BEACON ENVIRONMENTAL

GUIDING SOLUTIONS IN THE NATURAL ENVIRONMENT

Di Poce (Innisfil) Inc.

Geomorphic Assessment
Salem Secondary Plan Area
Bear Creek Watershed
City of Barrie, Simcoe County

Prepared For:

Di Poce (Innisfil) Inc.

Prepared By:

Beacon Environmental Limited

Date:	*Project:*
January 2019	**218066**

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1. Introduction

Beacon Environmental Limited (Beacon) has been retained by Di Poce (Innisfil) Inc. to undertake a geomorphic assessment support of the proposed residential and commercial development located within the City of Barrie. The subject property is located in the Barrie Annexed Lands, North of Salem Road, West of Essa Road, East of Country Road 27, and South of an existing residential area, (**Figure 1**).

The subject property falls within the Bear Creek subwatershed which is located within the jurisdiction of the Nottawasaga Valley Conservation Authority (NVCA). A tributary of Bear Creek (western tributary) transects the subject property; a portion of Bear Creek flows within a confined valley setting along the northeast corner of the property. The purpose of this geomorphic study will be to characterize existing conditions, contribute to the determination of limits of development through the provision of meander belt dimensions and geotechnical stable slope criteria, provision of road crossing recommendations (if applicable), and to provide technical support to the development of a stormwater servicing plan for the development.

Specifically, the following tasks were undertaken in support of the study:

- Background review of available materials (topographic mapping, aerial photography, and previous studies);
- Desktop assessment to delineate reaches based on underlying geomorphic controls;
- Rapid geomorphic assessment of existing field conditions;
- Collection of detailed geomorphic field data within Bear Creek (Reach BEA1-4);
- Determination of meander belt limits for the unconfined valley system portion of Bear Creek within the subject property;
- Recommendation of toe erosion allowance for the section of confined valley along the northeast corner of the subject property; and
- Recommendation of geomorphic road crossing design requirements.

2. Policy Context

2.1 Provincial Policy Statement (2014)

The Provincial Policy Statement (MNRF 2014) issued under the Planning Act (1990) outlines areas of provincial interest with respect to natural hazards. In support of the Policy Statement, a Technical Guide - Rivers and Streams: Erosion Hazard Limit document was prepared (MNR 2002) to outline standardized procedures for the delineation and management of riverine erosion hazards in the Province of Ontario. The guide presents erosion hazard protocols based on two generalized landform systems through which watercourses flow: confined and unconfined valley systems. Through this approach, the meander belt width plus an erosion access allowance is defined to determine the erosion hazard limit of an unconfined valley system. For confined valley systems, the erosion hazard limit is governed by geotechnical considerations, including the stable slope allowance and an applicable toe erosion allowance (i.e., channel migration component).

The intent of the toe erosion allowance is to mitigate risk to the adjacent tablelands by accounting for the potential of the stream to migrate laterally into the valley wall and erode the toe of slope. This process can result in subsequent slope adjustments or failure and cause the loss of property or pose a risk to human life. Policy dictates that, for confined valley systems, an initial screening must be undertaken to determine whether the valley wall is less than 15 m from the watercourse. Where soil conditions are not known, a 15 m toe erosion allowance is recommended. Based on a more detailed evaluation, the Technical Guide provides recommendations for the toe erosion allowance referencing existing soil structure and channel stability conditions (**Table 1**).

Table 1. Minimum Toe Erosion Allowance based on Existing Conditions (MNR 2002)

Type of Material Native Soil Structure	Evidence of Active Erosion or where the Bankfull Flow Velocity is Greater than Competent Flow Velocity	No Evidence of Active Erosion		
		Bankfull Width		
		<5m	5-30m	>30m
Hard Rock (e.g. granite)	0-2 m	0 m	0 m	1 m
Soft Rock (shale, limestone), cobbles, boulders	2-5 m	0 m	1 m	2 m
Clays, clay-silt, gravels	5-8 m	1 m	2 m	4 m
Sand, silt	8-15 m	1-2 m	5 m	7 m

2.2 Nottawasga Valley Conservation Authority Ontario Regulation 172/06 Planning and Regulation Guidelines (2009)

In February of 2007, the NVCA Board of Directors approved the administrative Procedures for the Implementation of Ontario Regulation 172/06. Specifically, this regulation allows the Authority to:

- Prohibit, regulate or provide permission for straightening, changing, diverting or interfering in any way with the existing channel of a river, creek, stream, watercourse or changing or interfering with a wetland.
- Prohibit, regulate or provide permission for development if the control of flooding, erosion, dynamic beaches, pollution or the conservation of land may be affected by the development

The following types of lands are regulated:

- Ravines, valleys, steep slopes (escarpment areas);
- Wetlands including swamps, marshes, bogs, fens and ponds;
- Any river, creek, flood plain or valley land; and
- Lake shorelines.

For the purposes of administering the Regulation, the following direction is provided with respect to development within NVCA jurisdiction with respect to river or stream valleys:

Site Location	Figure 1

Di Poce Subdivision
Geomorphic Assessment

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Last Revised: January, 2019

Client: Di Poce Management Inc.	Prepared by: DU Checked by: AG

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2.(1) Subject to section 3, no person shall undertake development or permit another person to undertake development in or on areas within the jurisdiction of the Authority that are,

(b) river or stream valleys that have depressional features associated with a river or stream, whether or not they contain a watercourse, the limits of which are determined in accordance with the following rules:

(i) where the river or stream valley is apparent and has stable slopes, the valley extends from the stable top of bank, plus 15 metres, to a similar point on the opposite side,

(ii) where the river or stream valley is apparent and has unstable slopes, the valley extends from the predicted long term stable slope projected from the existing stable toe of the slope or, if the toe of the slope is unstable, from the predicted location of the toe of slope as a result of stream erosion over a projected 100-year period, plus 15 metres, to a similar point on the opposite side, The NVCA regulates hazards lands including valleylands, wetlands, watercourses, and shorelines, including lands adjacent to these features.

(iii) *where the river or stream valley is not apparent, the valley extends the greater of,*

A. the distance from a point outside the edge of the maximum extent of the floodplain under the applicable flood event standard, plus 15 metres, to a similar point on the opposite side, and

B. the distance from the predicted meander belt of a watercourse, expanded as required to convey the flood flows under the applicable flood event standard, plus 15 metres, to a similar point on the opposite side.

Ontario Regulation 172/06 defers to the definitions of apparent (confined) and not apparent (unconfined) river and stream valley landforms as explained in the Technical Guide – River and Stream Systems (MNR 2002):

- *Apparent (confined) river and stream valleys: are ones in which the physical presence of a valley corridor containing a river or stream channel, which may or may not contain flowing water, is visibly discernible (i.e. valley walls are clearly definable) from the surrounding landscape by either field investigations, aerial photography and/or map interpretation. The location of the river or stream channel may be located at the base of the valley slope, in close proximity to the toe of the valley slope (i.e. within 15 metres), or removed from the toe of the valley slope (i.e. greater than 15 metres).*
- *Not Apparent (unconfined) river and stream valleys: are ones in which a river or stream is present but there is no discernible valley slope or bank that can be detected from the surrounding landscape. For the most part, unconfined systems are found in fairly flat or gently rolling landscapes and may be located within the headwater*

> *areas of drainage basins. The river or stream channels contain either perennial (i.e., year round) or ephemeral (i.e. seasonal or intermittent) flow and range in channel configuration from seepage and natural channels to detectable channels.*

Subject to conformity with the applicable Official Plan, and completion of appropriate studies and completion of the Conservation Authority permit process, development may be permitted within a regulated area. Application for development and interference in regulated areas requires the issuance of a permit from the NVCA.

