through an open field. At Hansen Road the channel was realigned to follow the roadway, where it was crossed by multiple driveways leading northward to Queen Street.

By 1981, the subwatershed was predominantly urbanized. Multiple residential communities were established north of Queen Street, and the subject channel was fully encompassed by industrial and commercial lots. The watercourse remained confined in a narrow valley between these lots and its adjoining tributaries were either piped or realigned to function as roadside ditches. The upstream extent of the study reach remained linear, while the downstream extent appeared to have adopted a subtle sinuosity within the confined valley. Channel reinforcement works were apparent downstream of the study site, beyond Rutherford Road.

Following 1981, land development trends persisted. Aerial assessment of the channel became difficult due to the presence of dense foliage within the narrow valley corridor as well as poor imagery quality. The first clear sign of the existing protective interlocking brick treatment installed along the channel bed throughout the study reach is apparent in 2005. Though, it is likely this treatment was installed much earlier (e.g., 1980's) based on the degree of observed tree growth within the treatment.

In 2013, the commercial complex north of the subject reach adjacent to Rutherford Road was demolished and re-established as a stockpiling location for wood and soil. In 2016, the channel corridor downstream of Rutherford Road was restored, likely as part of the construction of the City of Brampton Apparatus & Maintenance Facility within the adjacent lot. The restored channel consisted of a series of armourstone-based weirs with intermittent overwidened pool features.

In summary, landuse within the watershed has transitioned from an agricultural to a fully urbanized state. Land development has prompted the realignment, hardening, or piping of most watercourses within the catchment, although, with limited presence of stormwater management controls to assimilate urban drainage.

3 Channel Hydraulics

A HEC-RAS model and regulatory flood limits for the subject Tributary of Spring Creek were provided by the TRCA. The materials were reviewed to inform the geomorphological recommendations. According to the HEC-RAS model, the 2-year and 100-year event discharge for the subject reach (Reach 2c) at the downstream extent of the subject site (Station 21.835) measured 12.4 m3/s and 29.1 m3/s. For the same station the respective flow velocities were 1.1 m/s and 1.8 m/s. Reach slope was approximated from the HEC-RAS model and available contour mapping at 0.44%.

Generally, the bankfull discharge, or channel-forming discharge is considered to correspond to the 1.25-year event, which is roughly equivalent to 7.4 m^3/s (approximately two-thirds of the 2-year event discharge), as based on the HEC-RAS model. Following a simple Manning's approach, the associated channel geometries required to effectively convey the bankfull discharge were computed. Manning's equation is mathematically represented as:

$$V = \frac{1}{n}R^{2/3}S^{1/2}$$ **[Eq. 1]**

where, V is flow velocity, *d* is the hydraulic radius, *S* is the channel gradient, and *n* is the Manning's roughness. Applying the bankfull discharge and Manning's roughness of 0.04, the back-calculated bankfull width would range roughly from 6.4 m to 7.4 m, based on an 8 to 10 width-to-depth ratio. The corresponding computed bankfull flow velocity and shear stress would measure 1.4 m/s and 33 N/m^2, respectively.

4 Geomorphological Assessment

A geomorphological assessment of the Tributary of Spring Creek was carried out on June 4th, 2019 to characterize current watercourse conditions to assist with informing crossing sizing and orientation, and to identify opportunities for restoration within the channel corridor. Site photographs are provided in **Appendix B** and detailed fieldnotes are provided in **Appendix C**.

4.1 Reach Observations

Field observations were completed for the reach of channel from Hansen Road to approximately 100 m downstream of Rutherford Road. Additionally, the drainage pathways along Hansen Road and Eastern Avenue were documented.

Upstream (west) of Hansen Drive, field observations revealed multiple roadside drainage pathways. The ditch along Eastern Avenue was predominantly lined with sod. The ditch along Hansen Road consisted of a linear swale overgrown with cattails, which fed into an elevated catch-basin at the Tributary of Spring Creek crossing. The drainage pathway opposite the Hansen crossing (eastward) was piped within ~20 m of the roadway. The flow pathways ultimately converged within a 2100 mm concrete culvert below Hansen Road.

The culvert discharged into a 10 m wide, steep-walled, linear valley. The valley was heavily forested and littered with debris (e.g., trash, rubble, etc.), which had become entangled in the dense network of overhanging branches. The debris line extended to approximately 2 m in height, which was suggestive of past high-flow conditions. The entire length of channel was reinforced with an interlocking grid of enlarged concrete blocks / bricks. The protective treatment extended partially up the channel banks to a height of approximately 0.75 m. The treatment was generally exposed throughout, aside from several short stretches of channel that were inundated with sediment due to the occurrence of litter-based debris jams. A significant portion of the treatment had failed. For instance, a significant portion of the bricks were dislodged or had become outflanked due to overbank scouring. Additionally, numerous trees had grown into or over the treatment, resulting in local upheavals of the brick. Although, the presence of trees enhanced channel roughness, which would act to reduce flow velocities and lower shear / erosion potential. The presence of the erosion-resistant treatment inhibited scouring and the formation of any variable channel bed morphology such as riffles or pools. Erosional forces were instead directed towards the banks, which displayed indications of widening.

Channel substrates consisted predominantly of fine materials and small gravels, which occupied the interstitial space between bricks. Fresh deposits of sand were also observed in the overbank. Sediment input was likely driven by bank erosion and inputs from urban sources.

The channel bent sharply southward 200 m from Hansen Road, where an adjoining culvert contributed a trickle of flow into the creek. Multiple culverts stemming from the adjacent industrial / commercial lots were observed throughout the study reach. One such culvert, located approximately 100 m from Rutherford Road, discharged a concentrated, light, odorous slurry, which blanketed the channel bed. The slurry of unknown substance was eventually filtered through a woody-based obstruction.

The Rutherford Road crossing consisted of a 1.9 m concrete culvert enveloped in slumping gabion basket. Downstream of Rutherford Road, the culvert was joined by two others, which fed into an oversized pool. All three culverts were perched. The channel reach downstream of Rutherford Road followed a step-pool morphology. Aerial imagery revealed the reach was realigned in 2016. The “steps” were armourstone-based and were separated by overwidened pools. The first armourstone step was relatively elevated, limiting fish passage upstream.

The low flow channel of the study reach of the Tributary to Spring Creek ranged from 1.6 m to 5.0 m in width, and 0.40 m to 1.15 m in depth. However, true bankfull parameters were significantly larger, estimated in the range of 6 m in width and 2 m in height (approximately equivalent to the observed debris line). Bankfull indicators were difficult to discern with accuracy due to the heavily-modified nature of the channel.

4.2 Rapid Geomorphic Assessment Techniques

Generally, a geomorphic assessment for a given channel includes an evaluation through application of the Rapid Geomorphic Assessment (RGA; OME, 2003) and the Rapid Stream Assessment Technique (RSAT; Galli, 1996). The RGA provides a general evaluation of channel sensitivity based on aggradation, degradation, channel widening, and planimetric (planform) adjustment. The RSAT evaluates stream health and the ecological functioning of the watercourse. However, the rapid assessment techniques are intended for alluvial systems with naturally meandering planimetric forms, that have not undergone significant modification. As such, the technique results were not deemed to be applicable for the subject watercourse.

Instead, the channels were generally assessed based on the RGA and RSAT evaluation criteria. Following the RGA, it is noted that the channel displayed multiple indicators associated with channel adjustment. Predominantly, this included observations of aggradation (e.g., fresh sand deposits along the overbank, presence of medial bars, etc.) and channel widening (e.g., exposed tree roots, outflanked erosion mitigation treatments, etc.). Channel widening was likely augmented by the armoured bed, which would inhibit downcutting and instead direct potentially erosive forces laterally towards the banks. With regards to the RSAT, there were multiple observations indicative of “poor” channel health, including a limited riparian buffer, limited instream habitat (e.g., no riffles or pools), and poor water quality.

4.3 Future Trends in Stream Function

From these observations it is evident that the watercourse is undergoing some degree of systematic adjustment. A primary reason as to why the adjustment is occurring is that the channel is responding to the noted changes in the hydrological and sediment regime of the catchment due to urbanization and the increased abundance of impervious surfaces as well as climate change. Given that most of the land in the catchment has already been developed, it is not anticipated that landuse and the extents of impervious surfaces will undergo substantial change in the foreseeable future. Although, minor improvements to urban stormwater management are expected to occur gradually over time, with increased public outreach and adoption of community-based initiatives (e.g., such as enhanced efficiency of water use, increased downspout disconnection, or general replacement of concrete surfaces with more permeable-type materials to promote infiltration). Overall, however, there is limited opportunity to modify the existing hydrologic and hydraulic condition of the watershed, with the exception of potential impacts related to climate change. Therefore, if left unmitigated, it is expected that the observed trends in channel erosion and enlargement, coupled with poor overall stream health and ecological value, will persist, as is typical of urban streams (Vietz, 2013).

5 Erosion Hazard Assessment

5.1 Background

Most watercourses in southern Ontario have a natural tendency to develop and maintain a meandering planform, provided there are no spatial constraints. An understanding of these tendencies is therefore useful for informing the potential hazard to proposed activities in the vicinity of a stream as well as the need for supporting erosion mitigation measures.