2.2.1 Nottawasaga Valley Conservation Authority Stormwater Technical Guide (2013)

The Nottawasaga Valley Conservation Authority (NVCA) Stormwater Technical Guide was produced to provide technical considerations for the development submission. This document provides specific details concerning the management of stormwater volume and erosive power following development, with the overall objective of maintaining existing watershed conditions.

Stormwater volume should be managed so that existing watershed conditions are not adversely impacted following development. Unless otherwise specified, post-development peak flow rates must not exceed the corresponding pre-development rates for the 1:2-year, 1:5-year, 1:10-year, 1:25-year, 1:50-year, and 1:100-year design storm events for the 4-hour Chicago and 24-hour SCS Type II storm models.

To manage an increase in stormwater as a result of urbanization, a minimum of the first 5 mm of runoff produced over the entire development area should be retained through Low-Impact Development measures. To mitigate the potential impacts of increased erosion in the receiving watercourses, the NVCA recommends that a rapid geomorphic assessment (RGA) is completed in accordance with the TRCA and CVC Stormwater Management Criteria Document (2012) for all development applications were the outlet is directly into a watercourse.

If the RGA score for the receiving watercourse is greater than 0.2, a detailed geomorphic assessment is required. Further, if the RGA score is less than 0.2, but any of the individual scoring parameters is greater than 0.5, a detailed geomorphic assessment would be required. Such watercourses are deemed sensitive to increased erosion and require a minimum of 48-hour detention of the 25 mm storm event. Further mitigation efforts may be required based on the results of a detailed geomorphic assessment.

2.3 City of Barrie Official Plan (2010, Office Consolidation 2018)

On April 23, 2010 The Ministry of Municipal Affairs and Housing (MMAH) approved a new Official Plan for the City of Barrie. According to the plan, "*the City shall protect, maintain and enhance water and water related resources on an integrated watershed management basis"*.

Activities interfering in any way with an existing watercourse, such as channel straightening or diversions, are prohibited except with written approval from the Conservation Authority. Development limits shall be established by the limit of the valley or stream corridor which includes the watercourse, associated riparian vegetation, floodplain or erosion hazard lands, top of bank, and any additional lands.

Site alteration shall not be permitted within fish habitat area except in accordance with Provincial and Federal requirements and may require authorization from Fisheries and Oceans Canada.

Development adjacent to a valley and stream corridor must include protections and/or enhancements to the feature and its functions to facilitate a natural, open space corridor. Land uses within the vegetation zone shall be restricted to those that maintain or enhance the natural features and ecological functions of the area.

3. Background Review

3.1 Salem Annexed Lands Subwatershed Impact Study (Schaeffers *et al.* 2017)

In October 2013, AMEC Environment & Infrastructure completed a Drainage and Stormwater Management Master Plan (DSWMMP) for the City of Barrie. The DSWMMP provided an integrated assessment of existing stormwater systems, existing infrastructure and land uses, as well as the overall water cycle. One of the recommendations arising from the DSWMMP was to conduct Environmental Impact Studies (EIS) and Subwatershed Impact Study (SIS) in the watershed areas where multiple land ownership occurs. In December 2017, Schaeffers et al. completed an SIS study for the Salem Annexed lands. The SIS identified site-specific constraints associated with natural heritage features and assessed preferred servicing solutions within the limits of Salem Annexed Lands (The Salem Secondary Plan Area, also known as Official Plan Amendment #38).

The goal of the SIS was to achieve a greater level of detail in the integration of land use, servicing and stormwater management. The objectives of the SIS were as follows:

i. *Identification of a final preferred servicing plan (including public/private utilities);*
ii. *Identification of a final preferred road layout;*
iii. *Integration of stormwater management facilities;*
iv. *Exploration of opportunities to integrate recreation opportunities with stormwater management;*
v. *Phasing and cost sharing in areas of multiple ownership;*
vi. *Validation of fisheries mitigation and compensation; and*
vii. *The survey of the boundary of Natural Heritage System.*

Within the SIS, the subject property was identified as 'Parcel #1'.

3.1.1 Geology

The planimetric form of a watercourse is fundamentally a product of the flow regime and the availability of sediment (i.e., surficial geology) within the stream corridor and upstream catchment area. The 'dynamic equilibrium' of these inputs governs channel planform. These factors are influenced in smaller systems by physiography, riparian vegetation and land use. The subject property falls within the Peterborough Drumlin Field. This region is characterized as a rolling, drumlinized, till plain. Overburden sediments in the subject property consist of stone-poor, carbonate-derived silty to sandy till with areas of glaciofluvial ice-contact stratified sediments of sand and gravel. The bedrock in the area is mapped as consisting primarily of Paleozoic limestone of the Middle Ordovician Simcoe Group (Schaeffers *et al.* 2017).

3.1.2 Hydrology

Pre-development flows were summarized in the SIS for the portion of Bear Creek within the Salem Secondary Plan Area. Modelled 2-year storm event peak flows for nodes relevant to the subject property are summarized in **Table 2**.

Table 2. Modelled 2-year Storm Peak Flows – Bear Creek (Schaeffers et al. 2017)

Bear Creek	Model Node	Peak Flow (m^3/s)	
		DSWMMP	SCE
Main Branch	9010 (upstream)	0.58	0.76
	9005 (downstream)	0.85	0.97
Western Tributary	506 (upstream)	0.08	0.072
	9001 (downstream)	0.40	0.43

3.1.3 Meander Belt Investigation

For the purposes of the SIS report, the geomorphic characterization of Bear Creek relied on recommendations provided in the AMEC (2013) DSWMMP. The DSWMMP delineated the reaches for the western tributary of Bear Creek within the subject property as Reaches BEA1-2, BEA1-3 and BEA1-4.

Final meander belt widths were determined based on the DSWMMP, which referenced a review of historical aerial photos to quantify the 100-year migration rates. Due to the relative accuracy of this approach, and as a result of consultation with the NVCA, a safety factor representing percentage of the preliminary belt width was applied to each side, plus an additional setback which included a 6.0 m access and erosion setback, as recommended by Provincial Policy Statement 3.1. For NVCA this total additional setback was 12 m (6 m each bank). **Table 3** summarizes meander belt widths and final corridor widths for the main branch and western tributary of Bear Creek as relevant to the subject property. The SIS noted that further geomorphological studies should be completed at the draft plan of subdivision stage to refine DSWMMP findings.

Table 3. Meander Belt Width and Corridor Width – Bear Creek (Schaeffers et al. 2017)

Bear Creek	Reach	Preliminary Meander Belt Width (m)	Erosion Setback	Final Meander Belt Width (m)	Erosion Access Allowance (m)	Final Corridor Width (m)
Main Branch	BEA2-5	16	3.2 (10%)	19.2	12	31.2
Western Tributary	BEA1-2	--	--	--	--	--
	BEA1-3	15	4.5	19.5	12	31.5

Bear Creek	Reach	Preliminary Meander Belt Width (m)	Erosion Setback	Final Meander Belt Width (m)	Erosion Access Allowance (m)	Final Corridor Width (m)
			(15%)			
	BEA1-4	18	3.6 (10%)	21.6	12	33.6

3.1.4 Geomorphic Constraint Rankings

Preliminary constraint rankings on a reach-by-reach basis were also established based upon DSWMMP findings regarding geomorphic form and function as follows:

- **High Geomorphic Constraint** - a defined channel that displays a well-defined morphology and/or valley system that would be difficult to replicate in a post-development scenario;
- **Medium Geomorphic Constraint** - a defined channel that may or may not have a well-defined morphology. Typically, such reaches have been heavily modified by historic land use practices and would benefit from rehabilitation; and
- **Low Geomorphic Constraint** - undefined (swale) ephemeral systems which may convey flow and sediment to downstream reaches. Such reaches could be replicated through appropriate stormwater management practices in a post-development scenario.

Figure 3.5 of the SIS presents the results of this analysis, which identified Reach BEA1-4 as high constraint. Reach BEA2-5 of Bear Creek and BEA-3 were characterized as medium geomorphic constraint, while Reach BEA1-2 was classified as low constraint. The erosion threshold analysis included in the SIS utilized results from the DSWMMP. Detailed geomorphological field data was not collected along Bear Creek to model erosion thresholds for the channel bed. A unitary flow rate of 0.012 m^3/s/ha was identified for both nodes 9001 (Bear Creek BEA1 - western tributary) and 9005 (BEA2 - main branch) of Bear Creek in the SIS.

3.2 Desktop Assessment

3.2.1 Climate

Climate provides the driving energy for a fluvial system and directly influences basin hydrology and rates of channel erosion, particularly through precipitation. Precipitation records obtained from climate normals (1981-2010) recorded at Barrie Water Pollution Control Centre, northwest of the subject lands, averaged 77 mm per month in winter (November through February), and 84 mm in summer (July and August; Environment Canada 2018). This increase over the summer months is likely a result of convective thunderstorms. While total precipitation amounts are greater during the summer months, snowmelt and rain-on-snow events tend to produce the highest flows within a watershed.

3.2.2 Watershed Conditions

Bear Creek watershed has a total drainage area of approximately 8863 ha, of which estimated 262 ha are located within the Salem Secondary Plan Area. Two tributaries to Bear Creek flow within or adjacent to the subject property. Both tributaries flow in a northwest direction and drain into the Bear Creek main branch then, ultimately, confluence with the Nottawasaga River (Schaeffers *et al.* 2017). According to the 2018 Watershed Report Card (NVCA), Bear Creek subwatershed received a grade of 'fair' with respect to surface water quality and forest conditions, an 'excellent' grade for wetland cover (NVCA).

3.2.3 Historical Assessment

The following section presents an overview of historical conditions in the vicinity of the subject property with respect to land use, land cover, and channel conditions. The scale of these natural and human induced changes can provide insight into the degree to which channel planform adjustment has occurred over time.

In support of the historical assessment, black and white aerial photographs and digital colour imagery were analysed and compared to obtain a simple, qualitative assessment of the degree of land use and channel planform change over time (**Appendix A**). **Table 4** provides a summary of specific observations regarding change in channel planform and land use based on available historical aerial imagery.

Table 4. Historic Assessment - Bear Creek

Time Period	Scale, Source	Observations
1973	1:15,840 Northway/Photomap/Remote Sensing Ltd.	Land use was predominantly agricultural, with some forested lands north of the subject property. Isolated residences were observed in the general area, including several on the subject property. Evidence of active aggregate excavation was noted in the southeast corner of the subject property.
		The western tributary of Bear Creek displayed minimal definition and a low degree of sinuosity. Evidence of channelization could be observed in the vicinity of the County Road 27 crossing. Other channel disturbances included an informal agricultural crossing of the tributary within the subject property.
1986	1:8,000 Northway/Photomap/Remote Sensing Ltd.	Land use remained largely unchanged since 1973. Further channelization of the western tributary within the subject property could be observed. Aggregate activities had also expanded.
2008	First Base Solutions	A residential subdivision immediately north of the subject lands (including Lougheed Road) has been constructed and includes two road crossings of Bear Creek. Aggregate activities can no longer be observed.
		Immediately south of the subject property, an online pond can be observed along the western tributary to Bear Creek.
2016	First Base Solutions	The online pond can no longer be discerned. No obvious changes to channel planform or land use were observed.

4. Existing Conditions

4.1 Reach Delineation

To facilitate a systematic evaluation of the relevant portion of the Bear Creek, watercourse reaches as delineated in the SIS were reviewed and refined, as appropriate. Reaches are homogenous sections of channel with regard to form and function and can, therefore, be expected to behave consistently along their length to changes in hydrology and sediment inputs, as well as to other modifying factors (Montgomery and Buffington 1997; Richards *et al.* 1997).

For the purposes of this study, reaches as defined through the SIS were generally retained, however reach limits were slightly refined based on field confirmation of existing conditions. Reach BEA1-3 was also subdivided into two sub-reaches (BEA1-3A and BEA1-3B) to reflect portions of the reach that were characterized as a defined channel, versus an intermittently defined channel with wetland characteristics. Reach numbering as defined through the SIS was also extended for the main branch of Bear Creek to include reaches BEA2-6 and BEA2-7. Reach extents are illustrated in **Figure 2**.

4.2 Rapid Assessments

4.2.1 Methods

In order to characterize existing geomorphic conditions along relevant reaches of Bear Creek, a geomorphic field investigation was conducted on October 3, 2018. The following standardized rapid visual assessment methods were applied:

Rapid Geomorphic Assessment (RGA – MOE 2003)

The RGA documents observed indicators of channel instability by quantifying observations using an index that identifies channel sensitivity. Sensitivity is based on evidence of aggradation, degradation, channel widening and planimetric form adjustment. The index produces values that indicate whether the channel is stable/in regime (score <0.20), stressed/transitional (score 0.21-0.40) or in adjustment (score >0.41).

Rapid Stream Assessment Technique (RSAT – Galli 1996)

The RSAT uses an index to quantify overall stream health and includes the consideration of biological indicators (Galli 1996). Observations concerning channel stability, channel scouring/sediment deposition, physical in-stream habitat, water quality, and riparian habitat conditions are used to calculate a rating that indicates whether the channel is in poor (<13), fair (13-24), good (25-34), or excellent (35-42) condition.

Downs Classification Method (Downs 1995)

The Downs (1995, outlined in Thorne *et al.* 1997) classification method infers present and future potential adjustments based on physical observations, which indicate the stage of evolution, and type of adjustments that can be anticipated based on the channel evolution model. The resultant index classifies streams as stable, laterally migrating, enlarging, undercutting, aggrading, or recovering.

4.2.2 Results

Results of the rapid field assessments are summarized in **Table 5** and **Table 6** below. A photographic record of site conditions at the time of the assessment is provided in **Appendix B**. Photo locations are identified on **Figure 2**.

4.2.2.1 Reach BEA1-3A

Reach BEA1-3A was characterized as a well-defined channel situated within an unconfined valley setting. The reach displayed a moderate gradient and a low degree of sinuosity and entrenchment. Riparian vegetation was characterized as continuous and extended >5 channel widths laterally and consisted of trees and herbaceous plants. Bank angles ranged between 30-90 degrees with signs of erosion evident along 5-30% of the reach. Bank materials consisted of clay/silt, sand, and cobble. Riffle substrate consisted of clay/silt, sand, gravel, cobble, and boulder. Pool substrate consisted of clay/silt, sand, and cobble. Bankfull channel widths and depths ranged between 2.0-3.0 and 0.3-0.35 m, respectively. Woody debris was present in low quantities within the channel.