When defining the erosion hazard for a watercourse, the Ministry of Natural Resources and Forestry (MNRF, 2002) guidelines treat unconfined and confined systems differently. Unconfined systems are those with poorly defined valleys or valley slopes well outside the limits where the channel could realistically migrate, as informed by a meander belt width assessment. Confined systems are those where the watercourse is contained within a defined valley, where valley wall contact is possible.

5.2 Erosion Hazard Delineation

There were numerous considerations with respect to delineating the erosion hazard for the subject Tributary to Spring Creek, including:

1) The watercourse was straightened prior to 1960 and later confined within an engineered valley
2) The 10 m wide engineered valley is undersized relative to the creek, which has a bankfull width of ~6 m
3) Channel migration rates cannot be estimated with accuracy given that the tributary has displayed limited evidence of planimetric adjustment, as a result of the historical modifications

Based on these considerations, a preliminary erosion hazard assessment was completed, which precluded a meander belt width assessment given that it is a confined system, to provide a measure of the potential limits of channel migration into the adjacent valley walls. The erosion hazard delineation, if used for planning purposes, must be refined based on detailed topographic data and the condition and extents of erosion mitigation measures.

The erosion hazard was defined following MNRF toe erosion guidelines (**Appendix D**), which assess the potential limits of channel migration into the valley wall based on channel processes and local soil conditions. In this case, a toe erosion allowance of 5 m would be applicable to either side of the existing bankfull channel according to the guidelines, in addition to a stable slope setback, as determined by a geotechnical engineer.

5.3 Meander Belt Width Estimation

A meander belt estimation exercise was also completed for the subject reach, as a supplementary exercise, to provide context in the event that a corridor realignment is selected as the preferred alternative to support the Clark Boulevard Extension. Completion of a meander belt width assessment was also considered appropriate given that the subject watercourse did not originally sit within a defined valley, having been set within an engineered valley in the 1980's.

Following the TRCA protocol (TRCA, 2004), the meander belt width is typically defined based on a review of the lateral extents in which the channel has historical occupied, plus the addition of an erosion setback to account for future channel migration and shifts to the meander belt axis. However, in the case of the study reach, the watercourse was already straightened prior to the earliest available aerial photography and has undergone multiple realignments and valley engineering throughout the study period. Channel reaches upstream and downstream of the watercourse were also straightened and therefore were not useable as surrogates to inform the naturally meandering form of the subject reach. Instead, a hypothetical meander belt was estimated based on the computed bankfull channel dimension (see **Section 3**) through application of empirical relations, as outlined by **Equations 7** and **8**.

1) Modified Williams-Width (1986) Approach

$$B_w = (18A^{0.65} + W_b)*SF \qquad \textbf{[Eq. 7]}$$

where B_w is the belt width (m), W_b is the average bankfull channel width (m), and A is the channel cross-sectional area (m^2). An additional 20% buffer, or factor of safety (FS), was applied to the computed results to address issues of under prediction.

2) TRCA – Procedure 5 (2004) Approach

$$B_w = -14.827 + 8.319(SP * DA) + SE \qquad \textbf{[Eq. 8]}$$

where B_w is the belt width(m), SP is stream power (Wm^{-2}), as based on the modelled 2-year discharge and channel gradient, DA is the watercourse drainage area (m^2), and SE is the standard error of the equation (equivalent to 8.63).

The results of the hypothetical meander belt width estimations are provided in **Table 1**.

Table 1: Preliminary Meander Belt Width Estimation

Approach	Computed Bankfull Width (m)	Hypothetical Meander Belt Width (m)
Equation 7 (Williams, 1986)	7.4	57.4
Equation 8 (TRCA, 2004)	7.4	55.3

The hypothetical meander belt estimates are provided for reference only in the event of a corridor realignment. Although, they are not considered to be practical parameters upon which to base corridor requirements in this study. Further details on this are provided in **Section 6**.

6 Geomorphological Recommendations

Following the May 2019 site walk with the TRCA and the City of Brampton, it is understood that several alignment options for the Clark Boulevard extension are being explored. The options range from piping of the subject channel to varied extents of channel realignment in order to permit a crossing orientation perpendicular to the creek. A review of each approach is provided below. We note that the recommendations provided herein are from a geomorphological perspective and may not account for local site constraints posed by infrastructure or planned property acquisition and development.

6.1 Review of Design Alternatives

Piping of the Channel

In general, crossing and channel realignment designs should address channel geomorphic form and function. This includes accounting for channel migration, sediment transport processes, and local ecology (e.g., fish and terrestrial passage). Therefore, piping is not a preferred solution from a geomorphological perspective.

Valley-Spanning Structure

Alternatively, the existing channel corridor may be maintained through provision of valley-spanning structure, which would limit any impact to the existing creek. Such a structure would likely require to be oversized (e.g., 60 m to 100 m span) to fully accommodate the diagonal alignment of the creek, the regulatory flood limits, as well as a channel erosion allowance. Therefore, a valley-spanning structure is not considered a practical and cost-effective approach.