RGA results indicated that Reach BEA1-3A was stable, or ‘in regime’, with a score of 0.03. There was minor evidence of degradation in the form of knickpoint migration and minor evidence of planimetric form adjustment due to thalweg misalignment. An RSAT score of 32 indicated a ‘good’ degree of overall ecological health. The Downs model for this reach confirmed the RGA results with a classification of S – ‘stable’.

4.2.2.2 Reach BEA1-3B

Reach BEA1-3B was characterized as an intermittently-defined channel within an unconfined valley setting. The reach displayed a low degree of sinuosity and entrenchment and a low gradient. Wetland characteristics dominated the reach, with riparian vegetation extending greater than 5 channel widths. Vegetation consisted of shrubs, grasses, and herbaceous plants. Emergent instream vegetation was observed through 30-90% of the reach. Bank angles were less than 30 degrees and exhibited minimal evidence of erosion. Bank materials consisted of clay/silt and sand. Pools and riffles were poorly defined and substrate consisted of clay/silt and sand. Where defined, bankfull dimensions were recorded to average 1.25 m in width and 0.6 m in depth.

RGA results indicated that Reach BEA1-3B was stable, or ‘in regime’, with a score of 0. An RSAT score of 26.5 indicated a ‘good’ degree of overall ecological health with riparian habitat conditions identified as the primary limiting factor. The Downs model reflected the RGA evaluation of this reach with a classification of S – ‘stable’ based on limited evidence of morphological change.

Reach and Photo Locations

Figure 2

Di Poce Subdivision
Geomorphic Assessment

Legend

- Subject Property (MHBC Planning, 2018)
- Photo Locations (Beacon, 2018)
- Extent Assessed (Beacon 2018)
- Reach Breaks (Beacon, 2018)
- Drainage Feature (Beacon, 2018)
- Watercourse (MHBC Planning, 2018)

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4.2.2.3 Reach BEA1-4

Reach BEA1-4 was characterized as a well-defined channel within an unconfined valley setting. The reach displayed a low degree of sinuosity and entrenchment and a low gradient. Riparian vegetation as characterized as continuous, extending 1-5 channel widths laterally, and consisting of trees and herbaceous plants while being dominated by grasses. Submergent vegetation was observed in approximately 20% of the reach. Channel bank angles ranged between 30-90 degrees and were composed of clay/silt and sand. Bank erosion was observed through 5-30% of the reach. Pool substrate consisted of clay/silt and sand, while riffle substrate consisted of clay/silt, sand, and gravel.

RGA results indicated that Reach BEA1-4 was stable, or 'in regime', with a score of 0. An RSAT score of 29 indicated a 'good' degree of overall ecological health with riparian habitat conditions identified as the primary limiting factor. The Downs model reflected the RGA evaluation of this reach with a classification of S – 'stable' based on limited evidence of morphological change. Evidence of channel disturbance included the County Road 27 crossing, and historic channelization. An informal crossing of the creek behind an existing residential dwelling was also noted.

4.2.2.4 Reach BEA2-6

Reach BEA2-6 was characterized as well-defined channel situated within a confined valley setting. The reach displayed a moderate gradient and a moderate degree of sinuosity and entrenchment. Riparian vegetation was characterized as continuous and extending >5 channel widths laterally. Vegetation was dominated by trees with grasses and herbaceous plants also present. Bank angles ranged from 30-90 degrees with evidence of erosion through 5-30% of the reach. Banks were composed of clay/silt, sand, cobble, and some boulder. Riffle substrate consisted of sand, gravel, cobble, and boulder. Pool substrate consisted of clay/silt, sand, and gravel. Bankfull widths and depths ranged between 1.8-3.6 m and 0.22-0.25 m, respectively. Woody debris was observed within the channel in moderate quantities.

RGA results indicated that Reach BEA2-6 was stable, or 'in regime', with a score of 0.18 with minor evidence of widening, planimetric form adjustment, and aggradation. Evidence of widening consisted of fallen and leaning trees, large organic debris within the channel, and exposed tree roots. Evidence of planimetric form adjustment consisted of the presence of valley wall contact points, chute formation and thalweg misalignment. Aggradation was observed in the form of pool siltation. An RSAT score of 25.5 indicated a 'good' degree of overall ecological health with physical instream habitat identified as the primary limiting factor. The Downs model indicated a combined evaluation of S – 'stable' and m – 'lateral migration', which reflects the RGA evaluation and the minor modes of adjustment that were observed.

4.2.2.5 Reach BEA2-7

Reach BEA2-7 was characterized as a moderately well-defined channel with a confined valley setting. The reach displayed a low degree of sinuosity, a moderate gradient, and a low to moderate degree of entrenchment. Bank angles ranged between 30-60 degrees with erosion observed through 5-30% of the reach. Undercutting of 0.3 m was observed along some stretches of the bank. Bank materials were composed of clay/silt, sand, gravel, and cobble. Pool-riffle morphology was poorly defined and substrate consisted of sand, gravel, and cobble. Bankfull widths and depths ranged between 1.8-3.45

m and 0.2-0.35 m, respectively. The channel was dry at the time of survey with isolated pockets of standing water. The upstream portion of the reach, downstream of the Lougheed Road culvert, appears to have undergone some degree of channel design with gabion baskets and rip-rap present along the bed and banks. Downstream of this modified reach there is evidence of downcutting. Woody debris was found within the channel in moderate quantities.

RGA results indicated that Reach BEA2-7 was 'in transition' with a score of 0.25. The channel displayed evidence of widening in the form of fallen trees, the occurrence of large organic debris, exposed tree roots, and basal scour on both sides of the channel through the riffle. Evidence of degradation was observed through undermined gabion baskets, knickpoint migration, and terracing through older bar material. Evidence of aggradation was observed in the form of medial/lateral bar formation. Evidence of planimetric form adjustment was observed in the channel evolution from a single thread to multiple. An RSAT evaluation of 19.5 indicated a 'fair' degree of overall ecological health with physical instream habitat and water quality identified as the primary limiting factors. The Downs model reflected the RGA evaluation through a classification of U – 'undercutting' based on observation of erosion along the outer bank and deposition along the inner.

Table 5. Summary of General Reach Characteristics – Bear Creek

Reach	Bankfull Width (m)	Bankfull Depth (m)	Pool Substrate	Riffle Substrate	Riparian vegetation	General Notes
BEA1-3A	2.0-3.0	0.30-0.35	Clay/silt, sand, cobble	Clay/silt, sand, gravel, cobble, boulder	Trees, herbaceous plants	Well-defined channel
BEA1-3B	1.3	0.60	Clay/silt	Clay/silt	Shrubs, grasses, herbaceous plants	Intermittently defined channel with emergent instream vegetation
BEA1-4	2.8-4.2	0.26-0.38	Clay/silt, sand	Clay/silt, sand, gravel	Grasses, trees, herbaceous plants	Evidence of channelization
BEA2-6	1.8-3.6	0.22-0.25	Clay/silt, sand, gravel	Sand, gravel, cobble, boulder	Trees, grasses, herbaceous plants	Valley wall contact points. Instream woody debris
BEA2-7	1.8-3.4	0.20-0.35	Sand, gravel, cobble	Sand, gravel, cobble	Trees, herbaceous plants	Gabion drop structure at Lougheed Road. Poorly defined riffle-pool morphology

Table 6. Summary of RGA and RSAT Scores – Bear Creek

Reach	Rapid Geomorphic Assessment (RGA)			Rapid Stream Assessment Technique (RSAT)		
	Score	Condition	Dominant Mode of Adjustment	Score	Condition	Limiting Factor(s)
BEA1-3A	0.03	In regime	Degradation	32.0	Good	N/A
BEA1-3B	0	In regime	N/A	26.5	Good	Riparian habitat
BEA1-4	0	In regime	N/A	29.0	Good	Riparian habitat
BEA2-6	0.18	In regime	Widening	25.5	Good	Physical instream habitat
BEA2-7	0.25	In transition	Widening	19.5	Fair	Physical instream habitat and water quality

4.3 Detailed Assessments

The selection of the detailed geomorphic field site location was governed by land ownership and the location of the proposed stormwater facility and outfall to the western tributary. While Reach BEA1-4 of the western tributary was deemed to be stable (RGA score of 0) and not sensitive to erosion, a detailed assessment was undertaken to ensure that sufficient field data would be available, should a detailed geomorphic analysis for stormwater erosion control be required.

4.3.1 Methods

Detailed geomorphic data collection was collected within Reach BEA1-4 on October 3, 2018. Field methods included measurements of bankfull or 'active' channel dimensions, using standard protocols and accepted field indicators. Additionally, a longitudinal survey of bed morphology, planform, and bankfull stage indicators was completed. Riparian cover, bed and bank materials (type and strength), and general channel condition were documented using standard field protocols. Six (6) channel cross-sections were surveyed along the reach, extending beyond the active (bankfull channel) to include a portion of the adjacent floodplain. Representative samples of channel substrate were collected for later analysis, if required.

4.3.2 Results

A summary of geomorphic characteristics and calculated hydraulic parameters for Reach BEA1-4 is provided below in **Table 7**, while a detailed summary of data collection results has been provided in **Appendix C**. The surveyed portion of Reach BEA1-4, extending approximately 131 m, displayed a well-defined active channel with low sinuosity (1.0) and moderate gradient (1.8%). While riffle-pool morphology was not well developed, evidence of sediment sorting was observed. Channel form was generally dominated by riffle and run/transitional zones with a few shallow pools. Existing channel disturbances included the County Road 27 culvert, historic straightening, and an informal crossing at the upstream extent of the reach.

Bankfull widths ranged from 2.8 – 4.5 m in dimension, and averaged 3.7 m. Bankfull depths ranged between 0.3 – 0.4 m. Bank angles ranged between 30 – 60 degrees and were typically composed of silt, clay, and sand. Riparian vegetation was dominated by dense grasses and herbaceous plants. Bed materials were generally classified as fine (composed of clay, silt and sand), with localized gravel zones. The underlying clay till subpavement was observed in localized areas.

Table 7. Summary of field based and calculated parameters – Reach BEA1-4

Parameter	BEA1-4
Governing energy gradient (%)	1.8
Average bankfull width (m)	3.7
Average bankfull depth (m)	0.3
Average width-depth ratio	11.6
Bank angles (degrees)	30-60
Bank materials	Sand, silt, clay
Undercut banks (%)	0
D_{50} (mm) – riffle	Fines
D_{84} (mm) - riffle	Fines
Manning’s n-value	0.037

5. Analysis

5.1 Meander Belt Width

The meander belt width is generally defined as the lateral extent that a meandering channel has historically occupied and will likely occupy in the future. Following the TRCA (2004) guidelines, the meander belt width was initially delineated based on the position of any existing meander bends within Reaches BEA1-3B and BEA1-4. Using high resolution digital aerial imagery, and topographic mapping, the belt width limits were then reviewed to ensure that the dimension was also sufficient to capture areas of standing water or saturated soil that had been observed during the field investigation. All of these observations are indicators of frequent floodplain inundation and should be captured by the meander belt, within the context of historic channel conditions.

In order to account for long-term adjustments in channel form (channel erosion and migration) in accordance with Provincial Policy Statement (MMAH, 2014), the MNR Technical Guide (MNR, 2002) and the TRCA (2004) guidelines, were used to establish the final meander belt width associated with the reaches. Since the 100-year migration rates could not be calculated for the western tributary due to the degree of historic channelization, a 20% factor of safety (erosion allowance) was applied to the belt width (10% either side). Based on the information available at the time of this study, this factor of safety is considered sufficient to address the potential for channel erosion over the planning timeframe.

In order to provide an additional level of confidence associated with the meander belt width dimension, an empirical modelling approach was also employed. As 2-year (post-development) flows were not available for the tributaries, the approach referenced previously published relations. These models use simple power functions based on field-based measurements of the average bankfull width (W_b) and cross-sectional area (A), following relations from Williams (1986 – Equations 1 and 2) and Ward (2001 – Equation 3). Research by Ward et al. (2002) indicated that the Williams (1986) equation, at times, under-predicted the belt width dimensions. As such, a modified approach to the relation, which incorporates the average bankfull width and a 20% factor of safety, was applied.

$$B_w = ([18*A^{0.65}]) \quad \text{[Eq. 1]}$$
$$B_w = ([4.3*W_b^{1.12}])*1.2 \quad \text{[Eq. 2]}$$
$$B_w = ([6*W_b^{1.12}]+W_b) \quad \text{[Eq. 3]}$$

Given the empirical models were not developed based on channels in Southern Ontario, and in order to ensure an integrated and comprehensive approach, model results were averaged to provide an output for the empirical method. Due to the intermittently-defined nature of Reach BEA1-3A, Reaches BEA1-3B and BEA1-4 were used as surrogate reaches in order to recommend a meander belt dimension. Results of the meander belt width analysis are summarized in **Table** 8 **8**. Meander belt limits for Reaches BEA1-3A, BEA1-3B and BEA1-4 are illustrated in **Figure 3**.

Table 8. Recommended Meander Belt Width

Reach	Empirical Approach				Desktop Approach (m)	Final Meander Belt Width (incl. 20% erosion allowance) (m)
	Williams – Area (m) (1986)	Williams – Width (m) (1986)	Ward – Width (m) (2001)	Average (m)		
BEA1-3A	--	--	--	--	--	21*
BEA1-3B	16	14	24	18	21	21
BEA1-4	19	19	25	21	21	21

* Reference reach approach

The erosion hazard limit for unconfined (non-apparent) valley systems, as defined under the Provincial Policy Statement (MMAH 2014), generally requires that an erosion access allowance be applied to the greater of the meander belt or flooding hazard limit (regulatory floodline). In accordance with Ontario Regulation 172/06, a 6 m erosion access allowance should be applied to determine the watercourse erosion hazard limit.

5.2 Toe Erosion Allowance

A portion of Reach BEA2-6 is located adjacent to the subject property. While a geotechnical study is required to determine the erosion hazard limit for this reach due to the confined nature of the valley setting, technical support to geotechnical studies is typically provided from a geomorphic perspective through the recommendation of a toe erosion allowance. In accordance with Provincial Policy (MMAH, 2014), and referencing available information and field observations regarding soil composition and watercourse conditions, a toe erosion allowance of 8 m is recommended (refer to **Table 1**, MNR 2002). This allowance is considered appropriate based on the bankfull channel dimensions, observed evidence of toe erosion at valley wall contact points, and the sandy soil conditions along the reach. This recommendation is consistent with the findings of the Geotechnical Investigation – Slope Stability Assessment and Geotechnical Setback Study (GeoPro Consulting Limited 2018) undertaken for the subject property.