Channel Realignment

The third option is to realign the existing creek, which is the preferred solution from a geomorphological perspective. Realignment of the creek corridor would be costly. However, it offers numerous opportunities to enhance upon the existing channel corridor condition, namely:

- Opportunity to rehabilitate a degraded section of engineered channel with a hybrid natural / engineered solution
- Improved geomorphological condition through provision of a morphologically-diverse channel
- Improved conveyance and containment of flood events
- Provision of a functional floodplain to enhance flow and energy attenuation and water detention in the overbank area

- Channel may be realigned to be perpendicular to future roadway (reduced crossing span extents, as compared with valley-spanning structures)
- Enhanced aesthetic appeal

With consideration to the computed channel hydraulics and anticipated dynamics associated with urban watersheds, a hybrid approach consisting of a cascade and reinforced-bioengineered bank treatment was deemed to represent a stable, practical solution. Cascades may be constructed in a relatively linear manner to reduce encroachment to adjacent property or nearby infrastructure while providing the necessary energy dissipation and maintaining a high degree of morphological diversity with spatially-varied flows. Additionally, bioengineering is likely required along the channel banks to reduce lateral migration. As an example, vegetated rock buttresses are considered a natural, stable solution when appropriately designed with hydraulically-sized materials. The cascade or bioengineering treatment can be supplemented with armourstone to augment treatment robustness and durability, as needed. A visual example of a constructed cascade is included in **Appendix E**.

Realignment of the channel following a reinforced cascade design approach is consistent with channel conditions observed downstream. For instance, the reach of channel located immediately downstream of Rutherford Road was realigned in 2014 and incorporated a cascade morphology. Cascade steps consisted of armourstone weir structures, while the channel banks were reinforced with riprap and gabion-basket. The restored valley corridor varied in width, trending from 15 m to 25 m to limit encroachment towards adjacent newly developed lots.

An appropriate design channel width would likely fall in the noted range of 6.4 m to 7.4 m, as computed in **Section 3**. This estimate is slightly larger than the field-estimated bankfull width of 6.0 m but deemed appropriate given that the channel displayed evidence of instability and adjustment towards a wider planimetric form. Typically, the corresponding channel corridor is sized based on the channel meander belt, which, in this case, could span over 50 m, depending on the selected methodology (see **Section 5.3**). However, it is recognized that construction of such a corridor is not feasible due to numerous local constraints related to available property and infrastructure presence. Moreover, the associated costs of property acquisition and construction would be immense. Alternatively, a relatively reduced channel corridor width would be considered appropriate as long as select erosion mitigation measures are incorporated to limit the potential for channel adjustment. From a geomorphological perspective, a corridor measuring 3x the width of the bioengineered / reinforced bankfull channel, approximately equivalent to 22.2 m, is likely appropriate. Essentially, this would provide one bankfull width of erosion allowance on either side of the creek, and would therefore likely address the erosion concern. With respect to a crossing, a span measuring in the range of 2x the bankfull width (e.g., ~14.8 m) of a suitably bioengineered / reinforced channel is likely appropriate.

Finally, a “valley-trending” approach, similar to that identified for the reach downstream of Rutherford, may also represent a practical solution for the subject reach, so long as there is no overall reduction in channel footprint as compared to the existing condition. Valley extents may vary to accommodate local infrastructure or planned development to adjacent lots.

6.2 Discussion

The erosion hazard, channel hydraulics, and potentially suitable erosion mitigation strategies were assessed at a preliminary level and should be refined during detailed design to more accurately reflect channel conditions. This includes completion of a detailed geomorphic assessment, which consists of a survey of the channel longitudinal profile and multiple channel transects to verify bankfull hydraulics. Design solutions should be cognizant of the urban nature of the system, which is considered to be “flashy” due to limited upstream stormwater management, and characterized by a reduced natural supply of sediments.

In case of a channel realignment, all materials are to be hydraulically-sized to withstand the regulatory flood event. Realigned sections of channel should seek to increase the overall channel footprint as compared to the existing condition.

Finally, a post-construction monitoring program is recommended to assess the performance of the implemented realignment design. Monitoring observations can also be used to determine the need for remedial works. Monitoring is recommended for three full calendar years following the year of construction.