6. Impact Assessment

6.1 Proposed Development

The Functional Servicing Report prepared by Schaeffers Consulting Engineers (2018) describes the proposed development as a subdivision that will contain townhouse units, medium density residential blocks, a school block, a park block, a commercial block and open space. The medium density residential blocks and commercial block, along with the park and School block will undergo a separate site plan application process. The subject property development plan is illustrated in **Figure 4**.

6.2 Stormwater Management

The proposed stormwater management plan has a dual drainage scheme consisting of a major and a minor system. The minor system will convey runoff from storms up to and including the 5-year event via underground sewers from the right-of-way (ROW) and front lots. A stormwater management pond (SWM Pond H) is proposed at the northwest corner of the subject property and will outlet to the western tributary of Bear Creek upstream of County Road 27. The proposed 1.25 ha SWM Pond H will provide quality, quantity and erosion control for majority of the subject property. An infiltration bed is proposed in the wet cell component of the SWM Pond to provide volumetric control and to assist in meeting water balance requirements.

6.2.1 Stormwater Erosion Control

Erosion control targets for SWM Pond H were established in accordance with the DSWMMP (Table 4.4.15). It is proposed that erosion control for catchments 203 & 204 (west of the Bear Creek tributary) be provided through the retention of 5 mm rainfall on-site. Erosion control for remaining portions of the subject property will be provided via SWM Pond H. The erosion control volume required was calculated using the Bear Creek tributary Outlet Node 9001 from the DSWMMP Table 4.4.15 based on the area

Meander Belt | **Figure 3**

Di Poce Subdivision
Geomorphic Assessment

Legend

- Subject Property (MHBC Planning, 2018)
- Meander Belt Width (Beacon, 2018)
- Reach Breaks (Beacon, 2018)
- Drainage Feature (Beacon, 2018)
- Watercourse (MHBC Planning, 2018)

Reach	Meander Belt Width (m)
BEA1-3A*	21
BEA1-3B*	21
BEA1-4	21

*reference reach approach

BEACON ENVIRONMENTAL

Project: 218066
Last Revised: January, 2019

Client: Di Poce Management Inc.

Prepared by: DU
Checked by: AG

N

1:3,000

0 50 100 m

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Proposed Development	**Figure 4**

Di Poce Subdivision
Geomorphic Assessment

Legend

- Subject Property (MHBC Planning, 2018)
- Proposed Development (MHBC Planning, 2018)
- Reach Breaks (Beacon, 2018)
- Drainage Feature (Beacon, 2018)
- Watercourse (MHBC Planning, 2018)

BEACON ENVIRONMENTAL

Project: 218066
Last Revised: January, 2019

Client: Di Poce Management Inc.

Prepared by: DU
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N

1:3,000

0 50 100 m

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C:\Dropbox\Dropbox (Beacon)\All GIS Projects\2018\218066\MXD\2019-01-24_Figure04_ProposedDevelopment_218066.mxd that drains to the SWM pond and correlates to a peak allowable release rate of approximately 0.047 m^3/s.

6.3 Road Crossing

The draft plan of subdivision proposes a road crossing of the western tributary of Bear Creek within Reach BEA1-3B (refer to **Figure 4**). Results of the rapid geomorphic assessment work identified Reach BEA1-3B as an intermittently-defined watercourse with wetland characteristics. As the reach lacked a defined channel and did not exhibit indicators of potential for future erosion and migration, a geomorphic span requirement was not identified for the road crossing. Instead, crossing span design requirements are deferred to hydraulic and ecological criteria.

7. Policy Conformance

It is our opinion that the findings of this report are in conformance with the Provincial Policy Statement (2014), the NVCA Planning and Regulation Guidelines (2009), City of Barrie Official Plan (2018), and the NVCA Stormwater Technical Guide (2013).

8. Summary

Beacon Environmental Limited (Beacon) was retained by Di Poce (Innisfil) Inc. to undertake a geomorphic assessment for the Di Poce Subdivision lands, located in the City of Barrie. In support of a development application for the subject property, this report summarized existing geomorphic conditions, provides direction with respect to watercourse constraint limits (i.e., meander belt and toe erosion allowance) and identifies road crossing design requirements.

The following points summarize the study findings:

- Reaches BEA1-3A, and BEA1-4 were characterized as well-defined channels within unconfined valley settings;
- Reach BEA1-3B was characterized as an intermittently defined channel with wetland characteristics within an unconfined valley setting;
- Reaches BEA2-6 and BEA2-7 were characterized as well-defined channels within confined valley settings;
- Rapid assessment protocols indicated that all reaches were ‘in-regime’, with the exception of BEA2-7, which was characterized as ‘in-transition’;
- A meander belt width dimension of 21 m was recommended for Reaches BEA1-3A, BEA1-3B, and BEA1-4 of the Bear Creek tributary;
- A toe erosion allowance of 8 m was recommended for Reach BEA2-6. This recommendation is consistent with the findings of the Geotechnical Investigation – Slope Stability Assessment and Geotechnical Setback Study undertaken by GeoPro Consulting Limited for the subject property;

- With an RGA score of 0, Reach BEA1-4 was deemed stable and not sensitive to erosion. In accordance with NVCA Stormwater Guidelines (2013), a detailed geomorphic analysis for stormwater erosion control was not undertaken; and
- Due to the poorly defined nature of Reach BEA1-3B, a geomorphic span requirement was not recommended for the proposed road crossing of the Bear Creek western tributary.

Prepared by:
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Reviewed by:
Beacon Environmental

Shelley Gorenc, M.Sc., P.Geo.
Senior Geomorphologist

9. References

Chapman and Putnam. 1984
Physiography of Southern Ontario. *Ontario Research Foundation.*

City of Barrie. 2010
City of Barrie Official Plan, 2018 Office Consolidation. January 2018.

Downs, P.W. 1995.
Estimating the probability of river channel adjustment. Earth Surface Processes and Landforms. 20: 687-705.

Downs, P.W. and Gregory, K.J. 2004.
River Channel Management: Towards Sustainable Catchment Hydrosystems. Oxford University Press Inc., New York, New York.

Environment Canada. 2018.
Canadian Climate Normals 1981-2010
http://climate.weatheroffice.gc.ca/climate_normals/index_e.html. Accessed September 5, 2018.

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

GeoPro Consulting Limited. 2018.
Geotechnical Investigation – Slope Stability Assessment and Geotechnical Setback Study Proposed Residential Developments, County Road 27, Barrie, Ontario.

Montgomery, D.R and J.M. Buffington. 1997.
Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin, 109 (5): 596-611.

Nottawasaga Valley Conservation Authority. 2009.
NVCA Planning and Regulation Guidelines. August 28, 2009.

Nottawasaga Valley Conservation Authority. 2013
NVCA Stormwater Technical Guide. December 2013.

Ontario Ministry of Municipal Affairs and Housing. 2014.
Provincial Policy Statement (Policy 3.1: Natural Hazards).

Ontario Ministry of Natural Resources. 2002.
Technical Guide River and Stream Systems: Erosion Hazard Limit.

Ontario Ministry of the Environment. 2003.
Stormwater Management Planning and Design Manual. Document # 4329e. Queen's Printer for Ontario, Ontario, Canada.

Schaeffers Consulting Engineers. 2018.
Functional Servicing Report, Di Poce (Innisfil) Inc. Properties - Proposed Mixed Use Development, City of Barrie.

Schaeffers Consulting Engineers et al. 2017.
Subwatershed Impact Study Report – Salem Annexed Lands, City of Barrie.

Ward, A. D. Mecklenberg, J. Mathews, and D. Farver. 2002.
Sizing Stream Setbacks to Help Maintain Stream Stability. 2002 ASAE International Meeting, Chicago, IL. July 28-21, 2002. Paper Number 0222239.

Williams, G.P. 1986
River meanders and channel size. *Journal of Hydrology*, 88: 147 – 164.

Toronto and Region Conservation Authority. 2004.
Belt Width Delineation Procedures. Prepared by: Parish Geomorphic Ltd.

TRCA and CVC. 2012.
Stormwater Management Criteria.

Appendix A

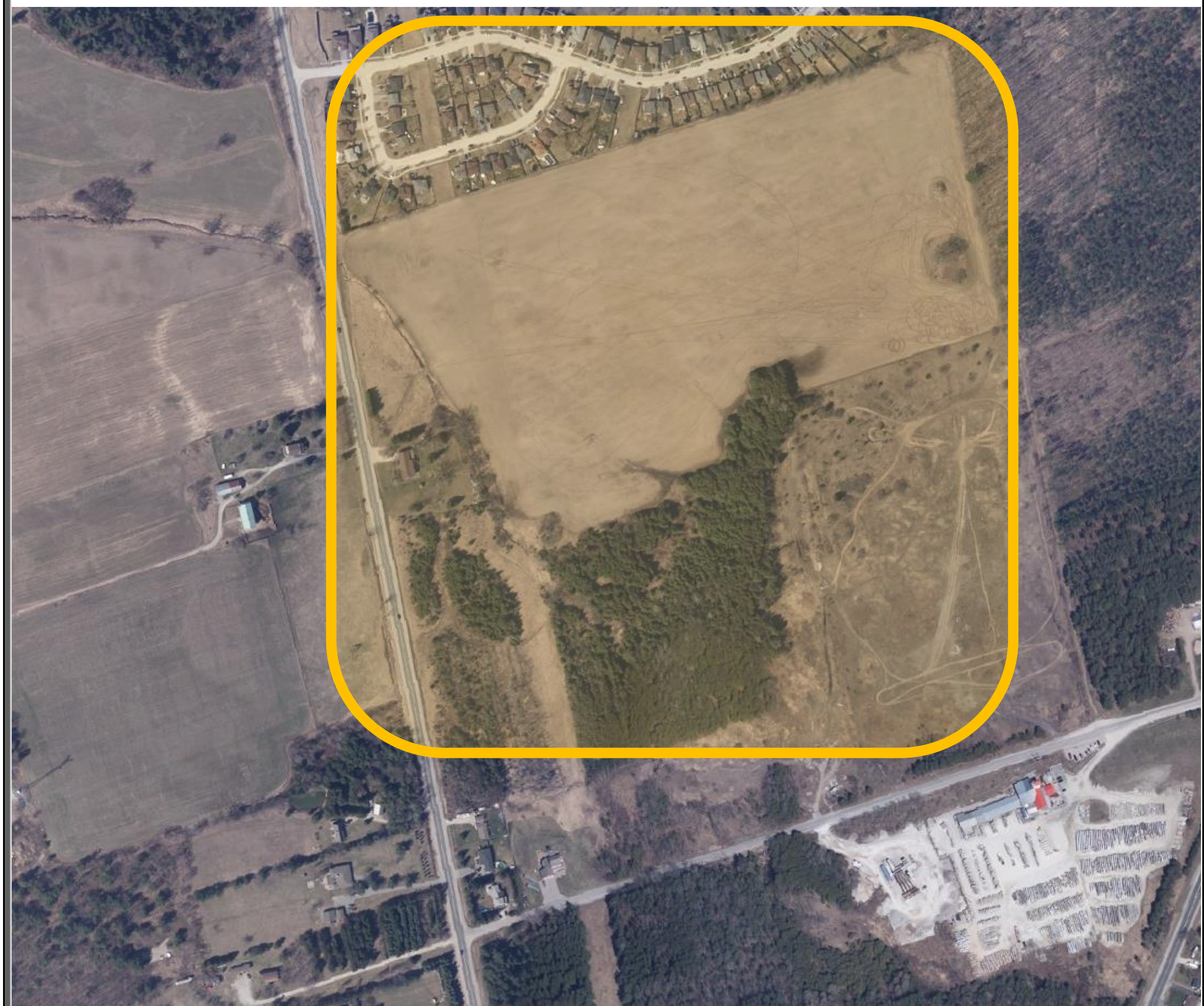
Historic Aerial Imagery

Coverage:	1973	**Scale:**	1:12:000
Image ID:	N/A	**Source:**	Northway Photomap

Coverage:	1986	**Scale:**	1:8:000
Image ID:	N/A	**Source:**	Northway Photomap

Coverage: 2008 **Scale:** 1:5,000

Image ID: N/A **Source:** First Base Solutions



Coverage:	2016	**Scale:**	1:5,000
Image ID:	N/A	**Source:**	First Base Solutions

Appendix B

Photographic Record

Photo 1 (Photo Location 1)

Reach BEA1-3A
Upstream view of general conditions.

Photo 2 (Photo Location 2)

Reach BEA1-3A
Upstream view of general conditions.

Photo 3 (Photo Location 3)

Reach BEA1-3A
Upstream view of channel with large cobble and boulder substrate.

Photo 4 (Photo Location 4)

Reach BEA1-3A
Downstream view of active bank erosion.

Photo 5 (Photo Location 5)

Reach BEA1-3A
Upstream view of general conditions.

Photo 6 (Photo Location 6)

Reach BEA1-3B
Upstream view of drainage feature that was observed adjacent to the existing residential dwelling.

Photo 7 (Photo Location 6)

Reach BEA1-3B
Upstream view of general conditions.

Photo 8 (Photo Location 6)

Reach BEA1-3B
Upstream view of channel with a tree root forming a knickpoint.

Photo 9 (Photo Location 14)

Reach BEA1-4
Downstream view of CSP (1250 mm) under County Road 27.

Photo 10 (Photo Location 11)

Reach BEA1-4
Upstream view of general conditions.

Photo 11 (Photo Location 10)

Reach BEA1-4
CSP (750 mm) under informal crossing.

Photo 12 (Photo Location 9)

Reach BEA1-4
Upstream view of channel.

Photo 13 (Photo Location 20)

Reach BEA2-6
Lougheed Road culvert with debris accumulation.

Photo 14 (Photo Location 19)

Reach BEA2-6
Upstream view of large lateral bar deposit with thalweg along photo right.

Photo 15 (Photo Location 18)

Reach BEA2-6
Downstream view of bank erosion and large boulders in the channel.

Photo 16 (Photo Location 17)

Reach BEA2-6
Upstream view of channel with informal pedestrian boardwalk crossing.

Photo 17 (Photo Location 16)

Reach BEA2-6
Upstream view of valley wall contact and large boulder substrate.

Photo 18 (Photo Location 21)

Reach BEA2-7
Upstream view of Lougheed Road culvert and gabion drop structure.