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

Respectfully submitted,

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

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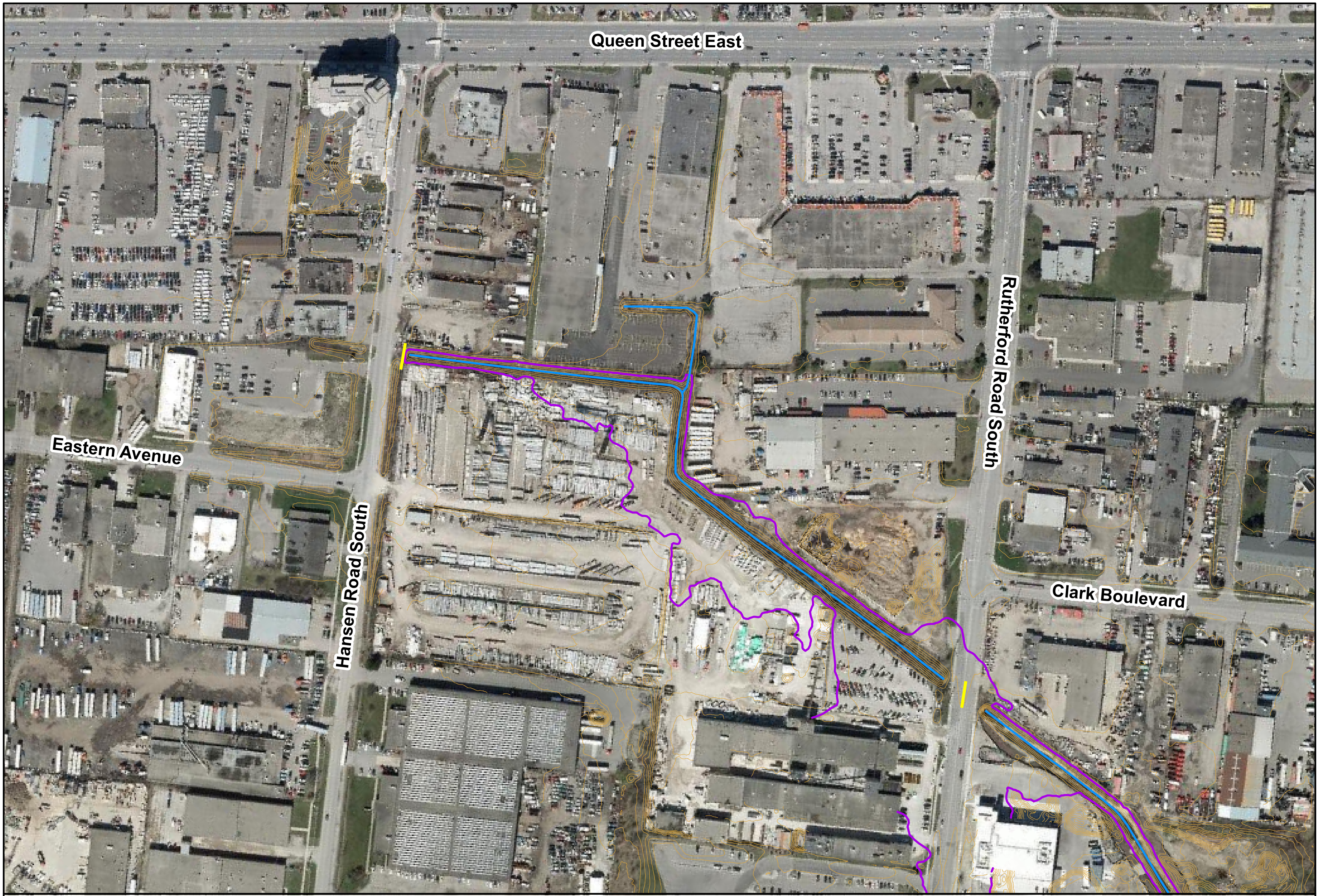
Appendix A
Overview of Study Limits



Legend

- Reach Break
- Subject Watercourse
- Regulatory Floodline
- Contour (0.5 m)

Tributary of Etobicoke Creek

Clark Boulevard and Eastern Avenue Environmental Assessment

Overview of Study Limits

GEO MORPHIX

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community Imagery: October, 2016.
Watercourse, Floodline, Contours: TRCA, 2018.
Reach Break: GEO Morphix Ltd., 2019.
Print Date: July, 2019. PN19055. Drawn By: W.B., B.M., S.S.

Appendix B
Site Photographs

Photo 1

The reach upstream of Hansen Road South was piped underground. The channel resurfaced briefly before entering a 1.4 m CSP culvert.

Photo 2

There was additional flow contributions from adjoining subsurface pipes beneath Hansen Road. The collective flows outlet through a 2.1 m concrete culvert encased within a gabion basket retaining wall.

Photo 3

The channel and overbank was laden with debris to heights of ~2 m, which was indicative of anticipated high flow conditions.

Photo 4

The entire length of channel and bank toe was underlain with an interlocking brick treatment, which had failed (e.g., dislodged) at multiple instances throughout the reach.

Photo 5	
	Multiple debris jams were observed throughout the subject reaches, leading to significant aggradation and burial of the brick treatment upstream.
Photo 6	
	There was a sharp bend in the channel 200 m downstream of Hansen Road, where an adjoining outfall contributed minor flows.

Photo 7

Mature trees had grown over the brickwork and provided indication of the dated nature of the protective treatment.

Photo 8

Multiple outlets stemming from adjacent lots fed into the channel from both banks throughout the subject reaches.

Photo 9	
	An outlet along the south bank near Rutherford Road discharged a slurry of unknown substance into the creek.
Photo 10	
	The lightly coloured slurry extended 25 m downstream where it was filtered through a woody debris jam.

Photo 11

The Rutherford Road crossing consisted of a 1.9 m concrete culvert flanked by slumped gabion basket retaining walls.

Photo 12

Three perched concrete culverts discharged to the creek downstream of Rutherford Road. The adjoining culverts likely conveyed subsurface storm water drainage from adjacent lots / roadways.

Photo 13

A particularly raised armourtsone weir located 65 m from Rutherford Road partially impounded flows and restricted fish passage.

Appendix C
Field Observations

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General Site Characteristics

Project Code: 19055

Date:	June 4, 2019	**Stream/Reach:**	Reach 2c (HEC)
Weather:	15°C, Clouds	**Location:**	Clark Blvd → Hansen Rd
Field Staff:	BM	**Watershed/Subwatershed:**	Trib. Etobicoke Ck

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Medial bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization/gabion
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Station location
- Vegetated island

Flow Type

H1	Standing water
H2	Scarcely perceptible flow
H3	Smooth surface flow
H4	Upwelling
H5	Rippled
H6	Unbroken standing wave
H7	Broken standing wave
H8	Chute
H9	Free fall

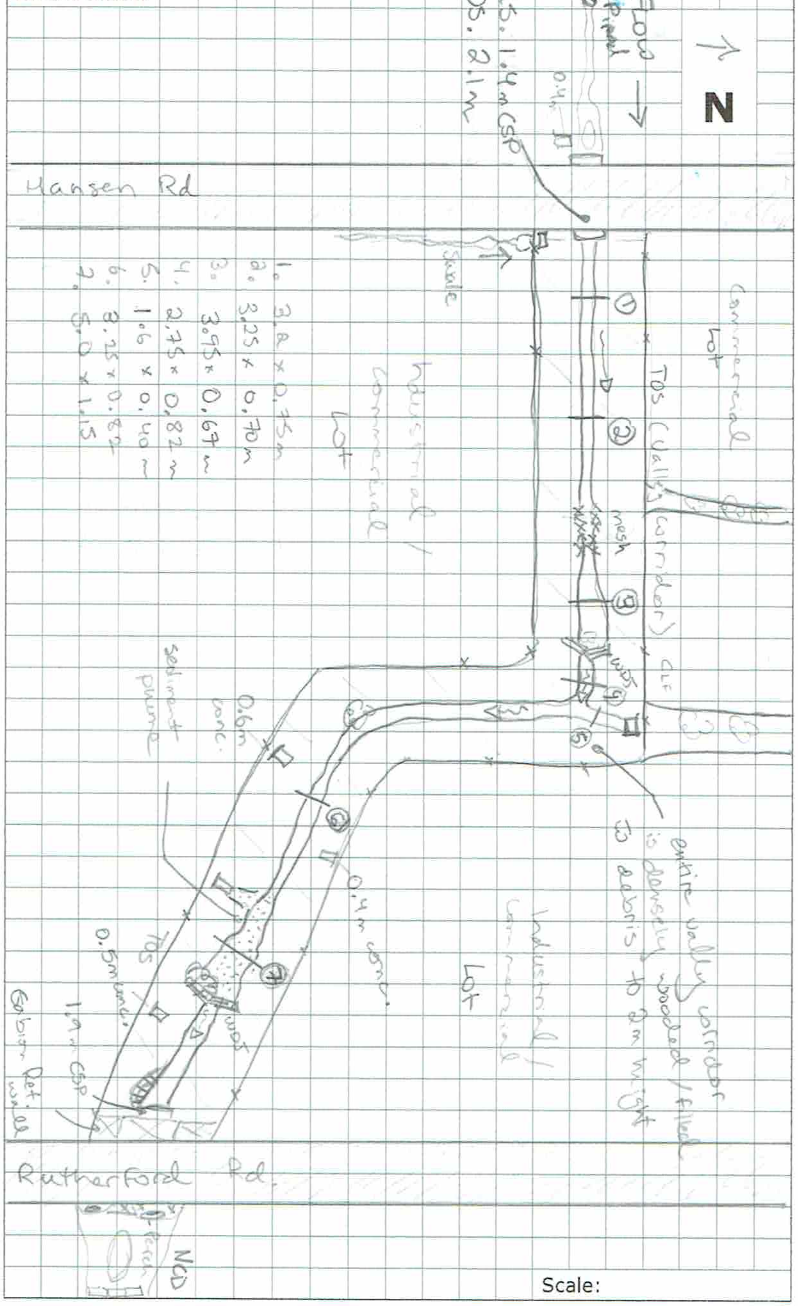
Substrate

S1	Silt	**S6**	Small boulder
S2	Sand	**S7**	Large boulder
S3	Gravel	**S8**	Bimodal
S4	Small cobble	**S9**	Bedrock/till
S5	Large cobble		