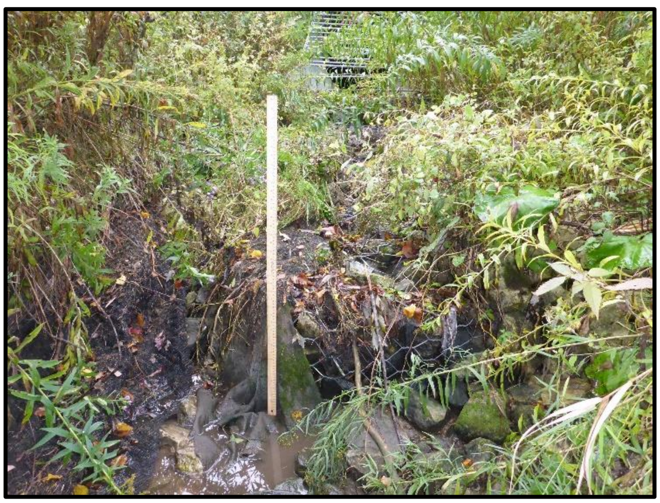


Photo 19 (Photo Location 22)

Reach BEA2-7
Upstream view at downstream transition of gabion gabion drop structure.

Photo 20 (Photo Location 22)

Reach BEA2-7
Upstream view of general conditions.

Photo 21 (Photo Location 23)

Reach BEA2-7
Downstream view of pool and tree root cascade.

Photo 22 (Photo Location 24)

Reach BEA2-7
Upstream view of log debris jam. Pool located downstream.

Photo 23 (Photo Location 25)

Reach BEA2-7
Downstream view of bank erosion. Note: minimal flow present within channel.

Photo 24 (Photo Location 26)

Reach BEA2-7
Upstream view of general conditions.

Appendix C

Detailed Field Data Summary

Geomorphology Group
Summary of Detailed Field Data

Date:	October 3, 2018	**Project:**	218066
Client:	Di Poce Management Inc.	**Watercourse:**	Bear Creek Tributary
Location:	City of Barrie	**Reach:**	BEA 1-4
Length Surveyed:	131 m	**Number of Cross Sections:**	6

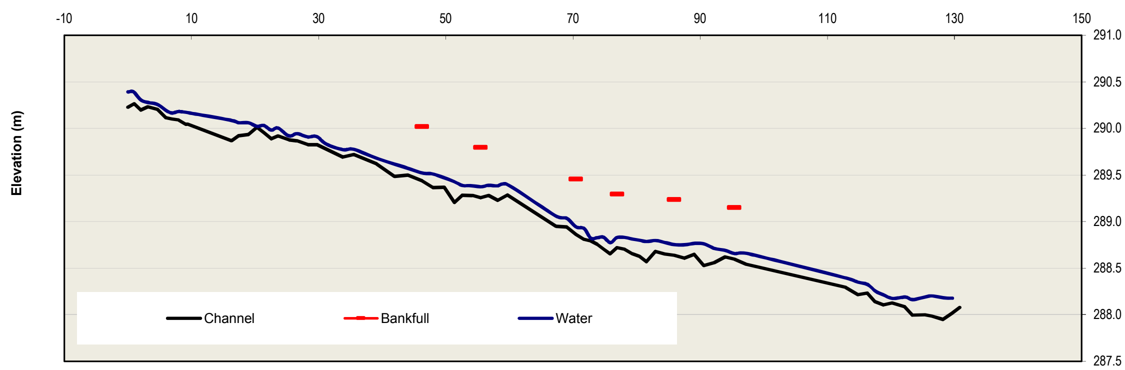
General Site Characteristics

Geology/Soils:	**Till Plains**	Riparian Vegetation:	
Surrounding Land Use:	**Agricultura, Meadow, Residential**	Dominant Type:	**Grasses**
Channel Disturbances:	**Culverts, channelization**	Buffer Zone Continuity:	**Continuous**
Aquatic Vegetation:		Channel Encroachment:	**Moderate**
Dominant Type:	**Grasses and Herbaceous**	Large Woody Debris:	**Not Present in Channel**
Portion of Reach:	**20%**		

Planform Characteristics

Bankfull Gradient: **1.8** % Channel Bed Gradient: **1.80** % Sinuosity: **1.0**

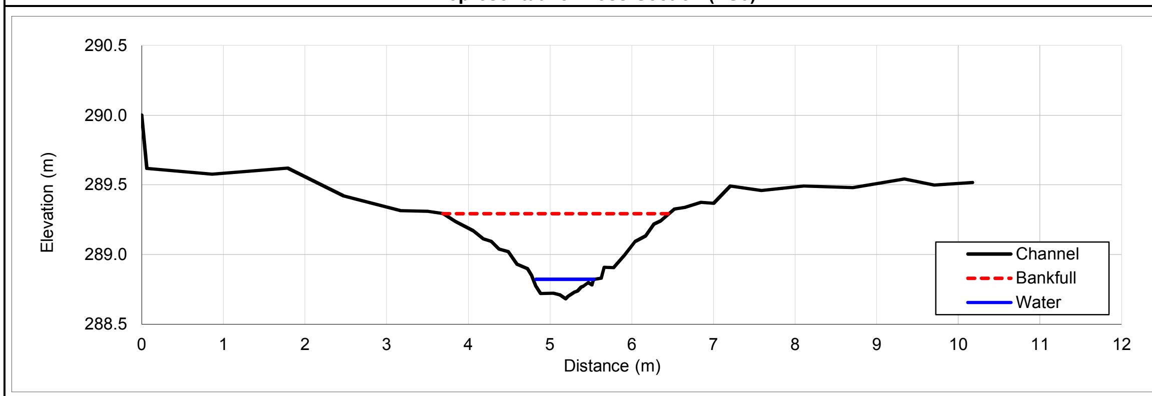
Longitudinal Profile



Cross-sectional Characteristics

	Minimum	*Maximum*	*Average*
Bankfull Width (m):	**2.8**	**4.5**	**3.7**
Average Bankfull Depth (m):	**0.31**	**0.38**	**0.34**
Bankfull Width/Depth:	**8.0**	**13.7**	**11.6**
Wetted Width (m):	**0.77**	**0.87**	**0.73**
Average Water Depth (m):		**0.34**	
Average Wetted Width/Depth:		**11**	
Max. Wetted Depth (m):		**0.077**	
Manning's n:		**0.037**	

Representative Cross-Section (XS3)



Bank Characteristics

	Minimum	Maximum	Average
Bank Height (m):	**0.75**	**1.50**	**0.97**
Bank Angle (degrees):	**6**	**60**	**36**
Root Depth (m):	**0.10**	**0.1**	**0.10**
Root Density (%):	**80**	**90**	**87**
Undercut Banks (%)		**0**	
Depth of Undercut (m):		**No undercuts present**	

Bank Material (range): **Sand and silt/clay**

Substrate Characterization (Visual)

Subpavement:	**clay till**	Particle range (riffle):	**clay/silt and sand**
Particle shape:	**sub-rounded**	Particle Range (pool):	**clay/silt, sand, and gravel**
Embeddedness (%):	**0-20**		

Hydrology

Measured Discharge:	**Not measured**	m^3/s	Calculated Bankfull Discharge:	**1.46**	m^3/s
Modelled 2-year Discharge:	**0.40**	m^3/s	Calculated Bankfull Velocity:	**1.40**	m/s
Modelled 2-year Velocity:	**Not available**	m/s			

Detailed Field Site Location