Other

BM	Benchmark	**EP**	Erosion pin
BS	Backsight	**RB**	Rebar
DS	Downstream	**US**	Upstream
WDJ	Woody debris jam	**TR**	Terrace
VWC	Valley wall contact	**FC**	Flood chute
BOS	Bottom of slope	**FP**	Flood plain
TOS	Top of slope	**KP**	Knick point

Site Sketch:



Scale:

Additional Notes: Full feature lined w̄ brick (bed banks) and occasional wire meshing. The materials are eroded/outflanked. WDJ's cause sedimentation U/S, burying reinforcem materials.

Completed by: BM Checked by: ______

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Reach Characteristics

Project Code: 19055

Date:	June 4, 2019	**Stream/Reach:**	Reach 2c (NEC)
Weather:	15°C, cloudy	**Location:**	Clark Blvd.
Field Staff:	BM.	**Watershed/Subwatershed:**	Trib. Etobicoke Ck
UTM (Upstream)	43°41'51.13" N 79°44'37.81"	**UTM (Downstream)**	43°41'56.64" N 79° 44' 18.67" W

Land Use (Table 1): 4/9
Valley Type (Table 2): 2
Channel Type (Table 3): 11
Channel Zone (Table 4): 2
Flow Type (Table 5): 1
☑ Groundwater
Evidence: Iron oxidation

Riparian Vegetation

Dominant Type: (Table 6) 1
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) 6
Coverage of Reach (%) 20

Woody Debris
☑ Present in Cutbank
☑ Present in Channel
☐ Not Present

Density of WD:
☐ Low
☑ Moderate
☐ High

WDJ/50m: 1

Water Quality

Odour (Table 16) 3
Turbidity (Table 17) 2

Channel Characteristics

Sinuosity (Type) (Table 9) 5
Sinuosity (Degree) (Table 10) 1
Gradient (Table 11) 2
Number of Channels (Table 12) 1

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

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

	Aug.		Max				
Bankfull Width (m) Low flow* (Terraced)	3.6	/	5.0	**Wetted Width (m)**	1.5	/	/
Bankfull Depth (m)	0.82	/	1.15	**Wetted Depth (m)**	0.2	/	/

Riffle/Pool Spacing (m) NA
% Riffles: NA
% Pools: NA
Meander Amplitude: NA

Pool Depth (m) 0.35*
Riffle Length (m) NA
Undercuts (m) 0.10

Velocity (m/s) 0.3 | 0.2 |
[✓ Wiffle ball] / ADV / Estimated

Comments: Fully realigned / reinforced channel

Bank Angle
☐ 0 – 30
☐ 30 – 60
☐ 60 – 90
☑ Undercut

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

Notes:
Terraced.
LF ~ 3m wide
Floodline ~ 5m wide.

Completed by: BM.
Checked by: ________

Appendix D
Toe Erosion Guidelines

MNRF Toe Erosion Allowance Table. Retrieved from: Technical Guide – River and Stream Systems: Erosion Hazard Limit (MNRF, 2002)

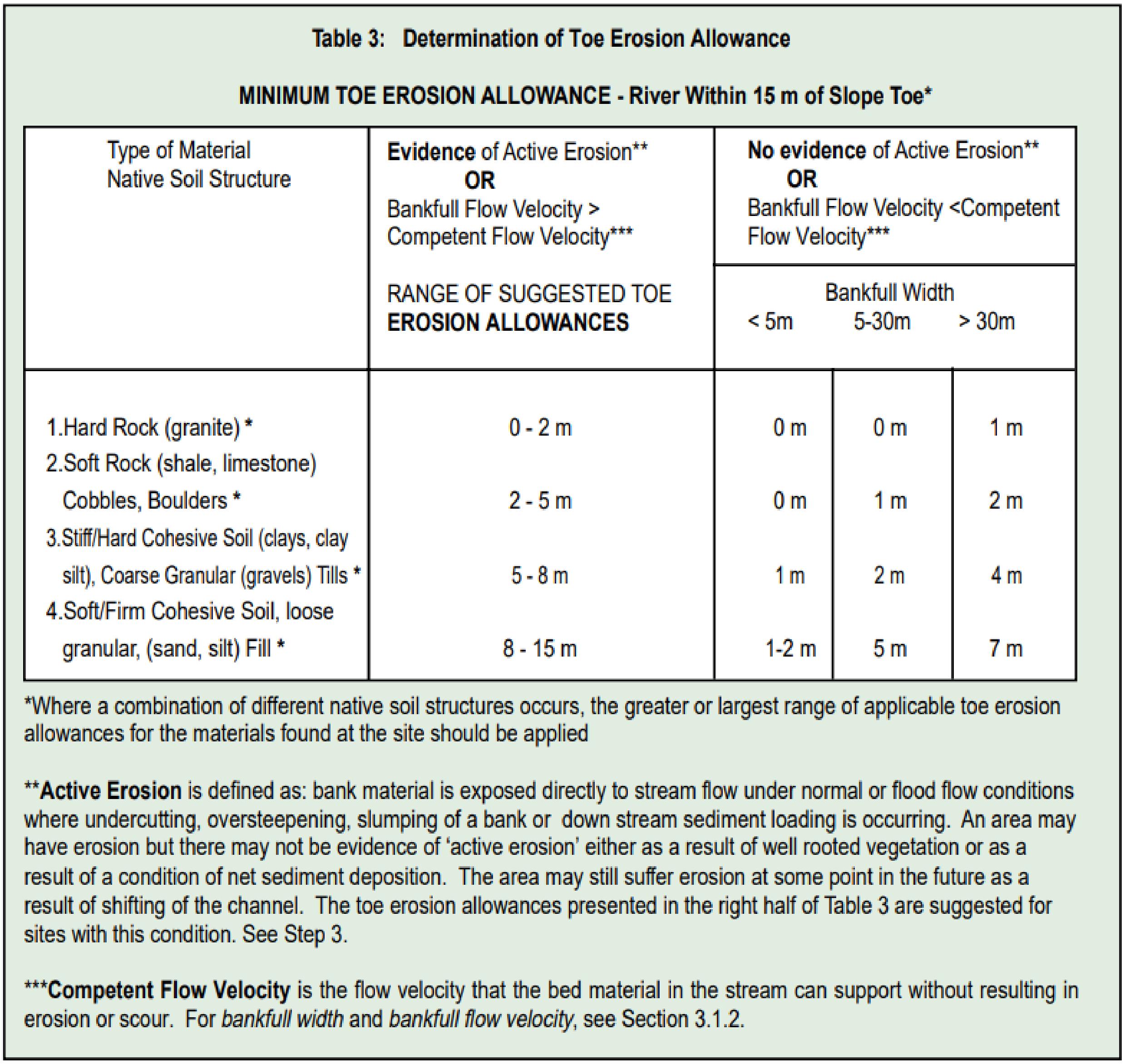

Table 3: Determination of Toe Erosion Allowance

MINIMUM TOE EROSION ALLOWANCE - River Within 15 m of Slope Toe*

Type of Material Native Soil Structure	**Evidence** of Active Erosion** **OR** Bankfull Flow Velocity > Competent Flow Velocity***	**No evidence** of Active Erosion** **OR** Bankfull Flow Velocity <Competent Flow Velocity***		
	RANGE OF SUGGESTED TOE **EROSION ALLOWANCES**	Bankfull Width		
		< 5m	5-30m	> 30m
1.Hard Rock (granite) *	0 - 2 m	0 m	0 m	1 m
2.Soft Rock (shale, limestone) Cobbles, Boulders *	2 - 5 m	0 m	1 m	2 m
3.Stiff/Hard Cohesive Soil (clays, clay silt), Coarse Granular (gravels) Tills *	5 - 8 m	1 m	2 m	4 m
4.Soft/Firm Cohesive Soil, loose granular, (sand, silt) Fill *	8 - 15 m	1-2 m	5 m	7 m

*Where a combination of different native soil structures occurs, the greater or largest range of applicable toe erosion allowances for the materials found at the site should be applied

****Active Erosion** is defined as: bank material is exposed directly to stream flow under normal or flood flow conditions where undercutting, oversteepening, slumping of a bank or down stream sediment loading is occurring. An area may have erosion but there may not be evidence of 'active erosion' either as a result of well rooted vegetation or as a result of a condition of net sediment deposition. The area may still suffer erosion at some point in the future as a result of shifting of the channel. The toe erosion allowances presented in the right half of Table 3 are suggested for sites with this condition. See Step 3.

*****Competent Flow Velocity** is the flow velocity that the bed material in the stream can support without resulting in erosion or scour. For *bankfull width* and *bankfull flow velocity*, see Section 3.1.2.

Appendix E
Example of Constructed Cascade

Example of constructed cascade in Toronto with boulder-type weirs and bioengineered banks. Photo by GEO Morphix Ltd. (2016).